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MOJAVE WATER AGENCY

NO FEE PER GOV'T. CODE SEC. 6103

SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF RIVERSIDE

Coordination Proceeding Special Title (Cal. Rules of Court, rule 3.550) MOJAVE BASIN WATER CASES CITY OF BARSTOW, et al., Plaintiff, vs. CITY OF ADELANTO, et al., Defendant,	Case No. CIV208568 (MF) JCCP NO.: 5265 Lead Case No.: CIV 208568 Dept. 1, Riverside Superior Court Hon. Harold W. Hopp, Judge Presiding **NOTICE OF MOTION AND MOTION TO ADJUST FREE PRODUCTION ALLOWANCE FOR WATER YEAR 2024-2025; MEMORANDUM OF POINTS AND AUTHORITIES AND DECLARATION OF ROBERT C. WAGNER IN SUPPORT THEREOF** Assigned for All Purposes to: Hon. Harold W. Hopp, Judge Presiding **DATE: June 4, 2024** **TIME: 8:30 a. m.** **DEPT: 1** **Reservation ID: 459779359960**
AND RELATED CROSS ACTIONS	

TO ALL PARTIES AND THEIR RESPECTIVE ATTORNEYS OF RECORD:

Please take notice that on June 4, 2024 at 8:30 a.m., or as soon thereafter as counsel may be heard, in Department 1 of the above entitled court located at 4050 Main Street, Riverside, California, Defendant/Cross-Complainant, Mojave Water Agency, acting in its capacity as the Mojave Basin Area Watermaster, will move, and hereby moves, pursuant to paragraph 24(o) and Exhibit H of the Judgment in the above entitled case, for approval of the Watermaster's recommendation in its Thirtieth Annual Report to adjust the Free Production Allowance (FPA) for each of the five (5) Subareas (Alto, Baja, Centro, Este and Oeste) of the Mojave Basin as set forth herein for the 2024-25 Water Year.

This motion is based upon this notice, the attached Memorandum of Points and Authorities, the Thirtieth Annual Report of the Watermaster lodged with the court concurrently with this motion, the Declaration of Robert C. Wagner filed concurrently herewith, the pleadings, papers, and records on file in this Action and upon such other further evidence, both oral and documentary, that may be presented at the hearing on the motion.

Dated: May 1, 2024

BRUNICK, McELHANEY & KENNEDY PLC

BY: ______________________

WILLIAM J. BRUNICK, ESQ.
LELAND P. McELHANEY, ESQ.
Attorneys for Defendant/Cross-Complainant,
MOJAVE WATER AGENCY

MEMORANDUM OF POINTS AND AUTHORITIES

I.

BACKGROUND

The original complaint was filed by the City of Barstow et al. on May 30, 1990 and alleged that the cumulative water production upstream of the City of Barstow had over drafted the Mojave River System and it requested that the Mojave Water Agency (MWA) be ordered to obtain and provide supplemental water for use within the Mojave Basin Area (Basin). MWA filed its First Amended Cross-Complaint naming substantially all producers of water within the Basin, including parties downstream of the City of Barstow, and requested a determination of all the water production from whatever source within the Basin.

After extensive negotiations, parties representing over 80% of the verified water production in the Basin agreed to a stipulated Judgment which among other things, established a Physical Solution to the water supply problems. A trial was conducted as to the claims of non-stipulating parties, and the final Judgment after trial adopted the Physical Solution set forth in the stipulated Judgment.

The Cardozo Group of the non-stipulating parties appealed the Judgment. Following opinions by the Court of Appeal and Supreme Court, the Judgment as to the stipulating parties was affirmed, but reversed as to the Cardozo Group of non-stipulating parties. As of August 23, 2002, Jess Ranch Water Co. (JRWC), previously a non-stipulating party, entered into a settlement agreement in which it stipulated to the Judgment. An amendment to the Judgment was filed on December 5, 2002 which incorporated the changes with respect to the Cardozo Group and JRWC.

II.

THE JUDGMENT'S PHYSICAL SOLUTION

On January 10, 1996 the court entered a Judgment which addressed the overdraft existing in the Basin by the creation of a Physical Solution for the Basin's five distinct, but hydrologically interrelated Subareas (Alto, Baja, Centro, Este, and Oeste). The court determined that all five (5) Subareas of the Basin had been in a state of overdraft since at least the 1950's, that the economy and population overlying the Basin had dramatically grown in reliance upon the overdraft, and that all producers had contributed to the overdraft. The court's Physical Solution established a limit on the amount of water each Subarea could produce in one year before having to purchase replacement water. This is known as the Free Production Allowance (FPA). The Judgment also established each producer's Base Annual Production (BAP). A producer's BAP is based upon that producer's highest year of water production during the base period of 1986-1990. A producer's BAP serves as the basis for the producer's Base Annual Production Right (BAPR). BAPR is the right of each producer to a percentage of the FPA within a given Subarea.

Although the serious nature of the overdraft warranted an immediate reduction for all water production within the Basin, the Court approved a gradual reduction in production in order to soften the economic impact upon producers. Therefore, the Judgment sets forth the terms for a gradual reduction or Rampdown of the FPA for all parties. After the first five years of the Judgment, the FPA for all parties was set at eighty percent (80%) of their original BAP. The Judgment also provides that the court can review and adjust, as necessary, the FPA for each Subarea on an annual basis.

Since entry of Judgment in January of 1996, the Parties to the Adjudication and the Court have attempted to achieve sustainability in the Mojave Basin Area by use of the tools within the Judgment to finance the importation of supplemental water. The Physical Solution mandates the definition of the individual rights of all Producers within the Basin Area which will equitably allocate the natural water supplies and will provide sharing of costs for supplemental water in each Subarea.

The waters derived from the Mojave River constitute a common source of supply for the five Subareas. Each Party has a declared production right in his or her respective Subarea to produce water for his or her use against other producers located in the Subarea. In addition, Producers within certain Subareas have rights as against those in adjoining upstream Subareas to receive average annual water supplies and in any one year to receive minimum annual water supplies equal to the amounts set forth in Exhibit G of the Judgment in addition to any storm flows. Exhibit G establishes these Subarea rights and obligations to insure historical flows to each Subarea within the Basin Area. Producers in the respective Subareas shall have the obligation to provide the following minimum annual subsurface flows and/or base flow per year:

Subsurface Obligations

Este to Alto	200 acre-feet	
Oeste to Alto	800 acre-feet	
Alto to Centro	2,000 acre-feet	(21,000 acre-feet surface obligation)
Centro to Baja	1,462 acre-feet	
Baja to Afton	0 acre-feet (400 acre-feet obligation was relieved by Court, 2006)	

In summary, a Party's existing Production Right would be exercised within the respective Subarea and the Parties' guaranteed subsurface flows, are set forth above. Sixty-year (1931-1990) average storm flow is assumed to be available to the Subareas from the Mojave River system. The water supply is episodic and assumed to repeat in the future as in the past. Each respective Subarea is assumed to receive the historic storm flow, as supply, on a long-term average basis, but not in any given year. The Subarea rights and obligations were decreed by the Judgment. A fundamental premise of the Physical Solution is that all Parties will be allowed, subject to the Judgment, to produce sufficient water to meet their reasonable beneficial use requirements. To the extent that production by a Producer in any Subarea exceeds such Producer's share of the Free Production Allowance of that Subarea, Watermaster will provide replacement water to replace such excess production, with the Producer being obligated to pay for such "replacement" water at the current replacement water rate. To the extent that any Subarea incurs a Makeup Obligation, Watermaster will provide supplemental water to satisfy such Makeup Obligation at the current makeup water rate.

III.

NECESSITY FOR ADJUSTMENT

Pursuant to the gradual Rampdown required in the Judgment, by the 1997-98 Water Year, each producer's FPA was set at eighty percent (80%) of that producer's BAP specified by the Judgment. Exhibit H of the Judgment requires Watermaster to recommend a decrease in the FPA for a Subarea when that Subarea's FPA exceeds its estimated Production Safe Yield (PSY) by five percent (5%) or more. Pursuant to Paragraph 24(o) of the Judgment, the Watermaster is required to make a recommendation to the Court for adjusting the FPA of each Subarea, if necessary.

The Watermaster Engineer has tracked and calculated consumptive use within the five Subareas on an annual basis. The Court in its hearing of July 6, 2018, and Status Conference of October 12, 2018, asked that the Watermaster Engineer complete the update to consumptive use and any other necessary updates to the Production Safe Yield elements. In 2019, the Watermaster Engineer completed an update to Production Safe Yield and Consumptive Use for each Subarea at the court's request (filed May 1, 2019). Previously, PSY was updated in August 2000. The report provided the basis for Watermaster's recommendations for Water Year 2019-20 and for future recommendations.

On June 9, 2023, the court entered its orders on Watermaster's Motion to Adjust FPA for Water Year 2023-24 (attached as Exhibit A). As a result, FPA for Water Year 2023-24 was set as follows:

Subarea	**2022-23 FPA**
Alto	50.4% of BAP
Baja	20.5% of BAP
Centro	55% of BAP
Este	55% of BAP
Oeste	50% of BAP

IV.

RECOMMENDED ADJUSTMENTS TO FPA FOR WATER YEAR 2024-25

The Watermaster conducted public hearings on February 28, 2024, and March 27, 2024, held separate workshops in each of the five subareas (flyers attached as Exhibit B), and adopted the FPA recommendations for the five Subareas for Water Year 2024-25, as required by the Judgment and consistent with previous direction from the court, as follows:

Subarea	**2024-25 FPA Recommendation**
Alto	53.3% of BAP
Baja	20.5% of BAP
Centro	60% of BAP
Este	50% of BAP
Oeste	50% of BAP

The table on page 38, Chapter 5, of the Thirtieth Annual Report of the Mojave Basin Area Watermaster shows the BAP, the FPA for 2023-24, the estimated PSY, the difference between them as a percentage of BAP as well as the 2022-23 Verified Production for each Subarea.

The basis of the recommendation for each Subarea is described in the declaration of Robert C. Wagner, Watermaster Engineer attached as Exhibit C.

Watermaster received and considered oral comments and correspondence from the Department of Fish and Wildlife, Golden State Water Company, and other producers within the Subareas. The written comments received by Watermaster during its public hearings in February and March are attached as Exhibit D.

V.

QUANTIFYING PRODUCTION NOT UNDER THE JUDGMENT

Pursuant to the Court's suggestion, Watermaster filed an action in the San Bernardino Superior Court (CIVSD2218461), which has been coordinated with this Action, to name as defendants therein additional persons who are believed to be producing within the Basin more than 10 acre-feet of groundwater annually, or who are using Basin groundwater for the unlawful cultivation of cannabis. The purpose of that action is to enjoin use of Basin groundwater to facilitate or support unlawful activity, and to determine and regulate the groundwater rights of persons identified as producing more than 10 acre-feet of Basin groundwater annually.

VI.

RELATED MWA ACTIVITIES

In April of 2022, the MWA authorized development of a policy to guide decisions for importation of supplemental water supply into the basin area for management purposes. The policy was adopted in August 2023. Funding for water purchases was included in MWA's budget for 2023-24. Prior to finalization of the plan, the MWA authorized up to 5,000 acre-feet to be delivered to the Centro Subarea for supply augmentation. A large amount of imported water (73,243 acre-feet) was also delivered between February and September 2023 for additional water supply storage in the Basin area.

In April 2022 , the MWA adopted Ordinance No. 14 for the administration of minimal producer wells permitted on or after July 1, 2022. This Ordinance requires that those with approved permits on or after July 1, 2022 pay for one acre-foot of water to replenish the Basin area. Additionally, the Ordinance provides that minimal producers production shall be confined to the parcel on which the water production facility exists, that sale or transfer of pumped water off the property or parcel is prohibited and such minimal producer's status would be conveyed or transferred to the new owner on any sale or alienation of the property or parcel. The program has been established and billing for water replacement began in July 2023, pursuant to this Ordinance.

MWA has begun evaluating the feasibility of a large-scale Groundwater Banking Program. The technical study will evaluate water banking alternatives and associated necessary capital improvements, financial benefits and implications, Basin effect, environmental permitting requirements, coordination with the Judgment and other technical issues associated with initiating a groundwater bank are being studied. Work began in February 2020 and will be a multi-year study.

Geotechnical and geohydrology investigations in the upper Alto, Oeste and western Este Subareas continued, and will provide better information and data to use in determining the best locations for future off-river recharge basins. Demonstration groundwater recharge facilities in the upper Alto, Oeste and Este Subareas have been developed on sites owned by MWA. In 2020 MWA recharged 15 acre-feet of water into the Este Subarea during the demonstration. Grant funding was obtained in 2022 to build a larger more permanent recharge site in the Este Subarea. Two monitoring wells were installed in the west Victorville area to help characterize the subsurface geology and provide permanent high-quality groundwater monitoring data points, and two similar wells were installed in Oeste and one additional well will be installed in Este. Each of these studies will characterize surface infiltration rates, subsurface hydrogeologic zones and properties, groundwater levels, hydraulic properties and alluvial sediments of the aquifer as well as identify favorable areas for recharge facilities and help assess the regional suitability of the projects. The Agency’s groundwater model for the upper Mojave River Basin was completed as part of these ongoing investigations. Additional modeling work will continue for the middle Mojave region starting in 2024-25.

MWA purchased 10 new weather stations in 2022, to be installed throughout its service area and also funded USGS to install 2 new stream gaging locations along the Mojave River at Hodge in the Centro Subarea and at Daggett in the Baja Subarea. Additional stream gages have been authorized and will be installed in 2024-25. These new gages and stations will greatly augment MWA's already extensive network for monitoring of natural supply for basin management purposes.

MWA is undergoing a master planning process to guide future decisions for growth and development and to maximize the efficiency of regional resources. The plan will assess existing facilities and local planning documents, develop master planning objectives for projects and purchases, analyze MWA's water supply portfolio, and evaluate for risk mitigation. The Master Plan work began in March 2023 and will be a multi-year study.

VII.

<u>CONCLUSION</u>

Any delay in implementation of the Judgment will jeopardize the Mojave Basin Area sustainability. The Judgment continues to provide the mechanism through the Physical Solution and Rampdown to achieve a sustainable water supply in the Mojave Basin Area. A substantial amount of investment by all parties to the Judgment has occurred over the last 30 years. The Mojave Water Agency, in support of the Physical Solution, constructed water supply facilities for delivering and storing water from the State Water Project (SWP) to meet needs in every Subarea. These include 14 recharge facilities and two major pipelines nearly 150 miles in length. The Physical Solution will work under the Judgment if implemented to its fullest extent. The only solutions to chronic overdraft and to achieving sustainability are to purchase imported water or reduce pumping. In order to achieve and maintain balance in each Subarea, further Rampdowns in all Subareas will be considered by the Watermaster annually. Droughts will continue to affect basin supplies and the availability of imported water from the SWP in the future, although the recent storm activity and MWA's increased State Water Project water allocation this year (which will make additional supplemental water available) gives reason for some cautious optimism.

Based upon the foregoing and the Declaration of Robert C. Wagner, filed concurrently herewith, and the court's prior rulings, Watermaster requests that the Court grant this motion and implement the recommended FPA for each Subarea as follows:

(1) **ALTO:** Set FPA in Alto at 53.3% of BAP

(2) **BAJA**: Set FPA in Baja at 20.5% of BAP

(3) **CENTRO**: Set FPA in Centro at 60% of BAP

(4) **ESTE**: Set FPA in Este at 50% of BAP; and

(5) **OESTE**: Set FPA in Oeste at 50% of BAP.

Dated: May 1, 2024

BRUNICK, McELHANEY & KENNEDY PLC

BY: ____________________

WILLIAM J. BRUNICK, ESQ.
LELAND P. McELHANEY, ESQ.
Attorneys for Defendant/Cross-Complainant,
MOJAVE WATER AGENCY

EXHIBIT A

SUPERIOR COURT OF THE STATE OF CALIFORNIA, COUNTY OF RIVERSIDE

CASE TITLE: Mojave Basin Water Cases / City of Barstow v. City of Adelanto	Department 1	FILED SUPERIOR COURT OF CALIFORNIA COUNTY OF RIVERSIDE
CASE NO.: JCCP5265 / CIV208568		JUN 09 2023
DATE: June 9, 2023		L. Howell

PROCEEDING: Ruling on the Watermaster's Annual Motion to Adjust Free Production Allowance for Water Year 2023-2024; Order to Watermaster

Watermaster's Motion to Adjust FPA

The City of Hesperia's request for judicial notice is granted as to Exhibits A and B, but otherwise denied.

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

Este:

The FPA (12,523) greatly exceeds the PSY (4,728). The Watermaster recommends that the FPA be reduced from 60% of BAP to 55%.

The Court adopts that recommendation. The verified production does not currently exceed PSY, and thus the area is not currently being overdrafted. However, the FPA should be ramped down now so that, if production increases in the future, the FPA will be low enough to ensure that any producer exceeding PSY will the charged for that excessive production.

The Court orders that the FPA for all producers in Este shall be reduced to 55% of BAP for Water Year 2023-2024.

Oeste:

The FPA (4,011) greatly exceeds the PSY (1,712). The Watermaster recommends that the FPA be reduced from 55% of BAP to 50%.

The Court adopts that recommendation. The verified production does not currently exceed PSY, and thus the area is not currently being overdrafted. However, the FPA should be ramped down now so that, if production increases in the future, the FPA will be low enough to ensure that any producer exceeding PSY will the charged for that excessive production.

The Court orders that the FPA for all producers in Oeste shall be reduced to 50% of BAP for Water Year 2023-2024.

Centro:

The FPA (31,260) greatly exceeds the PSY (21,088). The Watermaster recommends that the FPA be reduced from 60% of BAP to 55%.

The Court adopts that recommendation. The verified production does not currently exceed PSY, and thus the area is not currently being overdrafted. However, the FPA should be ramped down now so that, if production increases in the future, the FPA will be low enough to ensure that any producer exceeding PSY will the charged for that excessive production.

The Court orders that the FPA for all producers in Centro shall be reduced to 55% of BAP for Water Year 2023-2024.

Baja:

The FPA (12,213) marginally exceeds the PSY (12,189). The Watermaster recommends that FPA continue at 20.5% of BAP.

The Court adopts that recommendation. The Court orders that the FPA for all producers in Baja shall be 20.5% of BAP for Water Year 2023-2024.

Alto:

The FPA (64,337) exceeds both the previously set PSY (64,406) and the Watermaster's revised PSY (59,409). The Watermaster recommends that the FPA be reduced from 54.4% of BAP to 50%.

The Court adopts that recommendation in part. As the Court noted in 2022, the PSY for Alto is clearly incorrect, since the subarea had experienced 51,016 acre feet of groundwater depletion in 2020-2021 even though the estimated PSY was only slightly less than the FPA. Accordingly, the Court ordered the Watermaster to re-evaluate the PSY. The Watermaster has done so, albeit on the basis of what it labels a preliminary analysis.

In opposing the recommendation, the Victorville Water District raises three criticisms. The Court does not find any of them to be persuasive.

First, it criticizes the reliance upon estimates rather than "actual data." To the Court's understanding, all calculations of PSY are estimates. PSY is incapable of precise determination, and certainly cannot be confidently predicted for the coming year. Whether measuring the current conditions or the conditions as they may exist in the future, all determinations of PSY are estimates. As conditions change, those estimates must be revised.

Second, it urges the Court to wait until the analysis of the PSY in Alto and the other subareas is completed in December of this year. The Court declines to wait, for three reasons. (1) Mr. Wagner indicated that, although there is additional analysis to be done between now and December of 2023, he does not expect his final estimate of PSY to change materially from the preliminary estimate. (2) The Watermaster indicated that the accuracy of the revised PSY may not be known for another five years. (3) In the Court's mind, waiting for more precise information is not a viable action, because Alto's groundwater continues to be depleted. In water year 2021-2022, the subarea lost another 33,383 in groundwater storage. (29th Annual Report, p. 31, table 3.2.) Although Mr. Wagner estimates that the extraordinary precipitation in December of 2022 and in January and February of 2023 will result in 100,000 acre feet of recharge in Alto, the trend over the last 12 years has been one of continued depletion of groundwater. The Alto subarea can ill afford to simply maintain the status quo until a more complete analysis is possible. The status quo is one in which the subarea continues to lose tens of thousands of acre feet of groundwater storage per year. Finally,

Third, VWD asserts that, even under the new PSY, the spread between the current FPA and the recommended FPA is less than five percent, and therefore an adjustment in FPA is "not necessary." The VWD confuses when the Watermaster is *required* to recommend a reduction with when the Watermaster *may* recommend a reduction. That the judgment does not require the Watermaster to recommend an adjustment to FPA does not mean that it is precluded from doing so, or that the Court cannot consider that recommendation.

The City of Hesperia also opposes the proposed reduction of PSY. It argues that the decision should be deferred until the "atmospheric river events during 2022-2023" can be addressed by the Watermaster. But as Hesperia acknowledges, the Watermaster addressed that in the motion itself, concluding that one wet winter does not overcome the effects of the prolonged drought. And although the Court accepts Hesperia's observation that this year's rains provide "the Watermaster and MWA with substantial access to replacement water," the availability of imported water is not a factor affecting PSY.

Hesperia also urges the Court to defer any further rampdown until the Watermaster has completed its re-evaluation of PSY and has considered four other factors. For the same reasons as described above in response to the VWD's objections, the Court is not persuaded. In light of the continuing depletion of Alto's groundwater, the Court finds that the most prudent course of conduct is to act sooner rather than later. While the information available to the Court may not be perfect, it is the best evidence available at the present time. Moreover, it is not contradicted by any evidence cited by Hesperia.

Hesperia asserts that the Watermaster is failing to "take into account all available hydrologic data." It is not clear what currently existing data Hesperia claims is being overlooked. For instance, when discussing R-Cubed, Hesperia does not claim that relevant data currently exists. Instead, it says that any ruling on the rampdown recommendation should be continued "until such time as the Watermaster can conduct further studies to determine the impact of the R-Cubed project . . . ."

Hesperia also asserts that "[t]he Watermaster has failed to manage the Basin in accordance with the Judgment" because "the Watermaster did not deliver imported water as it was obliged to do." If that is the case, Hesperia is free to bring a motion to instruct the Watermaster, or even to replace the Watermaster. However, no such motion is before the Court at the present time.

The objections of Mitsubishi, Robertson's, and CalPortland are largely subsumed within the arguments presented by Hesperia.

Because the re-evaluation of PSY is not final, and because there is a chance that the final PSY could be slightly higher, the Court declines to adopt the full amount of the rampdown recommended by the Watermaster, 4.4%. Instead, the Court will impose a rampdown of 90% of that figure. Accordingly, The Court orders that the FPA for all producers in Alto shall be 50.4% of BAP for Water Year 2023-2024. That order is made without prejudice to a motion by any party to modify either the PSY, the FPA, or both after December 1, 2023.

The Court acknowledges that the Watermaster proposes to hold the FPA for Alto at 50% for the next five years. No decision on that recommendation is necessary until next year. The Court will evaluate that recommendation at that time.

Other Orders

1. In its Supplemental Report filed 5-1-23, the Watermaster described its unsuccessful attempts to persuade the County of San Bernardino to imposes conditions on the issuance of well permits, such as a requirement that the permittee be required to install a measuring device. It encouraged the Court to address the issue with the County, which is a party to the action. In response to the Court's question, counsel for the Watermaster opined that the Court has the power under the the Judgment to order the County to impose such a requirement. The County denied that the Court has such authority.

To explore that issue, the Watermaster is ordered to prepare and file a motion for an order directing the County to impose that or similar conditions. The motion shall be supported by a memorandum explaining (1) the Court's authority to require the County to exercise its permitting discretion in a particular way, and (2) why it is appropriate to exercise that authority by issuing the particular order proposed by the Watermaster. The hearing on such a motion shall be scheduled for a date no earlier than September 11, 2023, in Department 1.

2. The order coordinating the City of Barstow v. City Adelanto with the Mojave Water Agency v. All Persons was filed in JCCP5265 on 2-17-23, and an order

assigning Craig Riemer of the Riverside Superior Court as the coordination trial judge was filed 4-4-23 and served on the Watermaster. As yet, no portion of the file in the San Bernardino Superior Court has been received by Riverside Superior Court. Counsel for the Watermaster is ordered to file a notice of coordination in Mojave Water Agency v. All Persons, San Bernardino Superior Court Case Number CIVSB2218461. The notice shall attach copies of the 2-17-23 and 4-4-23 orders and shall provide notice of the following portion of this order:

Pursuant to the Order Granting Petition for Coordination in JCCP5265, by which San Bernardino Superior Court Case Number CIVSB2218461 has been coordinated in case JCCP5265, and the Order Assigning Coordination Trial Judge, by which Judge Craig G. Riemer of Riverside Superior Court has been appointed as the coordination trial judge, IT IS ORDERED that San Bernardino Superior Court Case Number CIVSB2218461 be transferred to Riverside Historic Courthouse, Department 1, for all purposes. Case JCCP5265 is designated the master file.

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

Craig G. Riemer

Craig G. Riemer, Judge of the Superior Court

EXHIBIT B

MOJAVE BASIN AREA WATERMASTER

ESTE SUBAREA WORKSHOP

Discussion of the Re-evaluation of Production Safe Yield and the proposed Free Production Allowance for Water Year 2024-25

March 13, 2024
10:00 - 11:00 a.m.

Mojave Water Agency Office
13846 Conference Center Drive
Apple Valley, California 92307
760-946-7000
Website: www.mojavewater.org

The Watermaster is providing an opportunity for Este parties to ask questions and better understand the re-evaluation of Production Safe Yield ordered by the Court. Additionally, the proposed adjustment to Este Free Production Allowance for Water Year 2024-25 will be discussed, which is currently being circulated for comment by the Watermaster.

Interested parties are encouraged to participate in this "in-person" informal workshop along with MWA and Watermaster staff.

If you have any questions, please feel free to contact the Watermaster at 760-946-7000.

MOJAVE BASIN AREA WATERMASTER

OESTE SUBAREA WORKSHOP

Discussion of the Re-evaluation of Production Safe Yield and the proposed Free Production Allowance for Water Year 2024-25

March 13, 2024
11:00 a.m. - 12:00 p.m.

Mojave Water Agency Office
13846 Conference Center Drive
Apple Valley, California 92307
760-946-7000
Website: www.mojavewater.org

The Watermaster is providing an opportunity for Oeste parties to ask questions and better understand the re-evaluation of Production Safe Yield ordered by the Court. Additionally, the proposed adjustment to Oeste Free Production Allowance for Water Year 2024-25 will be discussed, which is currently being circulated for comment by the Watermaster.

Interested parties are encouraged to participate in this "in-person" informal workshop along with MWA and Watermaster staff.

If you have any questions, please feel free to contact the Watermaster at 760-946-7000.

MOJAVE BASIN AREA WATERMASTER

BAJA SUBAREA WORKSHOP

Discussion of the Re-evaluation of Production Safe Yield and the proposed Free Production Allowance for Water Year 2024-25

March 13, 2024
12:30 - 1:30 p.m.

Mojave Water Agency Office
13846 Conference Center Drive
Apple Valley, California 92307
760-946-7000
Website: www.mojavewater.org

The Watermaster is providing an opportunity for Baja parties to ask questions and better understand the re-evaluation of Production Safe Yield ordered by the Court. Additionally, the proposed adjustment to Baja Free Production Allowance for Water Year 2024-25 will be discussed, which is currently being circulated for comment by the Watermaster.

Interested parties are encouraged to participate in this "in-person" informal workshop along with MWA and Watermaster staff.

If you have any questions, please feel free to contact the Watermaster at 760-946-7000.

MOJAVE BASIN AREA WATERMASTER

ALTO - CENTRO SUBAREA WORKSHOP

Discussion of the Re-evaluation of Production Safe Yield and the proposed Free Production Allowance for Water Year 2024-25

March 14, 2024
1:30 - 2:30 p.m.

Mojave Water Agency Office
13846 Conference Center Drive
Apple Valley, California 92307
760-946-7000
Website: www.mojavewater.org

The Watermaster is providing an opportunity for Alto and Centro parties to ask questions and better understand the re-evaluation of Production Safe Yield ordered by the Court. Additionally, the proposed adjustment to the Alto and Centro Free Production Allowance for Water Year 2024-25 will be discussed, which is currently being circulated for comment by the Watermaster.

Interested parties are encouraged to participate in this "in-person" informal workshop along with MWA and Watermaster staff.

If you have any questions, please feel free to contact the Watermaster at 760-946-7000.

EXHIBIT C

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Attorneys for Defendant/Cross-Complainant
MOJAVE WATER AGENCY

NO FEE PER GOV'T. CODE SEC. 6103

SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF RIVERSIDE

Coordination Proceeding Special Title (Cal. Rules of Court, rule 3.550) MOJAVE BASIN WATER CASES CITY OF BARSTOW, et al., Plaintiff, vs. CITY OF ADELANTO, et al., Defendant, AND RELATED CROSS ACTIONS	JCCP NO.: 5265 Lead Case No.: CIV 208568 Dept. 1, Riverside Superior Court Hon. Harold W. Hopp, Judge Presiding **DECLARATION OF ROBERT C. WAGNER, P.E. IN SUPPORT OF MOTION TO ADJUST FREE PRODUCTION ALLOWANCE FOR WATER YEAR 2024-2025** Assigned for All Purposes to: Hon. Harold W. Hopp, Judge Presiding **DATE: June 4, 2024** **TIME: 8:30 AM** **DEPT: 1** **Reservation ID: 459779359960**

I, Robert C. Wagner, declare as follows:

I am a licensed Civil Engineer in the State of California and President of the firm of Wagner and Bonsignore, Consulting Civil Engineers in Sacramento, California. A copy of my professional resume is attached as Exhibit 1 and list of sources used in support of this declaration is attached as Exhibit 2. I serve in the capacity of Engineer for the Mojave Basin Area Watermaster in performance of its duties specified on Exhibit 3. I am providing the following information in support of Watermaster's recommendations regarding Free Production Allowance (FPA) and to address other matters related to water supply use and disposal within the five Subareas. I incorporate by reference, as though fully set forth herein, my declarations and all attachments thereto that were filed with the court in this action in support of prior Motions to Adjust FPA.

In my capacity as Engineer for the Mojave Basin Area Watermaster, I have reviewed the Motion to Adjust FPA for Water Year 2024-25 and the Watermaster's Thirtieth Annual Report. Each of the facts set forth in the Motion to Adjust FPA for Water Year 2024-25 are true and correct to the best of my knowledge and I could competently testify thereto.

I have reviewed the recommended adjustments to FPA for Water Year 2024-25 set forth in the pending motion and each of the recommendations set forth therein for each of the Subareas is consistent with my opinions and recommendations as conveyed to the Watermaster. The recommendation to adjust FPA for each Subarea was presented at the February 28, 2024 and the March 27, 2024 hearings held by Watermaster as required by the Judgment. Public workshops were held for each Subarea to present information about proposed Production Safe Yield (PSY) and FPA adjustments on March 13, and 14, 2024. The presentations for the Watermaster meetings and workshops are attached as Exhibit 4.

The following table shows the current FPA for each Subarea and the PSY adopted by Watermaster.

Subarea	**Base Annual Production**	**2023-24 FPA**	**Production Safe Yield**	**Percent Difference[1]**	**2022-23 Verified Production**
Alto	116,412	59,771	62,005	-1.9%	68,751
Baja	66,157	15,414	12,749	4.0%	9,191
Centro	51,030	28,793	31,420	-5.1%	14,840
Este	20,205	11,568	6,582	24.7%	3,547
Oeste	7,095	3,667	3,634	0.5%	2,607

[1]This value represents the percent of BAP that PSY departs from FPA.

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The following is the recommended FPA for Water Year 2024-25:

Subarea	Proposed 2024-25 Free Production Allowance
Alto	53.3% of Base Annual Production
Centro	60% of Base Annual Production
Baja	20.5% of Base Annual Production
Este	50% of Base Annual Production
Oeste	50% of Base Annual Production

Alto – 53.3% of BAP

I prepared an update to the PSY for Alto (Production Safe Yield and Consumptive Use Update, February 28, 2024) included herein as Appendix A of Exhibit 5, based on output from the Upper Mojave Basin Model prepared by Mojave Water Agency. The model incorporates hydrologic data and analysis to represent the conditions in the Alto subarea for the period 1951-2020. A description of the Model and its assumptions and output is available as Appendix A-G of Exhibit 5.

Watermaster adopted findings developed from the model to establish the PSY for Alto, at its March 27, 2024 meeting.

The current estimate of PSY is 62,005 acre-feet, an increase of about 4.4% (59,409 acre-feet) over the previous estimate. Under current conditions of water supply use and disposal, and pursuant to the transfer provisions of the Judgment, we expect that Alto producers will purchase from Watermaster about 17,475 acre-feet per year to offset the annual deficit in Alto (Exhibit 5, Summary, (Table 1).

Pursuant to Exhibit H of the Judgment, if FPA exceeds PSY by 5% or more, Watermaster shall recommend a reduction equal to a full five percent of the Subarea Base Annual Production. There is no restriction for Watermaster to increase FPA, however in considering whether to increase or decrease the FPA in a Subarea, Watermaster shall, among other factors, take into consideration the areas shown on Figure H-1, the Consumptive Use of water by riparian habitat, the protection of public trust resources, including the species listed in Table H-1 and the riparian habitat areas shown on Figure H-1, and whether an increase would be detrimental to the protection of public trust resources. The UMBM, has recognized that the habitat is using about 11,000 acre-feet (Exhibit 5, Appendix G).

The model output for future conditions resulting from importing 17,475 acre-feet per year in Alto will increase water flow at the Upper Narrows at the Mojave Narrows Regional Park, increase flow through the Lower Narrows and support habitat throughout the Transition Zone, while also increasing flow downstream to Centro across the Helendale Fault. The modeling output shows that average annual flow as measured at Lower Narrows will increase by about 9,000 acre-feet per year (Exhibit 5, Appendix A, Figure 4).

Watermaster adopted the Alto PSY of 62,005 acre-feet and set the FPA at 53.3% of BAP for the 2024-25 Water Year

Centro – 60% of BAP

PSY for Centro has been reevaluated and should be set at 31,420 acre-feet (Exhibit 5, Appendix A, Table 1). The indicated FPA for Centro based on the PSY update would be 61.6% of BAP. We note that Golden State Water Company has experienced problems with its production wells in some areas due to declining water levels. We have presented Watermaster with data showing that concentrated pumping (Exhibit 6) in small, segmented aquifers along the river are depleted faster than they can be recharged through long dry periods (2012-2022 for example). Exhibit 6, was prepared by MWA personnel under my supervision.

In 2022 MWA committed to deliver 5,000 acre-feet of supplemental water as a temporary relief for Centro Producers. The storms of 2023 (199,660 acre-feet at the Forks of native water supply) and the release of about 73,000 acre-feet to the Mojave River by MWA have increased water levels downstream (Watermaster Annual Report, May 1, 2024, Figure 3-15). Water levels in this area of Centro are variable dependent on Mojave River storm flow. Due to concentrated pumping in this area by Industrial, agricultural, and municipal parties, water levels are depressed during long drought periods, and respond positively to storm events. The continuous importation of water to satisfy the annual deficit in the upstream subarea will help mitigate this and other downstream issues.

The Mojave River flows between the Alto Subarea and the Centro Subarea across the Helendale fault, just north of the community of Helendale. The TZ is the area between the Lower Narrows and the Helendale Fault and is part of the Alto Subarea. There is a subarea flow obligation between Alto and Centro of 21,000 acre-feet of surface flow and 2,000 acre-feet of subsurface flow. This obligation is to the Transition Zone (TZ). (Judgment After Trial, Exhibit G (e), page G-2) and has been met every year since entry of Judgment.

We have estimated the average annual flow at Helendale Fault to be 36,725 acre-feet per year (Exhibit 5, Appendix A, Table 1). Previous estimates of the flow at Helendale Fault have been made by the California Department of Water Resources, Bulletin 84, 1967 (35,200 AFA, 1936-1961), USGS, Stamos 2001, 1951-1999 (35,819 AFA at Vista Road near Helendale), and Webb Associates (2000), 36,700 acre-feet, indicating the estimated average annual flow at Helendale has been consistent since the 1930's.

Watermaster adopted the Centro PSY of 31,420 acre-feet and set the FPA at 60% of BAP for the 2024-25, Water Year.

Baja – 20.5% of BAP

We have updated the PSY for Baja based on a subarea wide assessment of water levels and decreases in pumping in Baja (Exhibit 5, Appendix E). Pumping has declined 75% since entry of Judgment (1996) and 60% from the 2016 level. The pumping decline since 2016 has caused some water levels to slow the historic drop, and even recover in some wells (Exhibit 5, Appendix E). This trend is likely to continue and is an indication that the PSY in Baja is close to the average amount of pumping for the past several years. Our assessment of the Baja water balance, for long term conditions and existing pumping and outflow, also suggests that Baja has reached a level of sustainability. We note that any increase in pumping in the future will likely cause water level declines.

The California Department of Fish and Wildlife (CDFW) provided comments to Watermaster addressing concerns for water loss in the Baja Subarea and water use by riparian habitat. Watermaster met with CDFW on March 11, 2024 and April 17, 2024 to discuss these concerns. CDFW objected to the characterization that water use by riparian habitat has decreased as indicated by Exhibit 5, Appendix E. Watermaster recognizes the importance of protecting the sensitive habitats in Baja and will work with CDFW to update estimates of riparian water use and identifying causes of the decline. CDFW has agreed with the recommendation to leave Baja FPA unchanged at 20.5% of Base Annual Production.

Watermaster adopted the Baja PSY of 12,749 acre-feet and set the FPA at 20.5% of BAP for the 2024-25, Water Year.

Este – 50% of BAP

PSY has been reevaluated and should be set at 6582 acre-feet. As FPA remains higher than PSY in Este, additional Rampdown is warranted. The Este water levels over a long period of time suggest there is little or no loss of storage. An evaluation of water supply and water levels is provided in the Exhibit 5, Appendix D. The UMBM indicates a loss of storage of 191 acre-feet per year for the 70-year model period of record, but an increase of 134 acre-feet per year in the 20-year base period (2001-2022). For Lucerne Valley, we note that water level changes are small and stable for many years, including some water levels showing increases. Assuming limited or no change in storage, the PSY for Este is about equal to the pumping, or about an average 5,108 acre-feet for the past 5 years and 6,582 acre-feet for the 20-year base period (2001-2022). Assuming water levels indicate lack of storage change during the past 20 plus years, the PSY might be as high as 6,582 acre-feet.

Watermaster adopted the Este PSY of 6,582 acre-feet and set the FPA at 50% of BAP for the 2024-25, Water Year.

Oeste – 50% of BAP

PSY for Oeste has been reevaluated and we recommend setting PSY equal to the average pumping for the past 5 years, 3,634 acre-feet. The water supply conditions in Oeste are not well understood, despite numerous investigations. Inflow to Oeste from Sheep Creek wash, and other local washes is unmeasured, and difficult to quantify. Water levels over time are variable but have generally fluctuated within a range. Assuming water levels are indicating little or no loss of storage, the PSY would be about equal to the pumping. Our evaluation suggests that there might be some minor loss in storage, but it isn't easily quantified (Exhibit 5, Appendix C). The UMBM indicates a loss in storage of 1,558 acre-feet per year for the past 20 years. Assuming the average pumping for the past 20 years, the PSY would be 2,983 acre-feet. However, many changes have occurred over the past 20 years that would affect the water balance. There is now only one major producer that pumps more than 90% of all the water, and exclusively for domestic and commercial uses. The current pumping in Oeste is about 2,600 acre-feet. Given the changes in land use, and pumping patterns (agriculture is no longer active) it is expected that there will be lower consumptive uses in the future. Small errors in inflow, recharge, and consumptive use could result in a lower estimate of storage loss.

While the UMBM is a tool that we plan to rely on for PSY calculations and basin management, for Oeste for 2024-25, we are suggesting that FPA remain at 50% and we continue to monitor production and water levels, consistent with recommendations we have made previously. We are continuing to gather data from local pumpers regarding water level changes in wells that are outside, but tributary to the Oeste Subarea and could represent a source of supply that is not currently captured by the UMBM and may show a reduction in the indicating deficit in Oeste.

Watermaster adopted the Oeste PSY of 3,634 acre-feet and set the FPA at 50% of BAP for the 2024-25, Water Year.

I declare under penalty of perjury, under the laws of the State of California, that the foregoing is true and correct.

Dated: May 1, 2024

Robert C. Wagner, P.E.

EXHIBIT 1

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ROBERT C. WAGNER
PROFESSIONAL RESUME

REGISTRATION:

Civil Engineer, California (License No. 52903)

EDUCATION:

B.S. Civil Engineering – California State University, Sacramento – 1988

EXPERIENCE:

Mr. Wagner is the president of Wagner & Bonsignore Engineers and is a Registered Civil Engineer in California, with 25 years experience in water resources management, water right analysis, surface and groundwater water hydrology and land use evaluations for municipal and agricultural projects. Mr. Wagner has been the court appointed engineer for the Mojave Watermaster for over 20 years and has provided expert witness testimony on various matters related to water resources and water rights in court and before the State Water Resources Control Board. Mr. Wagner has demonstrated expertise in areas of consumptive use analysis, watershed hydrology, facility design for storm water capture and analysis of return flow to support water transfers, administration of court ordered judgments and water supply sustainability.

Mr. Wagner serves a wide variety of private and public clients throughout California, managing projects from concept to implementation. Mr. Wagner's work includes pre-1914 appropriative water right investigation, analysis of riparian and overlying water rights and appropriative rights administered by the State Water Resources Control Board.

Mr. Wagner has demonstrated communication skills to work with a wide range of legal and technical professional and stakeholder groups. He has strong organizational and analytical skills and a recognized ability to provide cost effective solutions to difficult water resource problems.

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RECENT EXPERIENCE INCLUDES THE FOLLOWING:

- District Engineer for Reclamation District No. 38, Staten Island, San Joaquin County
- District Engineer for Reclamation District No. 341, Sherman Island, Sacramento County
- District Engineer for Reclamation District No. 348, New Hope Tract, San Joaquin County
- District Engineer for Reclamation District No. 800, Cosumnes River, Sacramento County
- Provide engineering consulting services on behalf of Antelope Valley East Kern Water Agency in connection with quantification of return flow from water used for irrigation and other uses.
- Provide engineering consulting services on behalf of Los Angeles World Airports in connection with quantifying water use from various sources for irrigation.
- Provide engineering consulting services on behalf of San Joaquin County in connection with water right applications and water resources management within San Joaquin County.
- Provide engineering services for Chino Basin Water Conservation District, San Bernardino County in connection with storm water recharge in Chino Basin.
- Watermaster Engineer for Orange County Water District; perform analysis of hydrologic and water quality data for the Santa Ana River Watershed for Water Year 2009-10; distinguish storm flow and base flow at Prado Dam and at Riverside Narrows, preparation of portions of the Watermaster's annual report to the Court.
- Provide engineering services for Lake Alpine Water Company / Alpine County in connection with the State Water Resources Control Board water right hearing and hydrology of South Fork Stanislaus River for State Filed Application 5648.
- Provide Engineering services for Natomas Mutual Water Company, in connection with the water rights. Evaluation of water rights for 51,000 acres of agricultural operation, water right analysis and water transfers.
- Provide engineering services on behalf of City of Sacramento in connection with the Water Resources of the American River.

- Provide engineering services on behalf of City of Ukiah in connection with water rights and hydrology of the Russian River, Mendocino County.

- Provide engineering services on behalf of Sonoma County Water Agency in connection with development of agricultural reuse project for use of treated wastewater for vineyard irrigation.

- Provide engineering services in connection with analysis of water production and hydrologic data for development of water use agreements for over 100 growers in the Dry Creek Valley in Sonoma County.

- Provide engineering services for City of Santa Maria in connection with the hydrologic resources of the Santa Maria Groundwater Basin.

- Engineering expert in the matter of Bonadiman v. Evans in San Bernardino Superior Court on behalf of prevailing party Evans. Research and documentation of water development and water right acquisition dating to 1883.

- Provide engineering services for The Wildlands Conservancy in connection with water resource matters for extensive land holdings in San Bernardino and Kern Counties.

- Provide engineering services for Wells Fargo Bank in connection with the analysis of water rights and water availability on the Kern River.

- Watermaster Engineer for the Mojave Basin Area Watermaster in the matter of the Mojave River Adjudication, City of Barstow, et al, vs. City of Adelanto, et al. Collection and analysis of data for preparation of Annual Watermaster Report, including groundwater production and hydrology studies of the Mojave River System and groundwater basin in connection with storm flow base flow separation determination and the analysis of water transfers and land use changes. Preparation of Annual Watermaster report.

- Provide engineering services on behalf of the Mojave Water Agency in connection with Mojave Basin Area Adjudication. Coordinate activities for professional and sub-professional staff for collection, analysis and verification of water production records for approximately 7,000 wells in the Mojave River Basin. Participate in meetings of the Joint Engineer-Attorney Drafting Committee formed to negotiate and draft the Stipulated Judgment. Participation in the drafting and ongoing revisions of the Watermaster Rules and Regulations.

- Provide engineering services in connection with for the Warren Valley Basin Watermaster, San Bernardino County. Analysis of groundwater production records and basin hydrology for preparation of Annual Watermaster Report.

- Provide engineering services in connection with work for East Valley Water District, San Bernardino County, regarding the analysis of surface and subsurface hydrology of the Santa Ana River and the availability of water for the Seven Oaks Dam Project and fully appropriated listing of the Santa Ana River.

- Provide engineering services on behalf of Kirkwood Associates before the State Water Resources Control Board in the matter of South Fork American River Hearings, October 1995. Analysis of the South Fork American River and Caples Creek hydrology in connection with same.

- Provide engineering services in connection with work for High Desert Water District, San Bernardino County, regarding the analysis of water quality and ground water elevation data for monitoring the potential impacts of ground water extractions from the Ames Valley Basin.

- Provide engineering services in connection with work for Hidden Valley Lake Community Services District, Lake County, regarding the hydrologic analysis of Upper Putah Creek Watershed and the Coyote Valley groundwater basin in support of amendments to fully appropriated stream status and applications to appropriate surface and subsurface water from Putah Creek; continued monitoring of the Coyote Valley groundwater basin in connection with administration of water rights.

CONTINUING EDUCATION:

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"California Water Law", University of California, Davis - November 1989 to January 1990

"Understanding Wetlands and 404 Permitting", ASCE July 1997

"Fundamentals of Water Rights and Colorado River Issues", University of Nevada, Las Vegas January 1998

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EXHIBIT 2

EXHIBIT 2

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- Oeste Hydrologic Sub-Area Hydrogeologic Report, California State University, Fullerton, Laton, W.R., Foster, J., Blazevic, M., Velarde, J., and Cruikshank, M., (2009)
- 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, Thomas Harder & Co., (2010)
- Status Update, Oeste Subarea Managed Aquifer Recharge (MAR) Feasibility Studies: unpublished consultant's presentation to Mojave Water Agency, Todd Groundwater and Applied Geoscience and Engineering (AGE), (2020)
- Groundwater Quality of the Lucerne Groundwater Basin, California: United States Geological Survey, Open File Report 2022-1063, (2022)
- Technical Memorandum; Upper Mojave River Basin Groundwater Model Update – TM-1: Data Review and Analysis (Final): Consultant's report to the Mojave Water Agency, Geoscience Support Services, Inc., (2020)
- Ground-Water Conditions and Potential for Artificial Recharge In Lucerne Valley, San Bernardino County, California, United States Geological Survey, Water-Resources Investigation 78-118, (1979)
- Geohydrology and Simulation of Groundwater Flow in the Lucerne Valley Groundwater Basin, California, United States Geological Survey, Scientific Investigations Report 2022-5048, (2020)

- Groundwater Quality Evaluation at the Lucerne Valley Land Discharge Location: unpublished consultant's report to the Big Bear Area Regional Wastewater Agency, Thomas Harder & Co. Groundwater Consulting, (2017)
- Findings and Preliminary Conclusions, Soil Moisture Study, Mojave Water Agency Sites: unpublished report to the Mojave Water Agency, Wagner & Bonsignore Consulting Civil Engineers, (2015)
- Update of Este Subarea Water Budget: unpublished draft report to Mojave Basin Area Watermaster, Wagner & Bonsignore Consulting Civil Engineers, (2016)
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- Big Bear Area Regional Wastewater Agency Draft Irrigation Management Plan: unpublished consultant's report to the Colorado River Basin Regional Water Quality Control Board, Water Systems Consulting, Inc., (2016)
- 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, Allen, R., Irmak, A., Trezza, R., Hendrickx, JMH., Bastiaanssen, WGM., & Kjaersgaard, J. (2011)
- Project Completion Report – Integrated Surface Water / Groundwater Model, Upper Mojave River Basin, Apple Valley, CA, Wood (2021)
- Upper Mojave River Basin Groundwater Model, Kapo Coulibaly PhD, P.G., Mojave Water Agency, (2024)
- Production Safe Yield & Consumptive Use Update, Wagner & Bonsignore, Engineers, (2024)

EXHIBIT 3

EXHIBIT 3

Duties of the Watermaster and Engineer as outlined in the Judgment

MWA was appointed as the initial Watermaster and has duties separate from the Court Appointed Watermaster. MWA Obligations under the Judgment are specified in paragraph 9.0 as follows:

"The Physical Solution is intended to provide delivery and equitable distribution to the respective Subareas by MWA of the best quality of Supplemental Water reasonably available. MWA shall develop conveyance or other facilities to deliver this Supplemental Water to the areas depicted in Exhibit "I" unless prevented by forces outside its reasonable control such as the inability to secure financing consistent with the sound municipal financing practices and standards. "

MWA's obligations under the Judgment relate to purchasing, importing and recharging the groundwater basin with supplemental water. MWA has engaged in various activities since implementation of the Judgment to meet this obligation including acquisition of additional State Water Project Entitlement and development of conveyance, recharge and extraction facilities, and the financing of those facilities.

Watermaster's powers and duties are specified in Paragraph 24 (a) through (x) and include all of the data collection and analyses and functions reported to Court in the Watermaster Annual Reports. The engineer is responsible to Watermaster and the Court to ensure that requirements as set forth in 24 (a) through (x) are carried out as intended and consistent with the Physical Solution embodied in the Judgment. The activities described in this declaration are a result of Watermaster exercising its obligations under the Judgment. The Watermaster staff and the engineer's duties on behalf of Watermaster include some or all of the following annually:

- Interpret and enforce the Rules and Regulations
- Calculate Subarea Make Up Obligations, and Producer Replacement Water Obligations
- Evaluate various methods of monitoring and measuring and work with producers to ensure production data is reliable
- Collect and evaluate Hydrologic, and Climate data, and monitor and evaluate phreatophyte consumptive use
- Prepare detailed producer consumptive use analyses for estimating supply to the basin from return flows of production
- Evaluate crop water requirements and various categories of water use
- Evaluate and process transfers for producers
- Maintain a database of individual producers water use, property location, wells, water production, etc.
- Calculate individual assessments as required by the Judgment
- Hold public hearings as required
- Calculate Free Production Allowance and make recommendations for adjustments
- Prepare annual report the Court on the above and all matters as delineated in Paragraph 24 (a) through (x) of Judgment.

EXHIBIT 4

Production Safe Yield Update and Proposed Free Production Allowance (2024-2025)

February 28, 2024
Robert C. Wagner

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield Update

- Production Safe Yield Update, Base Period, Safe Yield Year
- Upper Mojave Basin Model (UMBM)
- Table 5-1 Alto, Centro, Baja
- Future Model Scenario
- Subarea Conditions
  - Historic Water Levels (1964)
    - Barstow area and Waterman Fault
- FPA Recommendations

Production Safe Yield
Judgment after Trial 1996

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

(1) Production Safe Yield

- Base Period
  - Over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea
  - 1931-1990 set by the judgment
- Proposed Base Period
  - 2001-2020

(2 & 3) Production Safe Yield

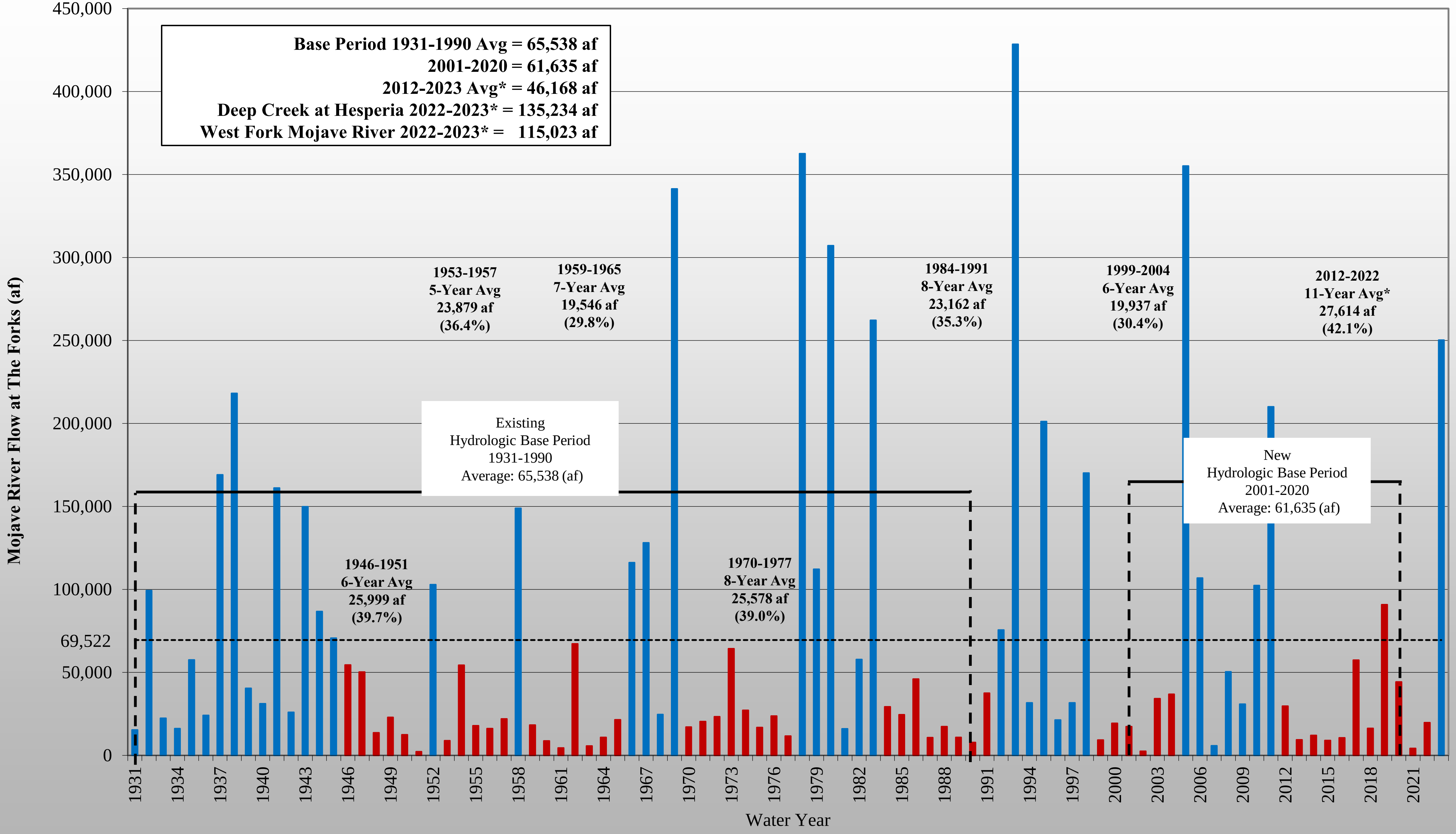
- Safe Yield Year
  - (2) Under given patterns of Production, applied water, return flows and Consumptive Use (Cultural Conditions)
    - Assumed by the Judgment to be 1990 land use conditions
    - Previously 1997-1998, 2017-2018
    - Proposed 2022
  - Cultural conditions are assumed to be reasonably representative of future conditions (evaluated periodically)
  - (3) Without resulting in a long-term net reduction of groundwater in storage in the Subarea
- PSY = Production + Change in Storage

Production Safe Yield

- Base Period from Department of Water Resources Bulletin 84 (1967)
- 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.

* Preliminary data, subject to revision.

Mojave River Flow at The Forks
Water Years 1931 - 2023



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.

Estimated Pumping 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	64,986	61,033	64,129	69,593	67,232	62,354	64,888
TZ	12,700	11,939	12,618	11,809	10,914	10,039	11,670
Alto Total	77,686	72,972	76,747	81,402	78,146	72,393	76,558
Baja	24,524	23,389	20,912	15,095	12,579	11,343	17,974
Centro	20,665	19,784	18,309	19,685	16,983	16,392	18,636
Este	5,055	4,983	5,181	5,258	5,068	4,501	5,008
Oeste	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

Estimated Consumptive Use 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	34,001	30,386	33,489	37,871	33,745	31,927	33,570
TZ	7,913	7,294	8,052	7,301	7,375	6,859	7,466
Alto Total	41,914	37,680	41,541	45,172	41,120	38,786	41,035
Baja	24,002	22,611	20,144	13,589	12,025	10,834	17,201
Centro	16,451	15,094	14,044	14,035	12,748	12,279	14,108
Este	3,827	3,634	4,116	4,377	4,388	3,812	4,026
Oeste	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

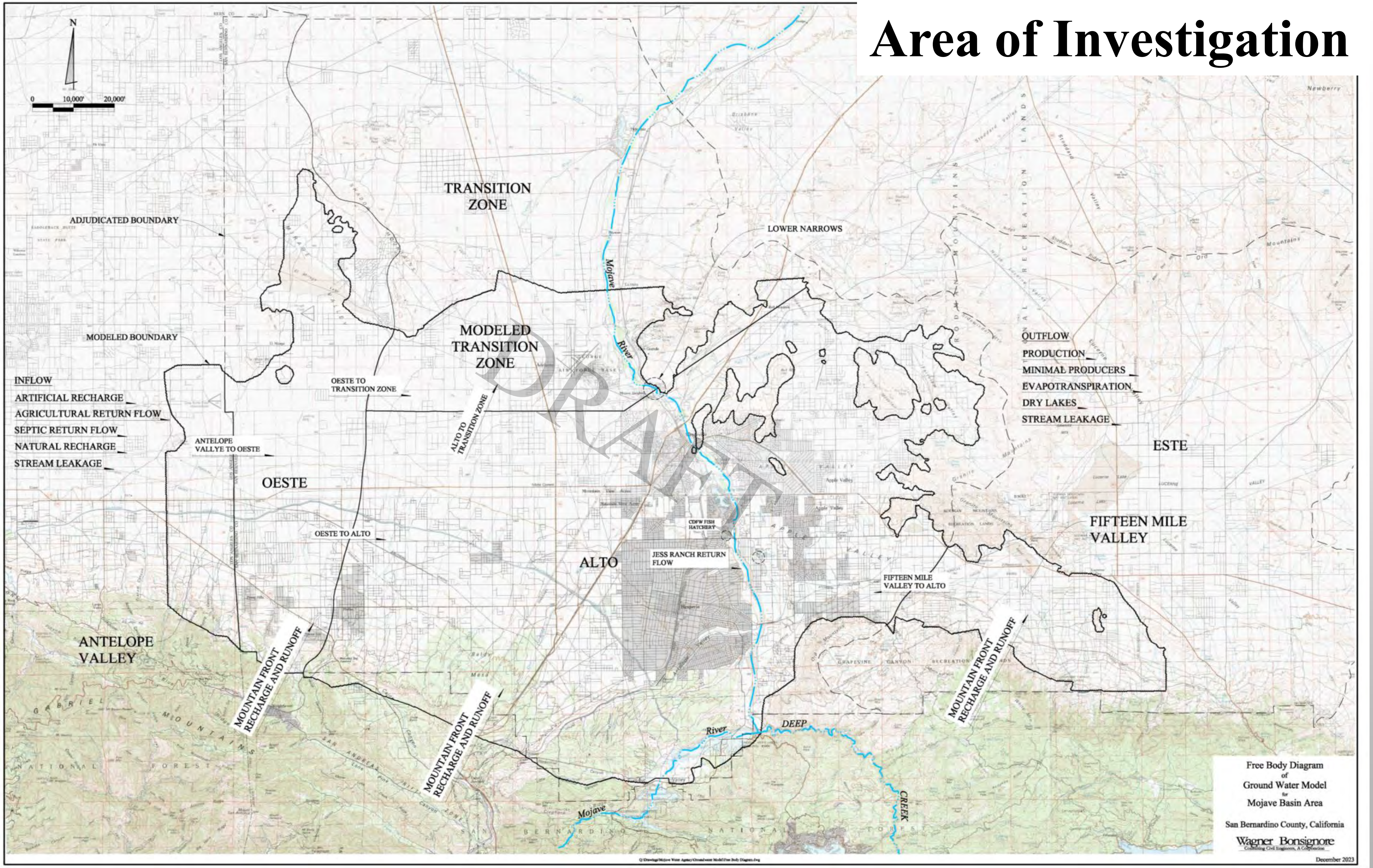
Safe Yield Year

Mojave Basin Groundwater Models

- Earlier versions of the Model
  - Hardt, USGS 1971 (Analog)
  - Stamos, USGS 2001 (MODFLOW)

- Upper Mojave Basin Model
  - Coulibaly, Kapo MWA 2023 (MODFLOW)

Area of Investigation



Alto (Above Lower Narrows)

Upper Mojave Basin Model Change in Storage

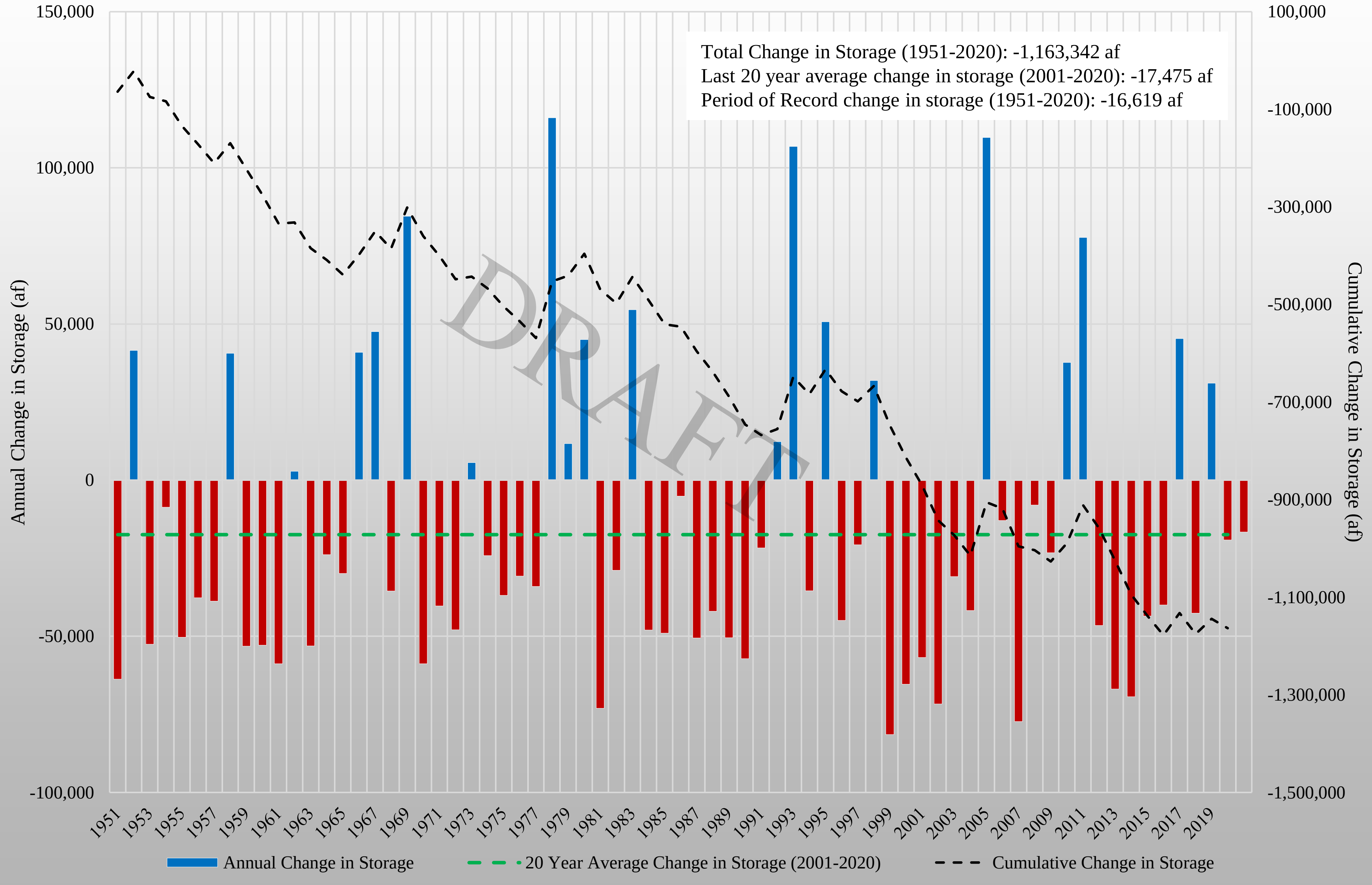


Table 5-1

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
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**

Comparison: Model Output and Table 5-1 (Alto Subarea)

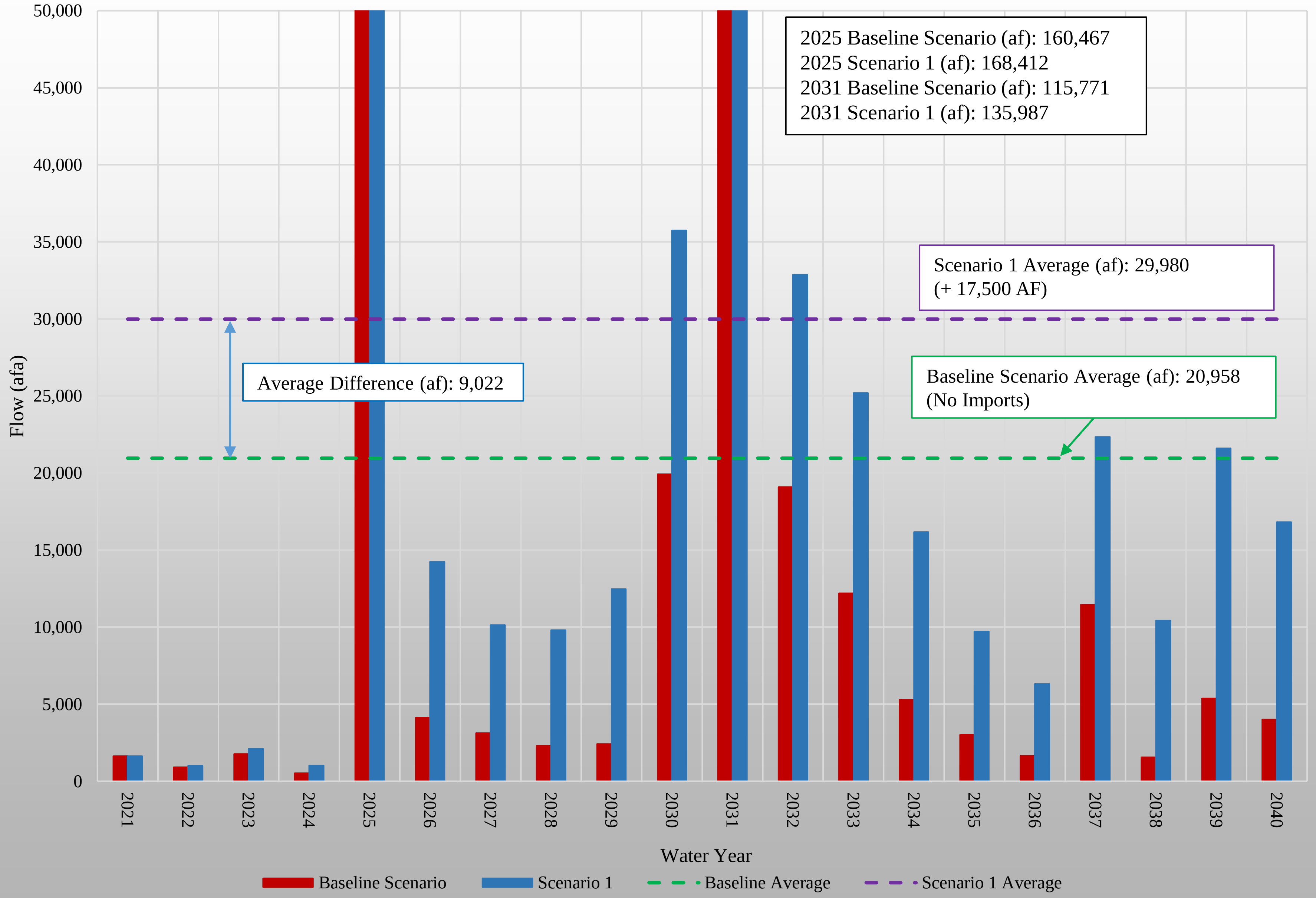
Production Safe Yield Based on Model Output and 2021-2022 Current Year Pumping and Consumptive Use (Alto Subarea)	
Alto above Narrows Production Average 2001 - 2020 (acre-feet)	81,968
2001 - 2020 Average Alto B2 Pumping (acre-feet)	14,118
Alto above Narrows B1 Pumping (acre-feet)	67,850
TZ (2001 - 2020) 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

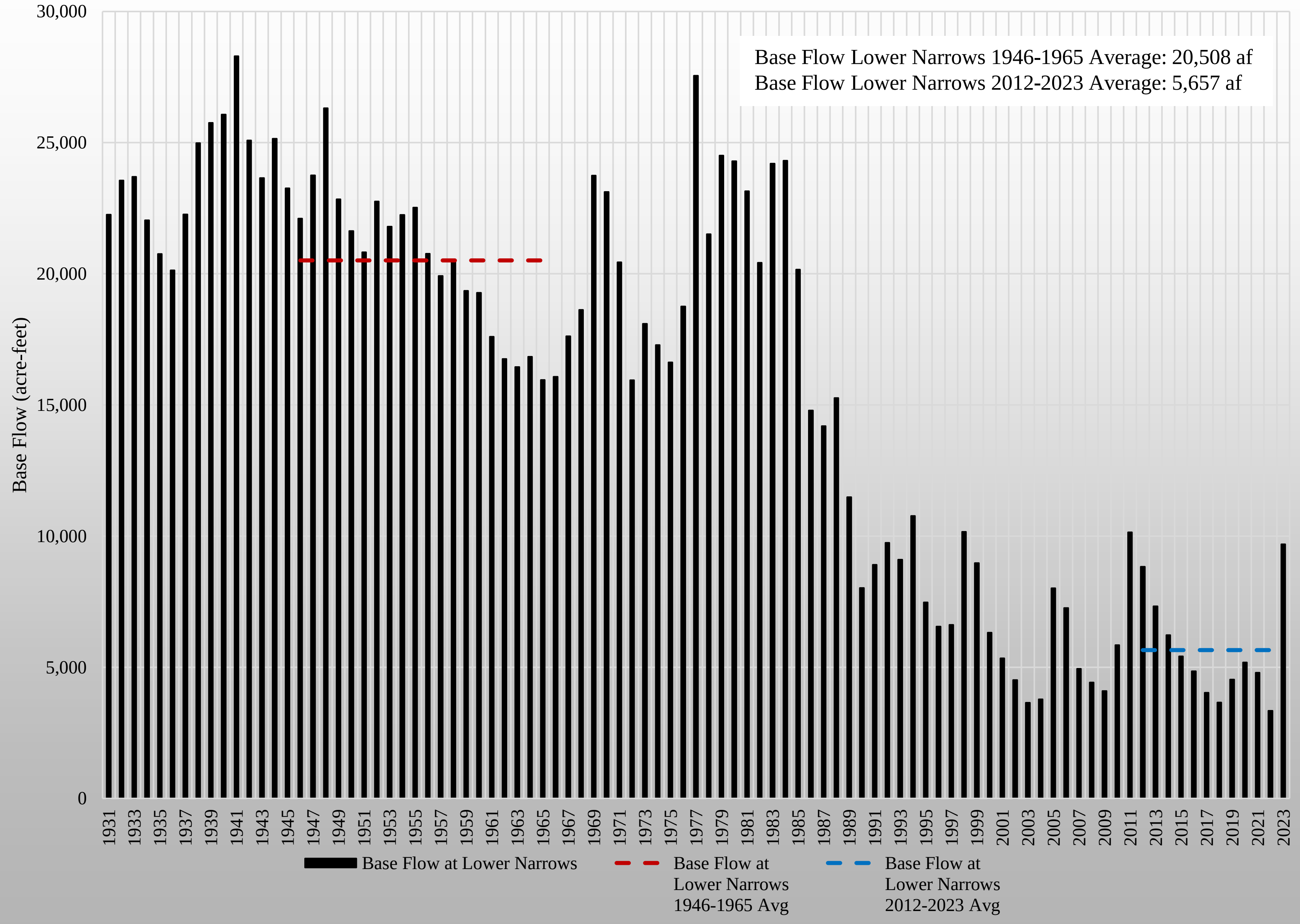
Future Scenario

- Baseline Scenario: The last 20 years hydrology extended in the future with 2020 levels of production and return flows.
- Scenario 1: Baseline Scenario plus 17,500 acre-feet of imports per year spread out over three months (June-July-August) and delivered at Deep Creek.

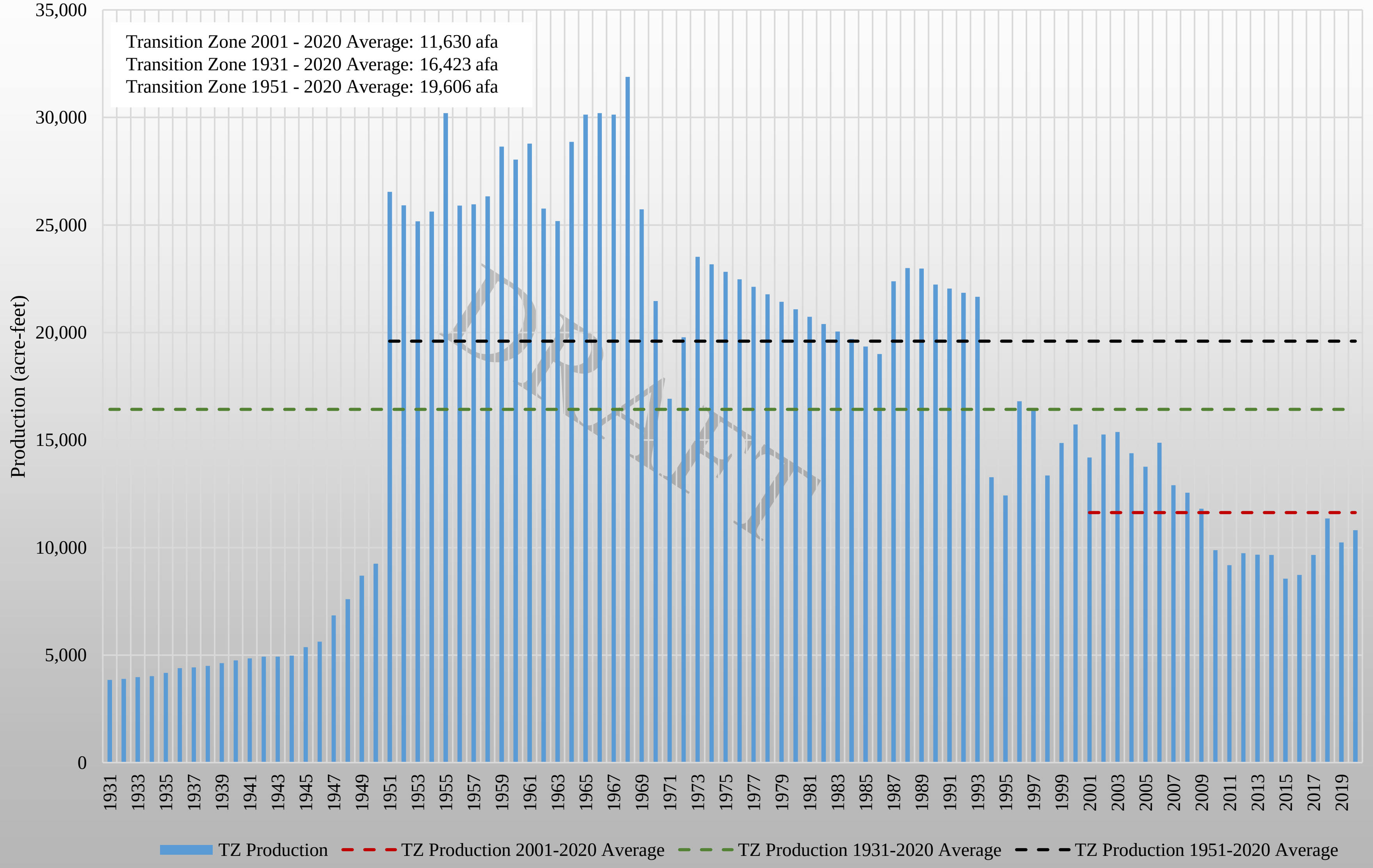
Future Scenario



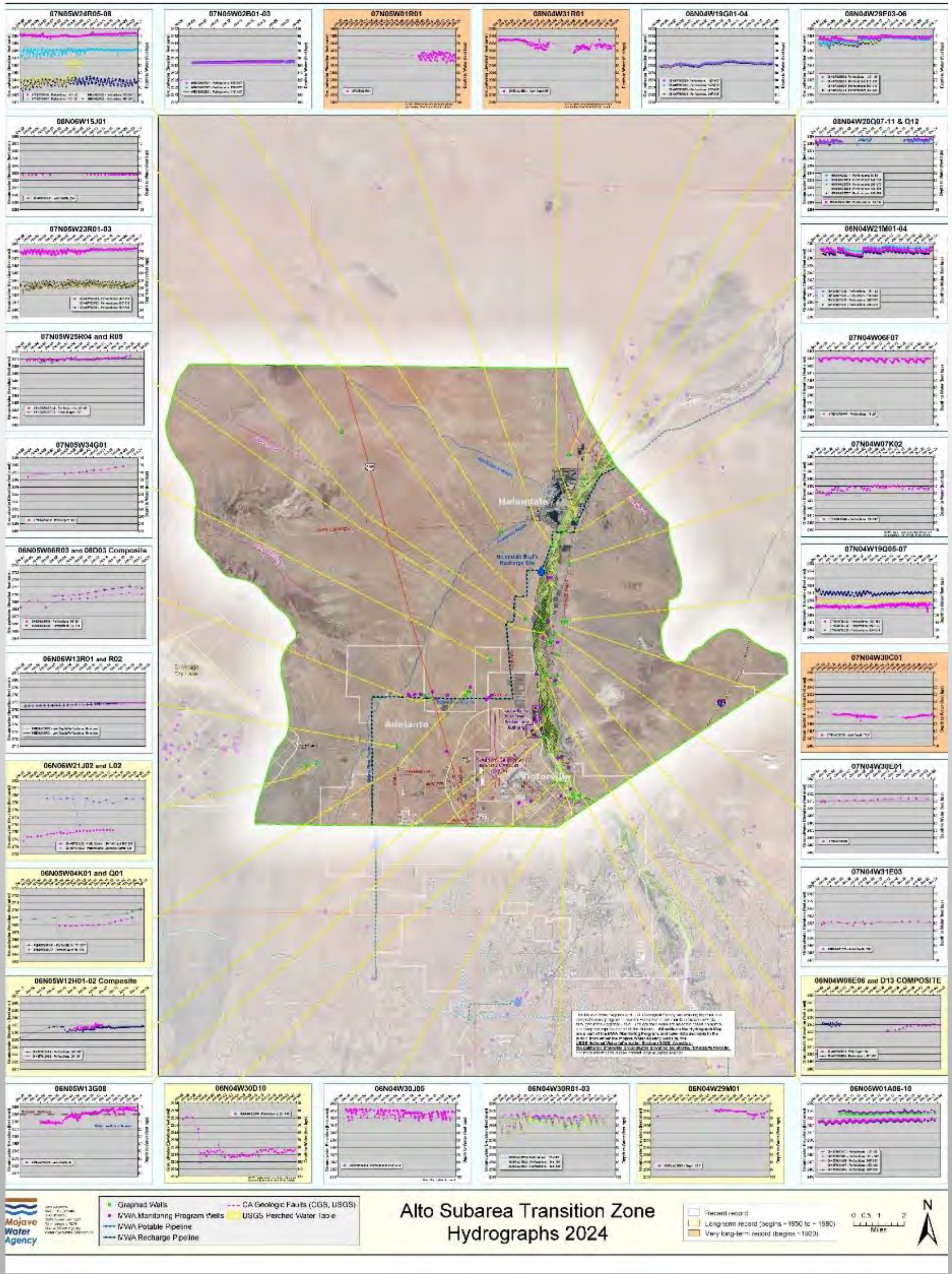
Baseflow Lower Narrows 1946-1965 vs 2012-2023



Transition Zone Historic Production



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.



07N05W24R05-08
07N05W02R01-03
07N05W01R01
08N04W31R01
08N04W19G01-04
08N04W29F03-06
08N06W15J01
08N04W20Q07-11 & Q12
07N05W23R01-03
08N04W21M01-04
07N05W25R04 and R05
07N04W06F07
07N05W34G01
07N04W07K02
06N05W06R03 and 08D03 Composite
07N04W19Q05-07
06N06W13R01 and R02
07N04W30C01
06N06W21J02 and L02
07N04W30L01
06N05W04K01 and Q01
07N04W31E03
06N05W12H01-02 Composite
06N04W06E06 and D13 COMPOSITE
06N05W13G08
06N04W30D10
06N04W30J05
06N04W30R01-03
06N04W29M01
06N05W01A06-10
Helendale
Adelanto
Victorville
Mojave Water Agency
Graphed Wells
MWA Monitoring Program Wells
MWA Potable Pipeline
MWA Recharge Pipeline
CA Geologic Faults (CGS, USGS)
USGS Perched Water Table
Alto Subarea Transition Zone
Hydrographs 2024
Recent record
Long-term record (begins ~1950 to ~1980)
Very long-term record (begins ~1920)
Miles
N

Table 5-1

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
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**

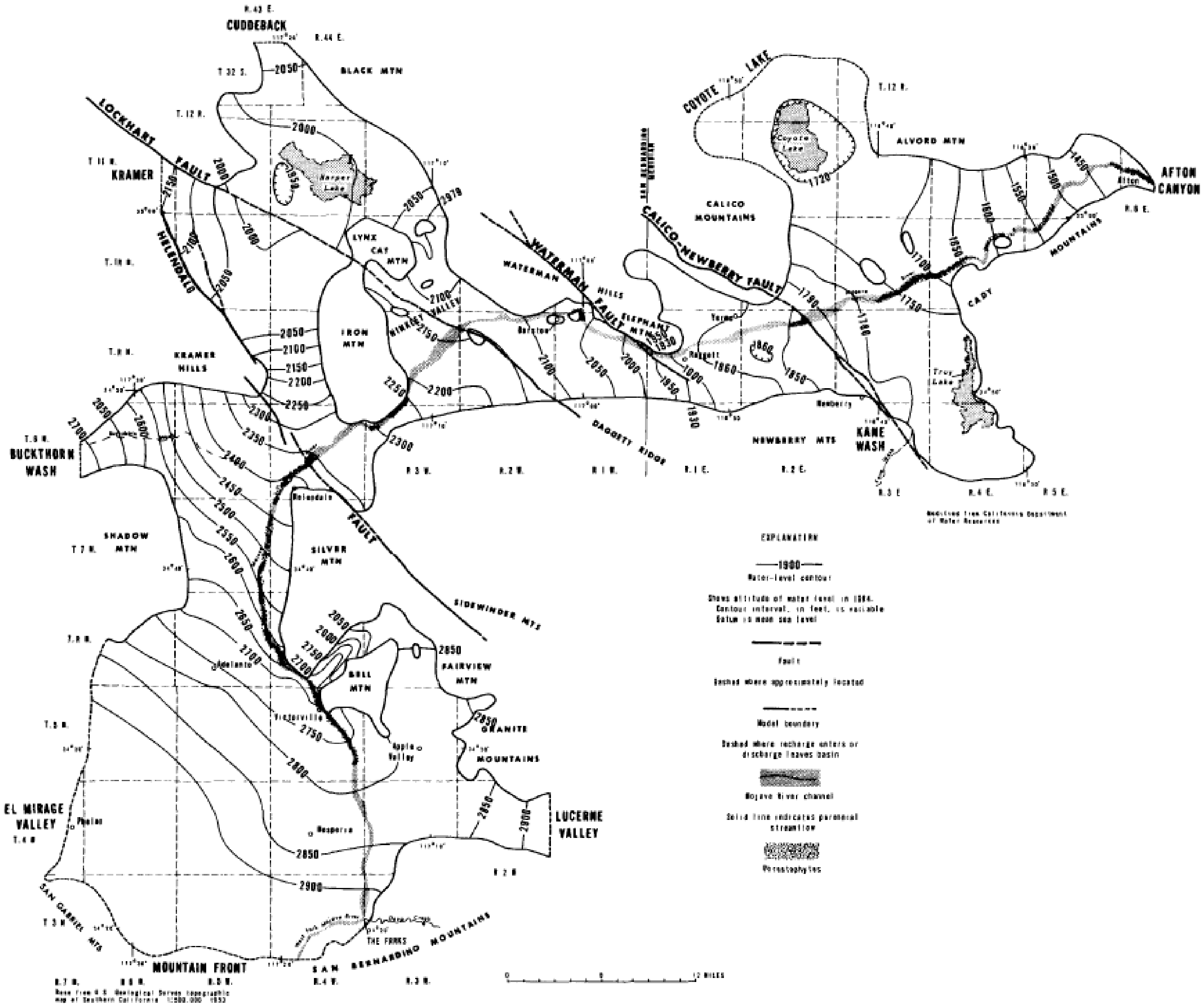
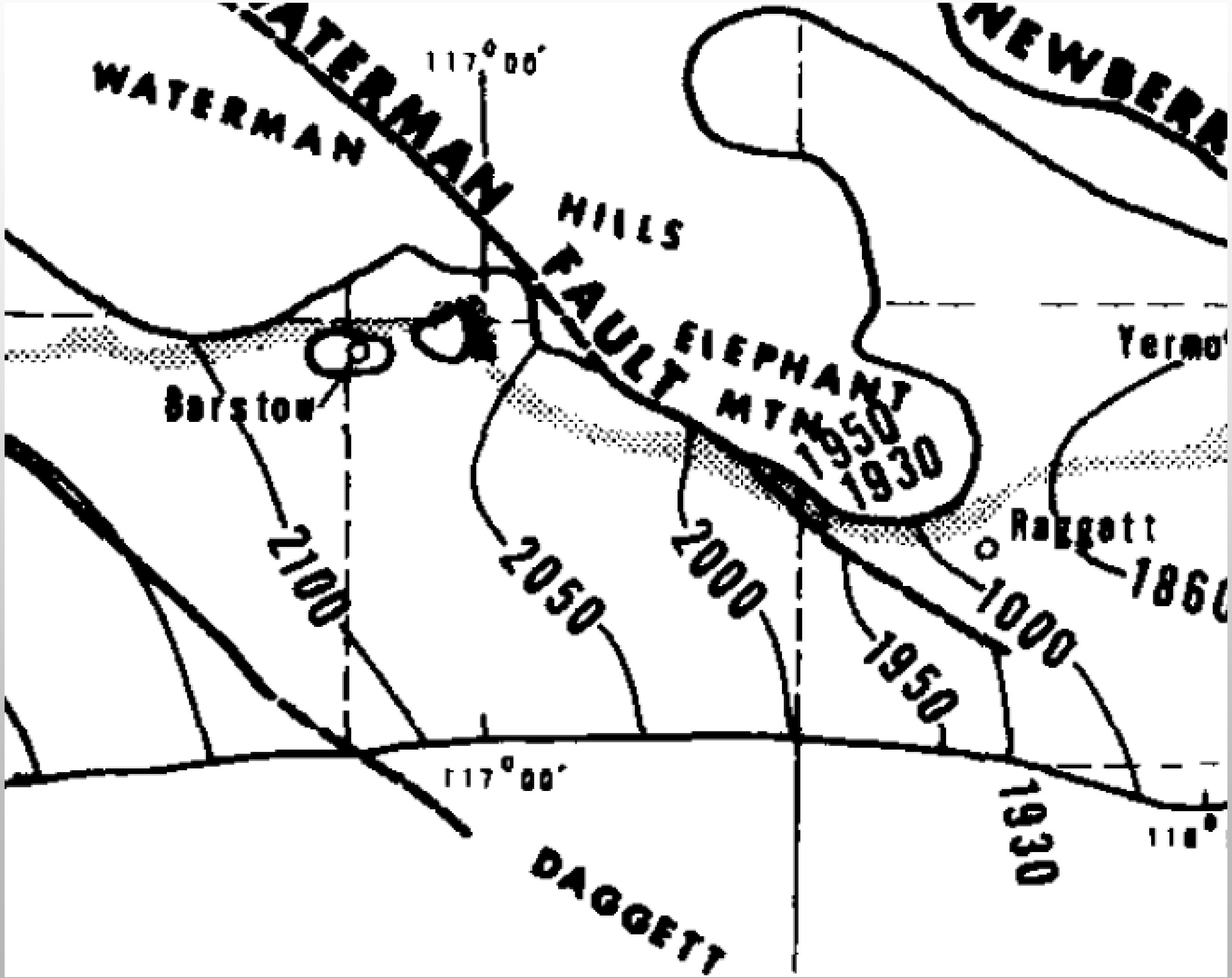
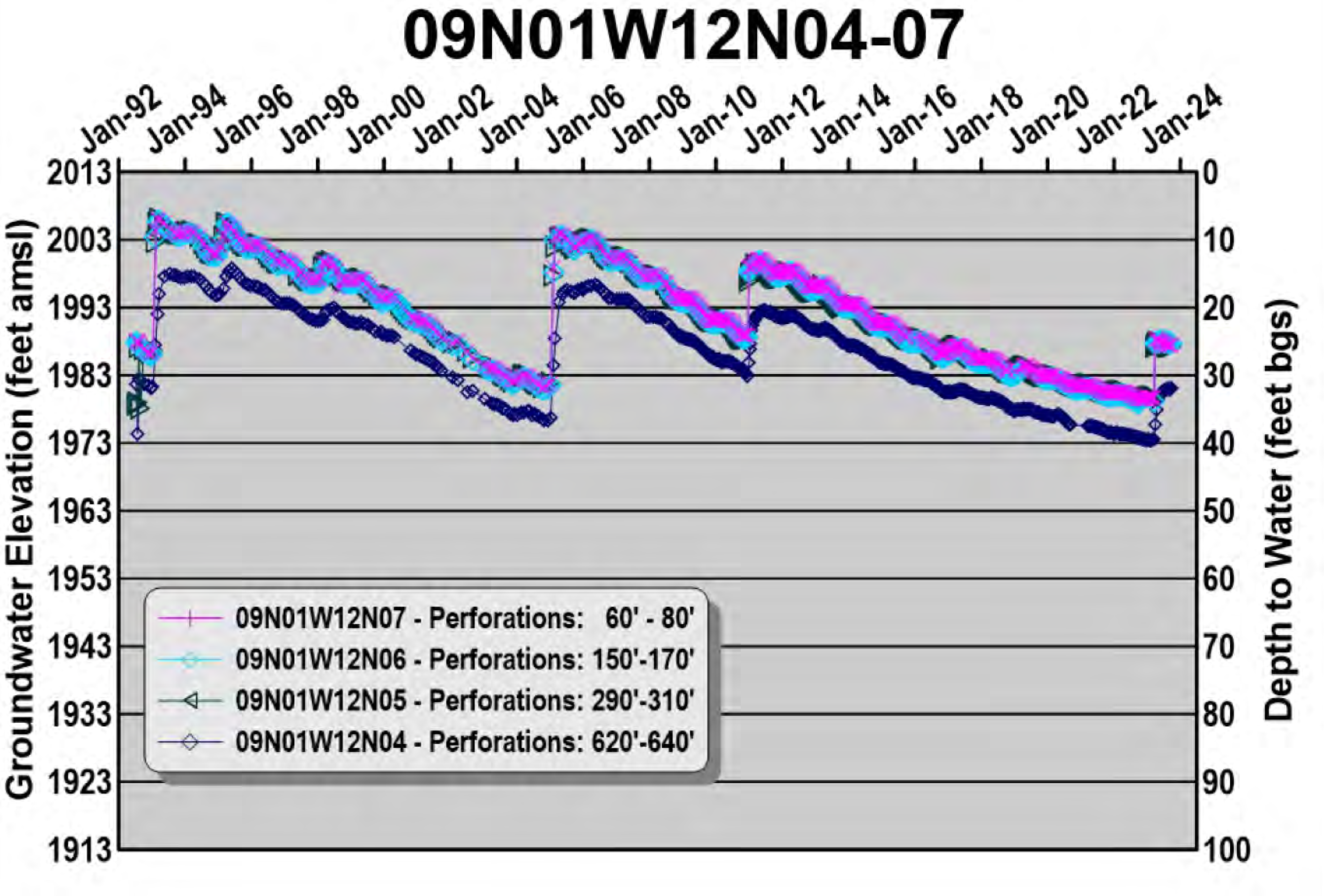


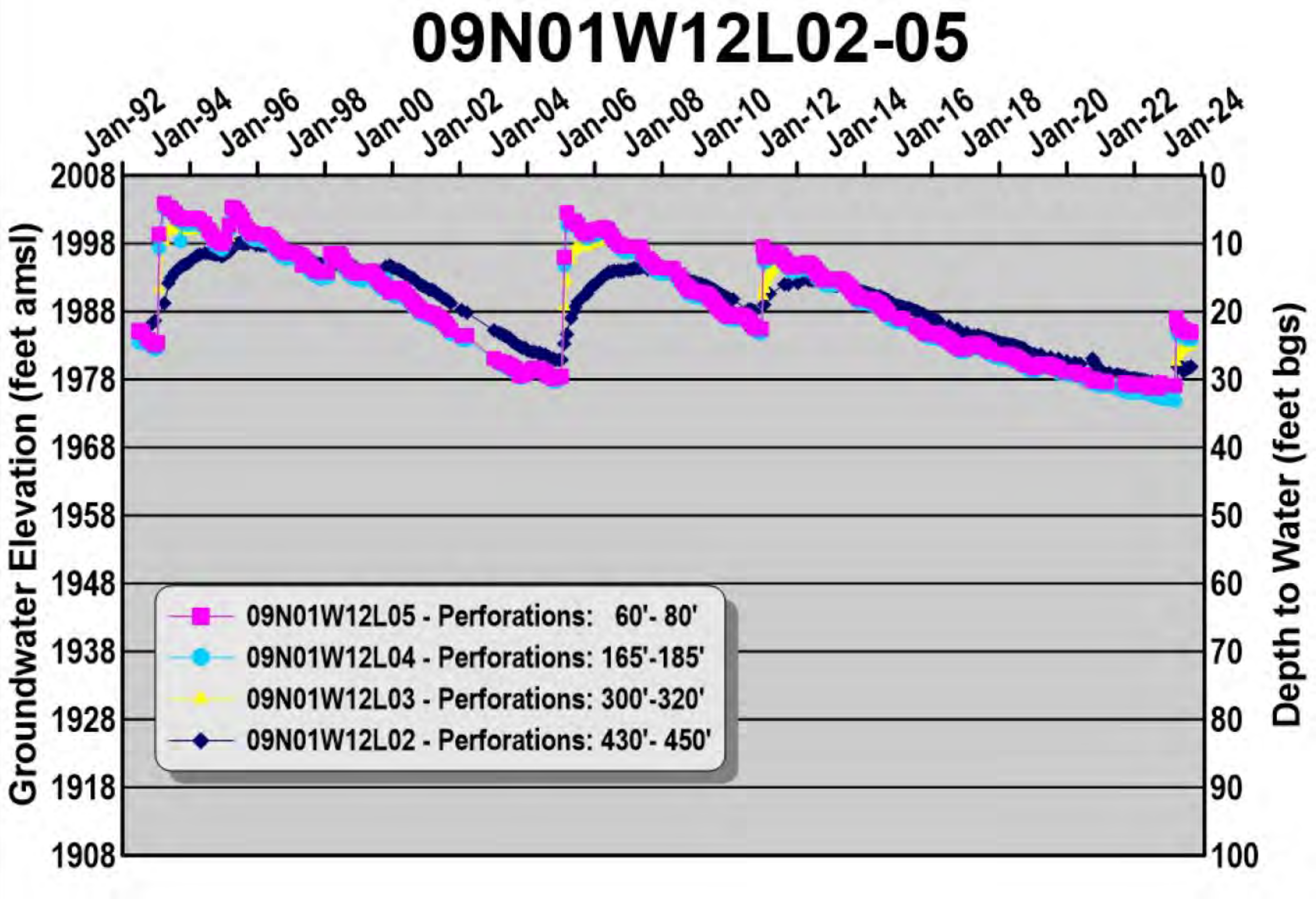
FIGURE 16.--Ground-water level, spring 1964.

Waterman Fault (Hardt)

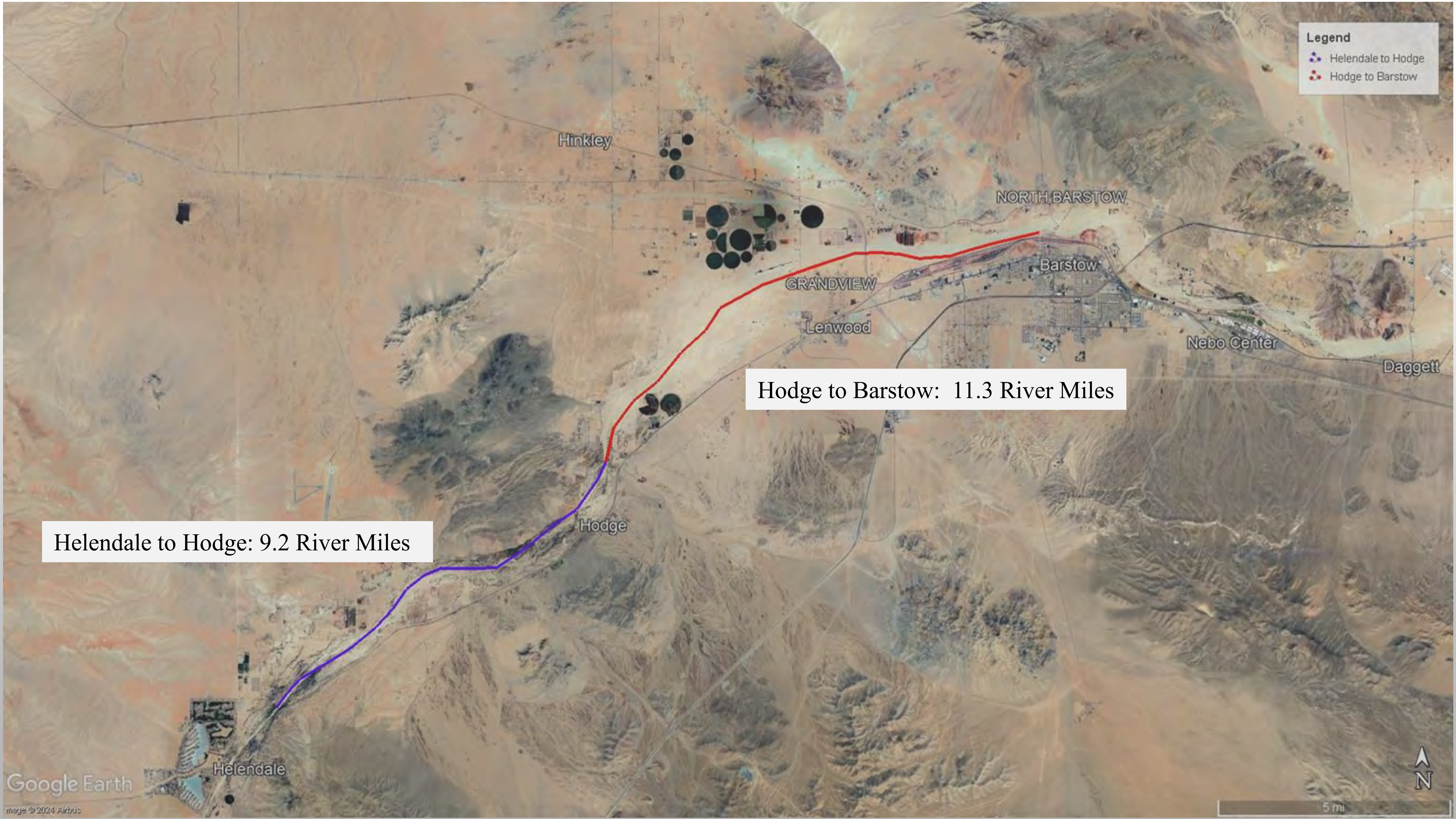




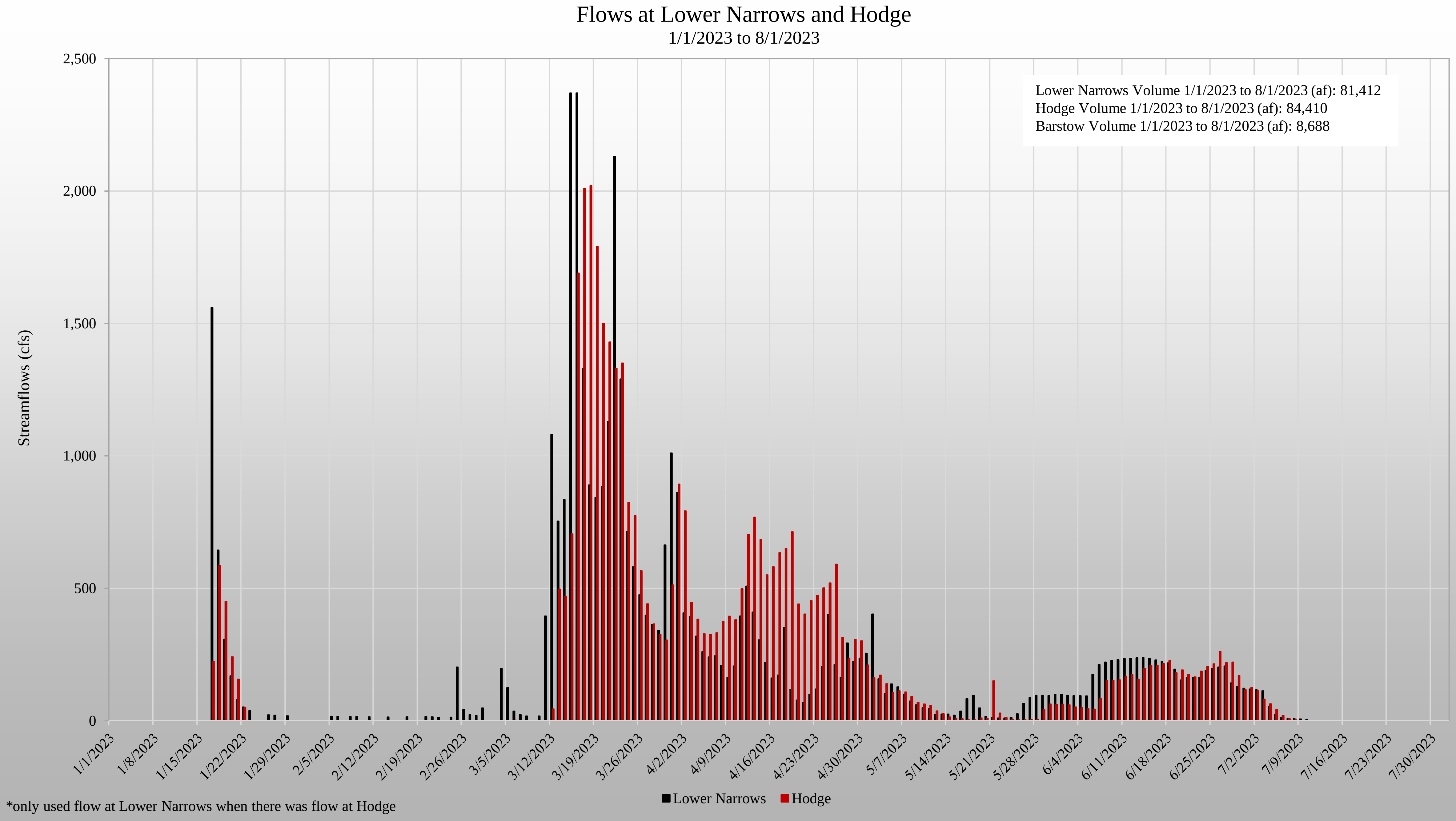
09N01W12N04-07
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22
Jan-24
Groundwater Elevation (feet amsl)
2013
2003
1993
1983
1973
1963
1953
1943
1933
1923
1913
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
09N01W12N07 - Perforations: 60' - 80'
09N01W12N06 - Perforations: 150'-170'
09N01W12N05 - Perforations: 290'-310'
09N01W12N04 - Perforations: 620'-640'



09N01W12L02-05
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22
Jan-24
Groundwater Elevation (feet amsl)
2008
1998
1988
1978
1968
1958
1948
1938
1928
1918
1908
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
09N01W12L05 - Perforations: 60'- 80'
09N01W12L04 - Perforations: 165'-185'
09N01W12L03 - Perforations: 300'-320'
09N01W12L02 - Perforations: 430'- 450'



Legend
Helendale to Hodge
Hodge to Barstow
Hinkley
NORTH BARSTOW
Barstow
GRANDVIEW
Lenwood
Nebo Center
Daggett
Hodge to Barstow: 11.3 River Miles
Hodge
Helendale to Hodge: 9.2 River Miles
Helendale
Google Earth
Image © 2024 Airbus
5 mi
N



Flows at Lower Narrows and Hodge
1/1/2023 to 8/1/2023
Lower Narrows Volume 1/1/2023 to 8/1/2023 (af): 81,412
Hodge Volume 1/1/2023 to 8/1/2023 (af): 84,410
Barstow Volume 1/1/2023 to 8/1/2023 (af): 8,688
Streamflows (cfs)
2,500
2,000
1,500
1,000
500
0
1/1/2023
1/8/2023
1/15/2023
1/22/2023
1/29/2023
2/5/2023
2/12/2023
2/19/2023
2/26/2023
3/5/2023
3/12/2023
3/19/2023
3/26/2023
4/2/2023
4/9/2023
4/16/2023
4/23/2023
4/30/2023
5/7/2023
5/14/2023
5/21/2023
5/28/2023
6/4/2023
6/11/2023
6/18/2023
6/25/2023
7/2/2023
7/9/2023
7/16/2023
7/23/2023
7/30/2023
Lower Narrows
Hodge
*only used flow at Lower Narrows when there was flow at Hodge

Este Water Production & Water Levels

- Average Water Production (2018-2022): 5,108 acre-feet
- Average Water Production (2001-2020): 6,582 acre-feet
  - Fifteen Mile Valley Change in Storage (2001-2020): 134 acre-feet
- Water levels have been relatively stable for 20 years
- Assuming change in storage is zero PSY = Pumping
  - Conservatively Production Safe Yield = 5,108 acre-feet
    - Inflow – unknown
    - Outflow – unknown
    - Precipitation – limited data

Oeste Water Production & Water Levels

- Average Water Production (2018-2022): 3,634 acre-feet
- Average Water Production (2001-2020): 4,541 acre-feet
  - Oeste change in Storage (2001-2020): -1,566 acre-feet (UMBM)
- Water levels have been relatively stable for 20 years
  - Indicating change in storage: 0 acre-feet
- Assuming change in storage is zero PSY = Pumping
  - Production Safe Yield = 3,634 acre-feet
    - Inflow – UMBM
    - Recharge - UMBM
    - Outflow – UMBM
    - Precipitation – limited data

Baja Water Production & Water Levels

- Average Water Production (2017-2023): 19,144 acre-feet
- Average Water Production (2019-2023): 16,709 acre-feet
- Average Water Production (2021-2023): 13,088 acre-feet
- Water levels appear to be stabilizing
- Assuming change in storage is zero PSY = Pumping
- Production Safe Yield estimated over two time periods:
  - (1931-1990): 14,544 acre-feet
  - (2001-2020): 10,866 acre-feet

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
Subsurface Inflow		1,581
Deep Percolation of Precipitation		100
Tributary Inflow		3,571
	TOTAL	**22,610**
CONSUMPTIVE USE AND OUTFLOW		
Surface Water Outflow		6,066
Subsurface Outflow		0
Consumptive use		
Agriculture		6,092
Urban		6,657
Phreatophytes		2,000
	TOTAL	**20,815**
Surplus / (Deficit)		1,795
Total Estimated Production		12,749
PRODUCTION SAFE YIELD		**14,544**

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	7,500
Tributary Inflow	1,568
Subsurface Inflow	1,751
Mountain Front Recharge	647
Barstow Treatment Plan	2,455
Return Flow	554
Deep Percolation of Precipitation	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**

Updated Production Safe Yield and Indicated 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	20.5%	---	12,749	19.3%	20.5%
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%

TABLE 3-2

ANNUAL CHANGE IN STORAGE BY SUBAREA
WATER YEAR 2022-23
(AMOUNTS IN ACRE-FEET)

	Este[1]	Oeste[2]	Alto	Centro	Baja	Total
Total Water Supply	5,108	3,634	263,022	108,359	15,256	**395,379**
Total Outflow and Consumptive Use	5,108	3,634	143,991	27,903	12,625	**193,261**
Net Change in Storage	**0**	**0**	**119,031**	**80,456**	**2,631**	**202,118**

Notes

1. Water level data indicates little or no change in storage on an average annual basis; water supply is estimated to balance outflow and consumptive use.

2. Short term water levels indicate balance supply and demand for the past 15-20 years. Assume change in storage = 0.

Next Steps

- February 29, 2024
  - Notice to Parties, proposed FPA recommendation
- March 13, 2024 and March 14, 2024
  - Public Workshop (all Subareas)
- March 27, 2024
  - Public Hearing on FPA recommendation
- May 1, 2024
  - Report to the Court
- June 14, 2024
  - Court Hearing to adopt Watermaster recommendation

Production Safe Yield Update and Proposed Free Production Allowance (2024-2025) Este Subarea

March 13, 2024
Robert C. Wagner

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield Update

- Production Safe Yield Update, Base Period, Safe Yield Year
- Upper Mojave Basin Model (UMBM)
- Table 5-1 Alto, Centro, Baja
- Future Model Scenario
- Subarea Conditions
  - Historic Water Levels (1964)
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Production Safe Yield
Judgment after Trial 1996

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

(1) Production Safe Yield

- Base Period
  - Over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea
  - 1931-1990 set by the judgment
- Proposed Base Period
  - 2001-2020

(2 & 3) Production Safe Yield

- Safe Yield Year
  - (2) Under given patterns of Production, applied water, return flows and Consumptive Use (Cultural Conditions)
    - Assumed by the Judgment to be 1990 land use conditions
    - Previously 1997-1998, 2017-2018
    - Proposed 2022
  - Cultural conditions are assumed to be reasonably representative of future conditions (evaluated periodically)
  - (3) Without resulting in a long-term net reduction of groundwater in storage in the Subarea
- PSY = Production + Change in Storage

Production Safe Yield

- Base Period from Department of Water Resources Bulletin 84 (1967)
- 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.

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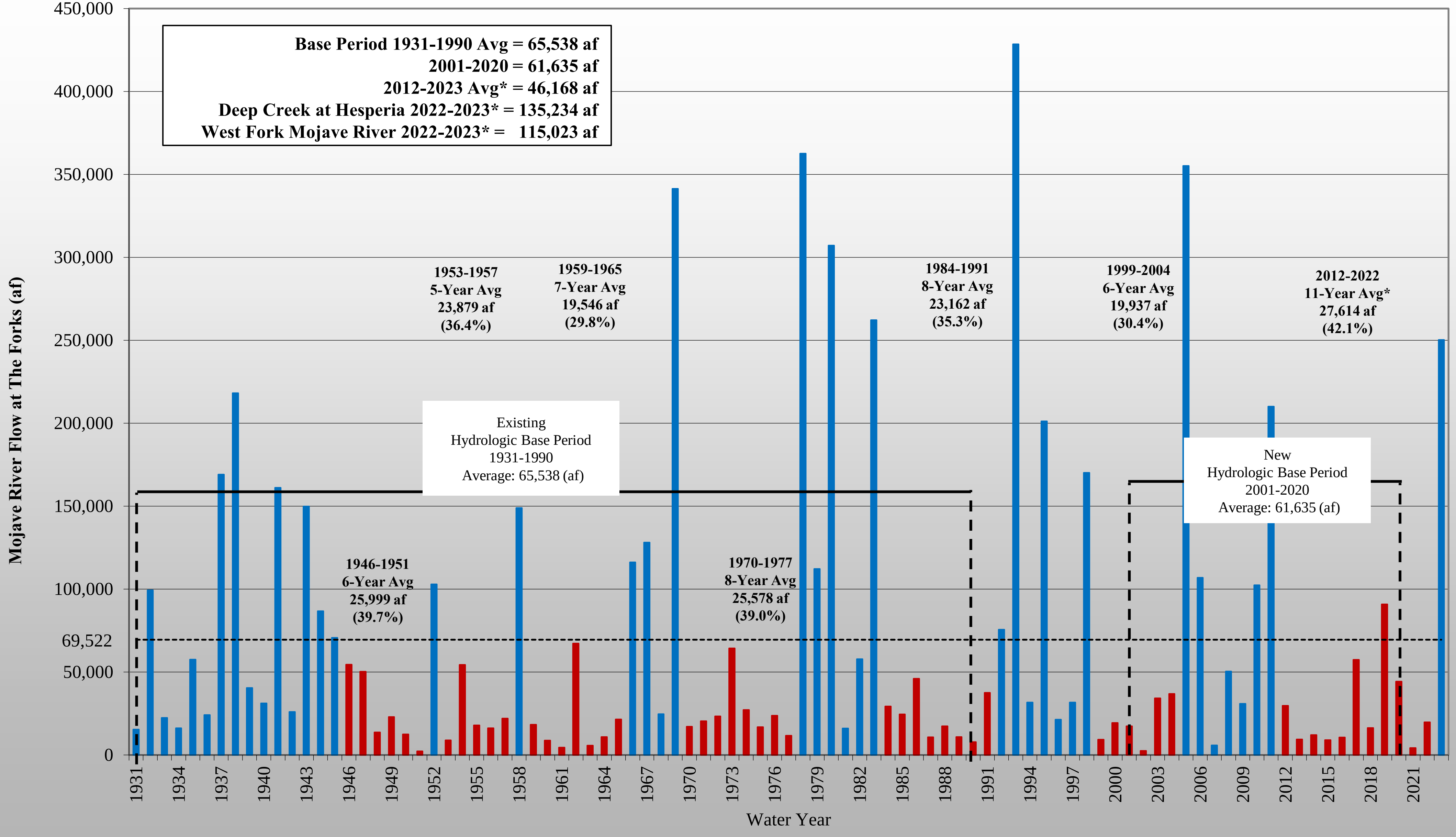
Mojave River Flow at The Forks
Water Years 1931 - 2023



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Estimated Pumping 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	64,986	61,033	64,129	69,593	67,232	62,354	64,888
TZ	12,700	11,939	12,618	11,809	10,914	10,039	11,670
Alto Total	77,686	72,972	76,747	81,402	78,146	72,393	76,558
Baja	24,524	23,389	20,912	15,095	12,579	11,343	17,974
Centro	20,665	19,784	18,309	19,685	16,983	16,392	18,636
Este	5,055	4,983	5,181	5,258	5,068	4,501	5,008
Oeste	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

Estimated Consumptive Use 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	34,001	30,386	33,489	37,871	33,745	31,927	33,570
TZ	7,913	7,294	8,052	7,301	7,375	6,859	7,466
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Centro	16,451	15,094	14,044	14,035	12,748	12,279	14,108
Este	3,827	3,634	4,116	4,377	4,388	3,812	4,026
Oeste	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

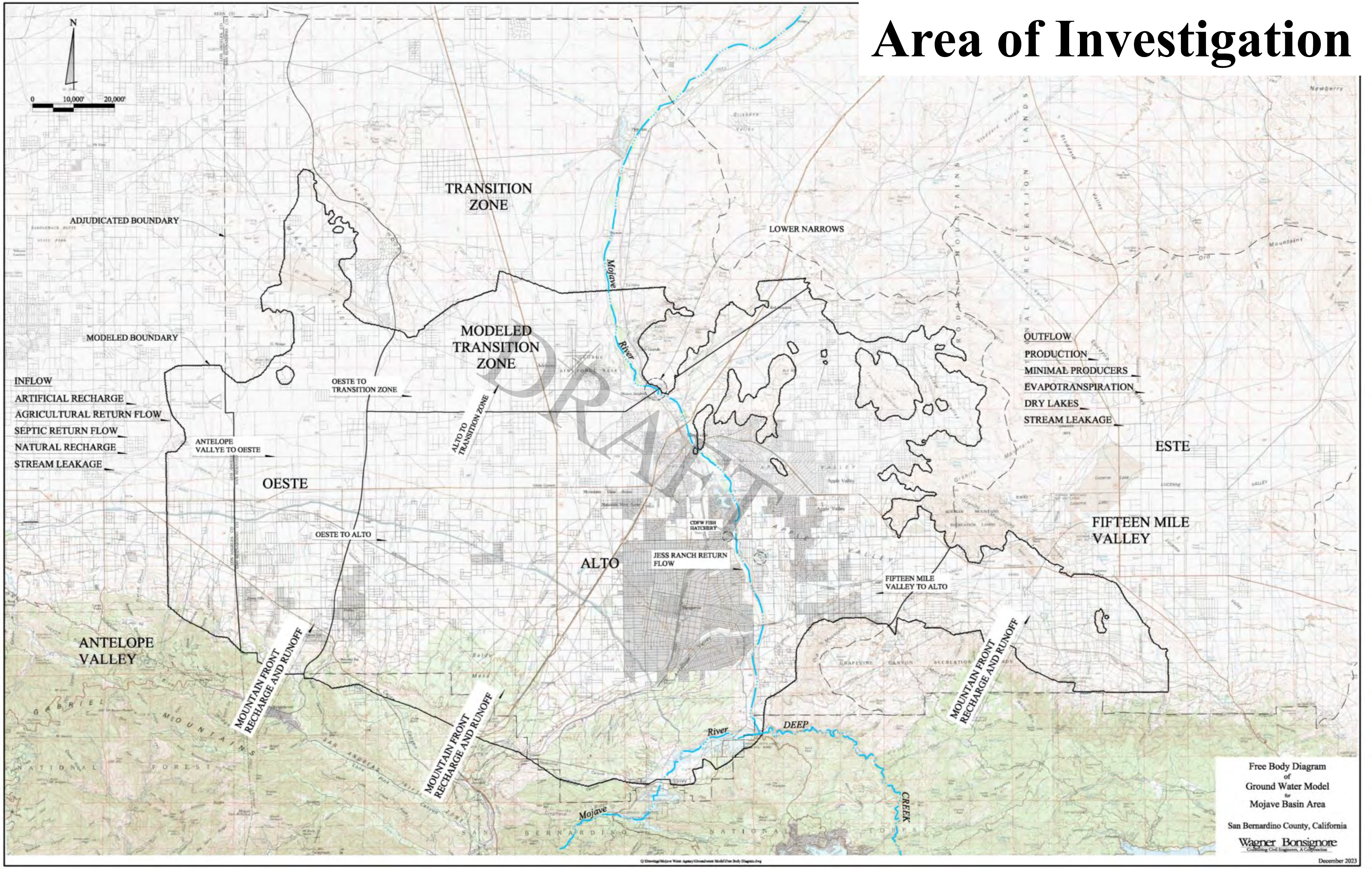
Safe Yield Year

Mojave Basin Groundwater Models

- Earlier versions of the Model
  - Hardt, USGS 1971 (Analog)
  - Stamos, USGS 2001 (MODFLOW)

- Upper Mojave Basin Model
  - Coulibaly, Kapo MWA 2023 (MODFLOW)

Area of Investigation



Este Water Production & Water Levels

- Average Water Production (2018-2022): 5,108 acre-feet
- Average Water Production (2001-2020): 6,582 acre-feet
  - Fifteen Mile Valley Change in Storage (2001-2020): 134 acre-feet
- Water levels have been relatively stable for 20 years
- Assuming change in storage is zero PSY = Pumping
  - Conservatively Production Safe Yield = 5,108 acre-feet
    - Inflow – unknown
    - Outflow – unknown
    - Precipitation – limited data

Updated Production Safe Yield and Indicated 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	20.5%	---	12,749	19.3%	20.5%
Centro	21,088	55.0%	11,540	31,420	61.6%	60.0%
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Oeste	1,712	50.0%	(1,566)	2,970	41.9%	50.0%

TABLE 3-2

ANNUAL CHANGE IN STORAGE BY SUBAREA
WATER YEAR 2022-23
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	Este[1]	Oeste[2]	Alto	Centro	Baja	Total
Total Water Supply	5,108	3,634	263,022	108,359	15,256	**395,379**
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Net Change in Storage	**0**	**0**	**119,031**	**80,456**	**2,631**	**202,118**

Notes

1. Water level data indicates little or no change in storage on an average annual basis; water supply is estimated to balance outflow and consumptive use.

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Next Steps

- March 27, 2024
  - Public Hearing on FPA recommendation
- May 1, 2024
  - Report to the Court
- June 14, 2024
  - Court Hearing to adopt Watermaster recommendation

Production Safe Yield Update and Proposed Free Production Allowance (2024-2025) Oeste Subarea

March 13, 2024
Robert C. Wagner

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield Update

- Production Safe Yield Update, Base Period, Safe Yield Year
- Upper Mojave Basin Model (UMBM)
- Table 5-1 Alto, Centro, Baja
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  - Historic Water Levels (1964)
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- FPA Recommendations

Production Safe Yield
Judgment after Trial 1996

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

(1) Production Safe Yield

- Base Period
  - Over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea
  - 1931-1990 set by the judgment
- Proposed Base Period
  - 2001-2020

(2 & 3) Production Safe Yield

- Safe Yield Year
  - (2) Under given patterns of Production, applied water, return flows and Consumptive Use (Cultural Conditions)
    - Assumed by the Judgment to be 1990 land use conditions
    - Previously 1997-1998, 2017-2018
    - Proposed 2022
  - Cultural conditions are assumed to be reasonably representative of future conditions (evaluated periodically)
  - (3) Without resulting in a long-term net reduction of groundwater in storage in the Subarea
- PSY = Production + Change in Storage

Production Safe Yield

- Base Period from Department of Water Resources Bulletin 84 (1967)
- 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.

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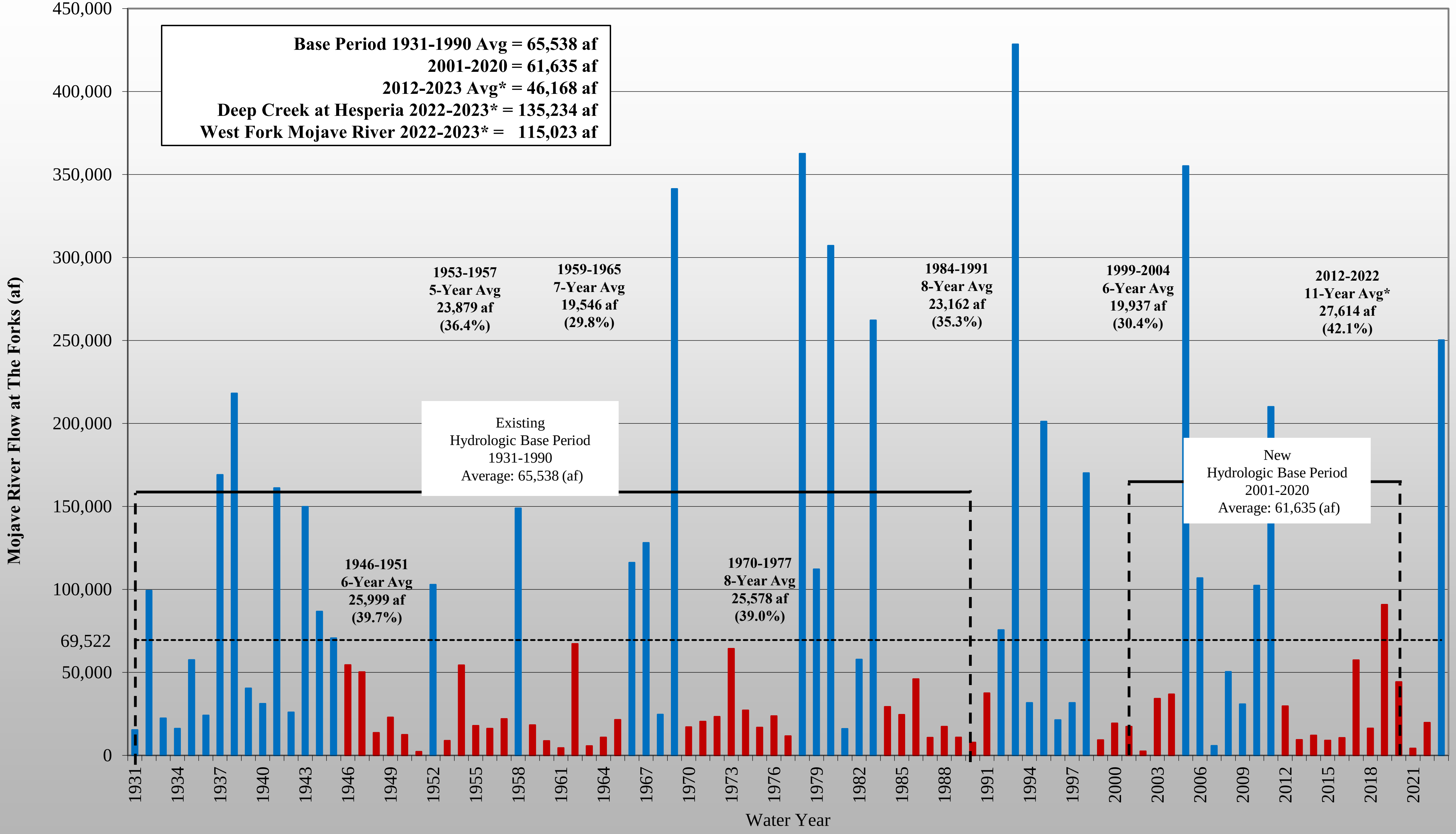

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Total	89,125	81,591	82,372	79,746	72,328	67,579	78,790

Safe Yield Year

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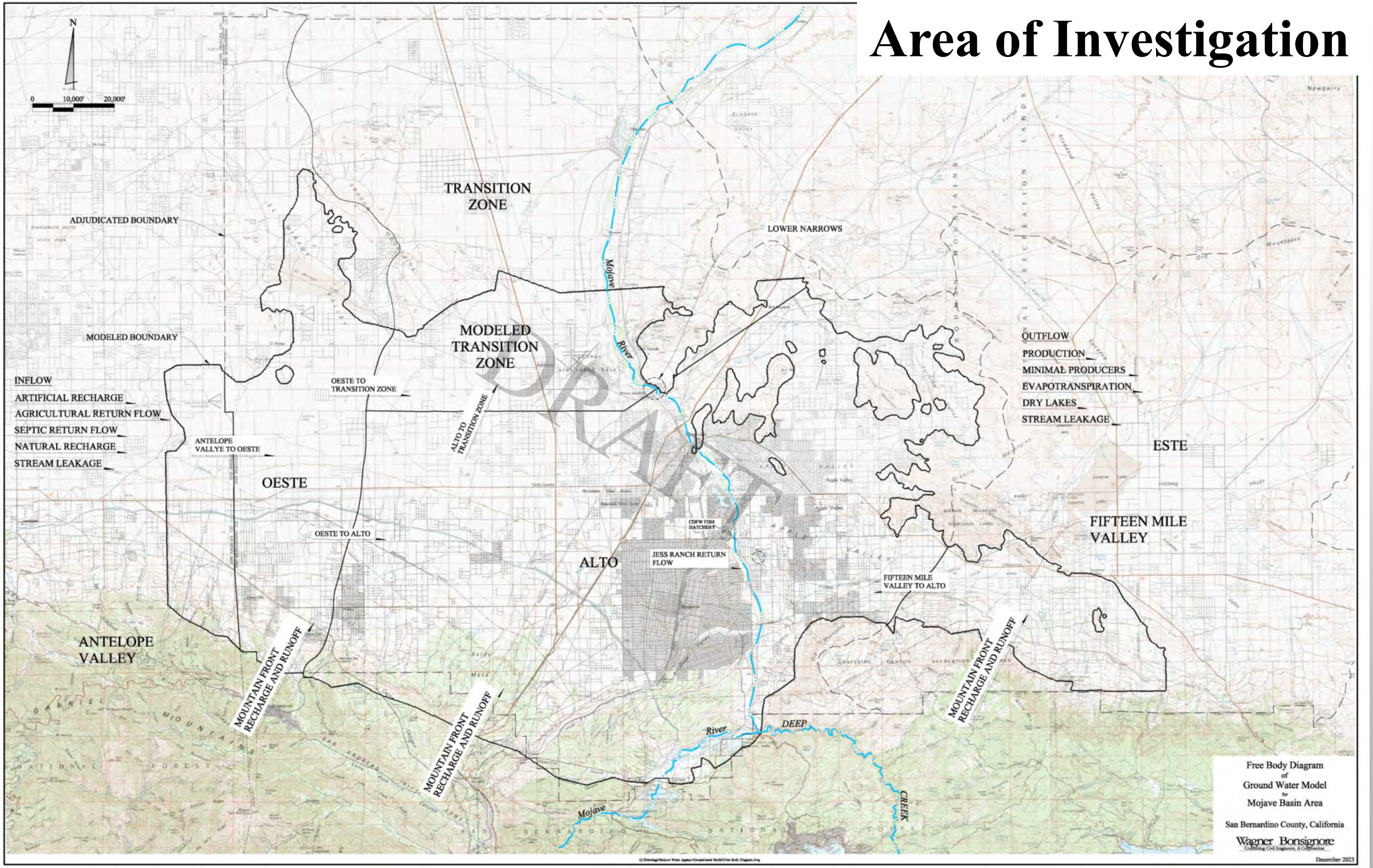
Area of Investigation



Oeste Water Production & Water Levels

- Average Water Production (2018-2022): 3,634 acre-feet
- Average Water Production (2001-2020): 4,541 acre-feet
  - Oeste change in Storage (2001-2020): -1,566 acre-feet (UMBM)
- Water levels have been relatively stable for 20 years
  - Indicating change in storage: 0 acre-feet
- Assuming change in storage is zero PSY = Pumping
  - Production Safe Yield = 3,634 acre-feet
    - Inflow – UMBM
    - Recharge - UMBM
    - Outflow – UMBM
    - Precipitation – limited data

Updated Production Safe Yield and Indicated Free Production Allowance 2024-25

Subarea	Current PSY	Current FPA	Surplus/ (Deficit)	Indicated PSY	Indicated FPA	Proposed FPA
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Next Steps

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Production Safe Yield Update and Proposed Free Production Allowance (2024-2025) Baja Subarea

March 13, 2024
Robert C. Wagner

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield Update

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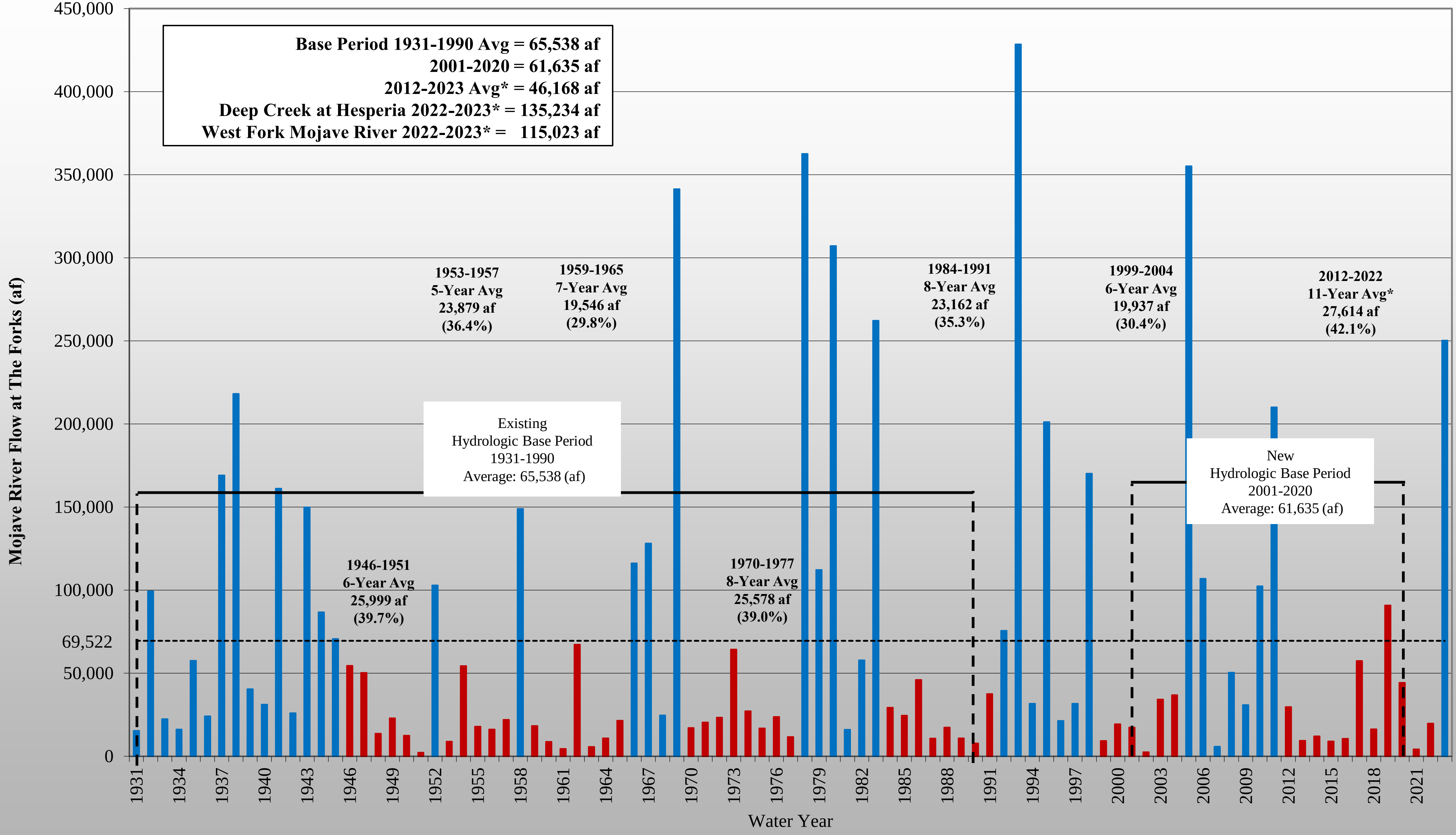

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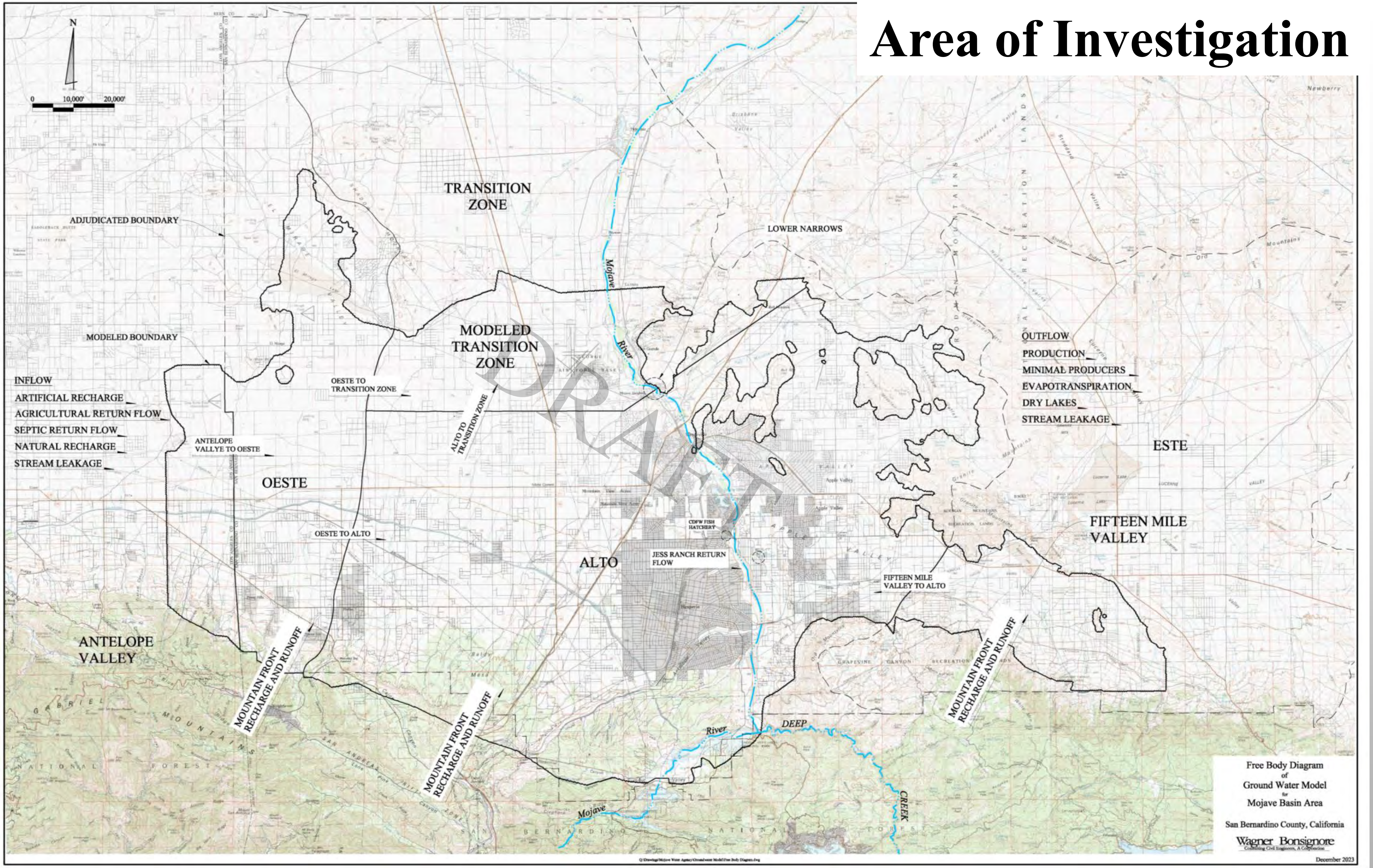
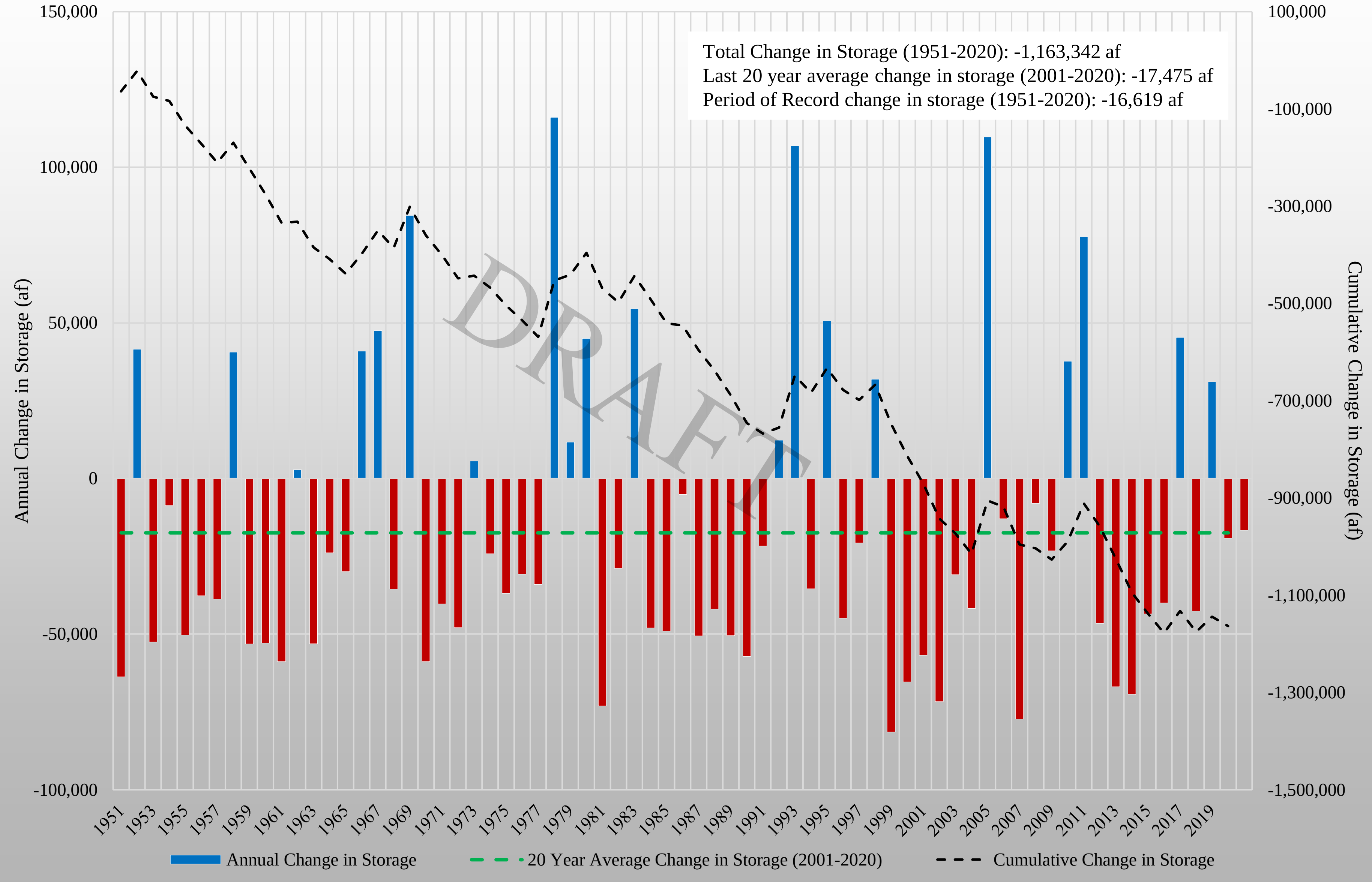
Area of Investigation



Alto (Above Lower Narrows)

Upper Mojave Basin Model Change in Storage



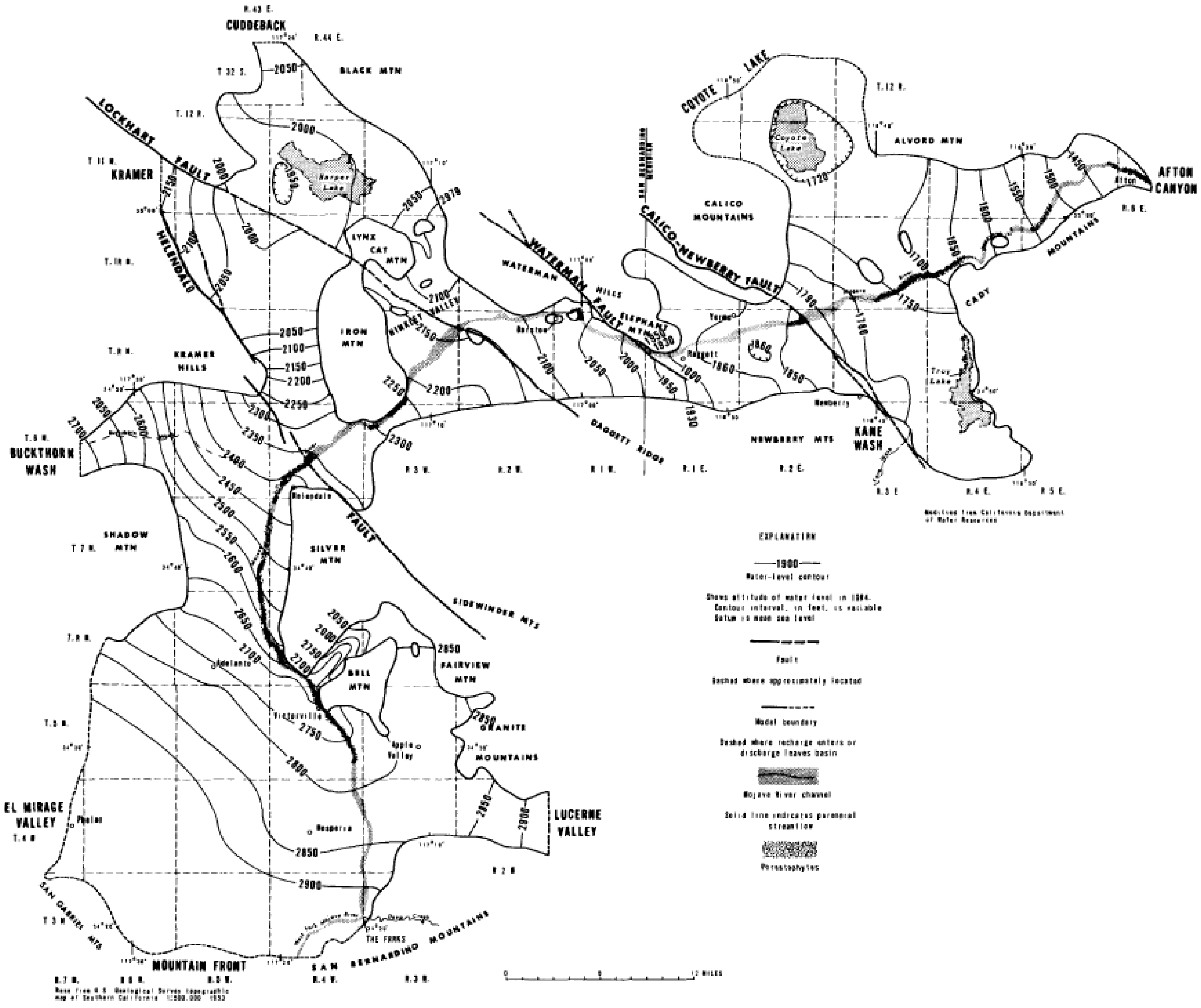
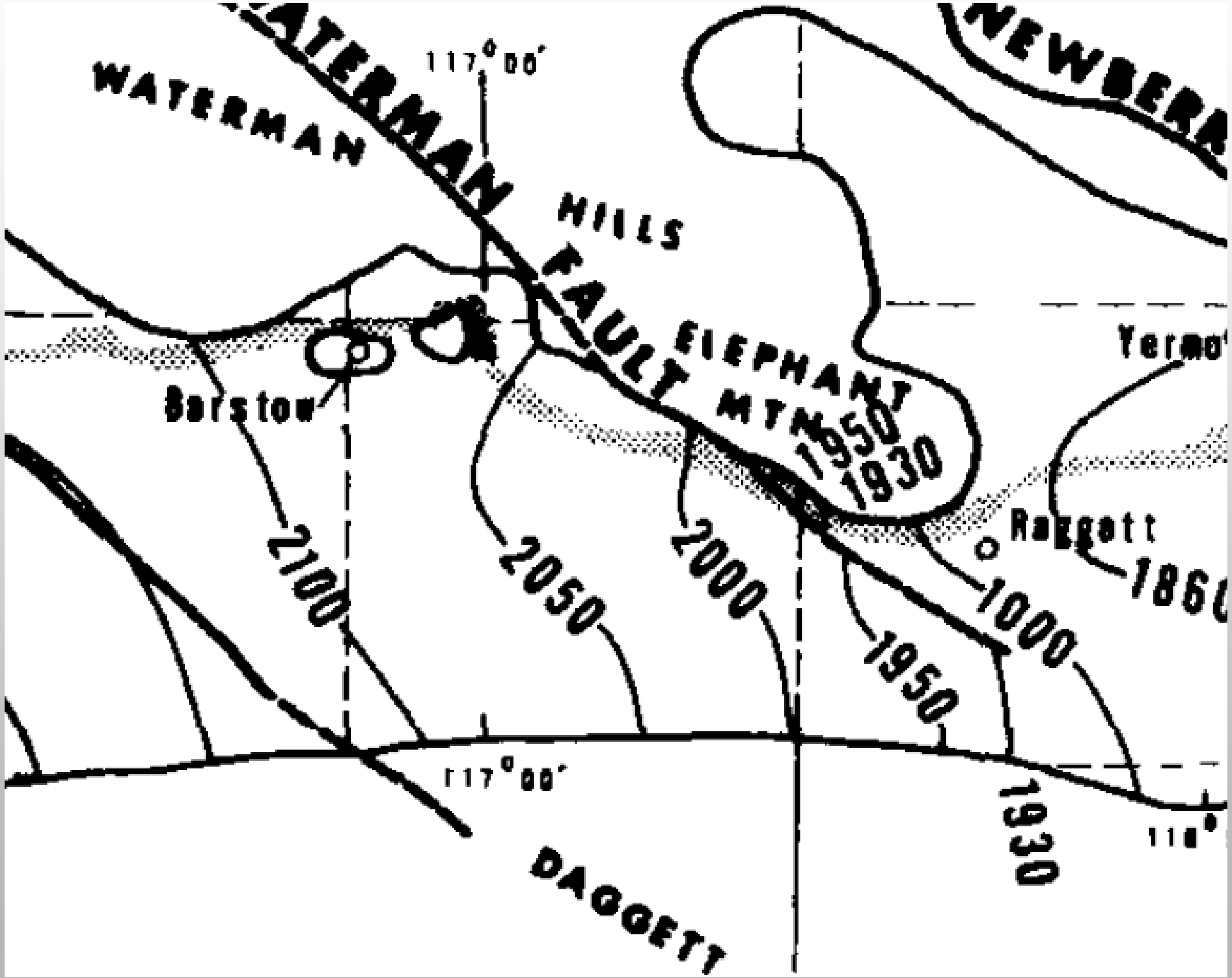


FIGURE 16.--Ground-water level, spring 1964.

Waterman Fault (Hardt)



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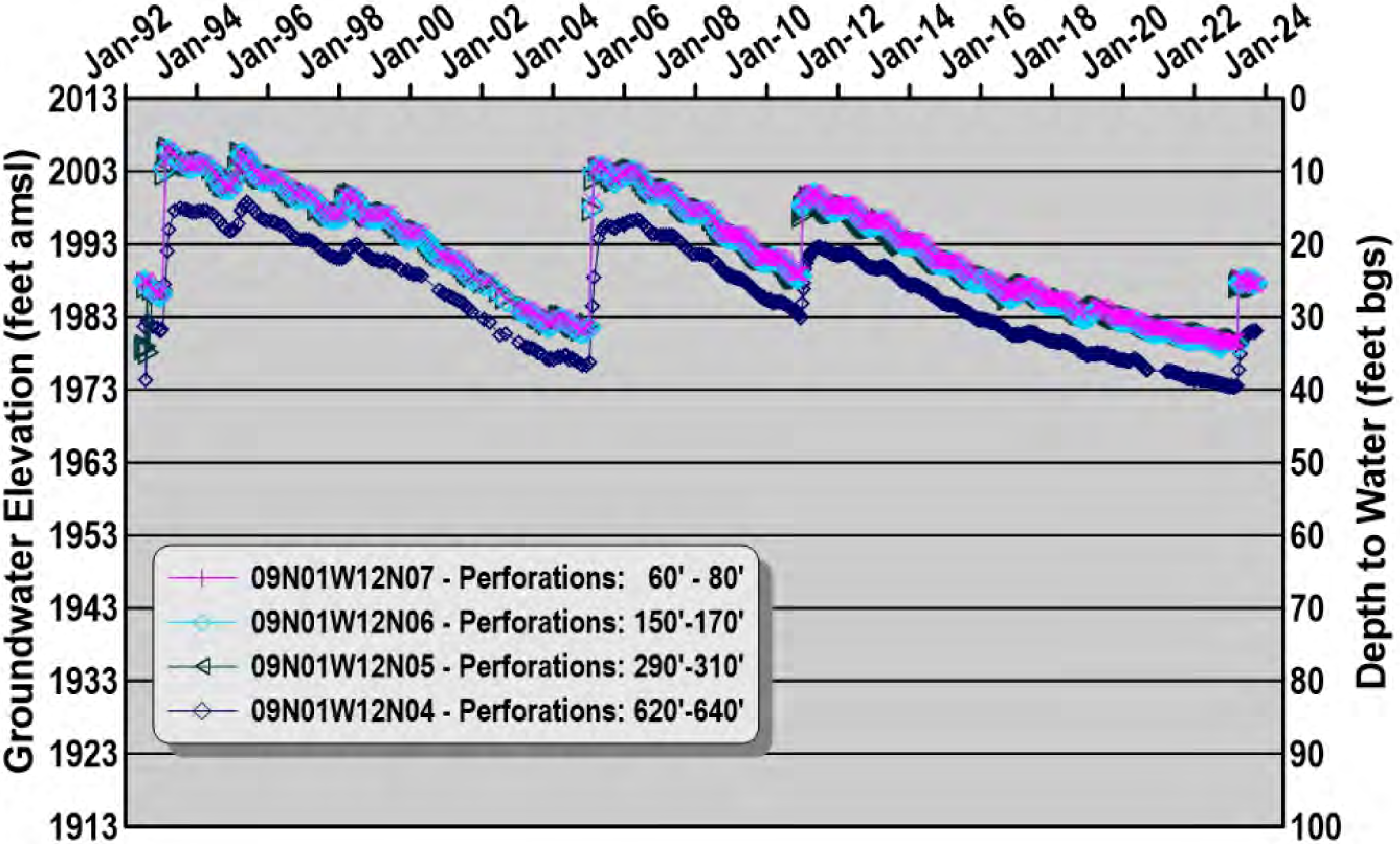

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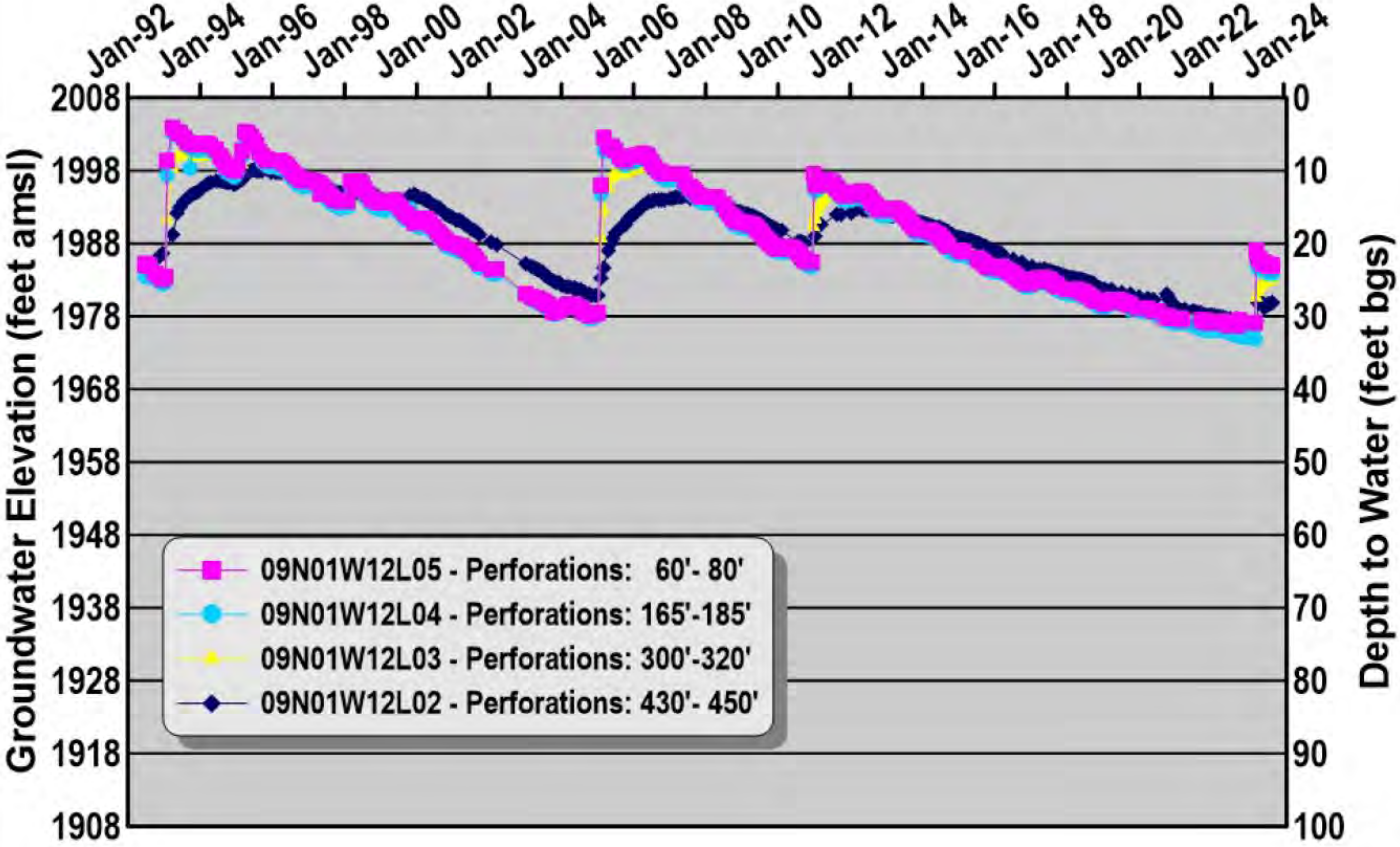

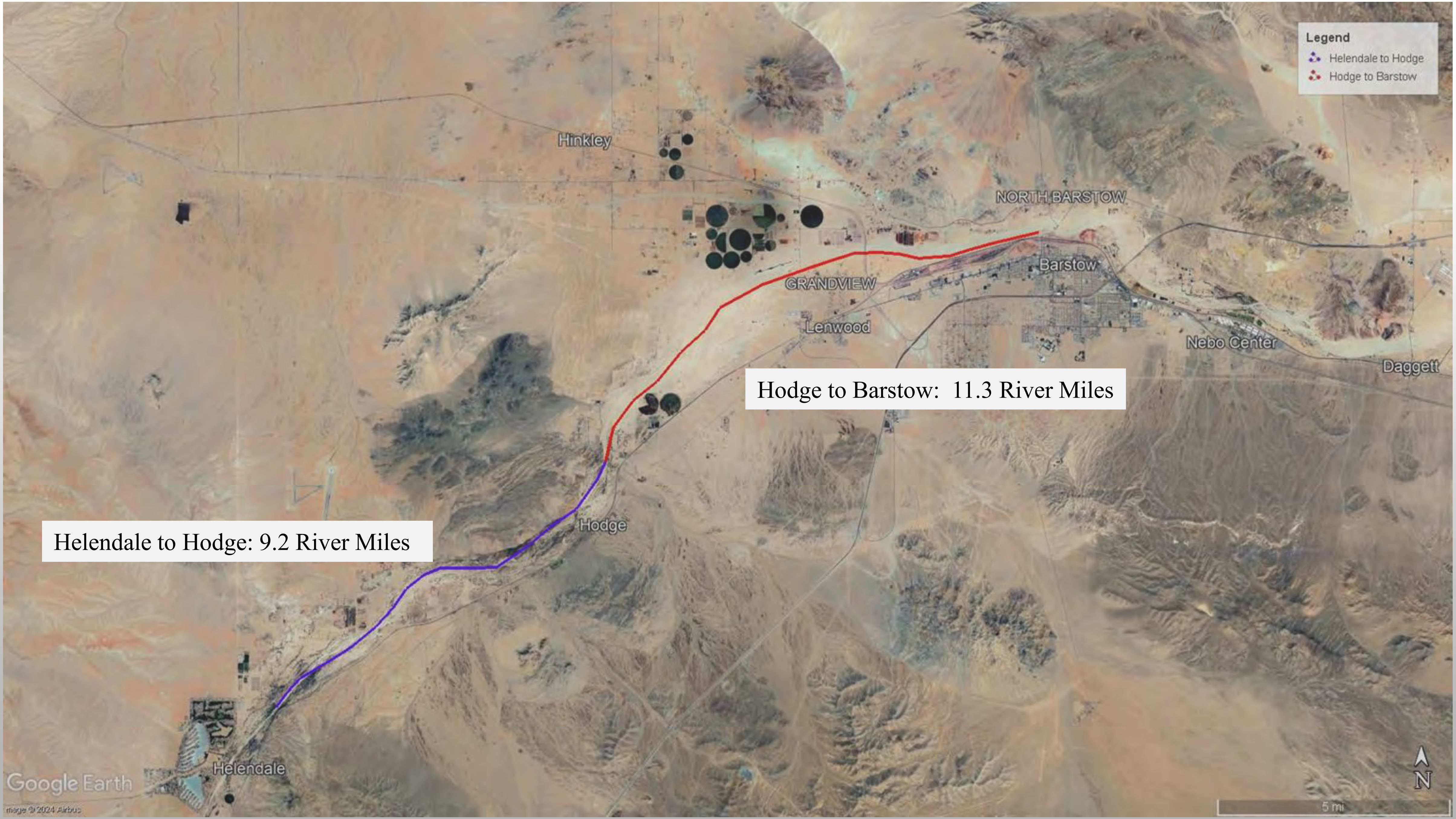
Legend
Helendale to Hodge
Hodge to Barstow
Hinkley
NORTH BARSTOW
Barstow
GRANDVIEW
Lenwood
Nebo Center
Daggett
Hodge to Barstow: 11.3 River Miles
Hodge
Helendale to Hodge: 9.2 River Miles
Helendale
Google Earth
5 mi
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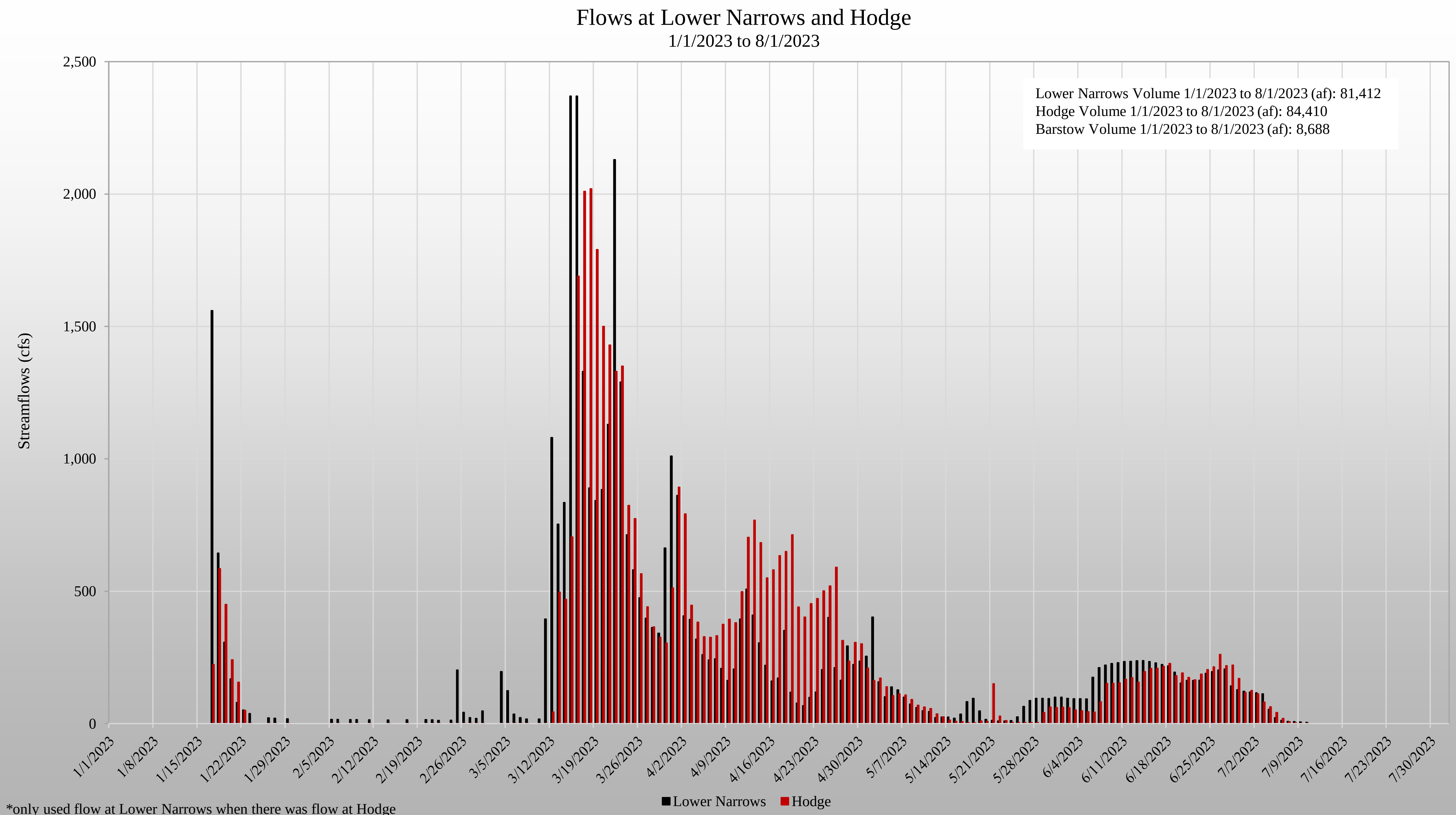


*only used flow at Lower Narrows when there was flow at Hodge

Baja Water Production & Water Levels

- Average Water Production (2017-2023): 19,144 acre-feet
- Average Water Production (2019-2023): 16,709 acre-feet
- Average Water Production (2021-2023): 13,088 acre-feet
- Water levels appear to be stabilizing
- Assuming change in storage is zero PSY = Pumping
- Production Safe Yield estimated over two time periods:
  - (1931-1990): 14,544 acre-feet
  - (2001-2020): 10,866 acre-feet

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
Subsurface Inflow		1,581
Deep Percolation of Precipitation		100
Tributary Inflow		3,571
	TOTAL	**22,610**
CONSUMPTIVE USE AND OUTFLOW		
Surface Water Outflow		6,066
Subsurface Outflow		0
Consumptive use		
Agriculture		6,092
Urban		6,657
Phreatophytes		2,000
	TOTAL	**20,815**
Surplus / (Deficit)		1,795
Total Estimated Production		12,749
PRODUCTION SAFE YIELD		**14,544**

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	7,500
Tributary Inflow	1,568
Subsurface Inflow	1,751
Mountain Front Recharge	647
Barstow Treatment Plan	2,455
Return Flow	554
Deep Percolation of Precipitation	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**

Updated Production Safe Yield and Indicated 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	20.5%	---	12,749	19.3%	20.5%
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%

TABLE 3-2

ANNUAL CHANGE IN STORAGE BY SUBAREA
WATER YEAR 2022-23
(AMOUNTS IN ACRE-FEET)

	Este[1]	Oeste[2]	Alto	Centro	Baja	Total
Total Water Supply	5,108	3,634	263,022	108,359	15,256	**395,379**
Total Outflow and Consumptive Use	5,108	3,634	143,991	27,903	12,625	**193,261**
Net Change in Storage	**0**	**0**	**119,031**	**80,456**	**2,631**	**202,118**

Notes

1. Water level data indicates little or no change in storage on an average annual basis; water supply is estimated to balance outflow and consumptive use.

2. Short term water levels indicate balance supply and demand for the past 15-20 years. Assume change in storage = 0.

Next Steps

- March 27, 2024
  - Public Hearing on FPA recommendation
- May 1, 2024
  - Report to the Court
- June 14, 2024
  - Court Hearing to adopt Watermaster recommendation

Production Safe Yield Update and Proposed Free Production Allowance (2024-2025) Alto and Centro Subareas

March 14, 2024
Robert C. Wagner

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield Update

- Production Safe Yield Update, Base Period, Safe Yield Year
- Upper Mojave Basin Model (UMBM)
- Table 5-1 Alto, Centro
- Future Model Scenario
- Subarea Conditions
  - Historic Water Levels (1964)
    - Barstow area and Waterman Fault
- FPA Recommendations

Production Safe Yield
Judgment after Trial 1996

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

(1) Production Safe Yield

- Base Period
  - Over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea
  - 1931-1990 set by the judgment
- Proposed Base Period
  - 2001-2020

(2 & 3) Production Safe Yield

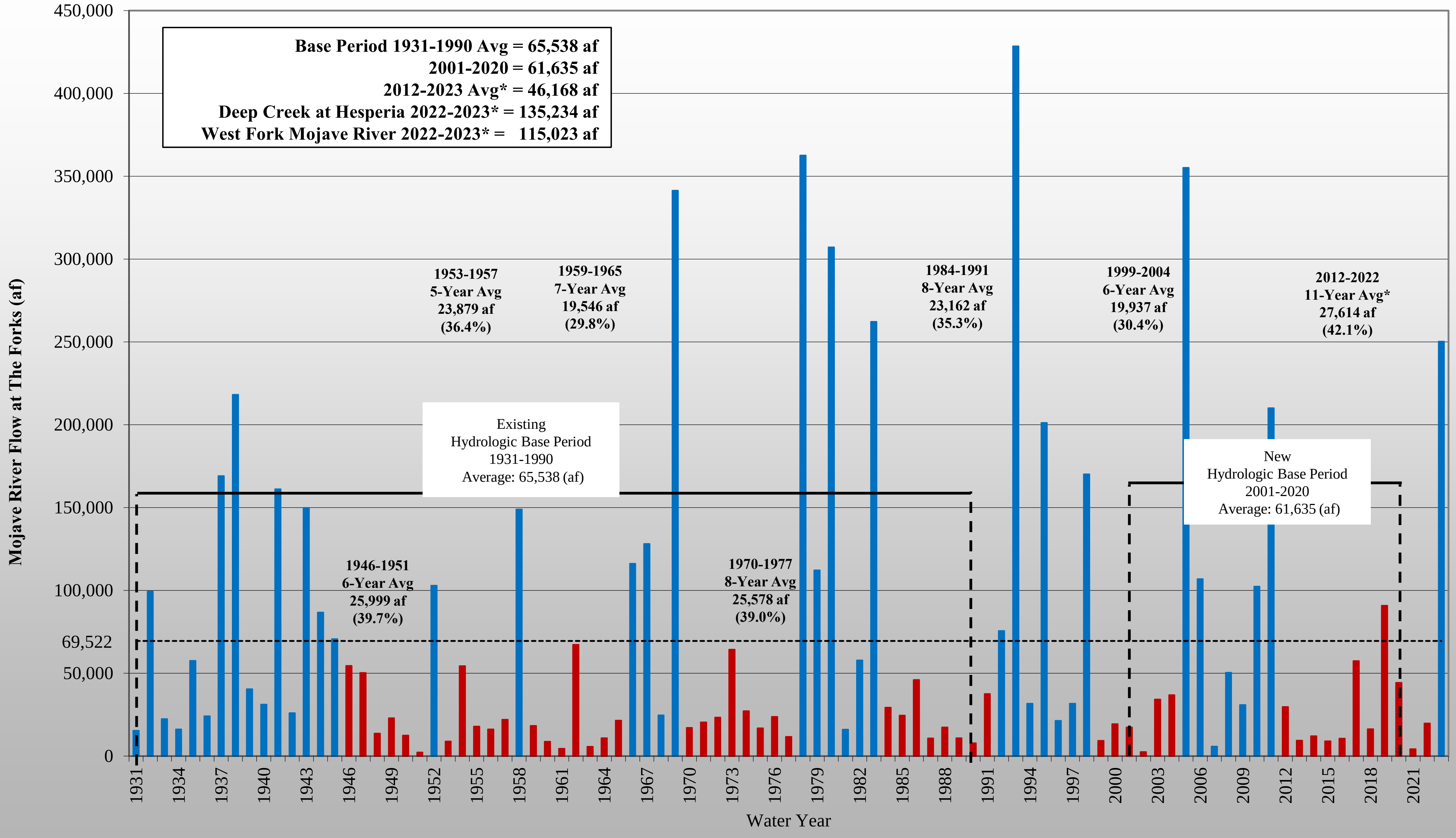
- Safe Yield Year
  - (2) Under given patterns of Production, applied water, return flows and Consumptive Use (Cultural Conditions)
    - Assumed by the Judgment to be 1990 land use conditions
    - Previously 1997-1998, 2017-2018
    - Proposed 2022
  - Cultural conditions are assumed to be reasonably representative of future conditions (evaluated periodically)
  - (3) Without resulting in a long-term net reduction of groundwater in storage in the Subarea
- PSY = Production + Change in Storage

Production Safe Yield

- Base Period from Department of Water Resources Bulletin 84 (1967)
- 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.

* Preliminary data, subject to revision.

Mojave River Flow at The Forks
Water Years 1931 - 2023



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.

Estimated Pumping 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	64,986	61,033	64,129	69,593	67,232	62,354	64,888
TZ	12,700	11,939	12,618	11,809	10,914	10,039	11,670
Alto Total	77,686	72,972	76,747	81,402	78,146	72,393	76,558
Baja	24,524	23,389	20,912	15,095	12,579	11,343	17,974
Centro	20,665	19,784	18,309	19,685	16,983	16,392	18,636
Este	5,055	4,983	5,181	5,258	5,068	4,501	5,008
Oeste	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

Estimated Consumptive Use 2018 – 2023 (acre-feet)

Subareas	2018	2019	2020	2021	2022	2023	Average
Alto	34,001	30,386	33,489	37,871	33,745	31,927	33,570
TZ	7,913	7,294	8,052	7,301	7,375	6,859	7,466
Alto Total	41,914	37,680	41,541	45,172	41,120	38,786	41,035
Baja	24,002	22,611	20,144	13,589	12,025	10,834	17,201
Centro	16,451	15,094	14,044	14,035	12,748	12,279	14,108
Este	3,827	3,634	4,116	4,377	4,388	3,812	4,026
Oeste	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

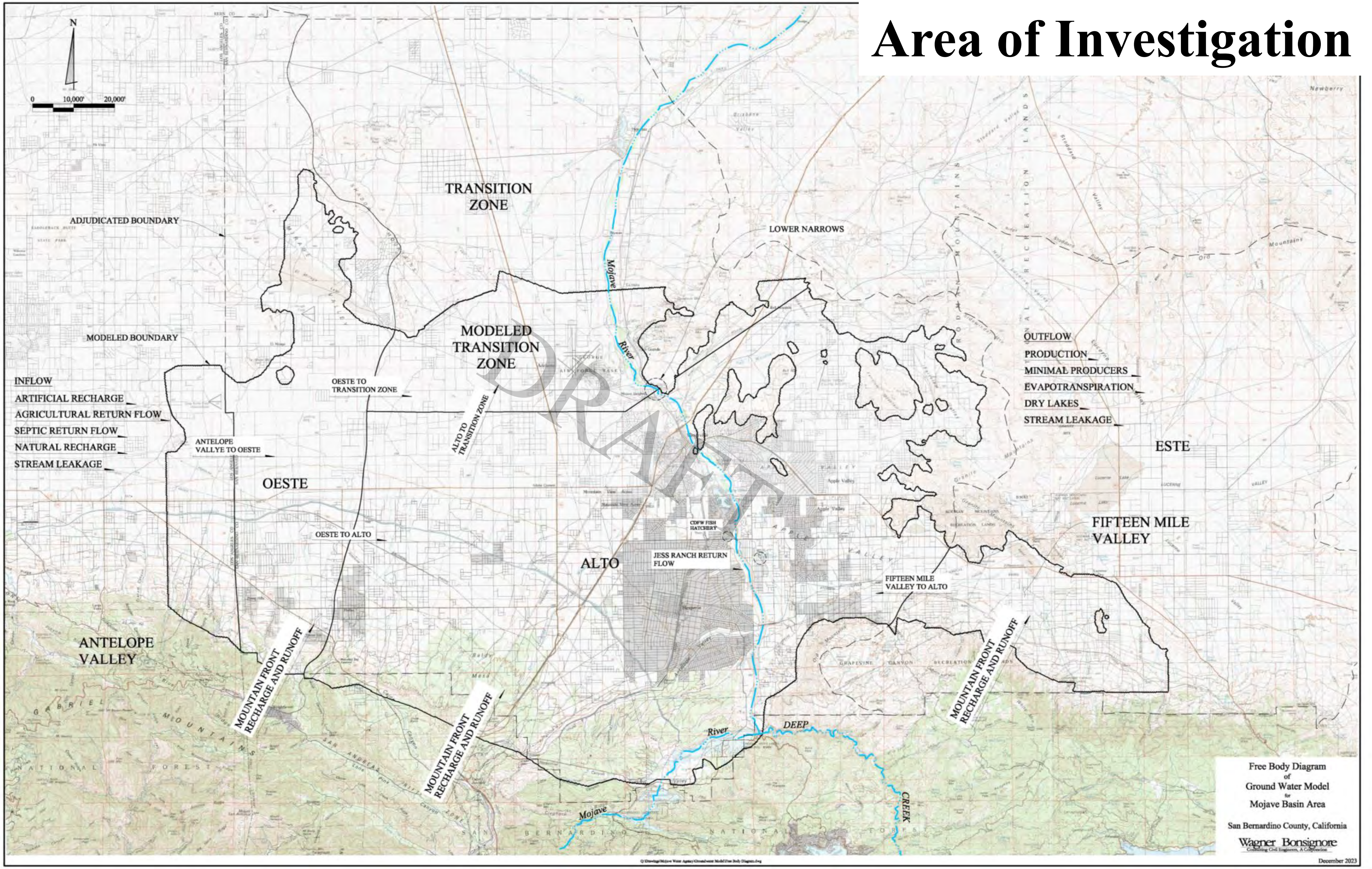
Safe Yield Year

Mojave Basin Groundwater Models

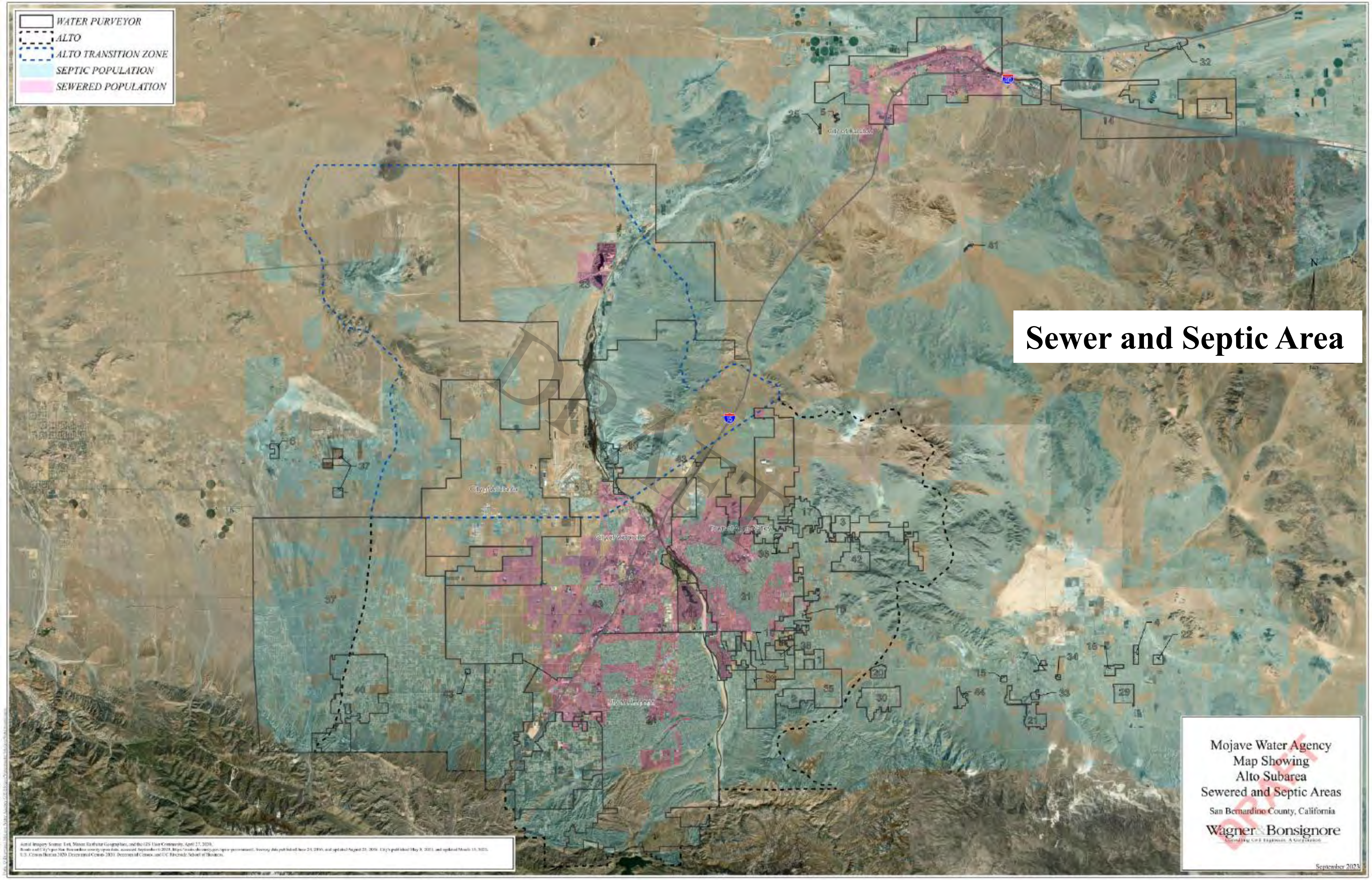
- Earlier versions of the Model
  - Hardt, USGS 1971 (Analog)
  - Stamos, USGS 2001 (MODFLOW)

- Upper Mojave Basin Model
  - Coulibaly, Kapo MWA 2023 (MODFLOW)

Area of Investigation



Sewer and Septic Area



Alto (Above Lower Narrows)
Upper Mojave Basin Model Change in Storage

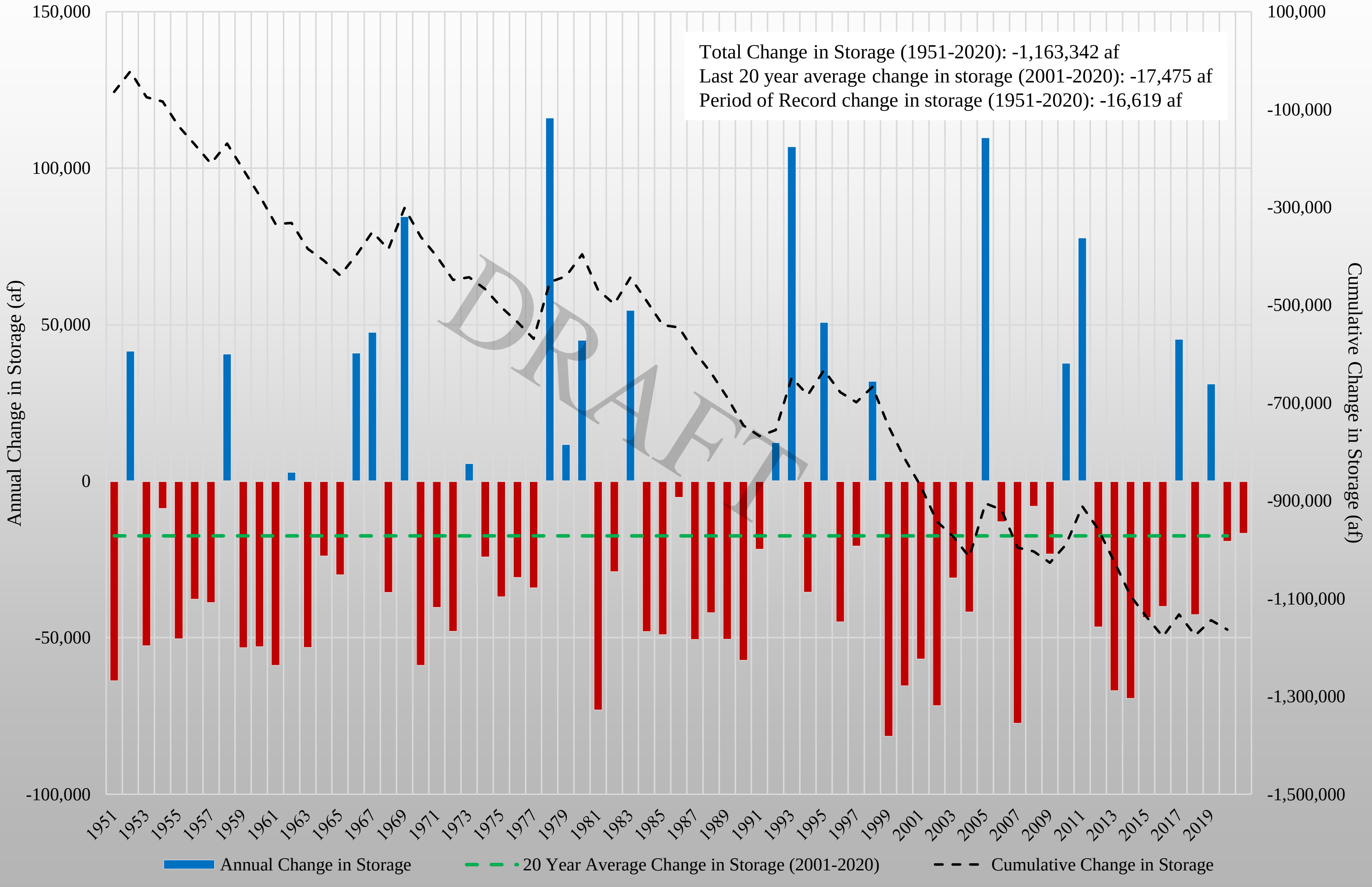


Table 5-1

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
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**

Comparison: Model Output and Table 5-1 (Alto Subarea)

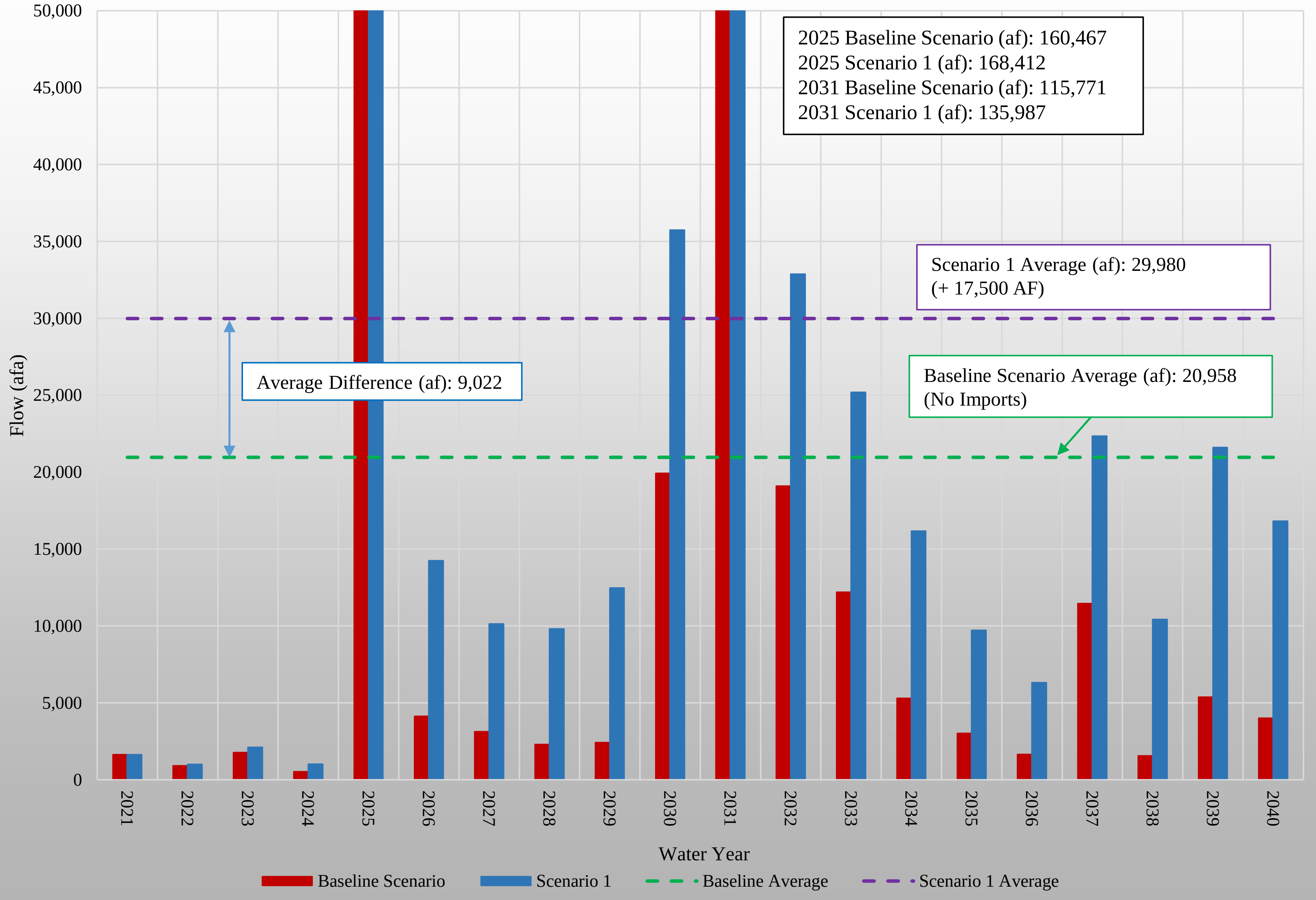
Production Safe Yield Based on Model Output and 2021-2022 Current Year Pumping and Consumptive Use (Alto Subarea)	
Alto above Narrows Production Average 2001 - 2020 (acre-feet)	81,968
2001 - 2020 Average Alto B2 Pumping (acre-feet)	14,118
Alto above Narrows B1 Pumping (acre-feet)	67,850
TZ (2001 - 2020) 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

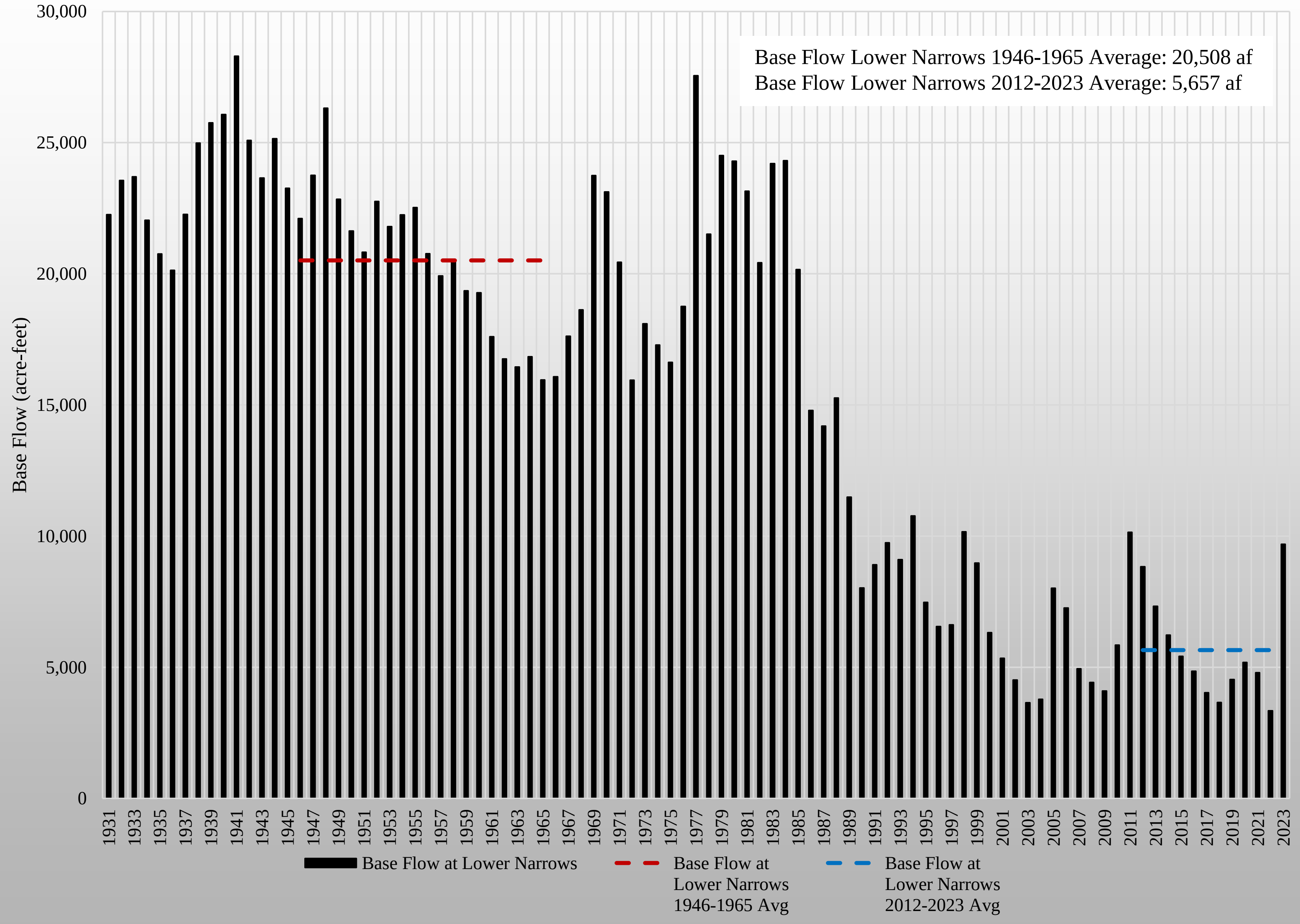
Future Scenario

- Baseline Scenario: The last 20 years hydrology extended in the future with 2020 levels of production and return flows.
- Scenario 1: Baseline Scenario plus 17,500 acre-feet of imports per year spread out over three months (June-July-August) and delivered at Deep Creek.

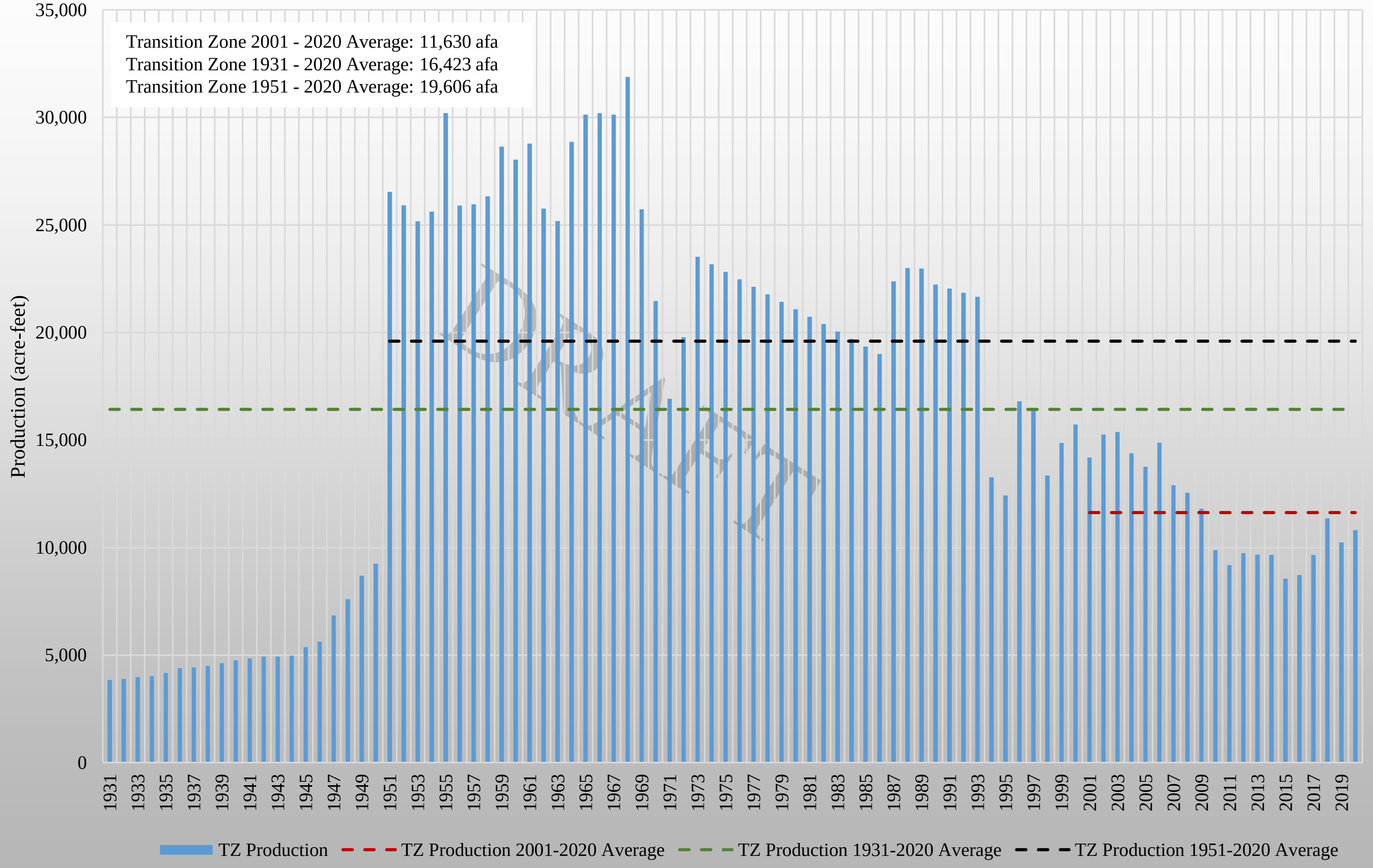
Future Scenario



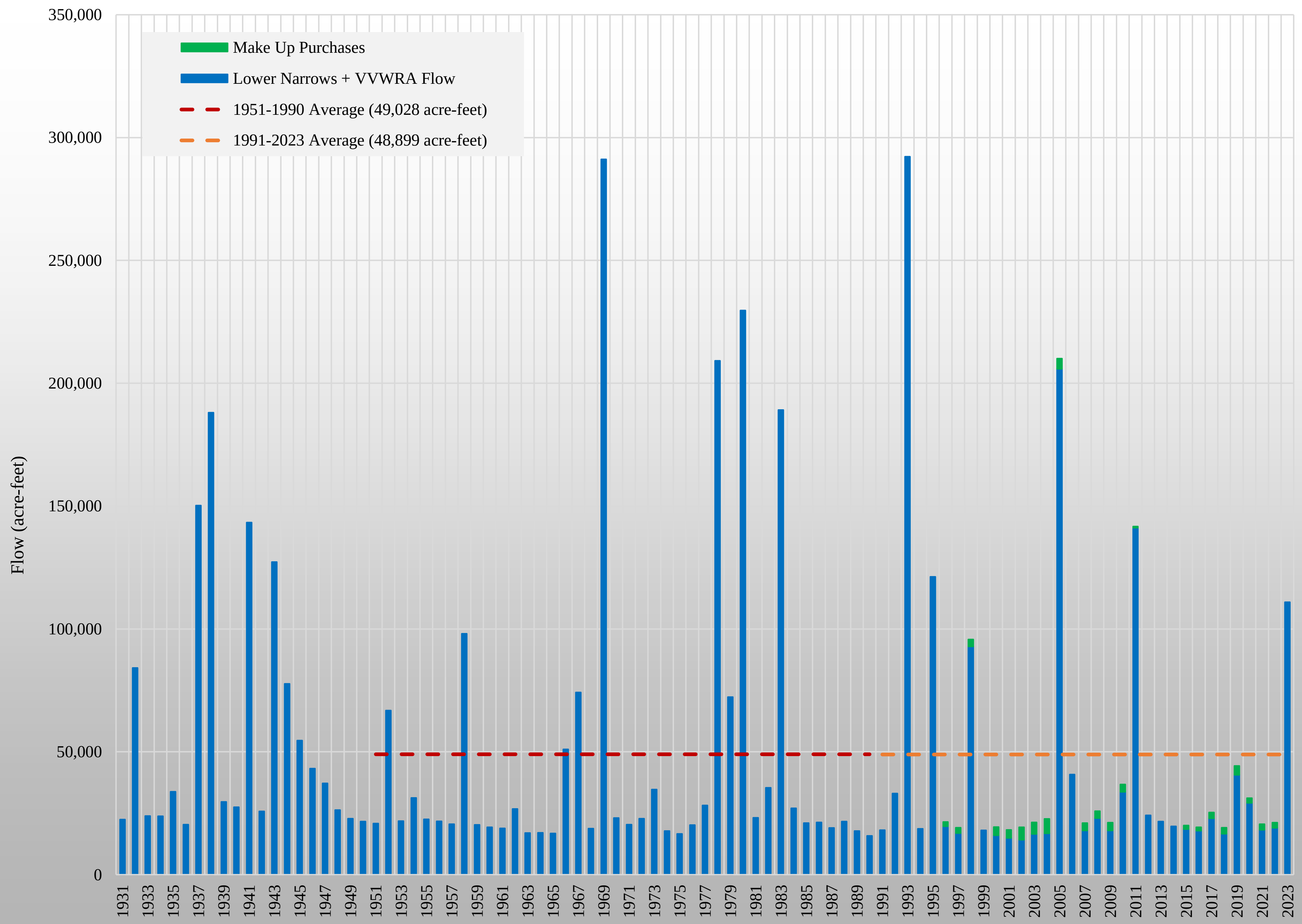
Baseflow Lower Narrows 1946-1965 vs 2012-2023



Transition Zone Historic Production



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.



Make Up Purchases
Lower Narrows + VVWRA Flow
1951-1990 Average (49,028 acre-feet)
1991-2023 Average (48,899 acre-feet)
Flow (acre-feet)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023

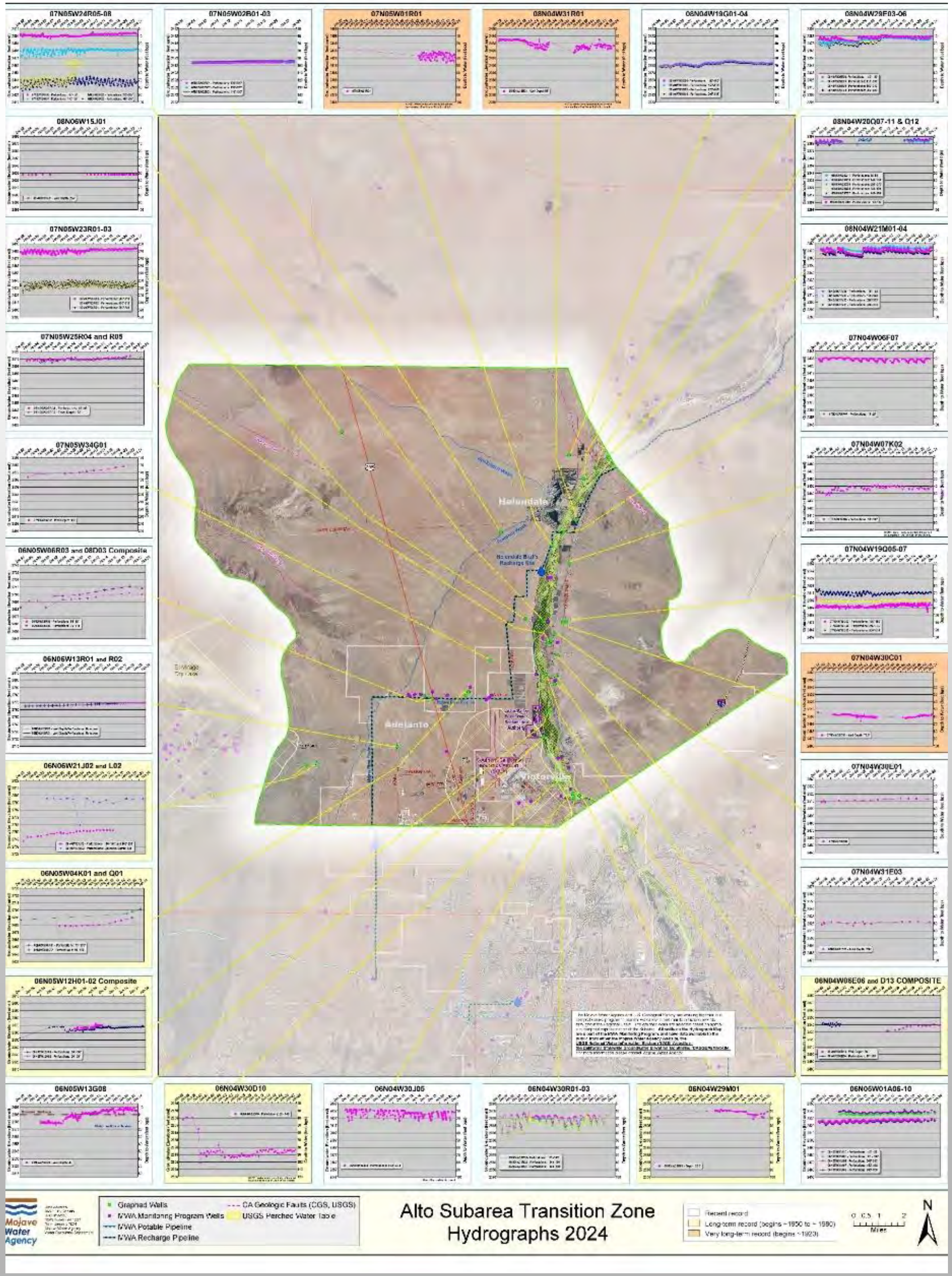

07N05W24R05-08
07N05W02R01-03
07N05W01R01
08N04W31R01
08N04W19G01-04
08N04W29F03-06
08N06W15J01
08N04W20Q07-11 & Q12
07N05W23R01-03
08N04W21M01-04
07N05W25R04 and R05
07N04W06F07
07N05W34G01
07N04W07K02
06N05W06R03 and 08D03 Composite
07N04W19Q05-07
06N06W13R01 and R02
07N04W30C01
06N06W21J02 and L02
07N04W30L01
06N05W04K01 and Q01
07N04W31E03
06N05W12H01-02 Composite
06N04W06E06 and D13 COMPOSITE
06N05W13G08
06N04W30D10
06N04W30J05
06N04W30R01-03
06N04W29M01
06N05W01A06-10
Helendale
Adelanto
Victorville
Mojave Water Agency
Graphed Wells
MWA Monitoring Program Wells
MWA Potable Pipeline
MWA Recharge Pipeline
CA Geologic Faults (CGS, USGS)
USGS Perched Water Table
Alto Subarea Transition Zone
Hydrographs 2024
Recent record
Long-term record (begins ~1950 to ~1980)
Very long-term record (begins ~1923)
0 0.5 1 2
Miles
N

Table 5-1

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
Barstow Treatment Plant Discharge			2,475
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Consumptive use [9]			
Agriculture	949	949	5,863
Urban	40,171	6,456	6,885
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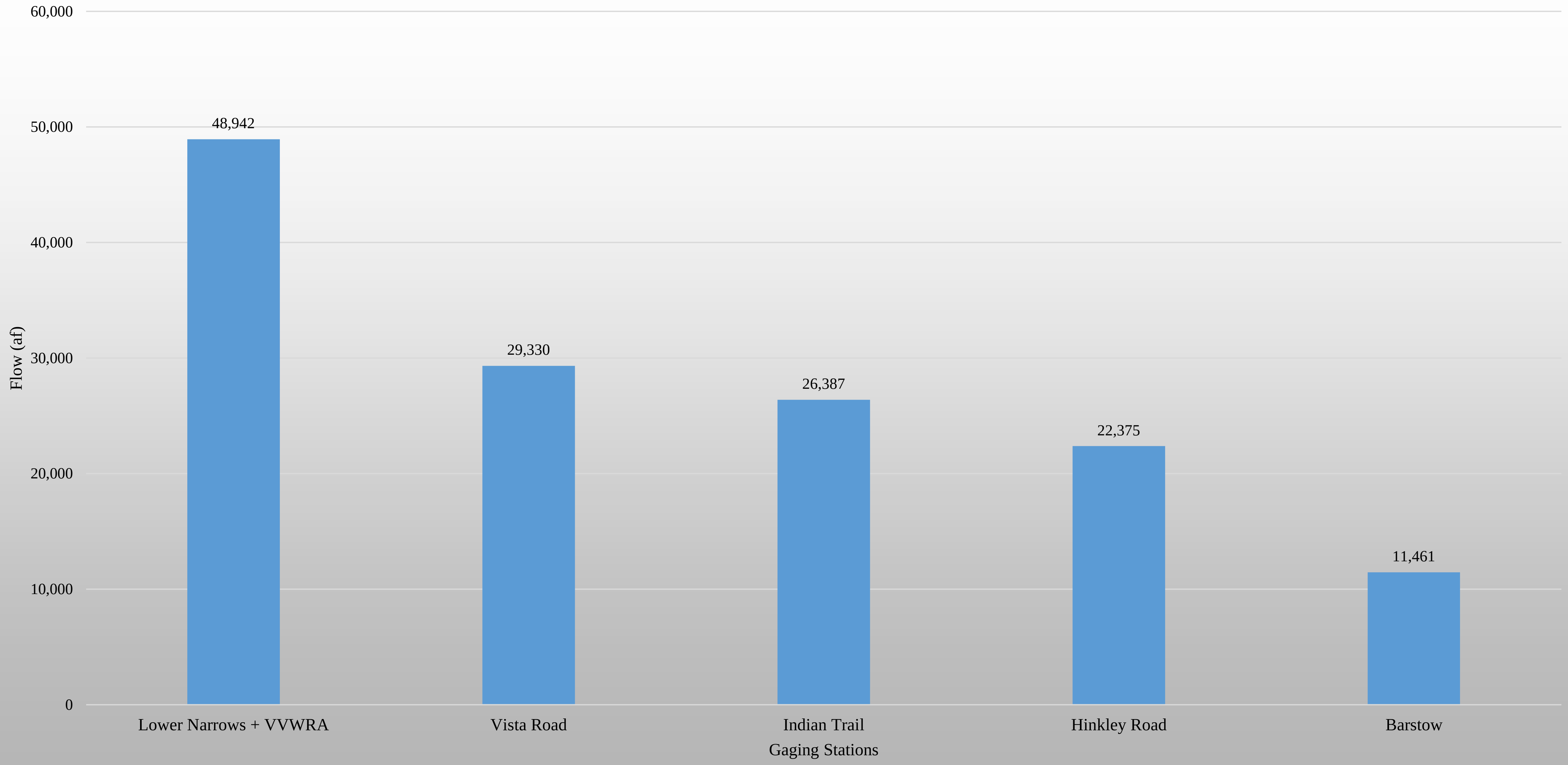
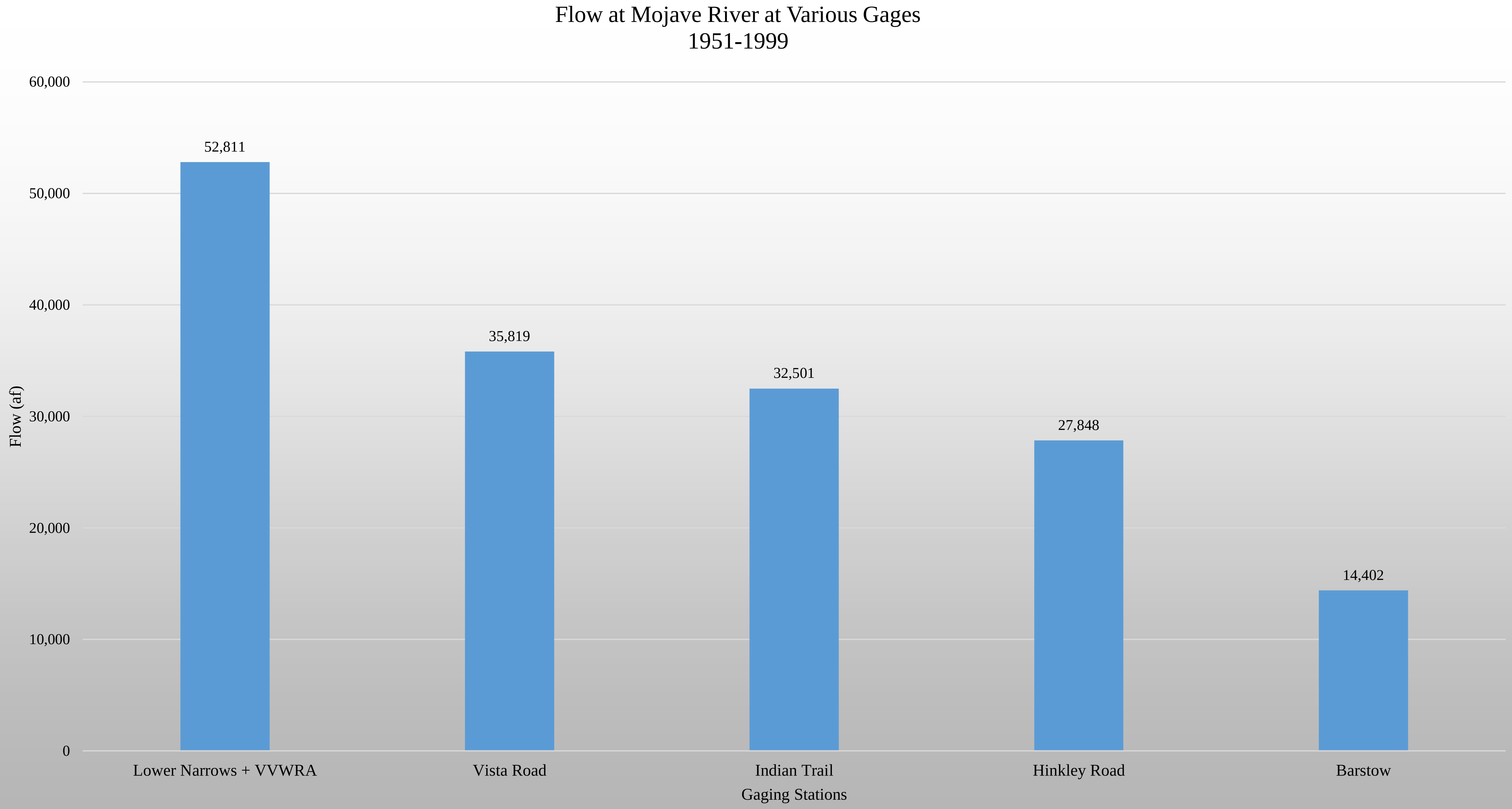
TOTAL	**90,845**	**52,130**	**27,185**
Surplus / (Deficit) [11]	(15,914)		11,540
Total Estimated Production[12]	78,147		16,995
Potential Return Flow from Surplus	0		2,885
PRODUCTION SAFE YIELD[13]	**62,233**		**31,420**

Flow at Mojave River at Various Gages
1951-1990



Note:
1. Lower Narrows + VVWRA, USGS Surface flow and watermaster.
2. Vista Road, Indian Trails, Hinkley Road, and Barstow from USGS 2001 Stamos model.



Note:
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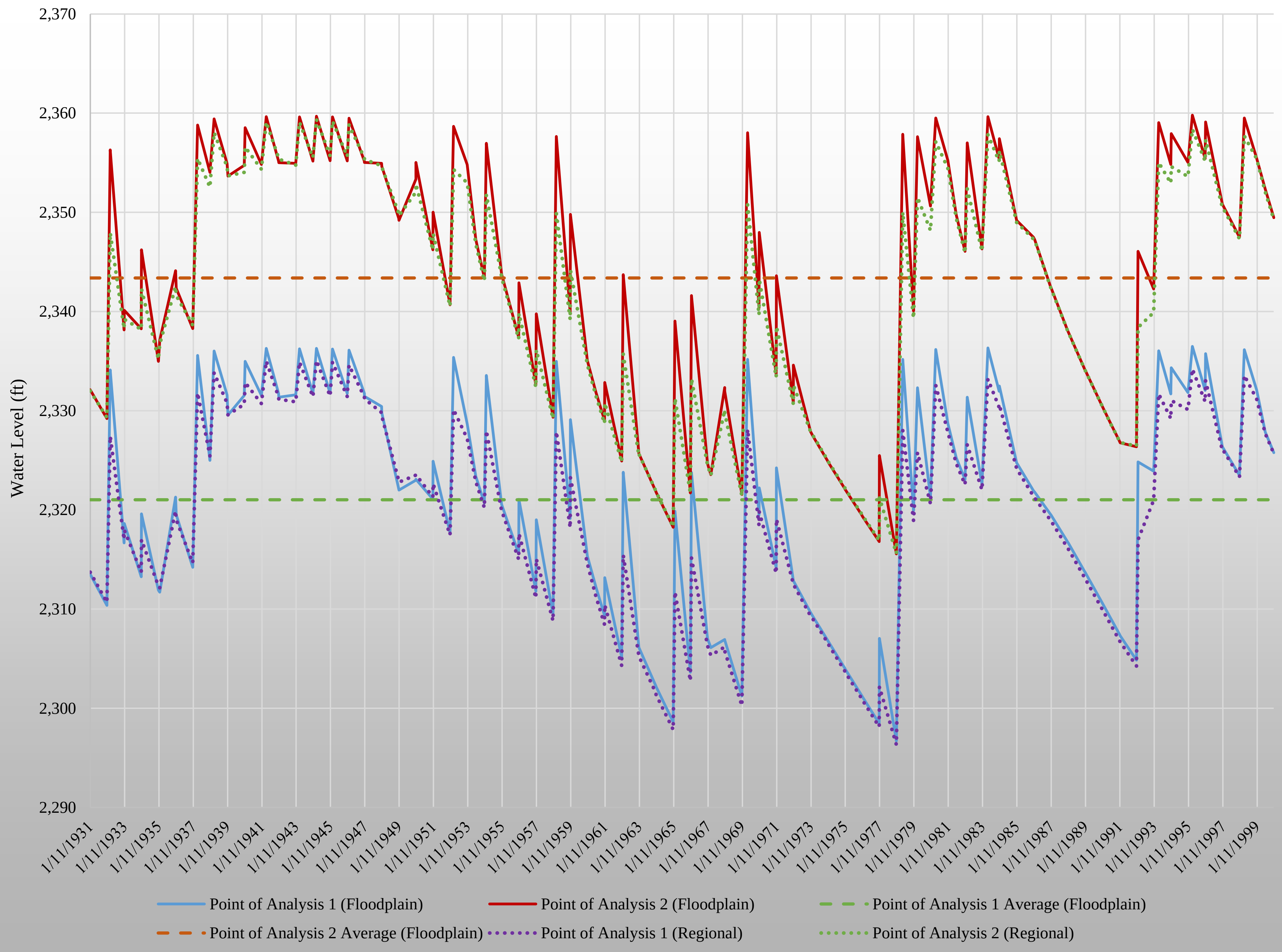
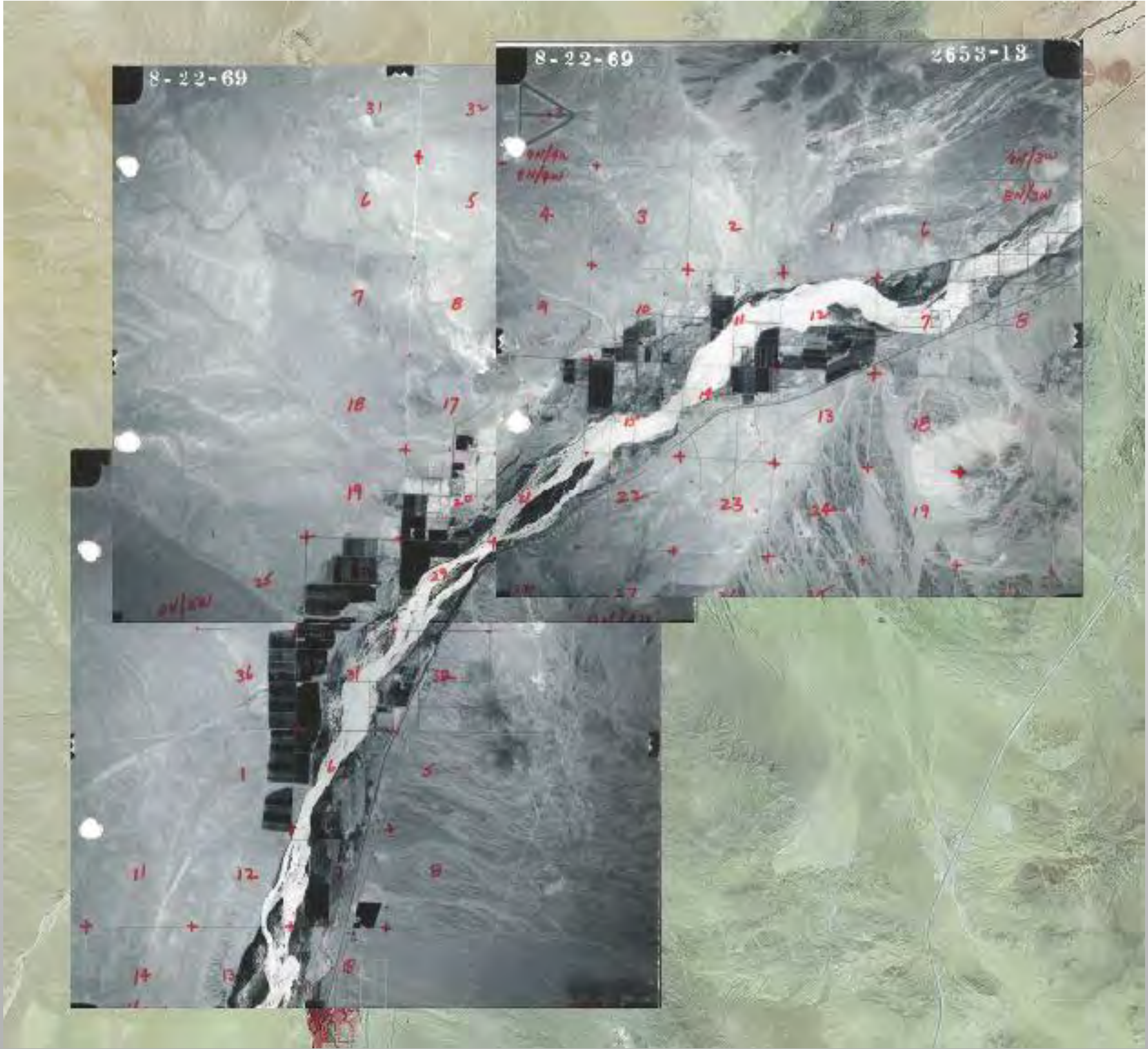
2. Vista Road, Indian Trails, Hinkley Road, and Barstow from USGS 2001 Stamos model.

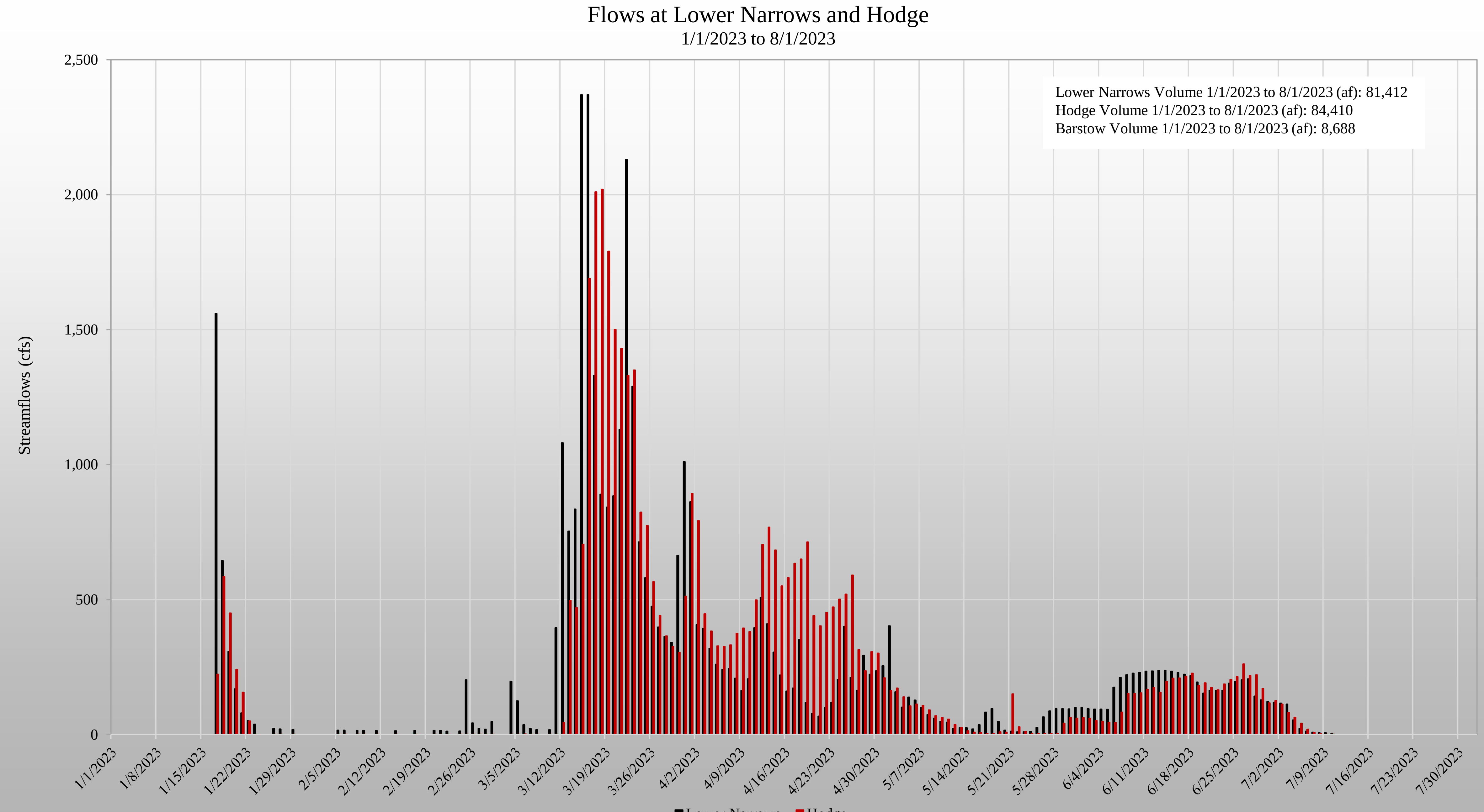


2,370
2,360
2,350
2,340
2,330
2,320
2,310
2,300
2,290
Water Level (ft)
1/11/1931
1/11/1933
1/11/1935
1/11/1937
1/11/1939
1/11/1941
1/11/1943
1/11/1945
1/11/1947
1/11/1949
1/11/1951
1/11/1953
1/11/1955
1/11/1957
1/11/1959
1/11/1961
1/11/1963
1/11/1965
1/11/1967
1/11/1969
1/11/1971
1/11/1973
1/11/1975
1/11/1977
1/11/1979
1/11/1981
1/11/1983
1/11/1985
1/11/1987
1/11/1989
1/11/1991
1/11/1993
1/11/1995
1/11/1997
1/11/1999
Point of Analysis 1 (Floodplain)
Point of Analysis 2 (Floodplain)
Point of Analysis 1 Average (Floodplain)
Point of Analysis 2 Average (Floodplain)
Point of Analysis 1 (Regional)
Point of Analysis 2 (Regional)


8-22-69
8-22-69
2653-13


Legend
Helendale to Hodge
Hodge to Barstow
Point of Analysis
Hodge to Barstow: 11.3 River Miles
Helendale to Hodge: 9.2 River Miles
Hinkley
Barstow
GRANDVIEW
Lenwood
Nebo Center
Daggett
Hodge
Point of Analysis 1
Point of Analysis 2
Helendale
58
15
247
40
Google Earth
N
6 mi


Legend
Helendale to Hodge
Hodge to Barstow
Point of Analysis
Maximum Perfo
Hodge
66
Point of Analysis 1
National Trails Hwy
Main St
Point of Analysis 2
Church Of The Americas
National Trails Hwy
66
Google Earth
1 mi
N

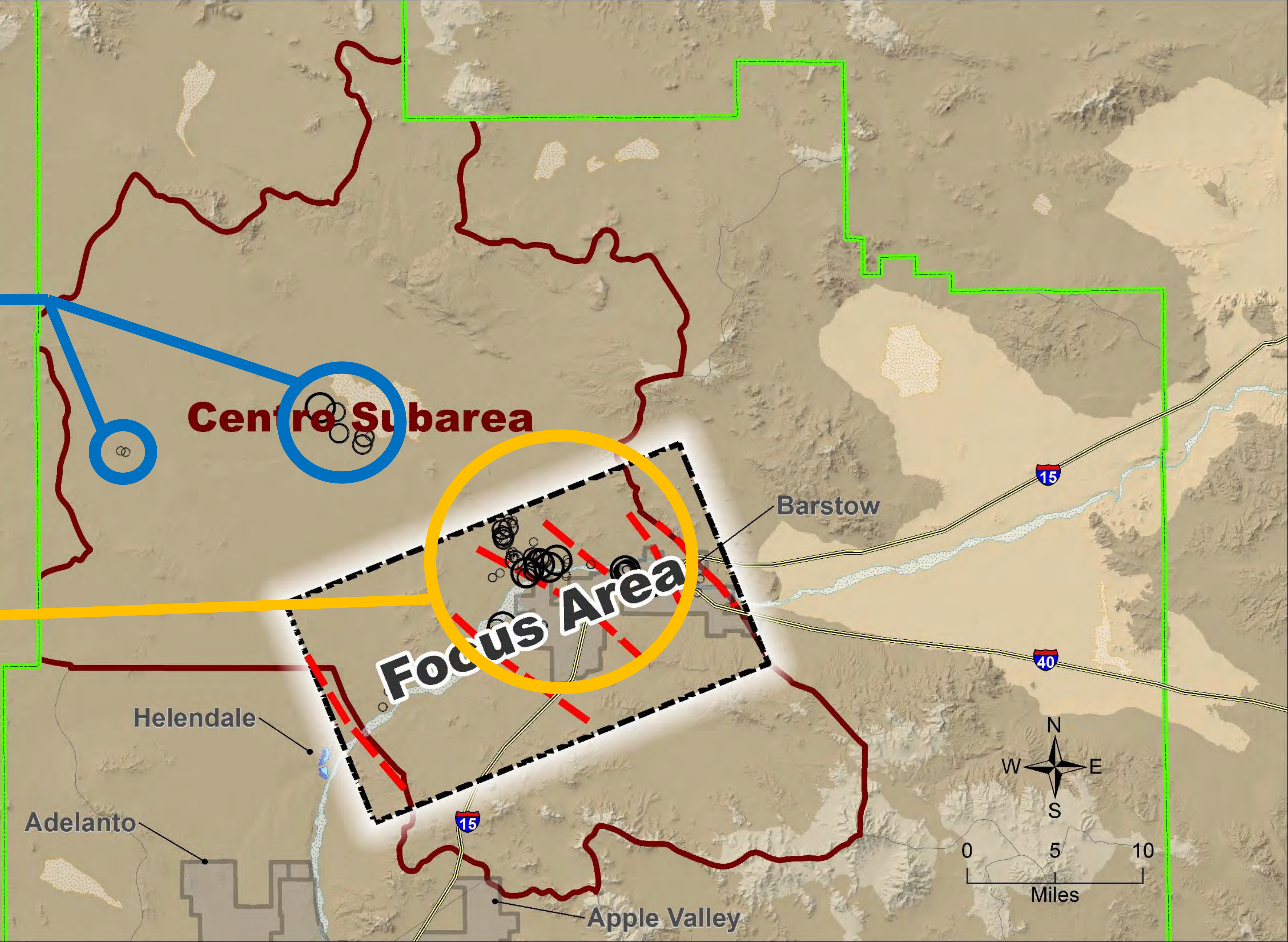


*only used flow at Lower Narrows when there was flow at Hodge

Areas of Production

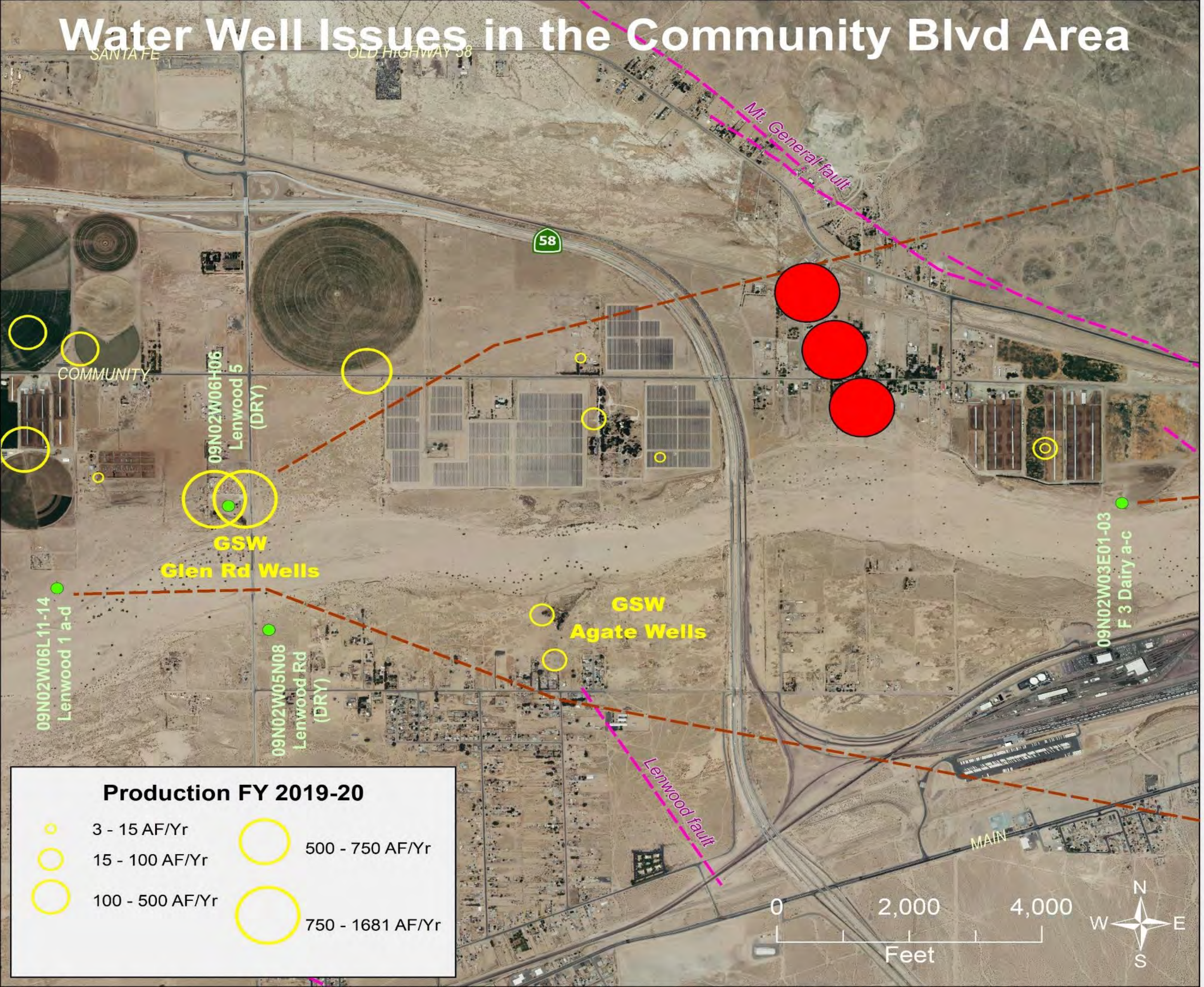
15% Outside Focus Area

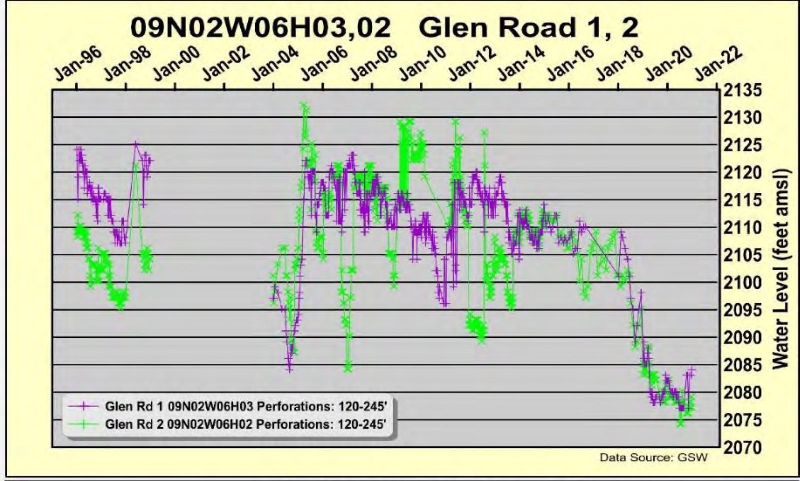
85% Inside Focus Area

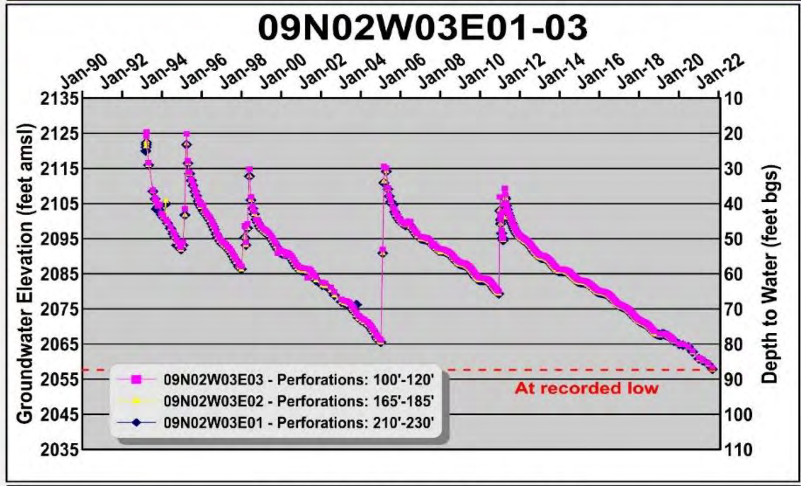


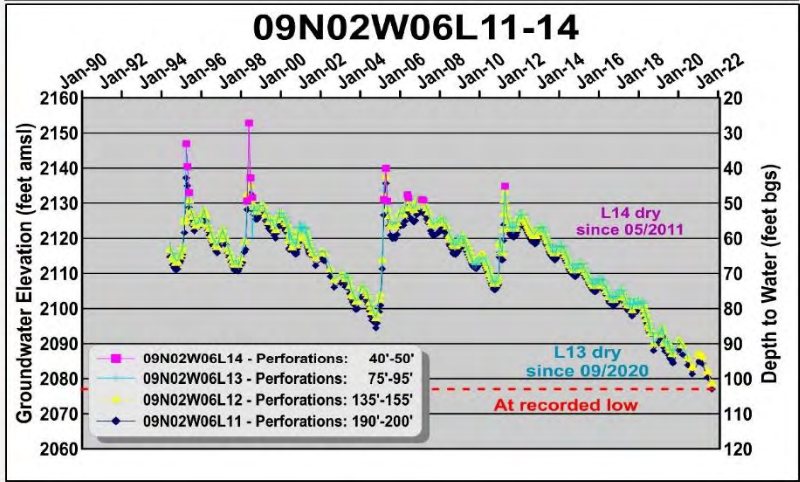
2023 Aerial Image

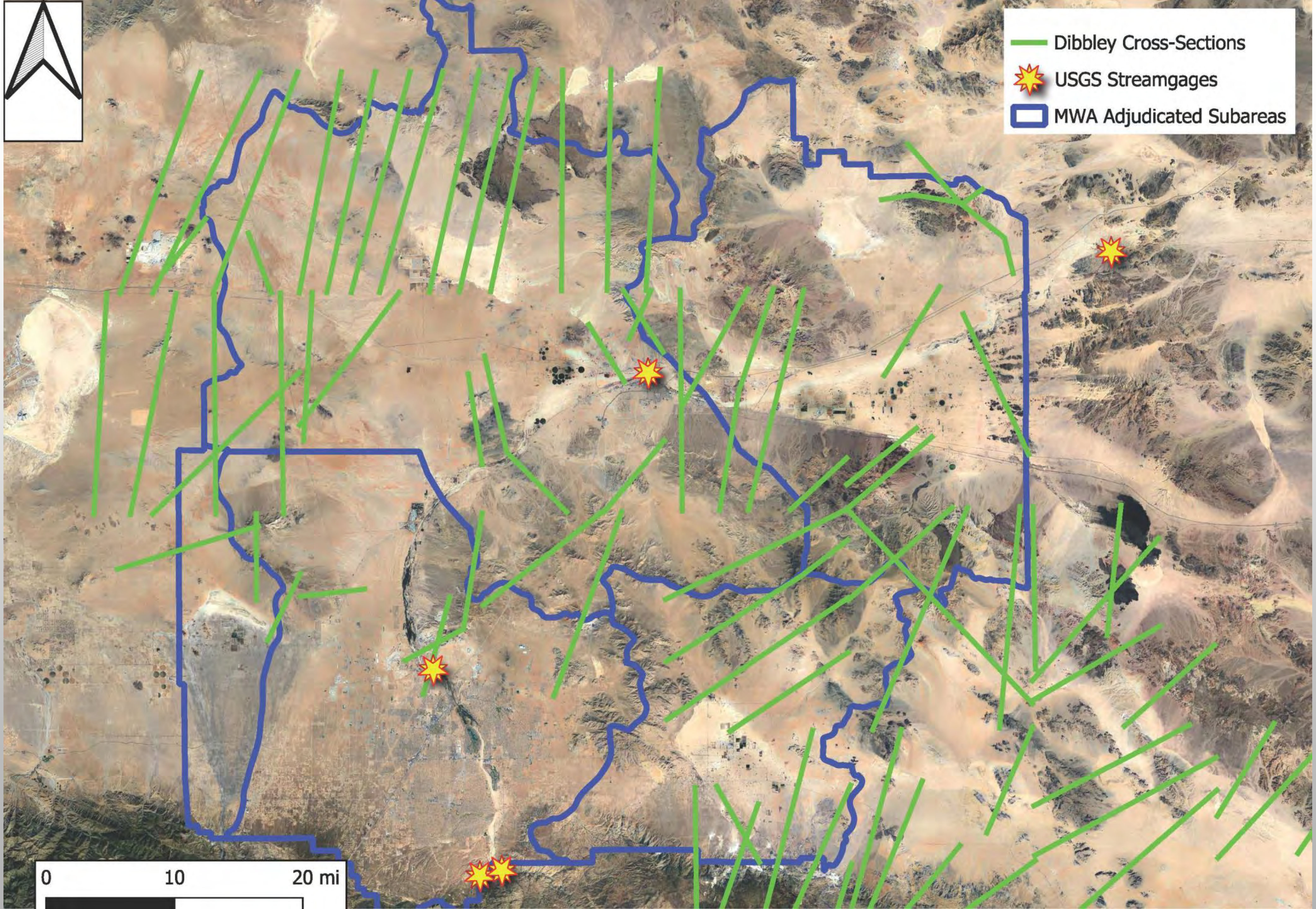
Water Well Issues in the Community Blvd Area

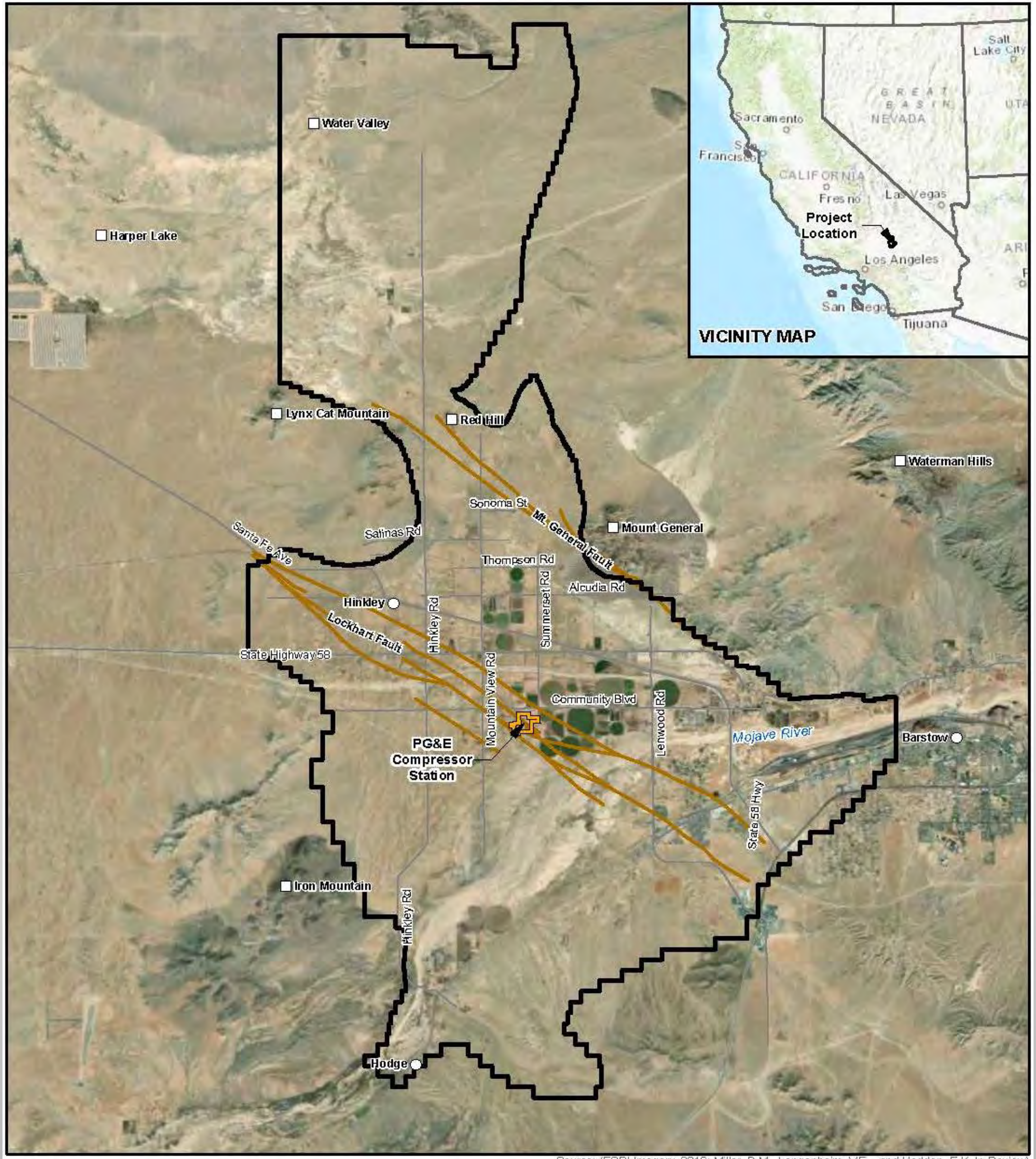









Dibbley Cross-Sections
USGS Streamgages
MWA Adjudicated Subareas
0
10
20 mi



Source: (ESRI Imagery, 2016; Miller, D.M., Langenheim, V.E., and Haddon, E.K, In Review)

LEGEND

- ○ Town/City Location
- □ Topographic Feature
- Fault Location
- Highway/Road
- Study Area
- PG&E Compressor Station

0 2.5 5 Miles

FIGURE 1-1
STUDY AREA
Groundwater Flow Modeling to Support the Hinkley Chromium Background Study San Bernardino County, California

R:\ENBG\00_PROJ\P\PGE\HINKLEY\MAPFILES\GWFLOWMODEL_CH_BGSTUDY\FIG01-01_STUDYAREA.MXD 6/4/2019 12:07:56 PM FELHADID

JACOBS

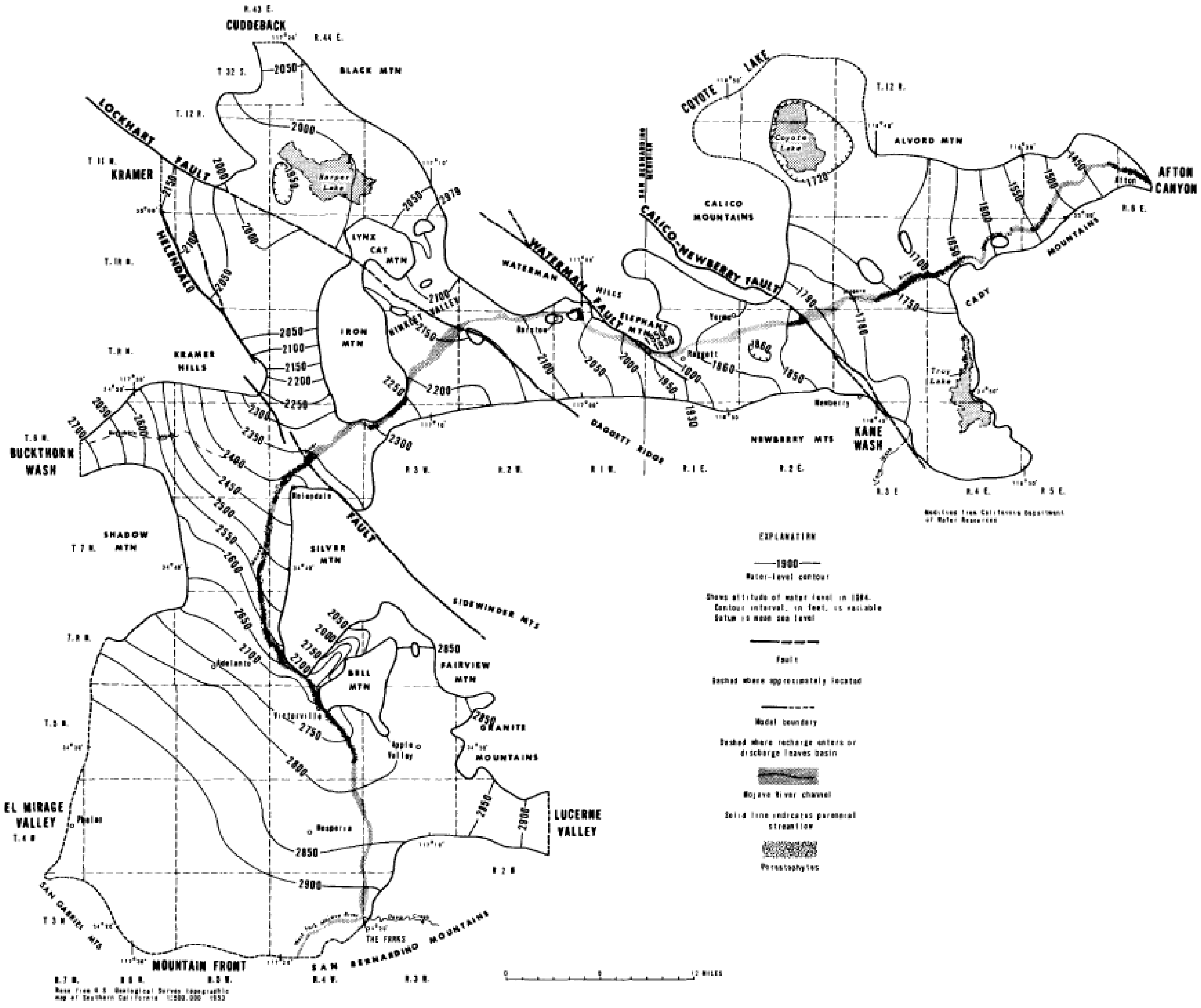
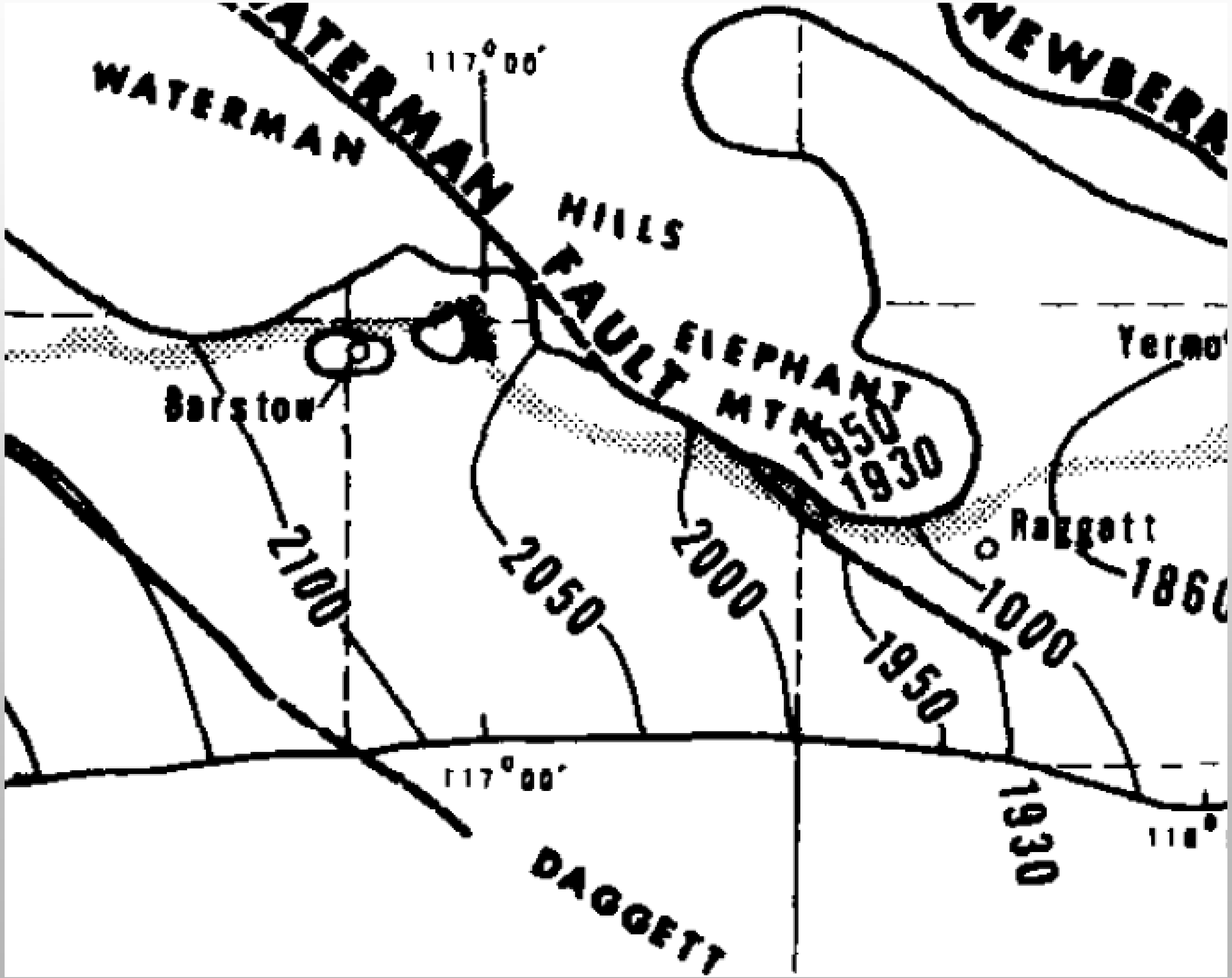
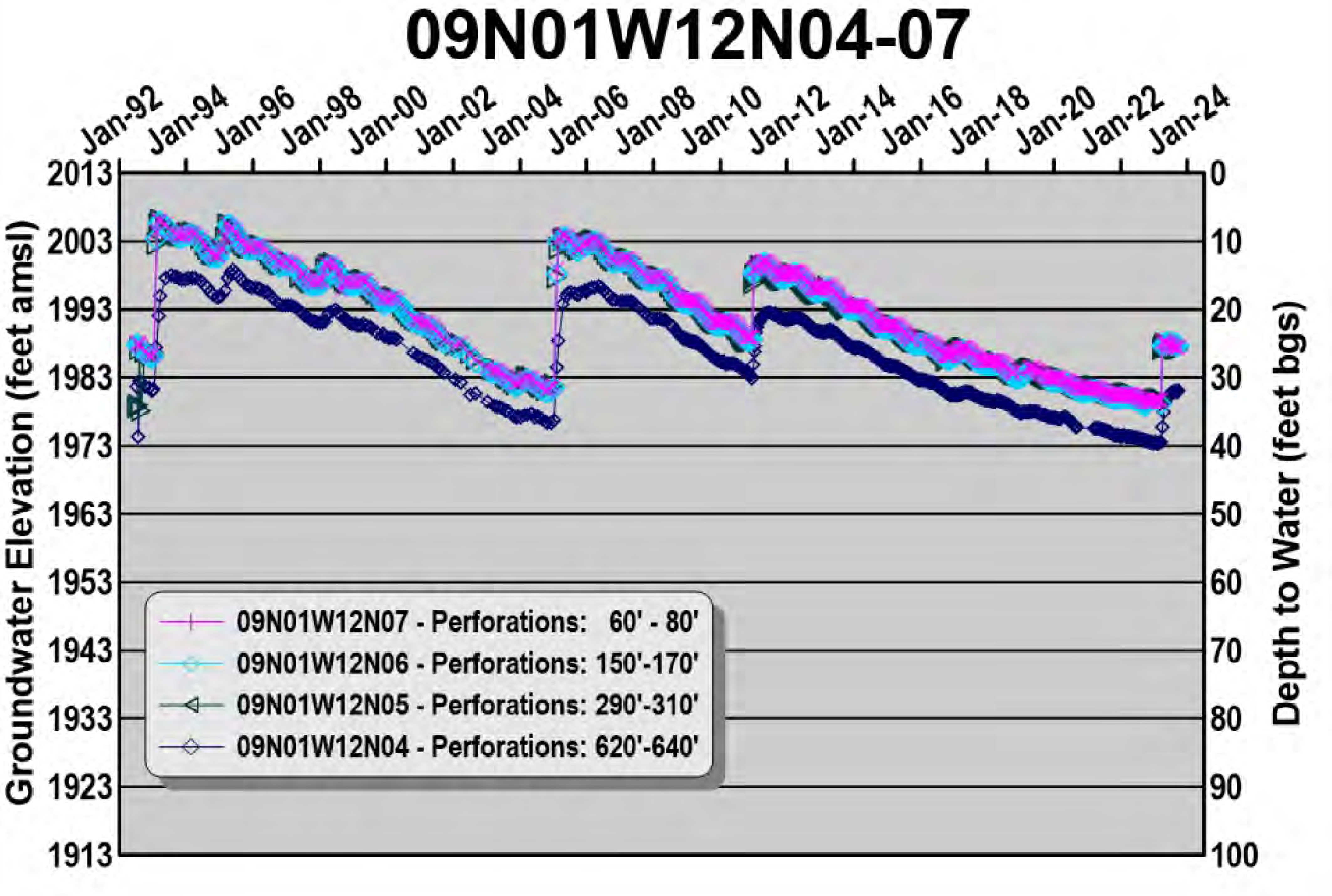


FIGURE 16.--Ground-water level, spring 1964.

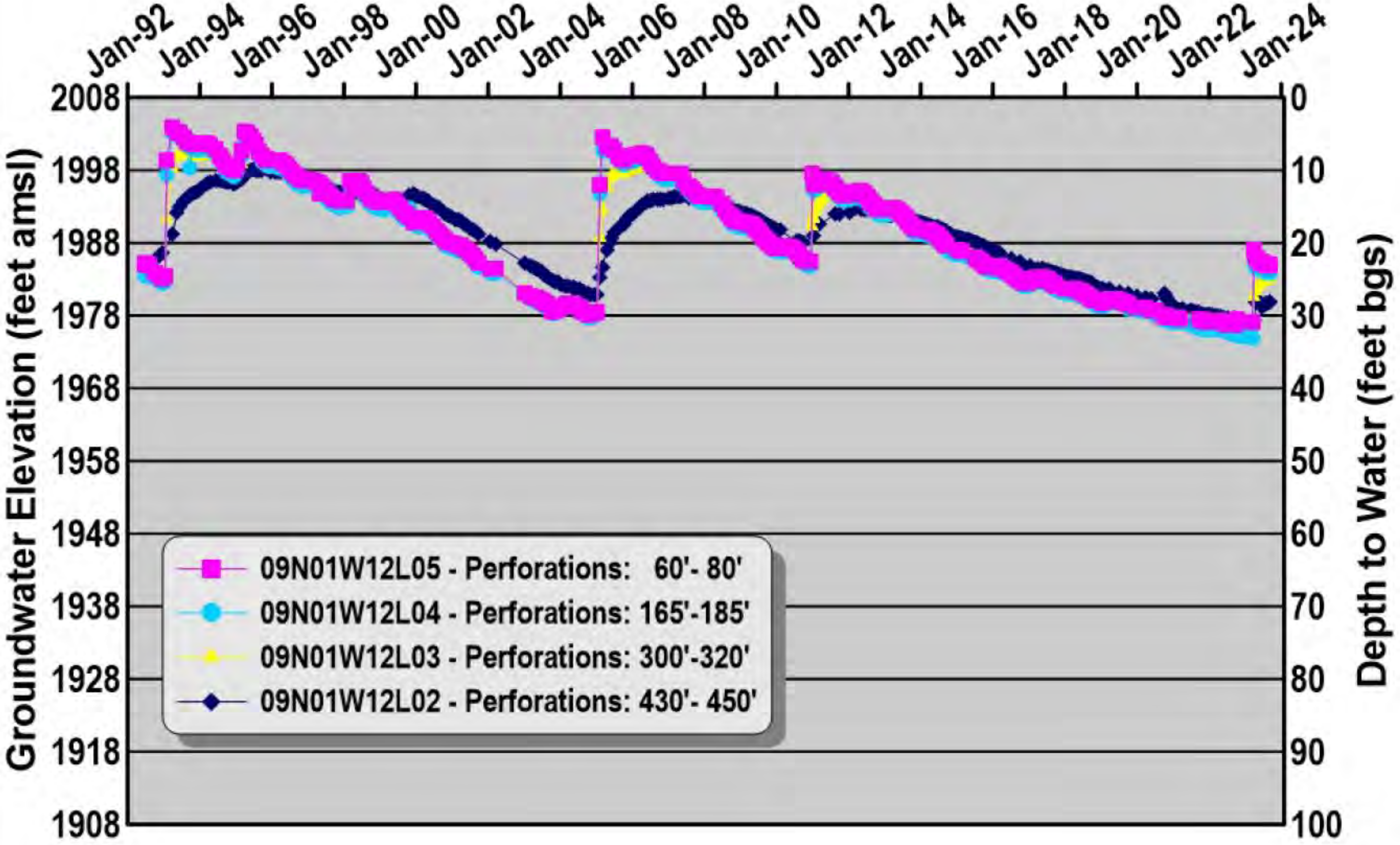
Waterman Fault (Hardt)





09N01W12N04-07
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22
Jan-24
Groundwater Elevation (feet amsl)
2013
2003
1993
1983
1973
1963
1953
1943
1933
1923
1913
Depth to Water (feet bgs)
0
10
20
30
40
50
60
70
80
90
100
09N01W12N07 - Perforations: 60' - 80'
09N01W12N06 - Perforations: 150'-170'
09N01W12N05 - Perforations: 290'-310'
09N01W12N04 - Perforations: 620'-640'

09N01W12L02-05



Updated Production Safe Yield and Indicated 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	20.5%	---	12,749	19.3%	20.5%
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%

TABLE 3-2

ANNUAL CHANGE IN STORAGE BY SUBAREA
WATER YEAR 2022-23
(AMOUNTS IN ACRE-FEET)

	Este[1]	Oeste[2]	Alto	Centro	Baja	Total
Total Water Supply	5,108	3,634	263,022	108,359	15,256	**395,379**
Total Outflow and Consumptive Use	5,108	3,634	143,991	27,903	12,625	**193,261**
Net Change in Storage	**0**	**0**	**119,031**	**80,456**	**2,631**	**202,118**

Notes

1. Water level data indicates little or no change in storage on an average annual basis; water supply is estimated to balance outflow and consumptive use.

2. Short term water levels indicate balance supply and demand for the past 15-20 years. Assume change in storage = 0.

Next Steps

- March 27, 2024
  - Public Hearing on FPA recommendation
- May 1, 2024
  - Report to the Court
- June 14, 2024
  - Court Hearing to adopt Watermaster recommendation

Production Safe Yield Update and Proposed Free Production Allowance (2024-2025)

March 27, 2024
Robert C. Wagner

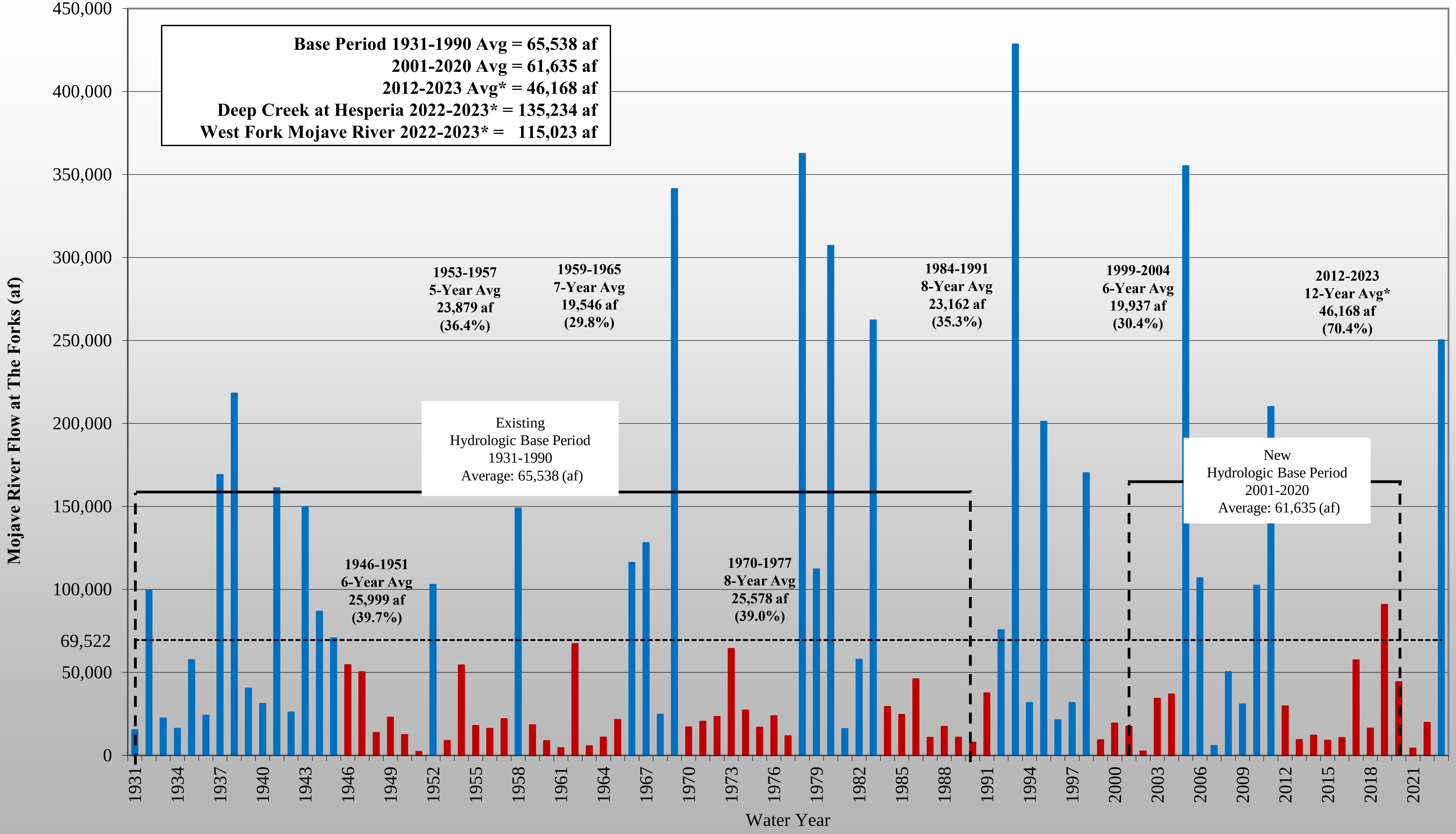
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Production Safe Yield – FPA Recommendation

- Production Safe Yield Update, Hydrologic Base Period
- Upper Mojave Basin Model (UMBM)
- Table 5-1 Alto, Centro
- Subarea Water Levels
  - Transition Zone
  - Este
  - Oeste
  - Baja
- FPA Recommendations

* Preliminary data, subject to revision.

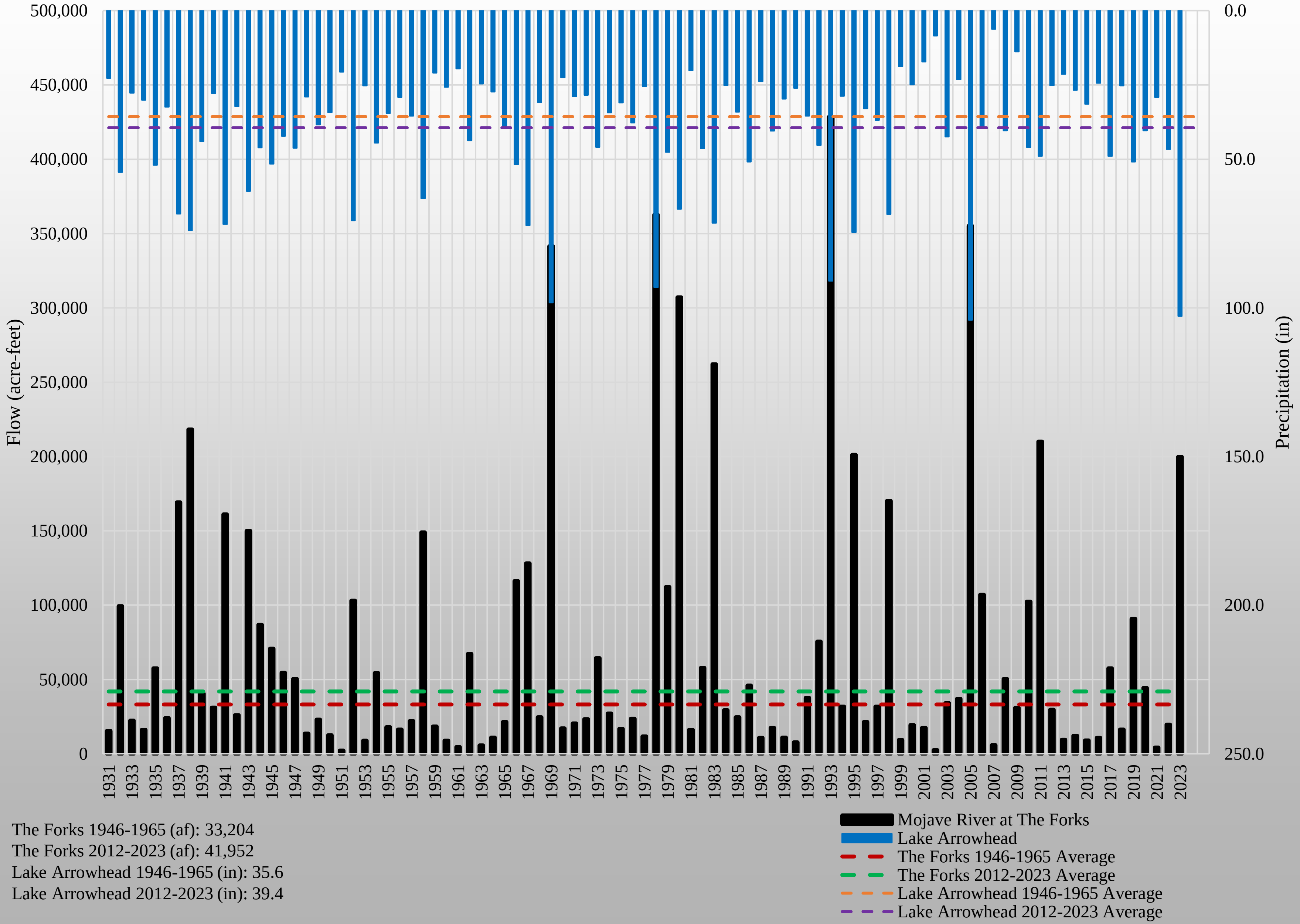
Mojave River Flow at The Forks
Water Years 1931 - 2023



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.

The Forks and Lake Arrowhead

1946-1965 vs 2012-2023

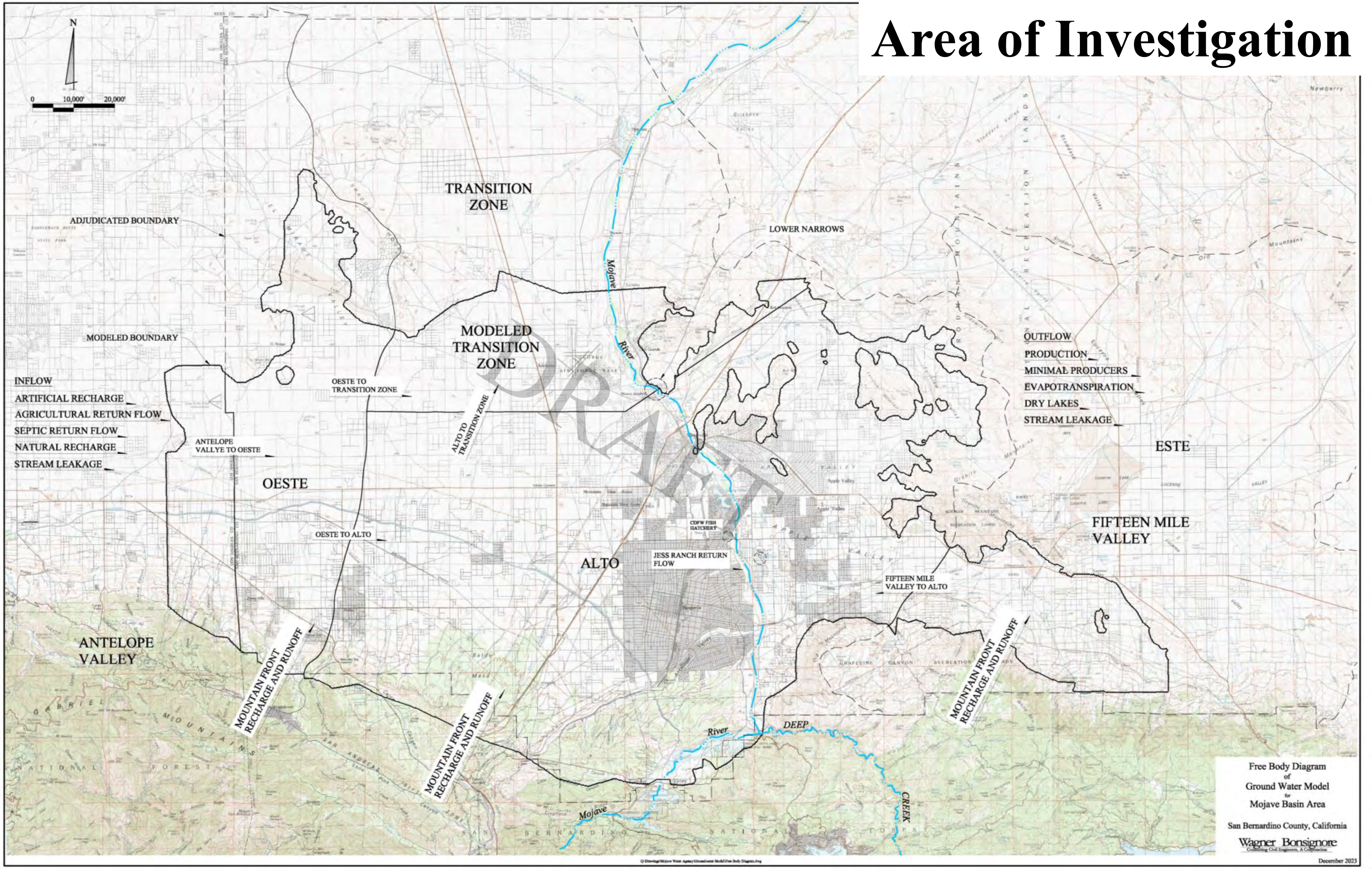


The Forks 1946-1965 (af): 33,204
The Forks 2012-2023 (af): 41,952
Lake Arrowhead 1946-1965 (in): 35.6
Lake Arrowhead 2012-2023 (in): 39.4

Mojave Basin Groundwater Models

- Earlier versions of the Model
  - Hardt, USGS 1971 (Analog)
  - Stamos, USGS 2001 (MODFLOW)
- Upper Mojave Basin Model
  - Coulibaly, Kapo MWA 2023 (MODFLOW)
    - Model is being expanded to include Centro and Baja

Area of Investigation



Comparison: Model Output and Table 5-1 (Alto Subarea)

Production Safe Yield Based on Model Output and 2021-2022 Current Year Pumping and Consumptive Use (Alto Subarea)	
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%

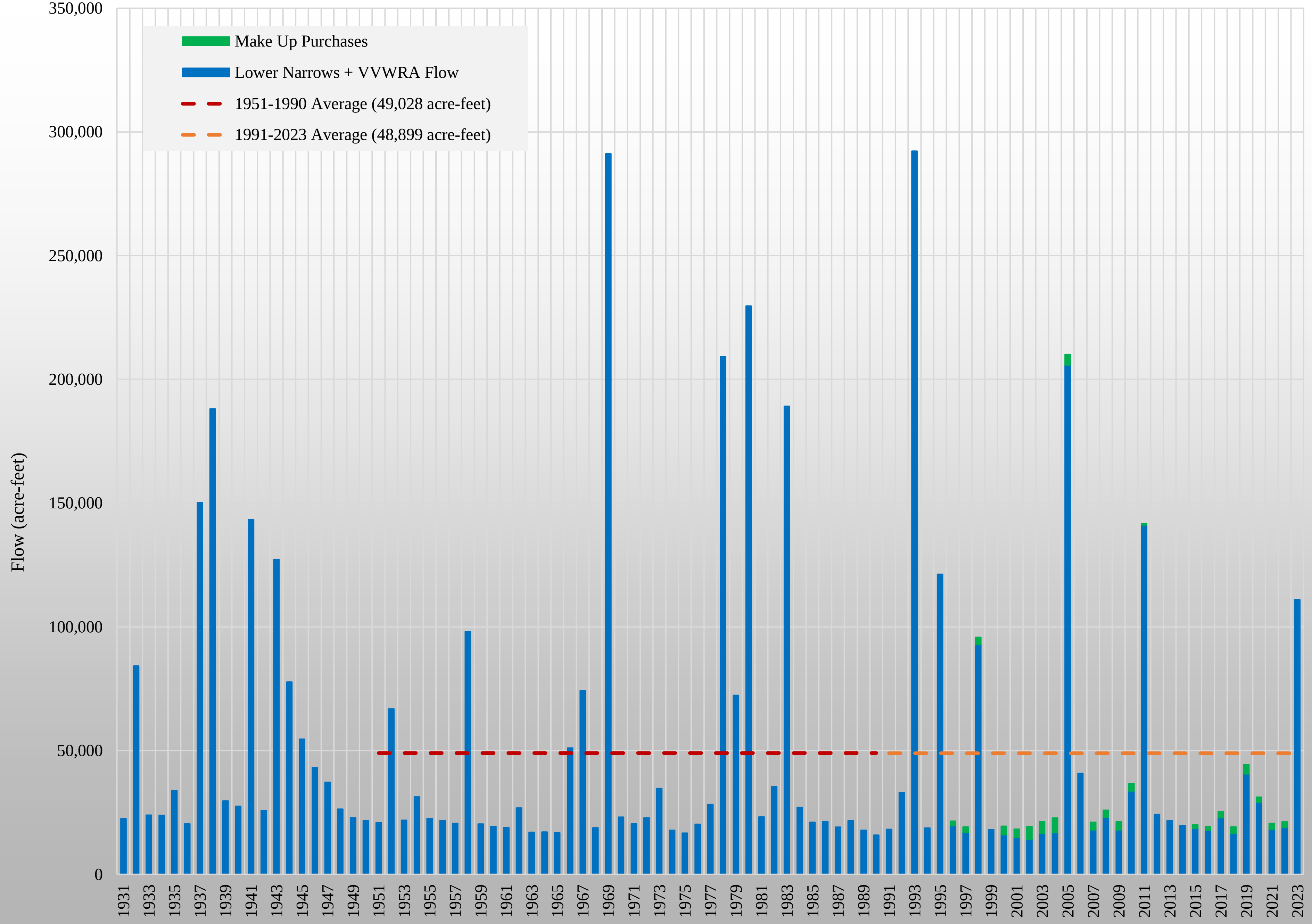
Current Production Safe Yield	59,409

Table 5-1

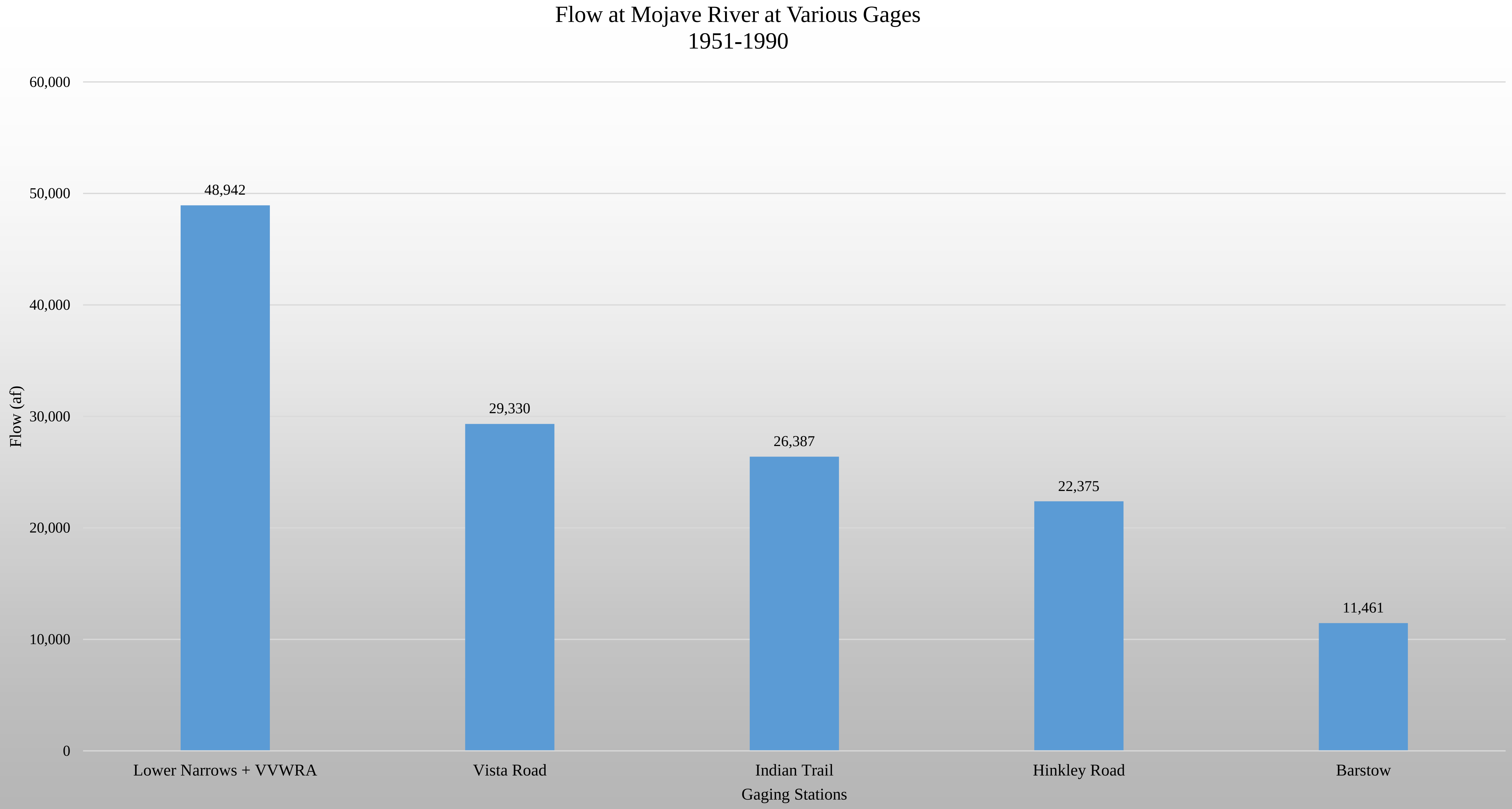
HYDROLOGICAL INVENTORY BASED ON VARIOUS SUPPLY ASSUMPTIONS AND 2021-22 CONSUMPTIVE USE, RETURN FLOW AND IMPORTS

(ALL AMOUNTS IN ACRE-FEET)

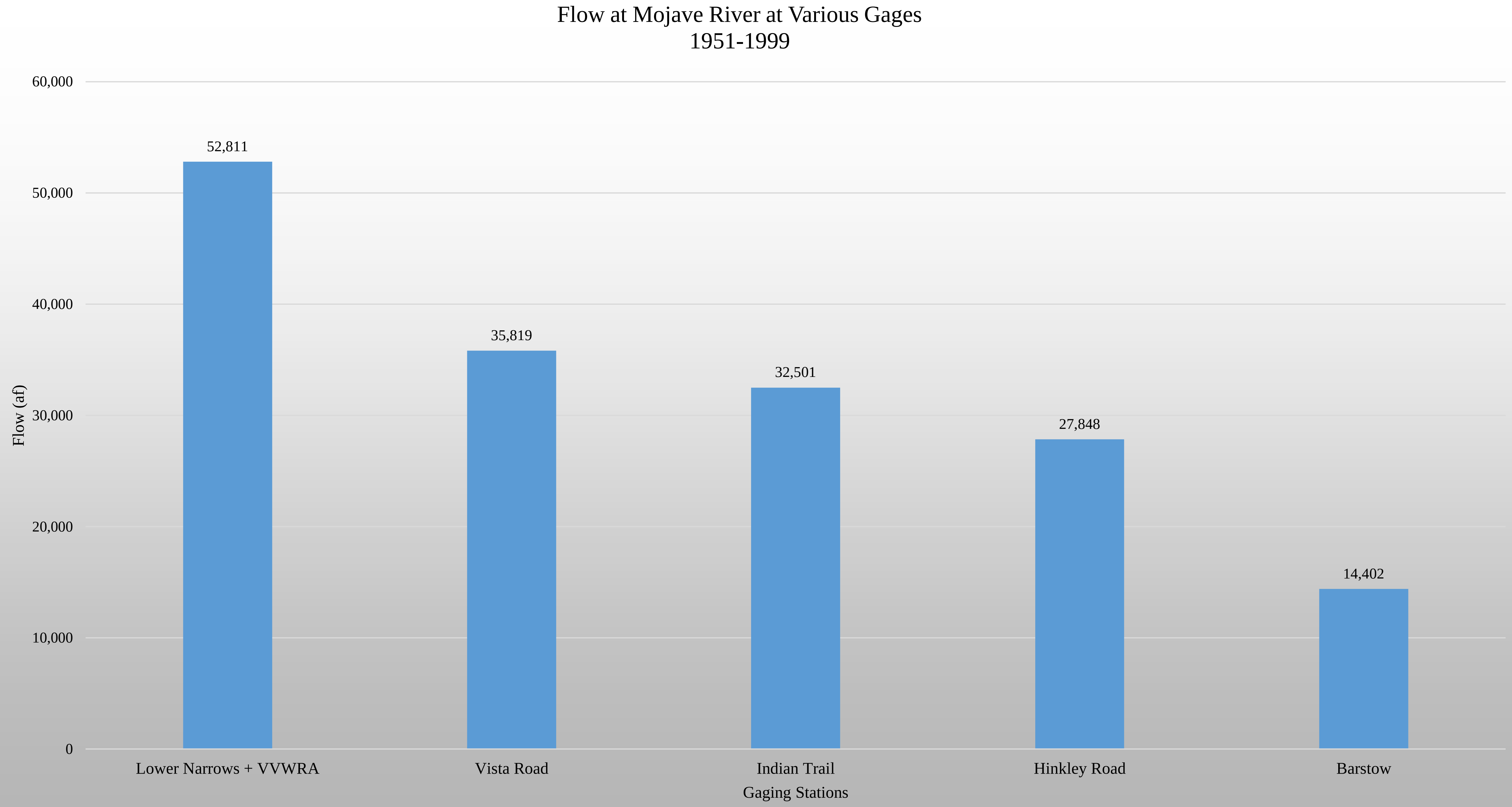
	ALTO	TRANSITION ZONE	CENTRO
WATER SUPPLY	2001-2020	2001-2020	2001-2020
Surface Water Inflow [1]	61,635	24,808	36,725
Mountain Front Recharge [2]	8,511	0	0
Groundwater Discharge to the Transition Zone [3]	0	5,112	0
Subsurface Inflow [4]	0	7,053	2,000
Este/Oeste Inflow [5]	4,785	62	
Imports[6]	0	15,095	
TOTAL	**74,931**	**52,130**	**38,725**
CONSUMPTIVE USE AND OUTFLOW			
Surface Water Outflow	36,725[7]	36,725[7]	7,500
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**



Make Up Purchases
Lower Narrows + VVWRA Flow
1951-1990 Average (49,028 acre-feet)
1991-2023 Average (48,899 acre-feet)
Flow (acre-feet)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023

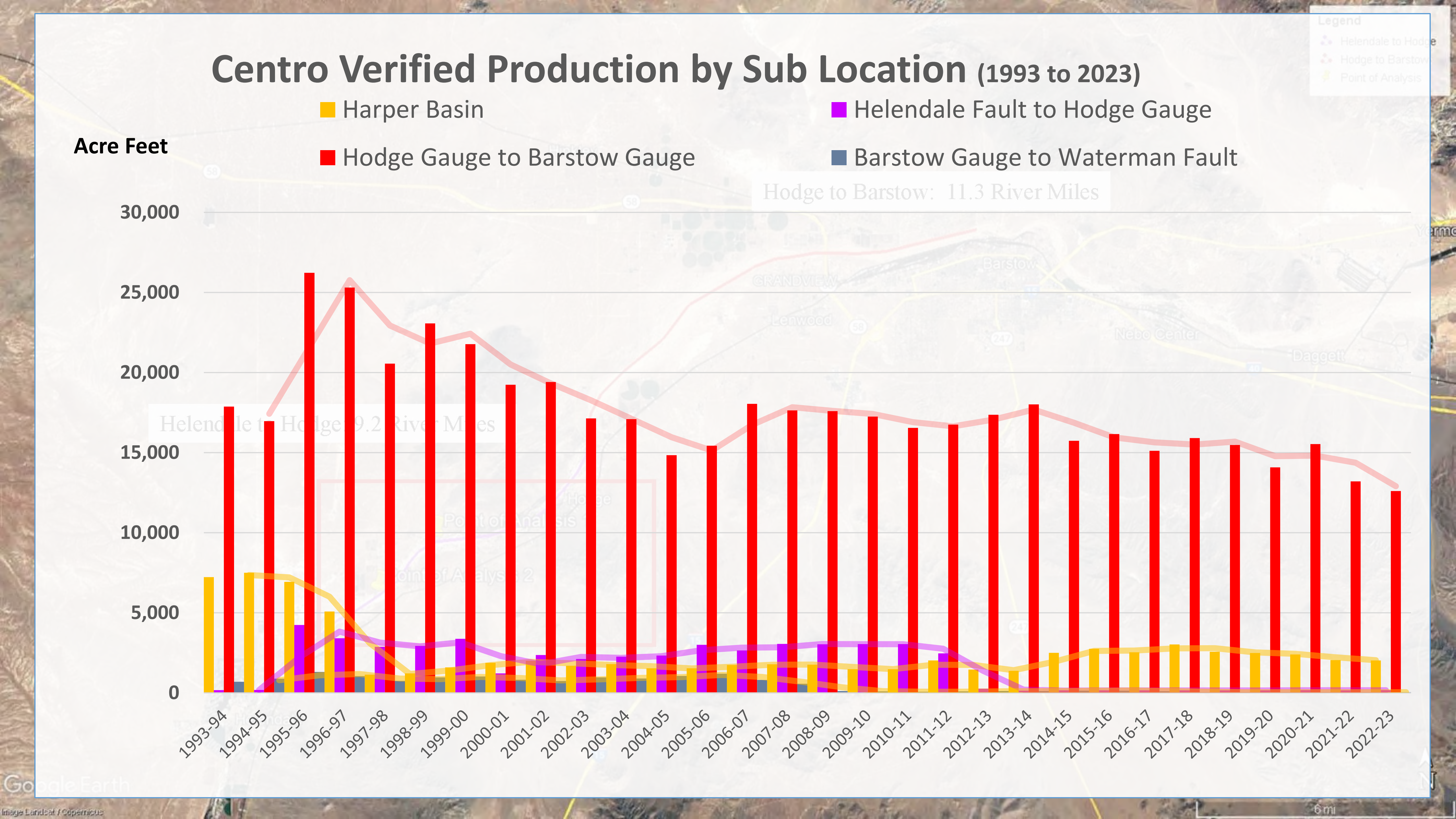


Note:
1. Lower Narrows + VVWRA, USGS Surface flow and watermaster.
2. Vista Road, Indian Trails, Hinkley Road, and Barstow from USGS 2001 Stamos model.

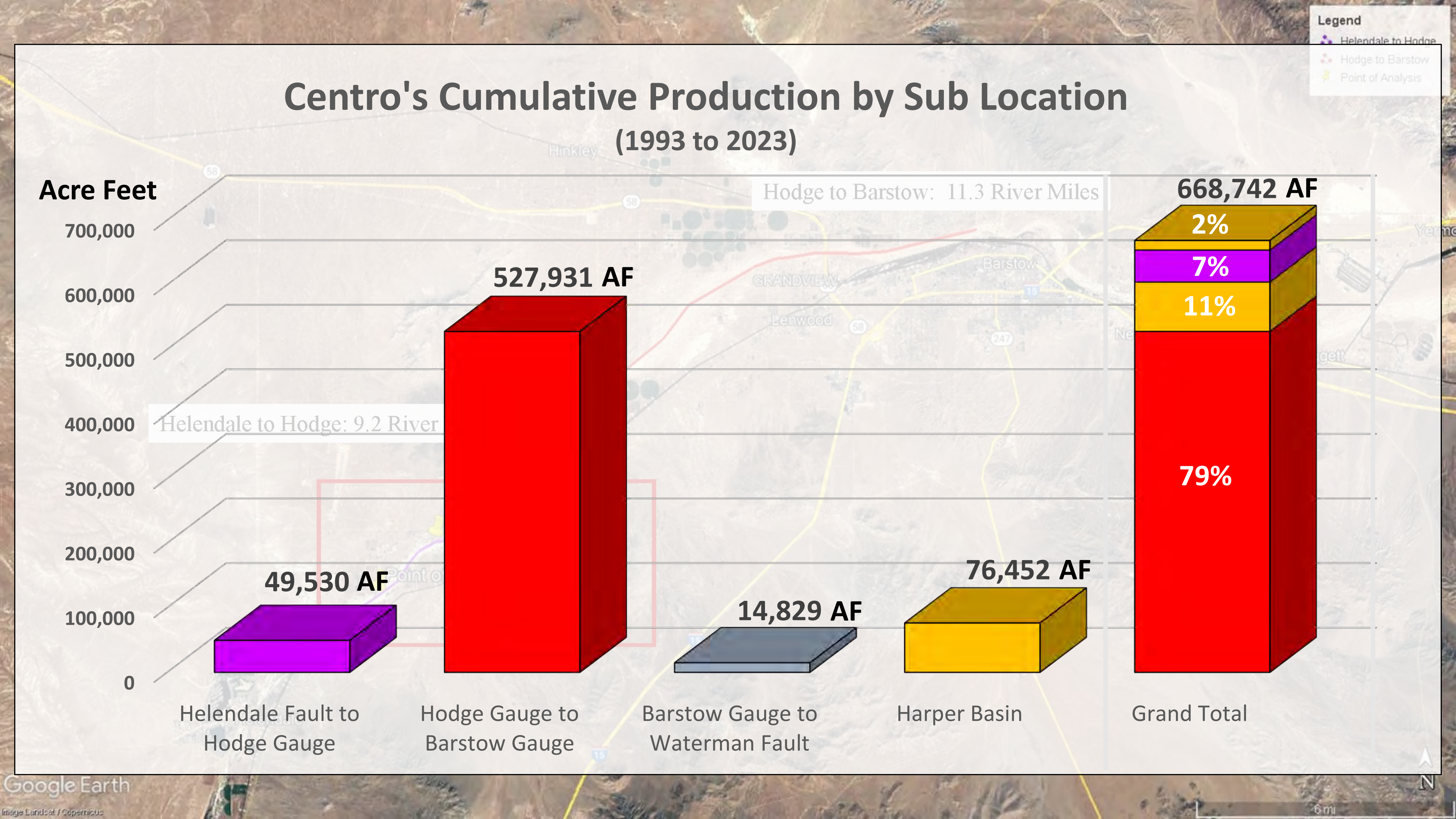


Note:
1. Lower Narrows + VVWRA, USGS Surface flow and watermaster.
2. Vista Road, Indian Trails, Hinkley Road, and Barstow from USGS 2001 Stamos model.

Legend
Helendale to Hodge
Hodge to Barstow
Point of Analysis
Hodge to Barstow: 11.3 River Miles
Helendale to Hodge: 9.2 River Miles
Hinkley
Barstow
GRANDVIEW
Lenwood
Nebo Center
Daggett
Hodge
Point of Analysis 1
Point of Analysis 2
Helendale
Google Earth
6 mi
N



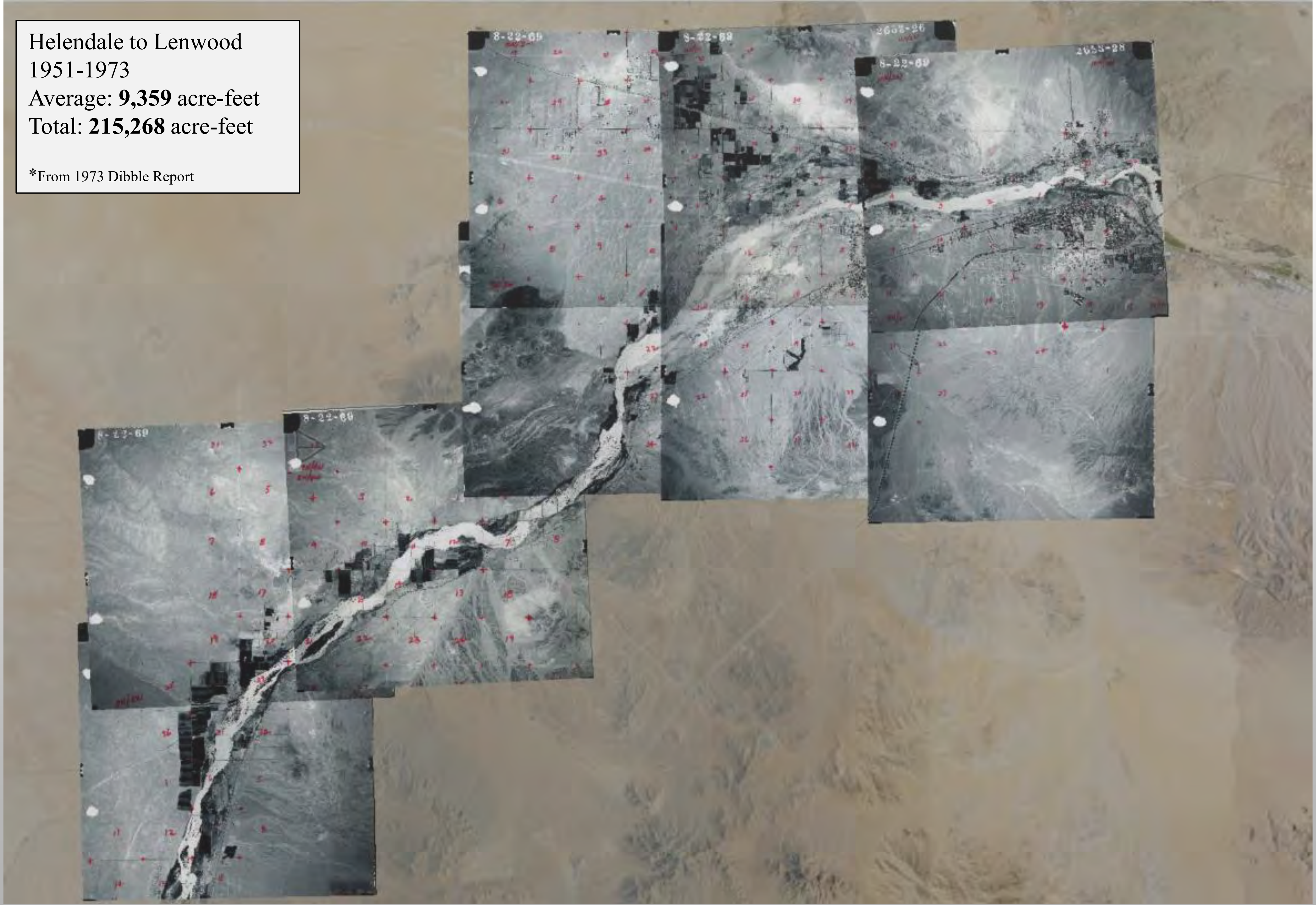
Centro Verified Production by Sub Location (1993 to 2023)
Harper Basin
Helendale Fault to Hodge Gauge
Hodge Gauge to Barstow Gauge
Barstow Gauge to Waterman Fault
Acre Feet
Hodge to Barstow: 11.3 River Miles
30,000
25,000
20,000
15,000
10,000
5,000
0
1993-94
1994-95
1995-96
1996-97
1997-98
1998-99
1999-00
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23

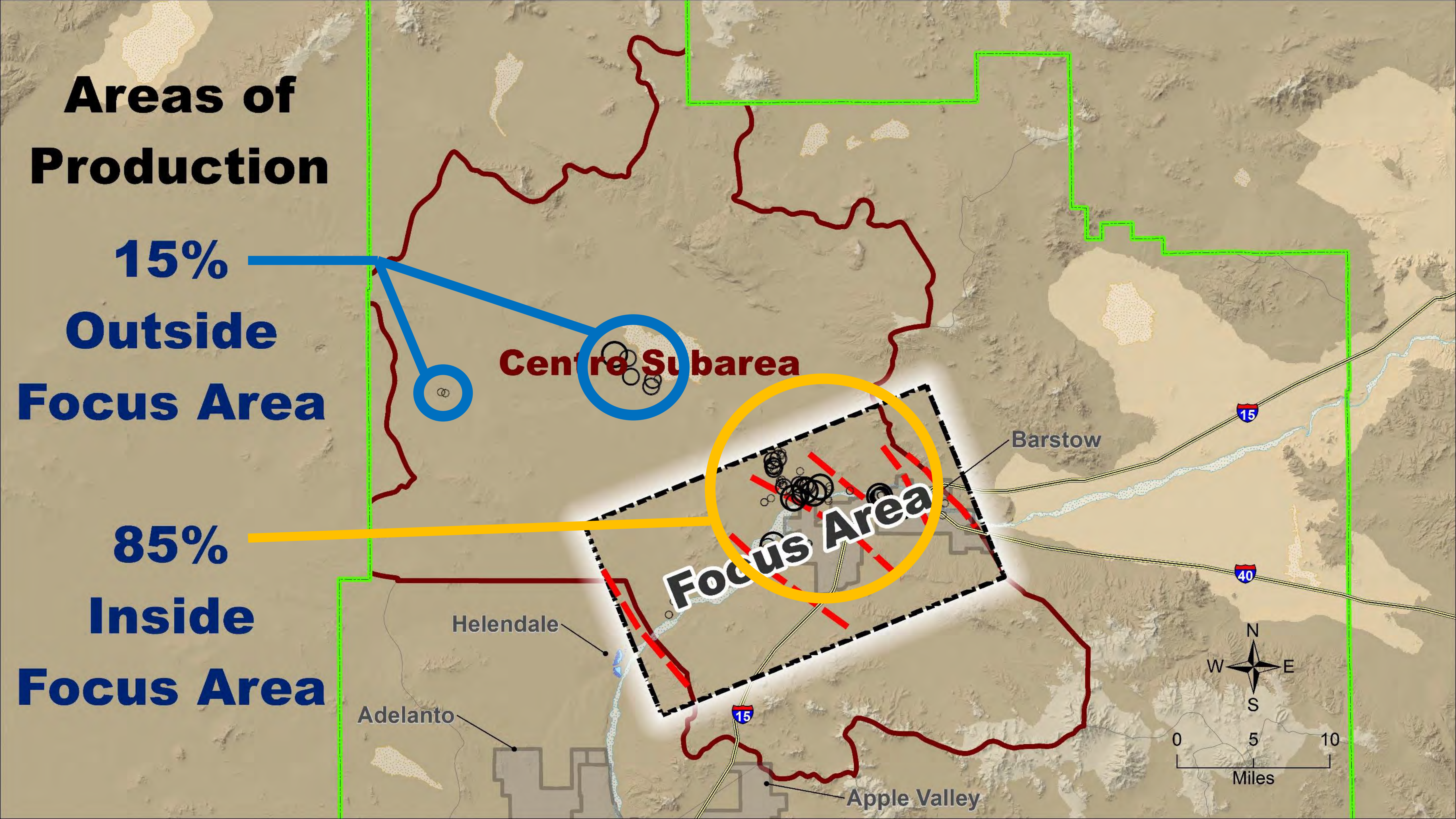


Centro's Cumulative Production by Sub Location
(1993 to 2023)
Acre Feet
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
49,530 AF
527,931 AF
14,829 AF
76,452 AF
668,742 AF
2%
7%
11%
79%
Helendale Fault to Hodge Gauge
Hodge Gauge to Barstow Gauge
Barstow Gauge to Waterman Fault
Harper Basin
Grand Total
Hodge to Barstow: 11.3 River Miles
Helendale to Hodge: 9.2 River
Legend
Helendale to Hodge
Hodge to Barstow
Point of Analysis
Google Earth

Helendale to Lenwood
1951-1973
Average: **9,359** acre-feet
Total: **215,268** acre-feet

*From 1973 Dibble Report

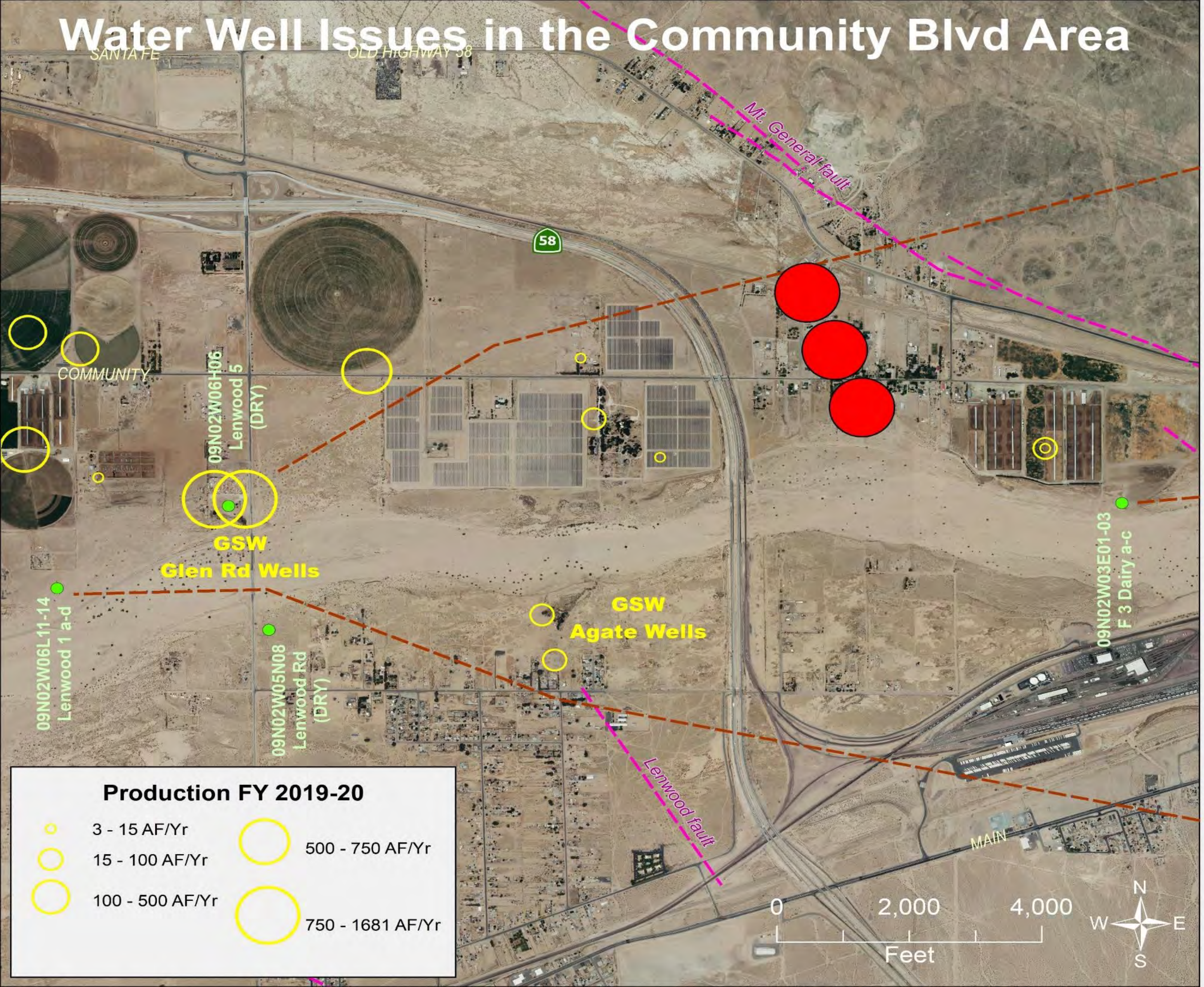


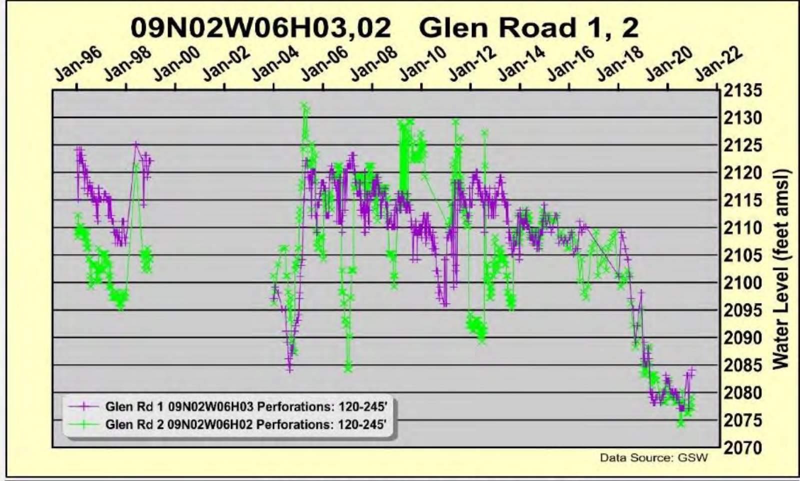


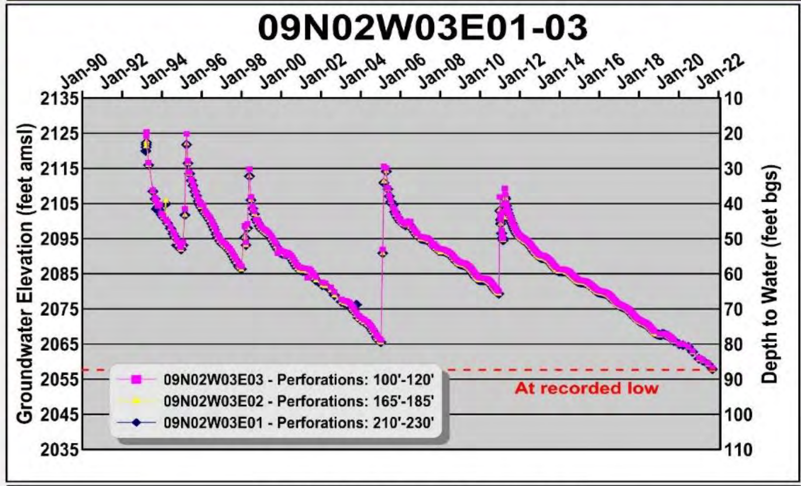
Areas of Production
15% Outside Focus Area
85% Inside Focus Area
Centro Subarea
Focus Area
Barstow
Helendale
Adelanto
Apple Valley
15
40
N
W
E
S
0
5
10
Miles

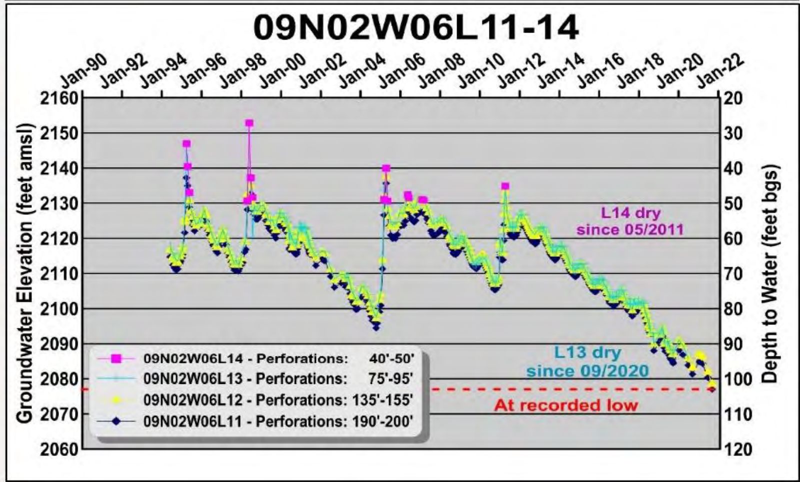
2023 Aerial Image

Water Well Issues in the Community Blvd Area

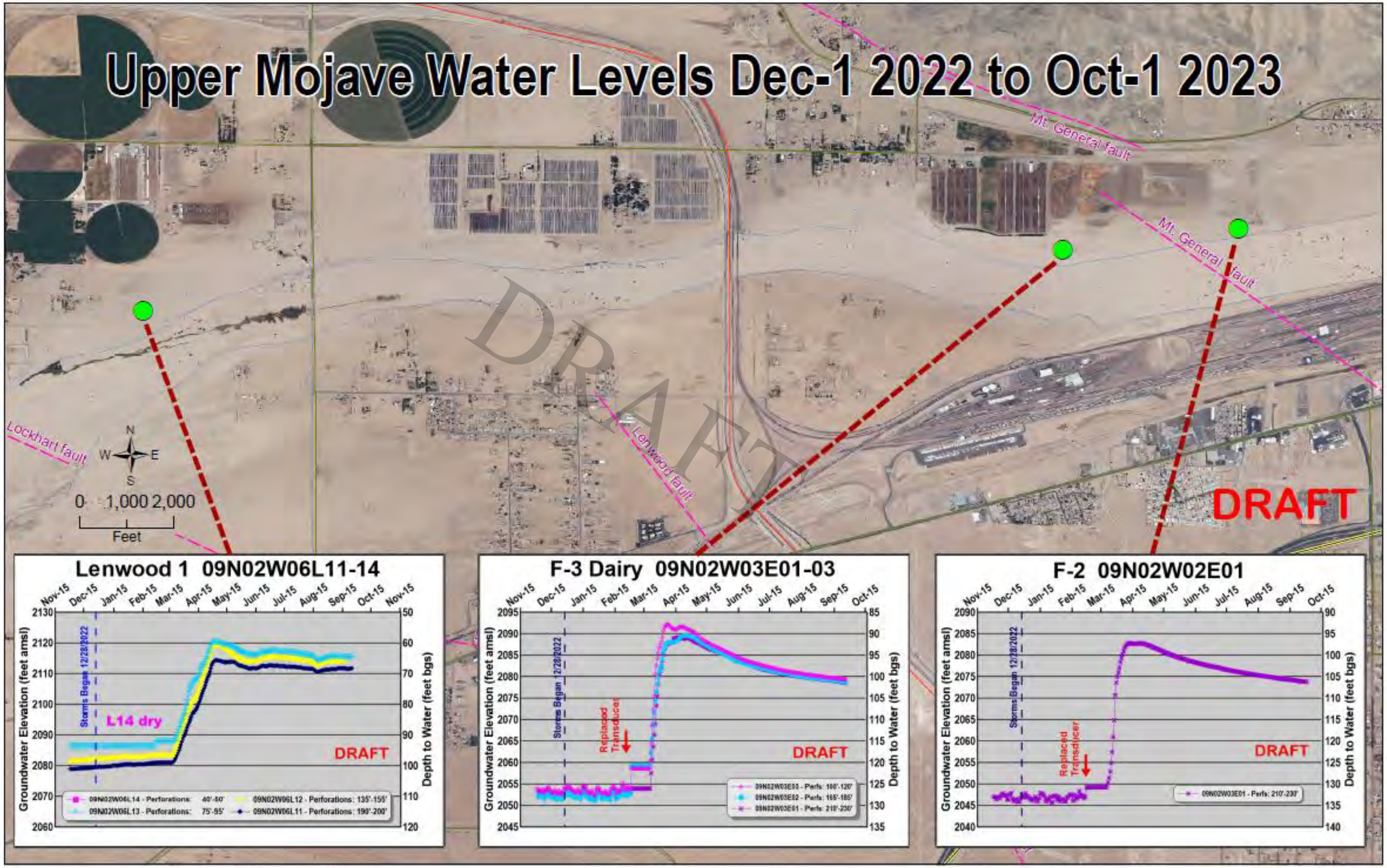








Response to 2023 Recharge



Este Water Production & Water Levels

- Average Water Production (2018-2022): 5,108 acre-feet
- Average Water Production (2001-2020): 6,582 acre-feet
  - Fifteen Mile Valley Change in Storage (2001-2020): 134 acre-feet
- Water levels have been relatively stable for 20 years
- Assuming change in storage is zero PSY = Pumping
  - Conservatively Production Safe Yield = 5,108 acre-feet
    - Inflow – unknown
    - Outflow – unknown
    - Precipitation – limited data

Oeste Water Production & Water Levels

- Average Water Production (2018-2022): 3,634 acre-feet
- Average Water Production (2001-2020): 4,541 acre-feet
  - Oeste change in Storage (2001-2020): -1,566 acre-feet (UMBM)
- Water levels have been relatively stable for 20 years
  - Indicating change in storage: 0 acre-feet
- Assuming change in storage is zero PSY = Pumping
  - Production Safe Yield = 3,634 acre-feet
    - Inflow – UMBM
    - Recharge - UMBM
    - Outflow – UMBM
    - Precipitation – limited data

Baja Water Production & Water Levels

- Average Water Production (2017-2023): 19,144 acre-feet
- Average Water Production (2019-2023): 16,709 acre-feet
- Average Water Production (2021-2023): 13,088 acre-feet
- Water levels appear to be stabilizing
- Assuming change in storage is zero PSY = Pumping
- Production Safe Yield estimated over two time periods:
  - (1931-1990): 14,544 acre-feet
  - (2001-2020): 10,866 acre-feet

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
Subsurface Inflow		1,581
Deep Percolation of Precipitation		100
Tributary Inflow		3,571
	TOTAL	**22,610**
CONSUMPTIVE USE AND OUTFLOW		
Surface Water Outflow		6,066
Subsurface Outflow		0
Consumptive use		
Agriculture		6,092
Urban		6,657
Phreatophytes		2,000
	TOTAL	**20,815**
Surplus / (Deficit)		1,795
Total Estimated Production		12,749
PRODUCTION SAFE YIELD		**14,544**

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)

	Baja
Water Supply	
Gaged Inflow	7,500
Tributary Inflow	1,568
Subsurface Inflow	1,751
Mountain Front Recharge	647
Barstow Treatment Plan	2,455
Return Flow	554
Deep Percolation of Precipitation	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**

Updated Production Safe Yield and Indicated 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	20.5%	---	12,749	19.3%	20.5%
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%

Current FPA for 2023-24 and Proposed FPA for 2024-25

	2023-24	2024-25
Alto	50.4%	53.3%
Baja	20.5%	20.5%
Centro	55%	60%
Este	55%	50%
Oeste	50%	50%

Next Steps

- March 27, 2024
  - Public Hearing on FPA recommendation
- May 1, 2024
  - Report to the Court
- June 14, 2024
  - Court Hearing to adopt Watermaster recommendation

Recommendation

- Staff recommends that Watermaster conduct a public hearing to receive comments, adopt the updated Production Safe Yield for the Este, Oeste, Alto, Centro and Baja Subareas, adopt the proposed Free Production Allowances for the Este, Oeste, Alto, Centro and Baja Subareas and direct legal counsel to request a hearing with the Court to consider the proposed Free Production Allowances for Water Year 2024-25.

EXHIBIT 5

MOJAVE BASIN AREA WATERMASTER

Production Safe Yield & Consumptive Use Update

February 28, 2024

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

Table of Contents

Appendix D: Este Water Supply Update

Appendix E: Baja Water Supply Update

Appendix F: Consumptive Use Update

Appendix G: Upper Mojave River Basin Groundwater Model

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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

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

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

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

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

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

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

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

2151 River Plaza Drive · Suite 100 · Sacramento, CA 95833-4133
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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

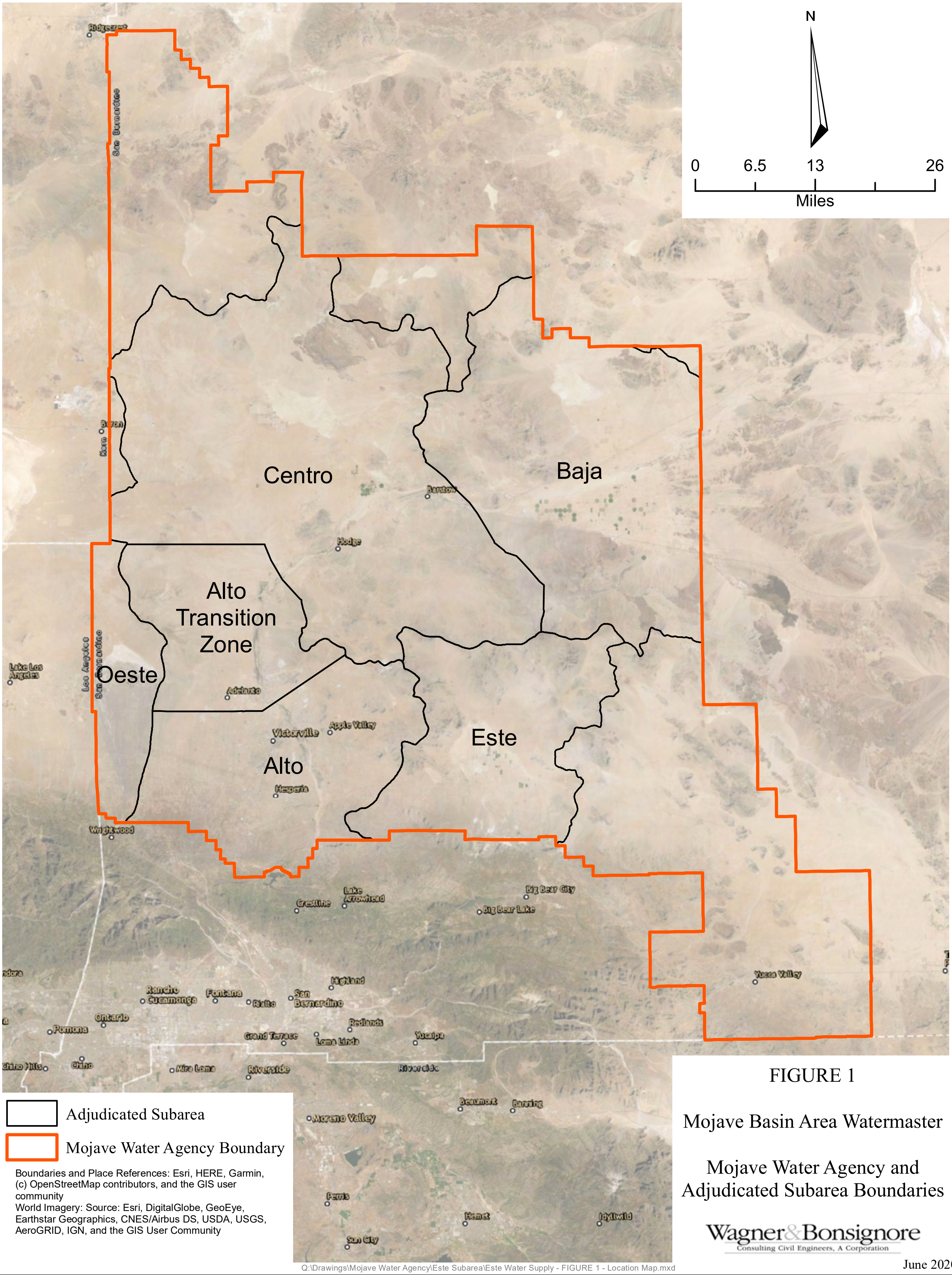


FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

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

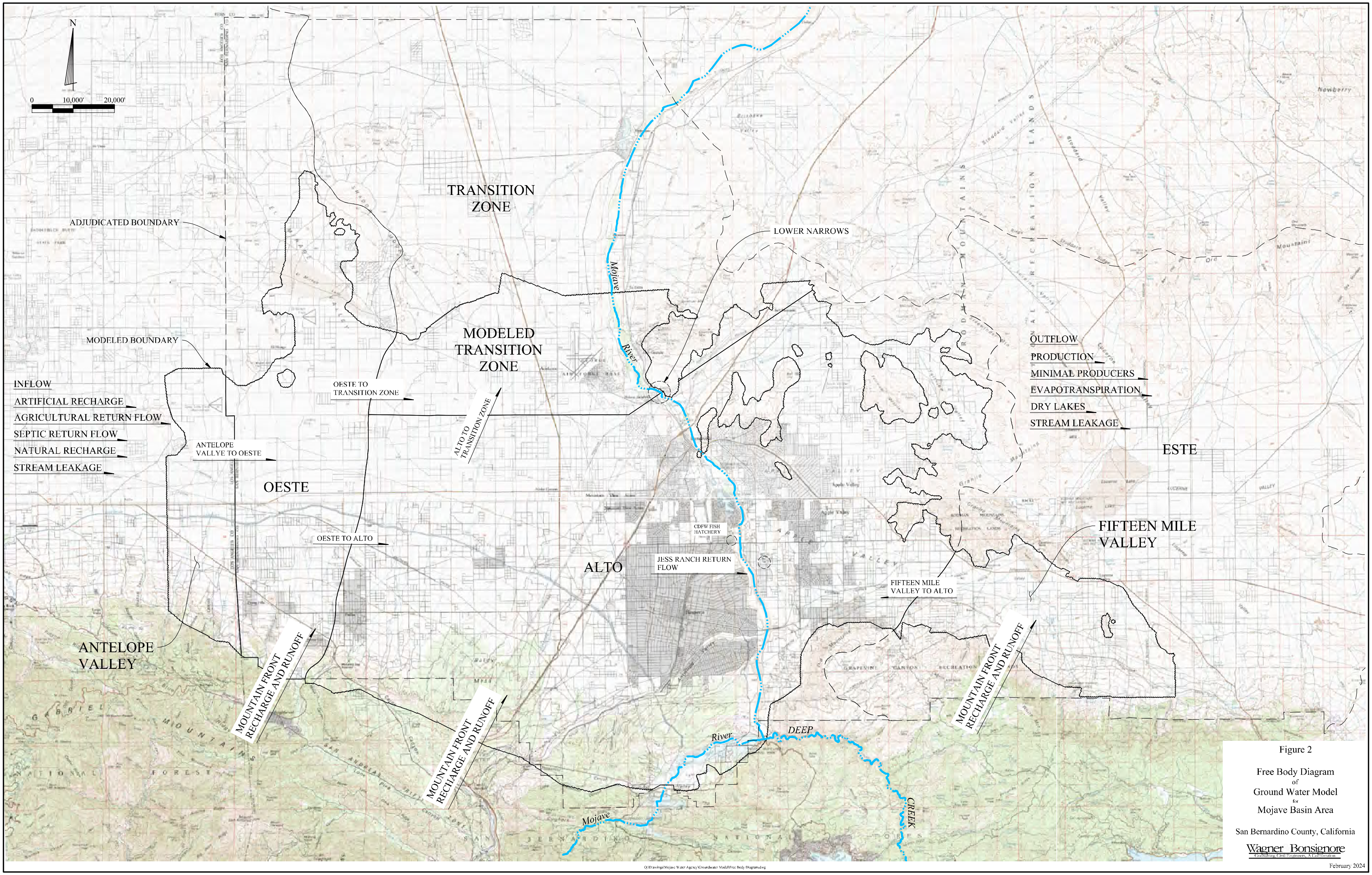


Figure 2

Free Body Diagram
of
Ground Water Model
for
Mojave Basin Area

San Bernardino County, California

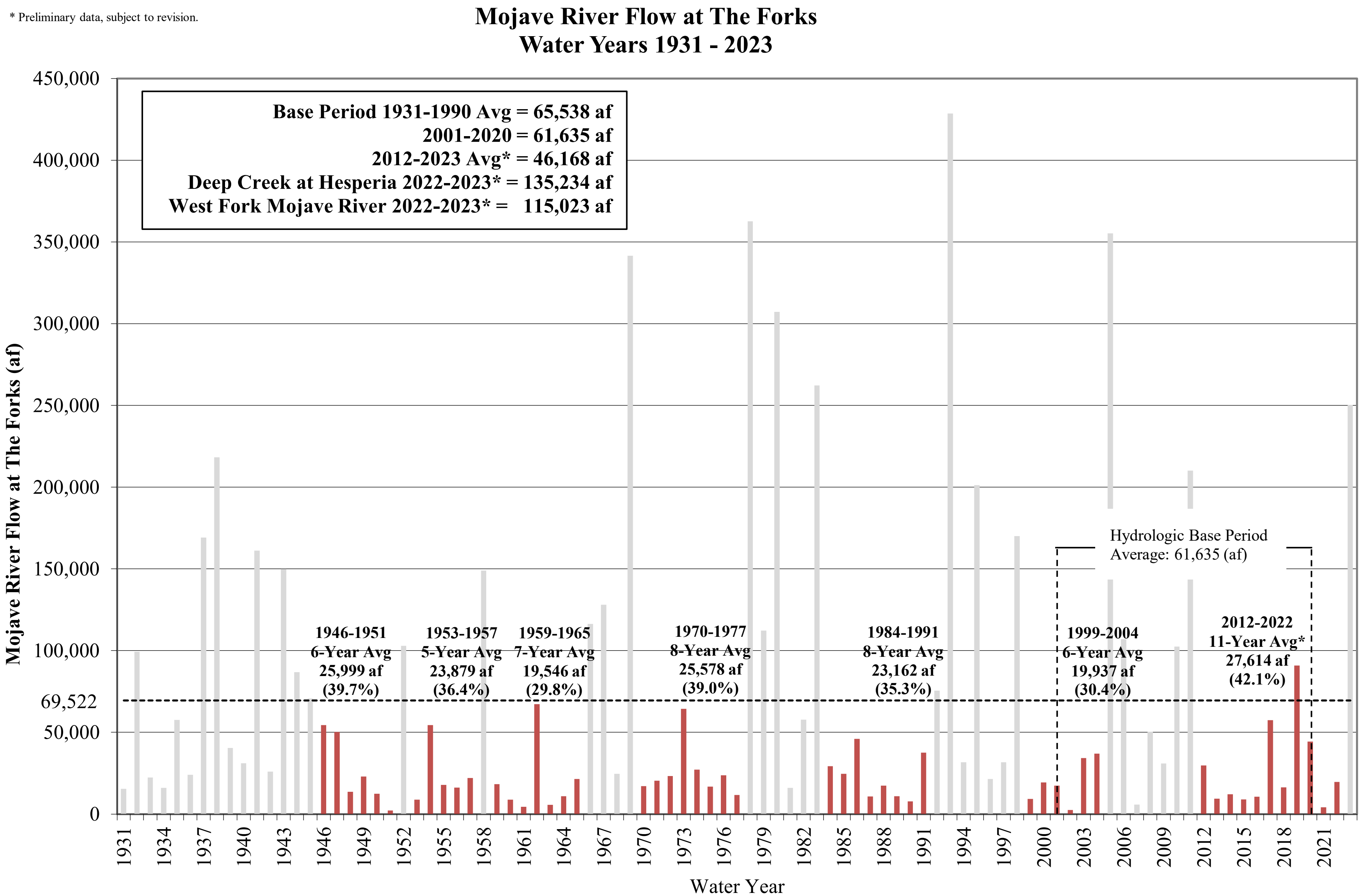
Wagner Bonsignore

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.

Mojave Basin Area Watermaster

Appendix A

Alto & Centro Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
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David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **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.

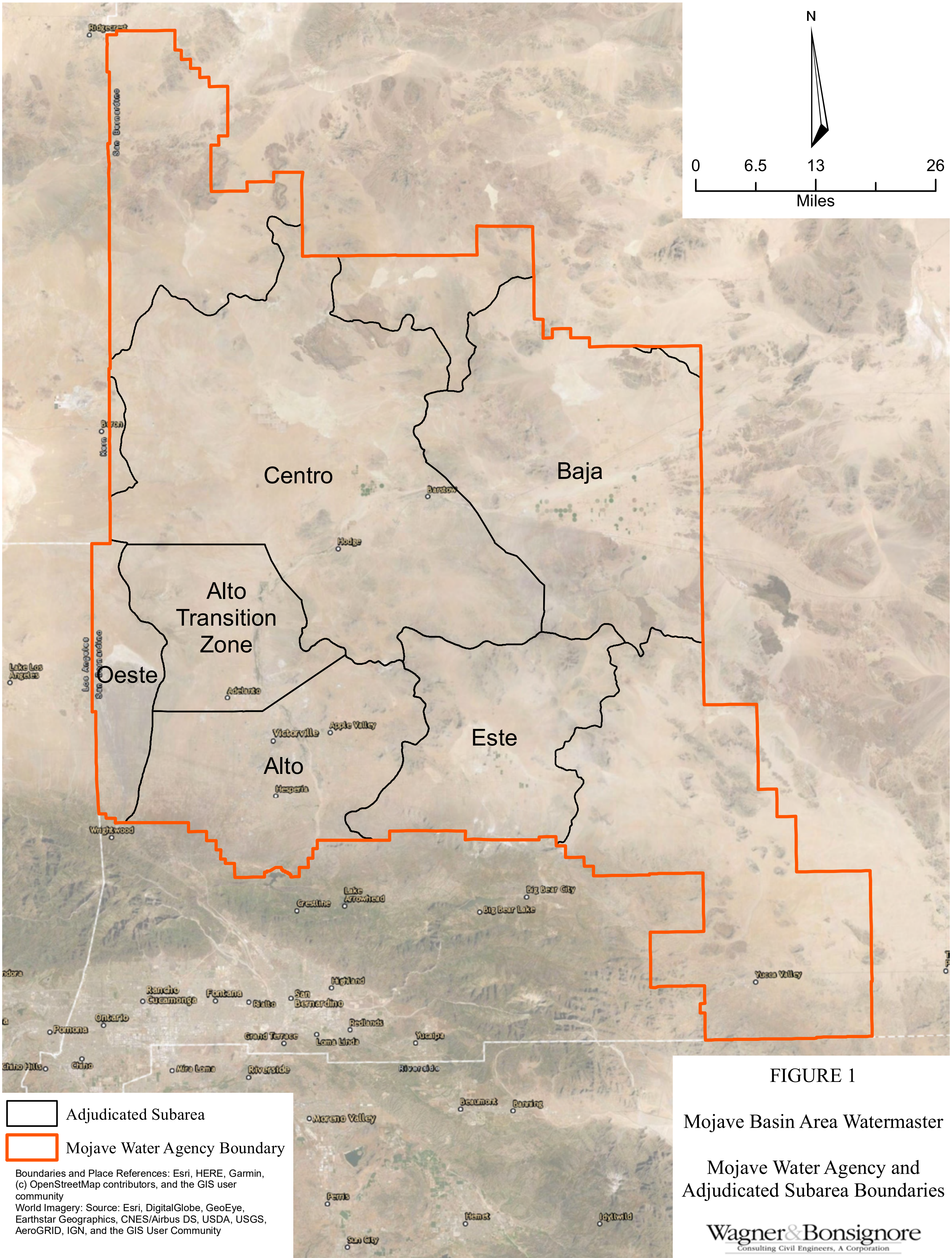


FIGURE 1

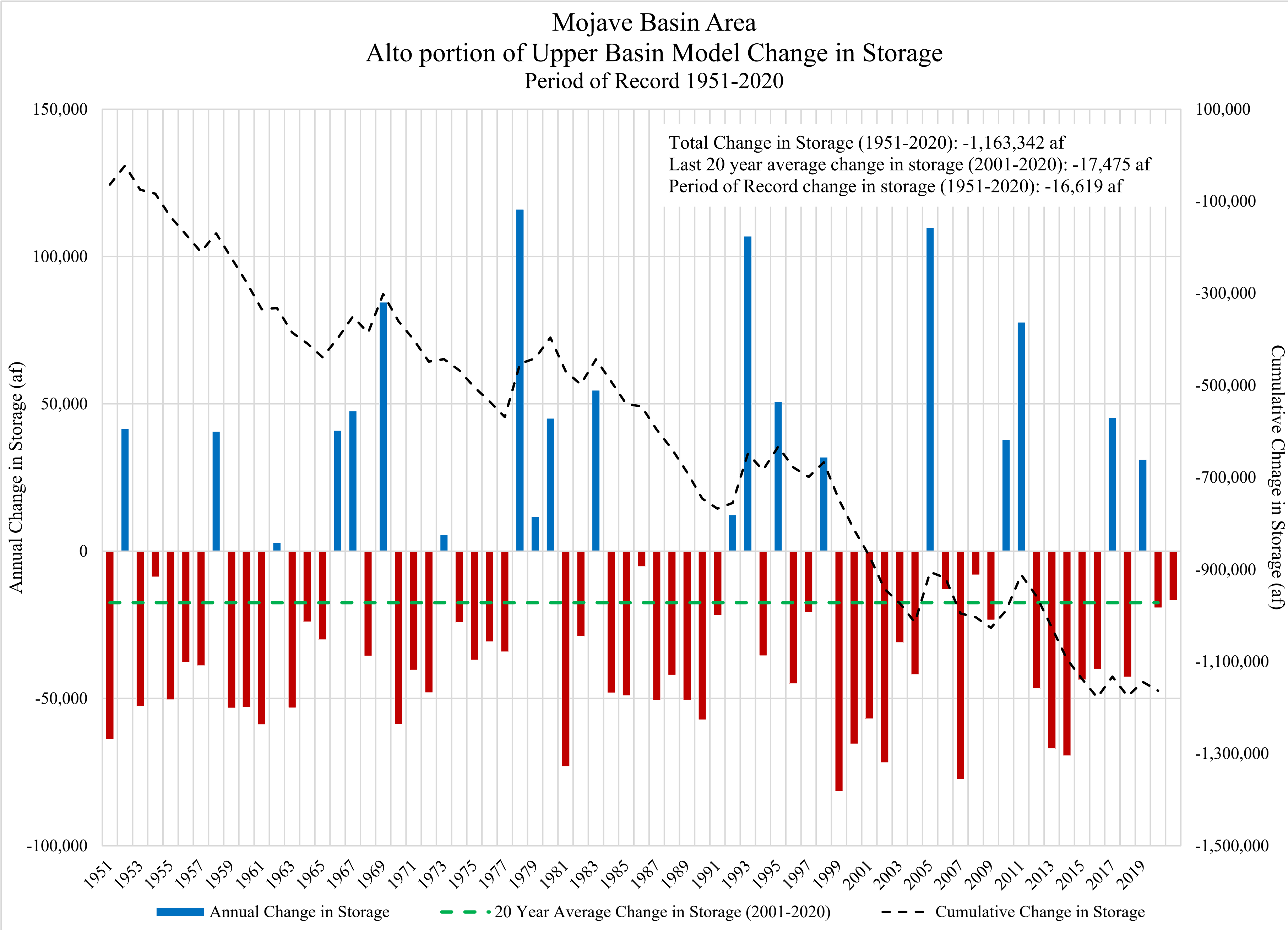
Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

FIGURE 2

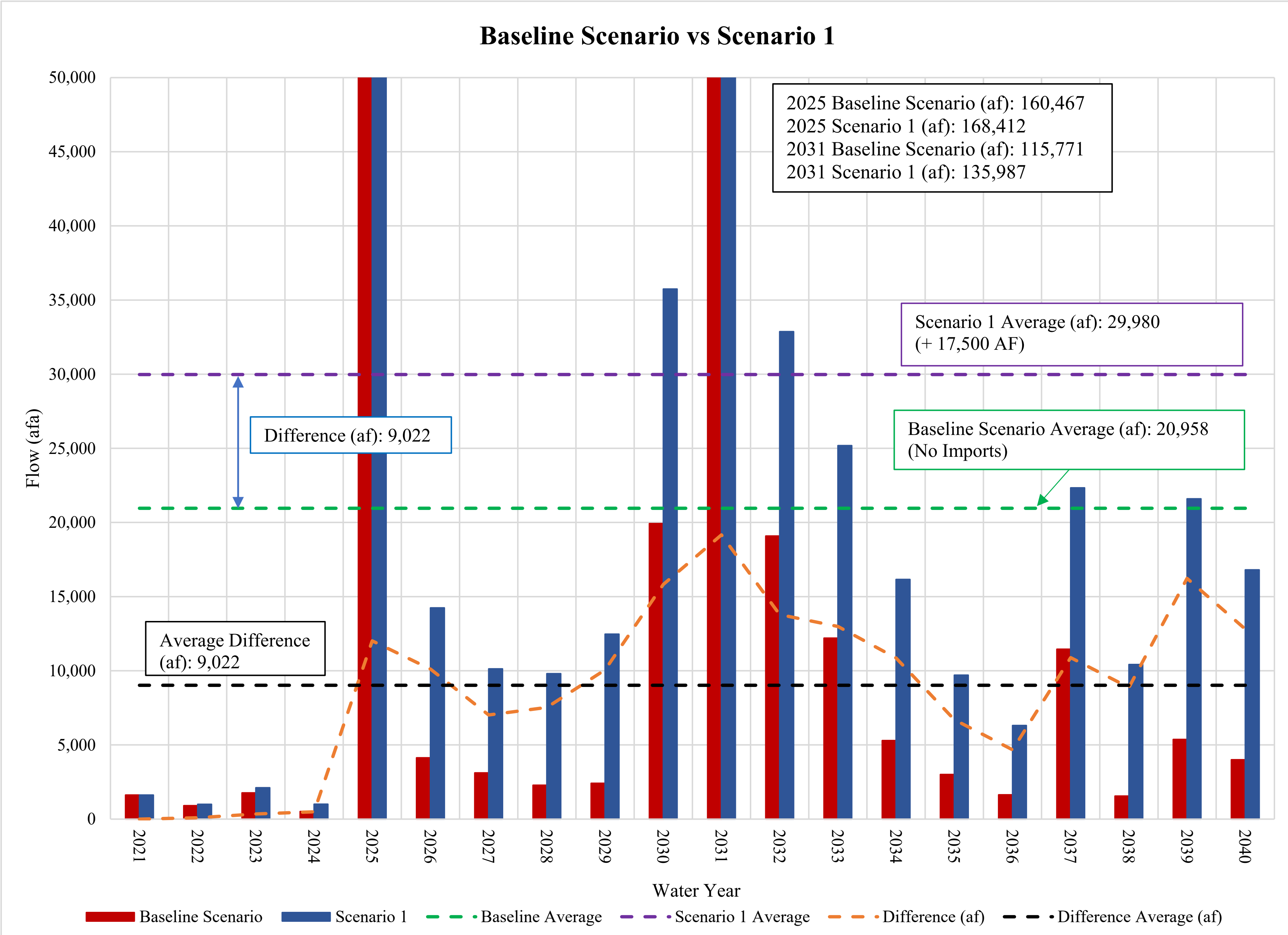


G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\1-Alto\3020-009M-Table 6.1 Summary of Model Parameters Alto-V4.xlsx

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



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\3020-007M-Computed Streamflow Scenario Runs and Total Model_v2.xlsx

DRAFT

TABLE 1

TABLE 5-1 Proposed

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

(ALL AMOUNTS IN ACRE-FEET)

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

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

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

3 Groundwater discharge lost to Transition Zone below the Narrows.

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

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

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

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

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

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

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

11 Amount necessary to offset overdraft under the above assumptions.

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

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

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

TABLE 2

Annual Flow at the Lower Narrows Under Baseline Scenario and Scenario 1 Water Year Stream Flow 20 Year Scenario Runs			
Water Year	Baseline Scenario (af)(1)	Scenario 1 (af)(2)	Difference (af)(3)
2021	1,623	1,623	0
2022	907	994	87
2023	1,768	2,110	343
2024	515	1,006	491
2025	183,550	195,565	12,015
2026	4,128	14,243	10,115
2027	3,117	10,132	7,015
2028	2,285	9,809	7,524
2029	2,417	12,474	10,057
2030	19,925	35,744	15,819
2031	135,332	154,500	19,167
2032	19,083	32,874	13,791
2033	12,198	25,182	12,984
2034	5,296	16,157	10,861
2035	3,005	9,710	6,704
2036	1,639	6,310	4,671
2037	11,451	22,336	10,885
2038	1,550	10,425	8,876
2039	5,367	21,595	16,228
2040	4,002	16,806	12,804
Average	**20,958**	**29,980**	**9,022**

Note:

(1) Baseline Scenario: The last 20 years hydrology extended in the future with 2020 levels of production and return flows

(2) Scenario 1: Similar to the Baseline Scenario with 17,500 acre-feet imports per year spread out over three months (June-July-August) and delivered at Deep Creek.

(3) Difference: Baseline Scenario flow subtracted from Scenario 1 flow at the Lower Narrows.

Mojave Basin Area Watermaster

Appendix B

Transition Zone

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
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David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Transition Zone Water Balance**

This memorandum describes the purpose of the Transition Zone (TZ) as envisioned by the Judgment and presents the method for calculating outflow to the Centro Subarea from the Alto Subarea. We include water level hydrographs to demonstrate the basic assumption that water levels within the TZ are relatively stable over time (see Fig. 2 and 3). Also presented is the pumping history of the TZ demonstrating reduced pumping demand since the early 1950's with significant reductions during the past 30 years (see Fig. 4).

The TZ is the area generally lying between the Lower Narrows, Mojave River, and the Helendale Fault (see Fig 1). Department of Water Resources Bulletin 84, 1967 was a foundational technical document guiding development of the Judgment. The Alto Subarea was drawn to be consistent with the Upper Mojave Subunit identified in Bulletin 84 (Bull., 84, fig. 2, page 7). As a result, the boundary between Alto and Centro, was placed at the Helendale Fault, where limited stream gaging data existed at the time the Judgment was drafted. The TZ was considered to pass storms from Alto to Centro, without interference from pumping within the TZ. It was assumed that the consumptive use within the TZ could be reasonably determined on annual basis.

The pumping history in the TZ is shown on Fig. 4 and shows the decline in pumping since the early 1950's. The decline in pumping as well as the decline in consumptive use has contributed to the water level stability in the TZ, demonstrated by the water levels within the TZ. Also, contributing to the stability is the discharge of treated effluent from the Victor Valley Wastewater Reclamation Authority. Water pumped and used by producers contributing to sewers, upstream of Lower Narrows, is conveyed, treated and discharged in the TZ. The discharges are part of the basin water supply, contribute to downstream subareas and support riparian habitat.

To calculate outflow from the TZ to Centro, the following elements of water supply use and disposal with the TZ are included: Elements of Inflow generally include : a) measured flow at Lower Narrows, b) VVWRA discharge c) subsurface inflow, d) ungaged inflow

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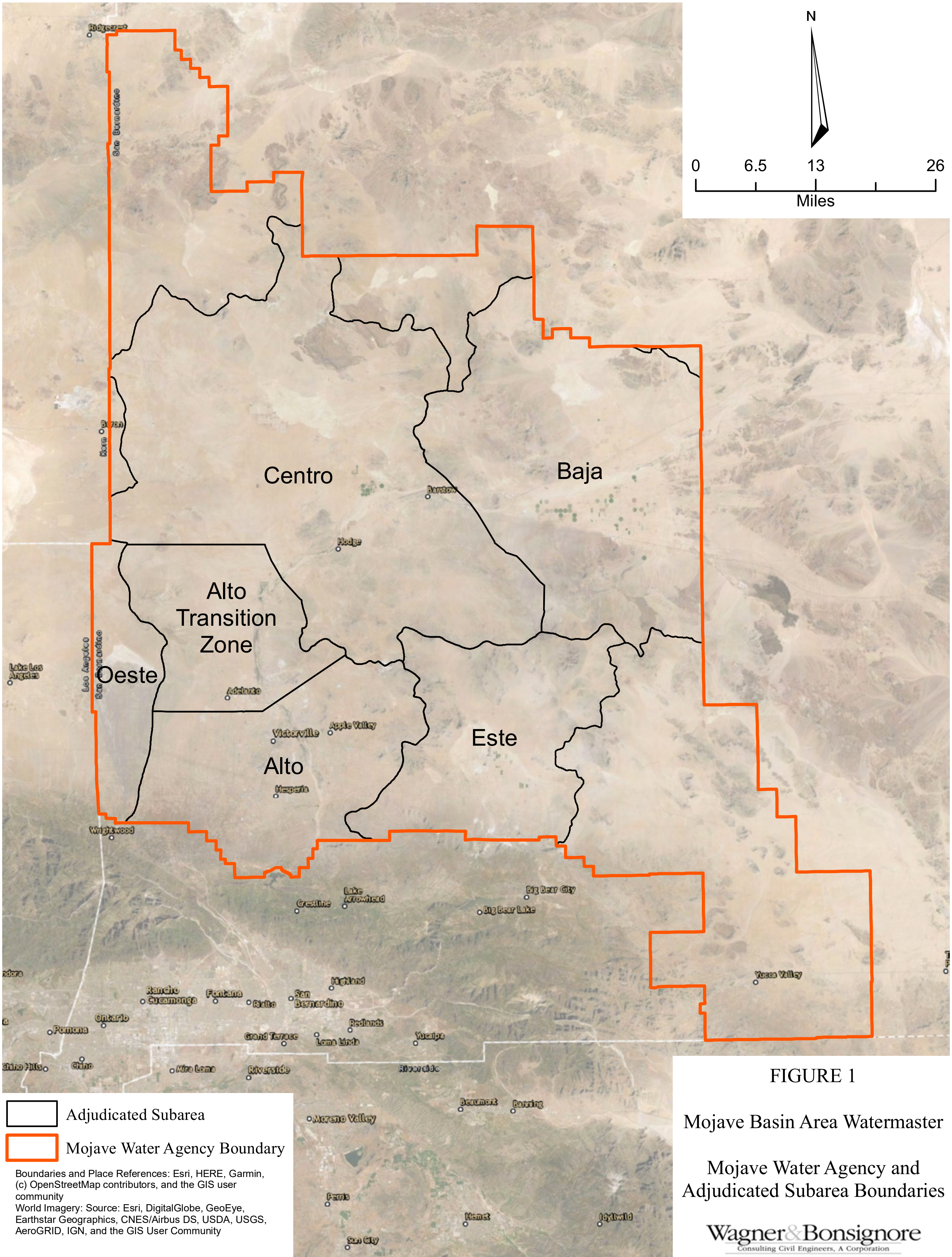
Ph: 916-441-6850 or 916-448-2821 · Fax: 916-779-3120

Elements of Outflow: generally, include e) subsurface outflow, f) consumptive use of production, g) phreatophyte water use, h) change in storage. For purposes of this analysis we assume, based on water levels, that change in storage over time is negligible or zero. Then by summing the elements of inflow and outflow, we calculate the outflow at Helendale Fault as supply to Centro. The calculation is shown Appendix A.

There is a makeup water obligation calculated on an annual basis that Alto owes to Centro. The obligation is to be satisfied every year, but is not part of the calculation of average annual outflow to Centro, as reported herein; however, it does contribute to the Centro water supply (see Watermaster Annual Reports, Figure 3-10, Tables 4-2, 4-3).



Adjudicated Subarea

Mojave Water Agency Boundary

Boundaries and Place References: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
World Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 1

Mojave Basin Area Watermaster

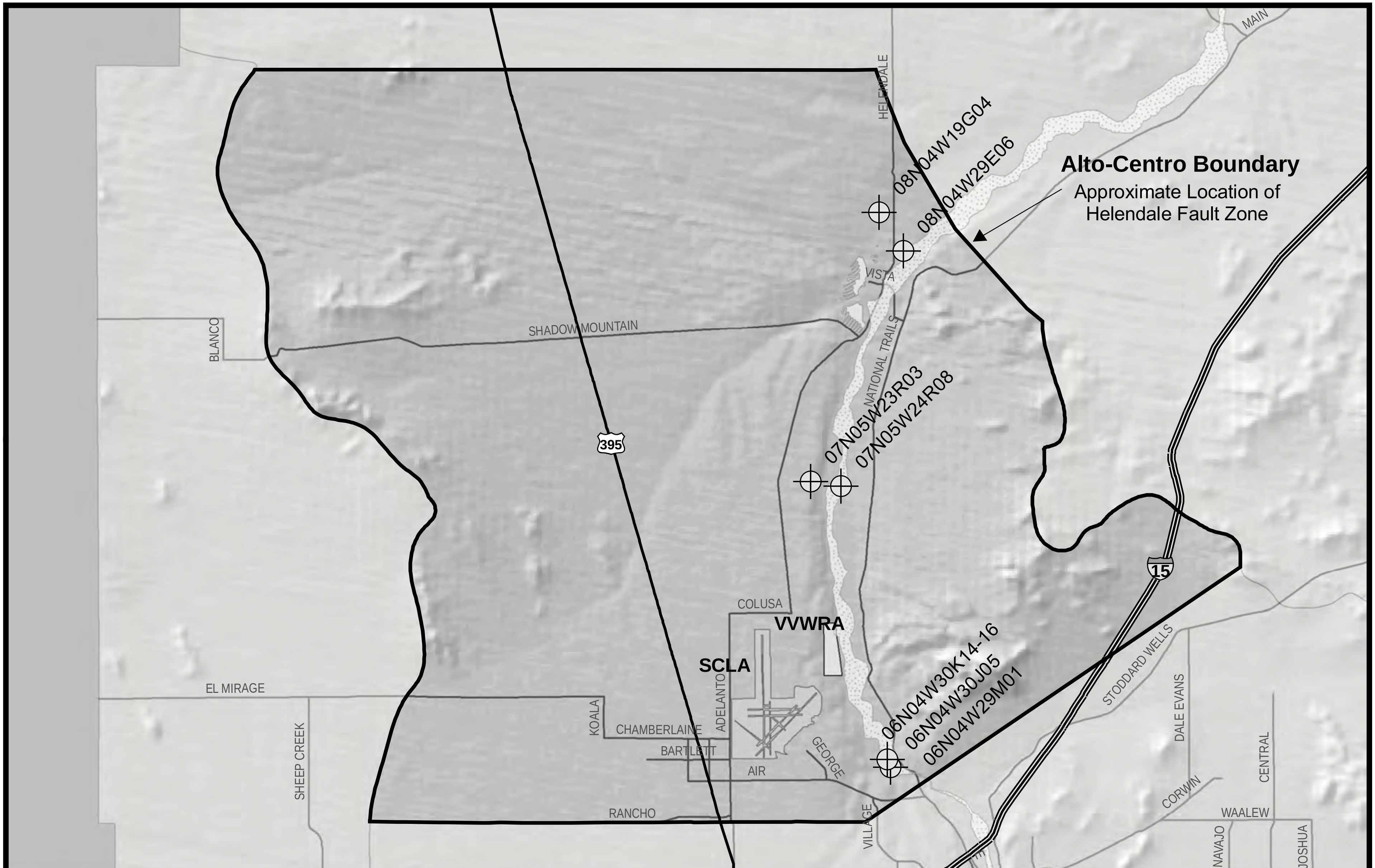
Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

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

FIGURE 2



MOJAVE BASIN AREA WATERMASTER

Monitoring Wells

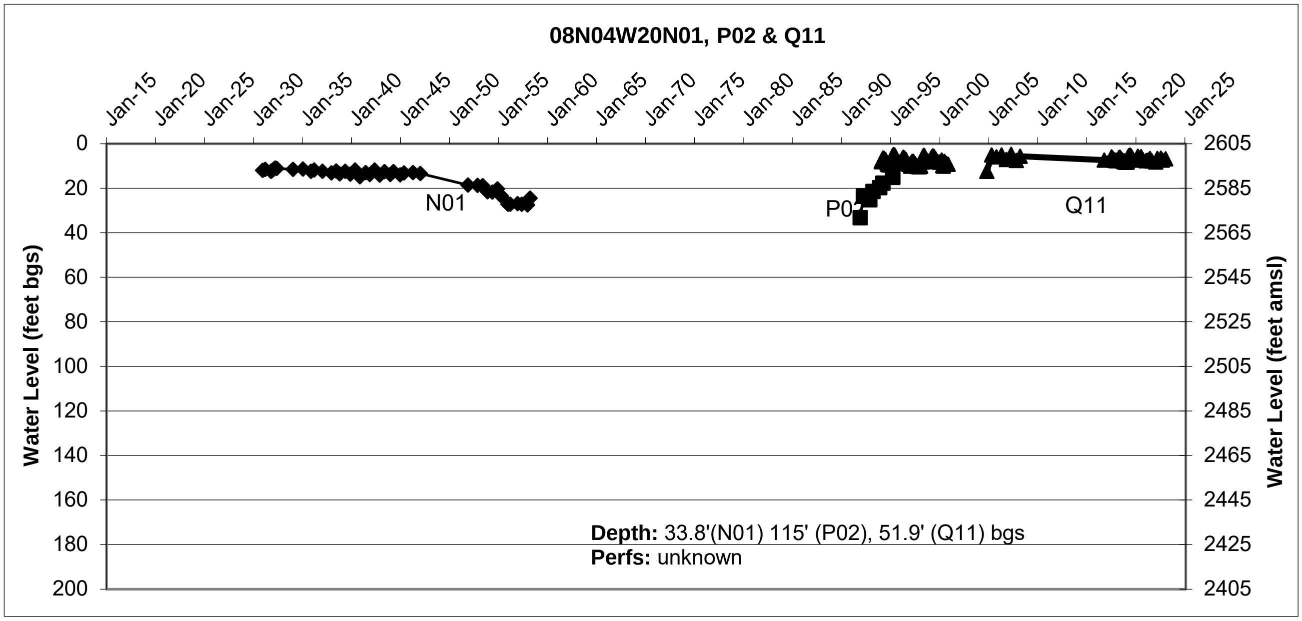
Alto Transition Zone
Location of
Water Level Monitoring Wells

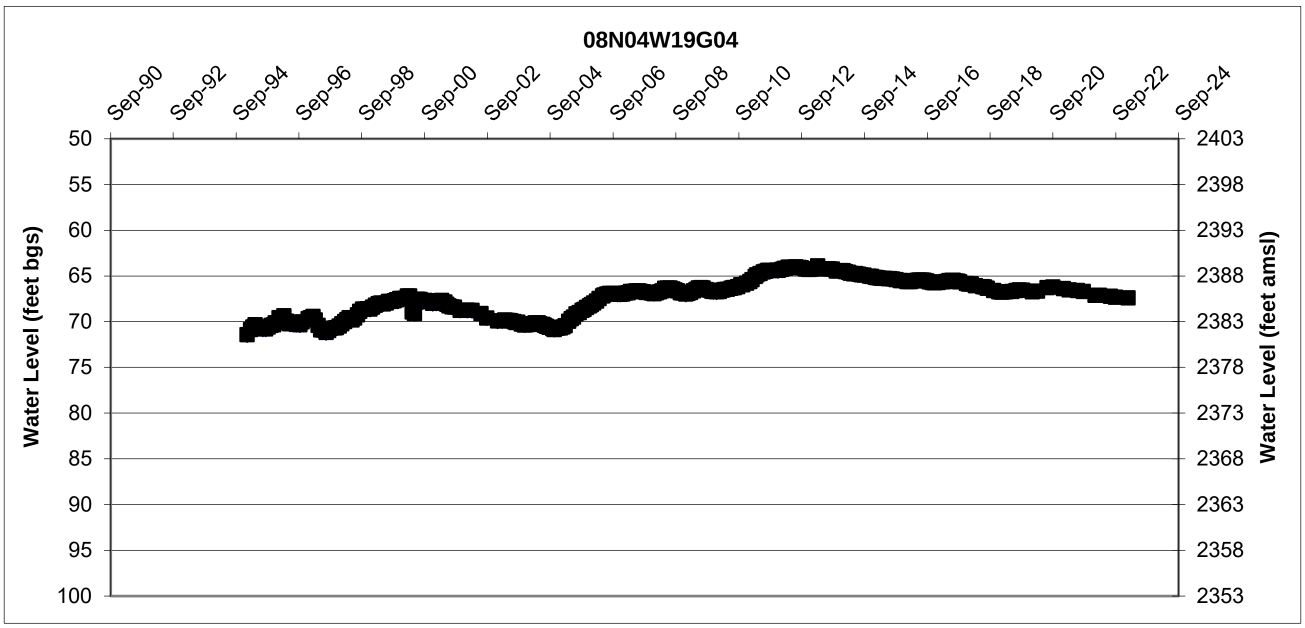
0 1 2 4
Miles

N

FIGURE 3-6

FIGURE 3


08N04W20N01, P02 & Q11
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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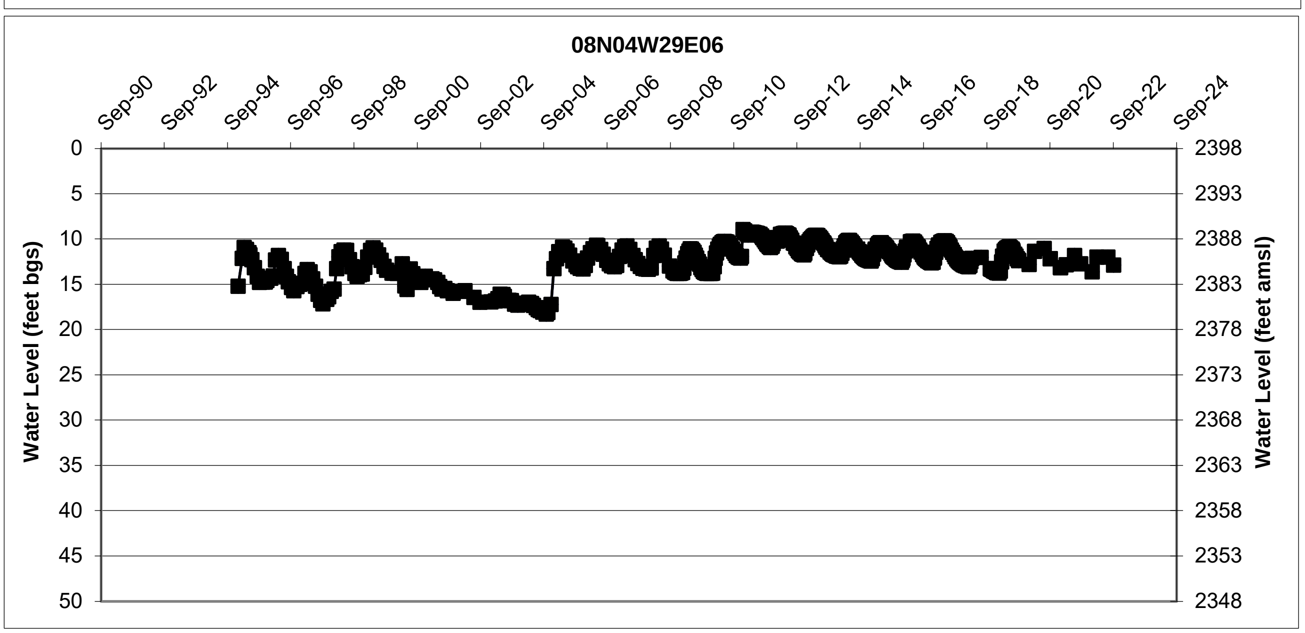
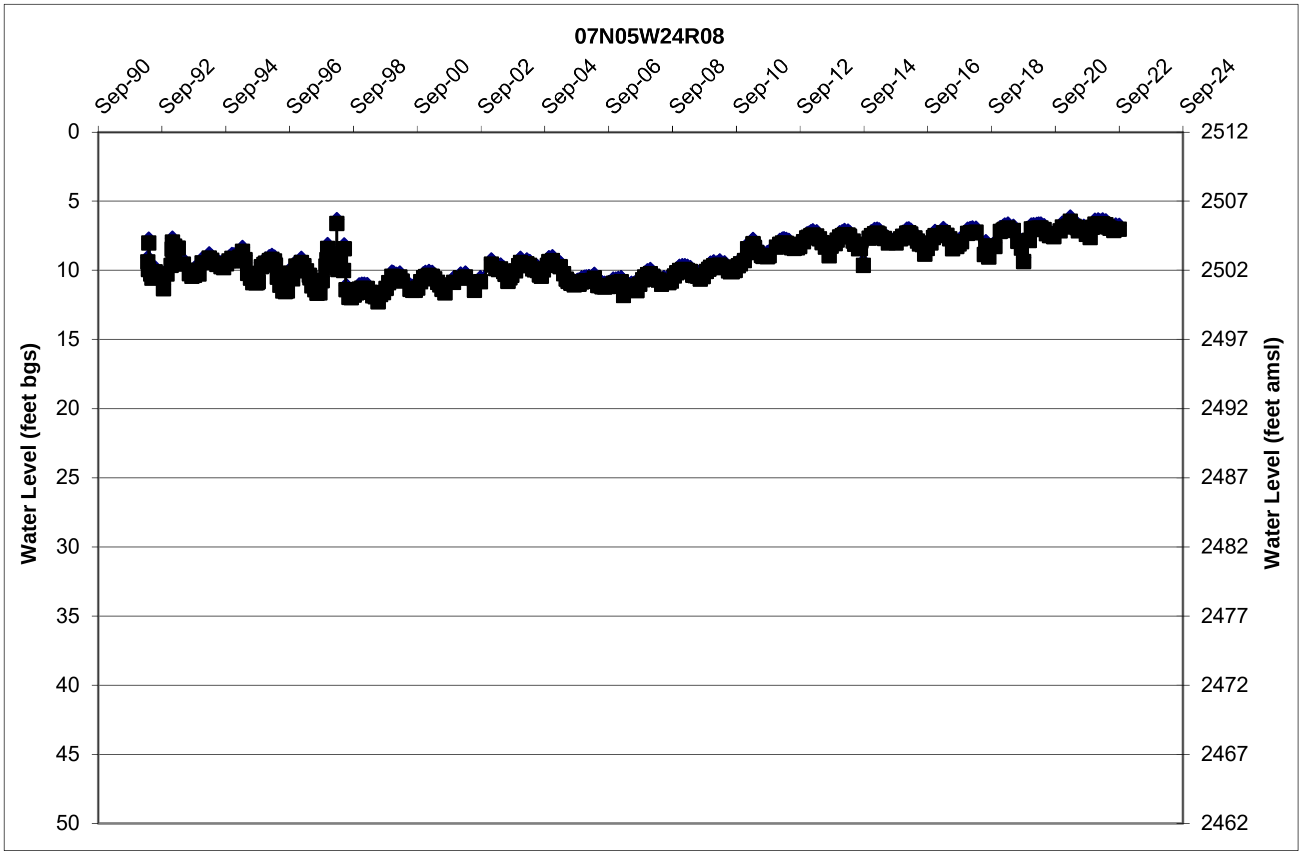
Water Level (feet bgs)
Water Level (feet amsl)


08N04W29E06
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
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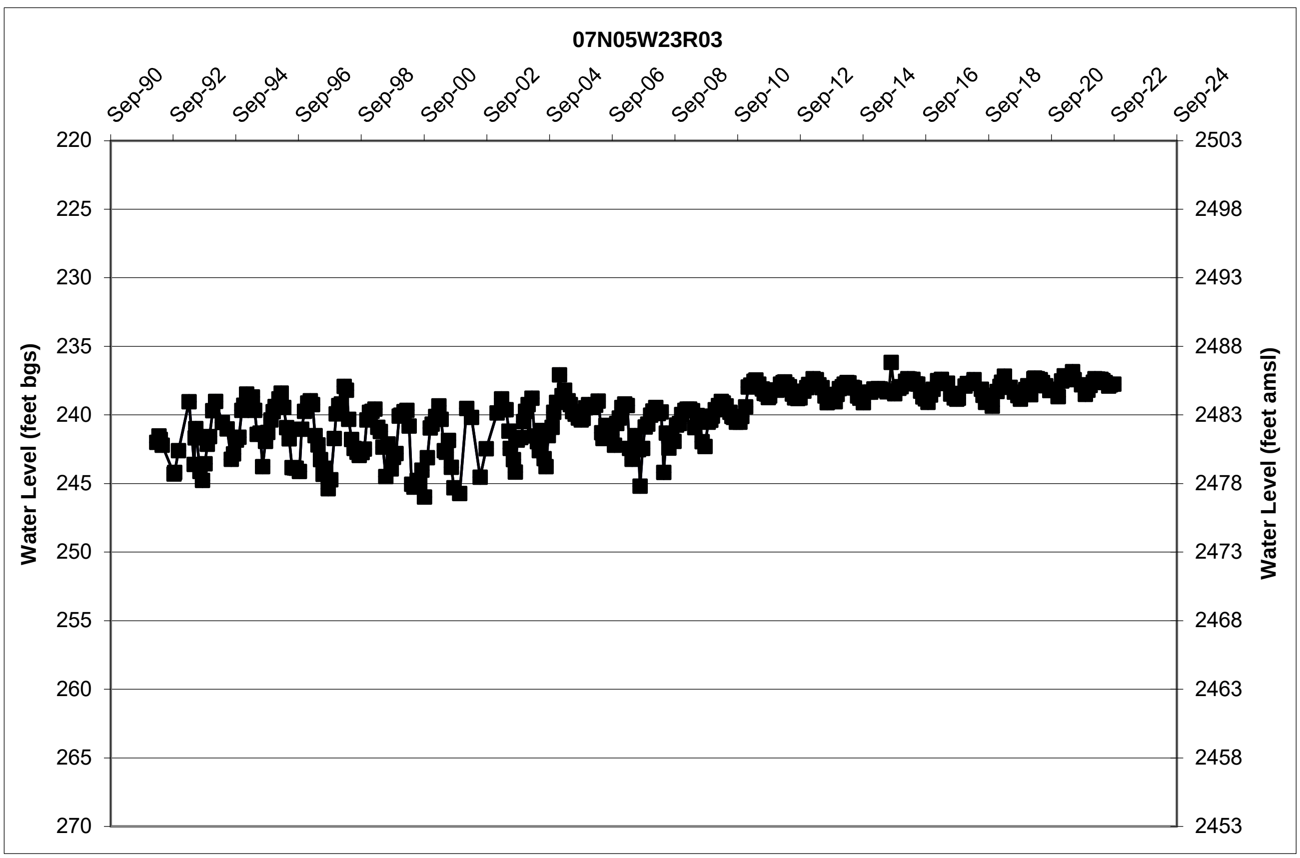
2477
2472
2467
2462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Sep-92
Sep-94
Sep-96
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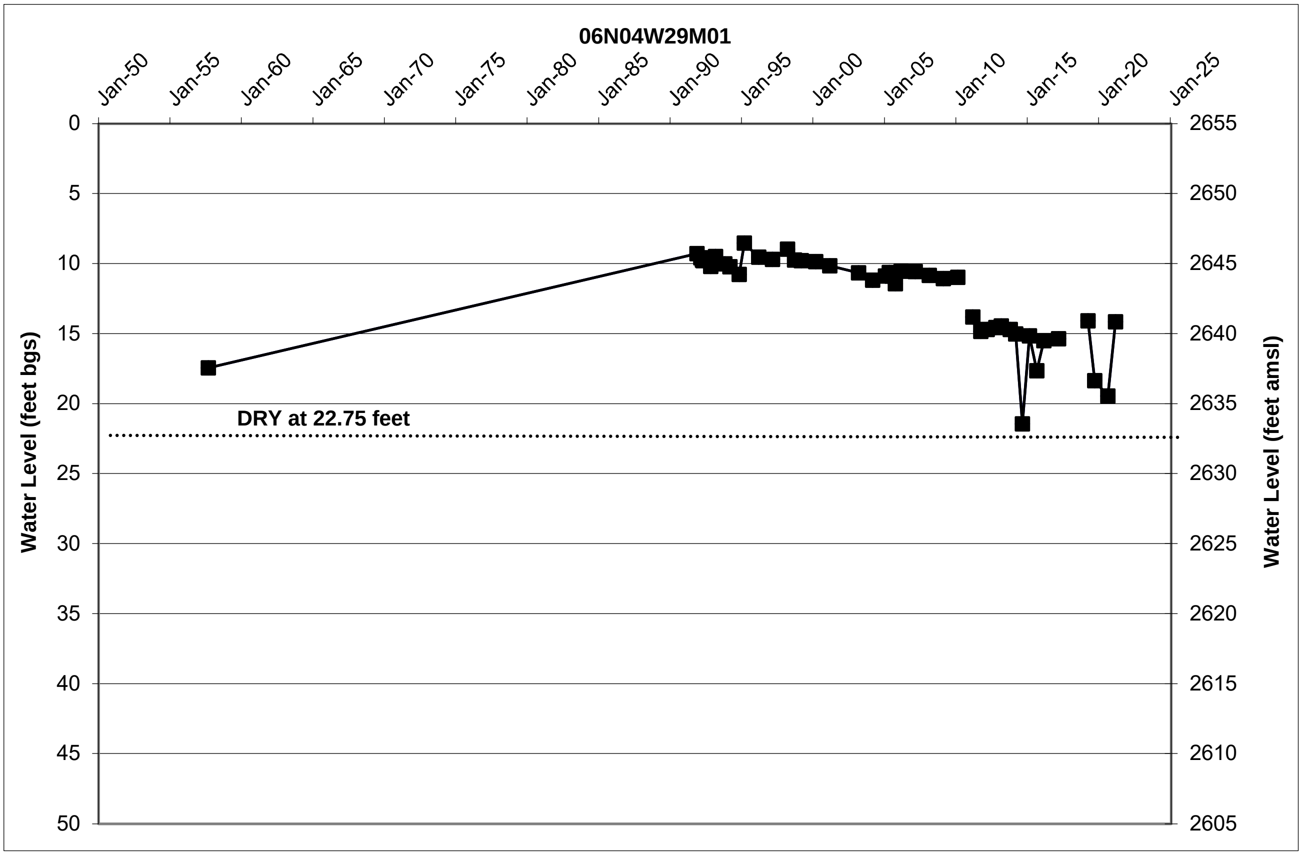
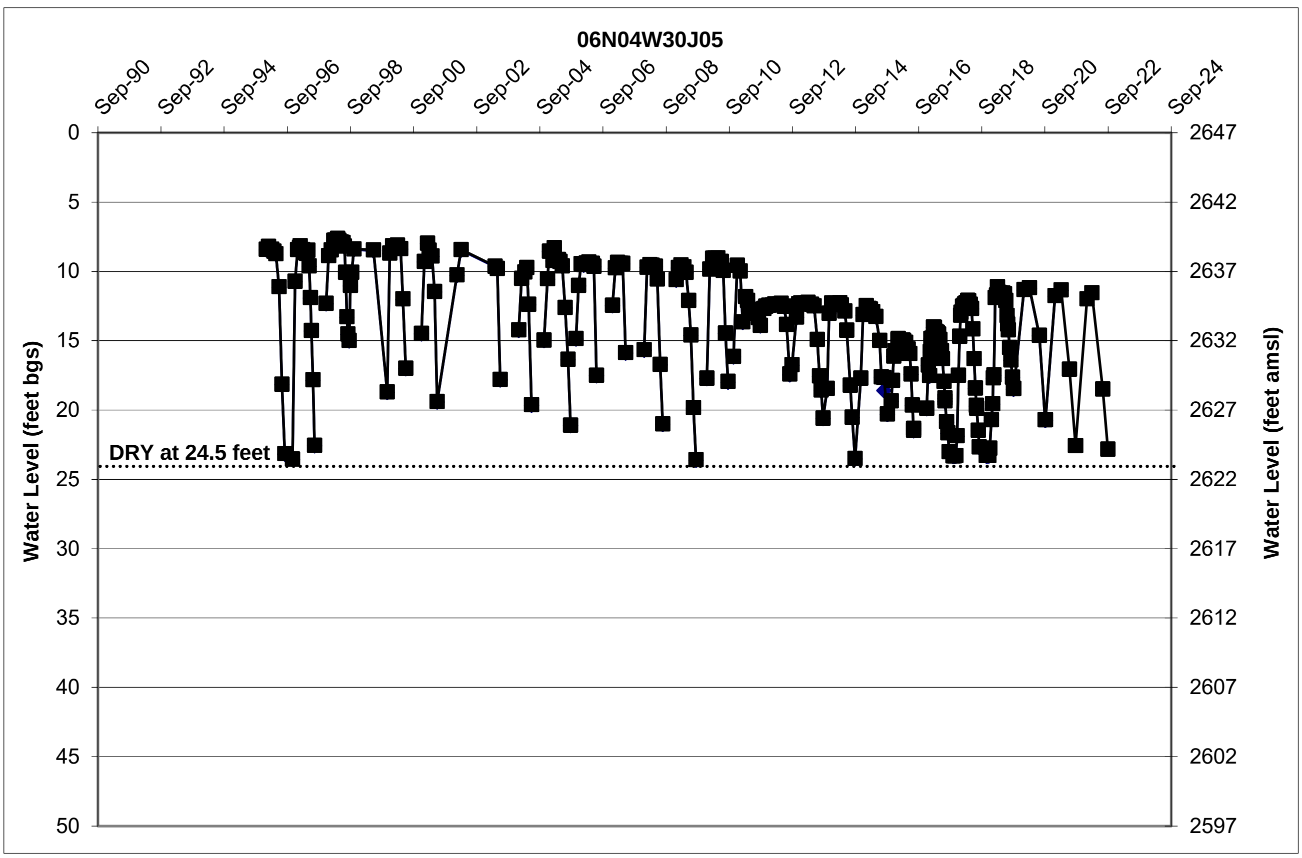
Sep-00
Sep-02
Sep-04
Sep-06
Sep-08
Sep-10
Sep-12
Sep-14
Sep-16
Sep-18
Sep-20
Sep-22
Sep-24
Water Level (feet bgs)
220
225
230
235
240
245
250
255
260
265
270
Water Level (feet amsl)
2503
2498
2493
2488
2483
2478
2473
2468
2463
2458
2453

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
Water Level (feet bgs)
0
5
10
15
20
25
30
35
40
45
50
Water Level (feet amsl)
2655
2650
2645
2640
2635
2630
2625
2620
2615
2610
2605
DRY at 22.75 feet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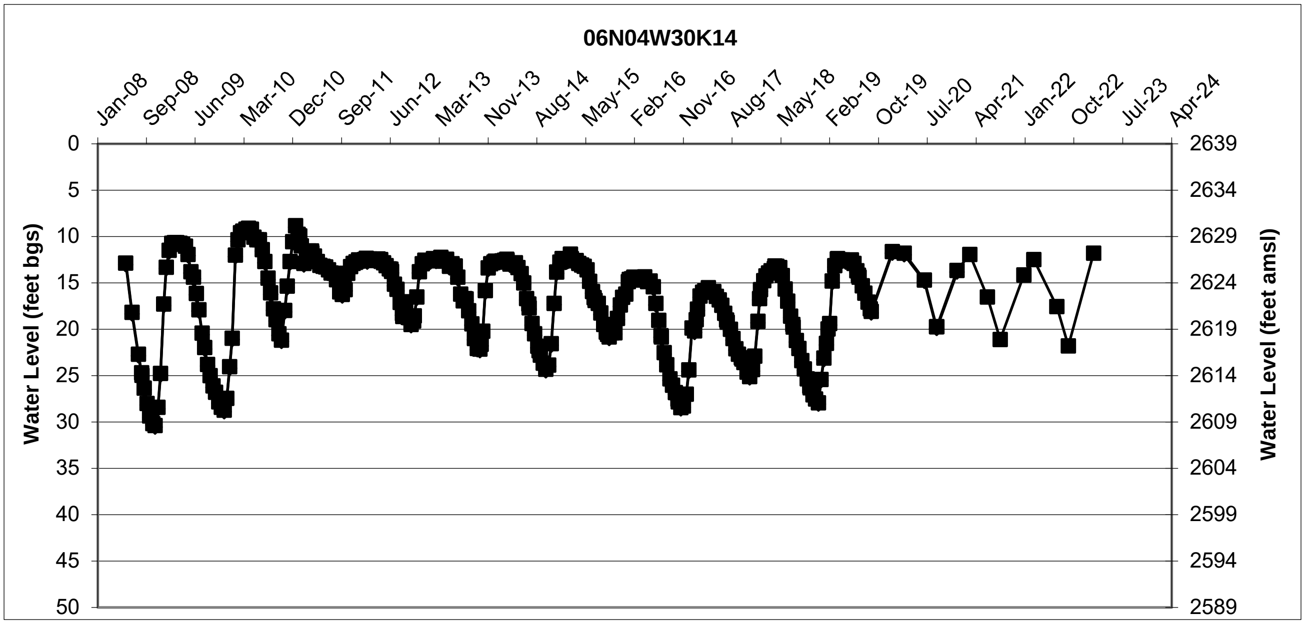
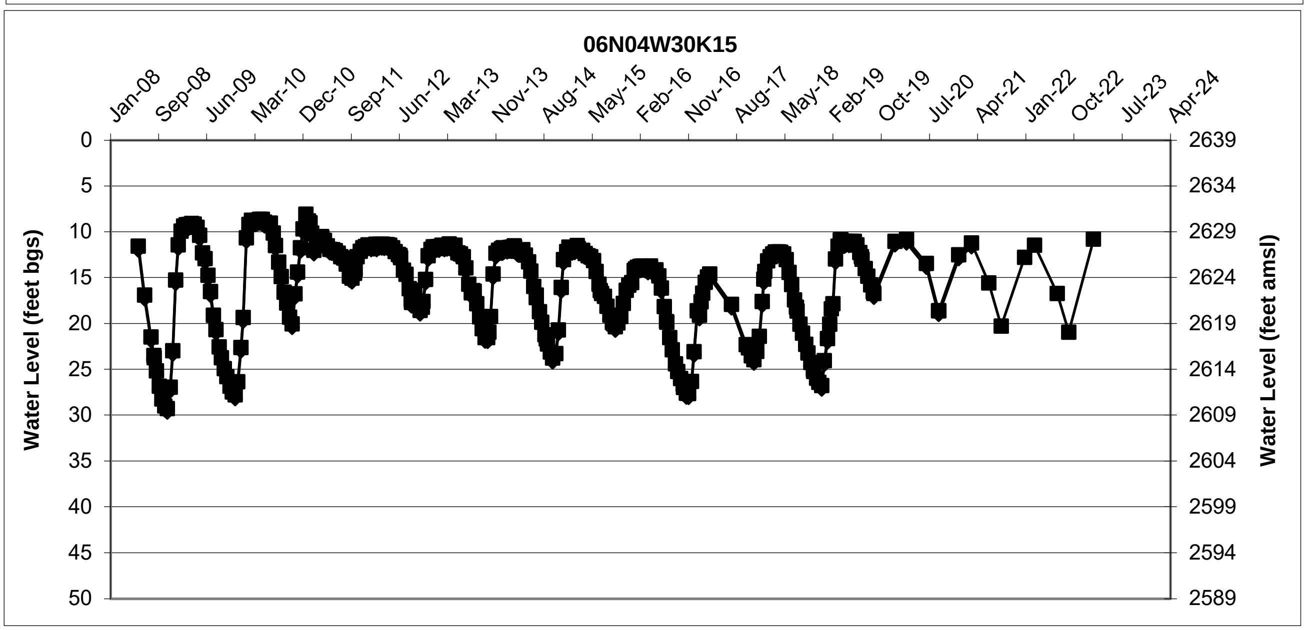
Sep-90
Sep-92
Sep-94
Sep-96
Sep-98
Sep-00
Sep-02
Sep-04
Sep-06
Sep-08
Sep-10
Sep-12
Sep-14
Sep-16
Sep-18
Sep-20
Sep-22
Sep-24
Water Level (feet bgs)
0
5
10
15
20
25
30
35
40
45
50
Water Level (feet amsl)
2647
2642
2637
2632
2627
2622
2617
2612
2607
2602
2597
DRY at 24.5 feet

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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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

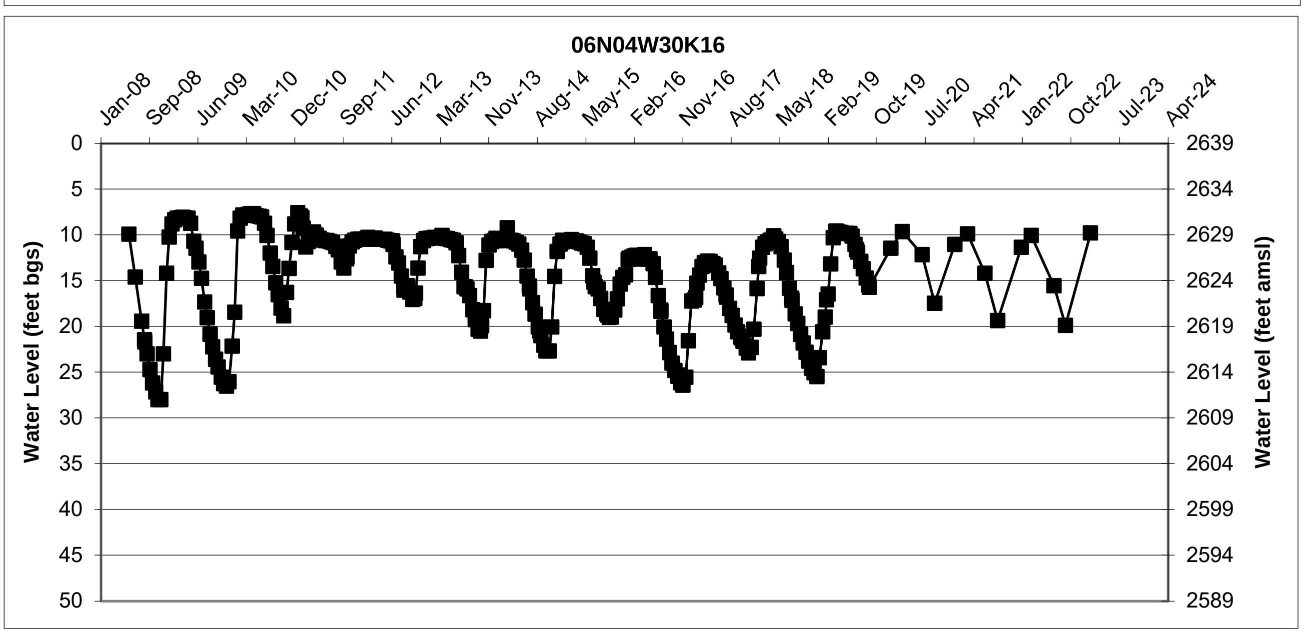
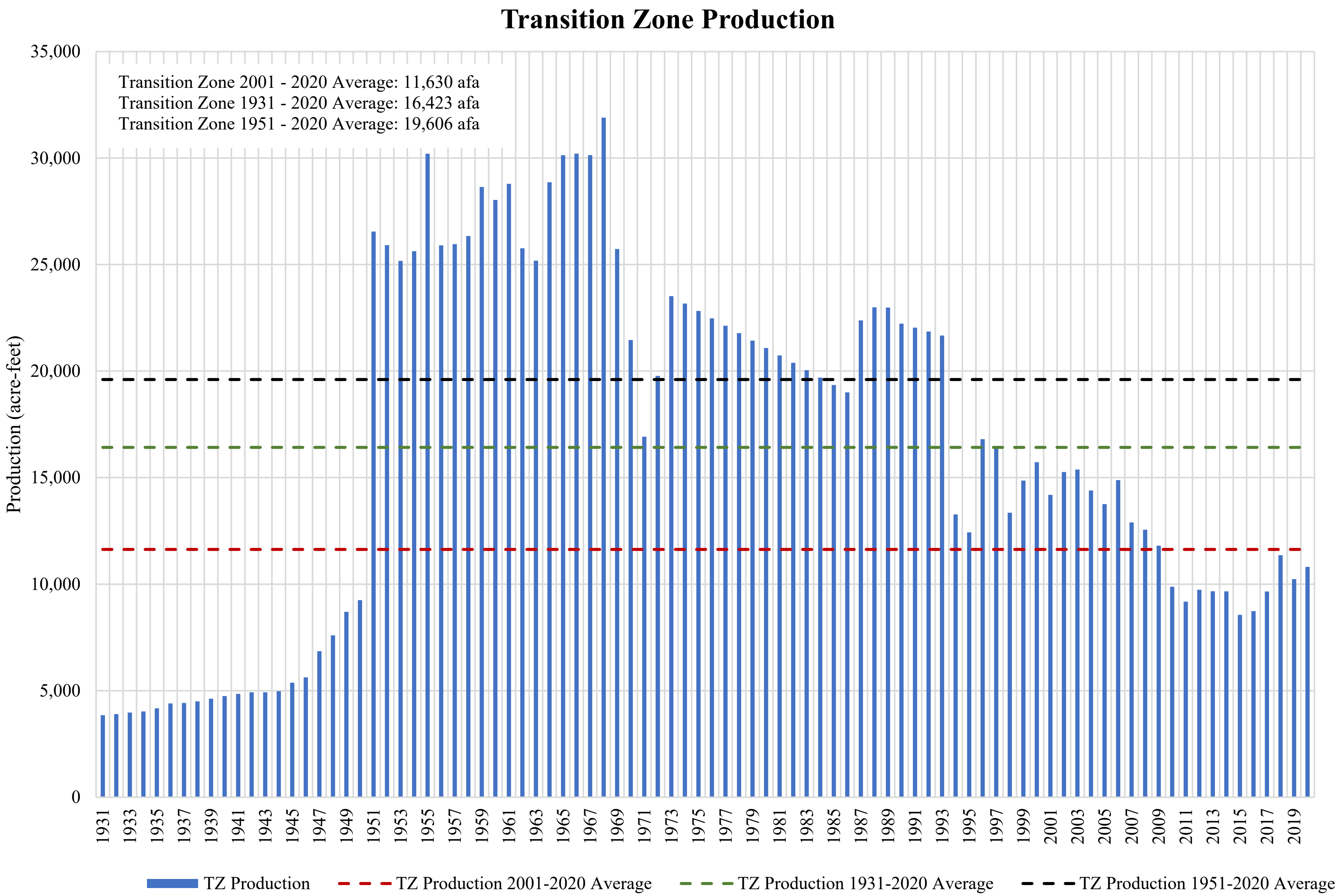

06N04W30K16
Jan-08 Sep-08 Jun-09 Mar-10 Dec-10 Sep-11 Jun-12 Mar-13 Nov-13 Aug-14 May-15 Feb-16 Nov-16 Aug-17 May-18 Feb-19 Oct-19 Jul-20 Apr-21 Jan-22 Oct-22 Jul-23 Apr-24
Water Level (feet bgs)
0 5 10 15 20 25 30 35 40 45 50
Water Level (feet amsl)
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 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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David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. and David H. Peterson, C.E.G., C.Hg

Date: February 28, 2024

Re: **Water Supply Update for 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;

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- 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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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

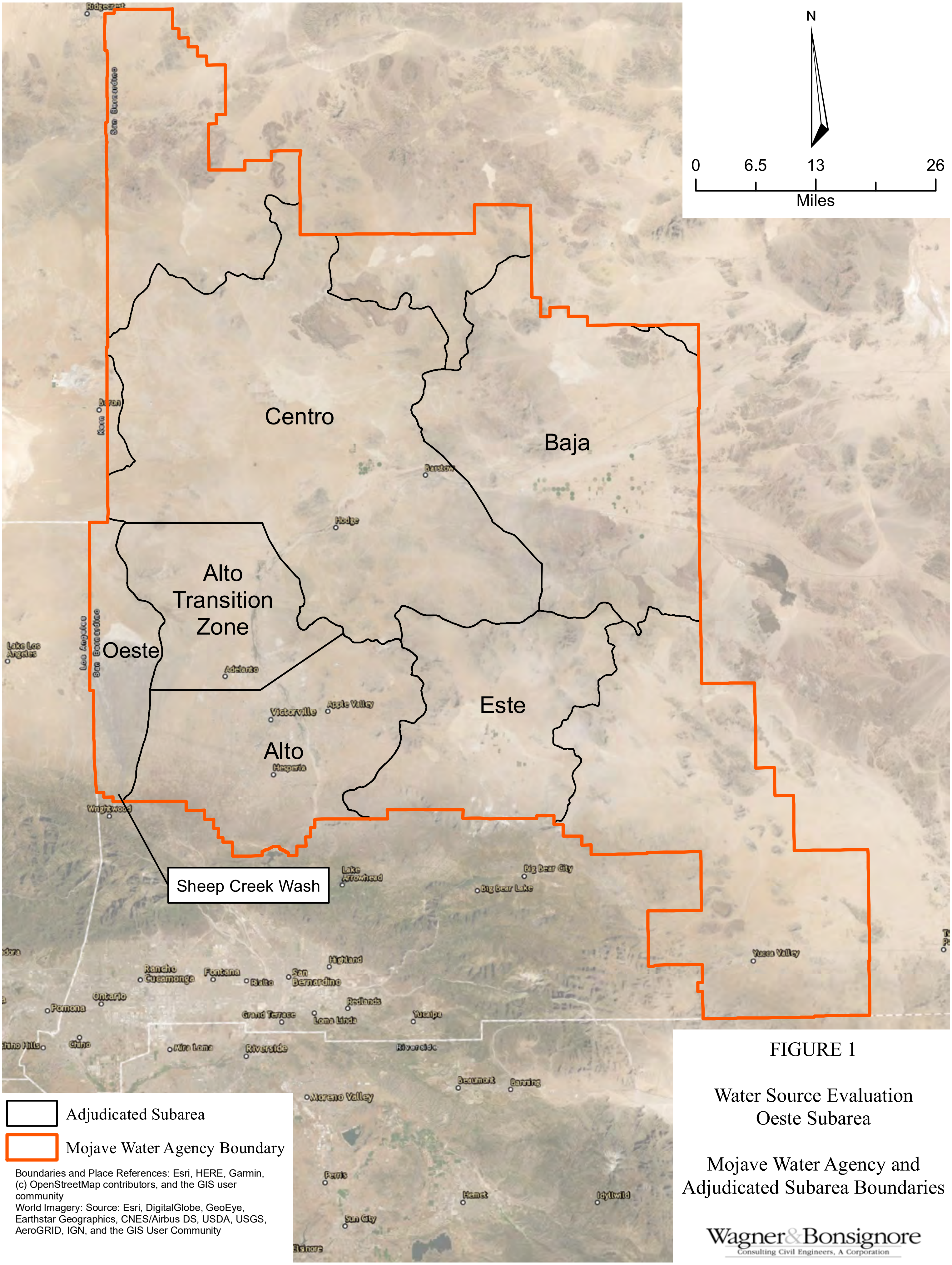


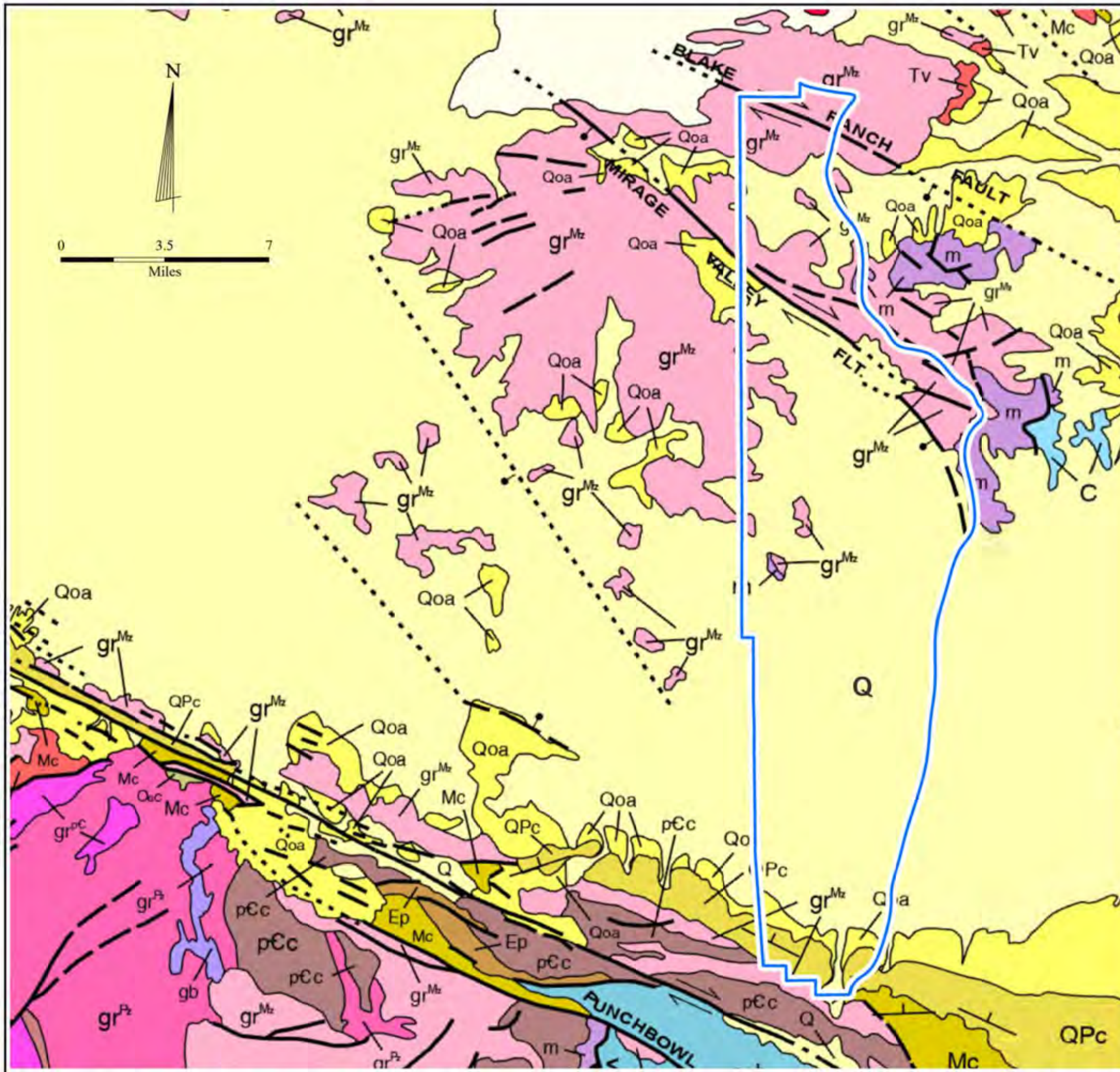
FIGURE 1

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

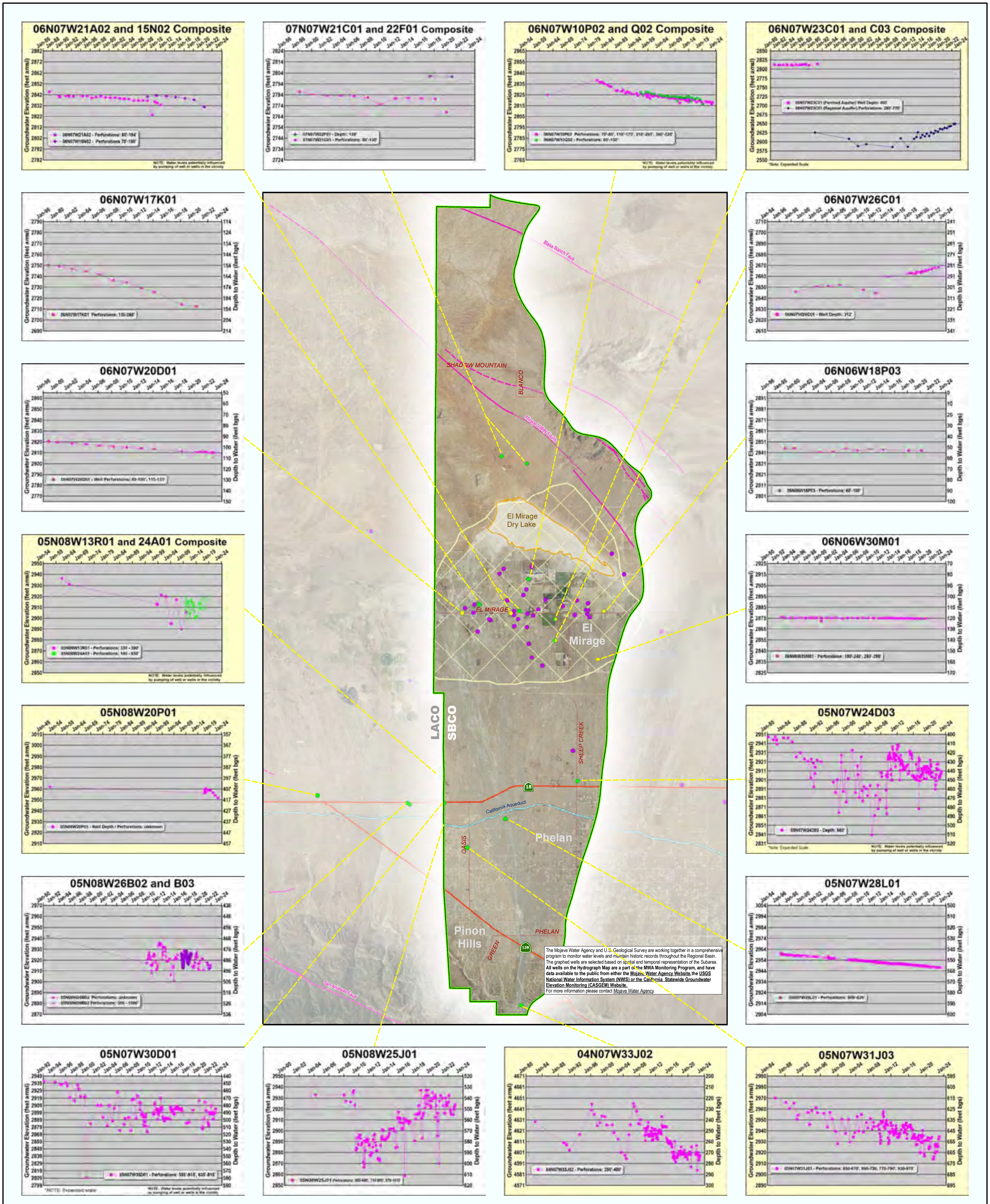
Mojave Basin Area Watermaster

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.

October 2023



Mojave Water Agency

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

Graphed Wells
- Perched
- Water Table
- Water Table and Perched
- MWA Monitoring Program Wells
- USGS Perched Water Table
- CA Geologic Faults (CGS, USGS)

Figure 3

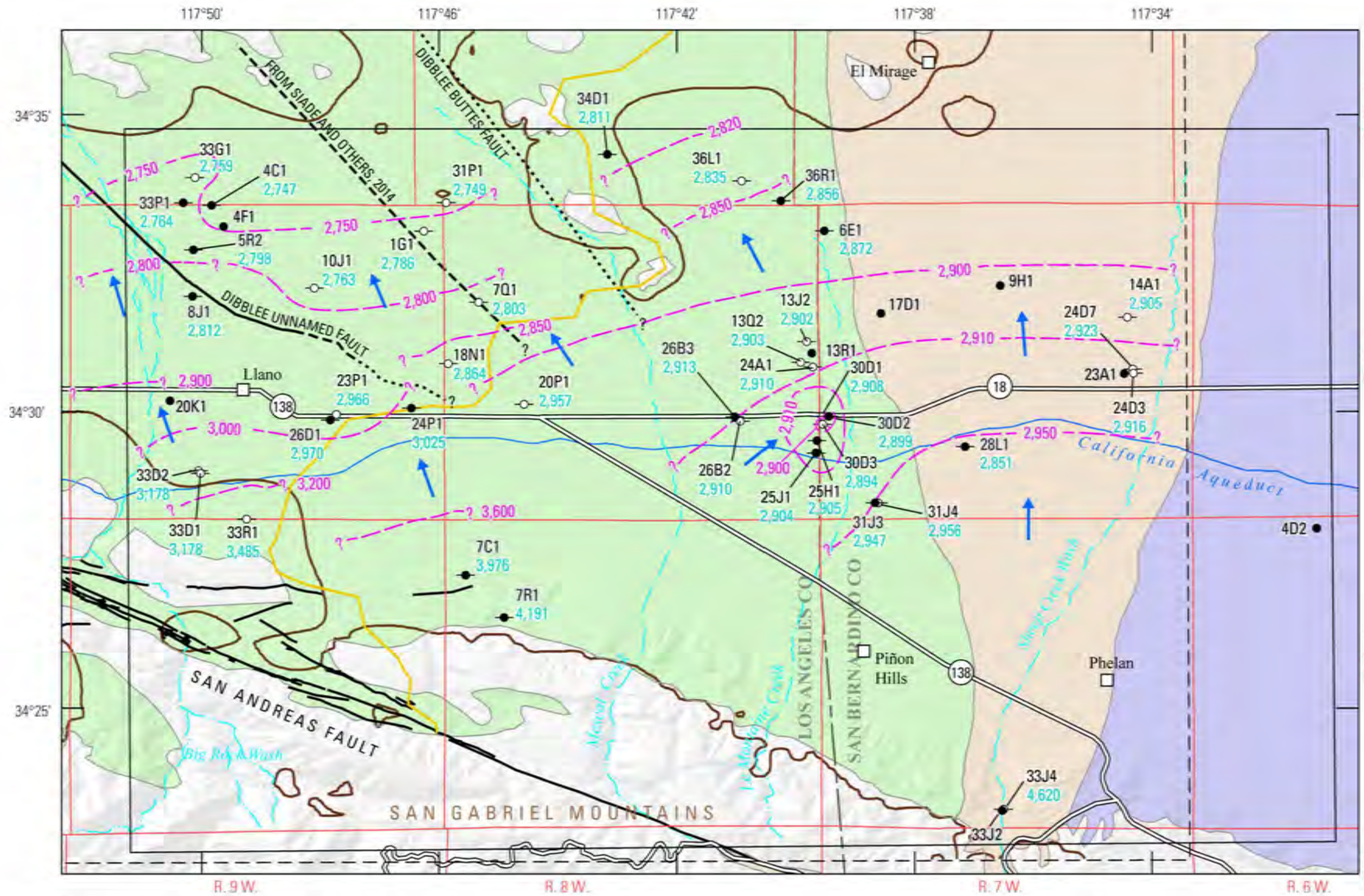
Oeste Subarea Hydrographs 2023

- Recent record
- Long-term record (begins ~1950 to ~1980)
- Very long-term record (begins ~1920)

0 0.5 1 2
Miles

N

FIGURE 4 - Groundwater Levels
Water Source Evaluation, Oeste Subarea



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Geographic Coordinate System; North American Datum of 1983

0 4 MILES
0 4 KILOMETERS

EXPLANATION

- **Antelope Valley groundwater basin**
- **El Mirage Valley groundwater basin**
- **Upper Mojave River Valley groundwater basin**
- **Groundwater-level study area**
- **Gravity study area**
- -2,900—? **Approximate line of equal groundwater-level altitude, 2014**—Interval varies; dashed where approximate; queried where uncertain; hachures indicate depression.
- **Fault**—Dashed where approximately located or inferred, dotted where concealed (modified from Dibblee, 1959, 1960c; Bryant, 2005; Siade and others, 2014).
- **Buried contact of alluvium and basement based on 2014 gravity data (see fig. 5)**
- **Ridge of highest basement altitude**
- **General direction of groundwater flow**
- 24P1 **Well with hydrograph shown in figure 11 and abbreviated state well number**
- 20P1 2,957 **Well with groundwater-level data and hydrograph shown in figure 11 and identifier**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.
- 33J4 2,956 **Well with groundwater-level data**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.

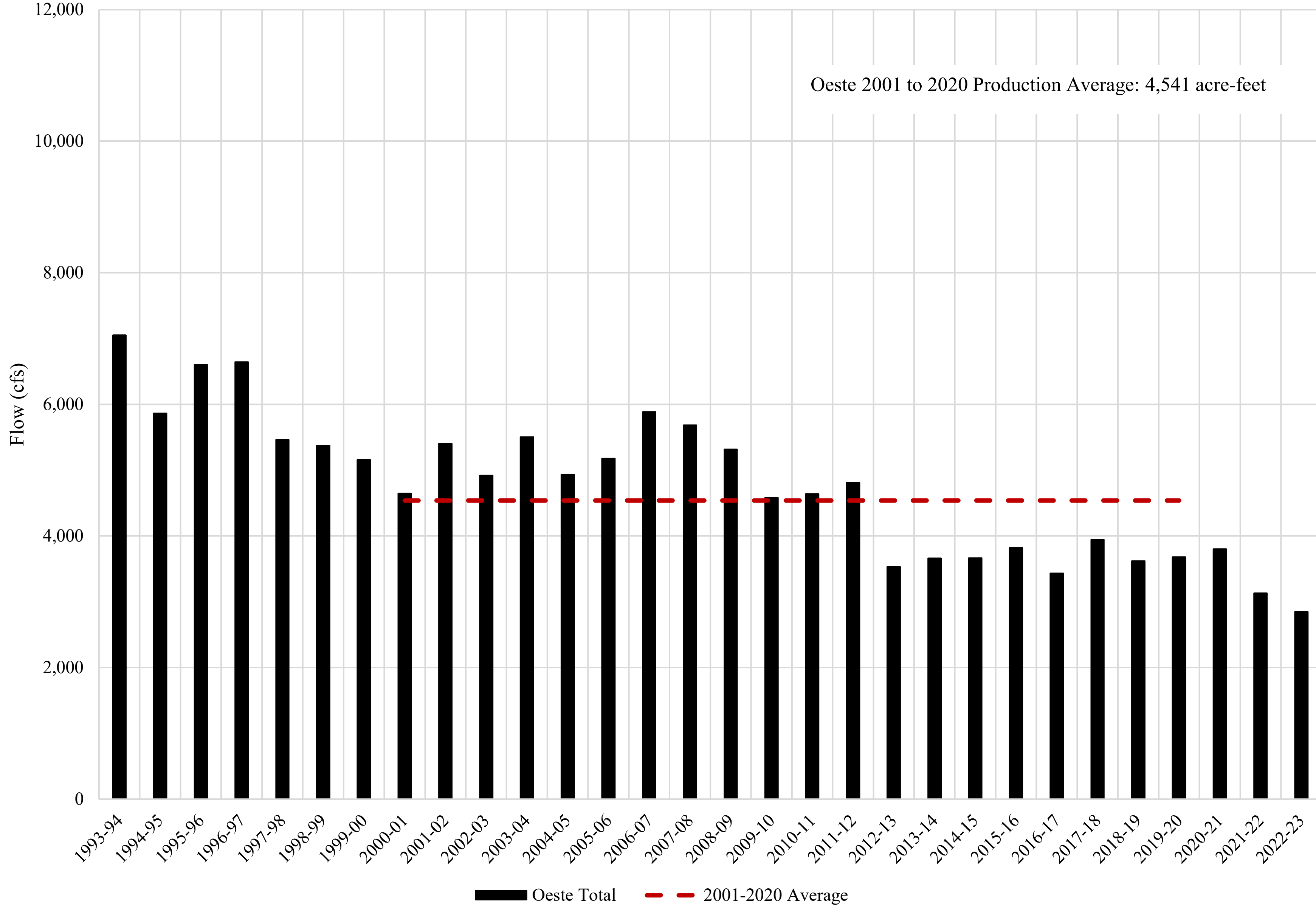
Figure 10. Groundwater-level altitude, general direction of groundwater flow, and location of wells with groundwater-level hydrographs shown in figure 11, near Piñon Hills, California.

Source: Stamos and others, 2017

FIGURE 5

Oeste Production

1993 to 2023



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Mojave Basin Area Watermaster

Appendix D

Este Subarea

Water Supply Update

Prepared by:

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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;

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- Infiltration of treated wastewater from irrigation and unlined storage basins at the Big Bear Area Regional Wastewater Agency (BBARWA) facility in Lucerne Valley and minor return flows from individual septic systems; and

- Infiltration of excess irrigation water in agricultural fields, also referred to as irrigation return flows. Agricultural irrigation has historically occurred mainly in Lucerne Valley, although small farms in Fifteenmile Valley are also irrigated with groundwater (mainly to grow jujubes).

From a hydrogeologic perspective, a fundamental challenge in estimating the various water supply and use inputs to the subarea is that Fifteenmile Valley and Lucerne Valley, which make up the subarea, are essentially separate groundwater basins, separated by a fault that reportedly allows minimal groundwater flow between them (Stamos and others, 2001). Therefore, estimates of recharge or change in storage are not uniform throughout the Este subarea and the two valleys are essentially non-connected basins.

Hydrogeologic Setting

Geologic Units and Aquifers

The geology of the subarea and vicinity is shown on Figure 2. Prior studies by the USGS generally show Fifteenmile Mile Valley as lying within the Mojave River Basin and the Lucerne Valley as lying within the adjacent Morongo Basin, with the Helendale fault representing the basin boundary. However, as defined by the 1996 Mojave Basin Area Adjudication, Fifteenmile and Lucerne Valleys are managed collectively as one of five subareas within the Mojave Basin Area. Prior geologic studies for the vicinity identify the Este Subarea as underlain and bounded to the south, north, and east by bedrock units, generally of pre-Tertiary age (older than about 65 million years). Locally, the bedrock upland areas also consist of volcanic units of Tertiary age. These older bedrock units are generally considered to be relatively impermeable and non-water-bearing, although wells have locally been developed in more fractured areas of the bedrock units.

Sediments deposited within Fifteenmile and Lucerne Valleys were derived from the bedrock upland areas bounding the valley. Within the Este Subarea, the oldest of the basin deposits are sedimentary strata of the Old Woman Sandstone of late Tertiary age. The formation underlies most of the Fifteenmile and Lucerne Valleys and ranges in thickness from about 600 to 1,000 feet. The formation is described in a study by CSU Fullerton (2005) as the primary water producing aquifer in the Este Subarea.

The Old Woman Sandstone is overlain in most areas of the subarea by unconsolidated alluvial fan deposits, basin alluvium, and playa deposits ranging from Pleistocene to Holocene in age. In the 2022 study of the geohydrology of the Lucerne Valley (Stamos and others, 2022), the alluvial units within the Lucerne Valley are divided by their depositional environment (lake, fan, playa units), underlain and surrounded by generally non-water bearing bedrock formations. The groundwater model developed for the valley breaks out the basin fill within Lucerne Valley as four units or layers; a surficial and generally unconfined aquifer extending to depths of about 150 to 180 feet, underlain by a laterally extensive, less permeable confining layer consisting primarily of lake deposits. This underlying impermeable layer generally correlates to the "perched zone" depicted on yearly hydrograph maps prepared by MWA (see Figure 4). The near-surface aquifer and confining (perched) layer are underlain by older alluvial deposits, divided by age and texture into two, generally confined to semi-confined aquifer units. Based on age, depth, and lateral extent, it appears that the deepest of the four hydrologic units in the USGS model is likely correlative to the Old Woman Sandstone.

Faulting

The Este Subarea is traversed by several west- to northwest-trending faults, including the North Frontal Fault Zone along the base of the San Bernardino Mountains, the Helendale fault dividing Fifteenmile and Lucerne Valleys, and the Lenwood fault, along the northeastern margin of the subarea. In general, these faults are considered to be potential barriers to groundwater flow. Groundwater level data collected by USGS studies from the subarea indicate that the Helendale fault zone represents a barrier to groundwater flow, with water levels on the southwest side of the fault higher than the northeast (Lucerne Valley) side, essentially separating Fifteenmile and Lucerne Valleys hydrogeologically. Groundwater monitoring data from wells near the Helendale fault indicate that water levels are generally higher on the southwest side of the fault, ranging from about 20 to 250 feet across the fault (CSU Fullerton, 2005). The potential for groundwater flow across the fault from Fifteenmile Valley into Lucerne Valley is not verified, although prior analysis by the USGS (Stamos and others, 2020) indicates that flow across the fault is minimal.

Groundwater Conditions

As discussed, the Helendale fault acts as a groundwater divide, in effect separating Fifteenmile and Lucerne Valleys hydrogeologically. Previous studies by USGS indicate that groundwater flow across the Helendale fault, from Fifteenmile Valley to Lucerne Valley is minimal (Stamos, 2001; Stamos and others, 2020). Water level data indicate that groundwater flow within the Fifteenmile Valley area is generally to the west-northwest, toward the Alto Subarea and Mojave River. Groundwater flow in the Lucerne Valley generally flows towards and converges in the vicinity of Lucerne Dry Lake, with no documented flow out of the valley.

Review of well hydrographs by MWA (see Figure 4) indicate that groundwater levels in the Lucerne Valley generally range from about 120 to 200 feet below ground surface. Typically, water levels in the vicinity of the perched zone identified by USGS are shallower than surrounding areas. In general, water levels trends over time in most of the hydrographs for Lucerne Valley area are relatively flat; that is, appear to be relatively stable or only slightly declining over time. Also, water levels in wells 05N01W25G01, 05N01E17D01, and 05N01W36R01 appear to have rebounded in the mid-1990s, after the Judgement.

Water levels in the Fifteenmile Valley are on the order of about 20 to 80 feet below ground surface, which is generally shallower than in Lucerne Valley. Locally however, water levels in Fifteenmile Valley are deeper, in the range of 200 to 350 feet deep (State Well No. 04N01W21J01 and 04N02W16E01, respectively). In general, the shallowest groundwater measurements appear to be from wells located near and on the southwest side of the Helendale fault. The hydrographs for wells in Fifteenmile Valley indicate that several continue to record declining water levels (04N01W07R01, 04N01W18Q01, 04N01W09P06, 04N01W10R01). However, the rate of decline appears to be small, on the order of about 0.15 to 0.2 feet per year.

Water Supply

Mountain-Front (Natural) Recharge

Areas of potential mountain-front recharge identified by USGS (Izbicki, 2004) are shown on Figure 3. Estimates of the volume of native recharge occurring along the mountain-front within the Este Subarea are approximate with the more recent estimates based largely on groundwater models. The Stipulated Judgment (Table C-1), provided a surface water inflow estimate of 1,700 acre-feet of ungaged surface water inflow into the Este Subarea, although the resulting amount of infiltration and groundwater recharge to deeper aquifers is not known. In the 2005 *Este Hydrologic Atlas*, CSU Fullerton cited estimates of groundwater recharge from several sources, although only the estimate from the Department of Water Resources (DWR; Bulletin 84, 1967) was for the entire Este Subarea. DWR estimated 1,050 AFY of recharge associated with surface inflow.

For the current update, the range of values of possible mountain front recharge to Este Subarea and Lucerne Valley are listed below:

Source of Data – Mountain-front Recharge	Average, AFY
DWR, Bull. 84 (1967), Este Subarea	1,050
USGS, Shaefer (1979) – Lucerne Valley only	1,000
Wagner & Bonsignore (2016) – Este Subarea (average of published data)	1,375
USGS, Stamos et al (2022) – Lucerne Valley only	635-940

The two estimates of recharge for the entire subarea (Shaefer, 1979 and Wagner & Bonsignore, 2016) indicate that mountain-front recharge is in the range of about 1,050 to 1,375 AFY.

As noted by the USGS (Stamos and others, 2001), the discharge from streams and washes draining the mountain front have never been directly measured. Given the infrequency of large storm events contributing significant recharge to the subarea, specific field-level measurements are not available. In general, the USGS estimates are model-derived, based on precipitation data and adjusted during model calibration. Of the estimates, the most recent mountain-front recharge to Lucerne Valley in the USGS 2020 model (635 to 940 AFY) appears to be most area-specific and was adjusted during model calibration to be consistent with groundwater level data. As such, it may represent a reasonable approximation of recharge to Lucerne Valley, but not the entire Este subarea.

The primary areas contributing the bulk of the mountain-front recharge to the Mojave River Basin appear to be in the Sheep Creek Wash (Oeste Subarea) and headwaters of the Mojave River (Alto Subarea; Izbicki and Michel, USGS, 2004), to the northwest. However, the USGS has also identified evidence of mountain-front recharge at the southeast end of Fifteenmile Valley. When the extent of the mountain-front recharge areas in Lucerne and Fifteenmile Valleys identified by USGS (Izbicki and Michel, 2004), are compared, the potential recharge to Fifteenmile valley appears to be several times larger than the area identified in Lucerne Valley. Presumably, the mountain-front recharge to Fifteenmile Valley is also greater than that to Lucerne Valley, although the actual amount remains unconfirmed. The USGS also performed isotopic analysis of groundwater samples from Fifteenmile and Lucerne Valley and found that groundwater at the base of the mountains was relatively young (less than about 70 years old), indicating recent recharge. However, away from the mountain front, estimated groundwater age was over 10,000 years old. This suggests that the rate of recharge of groundwater to the valleys from native recharge is very slow.

BBARWA Return Flows

Return flows from treated wastewater deliveries to the Big Bear Area RWA (BBARWA) to Lucerne Valley were calculated by Watermaster, based on reported deliveries, less the consumptive use for alfalfa. From the period of 1996 to 2018, Watermaster has calculated return flows ranging from a low of 63 AFY in 2018, to a high of 1,936 AFY in 1998, with an average over that period of 792 AFY. Consultants for the project known as “Replenish Big Bear” presented information to MWA (January 25, 2024) representatives indicating basin recharge from BBARWA to be 1610 acre feet per year for a 10 year period 2012-2024. While the “Replenish Big Bear” project is a potential loss of recharge to Este, it is not currently known when the project will be fully implemented.

Estimates of return flows were also developed for the years 1980 to 2016 from model simulations of the USGS Lucerne Valley Hydrologic Model (2020). Return flows simulated by USGS have ranged from 300 to over 2,000 AFY, with an average of 944 AFY.

Overall, the calculated average return flows between Watermaster and USGS are similar. As discussed, it has been observed that water levels are rising in the area of BBARWA, indicative of local recharge. However, as shown on Figure 3, the BBARWA facility is located within and overlying the area identified by USGS and depicted on MWA hydrographs as a shallow perched zone. Review of cross sections presented in the *Irrigation Management Plan* for the facility (Water Systems Consulting, Inc., 2016), as well as drillers reports for the monitoring wells at the BBARWA facility indicate that clays were encountered at depths of about 150 to 180 feet, likely corresponding to the perched or confined layer described by USGS (Layer 2 of Stamos et al, 2020). Therefore, it appears likely that infiltrated water at the BBARWA facility is limited by the confining layer. It is not currently known if the infiltrated water from BBARWA remains perched and isolated on the confining layer, or if it enters deeper aquifers down-gradient (northwest) of the facility.

In their 2022 report, the USGS (Stamos et al) indicated that recharge from water from septic systems from the town of Lucerne Valley and surrounding basin is difficult to quantify, but assumed to be negligible. Citing studies by others (Umari and others, 1995), the USGS indicated that using 1928 and 2010 population estimates, the amount of potential recharge from septic effluent ranged from about 20 to 455 AFY during those years. However, the USGS also indicated that actual amounts of recharge could be less, due to lower population before 1928, losses from evaporation of near-surface systems, and time required for effluent to migrate to the water table.

Irrigation Returns

Irrigation returns or return flows are defined by the USGS (2020) as water applied to agricultural fields that is not used by plants or lost through evaporation. It is presumed the water undergoes deep percolation to aquifers. For the Lucerne Valley Hydrologic Model (2020), the USGS evaluated historical crop use, groundwater production, both verified (since 1996) and estimated from crop consumptive use. Based on the model simulation, irrigation returns in Lucerne Valley for the period from 1942 to 2016 were calculated to average 1,900 AFY. No estimate for Fifteenmile Valley was made in that study.

In an updated water budget for Este Subarea, Watermaster estimated agricultural return flows during the period 1996 to 2018 ranged from 876 to 3,036 AFY, with an average of 1,896 AFY. Of the average, about 384 AFY was calculated for Fifteenmile Valley, with the remaining 1,512 AFY estimated for Lucerne Valley. The Watermaster analysis assumes that groundwater production (pumping) minus consumptive water use (i.e., crop irrigation) equals the return flows to the subsurface. As previously discussed though, soil-moisture data from Lucerne Valley suggests that at least locally, return flows may be lower than estimated by the consumptive use analysis.

As shown on Figure 4, many areas of agricultural irrigation in the Lucerne Valley lie within the area of the perched or confining layer identified by USGS. As with the infiltrated water from the BBARWA facility, it appears that infiltration of most of the agricultural return flows in Lucerne Valley would be limited by the confining layer at depth. As a result, most of the estimated 1,512 AFY return flows in Lucerne Valley may be limited to increasing storage of the uppermost aquifer. Agricultural acreage in Fifteenmile Valley has historically been less than Lucerne Valley, reflected by the lower calculated return flow average of 384 AFY. However, a widespread perched zone has not been documented.

Water Supply Summary

The estimated total annual water supply to the Este Subarea presented below represents studies spanning varying time frames. Based on consumptive use models, estimates of returns from the BBARWA facility and from agricultural irrigation are based on data from as recently as 2016 to 2018. However, the contribution of native mountain-front recharge to the water supply for the subarea is poorly understood, varies most widely, and represents varying base periods and geographic areas. Based on the information reviewed, estimates of the current ranges of input from the various water supply sources is listed below:

Water Supply Source	Time Period Evaluated	Annual Supply (AFY)
Agricultural Return Flows	1942 - 2018	1,896 - 1,900
BBARWA Disposal	1980 - 2024	792 – 1,600
Mountain-front Recharge	1936 - 2016	1,050 – 1,375
Total Estimated Range		3,738 - 4,875

Consumptive Use and Outflows

As provided in the Watermaster Annual Reports for the past five water years, the total consumptive use and outflows for the Este Subarea are listed below, in acre-feet:

2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	5-Year Average
4,027	3,834	4,318	4,579	4,706	4,393

The reported outflows shown above include 200 AFY of subsurface flow to Alto subarea.

Change in Storage

Based on the above estimates, the water supply and consumptive use/outflows appear to be relatively closely balanced.. This would indicate that storage loss in recent years is relatively small. This seems to be supported by the observation that annual changes in water levels shown on the MWA Hydrograph Map on Figure 4 are also small, especially since the mid-1990s. As discussed by USGS (2022), water level changes continue to be influenced by regional movement of groundwater to partially refill a historical pumping depression in the area of the Lucerne dry lake. They also note that water levels near the valley margins are declining as water moves to the middle of the valley. Therefore, it may be difficult to separate the relatively small effects of current pumping from the larger regional effect of long-term water-level recovery.

The USGS groundwater model for Lucerne Valley (Stamos and others, 2022) estimated that reduced pumping starting in the mid-1990s decreased the rate of storage depletion. From 1942 to 1995, the average depletion of groundwater storage in Lucerne Valley was calculated at about

7,700 AFY, decreasing to about 2,900 AFY for the period from 1996 to 2016. It should be noted however that verified pumping in Este also generally decreased over time and is reported by Watermaster to range from 4,029 to 4,304 AFY during the last five water years. Presumably, the overall decrease in pumping correlates to a smaller amount of storage loss over the past five years.

Discussion and Conclusions

The elements of water supply to the Este subarea are approximate values taken from several published sources, although none of the water supply inputs have been directly measured. Infiltration of treated wastewater or agricultural irrigation returns are based on consumptive use analysis, which assumes that any water not consumed by plants or directly evaporated is returned to the aquifer. While the analysis provides a reasonably estimate of water use, factors such as climatic conditions, salinity, and pests and diseases can affect the estimated water demand by crops.

Of the water supply sources discussed, the largest unknown with the widest range of published estimates is mountain-front recharge. MWA is currently in the early stages of a project to install a stream gauge in the watershed to the south of the subarea, to monitor periodic runoff events to Fifteenmile Valley. While this gauging data will eventually provide additional information to estimate mountain-front recharge, it may be several years before sufficient data are collected to understand this input to the water balance.

While most water supply inputs are estimated, one directly observable element of the water balance that can be measured is water levels in wells. In general, the historical water levels shown on the hydrograph (Figure 4) are relatively stable, or are only changing at a small rate. Interpretation of small water level changes, particularly in the Lucerne Valley, are difficult because water levels have been recovering near Lucerne Dry Lake, with associated declines in water levels at the valley margins (Stamos and others, 2022). Overall though, they appear to support the conclusion the water supply is very near to or slightly less than groundwater production.

Based on information provided from Watermaster, the total estimated pumping for Este subarea for the past five water years is shown below:

	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	Average
Verified Production	4,101	4,029	4,227	4,304	4,114	4,155
Non-Stipulating Parties*	954	954	954	954	954	954
Totals	5055	4983	5181	5258	5068	5108

* Estimated groundwater pumping based on land use, crop type, and climate data
See Fig 5

As indicated, verified and estimated pumping together appear to exceed the estimated water supply of 3,730 to 4,875 AFY. However, water levels throughout Lucerne Valley generally remain little changed in recent years and within Fifteenmile Valley, water levels are either relatively stable, or are declining slowly. Based on these observations, it appears that recharge and pumping are fairly closely balanced. Based on average production, this would indicate a production safe yield of 4484 AFY (Total Production minus deficit).

We note that results from the Upper Mojave Basin Model indicate that the losses/gains in Fifteen Mile Valley are negligible (70 year average, -191 acre feet, 20 year average +134 acre feet). The water levels, as shown on Figure 4, suggest little to no change in storage over at least the last 10-20 years; some wells show slight declining water levels, and some water levels are rising. In light the foregoing and Figure 4, the PSY could be considered to be equal to the pumping in Este or about 5100 acre feet.

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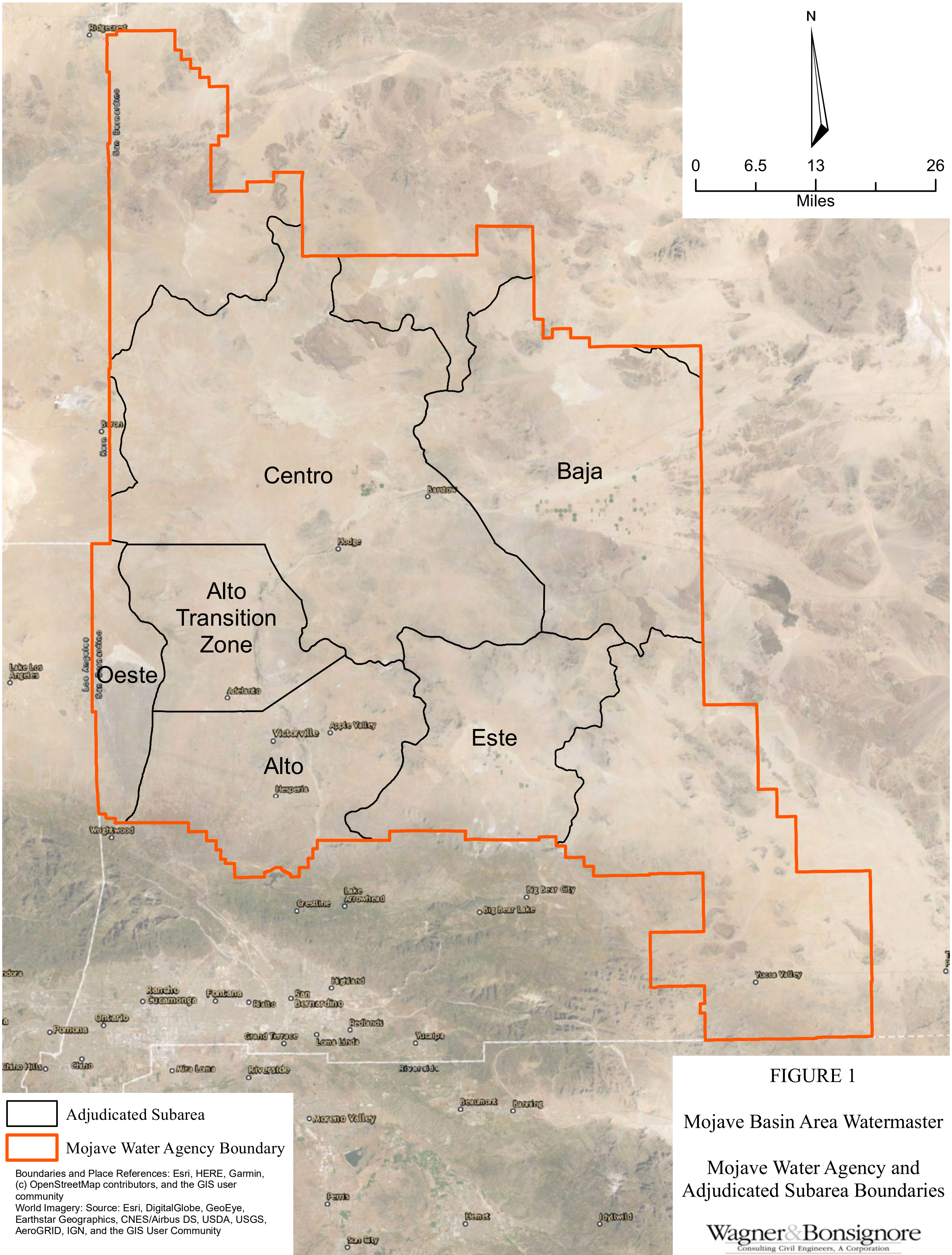


Boundaries and Place References: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
World Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 1

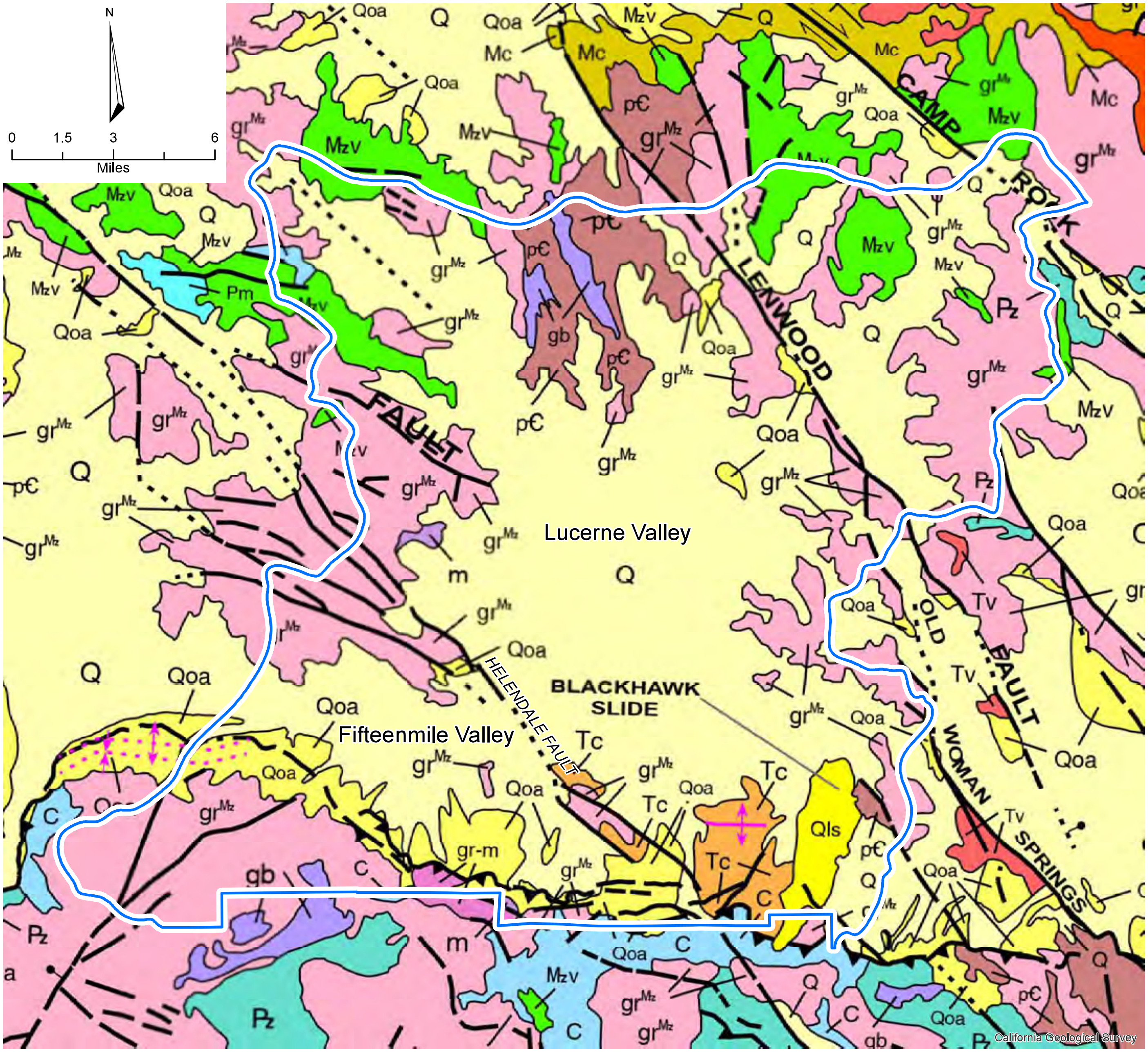
Mojave Basin Area Watermaster

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



- 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

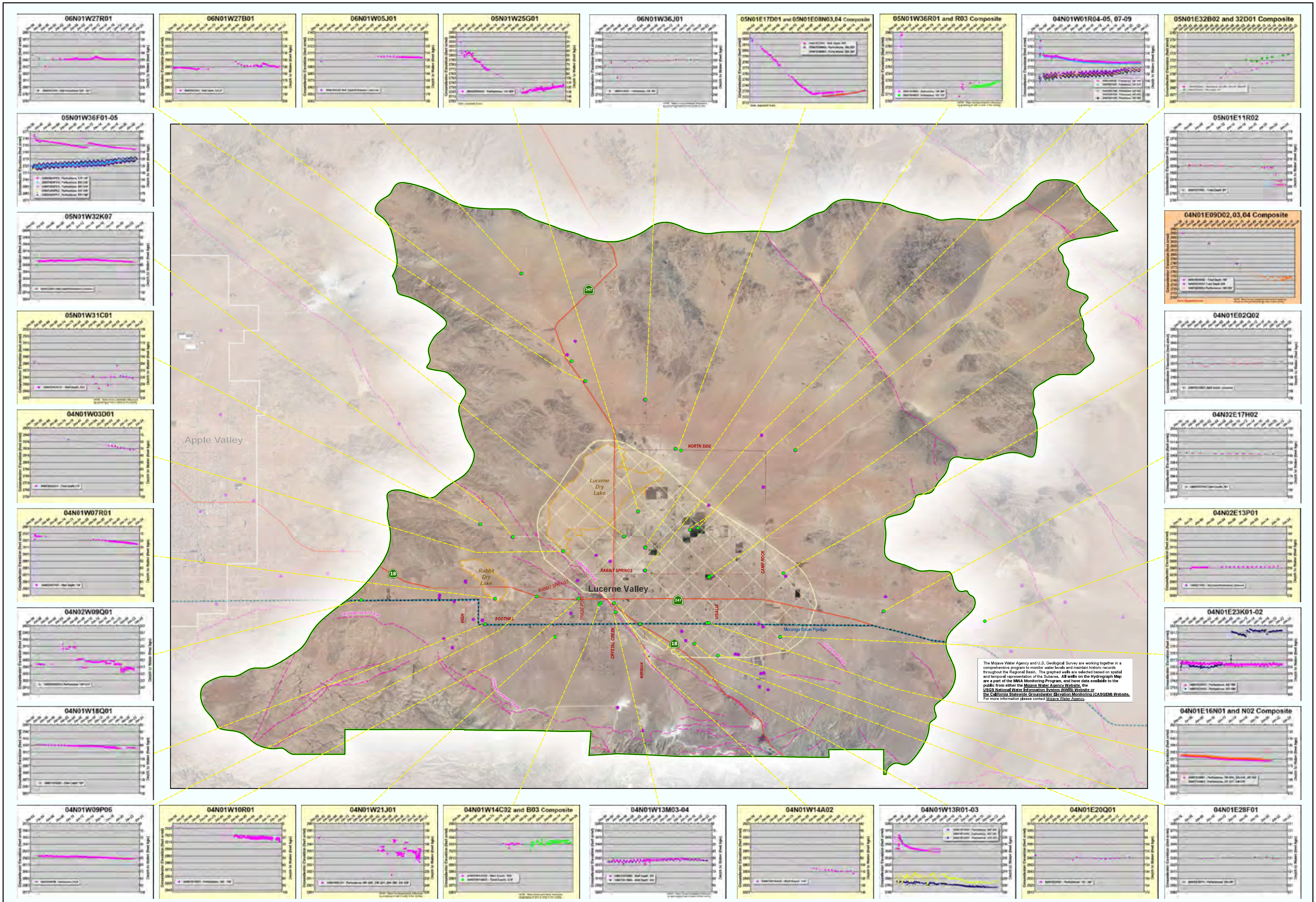
Mojave Basin Area Watermaster

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)

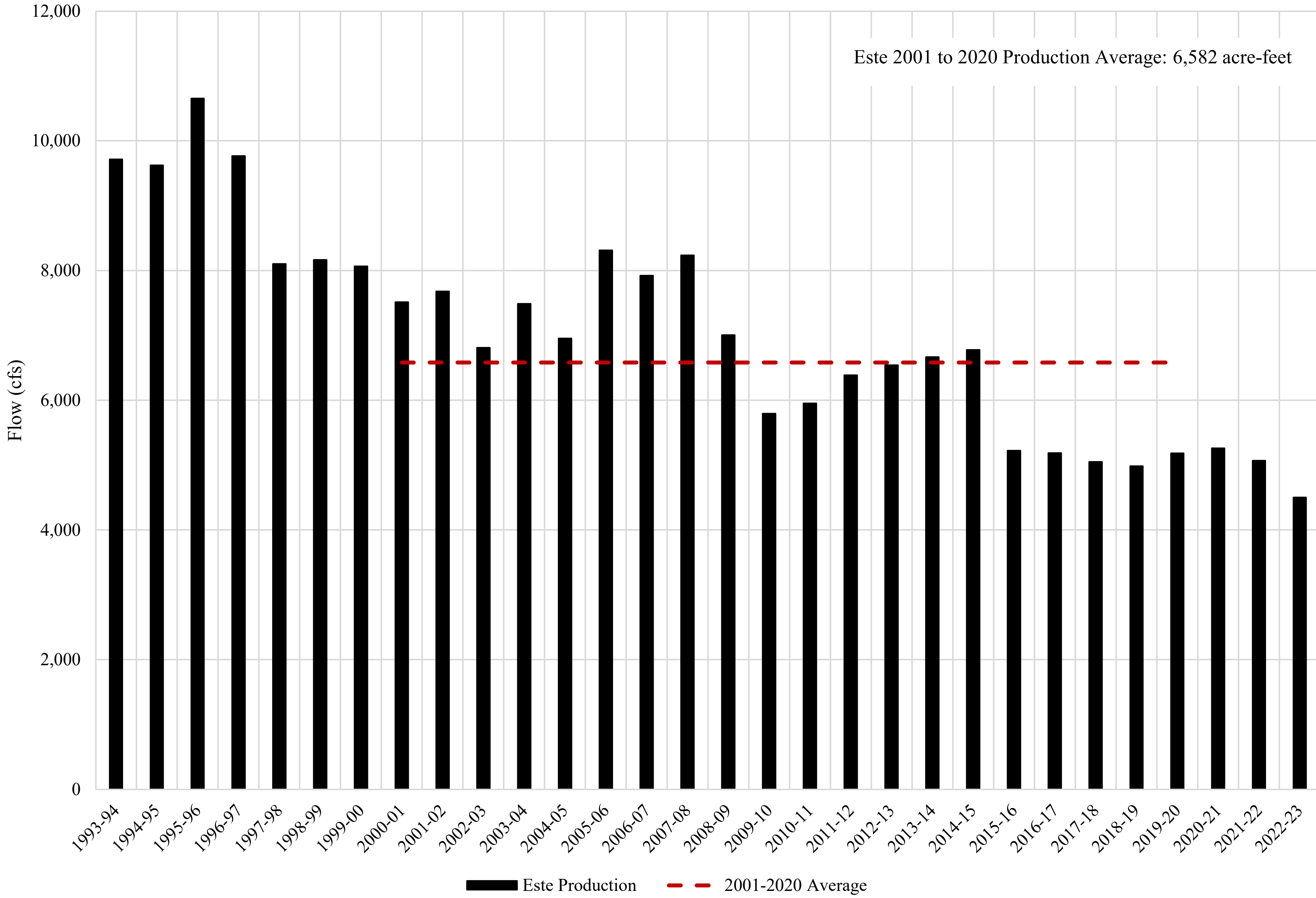
0 1 2 4
Miles

N

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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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.

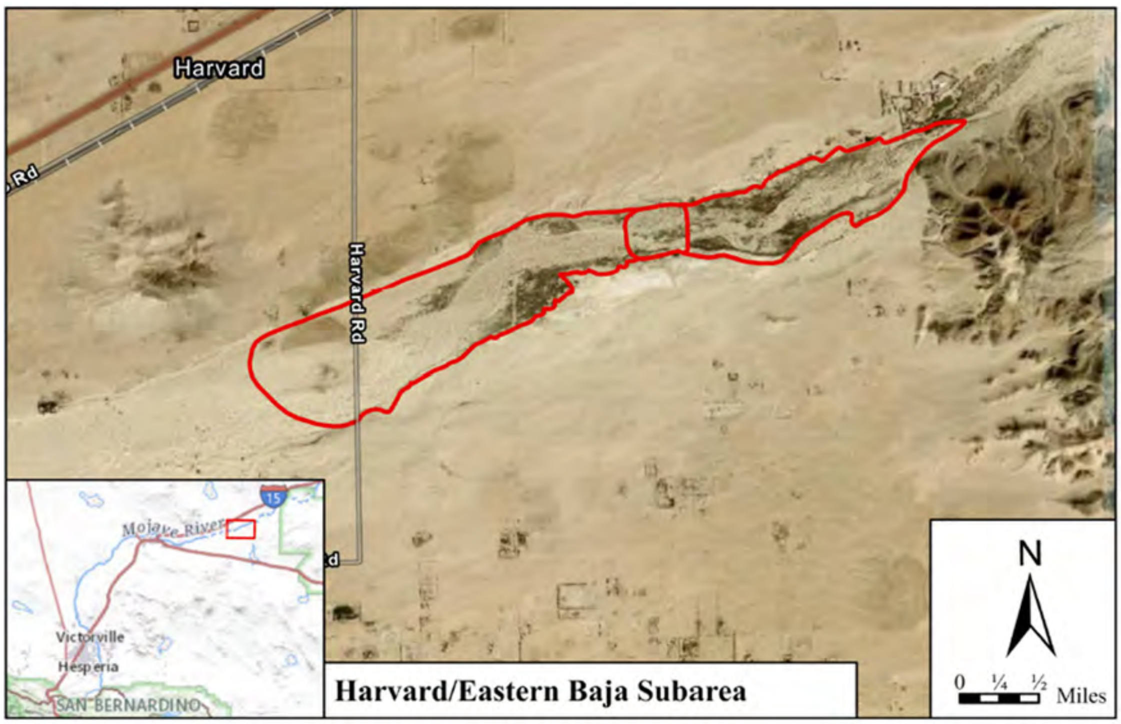


Figure 2. Harvard/Eastern Baja Riparian Zone.

[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

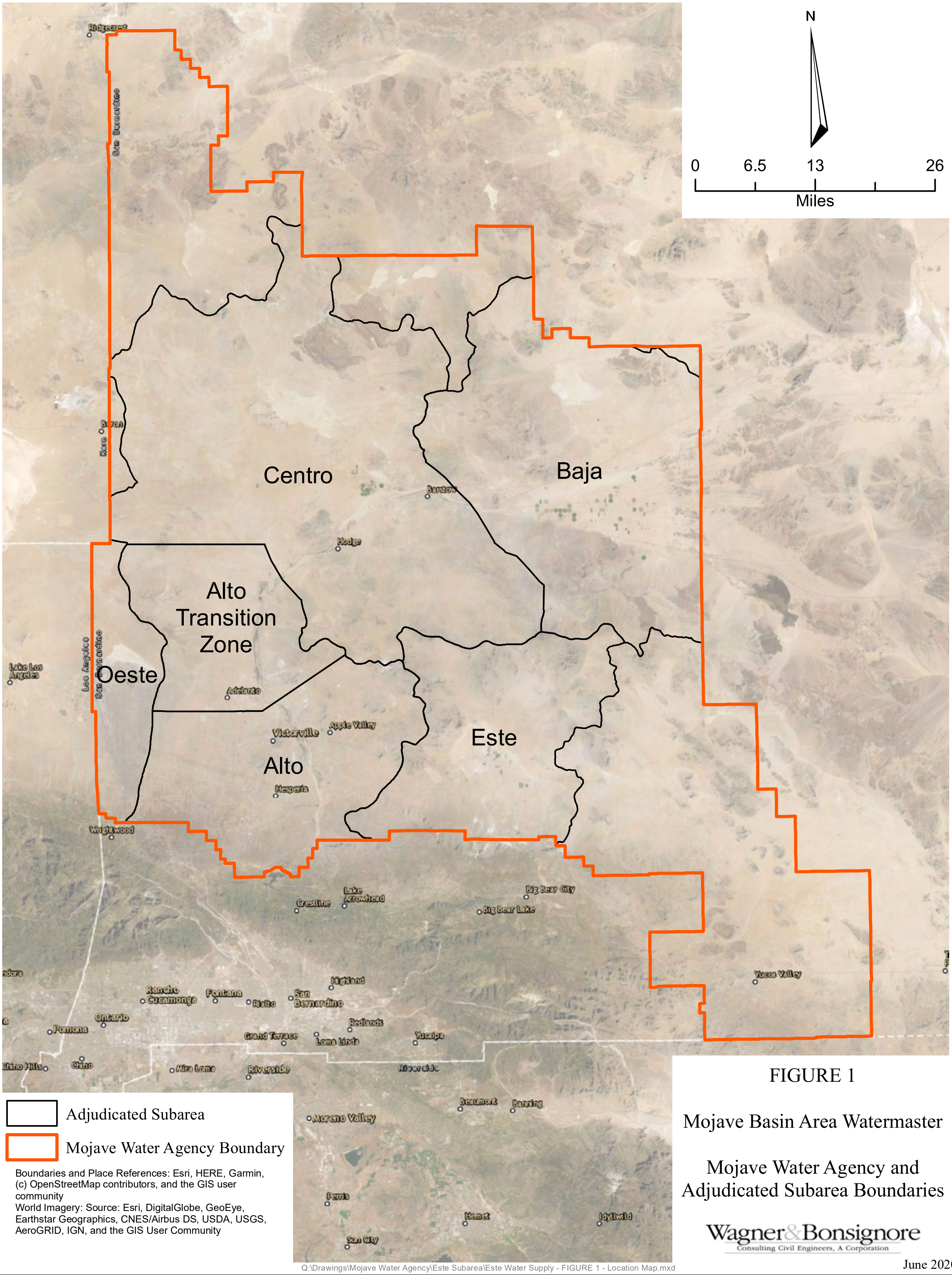
Allen, R., Irmak, A., Trezza, R., Hendrickx, JMH., Bastiaanssen, WGM., & Kjaersgaard, J. (2011). Satellite-based ET estimation in agriculture using SEBAL and METRIC. Hydrological Processes: an international journal, 25(26), 4011-4027. https://doi.org/10.1002/hyp.8408

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

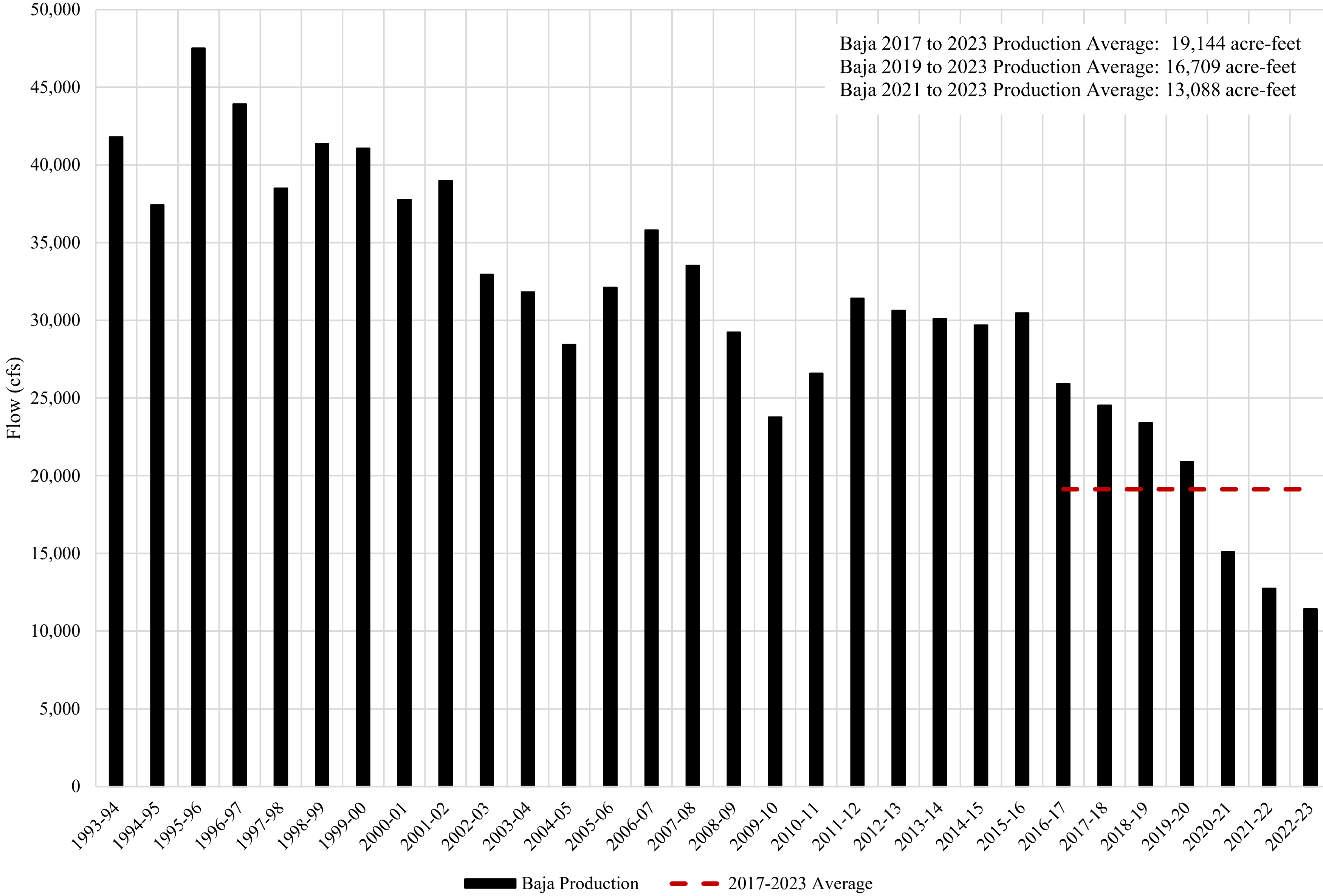
Mojave Water Agency and Adjudicated Subarea Boundaries

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



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

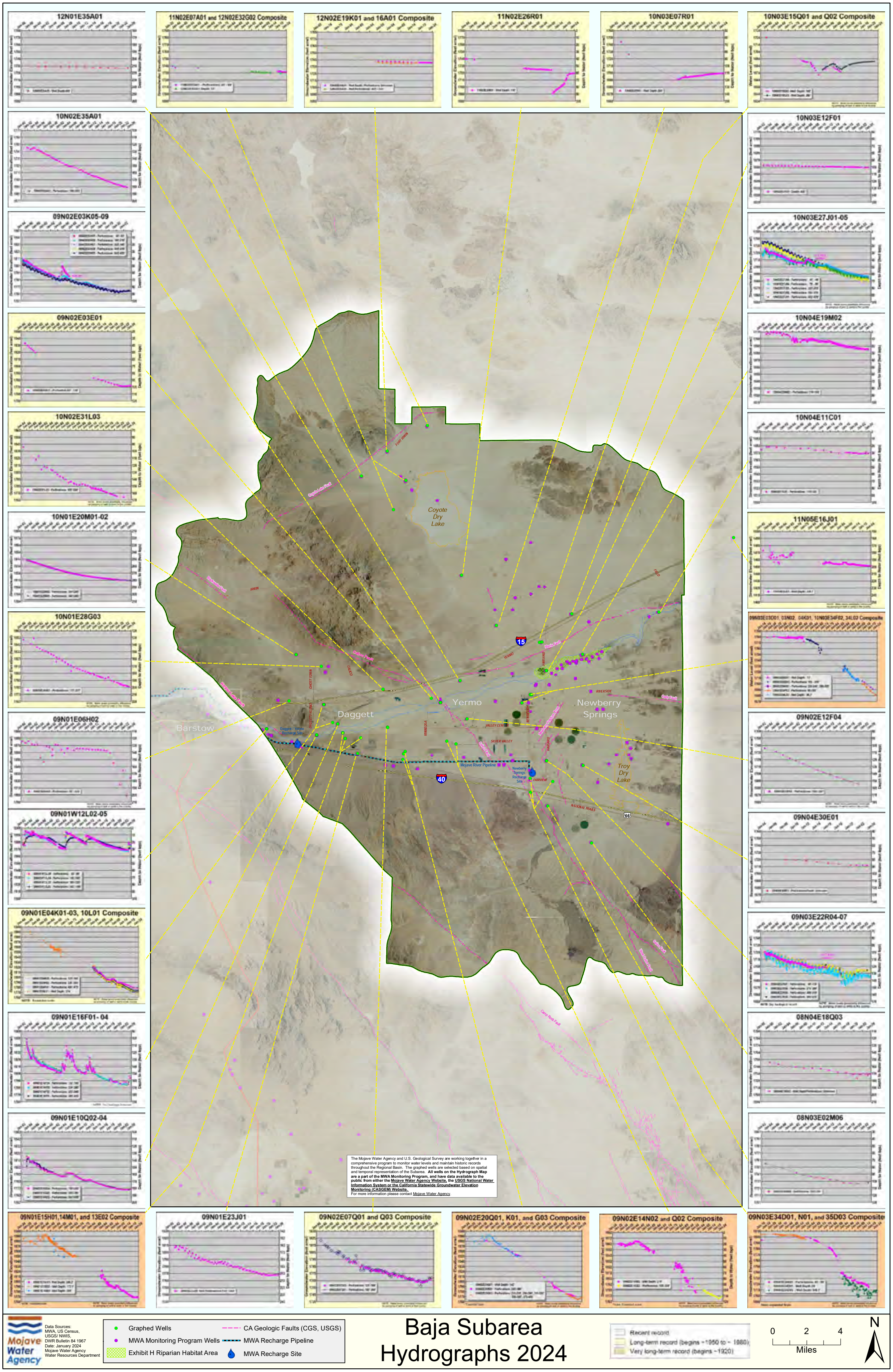

12N01E35A01
11N02E07A01 and 12N02E32G02 Composite
12N02E19K01 and 16A01 Composite
11N02E26R01
10N03E07R01
10N03E15Q01 and Q02 Composite
10N02E35A01
10N03E12F01
09N02E03K05-09
10N03E27J01-05
09N02E03E01
10N04E19M02
10N02E31L03
10N04E11C01
10N01E20M01-02
11N05E16J01
10N01E28G03
09N03E03D01, 03N02, 04K01, 10N03E34F02, 34L02 Composite
09N01E06H02
09N02E12F04
09N01W12L02-05
09N04E30E01
09N01E04K01-03, 10L01 Composite
09N03E22R04-07
09N01E16F01-04
08N04E18Q03
09N01E10Q02-04
08N03E02M06
09N01E15H01,14M01, and 13E02 Composite
09N01E23J01
09N02E07Q01 and Q03 Composite
09N02E20Q01, K01, and G03 Composite
09N02E14N02 and Q02 Composite
09N03E34D01, N01, and 35D03 Composite
Coyote Dry Lake
Yermo
Daggett
Barstow
Newberry Springs
Troy Dry Lake
Mojave River Pipeline
15
40
66
The Mojave Water Agency and U.S. Geological Survey are working together in a comprehensive program to monitor water levels and maintain historic records throughout the Regional Basin. The graphed wells are selected based on spatial and temporal representation of the Subarea. **All wells on the Hydrograph Map are a part of the MWA Monitoring Program, and have data available to the public from either the Mojave Water Agency Website, the USGS National Water Information System or the California Statewide Groundwater Elevation Monitoring (CASGEM) Website.**
For more information please contact Mojave Water Agency.
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)
0
2
4
Miles
N

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.

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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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.

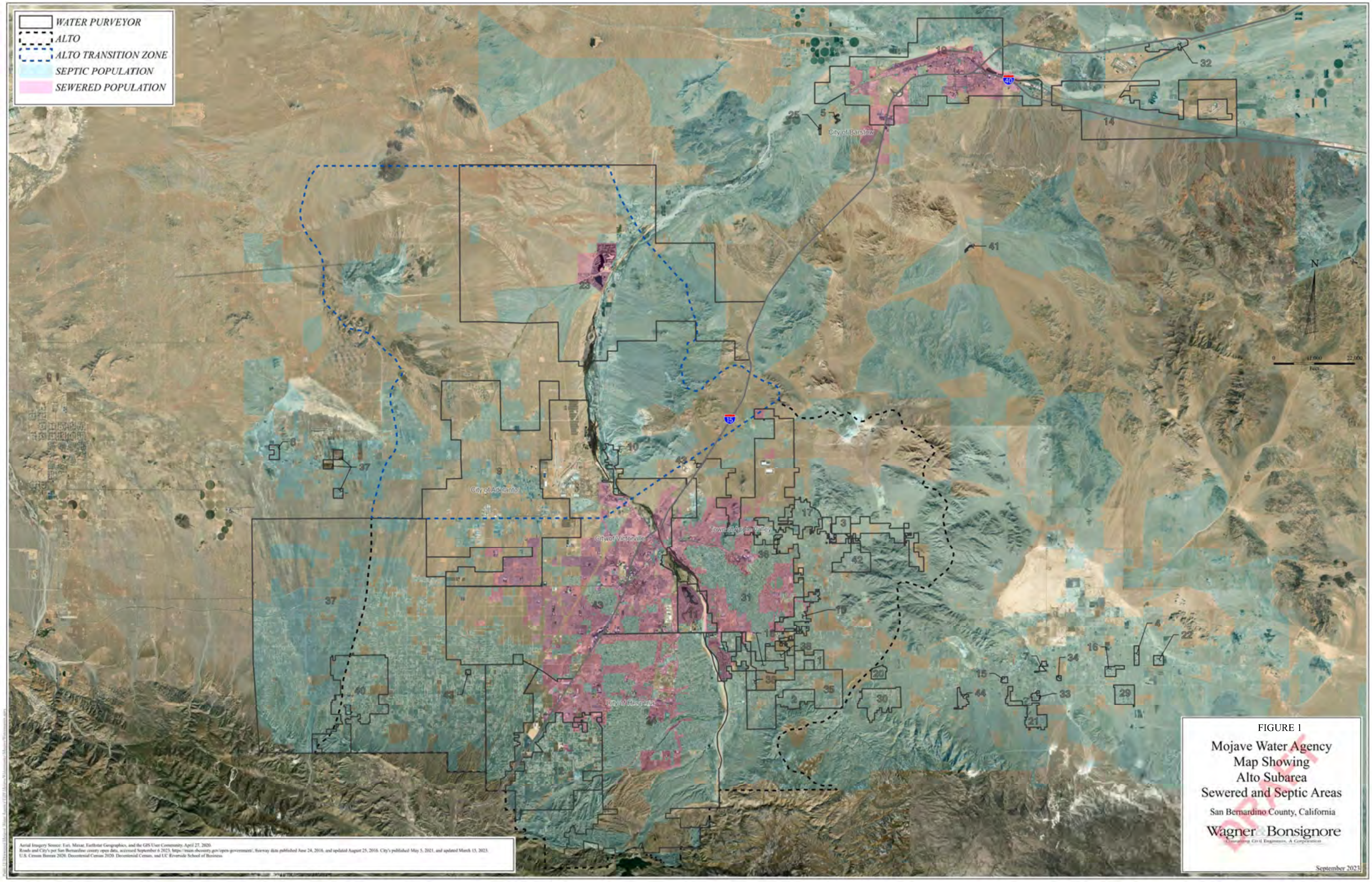
Consumptive use for golf courses is estimated in the same manner as other irrigated lands. Irrigated areas classified as grass, sod, and park were assumed to have the same consumptive use factor as golf courses.

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
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. Decennial Census 2020. Decennial Census, and UC Riverside School of Business.
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

Numbered Water Purveyors

1	Apple Valley Foothill County Water District	15	Desert Springs Mutual Water Company	29	Juniper-Riviera County Water District
2	Apple Valley Heights County Water District	16	Golden State Water Company Apple Valley North System	30	Liberty Utilities Apple Valley
3	Apple Valley View Mutual Water Company	17	Golden State Water Company Apple Valley South System	31	Liberty Utilities Yermo
4	Bar H Mutual Water Company	18	Golden State Water Company Barstow System	32	Lucerne Valley Mutual Water Company
5	Bighorn-Desert View Water Agency	19	Golden State Water Company Desert View System	33	Lucerne Vista Mutual Water Company
6	Center Water Company	20	Golden State Water Company Lucerne Valley System	34	Mariana Ranchos County Water District
7	Chamisal Mutual Water Company	21	Gordon Acres Water Company	35	Navajo Mutual Water Company
8	City of Adelanto Water District	22	Helendale Community Services District	36	Phelan Pinon Hills Community Services District
9	County Service Area 42	23	Hesperia Water District	37	Rancheritos Mutual Water Company
10	County Service Area 64	24	Hi-Desert Water District	38	Rand Communities Water District
11	County Service Area 70 J	25	Hi Desert Mutual Water Company	39	Sheep Creek Water Company
12	County Service Area 70 W4	26	Indian Wells Valley Water District	40	Thunderbird County Water District
13	Daggett Community Services District	27	Joshua Basin Water District	41	Victorville Water District
14	Desert Dawn Mutual Water Company	28	Jubilee Mutual Water Company	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

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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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Stamos, C.L., P. Martin, T. Nishikawa, and B. F. Cox. 2001. Simulation of Groundwater Flow in the Mojave River Basin, California. U. S. Geological Survey Water-Resources Investigations Report 01-4002, Version 1.1. 129 p

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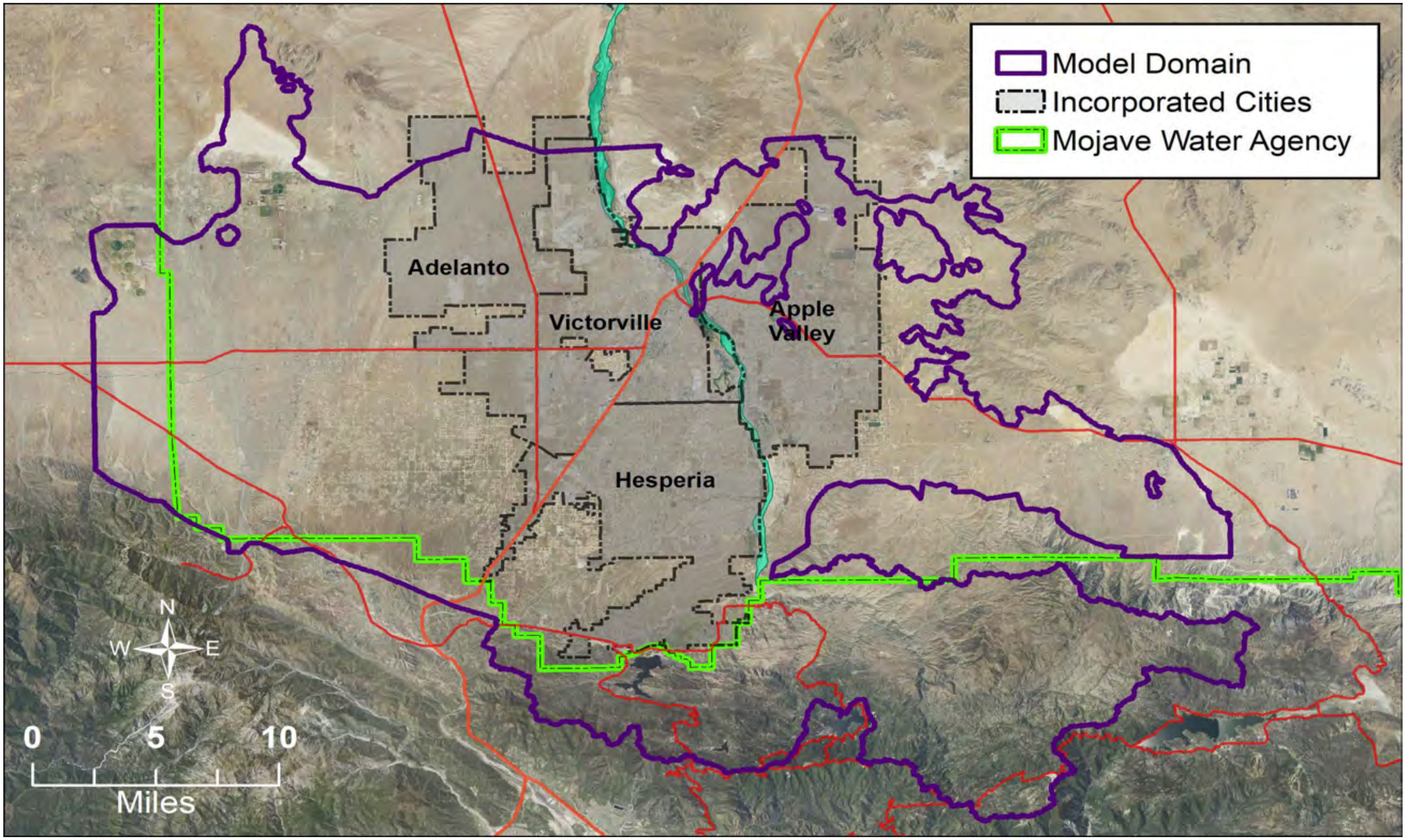
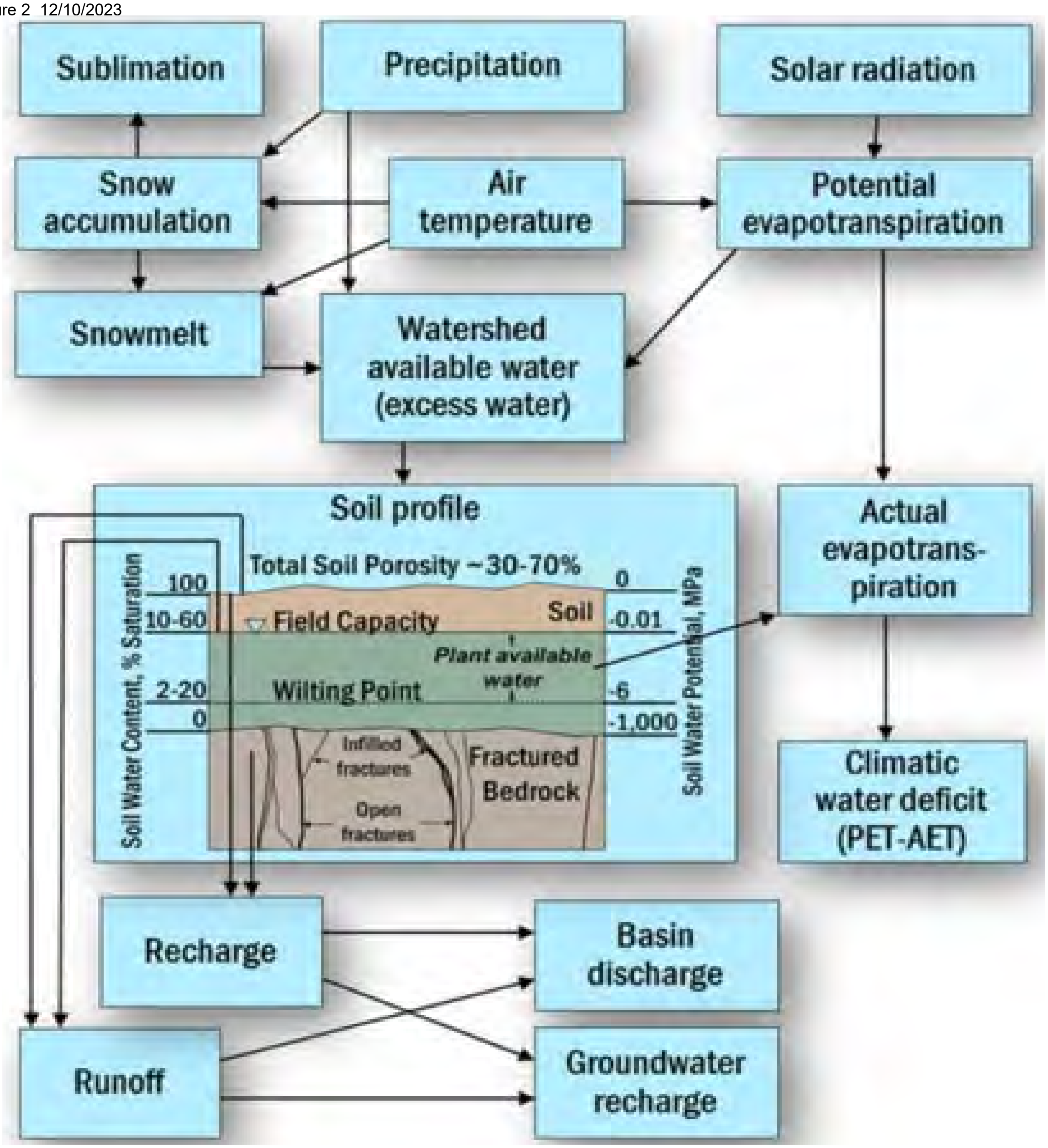
Wood, 2021. Project Completion report, Integrated Surface Water/Groundwater Model, Upper Mojave River Basin Prepared for Mojave Water Agency, dated October 2021.



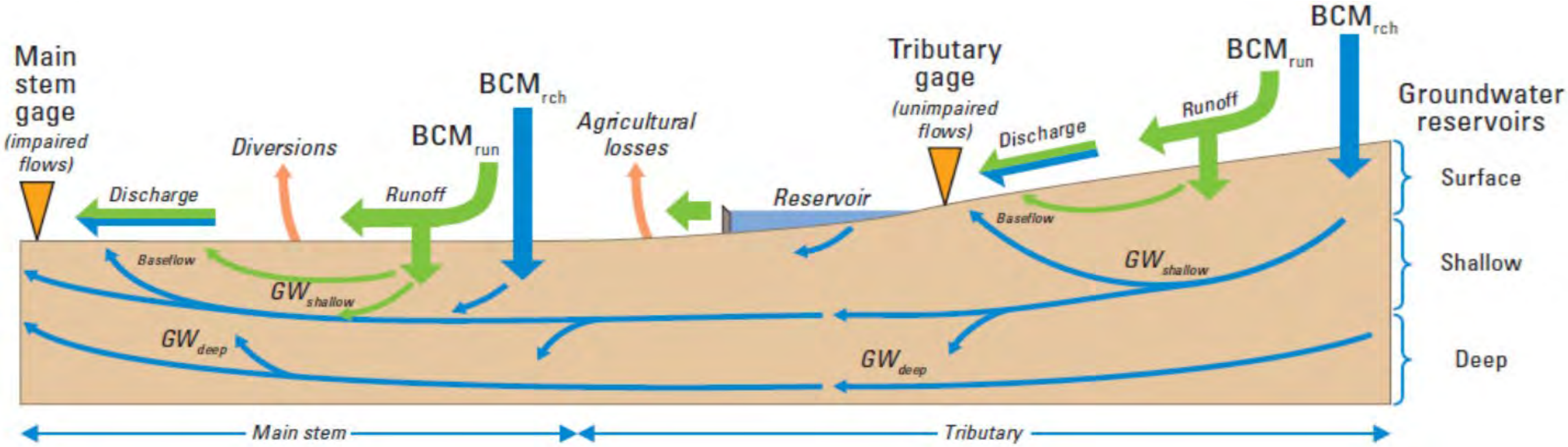
Model Location

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



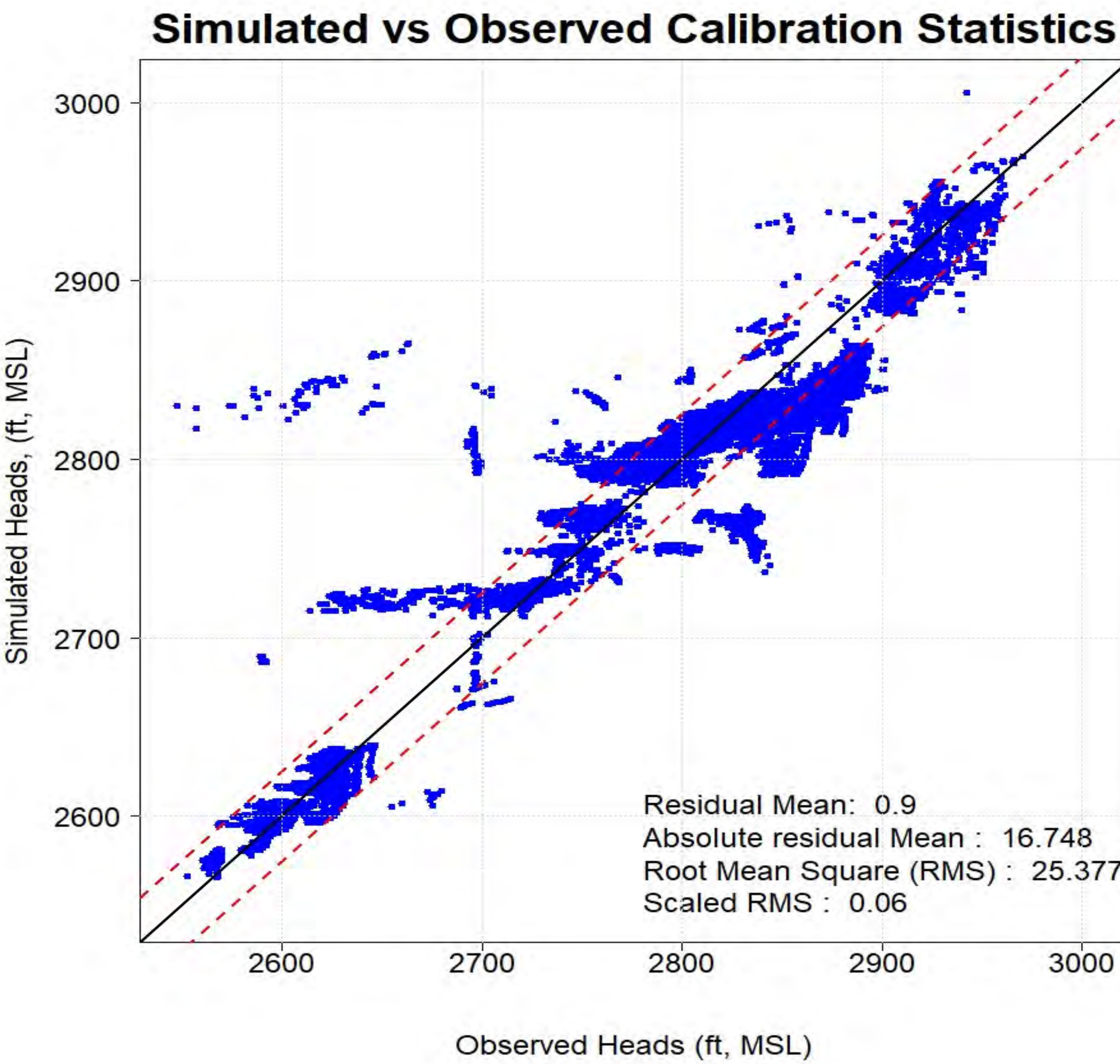
Basin Characterization Model Processes

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



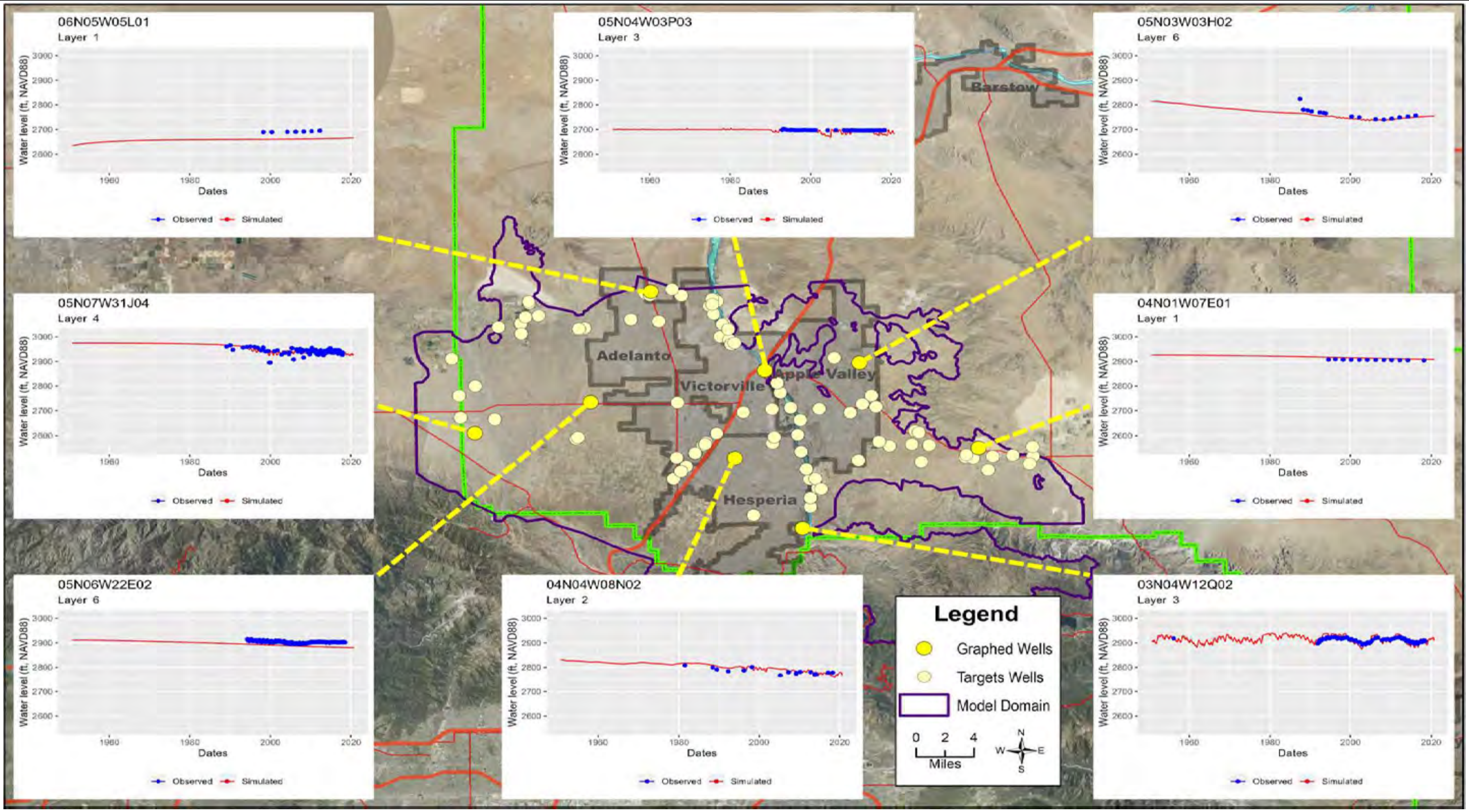
BCM Surface Water/Groundwater Conceptual Model

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



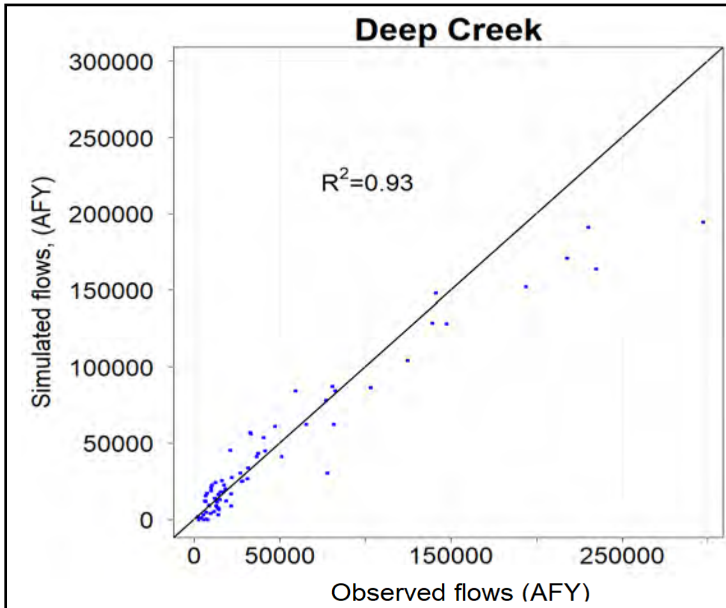
Simulated vs Observed Goundwater Levels

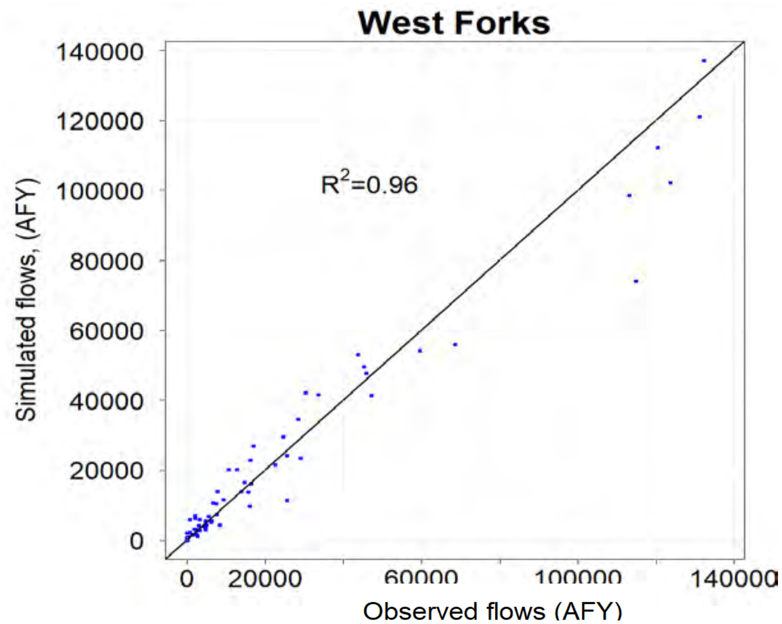
By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 4

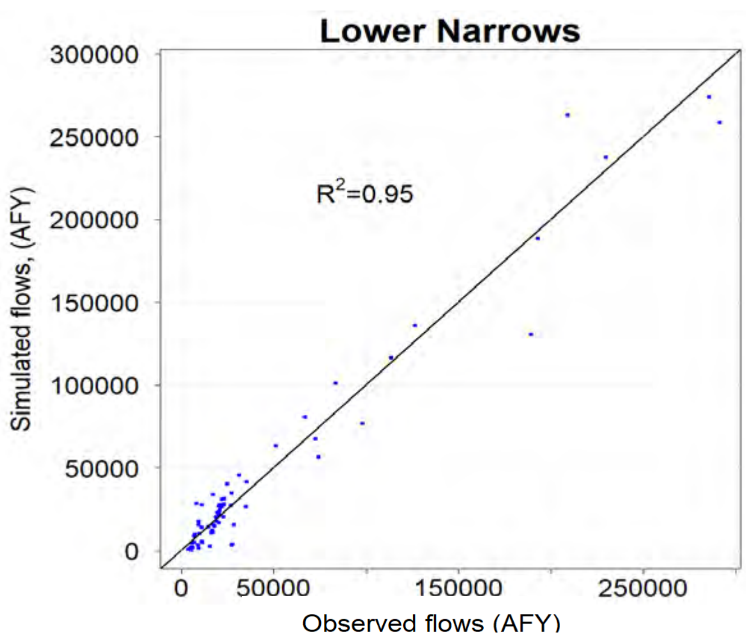


Selected Hydrograph

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

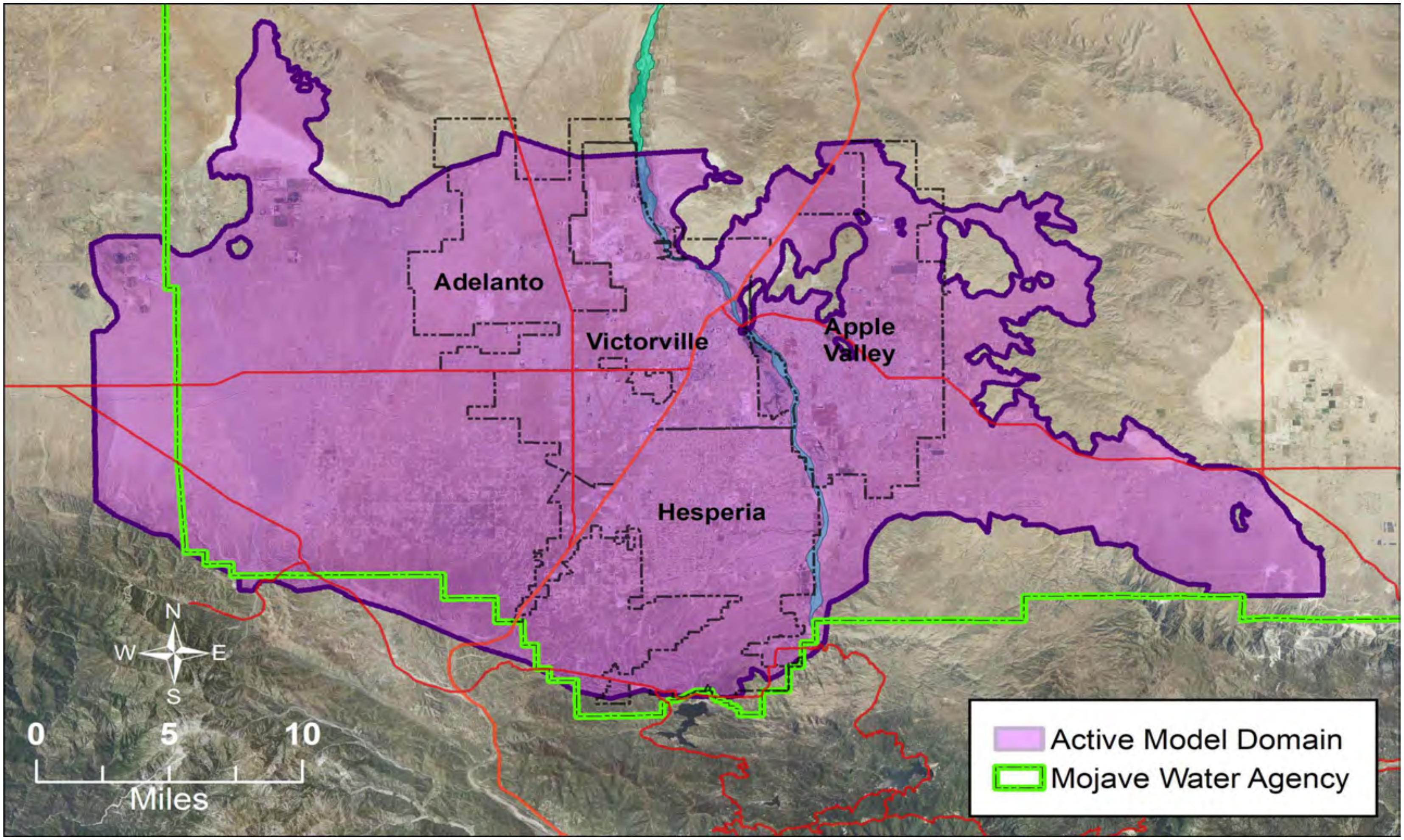






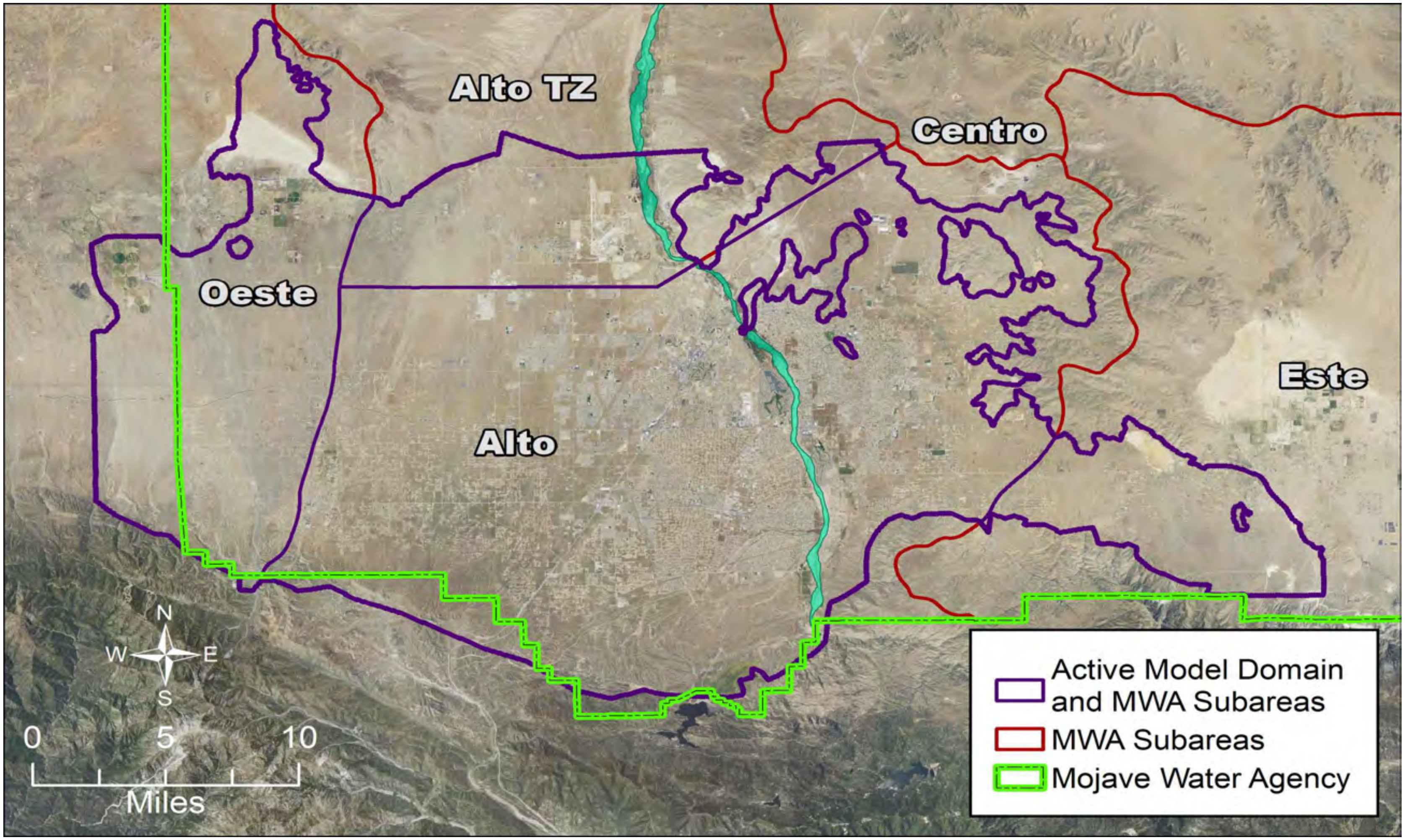
Obserbed vs Simulated Annual Flow

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



Model Water Budget Area

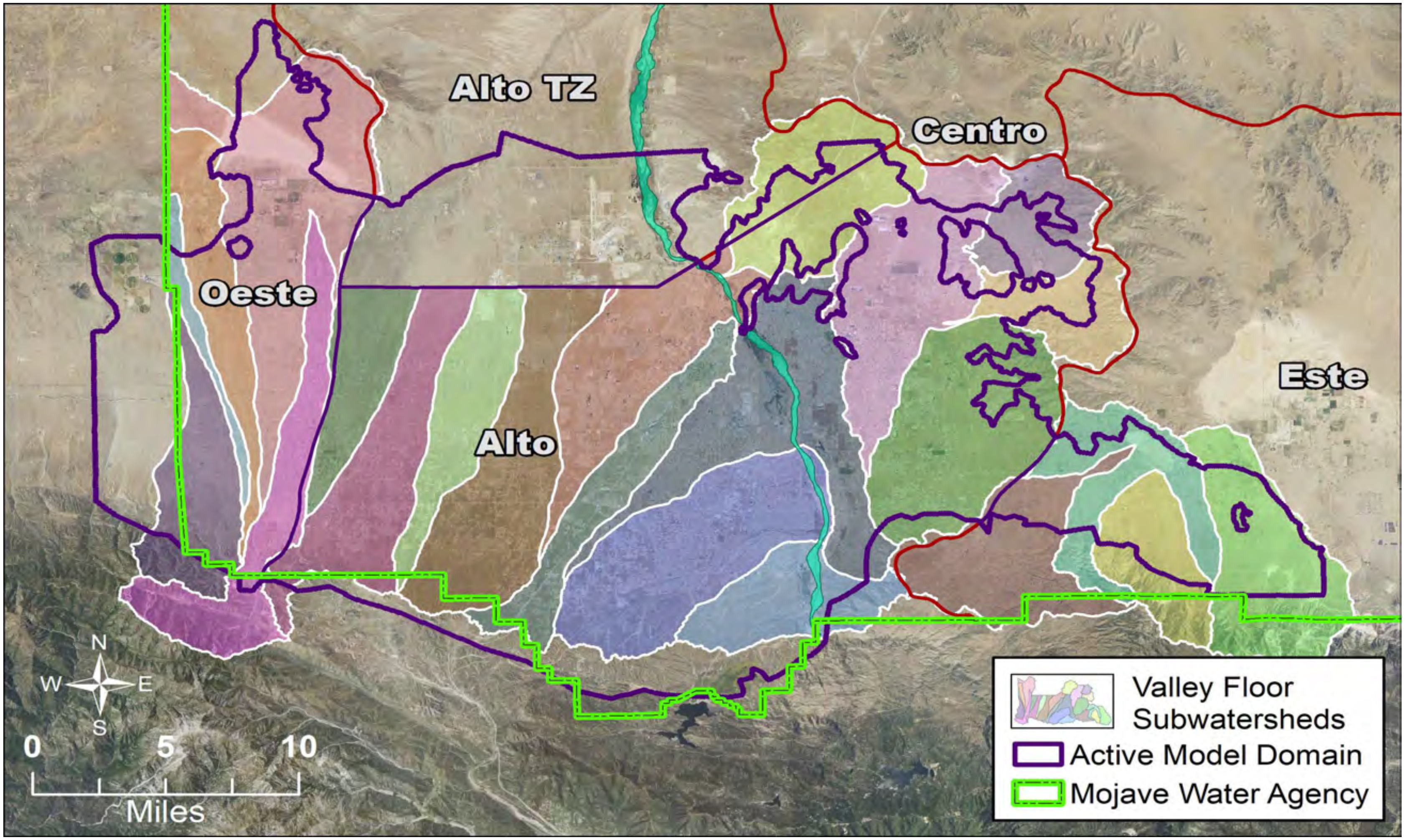
By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 7



Water Budget Subareas

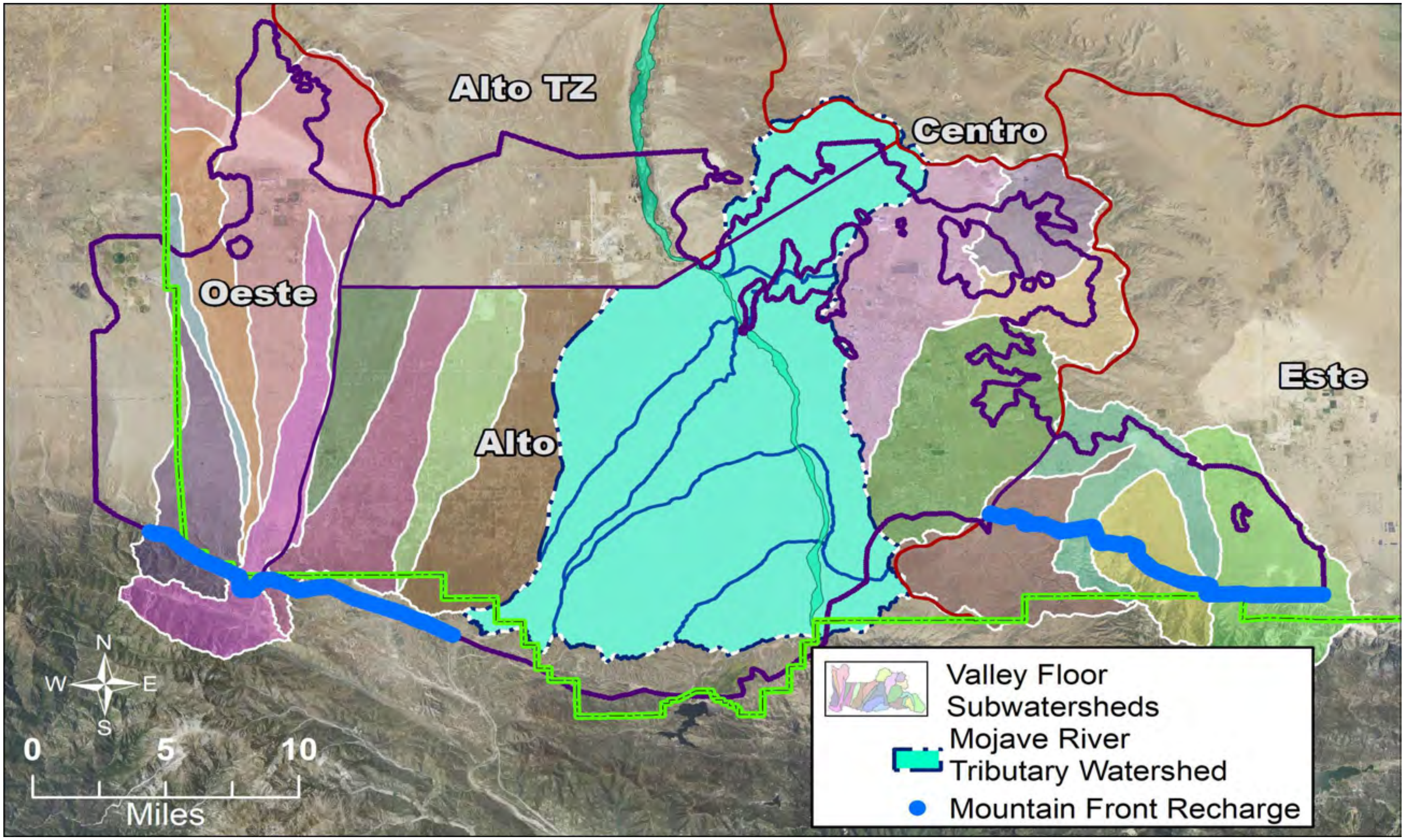
By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 8

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

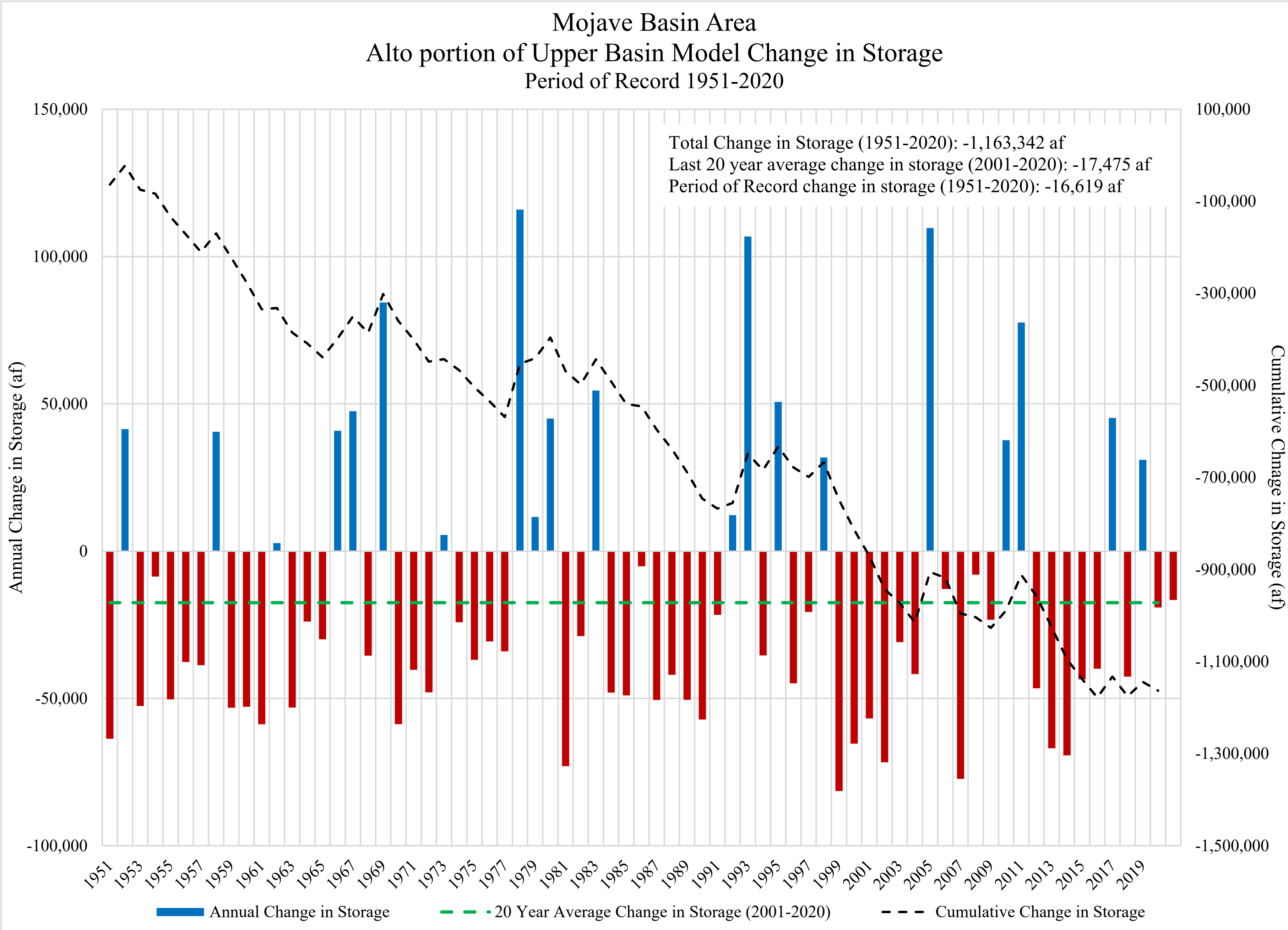
By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 9



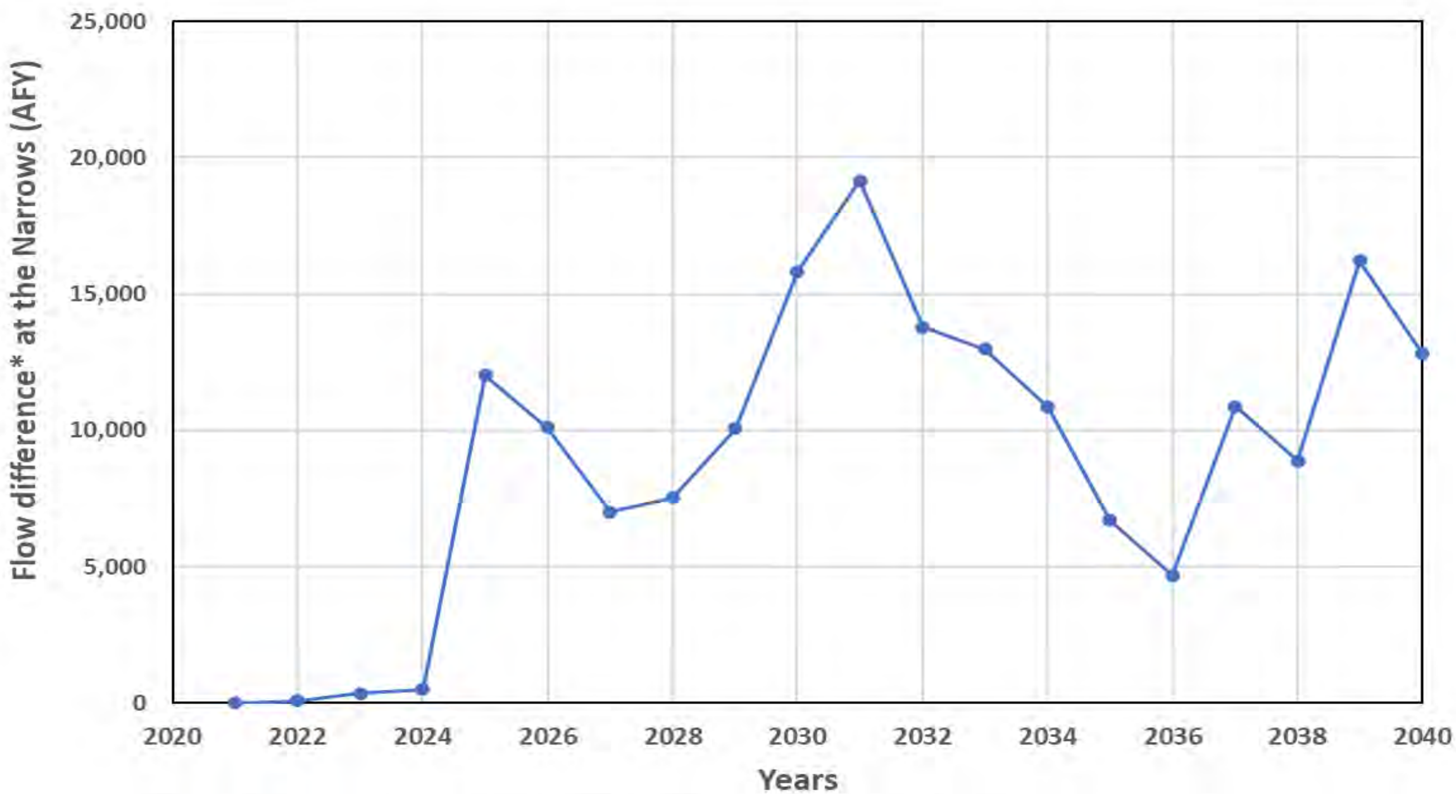
Upper Mojave Basin Subwatersheds Draining in the Mojave River (Tributaries)

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	

<u>Column</u>	<u>Description</u>	<u>Source</u>
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.	-

Project Completion Report - Integrated Surface Water/ Groundwater Model

Upper Mojave River Basin
Apple Valley, California

Project #CM20167800

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Project Completion Report
Integrated Surface Water/Groundwater Model
Upper Mojave River Basin
Apple Valley, California

October 29, 2021
Project # CM20167800

This report was prepared by the staff of Wood Environment & Infrastructure Solutions, Inc. under the supervision of the Engineer(s) and/or Geologist(s) whose signature(s) appear hereon.

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1.0 Introduction and Objectives

Wood Environment & Infrastructure Solutions, Inc. (Wood), has prepared this report on behalf of the Mojave Water Agency (MWA) to document the conversion of a previously-developed Upper Mojave River Basin (UMRB) calibrated groundwater model to an integrated surface water/groundwater model. The conversion process included the expansion of the model to include Silverwood Lake, Cedar Spring Dam, and the Mojave River tributary watersheds in the San Bernardino Mountains. The new integrated model is intended to support groundwater banking, conjunctive use, optimization of existing water supply projects, and potential future water resources projects. This report summarizes the design and calibration of the model and describes the results of two scenarios simulated using the calibrated model.

1.1 Background

MWA was created in 1960 to make sure that sufficient water would be available for any present or future beneficial use of the lands and inhabitants within the MWA's jurisdiction. Its jurisdiction encompasses 4,900 square miles in the High Desert of San Bernardino County. Over the years, MWA has implemented numerous water projects (Regional Recharge and Recovery [R3], wastewater infiltration, State Water Project [SWP]) to safeguard the availability of water resources.

To further reinforce the reliability of water resources in the UMRB, MWA is considering water banking and has initiated a comprehensive regional water banking study to assess the feasibility and conceptual design of an MWA groundwater banking program. MWA has also completed an updated groundwater model of the UMRB and has collaborated with the United States Bureau of Reclamation (USBR) to complete a spreadsheet surface water model of the Mojave River. MWA has decided to combine the surface water and groundwater models into an integrated surface water/groundwater model to support water resources projects in the area.

1.2 Previous Modeling Efforts

Previous modeling efforts conducted within the MWA service area have included four groundwater models and one surface water model.

1.2.1 Groundwater Models

An analog groundwater model was built by Hardt (1971). It covered the entire Mojave Groundwater Basin and consisted of two layers. The first layer represented the Floodplain Aquifer and was limited to the vicinity of the Mojave River. The rest of the basin was represented by a single layer representing the Regional Aquifer. The calibration period was from 1930 to 1963.

The United States Geological Survey (USGS) built a numerical model in 2001 using the Modular Flow (MODFLOW) groundwater modeling code. MODFLOW is a finite-difference groundwater modeling code (McDonald and Harbaugh, 1983) developed by the USGS. This effort was led by Stamos et al. (2001). The resulting model covered the entire Mojave Groundwater Basin and included two layers representing the Floodplain Aquifer and the Regional Aquifer. The grid size was 2000 x 2000 feet (ft), and the calibration period was from 1931 to 1999.

A groundwater model of the UMRB was designed by Schlumberger Water Services (SWS) et al. (2007c). Its calibration period covered water year (wy) 1996 to wy 2005 (a water year is defined as the period from October 1st of a calendar year through September 30th of the following calendar year) and it had a variable grid size (600 x 600 ft in the vicinity of the river to 2000 x 2000 ft away from the river) and 38 layers. The 38 model layers were a refined representation of six stratigraphic layers. Eclipse, a proprietary oilfield multiphase code, was used for this model, which also included vadose zone processes.

In 2020, the SWS model was revised, updated, and converted to MODFLOW-NWT with a calibration period extended from wy 1951 to wy 2017 (GEOSCIENCE, 2020). The layering was revised based on new findings by the MWA and the grid size made uniform at 200 x 200 ft. The current project uses the GEOSCIENCE model as a basis for an integrated groundwater/surface water model

1.2.2 Surface Water Model

The United States Bureau of Reclamation (USBR) developed a spreadsheet model of the Mojave River focused exclusively on surface water (USBR, 2020). The objective of this model was to provide a preliminary estimate of the volume of water that could be captured if the Mojave Dam had the ability to conserve inflows and/or State Water Project (SWP) deliveries and regulate outflows (USBR, 2020).

1.3 Modeling Objectives

The objectives of the current modeling are to:

- Build and calibrate an integrated surface water/groundwater model by modifying the existing groundwater model
- Use the calibrated model to assess the impact of specific existing and past projects on the hydrology of the UMRB

2.0 Hydrologic/Hydrogeologic Conceptual Model (HHCM)

A hydrologic/hydrogeologic conceptual model (HHCM) is a simplified representation of the natural hydrologic and hydrogeological flow system (Anderson & Woessner, 1992). The nature of the HHCM determines the dimensions of the numerical model and the design of the grid. The purpose of the HHCM is to establish an initial understanding of the groundwater system and organize the associated data so that the system can be analyzed more effectively. It represents our understanding of the natural system prior to it being translated into a numerical model.

Six steps were completed in developing the HHCM for the site including: (1) description of the study area, (2) delineation of the hydrostratigraphic units, (3) description of the hydraulic properties, (4) description of the geologic structure, (5) description of the groundwater budget components, and (6) description of the surface water flow system.

2.1 Study Area

The study area (UMRB) is located in San Bernardino County, California including the MWA subareas Oeste, Alto, and western portion of Este. It covers approximately 1,400 square miles in the southwestern portion of the MWA service area and includes the Oeste and Alto subareas of the Mojave groundwater basin and the western portion of the Este subarea (Figure 2.1). Approximately 200 square miles of the study area are located outside of the MWA service area and cover the watershed areas of Deep Creek and West Fork, which are two tributaries of the Mojave River (Figure 2.1)

2.2 Hydrostratigraphy

The hydrostratigraphy of the study area was updated from the SWS hydrostratigraphy (SWS et al., 2007a) to reflect the results of more recent studies by MWA. A summary description of the updated hydrostratigraphy is provided here; a more comprehensive description can be found in GEOSCIENCE (2020).

Like most basins in southern California, the Upper Mojave River Basin area is an alluvium-filled valley surrounded by mountains and bedrock outcrops. Two main aquifers have been identified in the valley: the Floodplain Aquifer and the Regional Aquifer. The Floodplain Aquifer is located along the Mojave River and is very permeable with very good water quality. It pinches out quickly away from the river. The Regional Aquifer occupies the rest of the valley area and tends to have lower permeability and water quality. The watersheds of West Fork and Deep Creek, which were added to the study area, are located in areas underlain by igneous and metamorphic rocks usually considered non-waterbearing. For the purpose of this modeling effort, they were assumed to comprise a low-yield aquifer that stores and transmits some groundwater in weathered bedrock and/or local fractures.

The aquifers in the valley were further subdivided into six units by the MWA based on their hydraulic behavior, observations made during drillling, and geophysical surveys by the MWA. These units are (Figure 2.2):

- Surface/Shallow Zone,
- Upper Production Zone,
- High Production Zone,
- Lower/Lesser Production Zone,
- Middle Lacustrine Unit (aquitard or potentially aquiclude), and
- Lower Alluvial Unit.

As shown on cross-sections B-B' (Figure 2.2) and R-R' (Figure 2.3) from GEOSCIENCE (2020) these units are relatively discontinuous.

The updated data provided by MWA did not cover the western portion of the study area so the previous hydrostratigraphy (SWS et al., 2007a) was used for that area and included (Figure 2.2):

- Surface Sediments
- W marker
- X marker
- Y marker
- Harold and Crowder Formations Undifferentiated (QThcu)
- Sub QThcu

Unlike the MWA subdivisions, these units were defined largely by marker beds. Marker beds W, X, and Y are identifiable coarser-grained zones that occur within the Composite Victorville Fan (QTof); each marker bed is 10 to 30 ft thick and can be recognized in most e-logs from the Victorville/Adelanto/Baldy Mesa/Hesperia area (SWS, et al. [2007a]).

2.3 Aquifer Properties

Aquifer properties of the Floodplain and Regional aquifers are summarized here. These properties were discussed in greater detail by SWS et al. (2007a) and the reader is referred to that report for additional information. As stated above, sediments of the Floodplain Aquifer are relatively permeable. Horizontal hydraulic conductivity (Kh) values interpreted for this unit range from 0.5 feet/day (ft/d) to 600 ft/d. Kh values for the Regional Aquifer are generally lower and range from 0.43 ft/d to 25 ft/d. Specific yield values reported for the Floodplain Aquifer vary from 0.25 to 0.39 while those reported for the Regional Aquifer range from 0.05 to 0.12. The portion of the model located in the San Bernardino Mountains was assigned an initial horizontal hydraulic conductivity of 1 ft/d, a specific yield of 0.05, and a specific storage of 10^{-5} 1/ft based on literature values for weathered bedrock.

2.4 Geologic Structure

The geologic structure of the study area was discussed in previous reports and the reader is referred to SWS et al. (2007a) and Stamos et al. (2001) for additional information on this topic. Major faults within and near the study are summarized in the following paragraphs.

Three major faults exist in the study area (Figure 2.1): the San Andreas fault zone, which is present in the southwestern portion of the study area; the Helendale fault, located in the southeastern portion of the study area; and the Mirage Valley fault, located in the northwestern portion of the study area. All three faults lie near the limits of the study area and have little or no direct local influence on groundwater flow in the central portions of the study area (SWS et al. [2007b]).

The San Andreas fault zone in the southwestern portion of the study area traverses basement complex rocks and undifferentiated Harold/Crowder Formation deposits (Morton and Miller, USGS 2003). These units are considered herein to be non-water bearing in the area of the San Andreas fault, and therefore, the San Andreas fault zone does not affect groundwater flow in the study area. The Helendale fault is interpreted to lie at the eastern end of the study area, as mapped by Dibblee (Dibblee 1960d). This fault is interpreted by Stamos et al. (2001) to act as a groundwater barrier between the Lucerne Valley to the east (not a part of the study area) and Fifteen Mile Valley to the west (SWS et al., 2007b). The Mirage Valley Fault is oriented northwest-southeast and located north of El Mirage Dry Lake, very near the edge of the active model domain.

2.5 Groundwater Budget

The groundwater budget describes the inflow to and outflow from the groundwater system. Inflow and outflow can occur from the hydraulic boundaries of the system, from various sources such as rainfall, streams, or lakes, various forms of artificial recharge, and from the exit points or sinks such as wells or drainage systems. The boundaries, sources, and sinks identified within the model domain are discussed below. Components of the water budget are quantified here based on information available for use in updating the model. Estimates for specific groundwater budget terms were refined through calibration of the updated model and are listed in Table 6-1.

2.5.1 Inflows

- **Mountain Front Recharge**

Mountain front recharge (MFR) is all water that enters a basin-fill aquifer from adjacent mountains. 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 the subsurface of an adjacent mountain block (Markovich et al., 2019).

The USGS estimated the MFR in three subareas (Alto, Oeste, and Este) in the Upper Mojave Basin as a total of 10,000 acre-feet/ year (AFY). Part of the Alto subarea is connected to the extended model domain where surface water processes (including those which result in groundwater recharge) will be fully modeled. The USGS MFR estimates from Oeste, Este, and the other part of Alto were used and totaled about 7,000 AFY.

- **Agricultural Return Flows**

Agricultural return flows were estimated to be 46% of groundwater produced for agricultural use from 1951 to 1995 based on the USGS modeling report (Stamos et al., 2001). Return flow was reduced to 19% starting in 1996 to reflect modern more efficient irrigation practices. The average annual agricultural return flow for the updated model calibration period from 1951 to 2017 is 16,056 AFY (GEOSCIENCE, 2020). Areas with agricultural return flow are shown on Figure 2.5 and summarized in Table 2.1.

- **Municipal Return Flows**

According to the 2015 MWA Urban Water Management Plan, water used for outdoor municipal applications is assumed to be 100% consumed (Kennedy/Jenks, 2016). Water used for municipal indoor use returns to the aquifer through either septic return flow or effluent from the Victor Valley Wastewater Reclamation Authority (VVWRA) treatment plant (GEOSCIENCE, 2020). These two components will be discussed separately. Septic return flows are described in the next section and return flow of treated VVWRA effluent is discussed in the subsequent section describing artificial recharge.

- **Septic Return Flows**

Septic return flows were estimated using data provided by MWA for 1978, 1990, 2000, 2010, and 2017. Values were interpolated between the available years. Septic return flows prior to 1978 were based on the USGS model, which was calibrated for the period from 1931 through 1999 (Stamos et al., 2001). Septic return flow for 1951 was extracted from the USGS model (Stamos et al., 2001) and septic return flows were interpolated between 1951 and 1978 (GEOSCIENCE, 2020). Return flow values for the updated model are summarized in Table 2.1 and their locations are shown on Figure 2.6. The long-term average for septic return flow is 5,032 AFY.

- **Artificial Recharge**

Five artificial recharge sites were identified during the course of the SWS model construction. They are: Lake Arrowhead recycled water, Oro Grande Wash, Victorville Wastewater Reclamation Authority (VVWRA), Deep Creek SWP, and Rock Springs SWP. Lake Arrowhead, Oro Grande Wash, and VVWRA are infiltration basins where SWP or recycled water is recharged via percolation to groundwater. Lake Arrowhead was converted from a spray field between 2000 and 2001. Recycled water applied on the spray field was considered to be 100% consumed. Therefore, only Lake Arrowhead artificial recharge post-2001 was considered for input into the model. The Deep Creek and Rock

Springs SWP recharge sites are locations where water can be diverted from the SWP aqueduct into the Mojave River channel and recharged via percolation. The locations of the infiltration ponds are shown on Figure 2.7 and summarized in Table 2.1. The locations of SWP diversion to the Mojave River are shown on Figure 2.8. The long term average of total artificial recharge from these sources from wy 1951 to wy 2017 is 1722 AFY based on data provided by MWA and summarized in GEOSCIENCE (2020).

- **Stream Leakage**

The bulk of the groundwater recharge in the Mojave Groundwater Basin comes from leakage from the Mojave River. Various estimates of this leakage have been made over the years by groundwater modeling or analyzing flow losses between consecutive stream gages. Stamos et al. (2001) estimated 28,170 AFY of stream leakage within the UMRB.

- **Underflow Inflow**

It is assumed that some underflow enters the Upper Mojave River Basin along its western boundary from the Antelope Valley. This approach was kept unchanged from the previous GEOSCIENCE model although this issue needs more investigation as various authors and models (including Stamos, et al., 2001) assumed a no-flow barrier between the basins. Although long-term water level data from locations near the boundary between the basins are limited there is evidence that the aquifer is continuous between these two basins and there is no natural barrier (Stamos et al, 2017). However, the available groundwater level contours from the USGS (2016) seem to indicate that the groundwater flow direction is parallel to the boundary (Figure 2.9). An estimate of 300 AFY was reported by GEOSCIENCE (2020).

- **Recharge from Precipitation**

Recharge from precipitation is the amount of rainfall that gets past the plant root zone and enters the groundwater system. Recharge from precipitation on the valley floor was assumed negligible because precipitation amounts are too small (5 inches/year) to generate any significant recharge (Stamos, 2001). Recharge from precipitation was therefore considered negligible in the valley. But precipitation in the mountains is substantial and does generate recharge, hence estimates were obtained from the California Basin Characterization Model (BCM) for these areas as discussed in section 4.6. These areas coincide with subwatersheds and are shown on Figure 2.10.

2.5.2 Outflows

Outflows from the Upper Mojave River Basin are from production wells (municipal, minimal [including domestic], industrial, and agricultural), discharge to the Mojave River (baseflow), evapotranspiration from phreatophytes, and underflow outflow to downstream portions of the Mojave River basin (Middle Mojave Basin).

- **Production Wells**

Data for all production wells within the model domain were compiled and updated. Well production data were provided by MWA from 1994 to 2017. Pumping data prior to 1994 were extracted from the USGS model (Stamos et al., 2001). In addition, pumping estimates for Jess Ranch from 1951 to 1991 were provided by Robert Wagner (Mojave Basin Area Watermaster Engineer). Pumping from Jess Ranch was not taken into account in any of the previous groundwater models of the area. Pumping data for Jess Ranch were provided as total pumping volumes, which included pumping for irrigation and for the Jess Ranch Fish Hatchery. Based on discussions with MWA, it was assumed that through 1991, 1/3 of the total volume of water extracted by Jess Ranch went to irrigation while the remainder went to the Jess Ranch Fish Hatchery. Return flows were estimated by removing evapotranspiration (ET) from these amounts. After 1991, Jess Ranch pumping was used exclusively for the Fish Hatchery (GEOSCIENCE, 2020).

A total of 979 wells were included in the model (Figure 2.11. Groundwater production from 1951 to 2017 is summarized in Table 2.3. On average 99,050 AFY was produced from the basin during that period.

- **Minimal Producers (Low Pumpers)**

The minimal producers, or low pumpers group, includes users who extract 10 AFY or less in sparsely populated areas. The locations of the minimal producers were provided by MWA and are shown on Figure 2.12. The average annual total production by the minimal producers from 1951 through 2007 was 2645 AFY (SWS et al., 2007b) and from 2008 through 2017 was 2660 AFY (Mojave Basin Area Watermaster, 2019).

- **Evapotranspiration (ET)**

Evapotranspiration on the valley floor is limited to areas along the Mojave River where phreatophytes occur (Figure 2.13). The actual area where ET occurs in the valley was provided by the MWA as a shapefile. The total amount of groundwater lost to ET in the valley has been estimated by Stamos et al. (2001) and Hardt (1971); their estimates range from 5,100 AFY to as high as 22,000 AFY. No prior study information was available for ET estimates or locations in the mountainous portions of the Study Area; therefore, ET from the BCM was used. It was assumed that groundwater in the mountains, when present, was shallow enough to allow some ET, hence the whole area was assumed subject to ET (Figure 2.13).

- **Dry Lakes**

Two dry lakes are located in the study area. Rabbit Lake is located in the southeastern portion of the Study Area close to the boundary with Lucerne Valley, and El Mirage Lake is located in the northwestern corner of the active model domain (Figure 2.1). Bare-soil evaporation that occurs at these lakes (Stamos, et al., 2001) results in discharge of groundwater and identifies them as natural sinks in the groundwater system. Groundwater development in the basin has resulted in a change in the groundwater gradients and in the direction of groundwater flow toward pumping wells and away from the dry lakes. Declining water levels probably have caused a decrease in groundwater discharge from the dry lakes (Stamos, et al., 2001). The long-term average (1951-2017) estimates of groundwater discharge to the dry lakes was estimated by GEOSCIENCE (2020) to be 135 AFY

- **Underflow Outflow**

Some underflow outflow occurs between the UMRB, and the Alto Transition Zone subarea located north of the study area. The amount of underflow was estimated with the calibrated model. The underflow outflow to Alto Transition Zone was estimated to be 1,723 AFY by GEOSCIENCE (2020).

2.6 Groundwater Flow

Groundwater in the Upper Mojave River Basin flows generally from south to north (Figure 2.9). The magnitude of horizontal hydraulic gradient ranges from approximately 0.0002 to 0.002.

2.7 Surface Water System

The main surface water body in the study area is the Mojave River. It is an intermittent river with a total length of 110 miles, of which only 22 miles are within the study area. It starts in the foothills of the San Bernardino Mountains and flows generally northward, through Afton Canyon and the Mojave sink and ultimately terminates at Silver Dry Lake near Baker, California. It is fed by precipitation and snowmelt in the San Bernardino Mountains. The Mojave River is formed by the confluence of two smaller streams, West Fork and Deep Creek, at a location known as The Forks (Figure 2.14). Generally, the presence of streamflow in the Mojave River results from storm runoff in the nearby mountains. One unique aspect of the Mojave River is that upgradient of the Lower Narrows the Mojave River is intermittent and only flows during heavy storms but downgradient of the Lower Narrows it is perennial within the model domain due to baseflow from the aquifer.

Dams have been constructed on the West Fork and on the Mojave River. The Cedar Spring Dam was constructed on the West Fork in 1971 as part of the State Water Project. It was designed as a water storage facility leading to the creation of the Silverwood Lake behind the dam. The lake has a capacity of 73,000 AF. Controlled releases from the dam have been used to supplement recharge in the Mojave River Basin. The Mojave River Dam is located immediately downgradient of the confluence of the West Fork and Deep Creek (Figure 2.14). It was also built in 1971 for flood control purposes and does not store water for longer than a few days.

Lake Arrowhead is an artificial lake built on a tributary of Deep Creek. It was not included in this study. It has very little recorded data regarding lake releases, and various inflows and outflows (for municipal use). Its watershed is a small portion (approximately 5%) of the Deep Creek watershed. Most of the runoff generated within the Lake Arrowhead subwatershed is captured in the lake. Controlled releases into Deep Creek through Willow Creek are conducted occasionally. Release records from 2008 to 2013 were available and were incorporated into the model as inflow into

Deep Creek. Turning these releases off in the model had very little impact on the model calibration, hence the impact of excluding Lake Arrowhead on the water balance of Deep Creek was considered negligible.

3.0 Model Code Selection

3.1 Code selection

The model code selection was the subject of a Technical Memorandum (Wood, 2020) and the reader is referred to that document for information on the topic. Although the Code Selection Technical Memorandum (TM) suggested the use of MODFLOW-OWHM (Hanson et al, 2014) due to its reservoir management capabilities, ultimately, MODFLOW-NWT (Niswonger et al, 2011), which is the model code for the existing GEOSCIENCE Model, was used because none of future scenarios for water banking involved reservoir management and therefore MODFLOW-OWHM was not necessary. Because these two codes are fully compatible, it would be possible to run this MODFLOW-NWT model with MODFLOW-OHWHM if necessary, with no modifications.

3.2 Graphic Pre/Post-Processor

To facilitate the preparation and evaluation of each model simulation, Wood utilized the graphics pre/post processor GWVistas™ Version 7.xx (GWV) by Environmental Simulations, Inc. (ESI). GWV is a Windows® program that utilizes a graphic user interface (GUI) to build and modify a database of model parameters. The model grid, hydraulic properties, and boundary conditions are input using the GUI, and then GWV creates the necessary MODFLOW data input files. The input files generated by GWV are generic (standard) MODFLOW files compatible with USGS MODFLOW.

GWV was also utilized to post-process the model simulations. GWV can display the simulated head results as plan views and cross sections. In plan view, the contour intervals and labels are specified by the user and dry cells are denoted by a different color. In cross-section view, the water table surface is also plotted. Most outputs to the screen can be saved in a number of formats (DXF, WMF, PCX, SURFER, etc.) for utilization in other graphics programs.

In addition to GWV, Wood utilized some in-house utilities and Microsoft EXCEL spreadsheets to generate standard MODFLOW data input files for selected simulations and for post-processing of some simulation results.

4.0 Model Design

This section describes the numerical groundwater flow model construction for the study area. The USGS MODFLOW-NWT finite difference model was used to construct the groundwater model. MODFLOW-NWT, which is derived from MODFLOW-2005, is modular, which means that the code has packages used to represent the individual components of the natural system being modeled. Where appropriate, the package used to represent a given component is mentioned and/or described below.

4.1 Spatial and Temporal Discretization

4.1.1 Model Domain and Discretization

The model domain is shown on Figure 4.1. For the most part, the unconsolidated alluvium deposits were considered water bearing and constitute the active domain of the model (Figure 4.1). The watersheds of Deep Creek and West Fork, although underlain by consolidated rocks, were included in the active domain of the model because of their importance for the surface water aspect of the model. Areas of consolidated bedrock outside of these watersheds were inactive.

The code selected is a finite-difference code, which requires the model domain to be discretized into rectangular cells. The cell size (200 ft x 200 ft), number of rows (900), and number of columns (1600) were retained from the GEOSCIENCE model (Figure 4.2). The model has six layers representing the aquifer subdivisions described in section 2.2. The layer thicknesses and lateral extents were identical to those of the previous model by GEOSCIENCE

(GEOSCIENCE, 2020) except in the San Bernardino Mountain portion of the active domain. In that area, Layer 1, which represents the Surface Sediments/Shallow Zone, was reduced to a 10-ft thick layer representing weathered bedrock.

4.1.2 Calibration Period and Stress Periods

The model calibration period is from wy 1951 to wy 2017. The calibration period was subdivided into 804 monthly stress periods. A stress period is a time interval during which flux rates are constant; in other words, pumping rates, ET rates, recharge rates, etc. remain constant during a given stress period. Stream discharge data, which are usually daily averages and some well extraction volumes, which were yearly, had to be aggregated or spread over monthly stress periods.

4.2 Hydraulic Parameters

The hydraulic properties assigned to model layers in the previous model (GEOSCIENCE, 2020) were modified from a cell-based distribution to a zone-based distribution (Figure 4.3). The new zones were derived from the USGS model (Stamos et al., 2001), which was based of geology and lithology. Also, the cell-based distribution showed unrealistic hydraulic conductivity distributions in some areas where very high hydraulic conductivity cells were mixed with very low ones at short distances with no actual geologic information to support such abrupt differences.

4.2.1 Hydraulic Conductivity

K_h values for each model layer were initially assigned based on values extracted from the USGS model (Stamos et al., 2001). Layers 1 and 2 had similar K_h distributions and layers 3 through 6 had similar distributions (Figure 4.3). Vertical hydraulic conductivity (K_z) was assumed to be 1/10 of the horizontal hydraulic conductivity.

4.2.2 Specific Storage and Specific Yield

Similar to the hydraulic conductivity distribution, the distributions of specific storage and specific yield were derived from the USGS model (Stamos et al., 2001). Layers 1 through 4 were simulated as convertible, which means that they will behave as unconfined layers if the simulated hydraulic head remains below the top of the layer and confined otherwise. Layers 5 and 6 were simulated as confined layers because they were assumed to be deep enough to be always saturated. Due to their confined status, they were not assigned a specific yield value. Storage zones are shown on Figure 4.4.

4.3 Boundary Conditions

The model domain represents a natural groundwater/surface water system that interacts with the rest of the environment that is not included in the model domain. This includes neighboring basins, the atmosphere, aquifers or streams extending outside of the model domain, lakes, dams etc. The model boundary conditions define how the model handles these interactions.

4.3.1 General Head Boundaries

General head boundaries (GHBs) were used to represent underflow inflow and underflow outflow described in Sections 2.5.1 and 2.5.2. Observed water levels were used to assign time-varying groundwater levels at these boundaries and conductances for these boundaries were adjusted during calibration. The locations of these GHBs are shown on Figure 4.5.

4.3.2 Mountain Front Recharge

The WEL package was used to represent MFR in the model. The locations of these simulated recharge features are the same as the locations of the MFR recharge shown on Figure 2.4 and Figure 4.5. This means that the MFR fluxes were introduced into the aquifer using injection wells at locations where the MFR is known to occur.

4.3.3 Rivers

The locations of the Mojave River and its tributaries represented in the model are shown on Figure 4.4. The Surface Flow Routing (SFR) packages was used to model surface water flow in the Mojave River, Deep Creek, and West Fork. Data from five stream gages were available and used for calibration (Figure 2.14). The five gages Included Lower

Narrows on the Mojave River, Deep Creek on Deep Creek, West Fork on West Fork, East Fork of Mojave (EFM) on a tributary of West Fork, and West of Mojave (WFM) on another tributary of West Fork. EFM and WFM are both located upgradient of the Cedar Spring Dam. The SFR package input included riverbed conductance, slopes, channel length and width, runoff, various artificial discharges, and stream roughness (Manning coefficient). The riverbed conductance was the main parameter adjusted to match measured flow at the different gages.

4.3.4 Lake

Silverwood Lake is the only lake implemented in the model and was represented using the LAK package of MODFLOW. The lake bathymetry, inflows, and outflows were provided by MWA and used as input for the LAK package. Two tributaries of West Fork (West Fork at Mojave and East Fork) feed the lake. Because the lake is behind a dam that was built in 1971, the lake is inactive in the model from wy 1951 to wy 1971. Due to the lack of good quality data[1] to establish the water balance of the lake, a calibration of the lake stages and volume was not attempted.

4.3.5 Dry Lakes

Dry lakes (discussed in Section 2.5.2) were represented by the DRAIN (DRN) package. The DRN package is a sink. If water levels exceed the head assigned to the DRN, water is discharged from the model based on head difference and the assigned conductance. Its parameters (prescribed heads and conductance) were kept unchanged from the previous modeling effort from GEOSCIENCE (2020).

4.4 Inflows

4.4.1 Return Flows and Recharge Ponds

Artificial inflows in the model include return flows and recharge ponds and were represented by the WEL package. The locations of these features are shown on Figures 2.5 through 2.8.

4.4.2 Mountain Front Recharge

MFR was discussed in sections 2.5.1 and 4.3.2 and was represented in the model by the WEL package. The locations of MFR are shown on Figure 2.10.

4.5 Outflows

4.5.1 Evapotranspiration (ET)

The ET package was used to simulate evapotranspiration. Inputs for this package include the ET rate and an extinction depth. The extinction depth is the water table depth below which no more ET occurs. Reference evapotranspiration (ETo) from the CIMIS Victorville station was used. Data from this station were available from 1994 to 2017. For 1951 to 1994, monthly averages published by CIMIS were used. Actual ET represents a model-calculated value that depends on the depth of the water table. ET was assumed to be at a maximum rate when the water table was at land surface and to decrease linearly to zero when the depth from ground surface to the water table was 25 ft (extinction depth) or greater. The extinction depth of 25 ft represents an average depth for deep-rooted (salt cedar, desert willow, and mesquite) and shallow-rooted (cottonwood, baccharis, and willow) riparian vegetation along the Mojave River channel (Stamos et al., 2001). The extinction depth was changed to 10 ft in the mountains and the ET rate was extracted from the BCM Model and adjusted during calibration. The locations of the study area where ET was applied are shown on Figure 2.12.

4.5.2 Groundwater Production

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1 Data for most of the components of the Silverwood Lake water balance (which include lake releases, SWP inflows, San Bernardino Pipeline outflows, lake volumes, and stages) were available primarily in poor quality paper format that needed to be converted to electronic format for use in the model. Preliminary attempts by MWA to convert the data yielded numerous inconsistencies and significant data gaps.

Groundwater production was compiled from pumping records provided by MWA. A more detailed discussion of the production data can be found in section 2.5.2 and summarized in Table 2.3. The spatial distribution of agricultural, municipal, and industrial production wells is shown on Figure 2.10. Minimal producers are shown on Figure (2.11). Pumping by all producers, including minimal producers, was represented by the WEL package as well.

4.6 Surface Water Model Integration

The surface water components of the model were extracted from 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 has grids of 270 meters (m) by 270 m (889 ft by 889 ft) and covers the period from 1896 to 2019.

Output from the BCM model includes ten parameters but only a subset was used for this project: PET (potential ET), runoff, recharge, and precipitation. An example of output from the BCM is shown on Figure 4.6.

A spreadsheet tool provided by the BCM authors allows the recalibration of the BCM to local gages. The BCM parameters were adjusted, and calibration was conducted for the four gages located in the San Bernardino Mountains (Figure 2.13); the Lower Narrows gage was not used for the BCM calibration because the bulk of its discharge is baseflow hence it is more dependent on groundwater processes rather than on the surface water conditions that are the focus of the BCM. The inputs for the spreadsheet tool were runoff and recharge from the BCM, observed gage data, and watershed areas. Conceptually the runoff and recharge are distributed between runoff (actual), shallow flow, and deep flow (Figure 4.7). The preliminary calibration of the BCM using the spreadsheet tool adjusts these three components to match the gage data both in total volume and monthly flow rates. Actual runoff makes it to the stream and the stream gage right after the storm while shallow flow can take longer (days to weeks) to reach the gage. Deep flow can become recharge to groundwater, which eventually can become baseflow. This is supported by a study of runoff in the San Bernardino Mountains (Troxell and others, 1954) which divided the runoff into "storm surface runoff" and "storm groundwater runoff." Storm surface runoff results from intense rates of precipitation that exceed the rates of infiltration of the rock. Storm groundwater runoff is delayed runoff that originates from a very temporary type of groundwater storage and can continue for days or even weeks after the storm has ceased. Some of the precipitation that infiltrates into the rocks recharges many small groundwater bodies situated at higher elevations in the mountain area. The seepage from this groundwater storage is intermittent, generally starting after the first rainfall of the year and ending by September or earlier, depending on the amount of precipitation. This type of runoff has been designated "seasonal ground-water runoff" (Troxell and others, 1954). Based on this conceptual model, after the BCM calibration, the runoff and shallow flow were input into the MODFLOW NWT package as runoff and the deep flow was used as recharge. All streams, creeks, and rivers in the model were represented by the Surface Flow Routing package (SFR) of MODFLOW

5.0 Calibration

5.1 Initial Conditions

To start the process of calibration, the model needs initial groundwater elevations and initial hydraulic parameters to run, thus an initial groundwater level was estimated for each cell in the model using the existing USGS model (Stamos et al., 2001) and GEOSCIENCE's model (GEOSCIENCE, 2020). Ideally the initial water levels for all parts of the model domain should be based on measured water levels, but the scarcity of water level data for wy 1951 (beginning of the calibration period) precluded the use of measured data in many areas. As a result, a trial-and-error process involving a combination of the USGS model results, the GEOSCIENCE model's initial heads, and measured water levels was used. The lack of measured groundwater level data in the portions of the model's active domain that lies in the San

Bernardino Mountains meant that initial water levels in these areas needed to be estimated. This was accomplished by devising a sub-model covering only the mountains and conducting a pseudo-steady state run to get stable water levels, which were then merged with water levels in the valley. The initial hydraulic parameters were derived from Stamos (2001) and modified during calibration. The initial distributions and values of horizontal hydraulic conductivity are shown on Figure 4.2 and those for specific storage and specific yield are shown on Figure 4.3.

5.2 Calibration Process

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 observed values in the real world. Observed values used for this calibration were the groundwater levels at 193 monitoring locations (Figure 5.1) and the surface water flows at five stream gages (Figure 2.14). 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 manual calibration, the modeler changes the parameters manually and uses a combination of visual trend matching and a set of statistical parameters to decide when calibration has been achieved. Because of the large size and long running time of this model, the automatic approach for calibration was impractical, hence the manual calibration approach was used.

5.3 Calibration Assessment

A combination of qualitative and quantitative calibration criteria were used to assess the goodness of fit and corresponding degree of model calibration. 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
- Spatial distribution of groundwater level residuals
- Hydrographs of observed versus model-simulated streamflow
- Scatterplots of observed versus model-simulated streamflow
- Water balance
- Residual statistics, including:
    - Residuals are defined as measured water level minus simulated water level
    - 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 model simulated versus observed water level data. Calibration seeks to minimize mean residual.
    - 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 of 0.1 (10%) is considered acceptable and lower values are desirable.
- 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).

5.4 Calibration Results

As the current model is an integrated surface water/groundwater model and the approaches used to assess the goodness of fit are different for surface water and groundwater, the surface water calibration and the groundwater calibration are presented separately.

5.4.1 Surface Water Calibration

The surface water calibration was assessed by plotting the simulated streamflow rates against the observed streamflow and estimating the R^2. Figure 5.2 through 5.4 show the calibration charts for all five stream gages. The West Fork gage exhibits a very good R^2 ($0.85<R^2<1$), while R^2 for the Deep Creek gage is good ($0.75<R^2<0.85$) and R^2 values for the WFM and EFM gages are fair ($0.65<R^2<0.75$). The model does not fully capture most of the extreme runoff values, especially for Deep Creek, due to the fact that the BCM, which is the basis for the surface water modeling, uses monthly timesteps that tend to average the extremes, unlike the measured data, which are measured daily and then aggregated. In addition, the USGS gage at Deep Creek is not set up to measure extremely high flood discharges, so various techniques have been used by the USGS to estimate these values, thus introducing a level of uncertainty into the target dataset and the resulting calibration.

The time series of observed and simulated streamflows are shown on Figures 5.5 through 5.7. Overall, the trends are fully captured. The baseflow at the Lower Narrows is also well captured. Most high streamflow rates are also well matched by the model except at Deep Creek and the Lower Narrows. The simulated baseflow at the Lower Narrows prior to 1991 is flatter than the observed baseflow. This is potentially because the additional pumping at Jess Ranch, which happened between 1951 and 1991, was only reported annually, so the distribution of pumping on a monthly basis (and also the corresponding distribution of return flow discharged into the river), was inferred from other pumping wells in the area, potentially altering the simulated fluctuation of baseflow.

Based on the study of two flood events in the Upper Mojave basin by Buono and Lang (1980), short, extreme flood events tend to generate less groundwater recharge than less extreme events that are spread over several months. Therefore, the fact that the model does not capture extreme discharge values will not significantly limit its ability to predict recharge and groundwater levels as long as medium and lower discharge rates are well matched, which is the case here.

5.4.2 Groundwater Calibration

The groundwater calibration is assessed by generating simulated versus (vs) observed groundwater levels and computing the statistics described in Section 5.2.1. Figure 5.8 shows that, overall, simulated versus observed water levels for most wells fall within two standard deviations of the 1:1 line and the adjusted RMS is below 0.1 (0.063), which is a generally-accepted threshold for goodness of fit (Spitz and Moreno, 1996). The majority of the wells that plot farther away from the 1:1 line are located in the El Mirage Dry Lake area as evidenced by the residual maps shown on Figure 5.9. In this area, the existence of a perched aquifer that was not modeled is contributing to higher-than-expected initial groundwater levels. For a regional model of this size, localized high residuals are due to local heterogeneities not captured by the regional model. These discrepancies are acceptable if the statistics for the overall model are good (Figure 5.8). Also, the model under-predicts groundwater levels in the Oro Grande area; Wood and MWA agree that additional study including collection and review of more data would be needed to resolve what appears to be a local anomaly in groundwater levels in this area. Selected hydrographs on Figure 5.10 and Figure 5.11 show that groundwater elevation trends are well captured by the model and that a good fit was achieved between observed and simulated groundwater levels. The simulated groundwater level contours from the calibrated model are shown on Figure 5.12 and the final calibrated distributions and values of horizontal hydraulic conductivity, specific yield, and specific storage are shown on Figures 5.13 through 5.15. Vertical hydraulic conductivity was assumed to be 1/10 of the horizontal hydraulic conductivity. The overall distribution of calibrated hydraulic conductivity is similar to that shown by Stamos (2001); in all model layers, hydraulic conductivity values are highest in the vicinity of the Mojave River and generally lower away from the river. Hydraulic conductivity is also generally higher in the non-mountainous areas of layers 1 and 2 than in corresponding areas in layers 3 through 6. Hydraulic conductivity varies from 1 ft/d to 450 ft/d in layers 1 and 2 and from 1 ft/d to 100 ft/d in layers 3 through 6. Specific yield, which was incorporated for unconfined model layers 1 through 4, varies from 0.01 to 0.25. Specific storage has the same distribution in all layers and is 10^{-5} 1/ft in the valley and 2×10^{-6} 1/ft in the mountains.

6.0 Water Budget

One of the main applications of a calibrated groundwater model is to estimate the water budget for the area the calibrated model represents. Estimating the water budget consists of estimating the inflows and outflows of the groundwater system and computing change of storage over time by subtracting the outflows from the inflows. Estimation of a water budget provides an assessment of the health of the basin and an indication of whether groundwater conditions in the basin are sustainable or may be in overdraft. For practical reasons and with the agreement of the MWA, the portion of the active domain located in the mountains was excluded (Figure 6.1) from the water budget calculations.

Table 6.1 summarizes the water budget on an annual basis and Figure 6.2 shows the annual change of storage and the cumulative change of storage. The cumulative change of storage shows a continuous drop for the duration of the calibration period (wy 1951 through wy 2017, or 67 years). The average change of storage is -16,800AFY, which amounts to a cumulative change in storage of slightly over 1 million AF over the 67-year simulation. Figure 6.3 is a schematic of the average annual water budget components from wy 1951 through wy 2017. ET, stream leakage, recharge, and underflows were estimated using the calibrated model while the remaining fluxes were inputs to the model and described in previous sections. The estimated fluxes are summarized here. On average, 10,500 AFY is lost to ET, 16,400 AFY to baseflow into the Mojave River, and 200 AFY to the dry lakes. 1,600 AFY leaves the model area as underflow to the Alto Transition Zone. The water budget domain (Figure 6.1) gains 74,300 AFY from stream leakage, 300 AFY from recharge. 3,000 AFY and 1,200 AFY enter the basin as underflow from the Antelope Valley and the San Bernardino Mountains respectively.

7.0 Scenarios

The MWA has invested in various projects intended to augment groundwater and sustain groundwater levels in the UMRB. Although the benefits of these projects to groundwater production have been evident, it has been difficult to quantify their long-term and spatial impact on the UMRB. Scenario 1 for this modeling study was devised to estimate the impact of these projects on the UMRB in time and space. Baseflow at the Lower Narrows is an important component of the water balance in the UMRB but the impact of past agricultural water use practices on base flow in this area has not been fully investigated. Scenario 2 was devised to start this process by investigating the impact of past water use at Jess Ranch on base flow at the Lower Narrows.

7.1 Scenario 1

The objective of scenario 1 was to estimate the impact of various recharge projects initiated by MWA in the past 30 to 40 years. Scenario 1 was simulated by running the model with the same hydrology and settings as the calibrated model but eliminating all the recharge projects initiated by MWA. The projects eliminated from Scenario 1 are: Deep Creek recharge, Rock Spring recharge, Oro Grande recharge, and a portion of the releases from Cedar Spring Dam into the West Fork (corresponding to release SWP amounts purchased by MWA).

To assess the impact of these projects on water levels, the resulting water levels over the entire basin were subtracted from the water levels simulated by the calibrated model. The differences were then plotted over time at selected locations (Figure 7.1). The time series plots of the water level differences between the calibrated model and Scenario 1 (Figure 7.2) show that simulated water levels near the Mojave River are as much as 30 ft higher with the projects than without the projects. The spatial distribution of these differences in November 2016 (the time of greatest calculated differences in the vicinity of the river) is shown on Figure 7.3. Water level differences beneath the riverbed reached 45 ft and the impact extends all the way to the Lower Narrows. At the Oro Grande Wash recharge site, the simulated water level differences are as great as 140 ft but are limited in time and space, diminishing quickly away from the infiltration site and after infiltration stopped. To show how water level differences change spatially over time when recharge is stopped, water levels were compared for two dates (December 2003 and October 2005) between which no recharge from the projects occurred. Figure 7.4 shows that groundwater levels in some areas remained as much as 7 ft higher almost two years after recharge from the projects..

7.2 Scenario 2

The objective of Scenario 2 was to assess the impact of the recently-identified additional pumping at Jess Ranch on the baseflow in the Mojave River at the Lower Narrows. Similar to Scenario 1, the model was run with the same hydrology and fluxes as the calibration model but with the additional Jess Ranch pumping and associated return flows removed from the model. The differences between the simulated discharge at the Lower Narrows predicted by the calibrated model and by Scenario 2 are shown on Figure 7.5. As shown on this figure, the simulated discharge in the Mojave River is less for the calibrated model than for Scenario 2.

A double mass curve comparing the discharge at the Lower Narrows as simulated by the calibrated model and Scenario 2 was implemented to further understand the changes introduced by the additional pumping at Jess Ranch. The double mass method compares the cumulative sum of two variables (in this case, the discharge at the Lower Narrows as simulated by the two versions of the model) over time. A change in slope (inflection point) on the curve is evidence that the correlation between the two variables changed at some point in time. So, the cumulative sum of the discharge at the Lower Narrows as simulated in Scenario 2 was plotted against the cumulative sum of the discharge at the Lower Narrows as simulated in the calibrated model (Figure 7.6). The double mass curve on Figure 7.6 shows that by 1992 the slope changes and becomes closer to 1, indicating the end of the impact of the additional Jess Ranch pumping, which stopped in 1991.

Overall, comparison of the results of Scenario 2 with the results of the calibrated model indicate that the additional pumping at Jess Ranch reduced the baseflow in the Mojave River at the Lower Narrows. Alternatively, if the additional pumping at Jess Ranch had not occurred, additional groundwater water from the Upper Mojave Basin would have been discharged from the basin via baseflow in the Mojave River.

8.0 Data Limitations and Uncertainty

Uncertainty in the model and its results stems from numerous factors. The estimates of water budget components are one major source of uncertainty. Mountain front recharge, for instance, cannot be directly measured but was based on estimates from Stamos et al. (2001). Similarly, various return flows were estimated by assuming deep percolation and recharge of a certain percentage of the water used. The uncertainty in estimates of agricultural return flows was compounded by the fact that agricultural water use was estimated because many agricultural supply wells were not metered during the calibration period. In many cases, production data were reported annually and had to be converted to monthly rates based on assumed similarity to wells for which monthly rates were available.

The definitions and interpreted geometries of hydrostratigraphic layers have uncertainties associated with the limited availability, distribution, and quality of well logs. The distribution of hydraulic properties (hydraulic conductivity and storage parameters was based on the zones defined by Stamos et al., which were derived from well logs of uneven distribution and quality. The accuracy of the calibrated values for hydraulic parameters is also dependent on the distribution of available water levels. Hence, uncertainty is lower in the vicinity of the Mojave River where more water level data are available and is greater in the Regional Aquifer away from the river where fewer data are available.

From a surface water perspective, the lack of long-term continuous rain gage data was a limiting factor in adjusting the BCM, leading to uncertainty. Also, only one streamflow gage was available for the Deep Creek subwatershed, which contributes 60% of the flow in the Mojave River.

9.0 Summary of Model Reliability

The groundwater flow model is an approximation of existing conditions in the study area. As such, the model can approximate, but not completely reproduce, all observations across the study area under all conditions. The groundwater flow model can reliably predict head changes in response to water management projects involving surface water and groundwater alternatives within the calibrated range of groundwater levels and surface water discharges. However, simulations with extreme ranges in head or discharges (i.e., severe drought conditions or extreme flooding) may produce less reliable results. Projects at locations close to the edges of the model or located in areas where very little data were available for calibration may also be less reliable and might need to be supplemented with field data collection and/or model update. Relatively little lithologic information or groundwater level data are available for the western portion of the Alto subarea and most of the monitoring in this area is along the Oro Grande Wash. Overall, the model would benefit from the availability of more data from the Western Alto and Southern Alto Transition Zone subareas and portions of the Oeste subarea. Such additional data might be obtained through monitoring of existing wells in some areas and through drilling, logging, construction, and monitoring of new wells in others.

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Tables

Table 2.1

Model Inflows

Upper Mojave River Basin Integrated Surfaces Water/Groundwater Model

Apple Valley, California

Water Year[1]	Artificial Recharge (AF)	Agricultural Return Flow (AF)	Jess Ranch Return Flow[2] (AF)	Industrial Return (AF)	Septic Return Flow (AF)
1951	0	18668	504	947	552
1952	0	23825	1332	926	624
1953	0	24369	1236	990	684
1954	0	23671	1020	926	744
1955	0	23953	1368	840	816
1956	0	21565	1512	606	876
1957	0	20865	1752	505	936
1958	0	21951	2376	576	996
1959	0	23953	2832	698	1068
1960	0	25961	3456	750	1128
1961	0	26209	3144	875	1188
1962	0	25292	2664	881	1260
1963	0	25693	3288	931	1320
1964	0	26703	2832	1089	1380
1965	0	27202	3252	1193	1452
1966	0	25977	2064	1300	1512
1967	0	25042	2448	1314	1572
1968	0	25594	2076	1453	1644
1969	0	26850	2100	1397	1704
1970	0	23981	1044	1427	1764
1971	0	23357	792	1377	1824
1972	0	21670	1356	1437	1896
1973	0	22141	3096	1549	1956
1974	0	22758	1824	1699	2016
1975	0	23052	1836	1852	2088
1976	0	23365	1860	2000	2148
1977	0	23633	1872	2149	2208
1978	0	23944	1896	2302	2580
1979	0	24238	1920	2453	2928
1980	0	24549	1932	2603	3264
1981	0	24811	1956	2750	3612
1982	420	25123	1968	2902	3948
1983	904	25420	1992	3052	4296
1984	972	25737	2004	3205	4632
1985	756	25997	1980	3353	4980
1986	624	26309	2244	3504	5316
1987	336	26007	1668	3801	5664
1988	468	26269	1308	4162	6000
1989	828	26859	1308	4545	6348
1990	72	25010	1152	5087	6696
1991	72	23428	2136	4960	6792
1992	708	22579	0	5125	6876
1993	564	21624	0	5395	6972
1994	684	5921	0	5936	7068
1995	804	4625	0	5609	7164
1996	528	1716	0	6641	7260
1997	996	2156	0	6654	7356

Table 2.1

Model Inflows

Upper Mojave River Basin Integrated Surfaces Water/Groundwater Model
Apple Valley, California

Water Year[1]	Artificial Recharge (AF)	Agricultural Return Flow (AF)	Jess Ranch Return Flow[2] (AF)	Industrial Return (AF)	Septic Return Flow (AF)
1998	1139	1451	0	5979	7452
1999	1414	1382	0	6675	7548
2000	798	1191	0	7276	7932
2001	1074	840	0	6955	8172
2002	3809	803	0	7554	8412
2003	6489	684	0	7460	8640
2004	6650	742	0	7927	8880
2005	7509	684	0	7502	9120
2006	4288	879	0	7743	9360
2007	5308	870	0	8026	9600
2008	6114	1109	0	7136	9840
2009	6256	1043	0	6578	10068
2010	5676	789	0	6179	10308
2011	6213	656	0	5858	10404
2012	5500	816	0	5962	10488
2013	7075	500	0	6444	10584
2014	8379	449	0	6663	10680
2015	7299	383	0	5518	10764
2016	8002	555	0	5113	10860
2017	6621	337	0	5189	10956
Average	**1722**	**16056**	**1200**	**3723**	**5032**

Notes

1. Water Year = Period from October 1st to September 30th
2. Jess Ranch Return Flow = Agricultural return flow at the Jess Ranch site

Abbreviation:

AF = Acre-feet

Table 2.3

Yearly Groundwater Production

Upper Mojave River Basin Integrated Surfaces
Apple Valley, California

Water Year[1]	Well Production (AF)	Minimal Producers (AF)
1951	63569	2645
1952	82058	2645
1953	86367	2645
1954	83489	2645
1955	83677	2645
1956	77954	2645
1957	77161	2645
1958	80861	2645
1959	89880	2645
1960	96901	2645
1961	97461	2645
1962	94693	2645
1963	99001	2645
1964	100718	2645
1965	104294	2645
1966	99927	2645
1967	98102	2645
1968	98804	2645
1969	101688	2645
1970	93745	2645
1971	88386	2645
1972	88604	2645
1973	102070	2645
1974	88384	2645
1975	90867	2645
1976	102645	2645
1977	108701	2645
1978	110384	2645
1979	111244	2645
1980	114732	2645
1981	113266	2645
1982	116239	2645
1983	118787	2645
1984	123197	2645
1985	125429	2645
1986	119407	2645

Table 2.3

Yearly Groundwater Production

Upper Mojave River Basin Integrated Surfaces
Apple Valley, California

Water Year[1]	Well Production (AF)	Minimal Producers (AF)
1987	120762	2645
1988	124639	2645
1989	128490	2645
1990	127897	2645
1991	127114	2645
1992	124117	2645
1993	121910	2645
1994	96385	2645
1995	86593	2645
1996	93663	2645
1997	94408	2645
1998	83789	2645
1999	92540	2645
2000	96419	2645
2001	91770	2645
2002	96770	2645
2003	95535	2645
2004	101752	2645
2005	98472	2645
2006	105850	2645
2007	107694	2645
2008	98368	2660
2009	95870	2660
2010	89042	2660
2011	86728	2660
2012	89889	2660
2013	92432	2660
2014	95112	2660
2015	82094	2660
2016	79048	2660
2017	78500	2660
Average	**99050**	**2647**

Notes
Water Year = Period from October 1st to September 30th

Abbreviation:
AF = Acre-feet

Table 6.1

Simulated Water Balance
Upper Mojave River Basin Integrated Surface Water/Groundwater Model
Apple Valley, California

Water Year	Inflows											Outflows								
	Artificial Recharge (AF)	Agricultural Return Flow (AF)	Jess Ranch Return Flows (AF)	Industrial Return Flow (AF)	Septic Return Flow (AF)	Mountain Front Recharge (AF)	Stream Leakage (AF)	Underflow Inflow From Antelope Valley (AF)	Underflow Inflow San Bernardino Mountains (AF)	Recharge (AF)	Total Outflow (AF)	Well Production (AF)	Minimal Producers (AF)	Evapotranspiration (AF)	Underflow Outflow Alto Transition Zone (AF)	Stream Leakage (AF)	Dry Lakes Discharge (AF)	Total Outflow (AFY)	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	0	18668	504	947	552	7229	20277	111	779	289	49356	63569	2639	11113	1345	18753	1227	98646	-49290	-49290
1952	0	23825	1332	926	624	7248	146738	426	1457	377	182953	82058	2646	11741	1135	18475	1000	117055	65898	16608
1953	0	24369	1236	990	684	7229	43203	489	1166	312	79678	86367	2639	11394	1155	18691	848	121094	-41416	-24808
1954	0	23671	1020	926	744	7229	91845	514	1147	259	127355	83489	2639	11537	1121	19214	772	118772	8583	-16225
1955	0	23953	1368	840	816	7229	40839	602	961	254	76862	83677	2639	11248	1081	18819	716	118180	-41318	-57543
1956	0	21565	1512	606	876	7248	46665	598	961	208	80239	77954	2646	11317	1130	18962	676	112685	-32446	-89989
1957	0	20865	1752	505	936	7229	48396	617	984	242	81526	77161	2639	11348	1206	18998	633	111985	-30459	-120448
1958	0	21951	2376	576	996	7229	125715	566	1502	328	161239	80861	2639	11620	1223	20583	597	117523	43716	-76732
1959	0	23953	2832	698	1068	7229	41510	625	960	189	79064	89880	2639	11498	1247	20852	562	126678	-47614	-124346
1960	0	25961	3456	750	1128	7248	41145	618	719	218	81243	96901	2646	11296	1270	19670	528	132311	-51068	-175414
1961	0	26209	3144	875	1188	7229	35172	628	616	166	75227	97461	2639	11092	1257	18630	493	131572	-56345	-231759
1962	0	25292	2664	881	1260	7229	86043	643	1582	304	125898	94693	2639	11085	1258	18191	461	128327	-2429	-234188
1963	0	25693	3288	931	1320	7229	37309	698	609	149	77226	99001	2639	10894	1270	17304	427	131535	-54309	-288497
1964	0	26703	2832	1089	1380	7248	50883	750	1236	340	92461	100718	2646	10631	1279	16450	395	132119	-39658	-328155
1965	0	27202	3252	1193	1452	7229	51571	753	1318	200	94170	104294	2639	10468	1265	15016	362	134044	-39874	-368029
1966	0	25977	2064	1300	1512	7229	128191	739	1538	356	168906	99927	2639	10894	1325	17227	329	132341	36565	-331464
1967	0	25042	2448	1314	1572	7229	141434	691	2213	338	182281	98102	2639	11246	1404	18864	295	132550	49731	-281733
1968	0	25594	2076	1453	1644	7248	50474	753	1302	328	90872	98804	2646	10995	1463	18521	262	132691	-41819	-323552
1969	0	26850	2100	1397	1704	7229	186262	716	1554	565	228377	101688	2639	11686	1551	20413	227	138204	90173	-233379
1970	0	23981	1044	1427	1764	7229	39800	794	930	187	77156	93745	2639	11427	1753	21248	194	131006	-53850	-287229
1971	0	23357	792	1377	1824	7229	42630	915	1207	267	79598	88386	2639	11308	2024	20100	160	124617	-45019	-332248
1972	0	21670	1356	1437	1896	7248	39033	970	1303	249	75162	88604	2646	11237	2092	18749	125	123453	-48291	-380539
1973	0	22141	3096	1549	1956	7229	98046	977	1464	322	136780	102070	2639	11364	2134	18408	101	136716	64	-380475
1974	0	22758	1824	1699	2016	7229	52242	984	1320	255	90327	88384	2639	11705	2230	18240	80	122778	-32451	-412926
1975	0	23052	1836	1852	2088	7229	37563	932	1024	224	75800	90867	2639	10999	2224	16886	66	123681	-47881	-460807
1976	0	23365	1860	2000	2148	7248	53560	935	1005	201	92322	102645	2646	10842	2204	15519	57	133913	-41591	-502398
1977	0	23633	1872	2149	2208	7229	55809	1025	1320	430	95675	108701	2639	10689	2207	14446	47	138729	-43054	-545452
1978	0	23944	1896	2302	2580	7229	220942	1034	1732	541	262200	110384	2639	11659	2235	16914	36	143867	118333	-427119
1979	0	24238	1920	2453	2928	7229	120058	696	1461	339	161322	111244	2639	11569	2090	19823	28	147393	13929	-413190
1980	0	24549	1932	2603	3264	7248	159813	476	1468	417	201770	114732	2646	11684	2052	22572	22	153708	48062	-365128
1981	0	24811	1956	2750	3612	7229	40128	514	693	172	81865	113266	2639	11422	2067	21665	12	151071	-69206	-434334
1982	420	25123	1968	2902	3948	7229	85499	984	1229	278	129580	116239	2639	11488	2300	19788	11	152465	-22885	-457219
1983	904	25420	1992	3052	4296	7229	167128	576	1733	408	212738	118787	2639	11660	2197	22164	0	157447	55291	-401928
1984	972	25737	2004	3205	4632	7248	65988	564	1174	236	111760	123197	2646	11445	2179	22032	0	161499	-49739	-451667
1985	756	25997	1980	3353	4980	7229	69441	846	1360	276	116218	125429	2639	11383	2275	19707	0	161433	-45215	-496882
1986	624	26309	2244	3504	5316	7229	91660	1084	1469	335	139774	119407	2639	11295	2398	18907	0	154646	-14872	-511754
1987	336	26007	1668	3801	5664	7229	43755	969	1280	275	90984	120762	2639	10886	2362	16736	0	153385	-62401	-574155
1988	468	26269	1308	4162	6000	7248	49324	963	1452	349	97543	124639	2646	10312	2321	14515	0	154433	-56890	-631045
1989	828	26859	1308	4545	6348	7229	43395	1199	1084	289	93084	128490	2639	9904	2447	12880	0	156360	-63276	-694321
1990	72	25010	1152	5087	6696	7229	35757	801	1035	235	83074	127897	2639	9261	2254	10994	0	153045	-69971	-764292
1991	72	23428	2136	4960	6792	7229	64077	647	1147	236	110724	127114	2639	8651	2123	9983	0	150510	-39786	-804078
1992	708	22579	0	5125	6876	7248	100250	544	1377	278	144985	124117	2646	9475	2132	11204	0	149574	-4589	-808667
1993	564	21624	0	5395	6972	7229	215583	827	1853	644	260691	121910	2639	11025	2183	14263	0	152020	108671	-699996
1994	684	5921	0	5936	7068	7229	49453	730	1337	219	78577	96385	2639	10495	2108	13996	0	125623	-47046	-747042
1995	804	4625	0	5609	7164	7229	152503	587	1661	316	180498	86593	2639	10921	2057	16955	0	119165	61333	-685709
1996	528	1716	0	6641	7260	7248	55803	583	1201	210	81190	93663	2646	10874	2060	16439	0	125682	-44492	-730201
1997	996	2156	0	6654	7356	7229	74406	10912	1505	261	111475	94408	2639	10894	220	15962	0	124123	-12648	-742849
1998	1139	1451	0	5979	7452	7229	134529	9165	1732	411	169087	83789	2639	10638	610	19028	0	116704	52383	-690466
1999	1414	1382	0	6675	7548	7229	20004	8095	686	68	53101	92540	2639	10910	1023	17516	0	124628	-71527	-761993
2000	798	1191	0	7276	7932	7248	26146	7231	962	193	58977	96419	2646	10737	1566	15328	0	126696	-67719	-829712

Table 6.1

Simulated Water Balance

Upper Mojave River Basin Integrated Surface Water/Groundwater Model

Apple Valley, California

Water Year	Inflows											Outflows							Change in Storage (AF)	Cumulative change in Storage (AF)
	Artificial Recharge (AF)	Agricultural Return Flow (AF)	Jess Ranch Return Flows (AF)	Industrial Return Flow (AF)	Septic Return Flow (AF)	Mountain Front Recharge (AF)	Stream Leakage (AF)	Underflow Inflow From Antelope Valley (AF)	Underflow Inflow San Bernardino Mountains (AF)	Recharge (AF)	Total Outflow (AF)	Well Production (AF)	Minimal Producers (AF)	Evapotranspiration (AF)	Underflow Outflow Alto Transition Zone (AF)	Stream Leakage (AF)	Dry Lakes Discharge (AF)	Total Outflow (AFY)		
2001	1074	840	0	6955	8172	7229	28604	8212	976	208	62270	91770	2639	9305	1052	12757	0	117523	-55253	-884965
2002	3809	803	0	7554	8412	7229	16090	8165	514	21	52597	96770	2639	8821	1084	10652	0	119966	-67369	-952334
2003	6489	684	0	7460	8640	7229	46399	7339	1119	267	85626	95535	2639	8360	1570	10796	0	118900	-33274	-985608
2004	6650	742	0	7927	8880	7248	27723	7965	944	200	68279	101752	2646	7805	1230	9858	0	123291	-55012	-1040620
2005	7509	684	0	7502	9120	7229	191636	8170	1915	627	234392	98472	2639	9165	1048	12555	0	123879	110513	-930107
2006	4288	879	0	7743	9360	7229	71294	7702	1161	273	109929	105850	2639	8954	1402	11977	0	130822	-20893	-951000
2007	5308	870	0	8026	9600	7229	21331	7771	463	29	60627	107694	2639	8974	1299	10328	0	130934	-70307	-1021307
2008	6114	1109	0	7136	9840	7248	67830	7640	1189	235	108341	98368	2646	8467	1430	10487	0	121398	-13057	-1034364
2009	6256	1043	0	6578	10068	7229	49479	7435	961	230	89279	95870	2639	8085	1539	9777	0	117910	-28631	-1062995
2010	5676	789	0	6179	10308	7229	119462	7844	1274	316	159077	89042	2639	9436	1303	12002	0	114422	44655	-1018340
2011	6213	656	0	5858	10404	7229	172139	7406	2236	421	212562	86728	2639	10873	1591	17150	0	118981	93581	-924759
2012	5500	816	0	5962	10488	7248	46996	7538	694	199	85441	89889	2646	10978	1498	15960	0	120971	-35530	-960289
2013	7075	500	0	6444	10584	7229	28999	7394	536	135	68896	92432	2639	10827	1602	15450	0	122950	-54054	-1014343
2014	8379	449	0	6663	10680	7229	20281	7453	602	146	61882	95112	2611	9951	1557	15466	0	124697	-62815	-1077158
2015	7299	383	0	5518	10764	7229	24980	7480	1089	247	64989	82094	2602	9667	1550	13547	0	109460	-44471	-1121629
2016	8002	555	0	5113	10860	7248	23434	7631	1096	239	64178	79048	2609	9431	1487	12893	0	105468	-41290	-1162919
2017	6621	337	0	5189	10956	7229	106005	7164	1448	311	145260	78500	2602	9753	1800	13318	0	105973	39287	-1123632
Average	**1722**	**16056**	**1200**	**3723**	**5032**	**7234**	**74338**	**2976**	**1209**	**278**	**113770**	**99050**	**2639**	**10591**	**1644**	**16441**	**175**	**130541**	**-16771**	

Notes

Water Year = Period from October 1st to September 30th

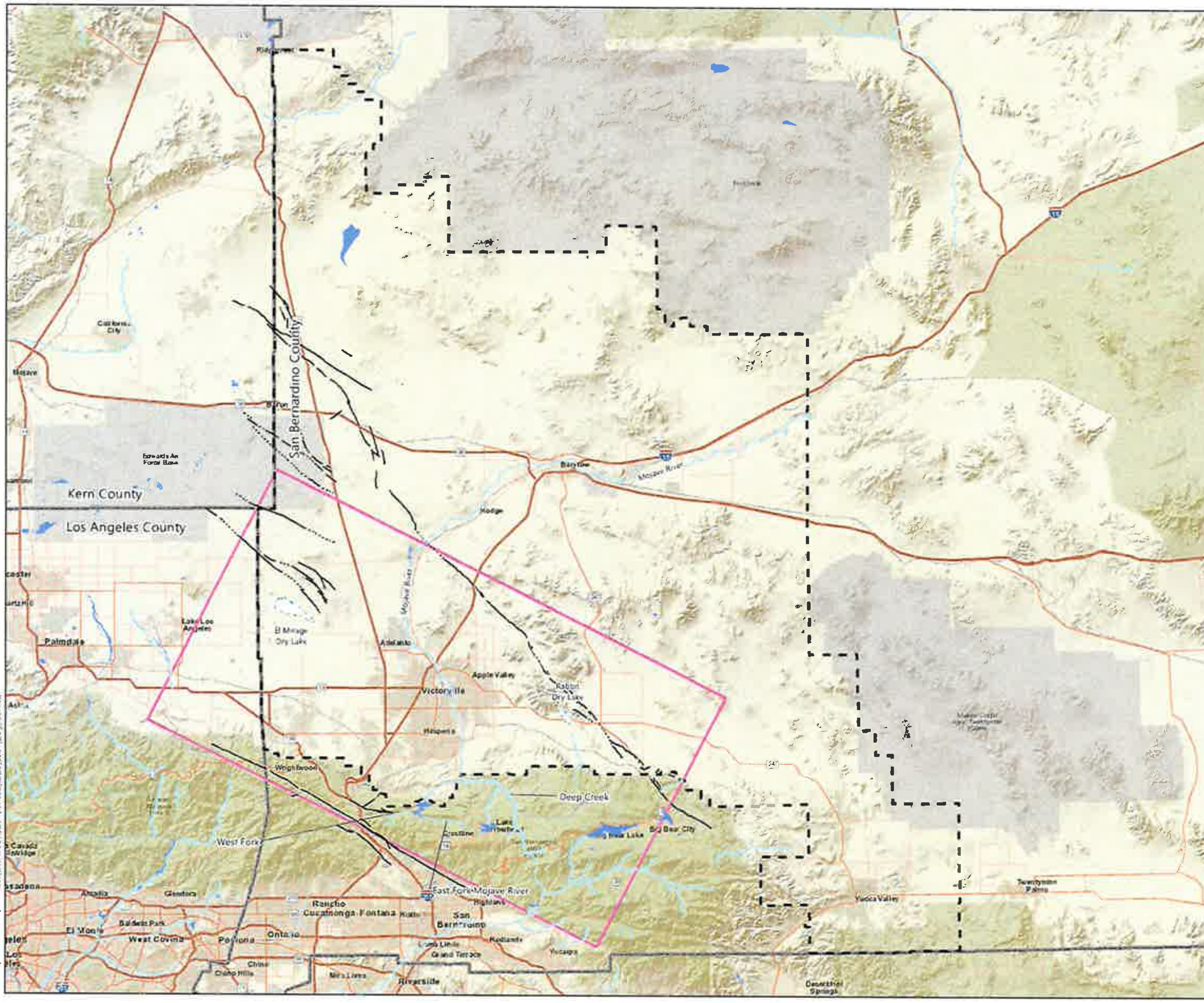
Abbreviation:

AF = Acre-feet

AFY = Acre-Feet/Year

wood.

Figures



Explanation:

- River/Stream
- Reservior/Lake
- Fault, certain
- Fault approximate
- Fault concealed
- Dry lake
- Mojave Water Agency (MWA) service area
- Model domain
- County boundary

0 6 12 24
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

PROJECT LOCATION
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.1

Date: 10/29/2021 Printed by: mike.wallace2
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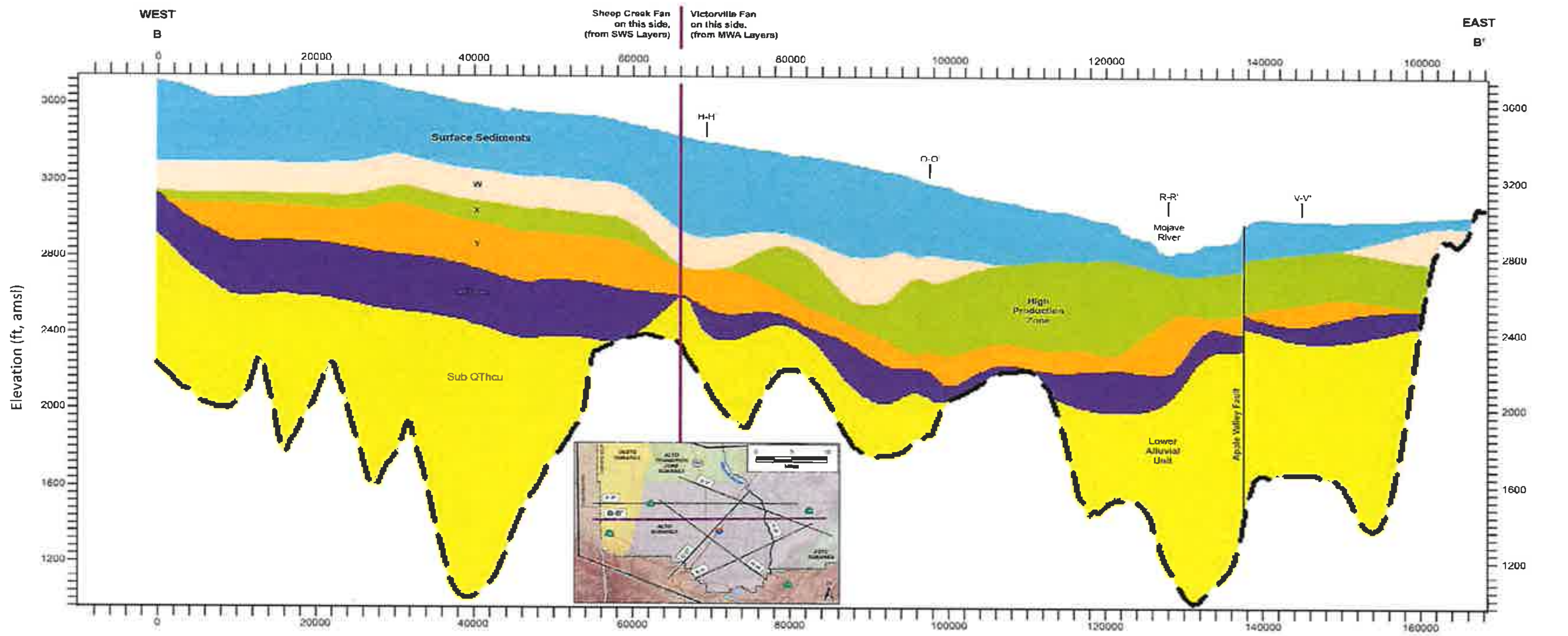


Sheep Creek Main Zones (from SWS Layers)
- Surface Sediments
- W
- X
- Y
- QThcu
- Sub QThcu

Victorville Fan Main Zones (from MWA Layers)
- Surficial Shallow
- Upper Production Unit
- High Production Unit
- Lower/Lesser Unit
- Middle Lacustrine Unit
- Lower Alluvial Unit

Bottom of Bedrock

Notes:

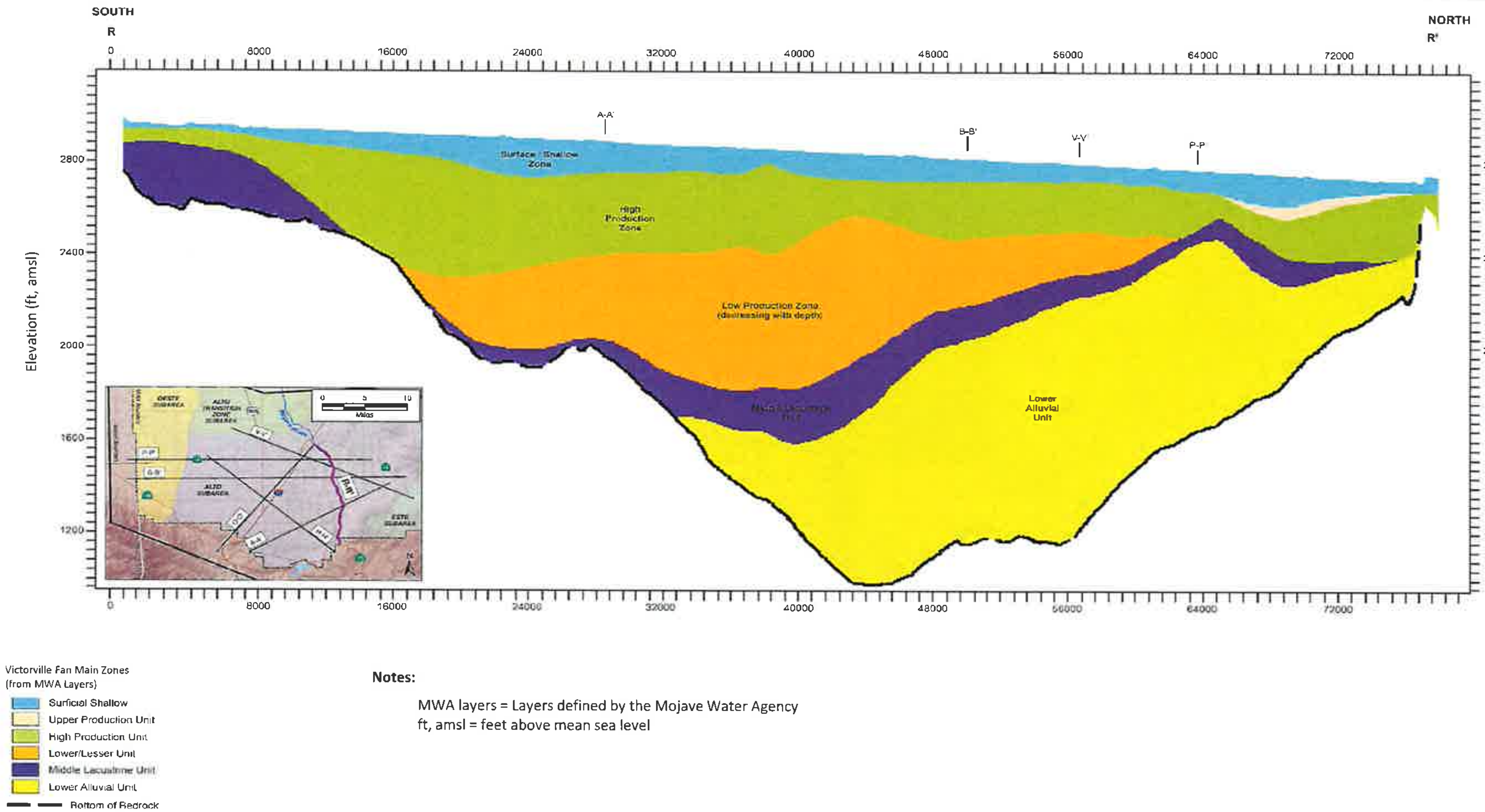
MWA layers = Layers defined by the Mojave Water Agency
SWS layers = layers defined by Schlumberger Water Services
ft, amsl = feet above mean sea level

Source: GEOSCIENCE, 2020

CROSS-SECTION B-B' SHOWING HYDROSTRATIGRAPHIC LAYERS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.	Figure	2.2

\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 2.3 10/29/2021



Notes:

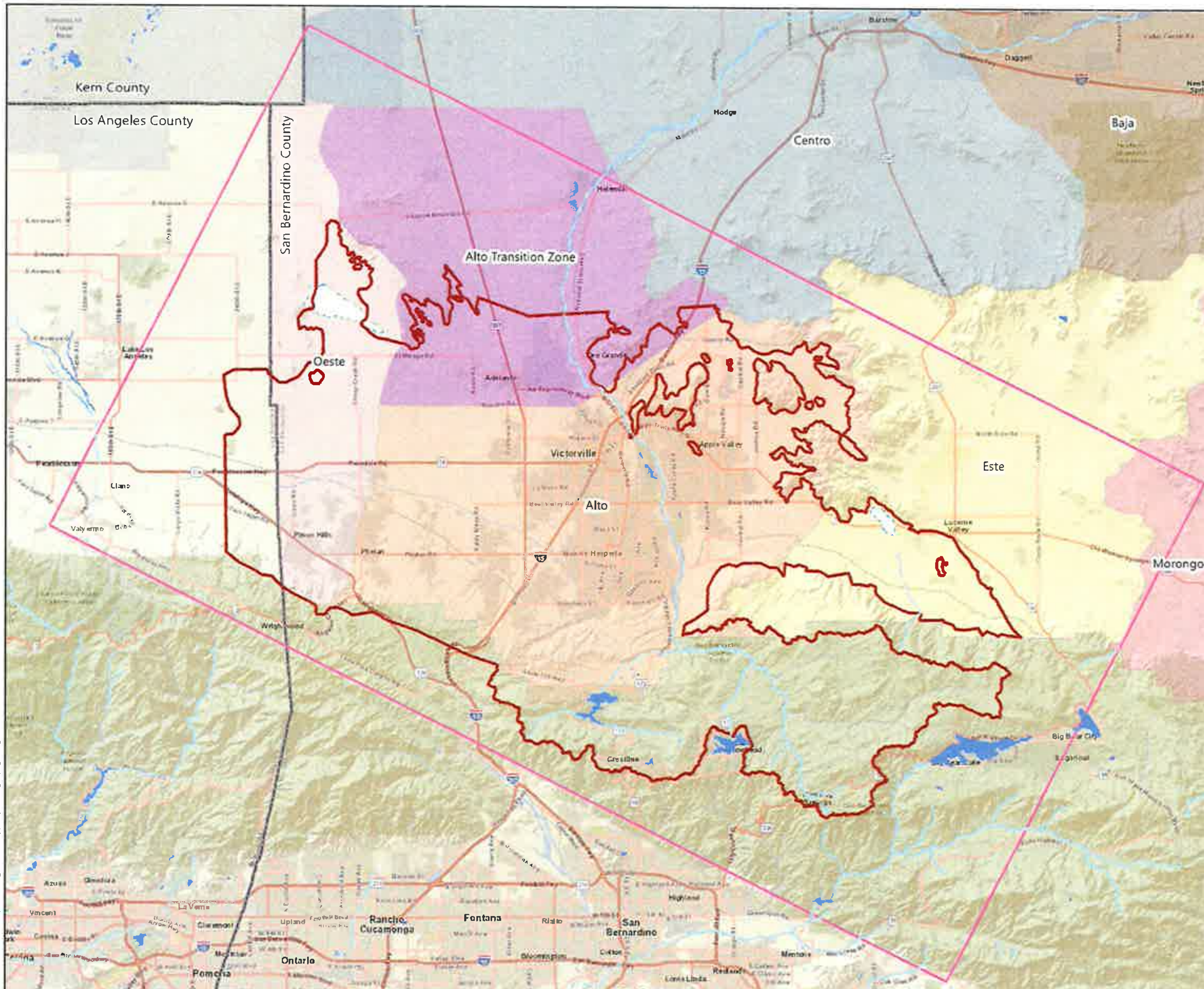
MWA layers = Layers defined by the Mojave Water Agency
ft, amsl = feet above mean sea level

Source: GEOSCIENCE, 2020

CROSS-SECTION R-R' SHOWING HYDROSTRATIGRAPHIC LAYERS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood. Figure 2.3



Explanation:

- River/Stream
- Reservior/Lake
- Dry lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

N

0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

MODEL DOMAIN
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.4

Date: 10/29/2021 Printed by: mike.wallace2
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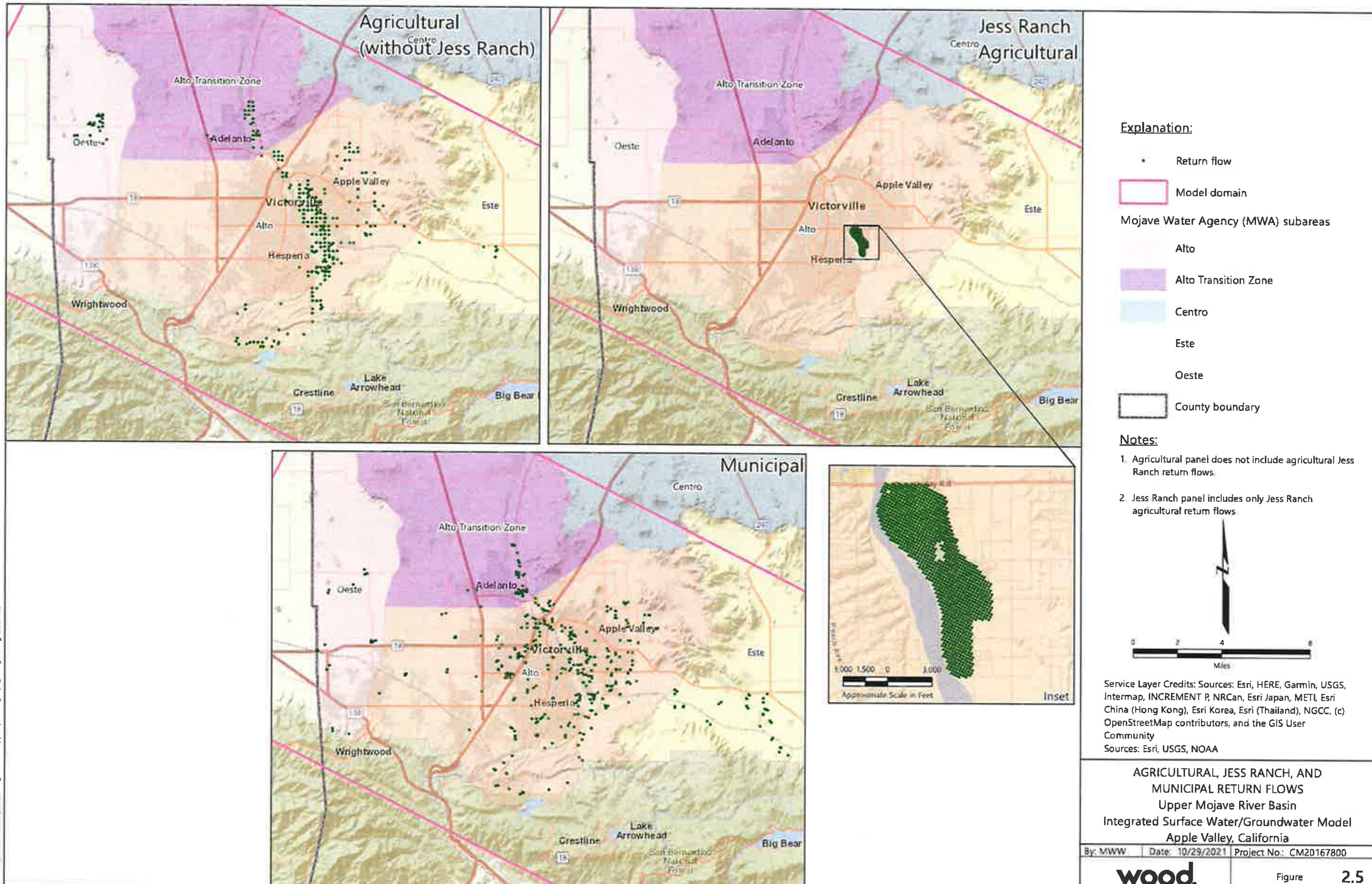


Notes:

1. Agricultural panel does not include agricultural Jess Ranch return flows.
2. Jess Ranch panel includes only Jess Ranch agricultural return flows.

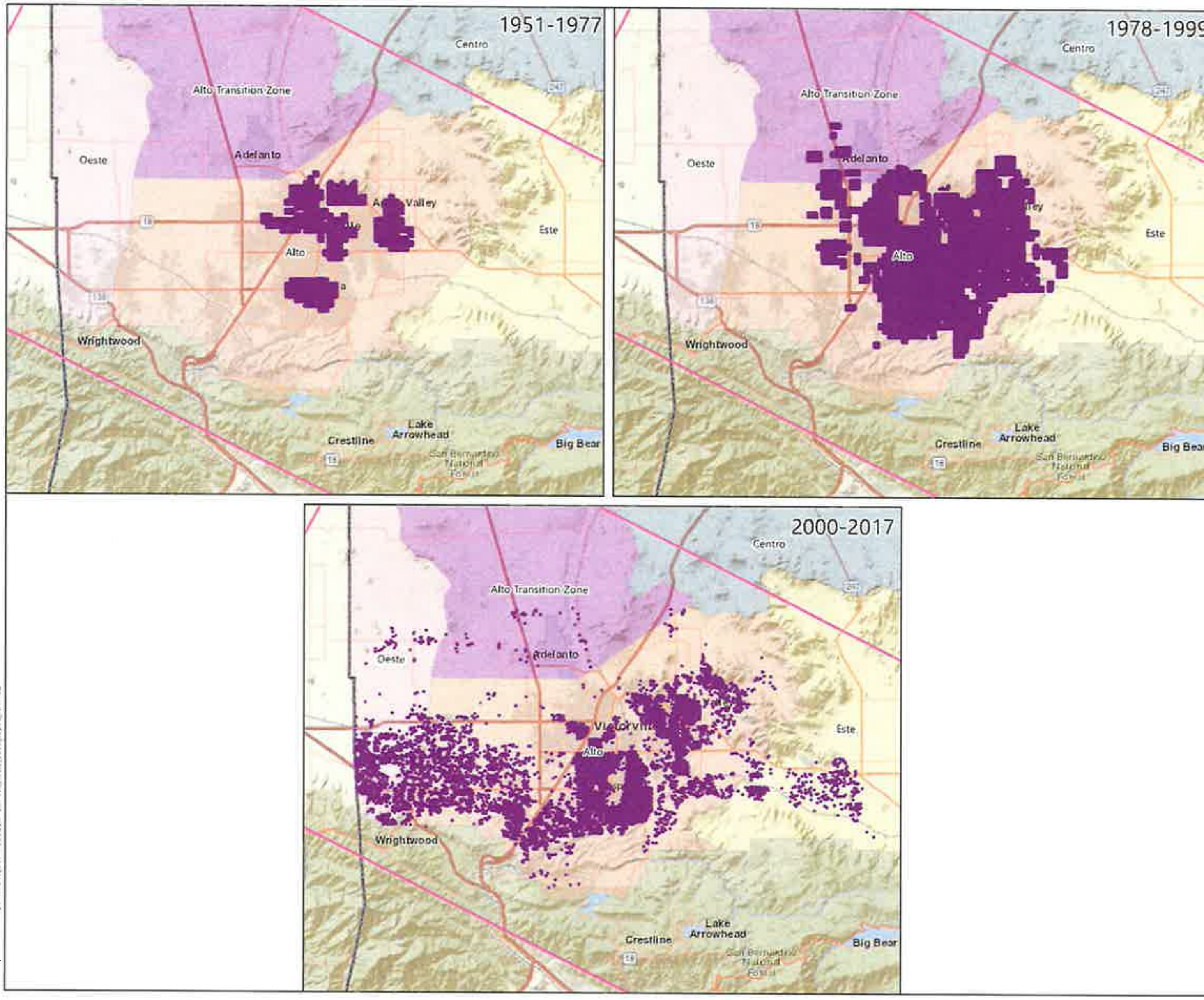
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

AGRICULTURAL, JESS RANCH, AND MUNICIPAL RETURN FLOWS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 2.5

Date 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\esri\revised_tb\tb_0205_return_flows.mxd



Explanation:

- Septic return flow
- Model domain

Mojave Water Agency (MWA) subareas

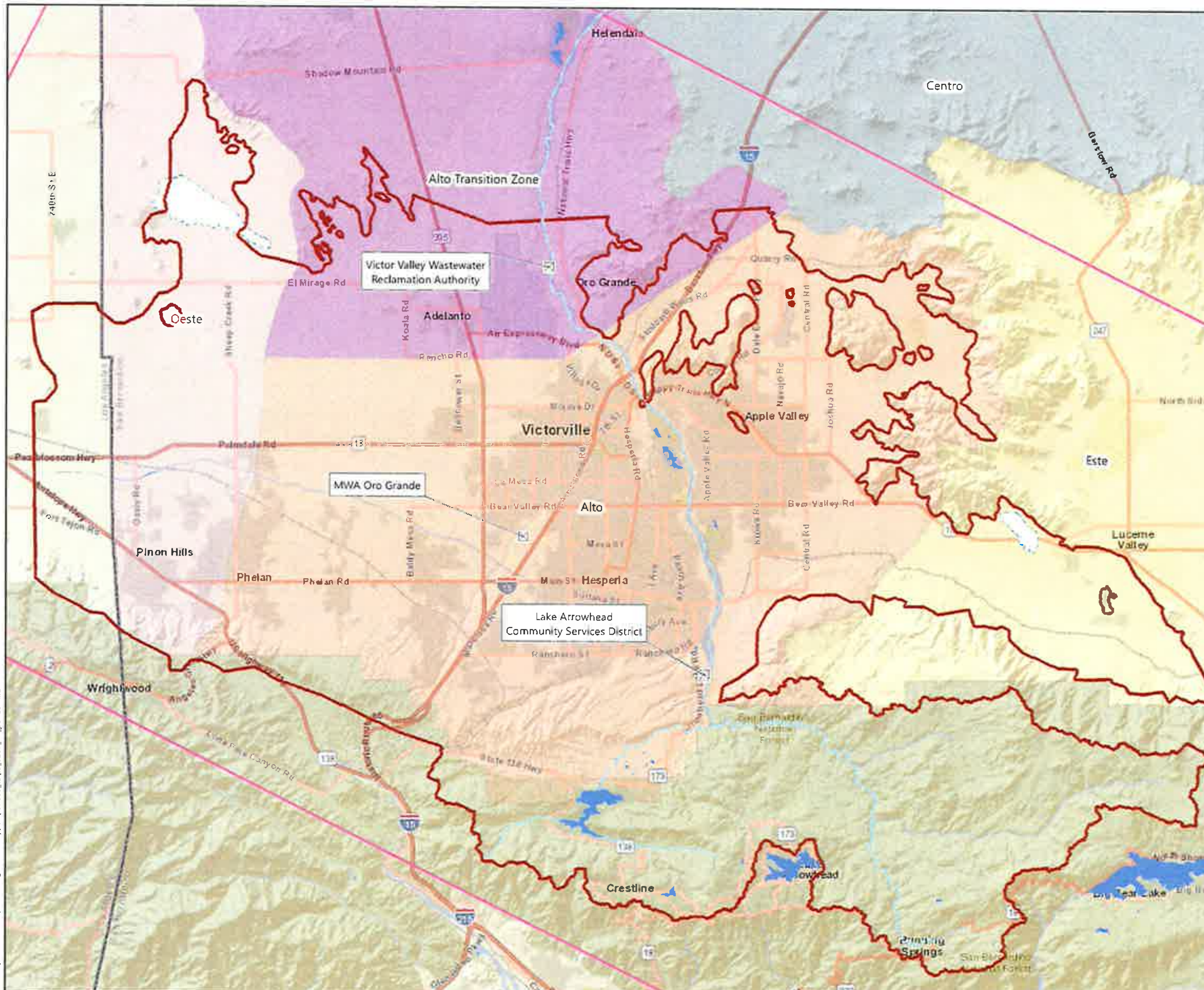
- Alto
- Alto Transition Zone
- Centro
- Este
- Oeste
- County boundary

0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

SEPTIC RETURN FLOWS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.6

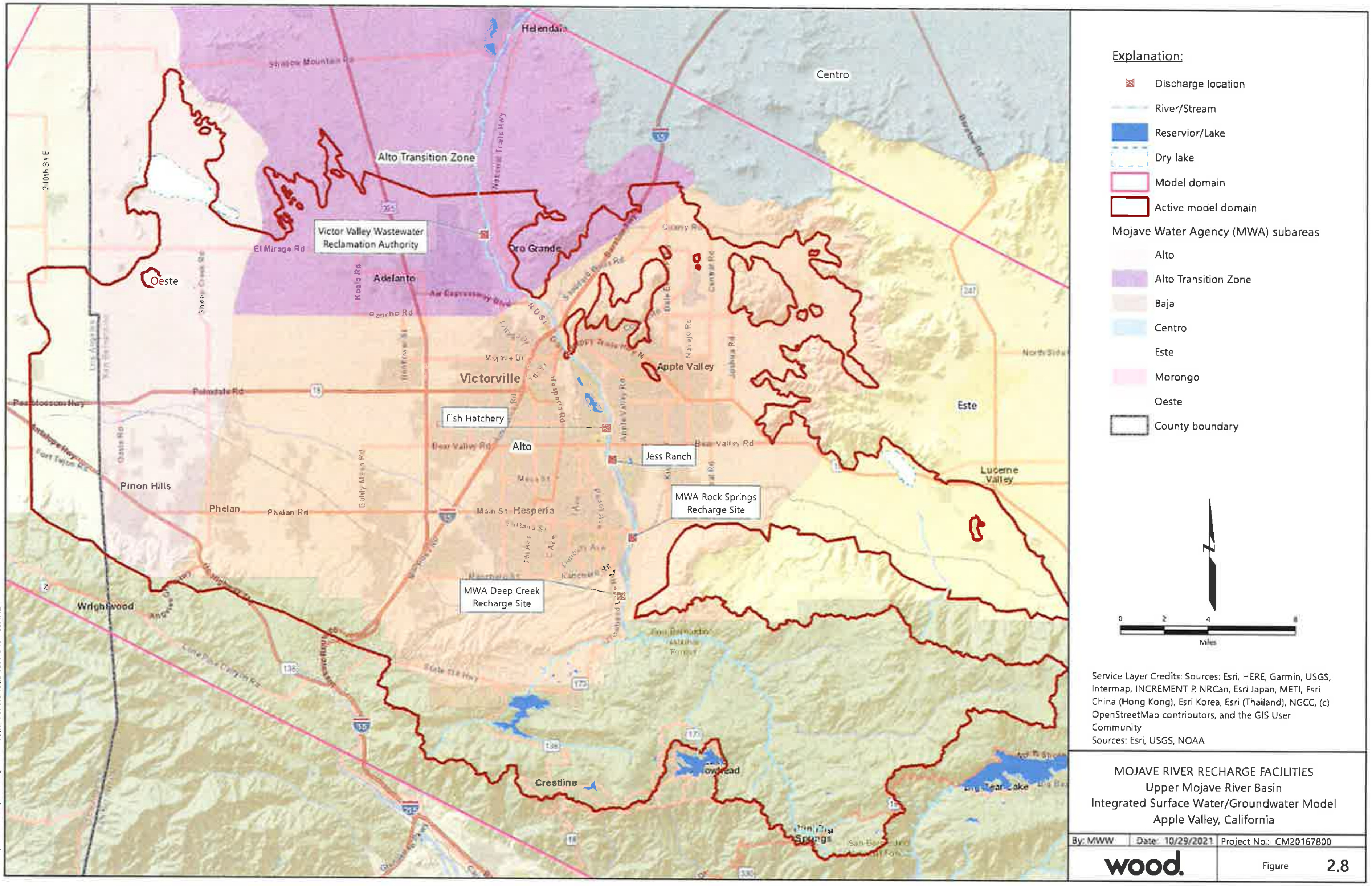


Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

RECHARGE PONDS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.7

Date 10/29/2021 Printed by mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\esri\revised_tb\tb_0207_inf_ponds.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

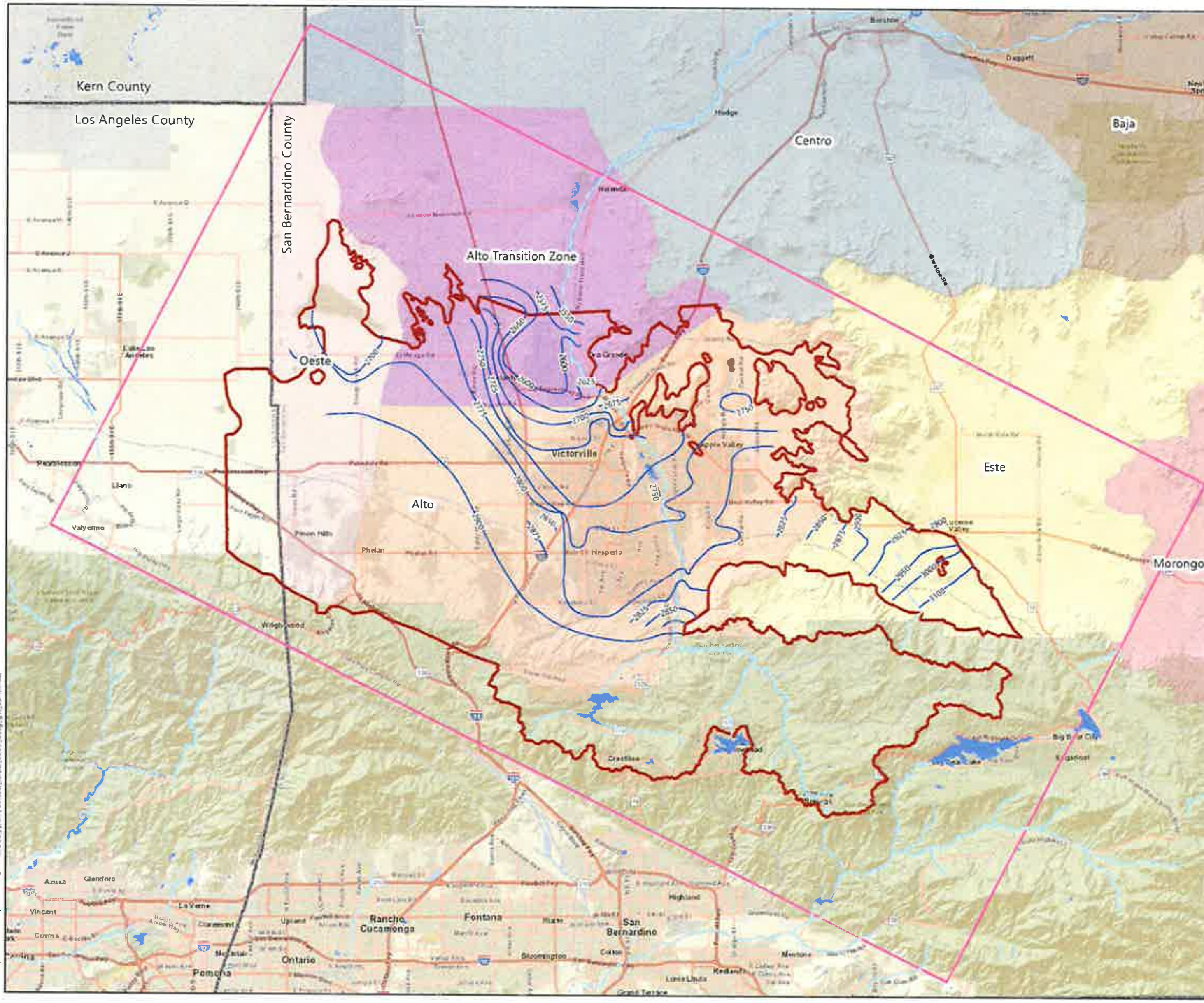
MOJAVE RIVER RECHARGE FACILITIES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 2.8

Date 10/29/2021 Printed by mike.wallace2
Path Y:\CM20167800 (MWA SW_GW Model)\esri\revised_lb\lb_0208_disch_locs.mxd



Explanation:

- USGS 2016 Mojave River Basins grounwater elevation contours [feet North American Vertical Datum 1988 (NAVD88)]
- River/Stream
- Reservior/Lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

Note

NAVD88 and Mean Sea Level (MSL) differ by approximately 2.86 feet. NAVD88 = MSL + 2.86 feet

0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

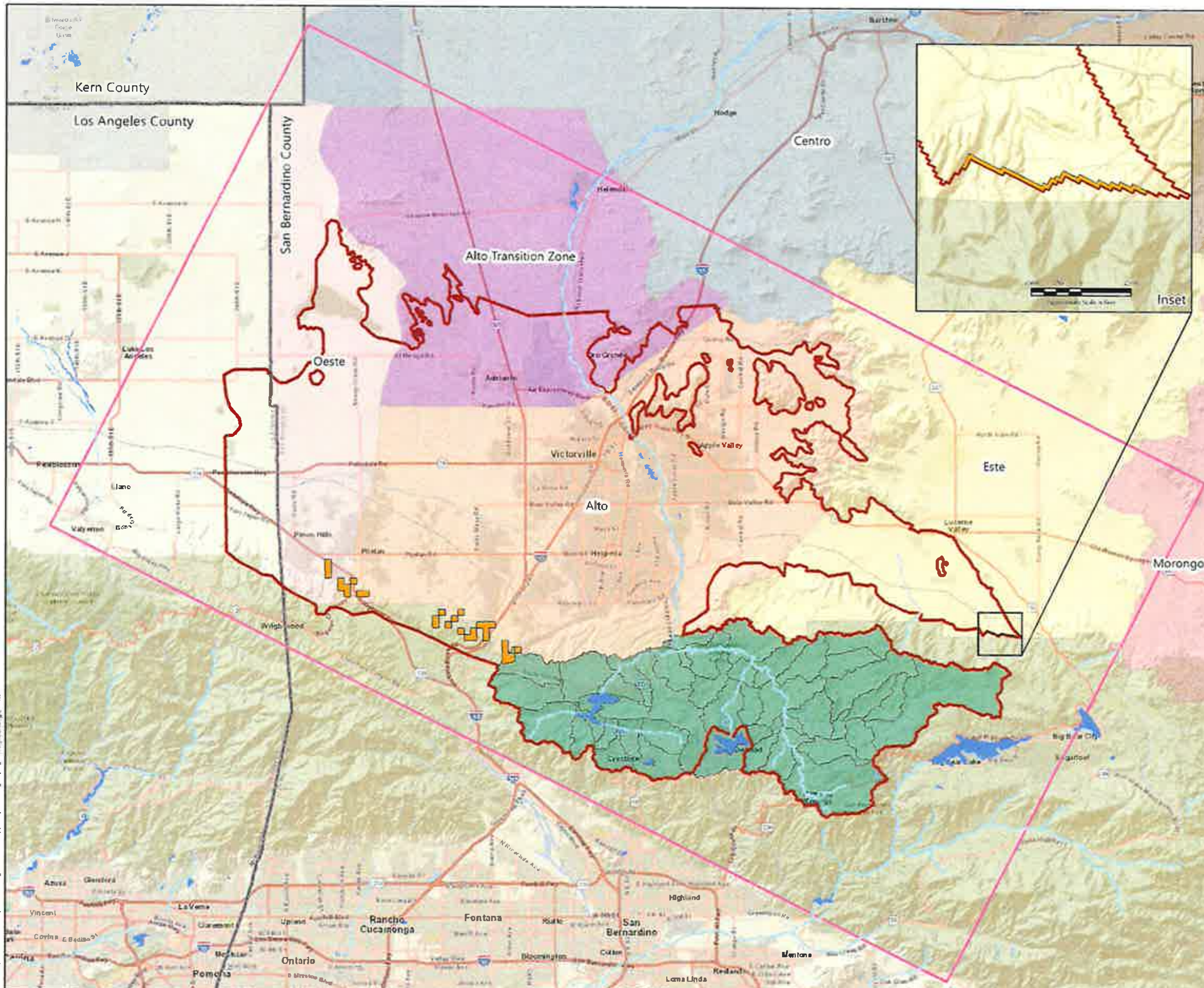
USGS 2016 MOJAVE RIVER BASINS
GROUNDWATER ELEVATION CONTOURS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800

wood.

Figure 2.9

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW GW Model)\gis\Revised_tlrtb_0209_usgs_gw_cont.mxd



Explanation:

- River/Stream
- Reservior/Lake
- Mountain front recharge area
- Model domain
- Active model domain
- Recharge zone

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

Note:

Recharge Zones are from the Basin Characterization Model (Flint and Flint, 2013) and Mountain Front Recharge areas are from the USGS Model (Stamos et al., 2001).

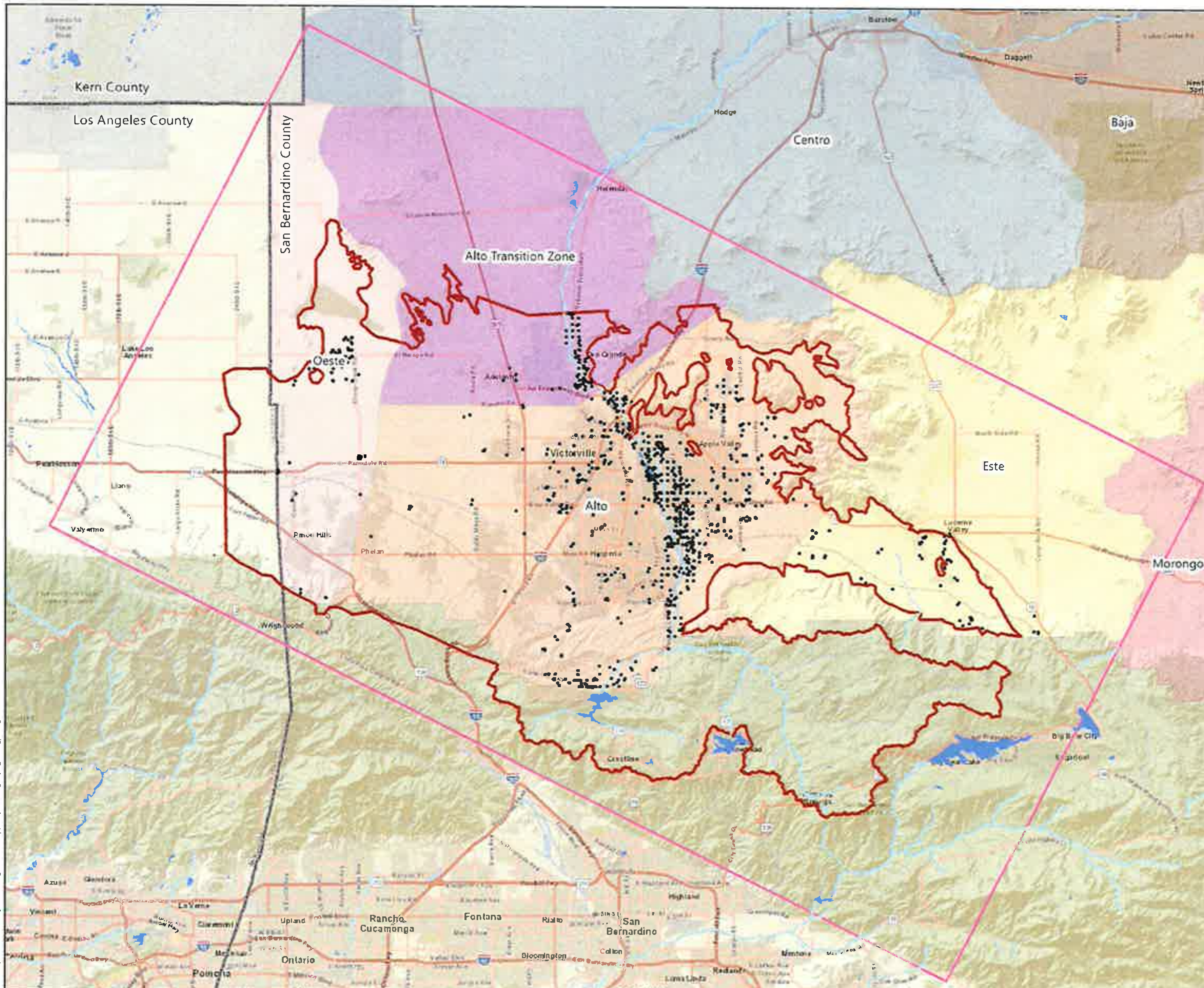
0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

RECHARGE ZONES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.10

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\esri\revised_tb\tb_0210_recharge.mxd



Explanation:

- Production well
- River/Stream
- Reservior/Lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 3 6 12
Miles

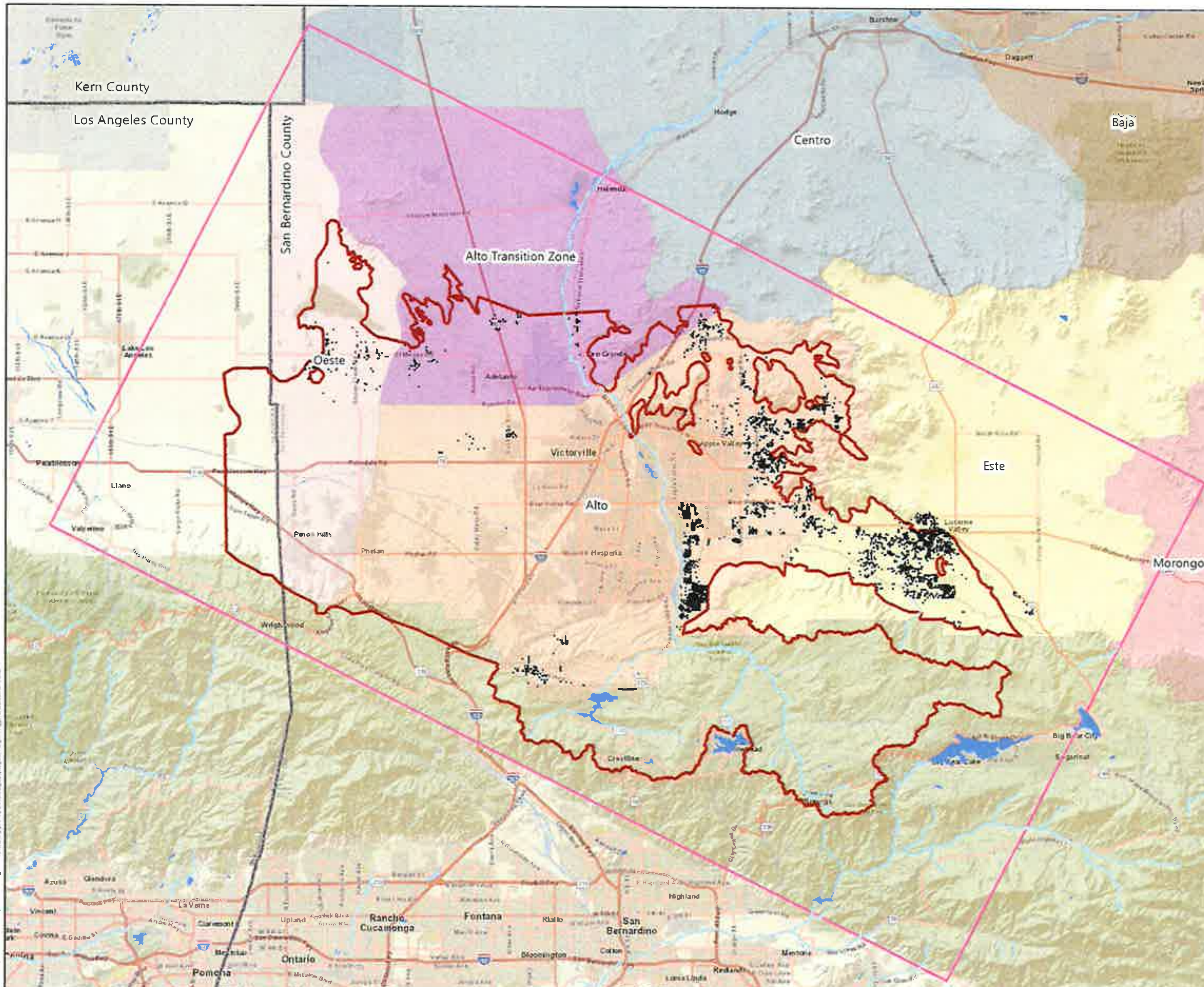
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

PRODUCTION WELLS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/12/2021	Project No.: CM20167800

wood. Figure 2.11

Date 10/29/2021 Printed by mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\esri\revised_db\ib_0211_prod_well.mxd



Explanation:

- Minimal producer
- River/Stream
- Reservior/Lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 3 6 12
Miles

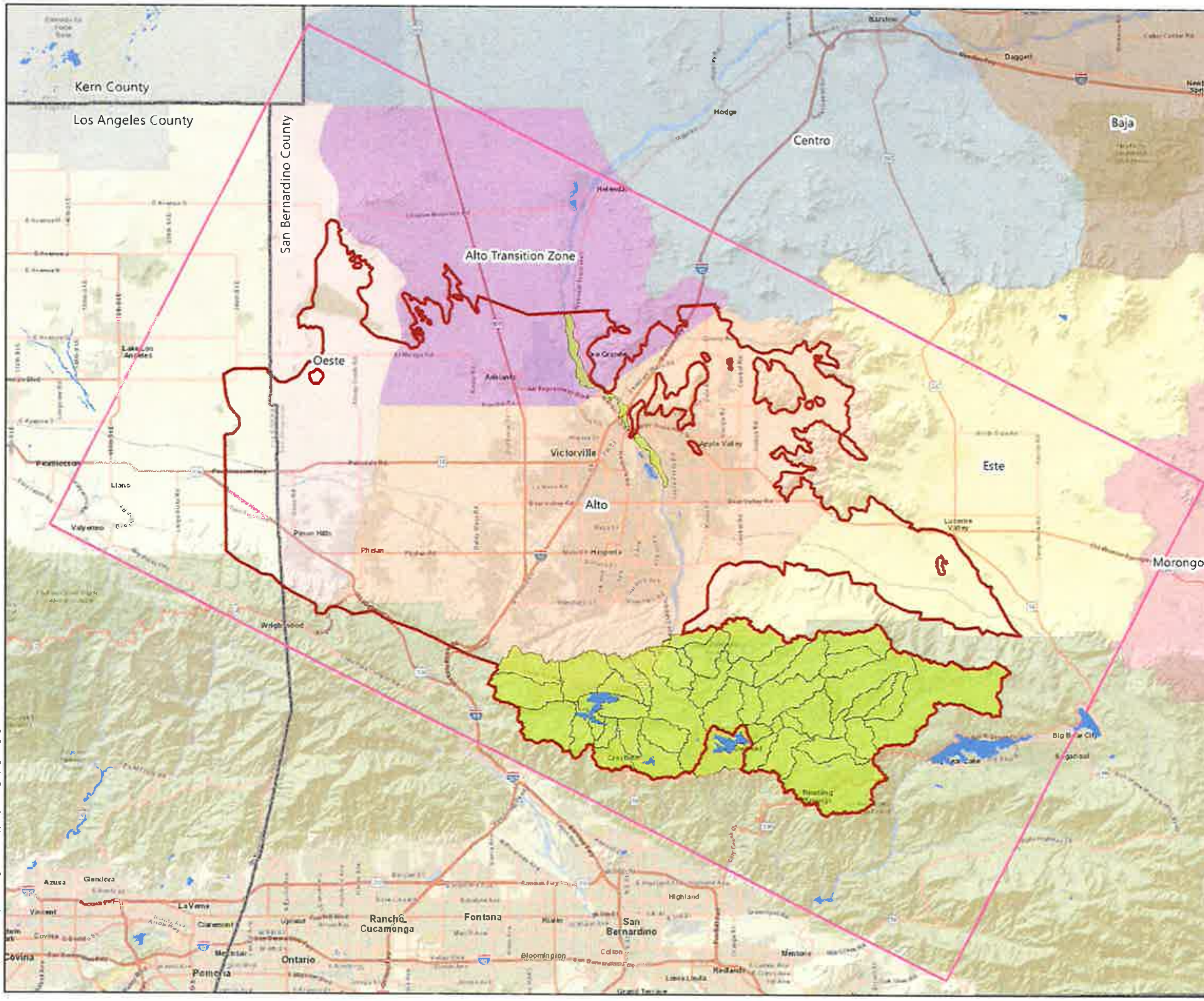
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

MINIMAL PRODUCERS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 2.12

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\gis\revised_0.0\fig_0212_min_producers.mxd



Explanation:

- Reservior/Lake
- Model domain
- Active model domain
- Evapotranspiration zone

Mojave Water Agency (MWA) subareas

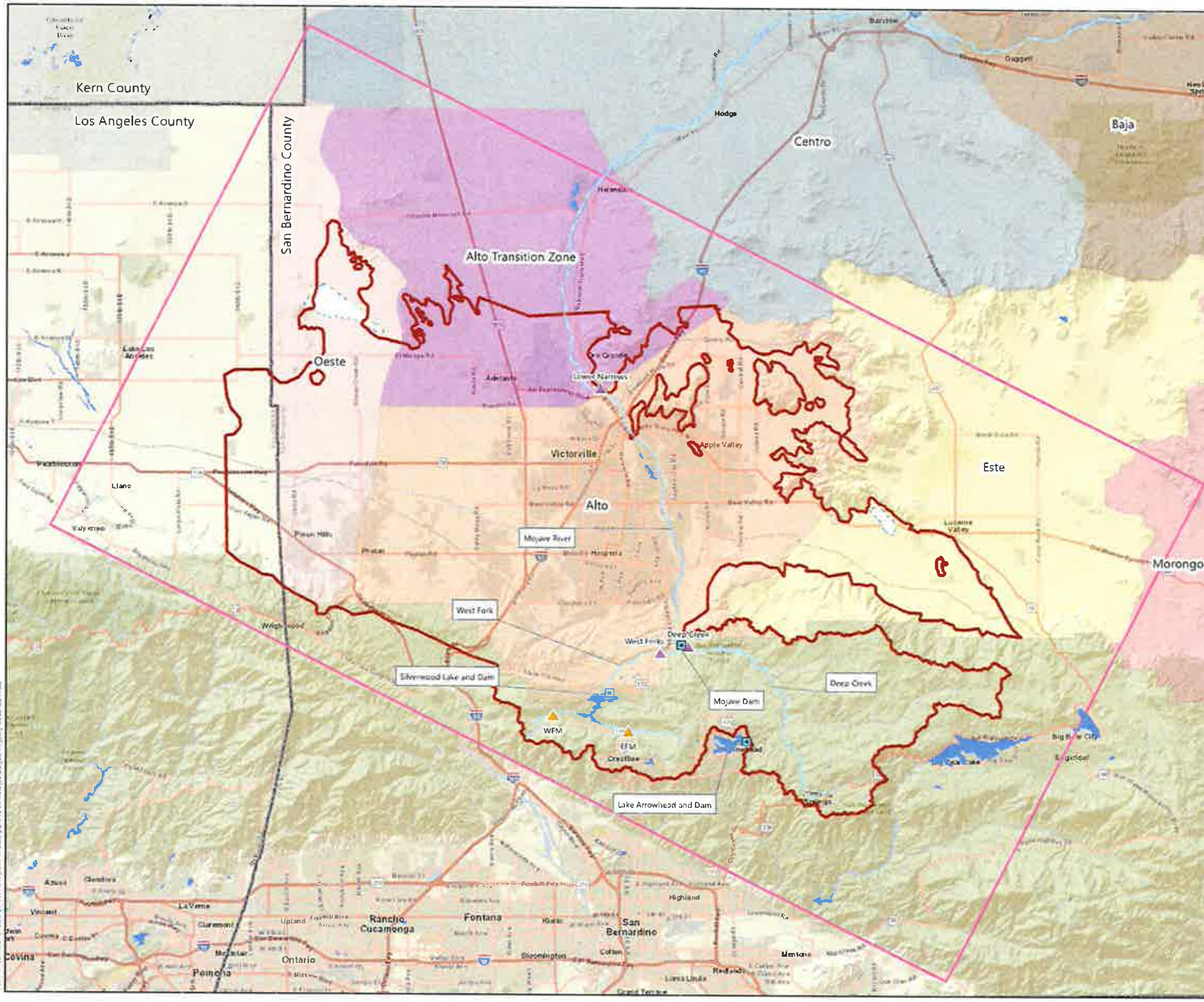
- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

EVAPOTRANSPIRATION ZONES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	2.13



Explanation:

- Department of Water Resources stream gage
- USGS stream gage
- Dam
- River/Stream
- Reservior/Lake
- Dry lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 3 6 12 Miles

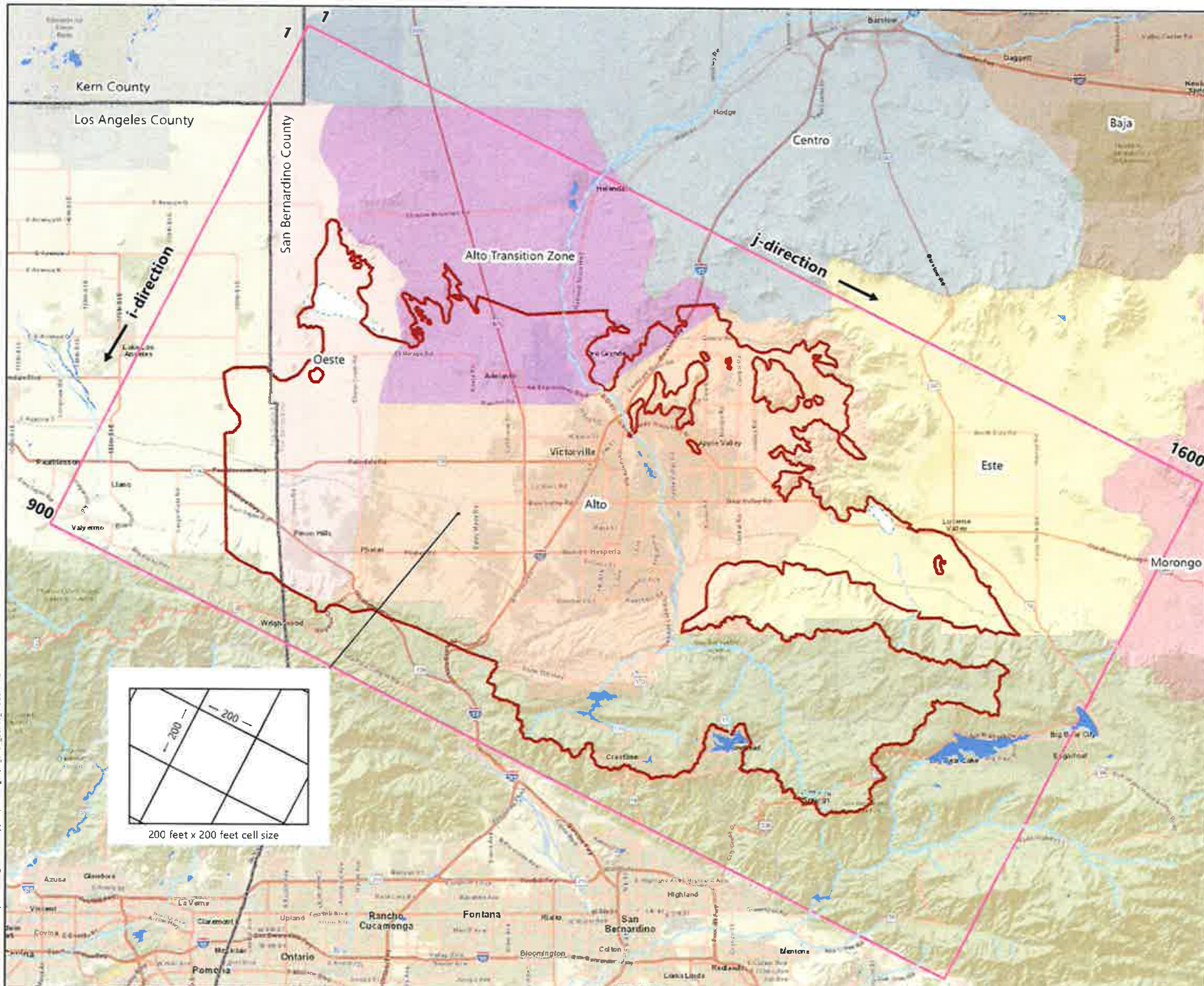
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

SURFACE WATER FEATURES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 2.14

Date 10/29/2021 Printed by mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\...\revised_0509_0214_sw_features.mxd



Explanation:

- River/Stream
- Reservior/Lake
- Dry lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

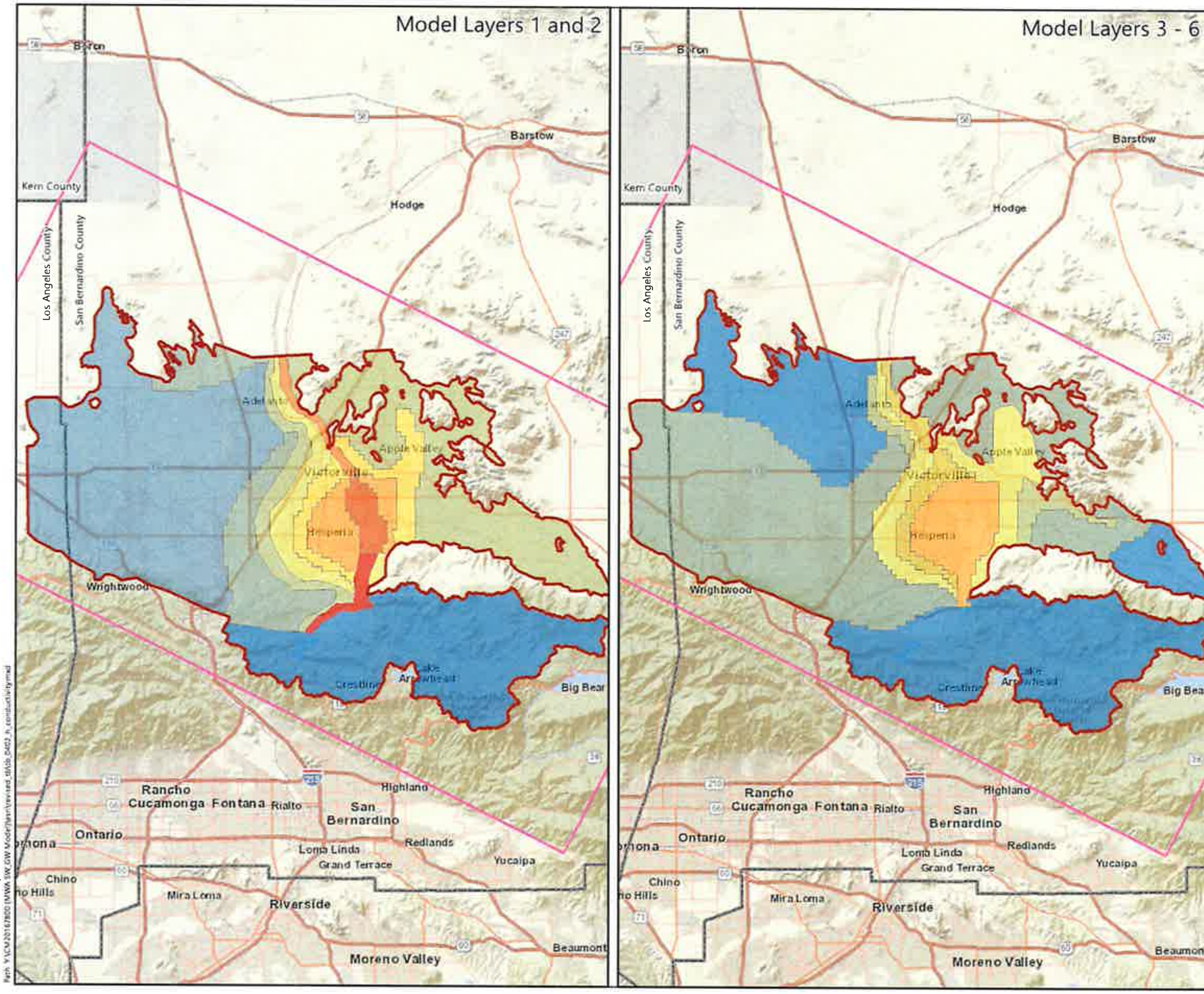
0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

MODEL GRID
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.		Figure 4.1

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\esri\revised_tb\tb_0401_active_model.mxd



Explanation

- Model domain
- Active model domain
- County boundary

Horizontal hydraulic conductivity (feet/day)

- 1
- 2
- 2.5
- 5
- 10
- 17
- 25
- 200
- 500
- 600

0 2 4 8
Miles

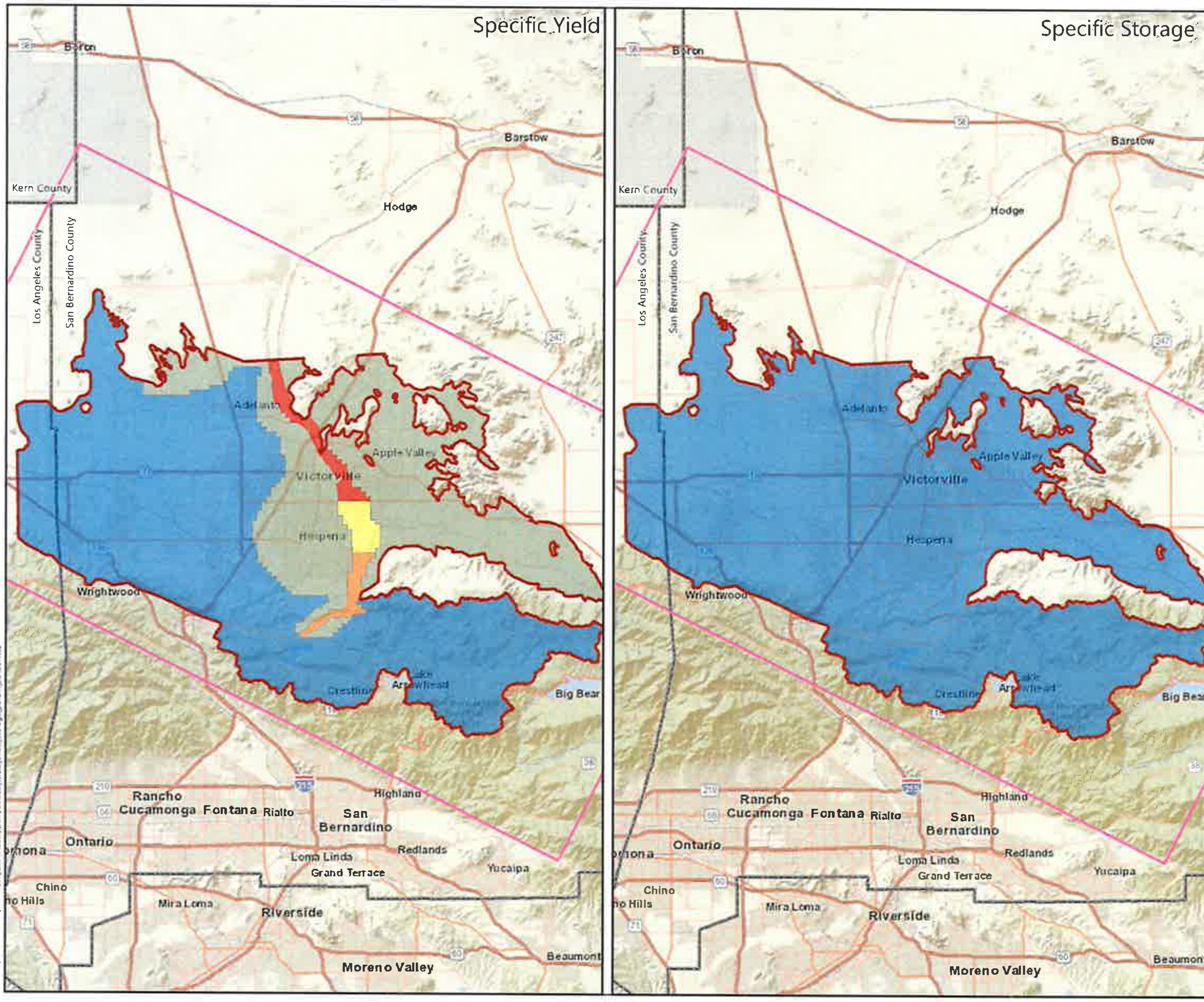
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

INITIAL HORIZONTAL HYDRAULIC CONDUCTIVITY ZONES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 4.2

Date 10/29/2021 Printed by mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\arc\revised_stds\b_0402_h_conductivity.mxd



Explanation

- Model domain
- Active model domain
- County boundary

Specific yield

- 0.05
- 0.12
- 0.26
- 0.38
- 0.39

Specific storage (1/foot)

- 0.000007

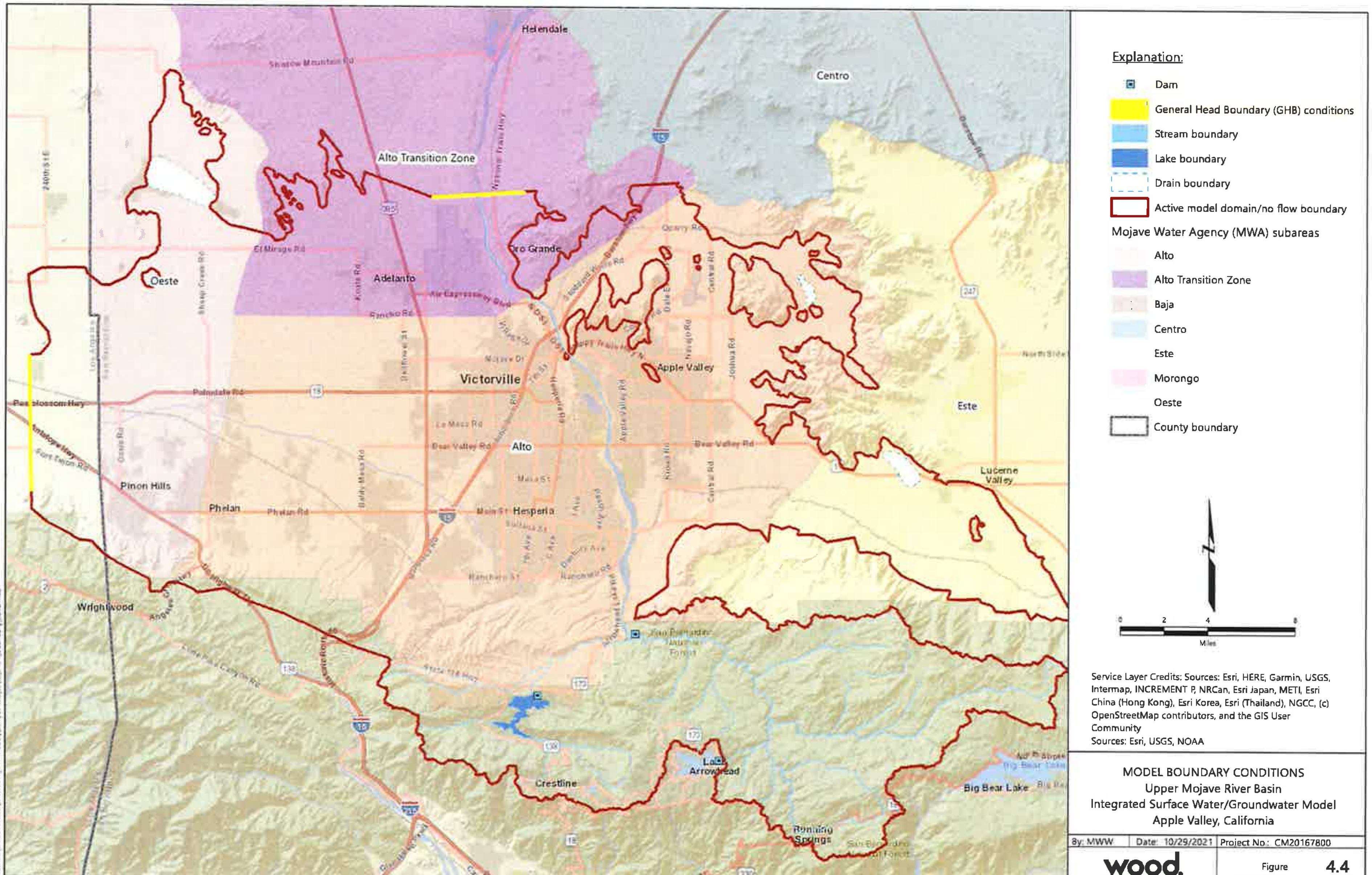
0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

INITIAL STORAGE
PARAMETER ZONES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	4.3

Date 10/29/2021 Printed by mikewallace2



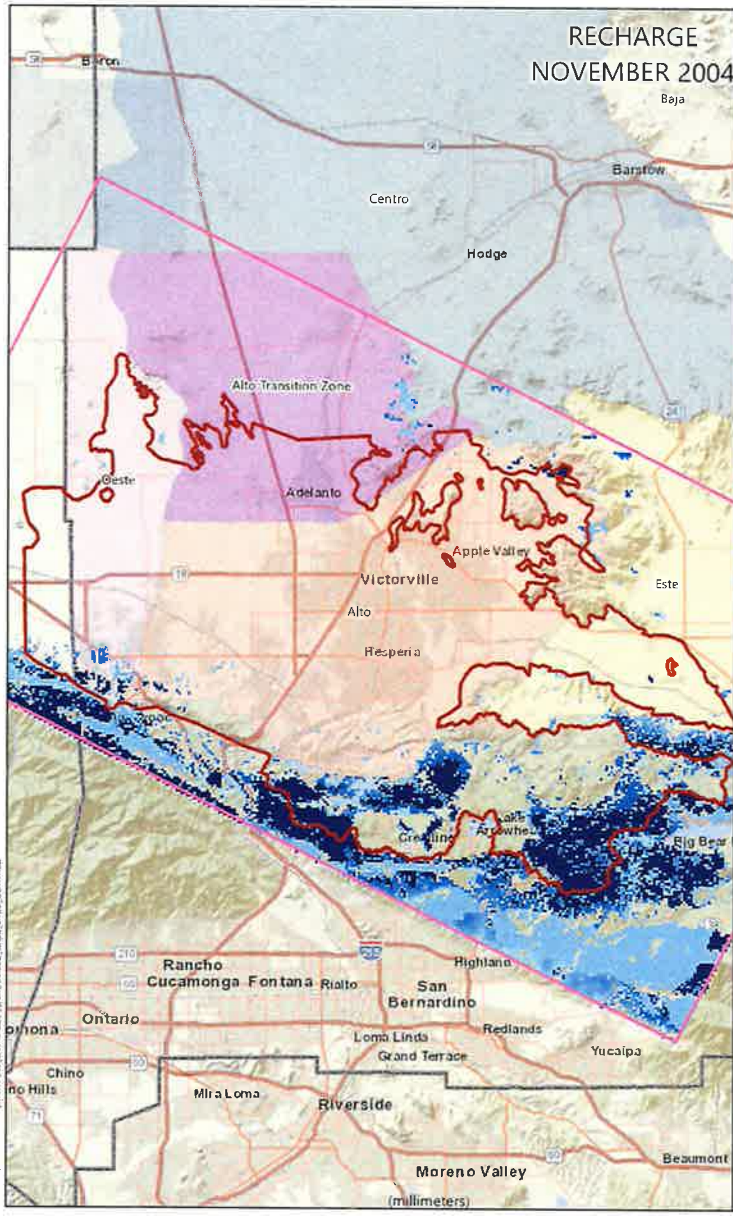
MODEL BOUNDARY CONDITIONS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

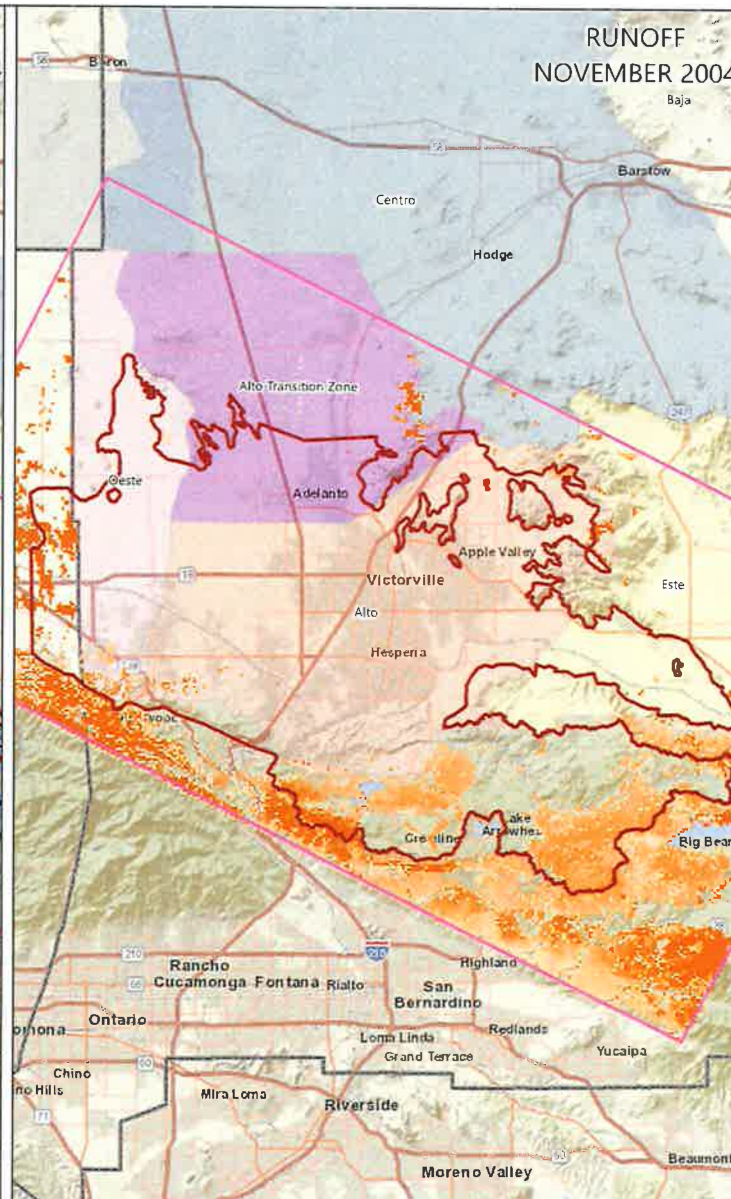
By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 4.4

Date 10/29/2021 Printed by mikewallace2





Explanation:

Model domain

Active model domain

Mojave Water Agency (MWA) subareas

Alto

Alto Transition Zone

Centro

Este

Oeste

County boundary

Recharge - November 2004 (millimeters)
142
70
0

Runoff - November 2004 (millimeters)
238
119
0

Note:

Output from Basin Characerization Model (BCM) used as input to MODFLOW-NWT Model.

0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

BASIN CHARATERIZATION
MODEL OUTPUT
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	4.5

Date 10/29/2021 Printed by mike.wallace2
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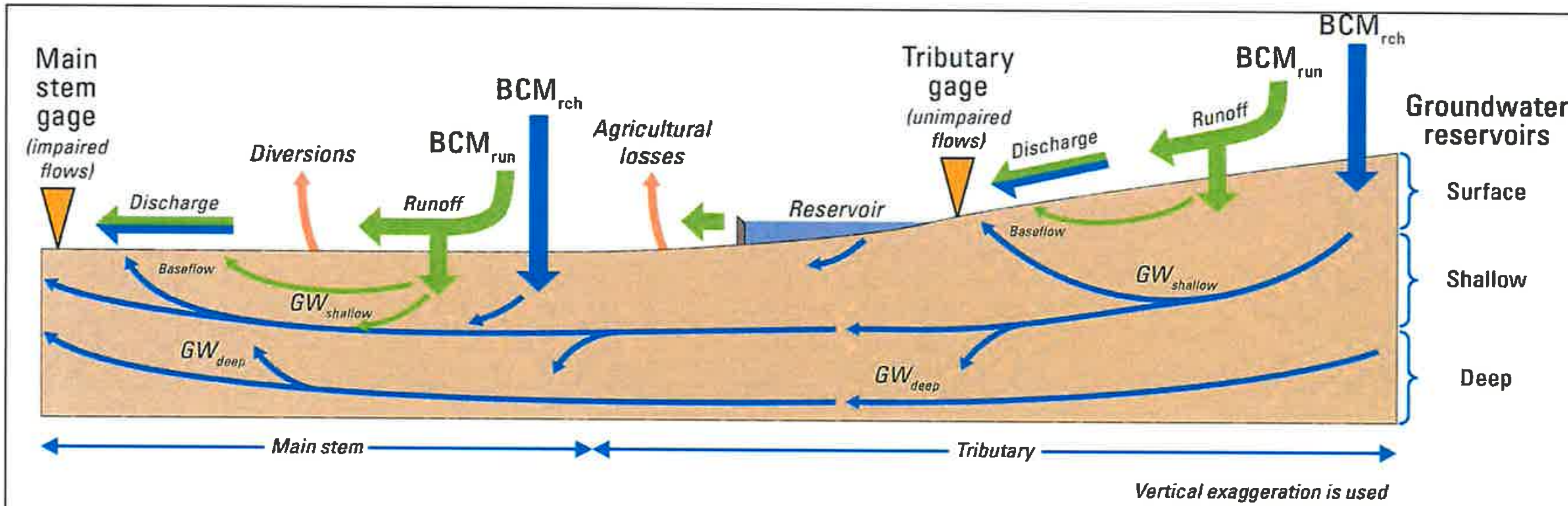


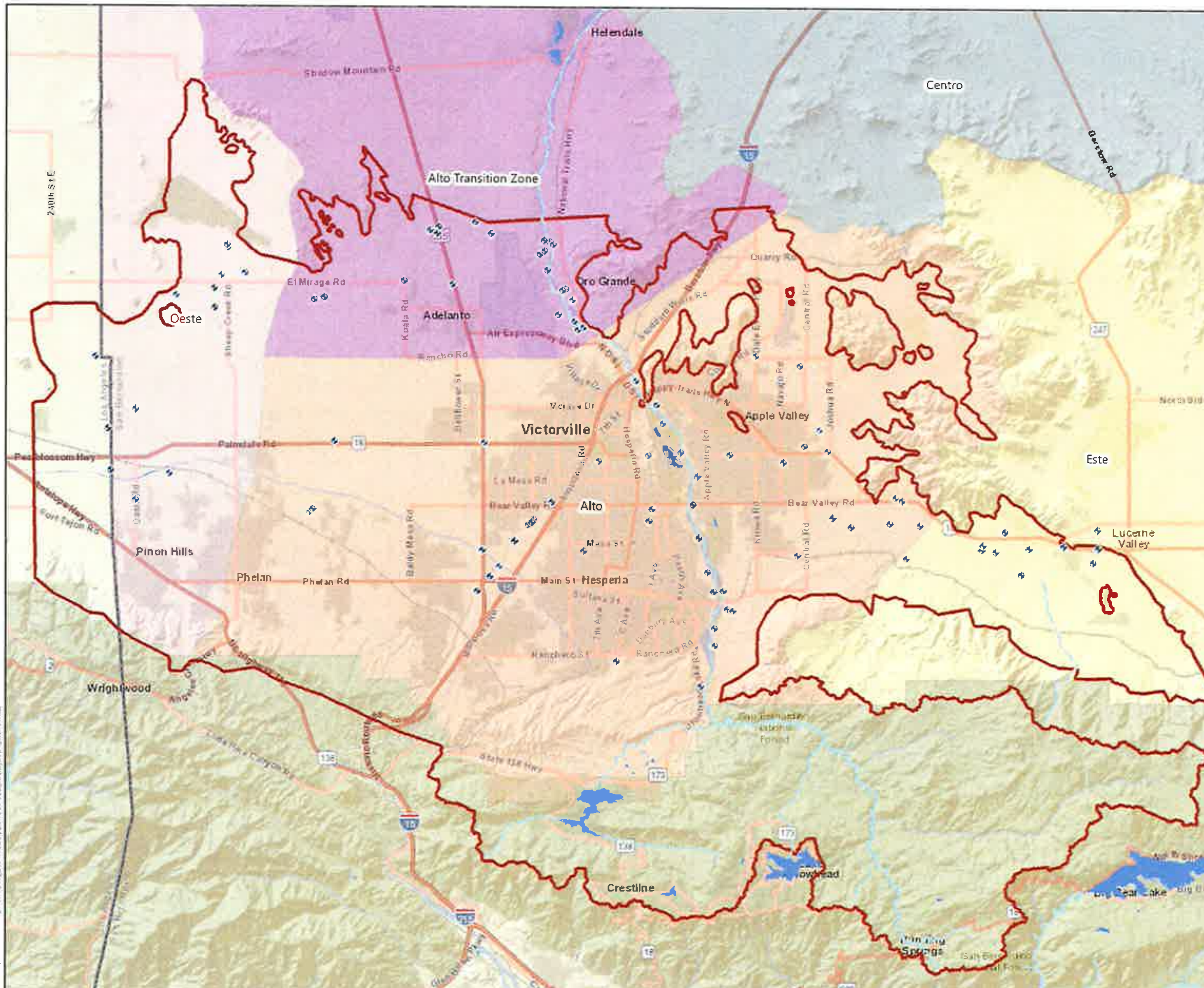
Source: Flint et al., 2019

BCM CONCEPTUAL MODEL FLUXES
UPPER MOJAVE RIVER BASIN
Integrated Surface Water/ Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 4.6



Explanation:

- Monitoring well
- River/Stream
- Reservior/Lake
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

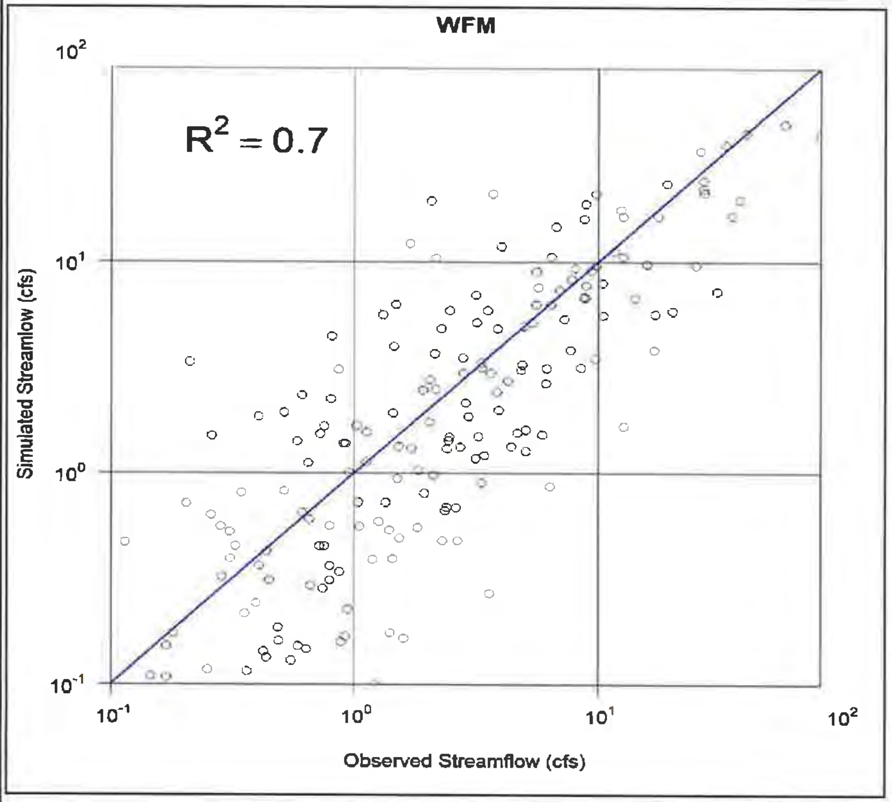
MONITORING WELL LOCATIONS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

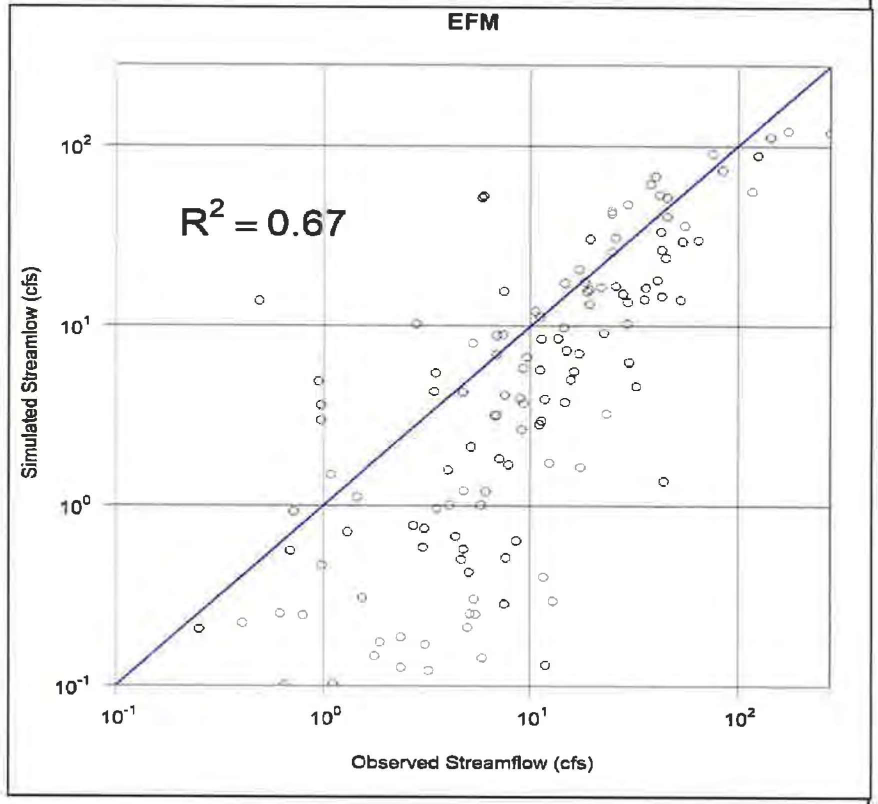
By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 5.1

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\ArcView\Map\ ...wells.mxd

\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 5.2 10/29/2021





Notes:

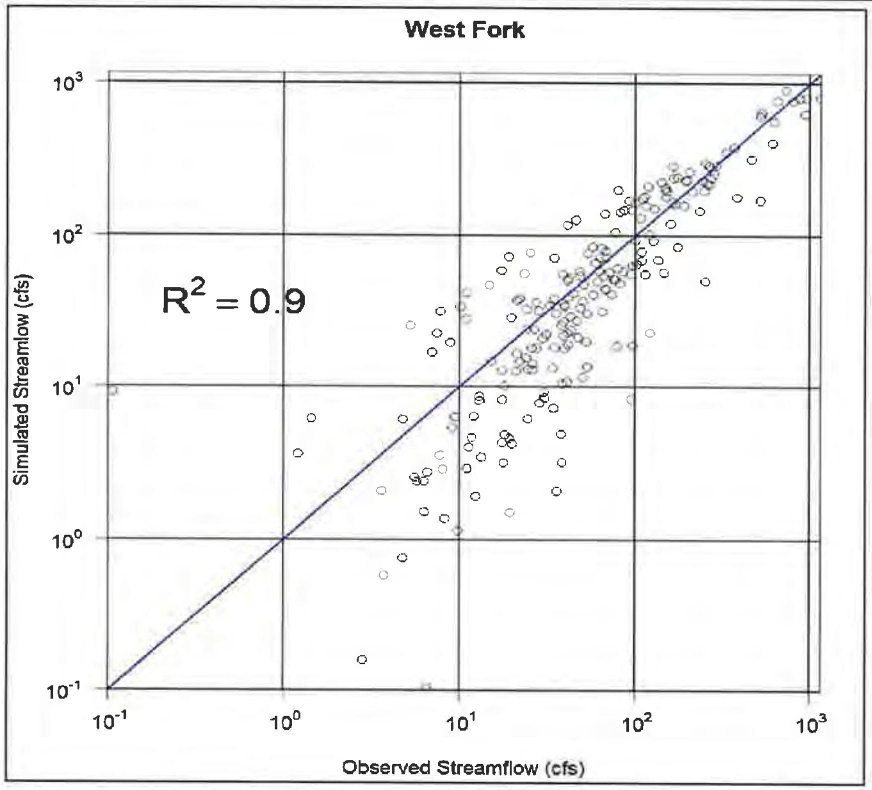
EFM = East Fort at Mojave
WFM = West Fork at Mojave
cfs = cubic feet per second

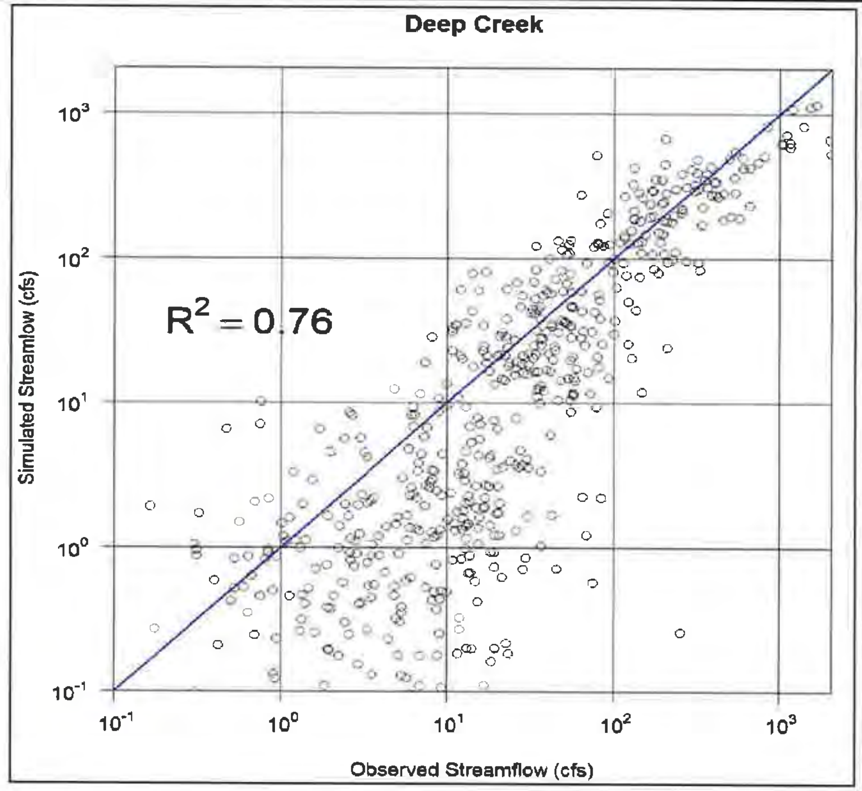
STREAMFLOW CALIBRATION: SIMULATED VERSUS OBSERVED VALUES (EFM AND WFM)
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 5.2





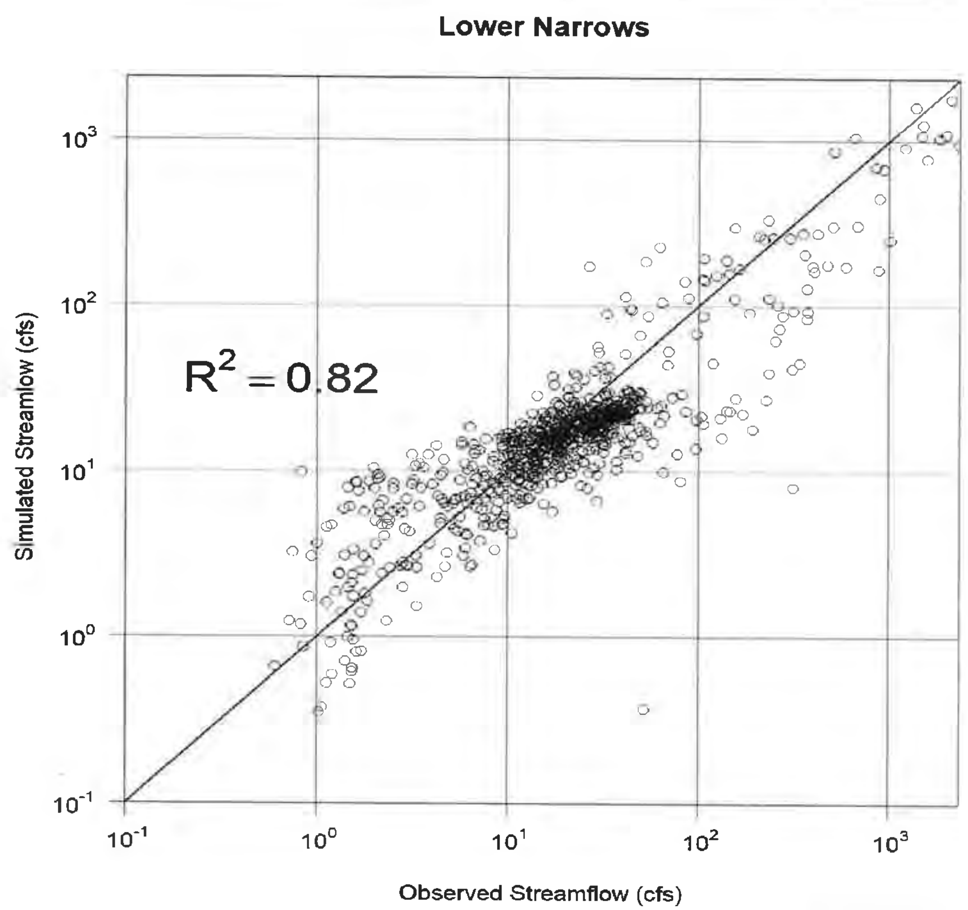
Notes:

cfs = cubic feet per second

STREAMFLOWS CALIBRATION: SIMULATED VERSUS OBSERVED VALUES (DEEP CREEK AND WEST FORK)
Upper Mojave River Basin
Integrated Surface Water/ Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.		Figure 5.3

\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 5.4 10/29/2021



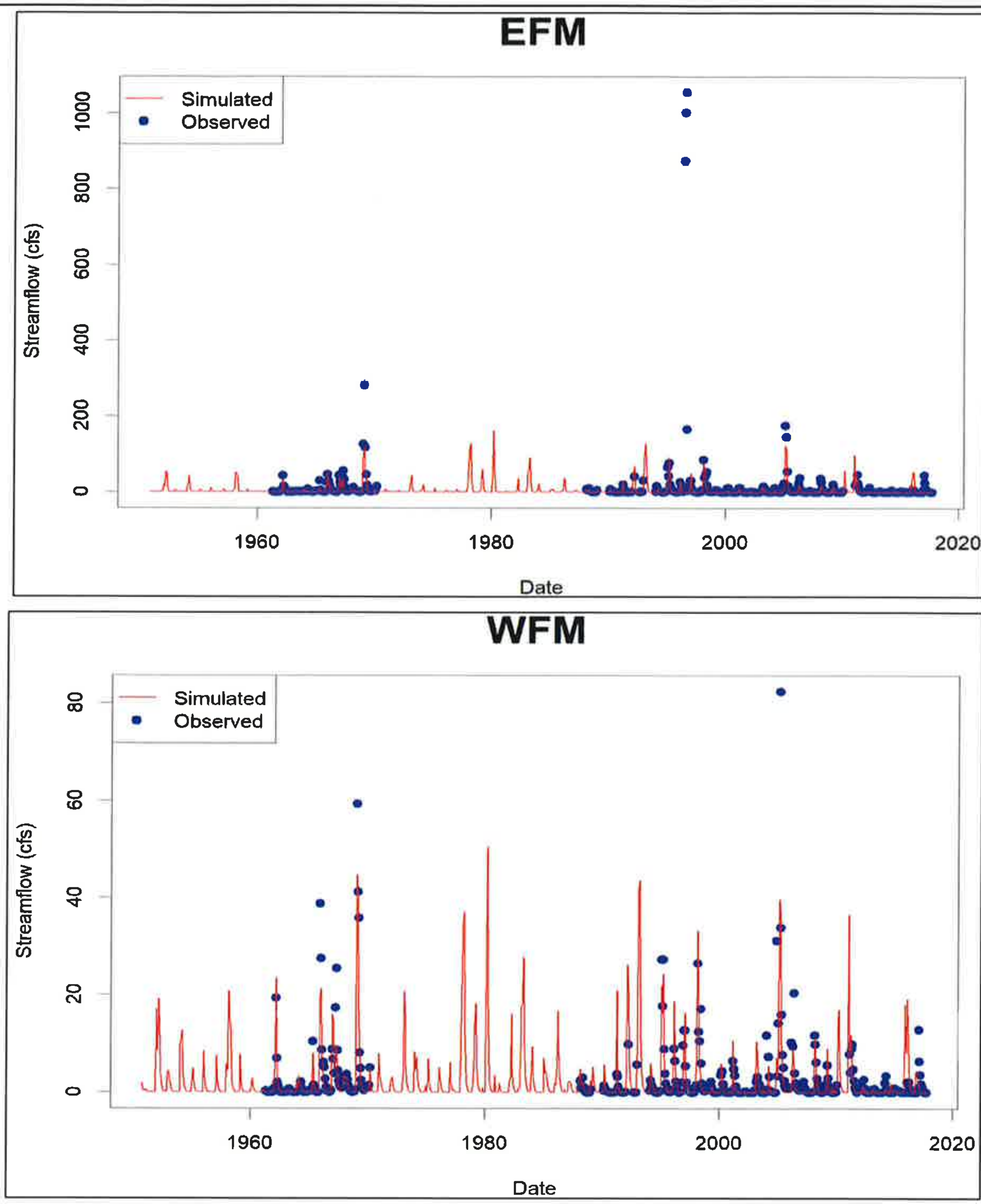
Notes:
cfs = cubic feet per second

STREAMFLOWS CALIBRATION: SIMULATED VERSUS OBSERVED VALUES (LOWER NARROWS)
Upper Mojave River Basin
Integrated Surface Water/ Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 5.4



Notes:

EFM = East Fork at Mojave

WFM = West Fork at Mojave

cfs = cubic feet per second

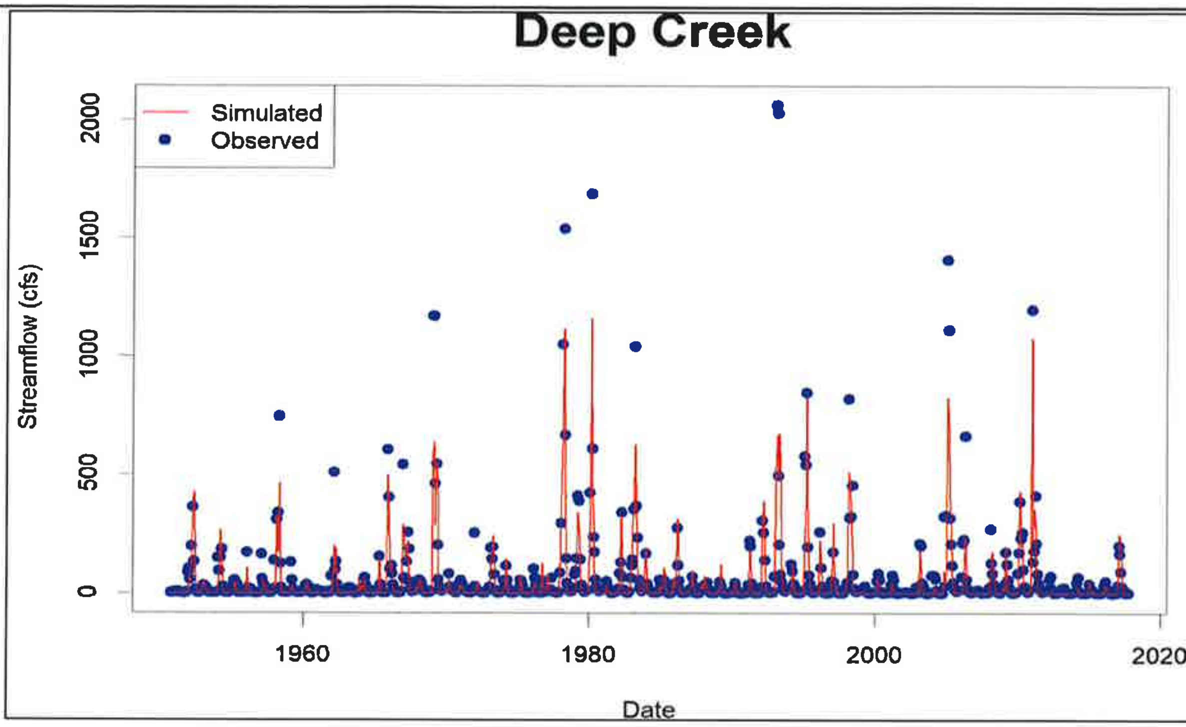
STREAMFLOWS CALIBRATION: OBSERVED AND SIMULATED TIME SERIES (EFM AND EFM)

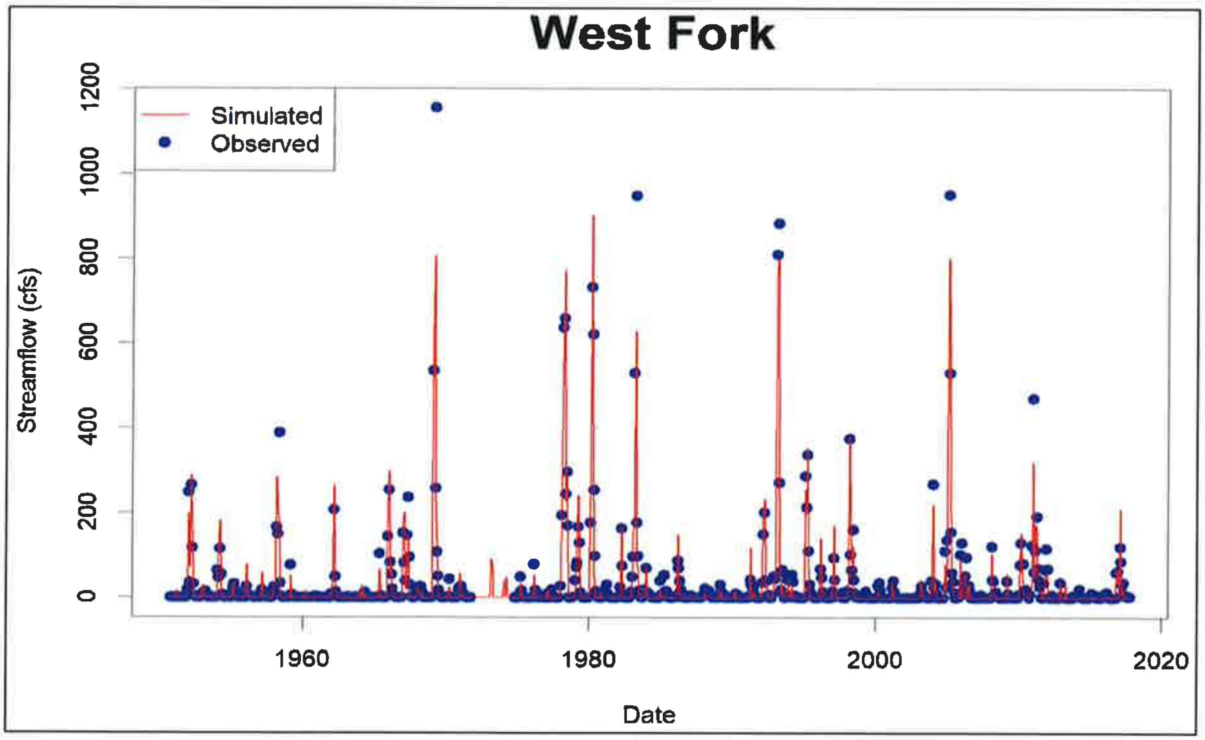
Upper Mojave River Basin

Integrated Surface Water/ Groundwater Model

Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.		Figure 5.5





Notes:

cfs = cubic feet per second

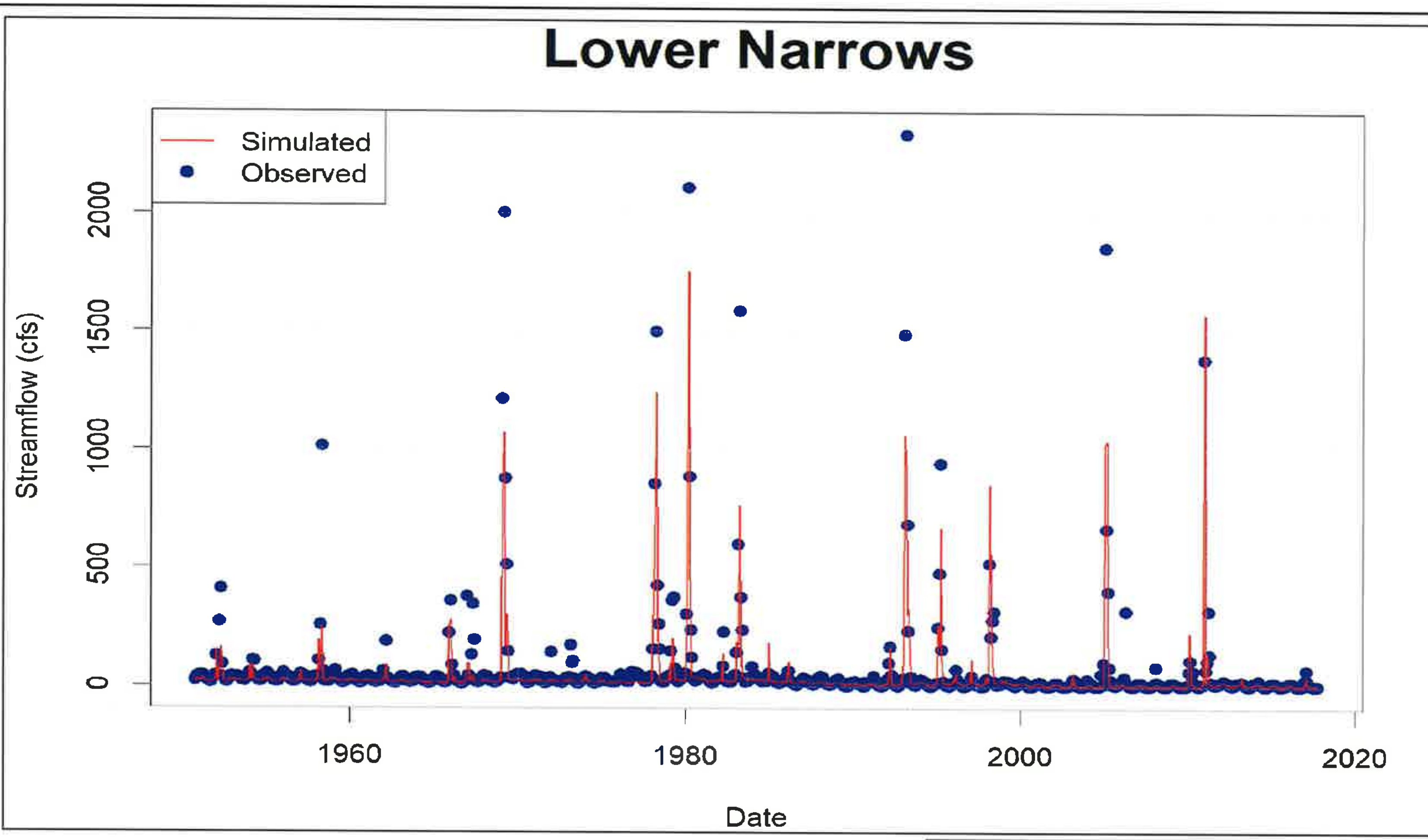
STREAMFLOWS CALIBRATION: OBSERVED AND SIMULATED TIME SERIES (DEEP CREEK AND WEST FORK)
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 5.6

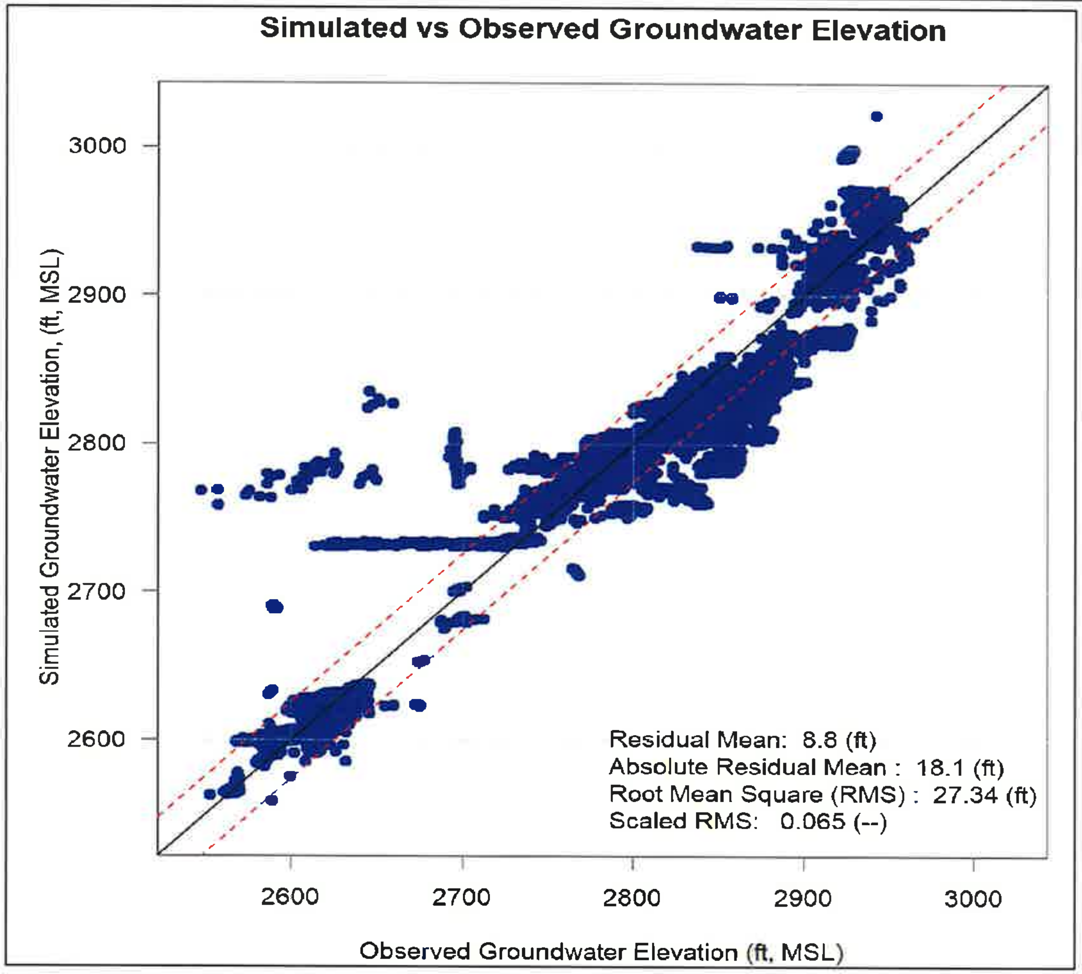
\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 5.7 10/29/2021



Notes:
cfs = cubic feet per second

STREAMFLOWS CALIBRATION: TIME SERIES OF SIMULATED AND OBSERVED VALUES (LOWER NARROWS)
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.		Figure 5.7

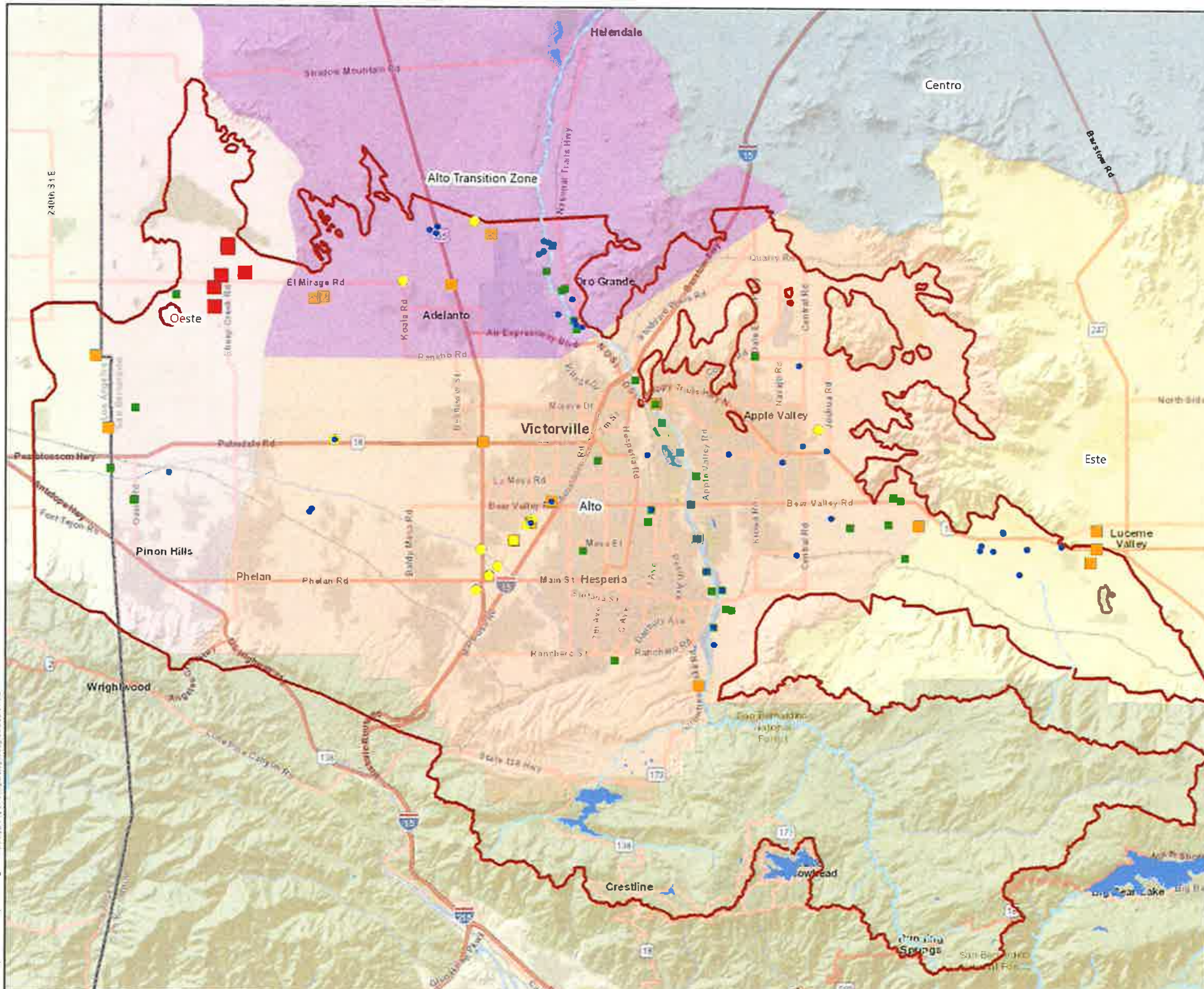


Notes:

MSL = Above Mean Sea Level

GROUNDWATER HEADS CALIBRATION:
SIMULATED VERSUS OBSERVED VALUES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.		Figure 5.8



Explanation:

Model calibration average residual (feet)

- <-150
- -150 - -25
- -25 - 0
- 0 - 25
- >25-150
- River/Stream
- Reservior/Lake
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

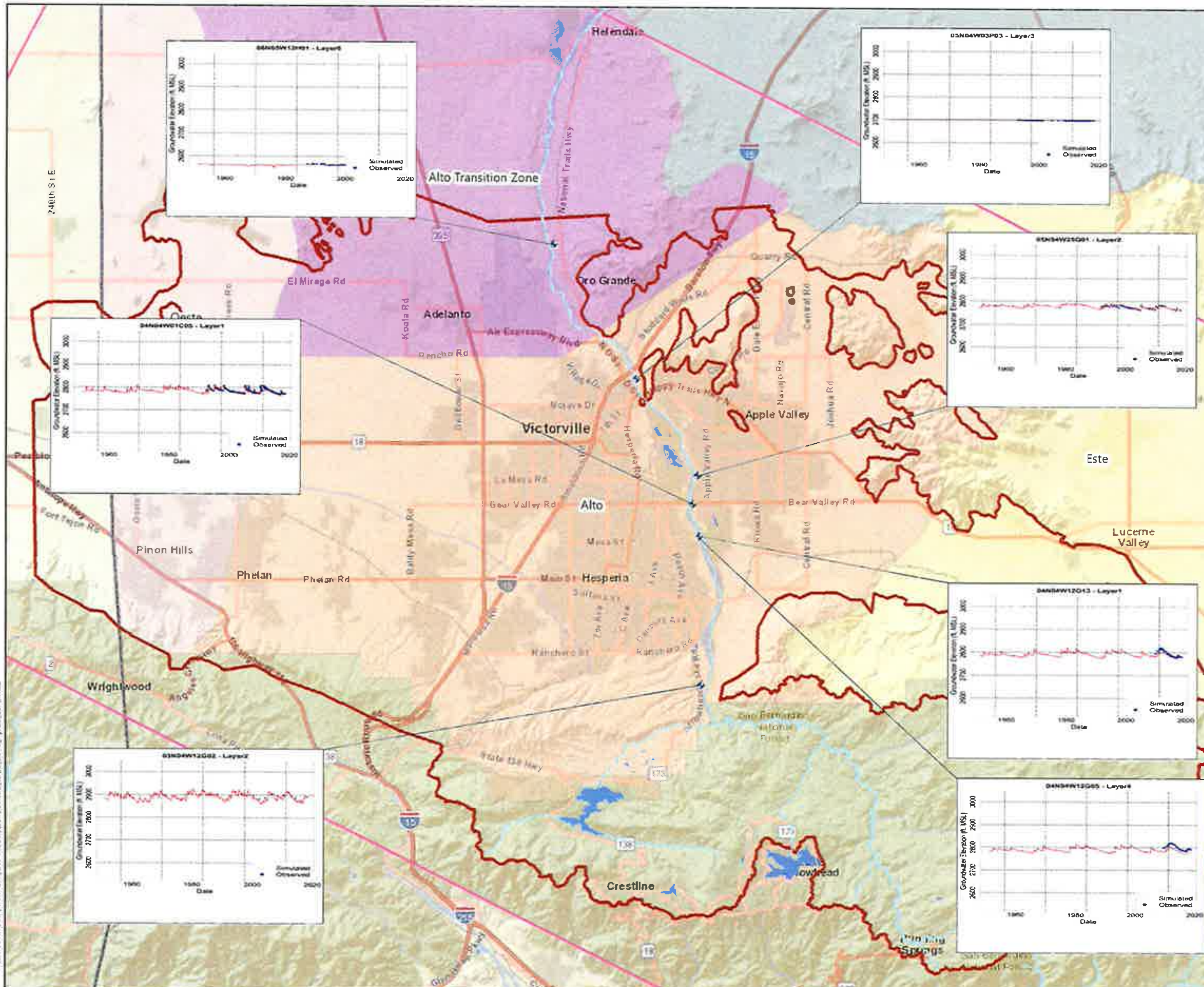
MODEL RESIDUALS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 5.9

Date 10/29/2021 Printed by mike.wallace2
Path Y:\CM20167800 (MWA SW_GW Model)\arc\revised_thru_0509_residuals.mxd



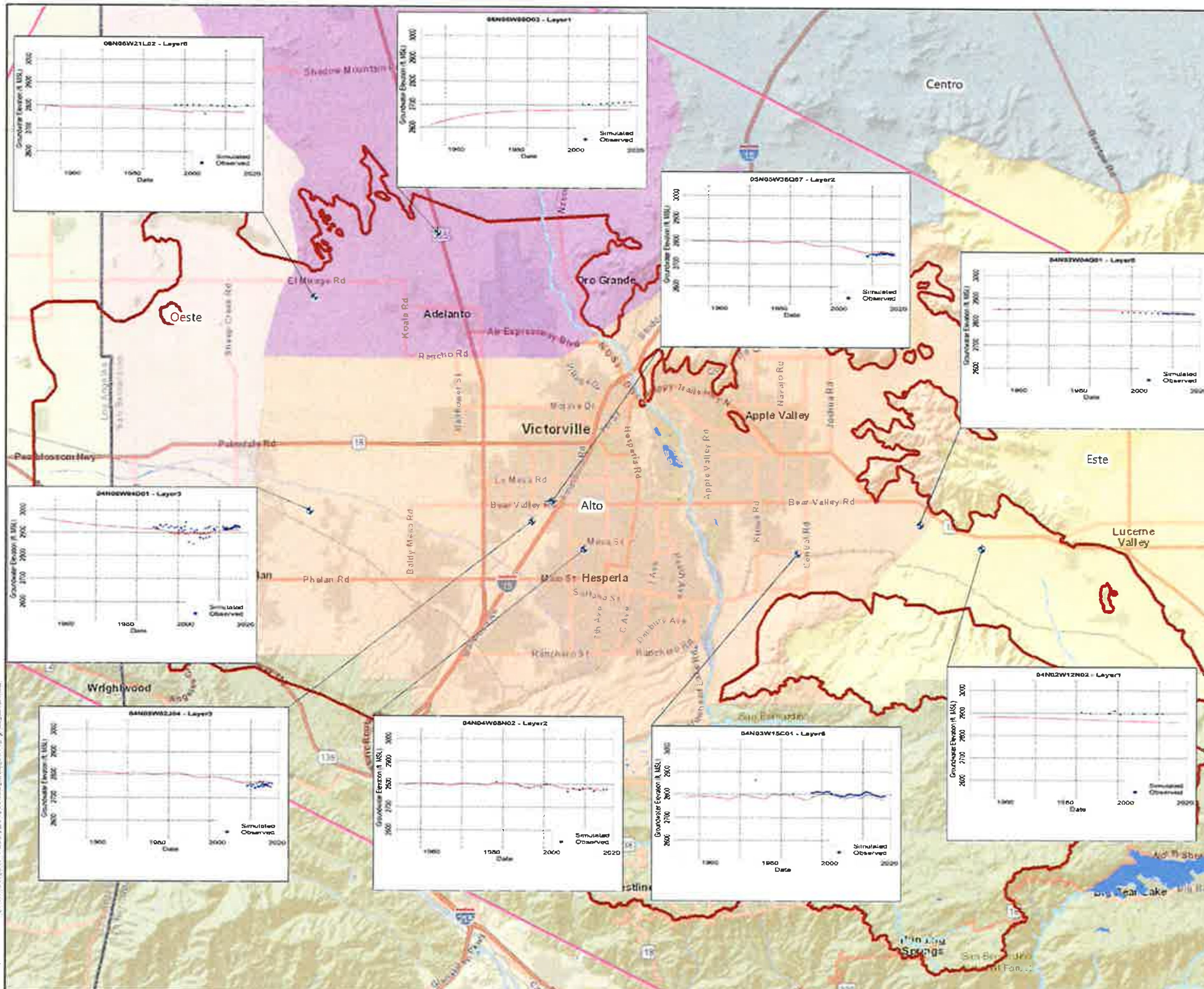
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

SELECTED MODEL CALIBRATION HYDROGRAPHS
ALONG MOJAVE RIVER
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 5.10



Explanation:

- Monitoring well
- River/Stream
- Reservior/Lake
- Model domain
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

0 2 4 8 Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

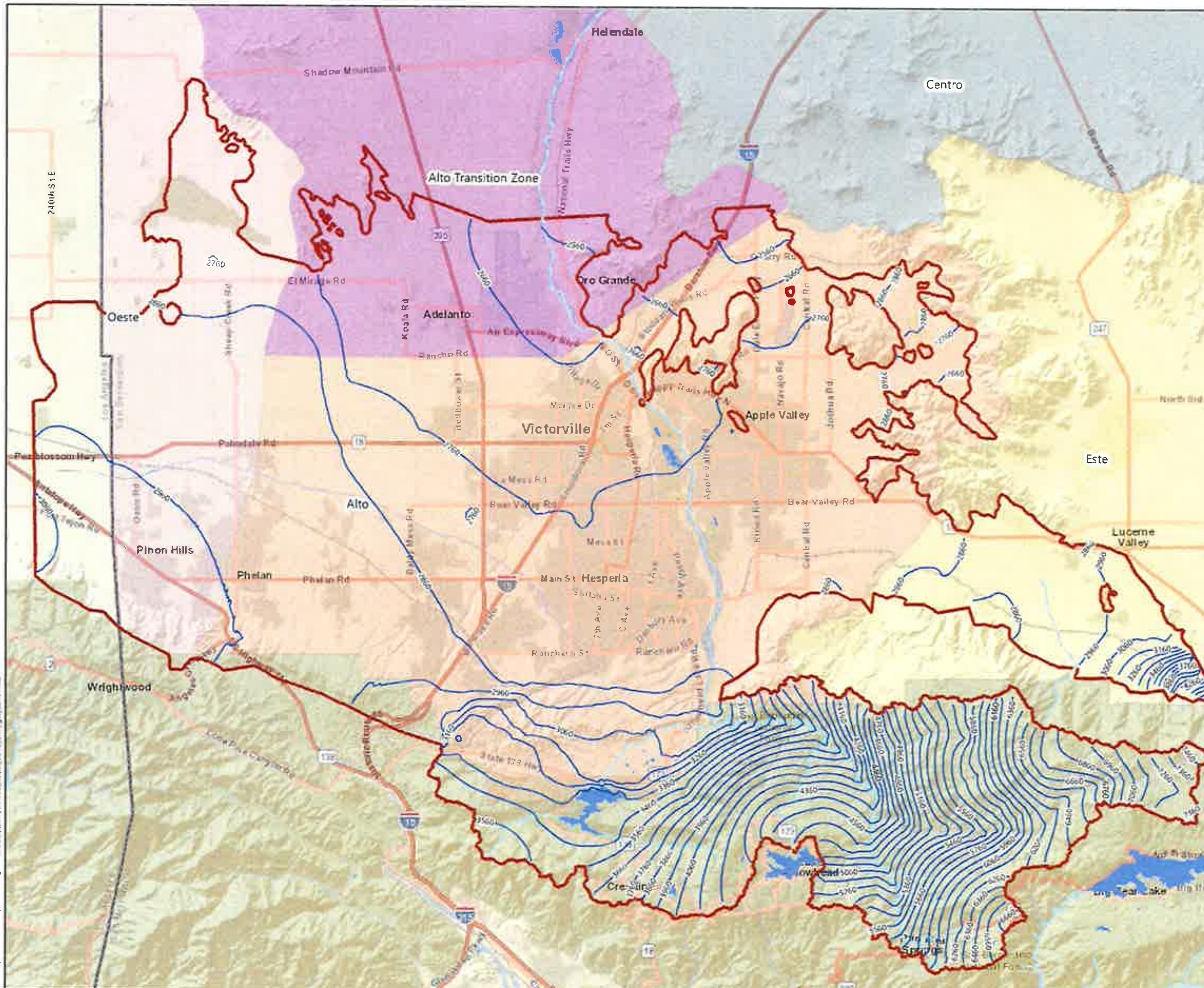
SELECTED MODEL CALIBRATION HYDROGRAPHS
REGIONAL
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 5.11

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\ArcMap\Revised_0519_0511_hydro_calib.mxd



Explanation:

- Calibrated groundwater elevation (feet above Mean Seal Level (MSL))
- River/Stream
- Reservior/Lake
- Active model domain

Mojave Water Agency (MWA) subareas

- Alto
- Alto Transition Zone
- Baja
- Centro
- Este
- Morongo
- Oeste
- County boundary

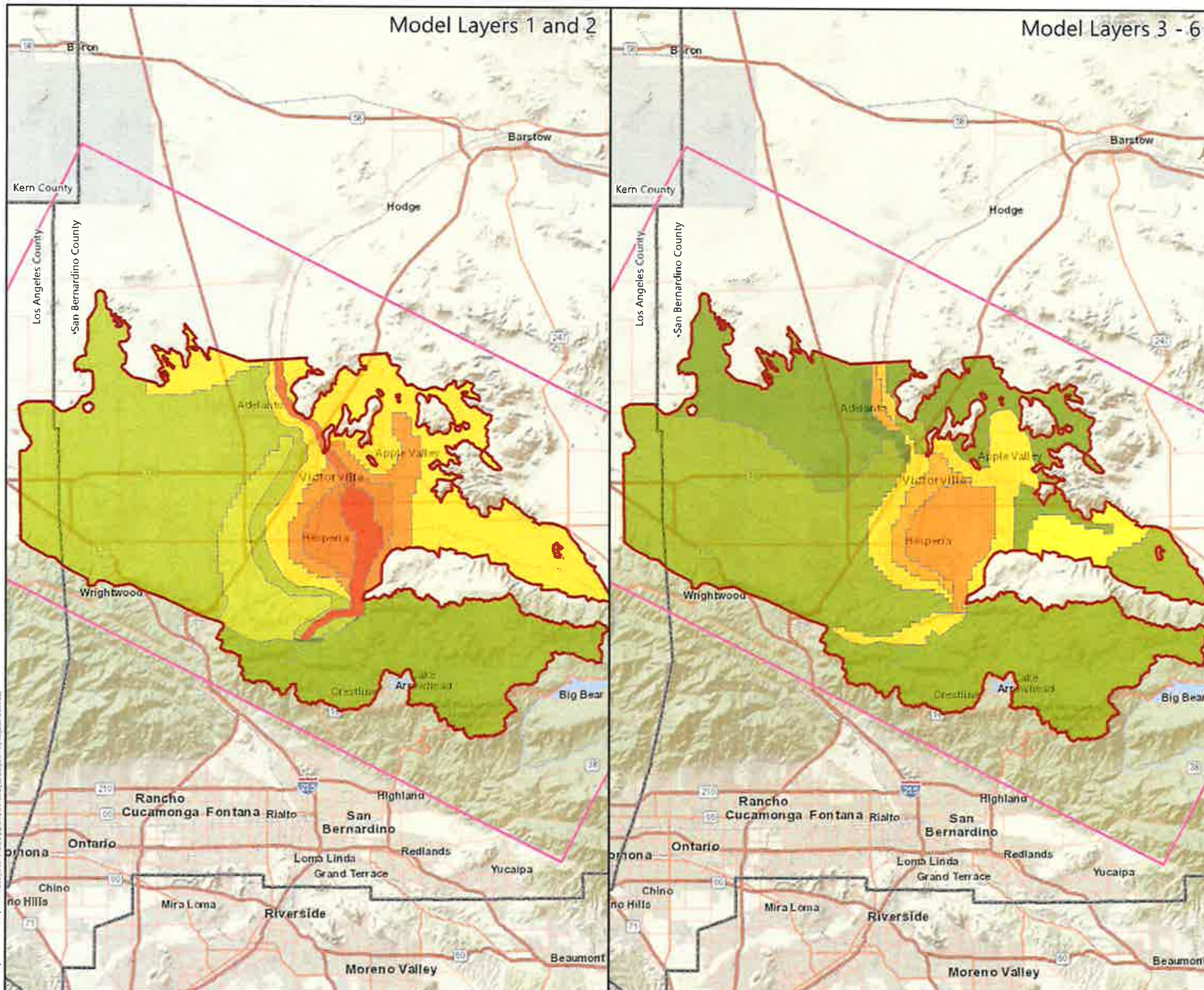
0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

SIMULATED GROUNDWATER CONTOURS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	5.12

Date 10/29/2021 Printed by mike.wallace2
Path Y:\CM20167800 MWA SW GW Model\arcview\mxd_0512_sim_gw_cont.mxd



Explanation:

- Model domain
- Active model domain
- County boundary

Hydraulic conductivity (feet)

- 1.0
- 2.6
- 3.0
- 5.0
- 7.5
- 8.0
- 10
- 20
- 30
- 60
- 75
- 100
- 150
- 450

0 2 4 8
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

CALIBRATED HYDRAULIC CONDUCTIVITIES
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 5.13

Date 10/29/2021 Printed by mike.wallace2
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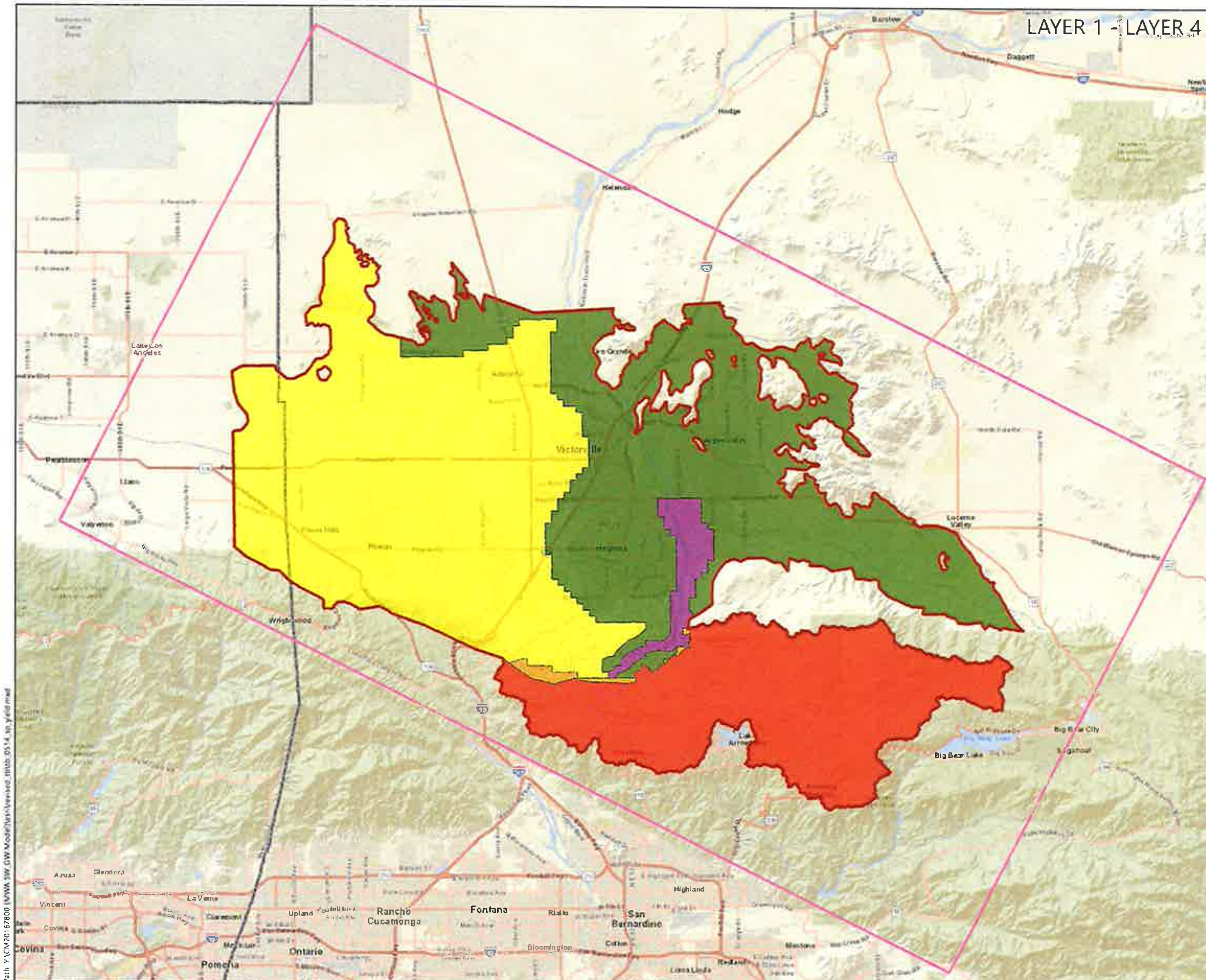
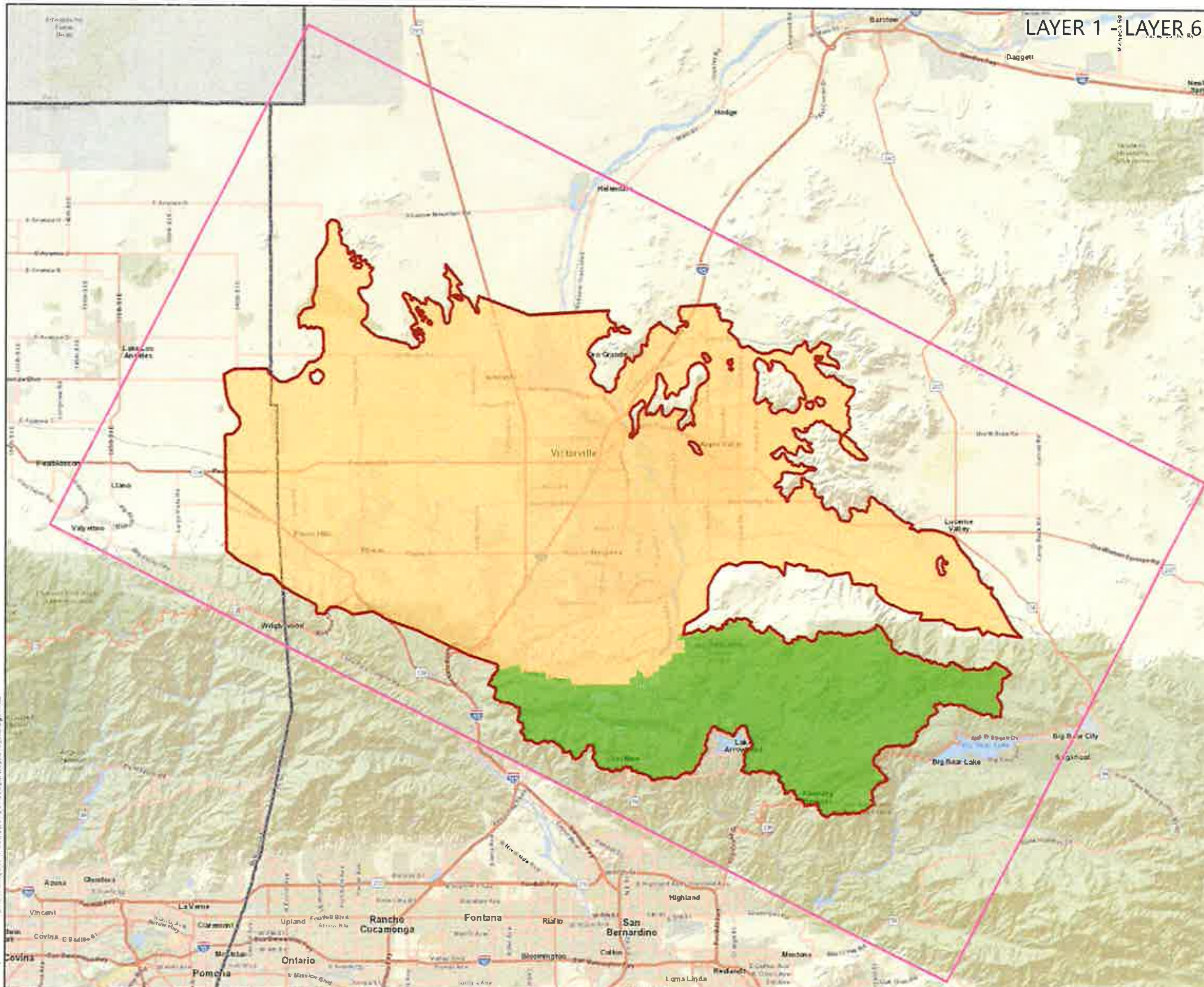


Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

CALIBRATED SPECIFIC YIELD
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	5.14

Date: 10/29/2021 Printed by: mike.wallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\ais\revised_mxds\0514_sp_yield.mxd



Explanation:

- Model domain
- Active model domain

Specific storage (1/foot)

- 0.000002
- 0.00001
- County boundary

0 3 6 12
Miles

Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

CALIBRATED SPECIFIC STORAGE
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/12/2021	Project No.: CM20167800
wood.	Figure	5.15

Date 10/29/2021 Printed by mike.wallace2
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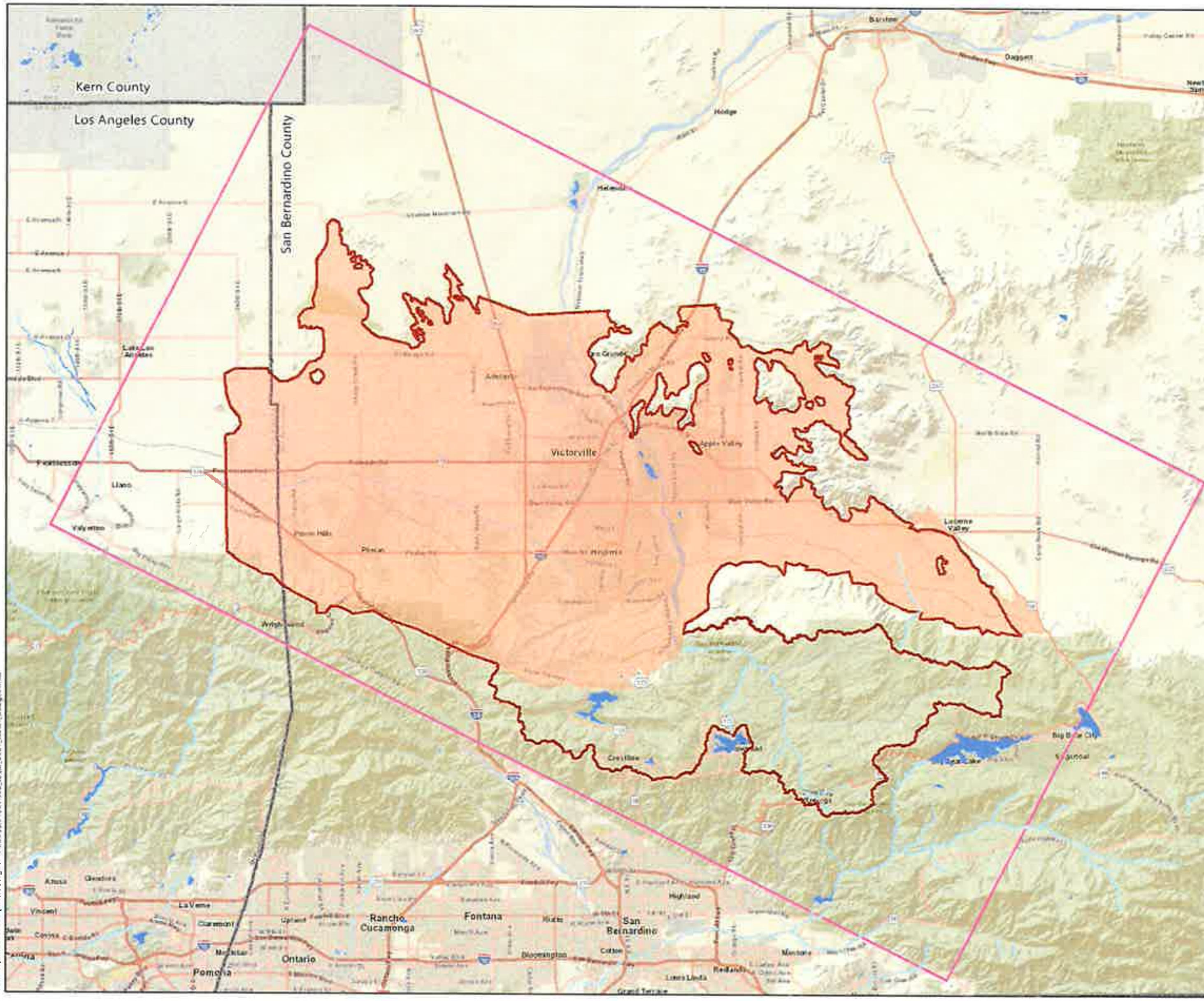


Explanation:

- Reservior/Lake
- Model domain
- Water budget area
- Active model domain
- County boundary

0 3 6 12
Miles

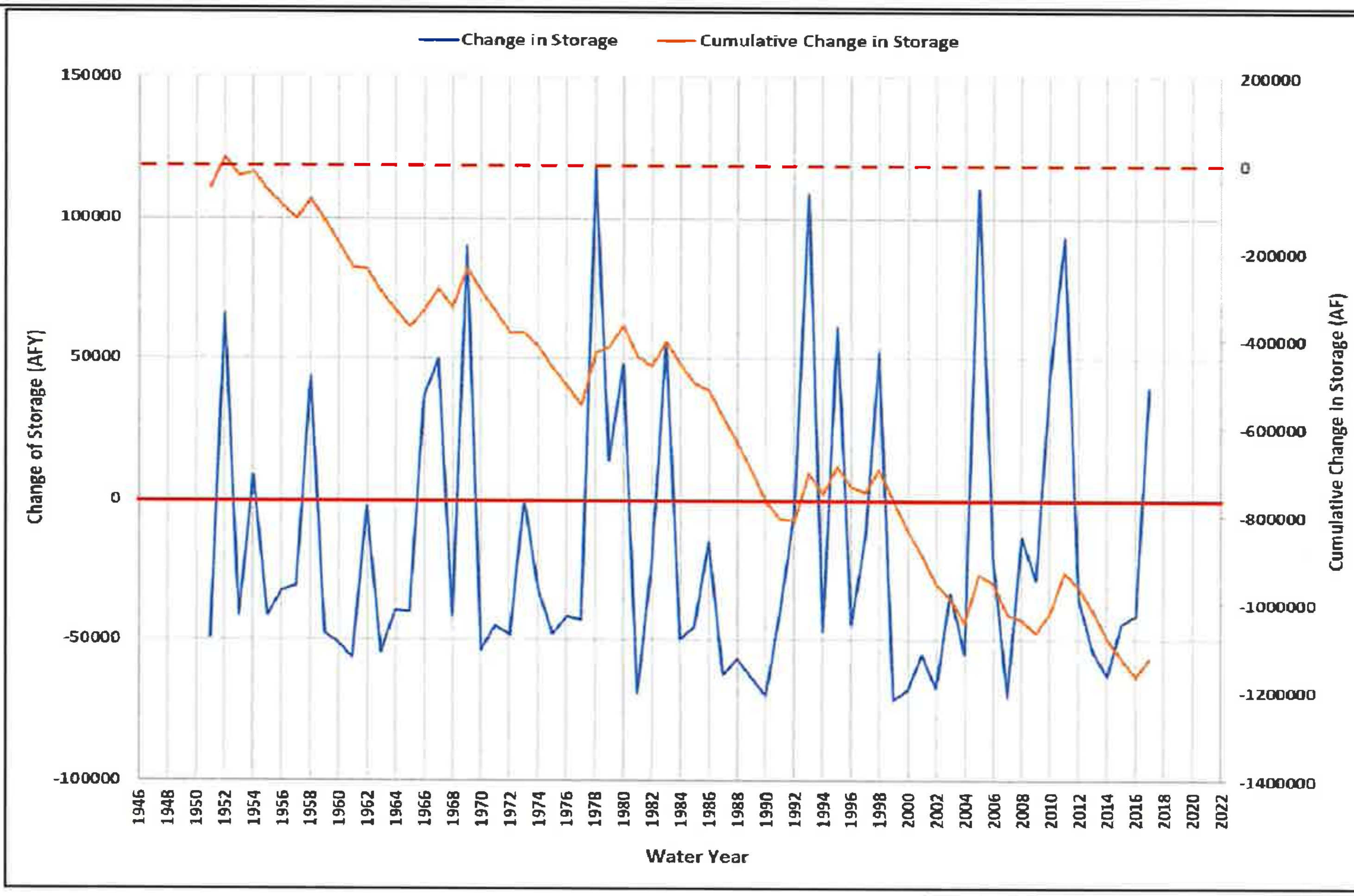
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

WATER BUDGET AREA
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	6.1

Date 10/29/2021 Printed by mike.wallace2
Path Y:\CM20167800 (MWA SW_GW Model)\Revised_draft_0601_water_budget.mxd

\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 6.2 12/14/2021



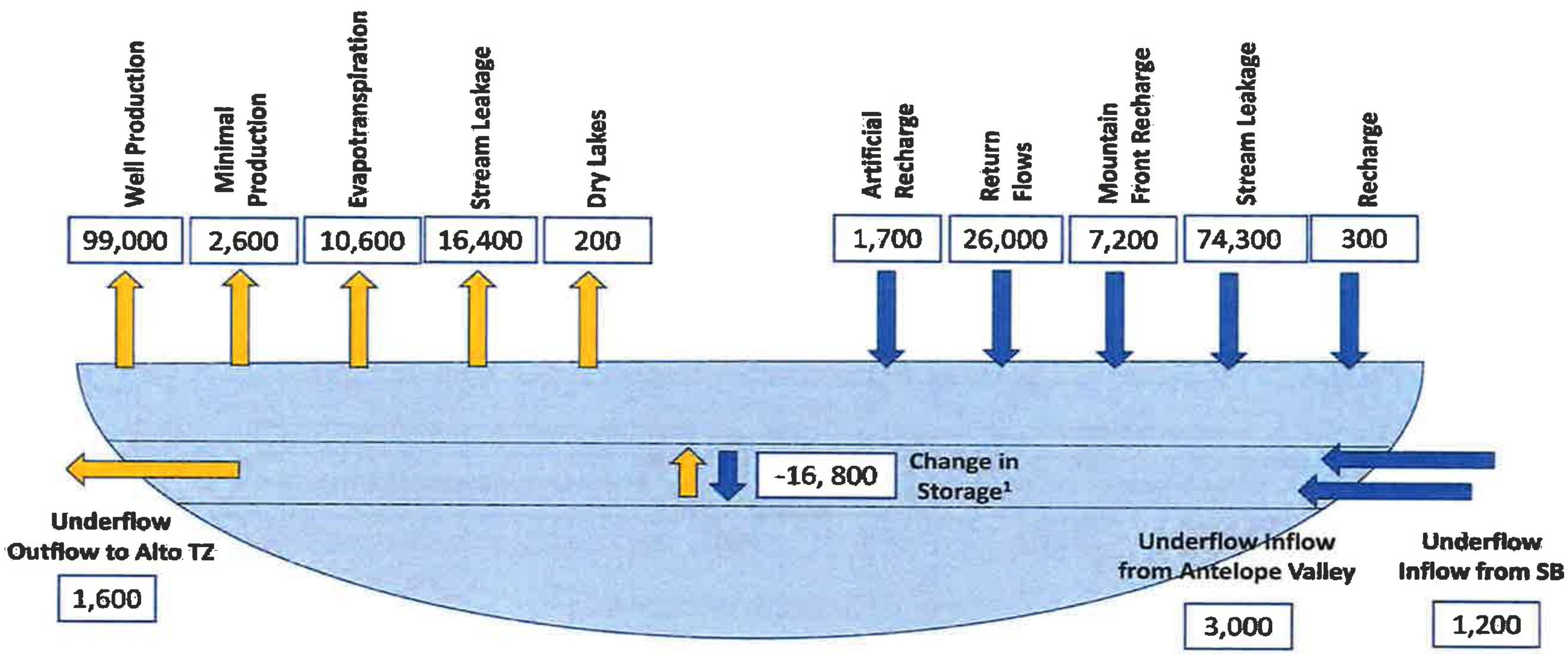
Notes:

AFY = Acre-feet per year

AF = Acre-feet

SIMULATED CHANGE OF STORAGE FROM WY 1951 TO WY 2017
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.		Figure 6.2



Notes:

All values in Acre-Feet per Year

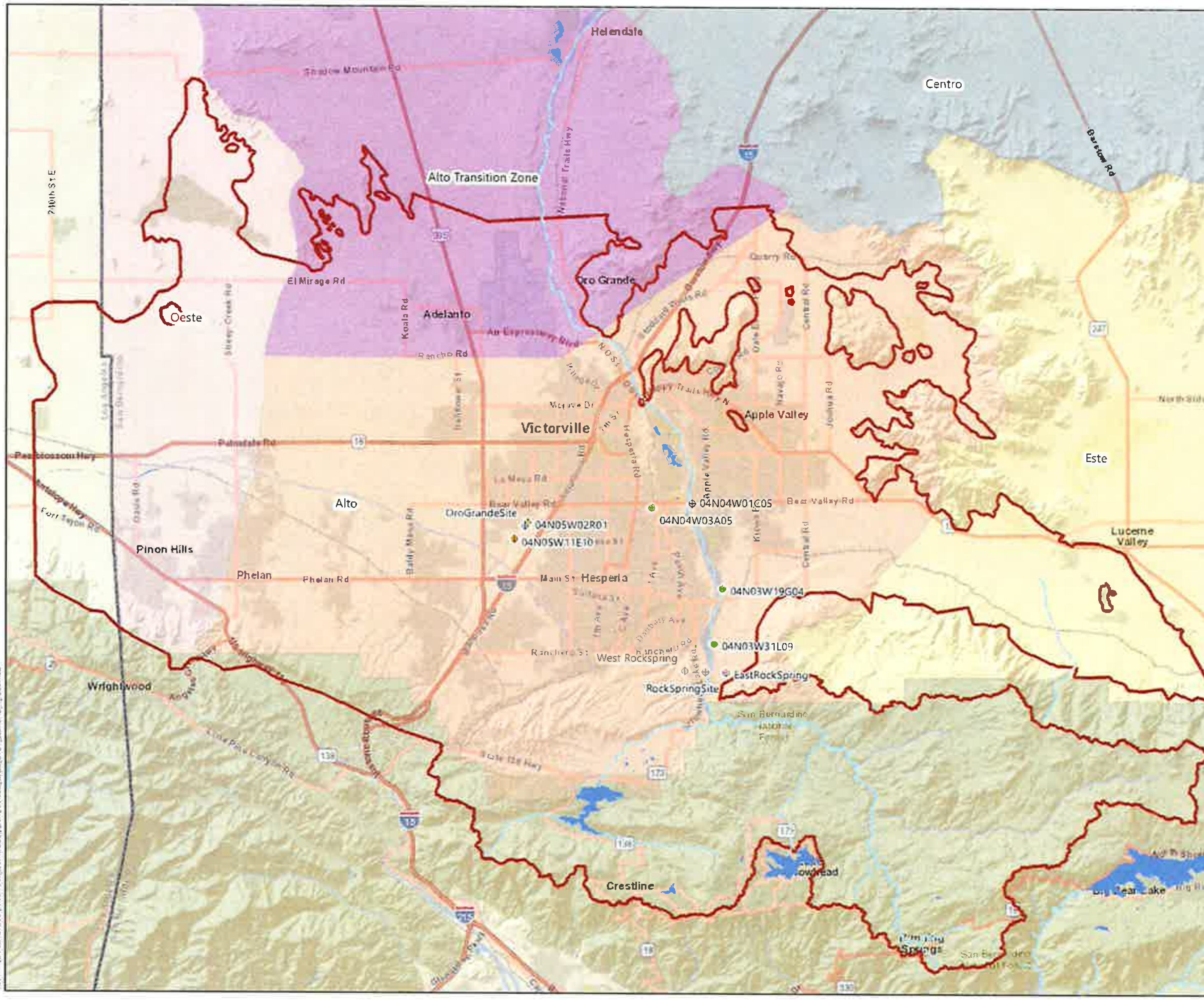
1. A positive sign indicates an increase in groundwater storage and a negative sign represents a decline in groundwater storage

AVERAGE ANNUAL WATER BUDGET (WY 1951 THROUGH WY 2017)
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By:KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 6.3

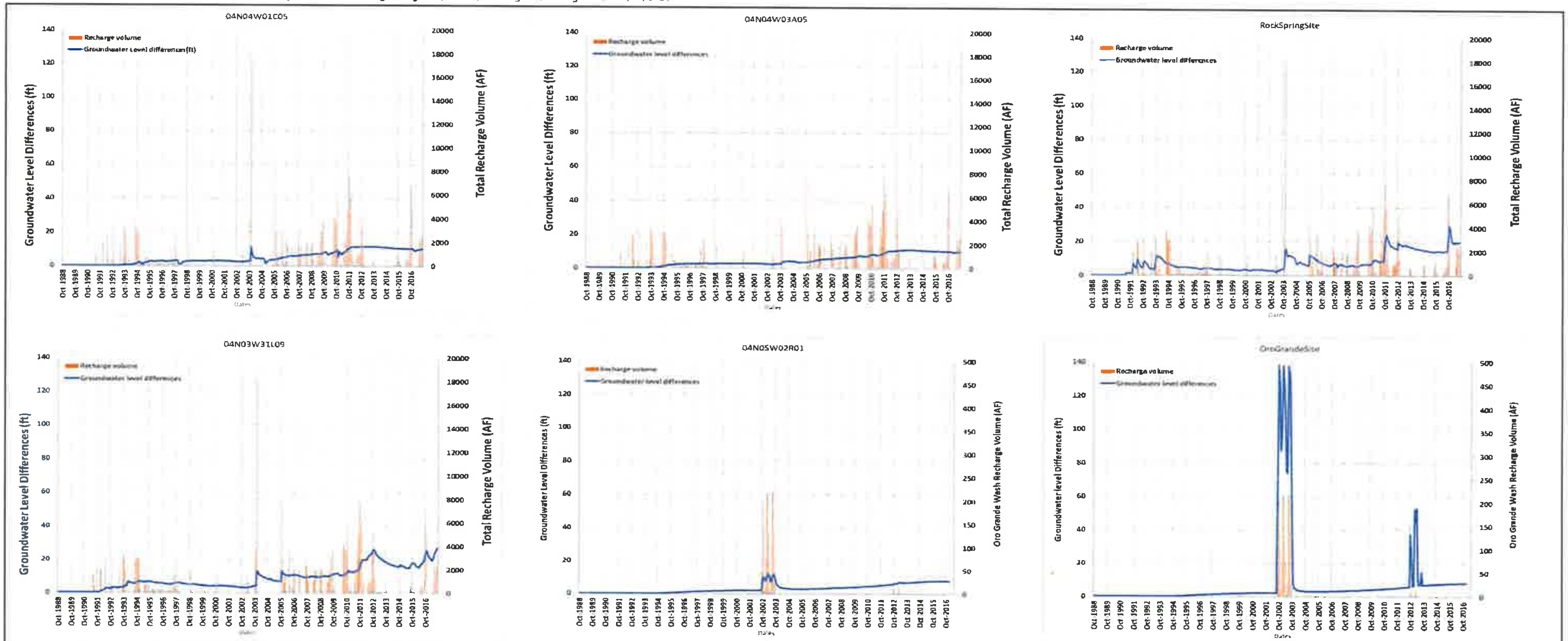


Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

SCENARIO ONE
MONITORING LOCATIONS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW	Date: 10/29/2021	Project No.: CM20167800
wood.	Figure	7.1

Date 10/29/2021 Printed by mikewallace2
Path: Y:\CM20167800 (MWA SW_GW Model)\em\Revised_Maps_0701_scenario_1_locs.mxd

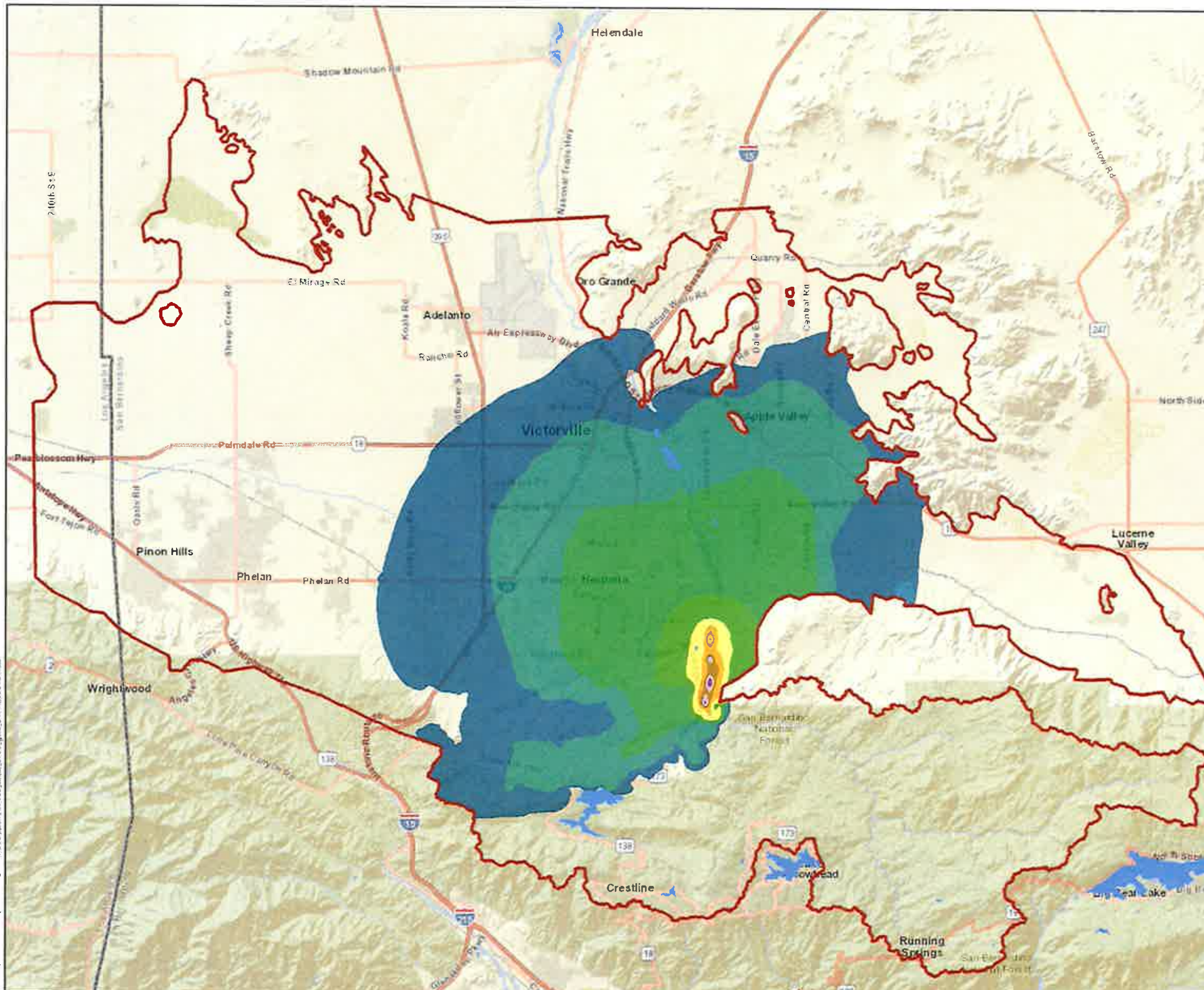


Notes:

Total Recharge Volume = Deep Creek Recharge + Rock Spring Recharge + Cedar Spring Dam Releases Purchased by MWA
AF = Acre-Feet per Month
ft = Feet

WATER ELEVATION DIFFERENCES BETWEEN THE CALIBRATED MODEL AND SCENARIO 2 AT SELECTED LOCATIONS
Upper Mojave River Basin
Integrated Surfaces Water/Groundwater Model
Apple Valley, California

By: KMC	Date: 08/31/2021	Project No.: CM20167800
wood.	Figure	7.2



Explanation:

- Reservior/Lake
- Active model domain
- County boundary

Groundwater elevation difference (feet) between the calibrated model and Scenario 1 November 2016

- <1
- 1 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45

0 2 4 8
Miles

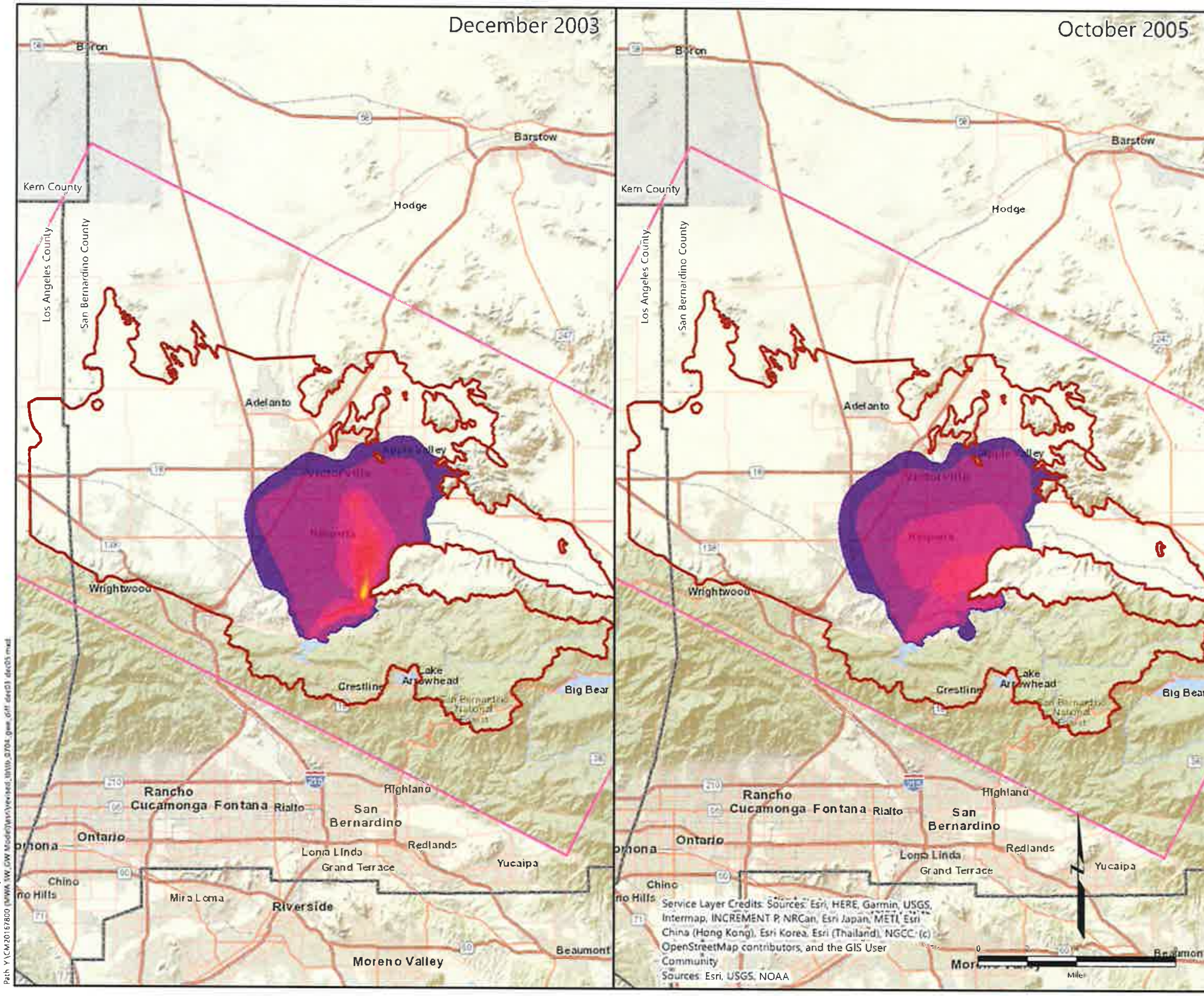
Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Sources: Esri, USGS, NOAA

GROUNDWATER ELEVATION DIFFERENCES BETWEEN THE CALIBRATED MODEL AND SCENARIO 1 - NOVEMBER 2016
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood. Figure 7.3

Date 10/29/2021 Printed by mikewallace2
Path Y:\CM20167800 (MWA SW_GW Model)\an\Vevised_illdb_0703_gwe_diff_nov2016.mxd



Explanation:

- Model domain
- Active model domain
- County boundary

Groundwater elevation difference (feet) between the calibrated model and Scenario 1 December 2003

- <1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26

Groundwater elevation difference (feet) between the calibrated model and Scenario 1 October 2005

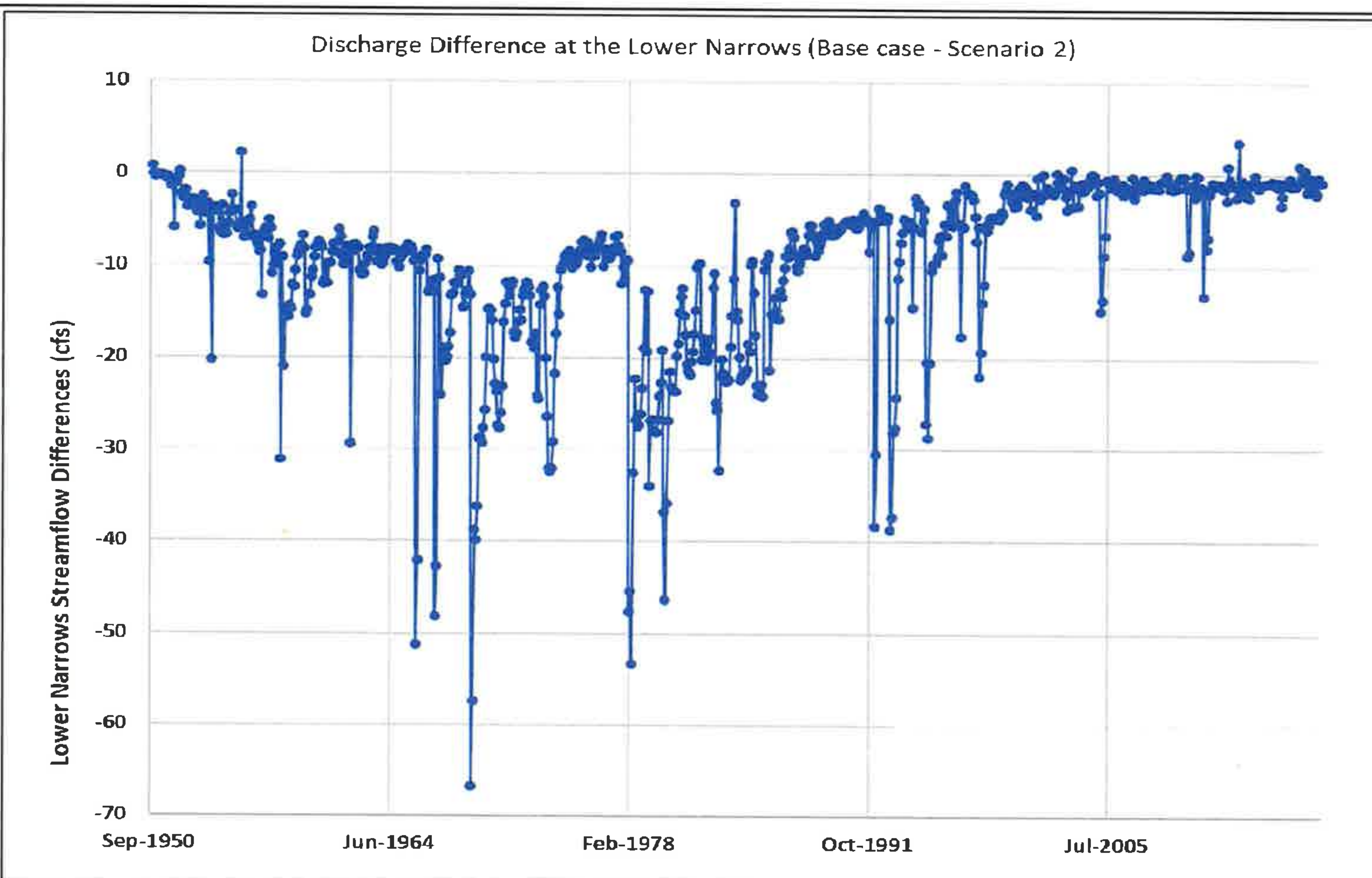
- <1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8

RESIDUAL GROUNDWATER LEVEL DIFFERENCES BETWEEN THE CALIBRATED MODEL AND SCENARIO 1 AFTER 23 MONTHS OF NO RECHARGE FROM PROJECTS
Upper Mojave River Basin
Integrated Surface Water/Groundwater Model
Apple Valley, California

By: MWW | Date: 10/29/2021 | Project No.: CM20167800

wood.

Figure 7.4

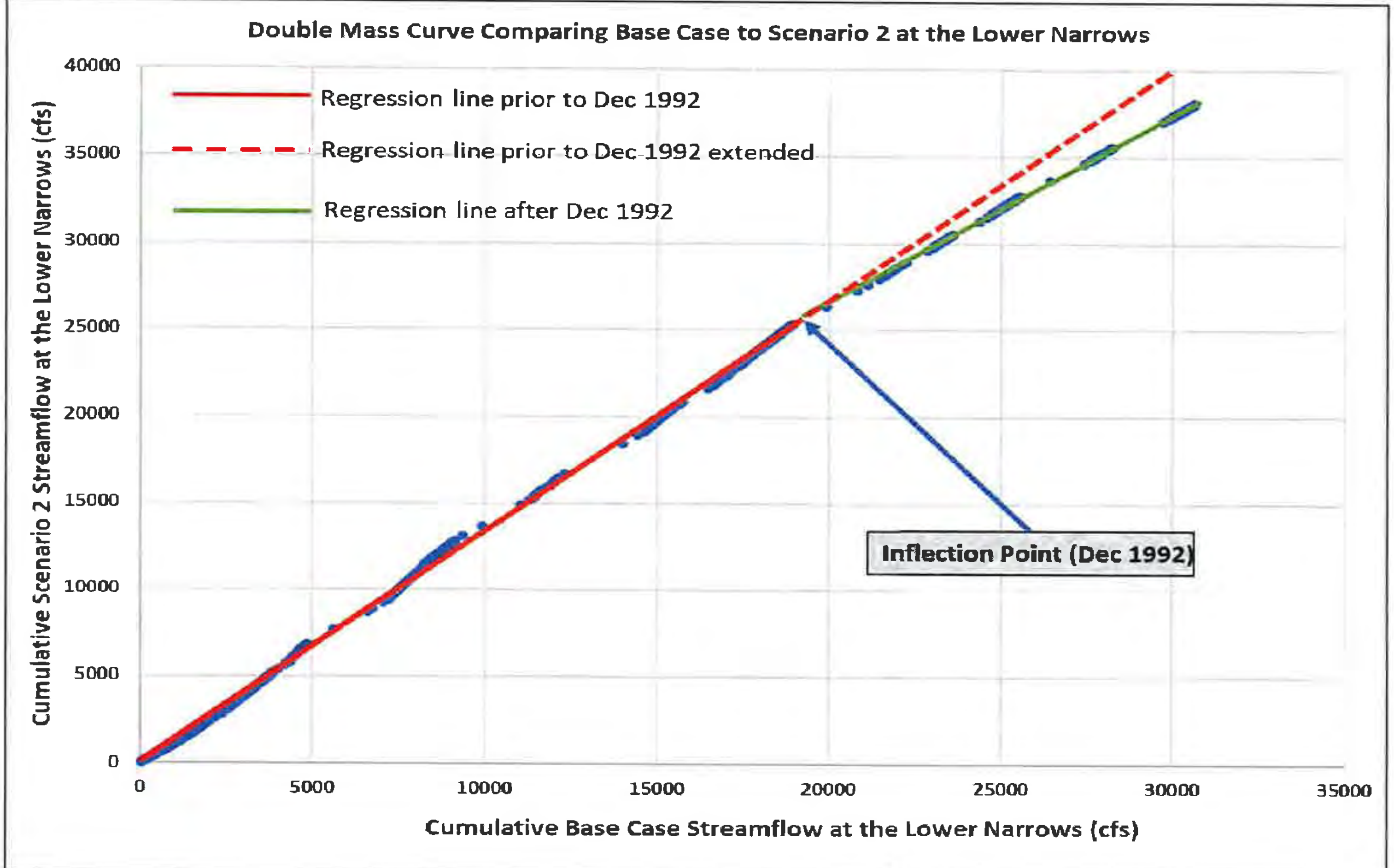


Notes:

cfs = cubic feet per second

STREAMFLOW DIFFERENCES BETWEEN THE CALIBRATED MODEL AND SCENARIO 2 AT THE LOWER NARROWS Upper Mojave River Basin Integrated Surfaces Water/Groundwater Model Apple Valley, California	
By: KMC Date: 08/31/2021	Project No.: CM20167800
wood.	Figure 7.5

\\IRV-FS1\Share\CM20167800 MWA SW_GW Model\02 ProjAdm\TMs\ModelingTm\Figures\Others\WoodFigures.xlsmFigure 7.6 10/29/2021



Notes:

cfs = cubic feet per second

Inflection point corresponds to the end of Jes Ranch Pumping

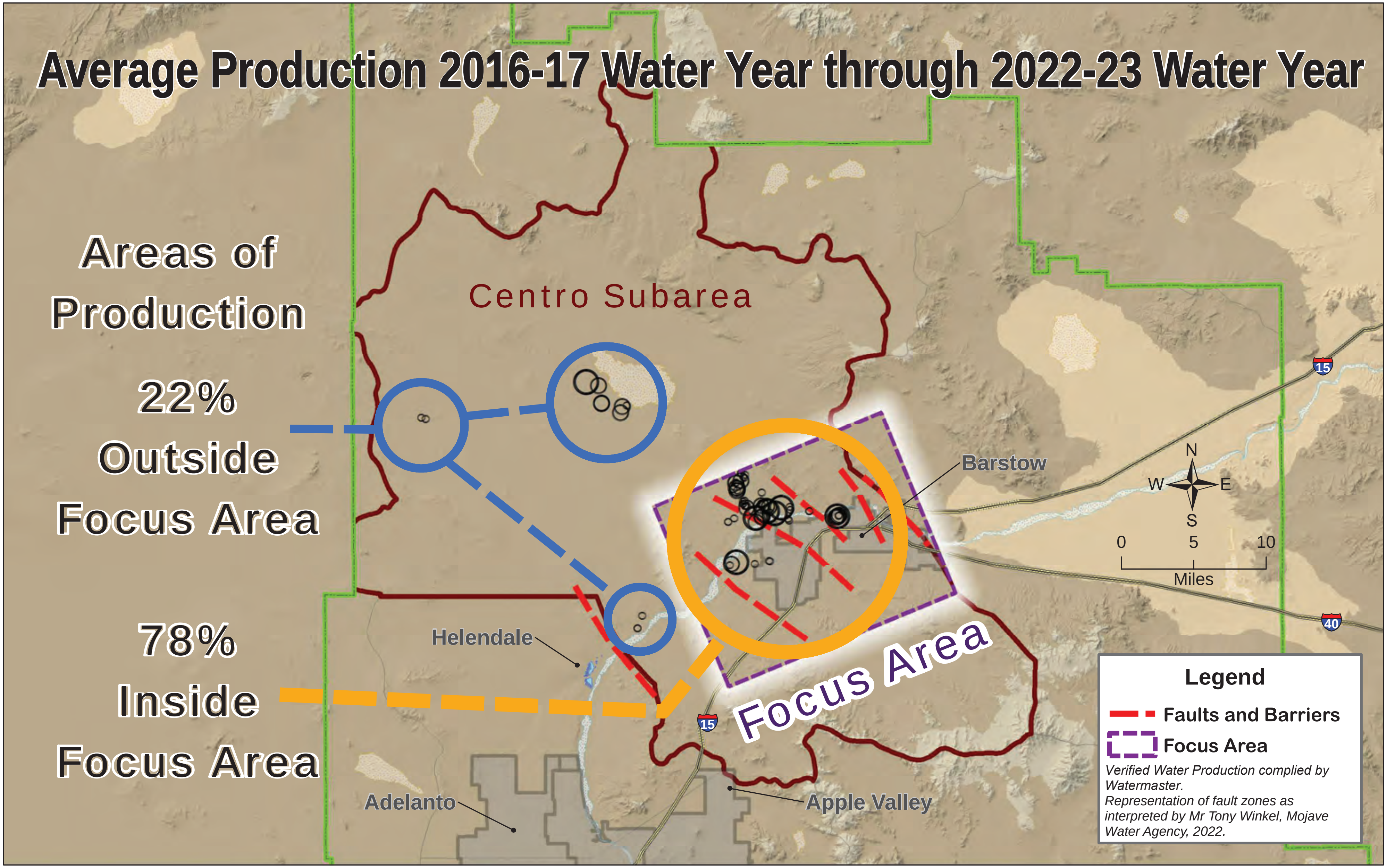
LOWER NARROWS STREAMFLOW DOUBLE MASS CURVE OF THE CALIBRATED MODEL AND SCENARIO 2
Upper Mojave River Basin
Integrated Surfaces Water/Groundwater Model
Apple Valley, California

By: KMC | Date: 08/31/2021 | Project No.: CM20167800

wood.

Figure 7.6

EXHIBIT 6

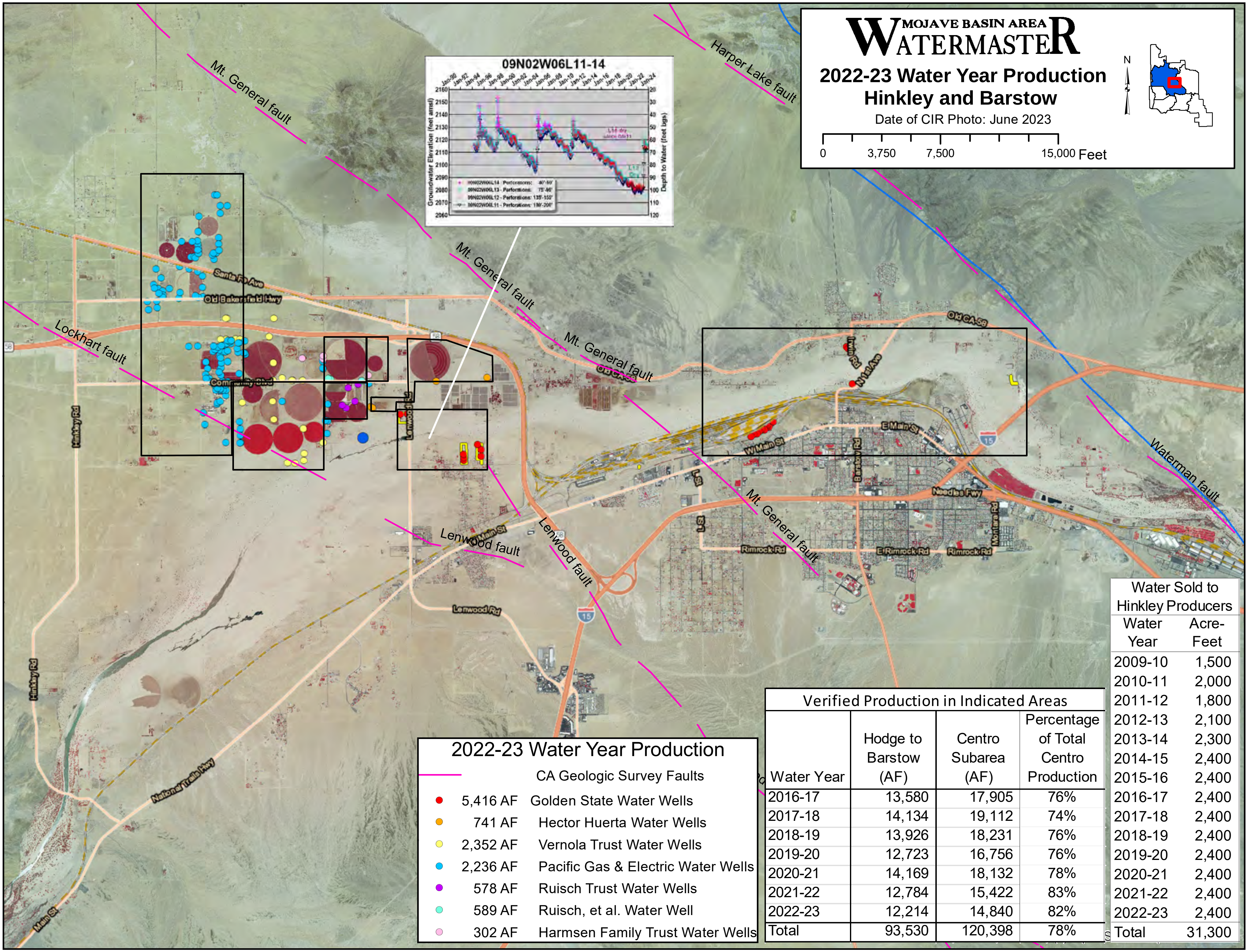


Average Production 2016-17 Water Year through 2022-23 Water Year
Areas of Production
22%
Outside Focus Area
78%
Inside Focus Area
Centro Subarea
Barstow
Helendale
Adelanto
Apple Valley
Focus Area
15
40
N
W
E
S
0
5
10
Miles
Legend
Faults and Barriers
Focus Area
Verified Water Production complied by Watermaster.
Representation of fault zones as interpreted by Mr Tony Winkel, Mojave Water Agency, 2022.

MOJAVE BASIN AREA WATERMASTER

2022-23 Water Year Production
Hinkley and Barstow

Date of CIR Photo: June 2023



2022-23 Water Year Production

	CA Geologic Survey Faults
5,416 AF	Golden State Water Wells
741 AF	Hector Huerta Water Wells
2,352 AF	Vernola Trust Water Wells
2,236 AF	Pacific Gas & Electric Water Wells
578 AF	Ruisch Trust Water Wells
589 AF	Ruisch, et al. Water Well
302 AF	Harmsen Family Trust Water Wells

Verified Production in Indicated Areas

Water Year	Hodge to Barstow (AF)	Centro Subarea (AF)	Percentage of Total Centro Production
2016-17	13,580	17,905	76%
2017-18	14,134	19,112	74%
2018-19	13,926	18,231	76%
2019-20	12,723	16,756	76%
2020-21	14,169	18,132	78%
2021-22	12,784	15,422	83%
2022-23	12,214	14,840	82%
Total	93,530	120,398	78%

Water Sold to Hinkley Producers

Water Year	Acre-Feet
2009-10	1,500
2010-11	2,000
2011-12	1,800
2012-13	2,100
2013-14	2,300
2014-15	2,400
2015-16	2,400
2016-17	2,400
2017-18	2,400
2018-19	2,400
2019-20	2,400
2020-21	2,400
2021-22	2,400
2022-23	2,400
Total	31,300

EXHIBIT D

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Inland Deserts Region
787 North Main Street, Suite 220
Bishop, CA 93514
www.wildlife.ca.gov

GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

February 20, 2024

Mojave Basin Area Watermaster
Mojave Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307-4377

Subject: Updates to Production Safe Yield and Free Production Allowance for Water Year 2024-2025

Dear Watermaster Board Members,

The California Department of Fish and Wildlife (CDFW) understands that Watermaster Engineer staff will be presenting its formal recommendation for free production allowance (FPA) for Water Year (WY) 2024-2025 at the upcoming February 28, 2024, Watermaster Board (Board) meeting. CDFW hereby submits its preliminary comments and concerns regarding recent changes to the process used to re-calculate production safe yield (PSY) and the resulting FPA in the Alto and Centro subareas. As explained below, CDFW is concerned that the Watermaster's new approach directly contradicts the Court's recommendation and the Watermaster's own conclusions in 2023. In addition, CDFW and the other parties have not had enough time to review and evaluate this new approach. For these reasons, we request that the Watermaster not adopt the new approach to calculating PSY in Alto and Centro subareas for the WY 2024-2025 FPA recommendations, and instead provide additional time for review and engagement by CDFW and the other parties to discuss new groundwater modeling information regarding water supply, the PSY calculations, and long-term groundwater elevation monitoring across the basin.

CDFW is the trustee agency for the state's fish and wildlife resources and is a party to the Judgment After Trial, dated January 10, 1996 (Judgment). In addition, CDFW is a landowner in two of the five subareas in the Judgment, the Baja and Alto Subareas. In the Baja Subarea, CDFW owns the Camp Cady Wildlife Area (Camp Cady), and in the Alto Subarea, CDFW owns the Mojave Narrows Regional Park and Mojave River Fish Hatchery.

In 1968, CDFW purchased the Mojave Narrows Regional Park, in large part for the extensive riparian habitat existing along the Mojave River which flows through the park. In 1969, CDFW purchased the Mojave River Fish Hatchery, the tailwater from which is a critical source of surface water for the Mojave Narrows Regional Park and other Verde Ranch Producers.

For more than a decade, CDFW has supported the Board's annual recommendations to the Court for reductions in FPA to bring the basin into balance, finding the recommendations consistent with the physical solution in the Judgment. However, CDFW is now concerned that Watermaster staff have introduced complex new methods to calculate PSY and has recommended increasing, rather than decreasing, FPA in some subareas, without the opportunity for CDFW to review and comment on the recommendations and the methods behind them.

CDFW first became aware of the new proposal to increase PSY and FPA in the Alto and Centro subareas in the Watermaster's status report to the court on December 27, 2023, "Watermaster's Status Report Regarding Production Safe Yield and Free Production Allowance Calculations," and again in the January 24, 2024, Watermaster meeting item, "Groundwater Model & Production Safe Yield Update" presented by Watermaster Engineer Robert Wagner. CDFW has not yet been provided with final FPA recommendations for WY 2024-2025. However, these two documents indicate that Watermaster staff are prepared to reverse both the Court's recommendation and its own recommendation by increasing PSY in the Alto and Centro subareas and recommending an increase in FPA.

In his May 2023 declaration to the Court, Mr. Wagner recommended holding FPA in the Alto subarea at 50% for five years, noting that a reduction in PSY was needed and the groundwater model supported the reduced PSY and FPA. Furthermore, the Court's June 2023 order noted the need for PSY in the Alto subarea to be adjusted downward and encouraged the Watermaster to consider variability in supply over different base periods, including the recent extended period of drought. In the September 2023 Court order Judge Reimer noted that "…Alto's FPA has been reduced to just above PSY. Nevertheless, the storage levels have continued to drop, just as they have for the last 10 years. If FPA is reduced to PSY, but groundwater storage is still declining…it's logical to question whether the PSY calculations are founded on correct assumptions."

CDFW has not had adequate time to evaluate the PSY re-calculation methods and results, or the new groundwater modeling that is apparently being used to support such increases. While CDFW supports evaluating new approaches to re-calculate PSY in the various subareas that take drought and climate change into account, as well as the use of improved tools, such as numerical groundwater models, CDFW also believes that it is too early to integrate such new methods into the PSY and FPA recommendations for the coming year, particularly when the outputs of such novel approaches appear to indicate such a substantial change in basin management. CDFW would like to engage more closely with the Watermaster staff to better understand the influence of the model on PSY, PSY re-calculation methods, changes to storage, and ongoing monitoring of the results of the rampdown in the subareas.

Exhibit H of the Judgment, Biological Resource Mitigation, states that the physical solution was developed in consideration of the water needs of public trust resources and seeks to achieve certain minimum groundwater table standards necessary to maintain sensitive riparian resources and species associated with the Mojave River system. CDFW does not believe that increasing either PSY or FPA in the Alto and

Centro subareas is consistent with the objectives of maintaining riparian resources in the basin at this time.

CDFW appreciates the opportunity to communicate its concerns regarding the Watermaster staff's proposal to integrate the recent PSY recalculations and groundwater modeling efforts into the FPA recommendations for WY 2024-2025. In summary, CDFW is concerned that increasing production in the Alto and Centro subareas this year is counter to the Court's direction to re-evaluate safe yield in light of recent decades of drought and continued depletion of storage in Alto, represents a significant change in direction by the Watermaster both in terms of the methods to calculate PSY and anticipated outcomes, and may result in undesirable impacts to groundwater levels and associated fish and wildlife resources. CDFW requests additional time to engage with the Watermaster staff on the new PSY calculations and groundwater model. Additionally, more time is needed to continue to review changes in monitoring well groundwater elevation data in response to the ongoing rampdown of pumping, particularly within the Exhibit H areas along the Mojave River where fish and wildlife species have been severely impacted since groundwater pumping increased dramatically in the 1950s. CDFW will be attending the February 28 and March 27, 2024, Board meetings when the Board will formally discuss and consider this matter.

Sincerely,

DocuSigned by:
Aaron Johnson
6477ACD4E0DE4DB...

Aaron Johnson
Senior Environmental Scientist
Inland Deserts Region

ec:

CDFW
Chris Hayes, Environmental Program Manager
chris.hayes@wildlife.ca.gov

Alisa Ellsworth, Environmental Program Manager
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Stephen Puccini, Attorney V
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Department of Justice
Marilyn H. Levin, Deputy Attorney General
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Noah Golden-Krasner, Deputy Attorney General V
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February 27, 2024

Stephanie Osler Hastings
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805.882.1415 direct
shastings@bhfs.com

VIA EMAIL TO: WATERMASTER@MOJAVEWATER.ORG

Board of Directors
Mojave Basin Area Watermaster
Mojave Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307-4377

RE: Agenda Item 7 - Comments on Watermaster's Production Safe Yield Update

Dear Board of Directors:

On behalf of Golden State Water Company (GSWC), we submit the following comments related to the Mojave Basin Area (Basin) Watermaster's evaluation and update of the Production Safe Yield (or PSY) for each Subarea of the Basin. We request that the Watermaster review our comments and consider the attached technical analysis by aquilogic, Inc. (aquilogic) as the Watermaster continues to refine its update of the PSY for each Subarea—specifically Watermaster's estimate of flow across the Transition Zone—and issues its Free Production Allowance for Water Year 2024-25 and Annual Report for 2023-24 required by the Mojave Basin Judgment.

Statement of Interest

GSWC, formerly Southern California Water Company and a party to the Judgment, is a division of American States Water Company, a "Class A" utility regulated by the California Public Utilities Commission, provides water service to approximately 260,000 customers throughout California. GSWC's Mountain Desert District operates water systems within three of the Mojave Basin Subareas—Alto, Este, and Centro—and provides water service to 15,275 water service connections and a population of approximately 50,400 in and around the cities and communities of Barstow, Apple Valley, and Lucerne Valley. GSWC has adjudicated Base Annual Production[1] rights of 1,940 acre-feet per year (AFY) in the Alto Subarea, 178 AFY in the Este Subarea, and 14,407 AFY in the Centro Subarea. Groundwater produced from 29 wells located in these Subareas provides GSWC's sole source of supply for its Mountain Desert District customers. Accordingly, GSWC has a significant interest in implementation of the Judgment and management of the Basin, and in particular the sustainability of those Subareas in which GSWC operates—especially in the Centro Subarea.

[1] All capitalized terms not defined herein have the same meaning as set forth in the Judgment.

Importance of the Accuracy of the Calculation of PSY

The accuracy of the PSY for each Subarea is critical to implement the Physical Solution imposed by the Judgment. Based on the PSY, Watermaster adjusts the Free Production Allowance (or FPA) for each Subarea. Given the importance of the calculation of PSY and FPA under the Judgment and its corresponding effects on Producers' rights, the Watermaster has the obligation to use the best available records and data, and install, operate, and maintain measurement devices to monitor streamflow and groundwater levels.[2]

Water Levels in the Centro Subarea Continue to Decline

Since entry of the Judgment in 1996, water levels in the Centro Subarea have remained the same or continued to decline, despite Centro Subarea Producers reducing pumping consistent with the FPAs and Alta Subarea Producers purportedly meeting their Minimum Subarea Obligations, as Watermaster has reported in its Annual Reports.[3] Falling water levels became particularly pronounced beginning in late 2017 near the City of Barstow and Lenwood and Hodge Recharge Sites resulting in water quality impacts to GSWC's Bradshaw Wellfield which consists of eleven active production wells. At the same time, nitrate levels in four of the production wells increased to levels exceeding the Nitrate MCL of 10 mg/l. GSWC was forced to take these wells out of service and to construct a $5 million dollar nitrate treatment facility to treat and contain the nitrate impacted supply. The on-going operation and maintenance cost of the nitrate system is on the order of $2 million per year. Nitrate impacts are continuing to expand to additional wells at the Bradshaw Wellfield and expansion of the newly constructed treatment facility may be necessary.

Concern with Accuracy of Watermaster's Estimate of Flow Across the Transition Zone and the Resulting Impact on Watermaster's Calculation of PSY

GSWC has reviewed the Watermaster Engineer's presentation to the Watermaster Board on January 24, 2024 and also the memorandum from Robert C. Wagner regarding the Transition Zone Water Balance memorandum, dated February 28, 2024, and recently posted to the Watermaster website. GSWC is concerned that the Watermaster's calculation of PSY and FPA do not accurately reflect observed conditions in the Centro subarea and that further study is required to ensure adequate and sustainable supplies to GSWC's Barstow System. The accuracy of the Watermaster's calculation of flow

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[2] Judgment, ¶¶ 24(e), (w), see also Judgment, Ex. G, ¶ 2(b), 6 (requiring installation of monitoring wells in the Transition Zone and at Subarea boundaries).

[3] See, e.g., Watermaster, 2021-2022 Twenty-ninth Annual Report, p. 28, Fig. 3-15 (May 1, 2023) available at https://www.mojavewater.org/wp-content/uploads/2023/10/29AR2122_Revised.pdf (acknowledging some seasonal variability in water levels but noting continuing decline in water levels for at least the past 10 years).

across the Transition Zone is of critical importance to the Watermaster's calculation of the PSY and FPAs for each Subarea.[4]

GSWC Commissioned an Independent Analysis of Flow Across the Transition Zone

In anticipation of the Watermaster's update of the PSY, GSWC asked aquilogic to analyze inflows into the Centro Subarea from the Transition Zone. Aquilogic's analysis, presented in the enclosed memorandum dated February 23, 2024 and titled "Progress Report and Mojave Basin Transition Zone Water Budget" (hereafter, "aquilogic memorandum") concludes that surface water inflow into the Centro Subarea is overestimated because the Watermaster's assumption that all inflows into the Transition Zone at the Lower Narrows gage are equal to inflows into the Centro Subarea is likely incorrect.

The aquilogic memorandum describes the available stream gages along the Mojave River in the vicinity of the Transition Zone. It identifies that Lower Narrows gage provides a long-term dataset at the upstream boundary of the Transition Zone (adjacent to the Alto Subarea), but no similar long-term downstream gage exists at the Transition Zone boundary with the Centro Subarea.[5] Aquilogic, however, identifies that the Wild Crossing gage historically existed near the Centro Subarea and Transition Zone boundary between March 1966 through October 1970.[6] The Wild Crossing gage provides the best available data that show the potential change in surface flows in the Mojave River across the Transition Zone by comparing flow rates at the Lower Narrows and Wild Crossing gages.[7] Based on the data available, surface water flows at the Wild Crossing gage, when operational, were significantly lower than those at the Lower Narrows gage, suggesting that the Mojave River recharges groundwater in the Transition Zone rather than flowing into the Centro Subarea, as Watermaster assumes.[8]

Further, aquilogic identified that the average annual net recharge within the Transition Zone between Water Year 1966-1970 was approximately 59,500 AFY.[9] When compared to the Judgment's estimate of 2,000 AFY of Subsurface Flow between the Transition Zone and the Centro Subarea, it is unclear without

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[4] The Judgment requires that the Watermaster rely on pertinent hydrologic data and estimates, including the factors and criteria identified in Exhibits C and H of the Judgment, to calculate the PSY and FPAs. (See Judgment, ¶¶ 2(a), 24(o), (w), Exes. C & H.) For example, Exhibit C to the Judgment explains the process to establish the Base Flow and Storm Flow in the Mojave River at the Lower Narrows (Transition Zone boundary with the Alto Subarea) to estimate inflows into the Centro Subarea that inform the calculation of PSY and FPA. (See Judgment, Ex. C, ¶ B(1).)

[5] The aquilogic memorandum identifies that closest gages to the Centro Subarea and Transition Zone boundary are the Barstow gage and the recently established Hodge/Hinkley gage, which are more than eight miles from the boundary and have significant limitations due to the width of the river channel at these locations. (aquilogic memorandum, p. 2.)

[6] *Id*. at p. 2.

[7] *Id*. at p. 3.

[8] See *id*. at p. 3, Fig. 2.

[9] See *id*. at pp. 3-4, Fig. 3.

additional analysis what happens to this additional recharge.[10] Based on available well information, the aquilogic memorandum finds that it is reasonable to conclude that groundwater pumping within the Transition Zone, along with environmental uses, remove the additional recharge from the Transition Zone.[11] Given this evidence of stream losses in the Transition Zone, surface water inflow into the Centro Subarea cannot equal stream discharge measured at the Lower Narrows gage.[12]

The aquilogic memorandum further analysis to estimate the PSY and FPA for the Centro Subarea more accurately, including:

- preparation of a more detailed Transition Zone water budget based on U.S. Geological Survey modeling and other data sources;[13]
- expansion of the model domain used for the PSY to include all of the Transition Zone, Centro and Baja Subareas; and
- preparation of a written draft report for stakeholder review and comment prior to submission to the court.[14]

Given the impacts of falling water levels in the Centro Subarea on GSWC operations and facilities, coupled with aquilogic's analysis and recommendations presented in the attached memorandum, GSWC believes additional analysis of flow across the Transition Zone is warranted to support implementation of the Judgment.

GSWC Request for Further Analysis of the Transition Zone as Part of the PSY Update

GSWC respectfully requests that the Watermaster consider these comments and the aquilogic memorandum before completing its update of PSY for each Subarea and before issuing its Free Production Allowance for Water Year 2024-25 and Annual Report for 2023-24. In addition, should the recommended analysis show the need for additional subsurface and surface monitoring to evaluate hydrogeologic conditions with the Transition Zone, especially at the Centro Subarea boundary, GSWC asks Watermaster to commit to install, operate, and maintain appropriate monitoring equipment to address data gaps.

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[10] *Id*. at p. 4; Judgment, Ex. G, ¶ 1(e).
[11] aquilogic memorandum, p. 5.
[12] The aquilogic memorandum also notes that 15,095 AF of treated wastewater was discharged in the Transition Zone downstream of the Lower Narrows gage in Water Year 2022, suggesting that Watermaster's assumptions for the Transition Zone require further review based on current conditions as well. (aquilogic memorandum, p. 5.)
[13] See *id*. at pp. 6-7.
[14] The February 28, 2024 Watermaster memorandum does not appear to include the recommended analyses.

Thank you for your consideration of these comments. GSWC appreciates the Watermaster's commitment to further evaluate Basin conditions as required by and as necessary to implement the Judgment effectively.

Respectfully,

Stephanie Osler Hastings

cc: Leland McElhaney, Brunick, McElhaney & Kennedy
Robert Wagner, Watermaster Engineer

Attached: aquilogic, Inc. memorandum, dated February 23, 2024

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environment • water • strategy

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MEMORANDUM

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

Subject: Progress Report and Mojave Basin Transition Zone Water Budget

Project No.: 018-10

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

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

BACKGROUND

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

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

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

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

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

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

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

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

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

STREAM DISCHARGE

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

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

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

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

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

[9] As stated or implied in multiple annual reports

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

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

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

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

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

DATA ANALYSIS

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

Stream Recharge to Groundwater

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

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

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

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

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

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

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

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

Groundwater Extractions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

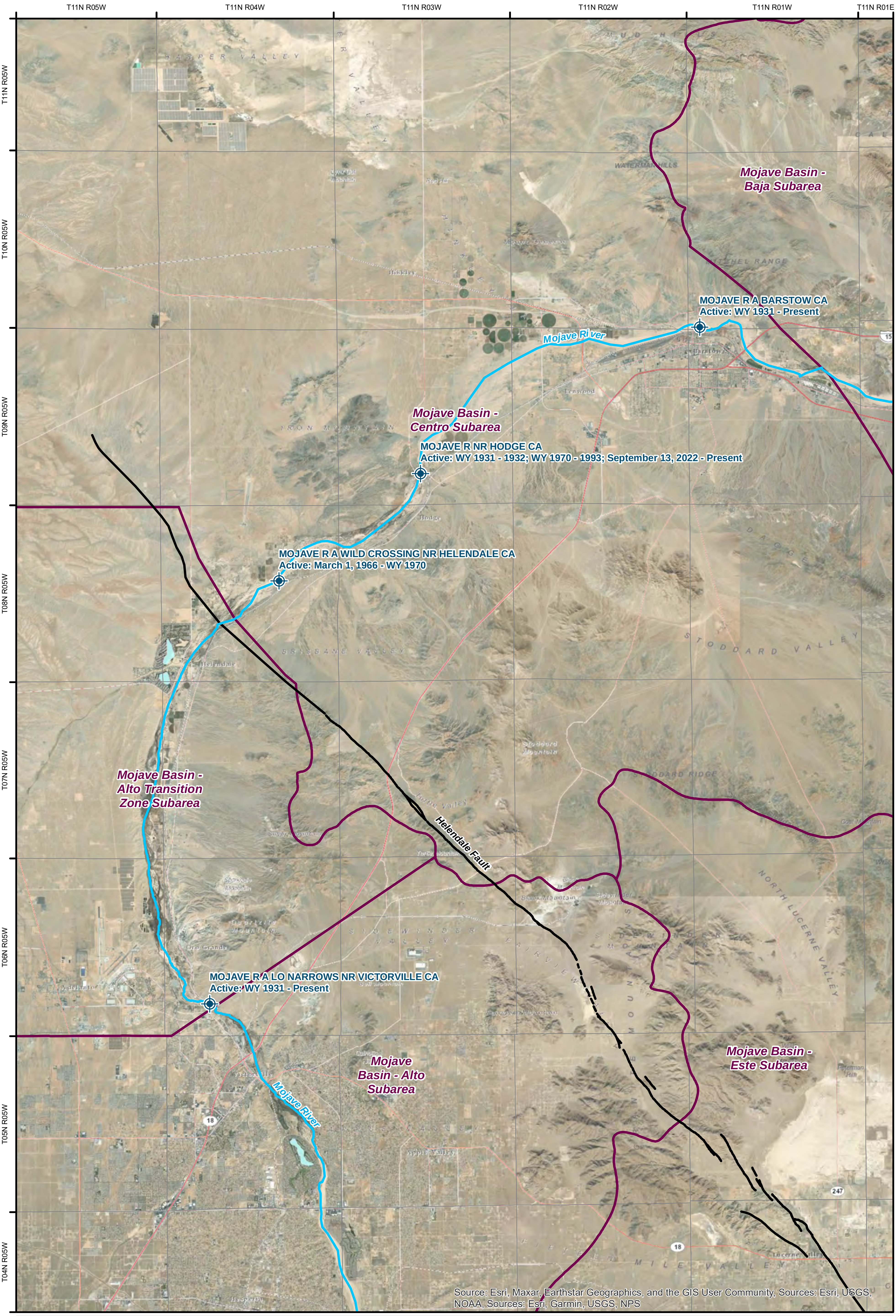
Groundwater flow into the Centro Subarea occurs in the Mojave River alluvium, in deeper horizons across the Helendale Fault, and other areas along the Transition Zone-Centro Subarea boundary (**Figure 1**). This flow rate is difficult to assess without using a groundwater flow model. A groundwater model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

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

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

[20] Watermaster (2024). Groundwater Model and Production Safe Yield Update. Watermaster presentation prepared by Wagner and Bonsignore, Consulting Civil Engineers. Mojave Water Agency / Watermaster Board Meeting, January 24, 2024.
[21] https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html
[22] https://prism.oregonstate.edu/

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



Stream Gages
Helendale Fault
Mojave River
Adjudicated Areas
Township/Range

Notes:
All locations approximate.
WY: Water Year

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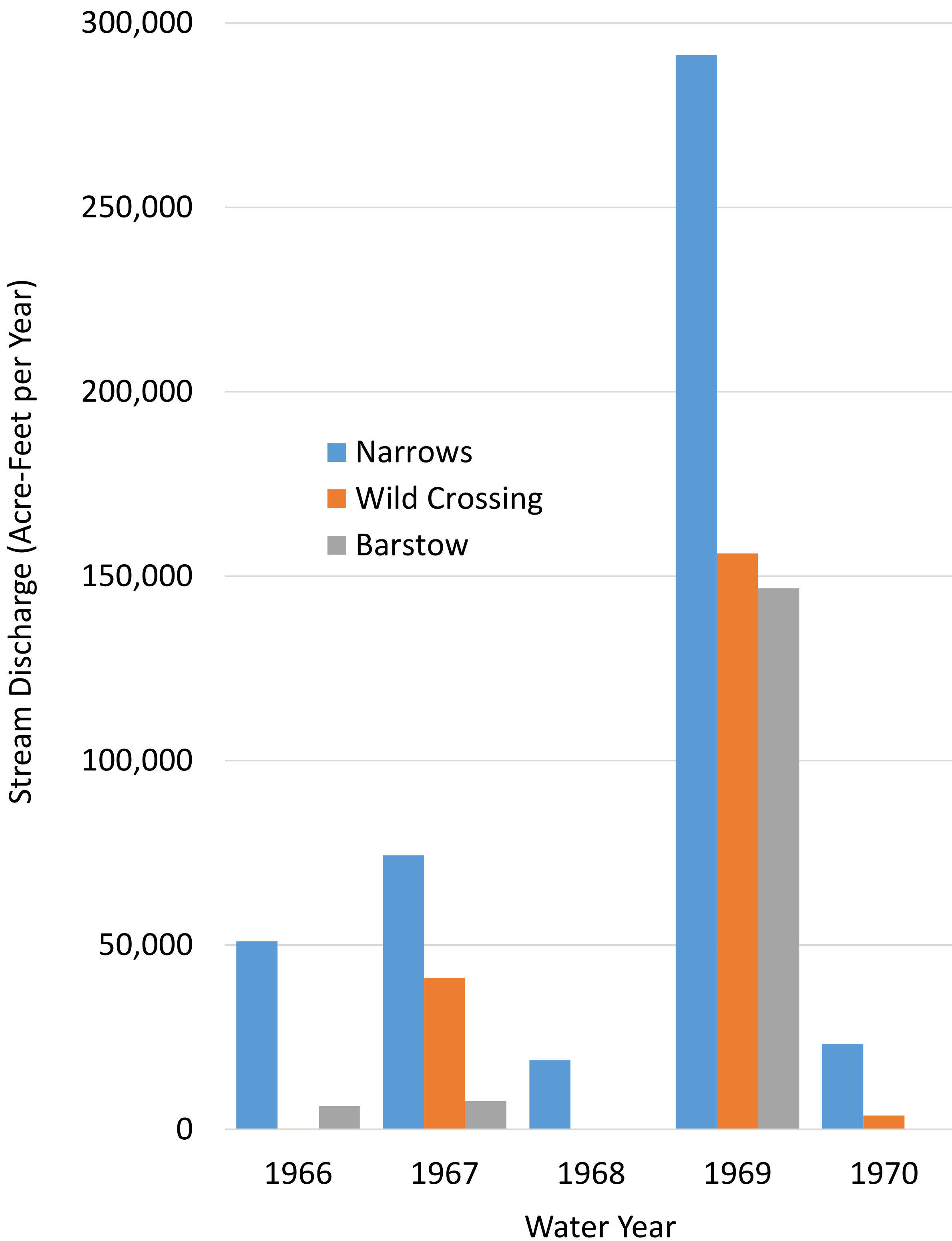
Miles

aquilogic, Inc.

BHFS - GSWC Mojave

Key Features in the Mojave Basin

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

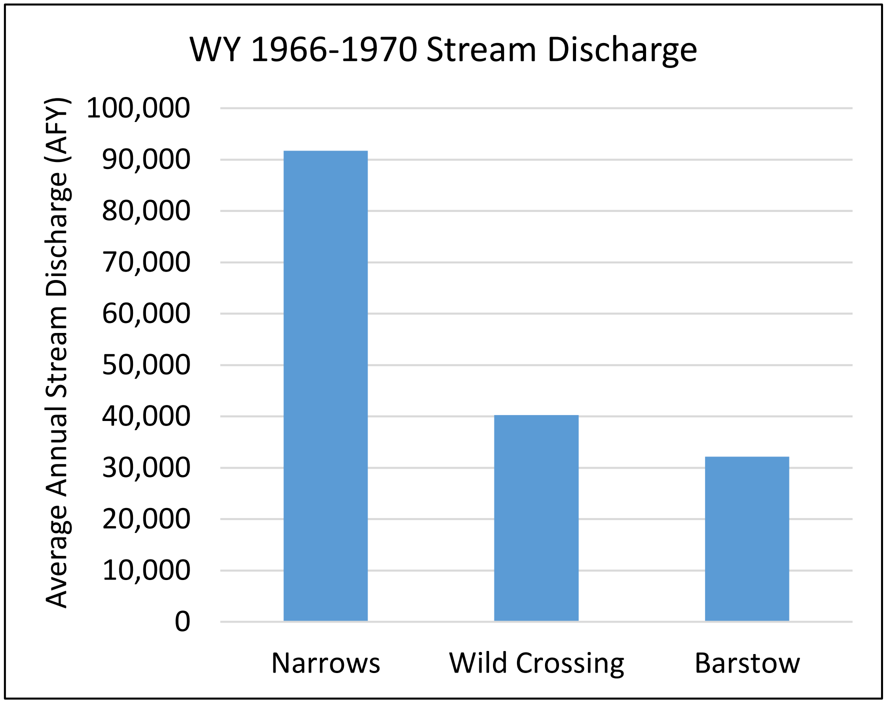


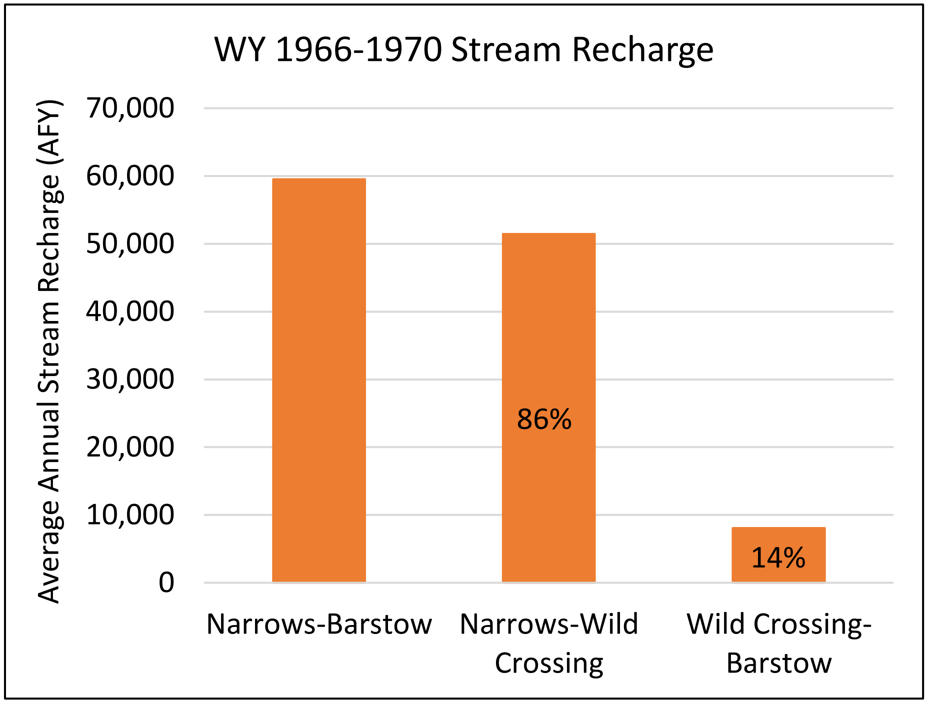
aquilogic, Inc.

BHFS- GSWC Mojave

Stream Discharge along the Mojave River

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





AFY: Acre-Feet per Year
WY: Water Year

aquilogic, Inc.

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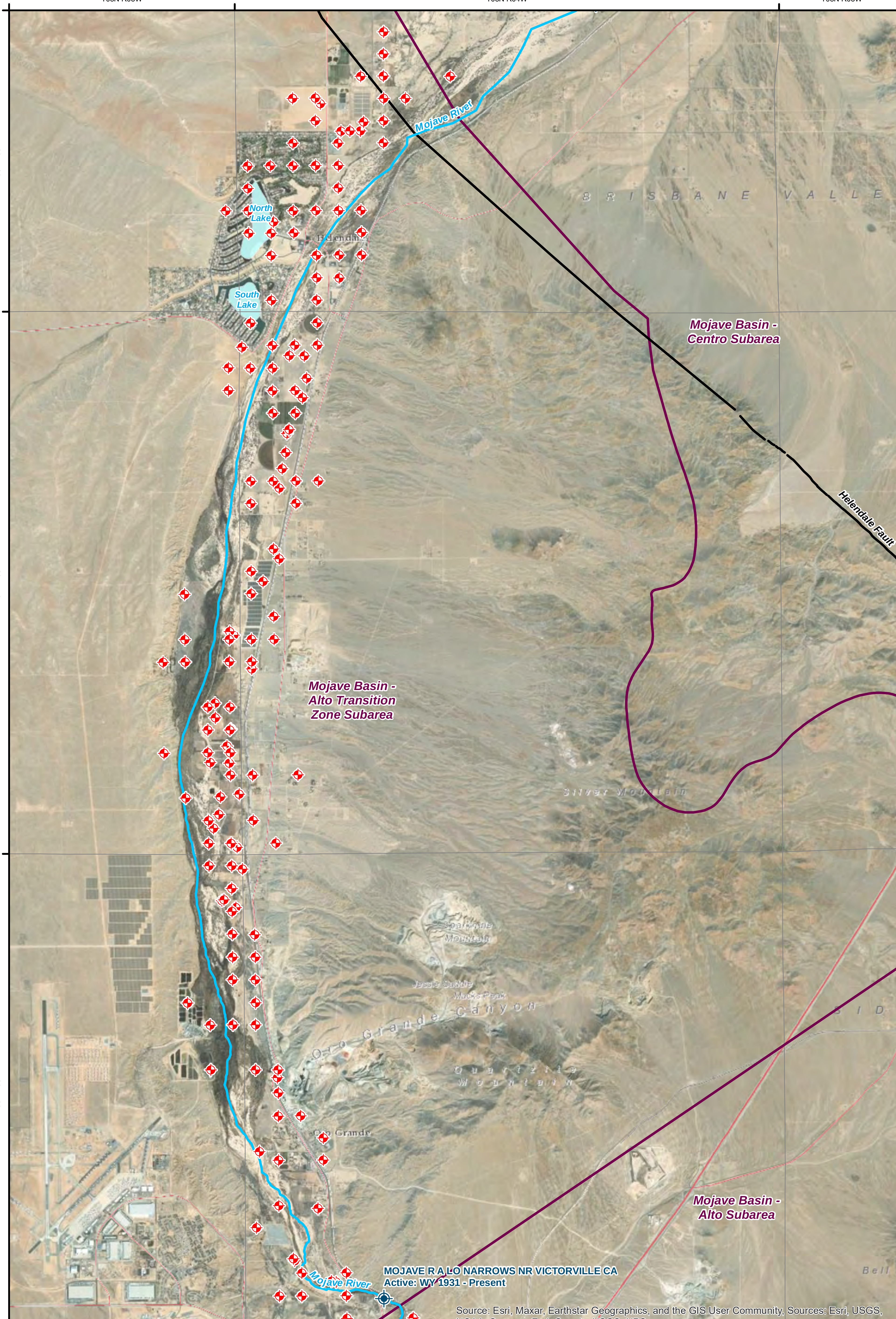
Stream Discharge and Recharge

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



Production Well Locations

Stream Gages

Helendale Fault

Mojave River

Adjudicated Areas

Township/Range

Notes:
All locations approximate.

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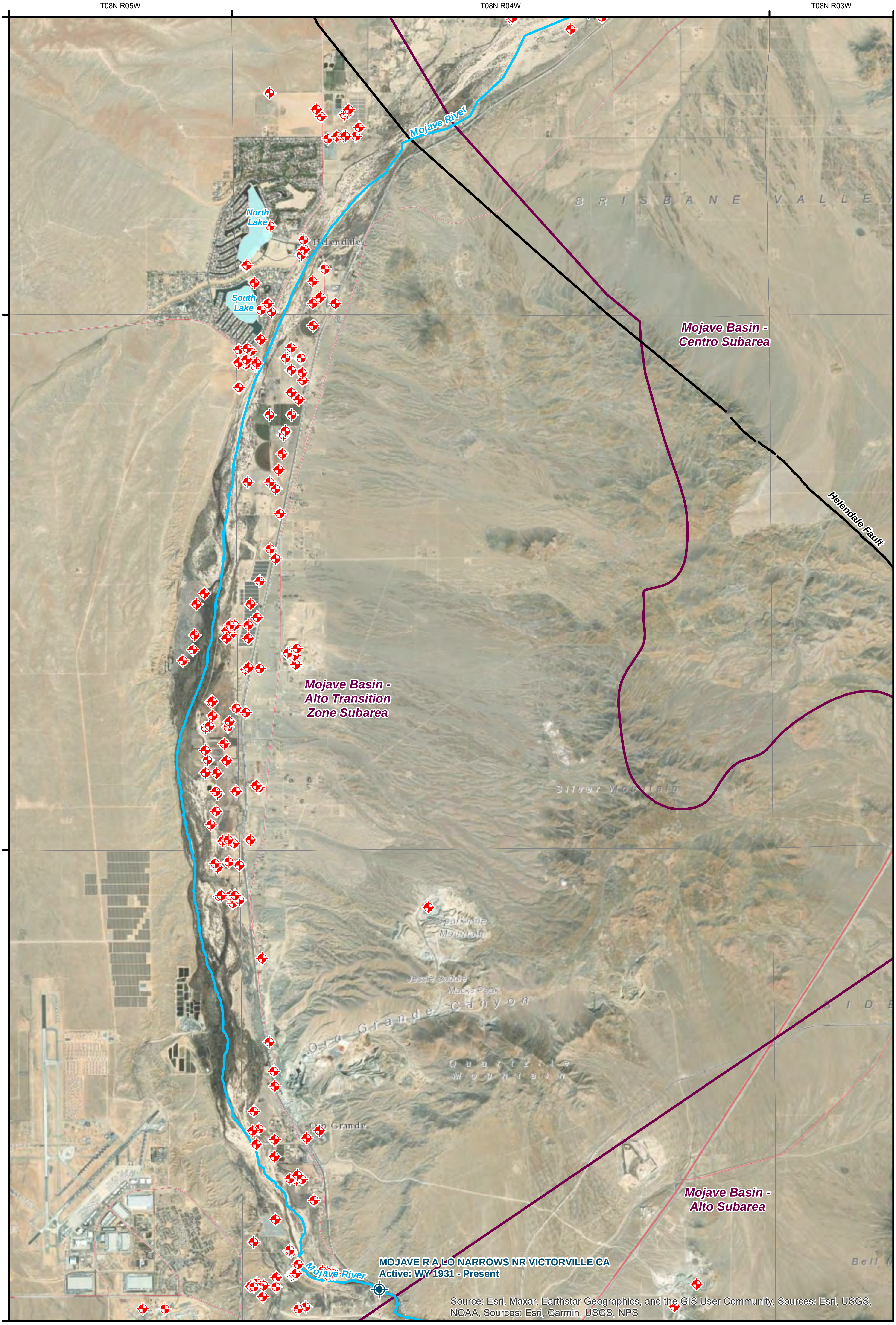
Transition Zone Production Wells 1966-1970

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



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

Notes:
All locations approximate.
WY: Water Year

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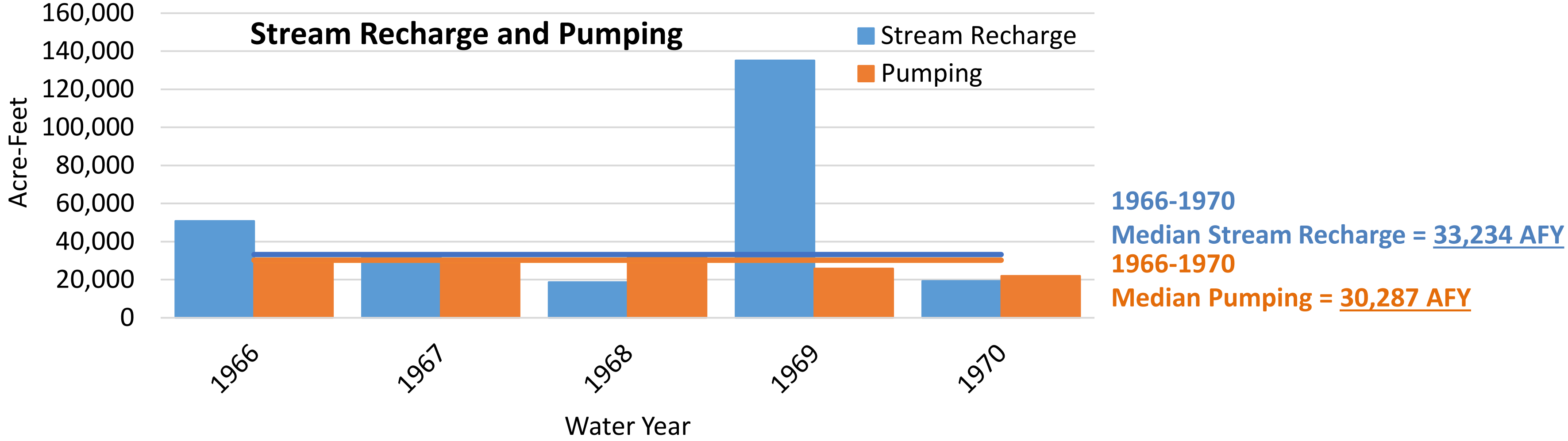
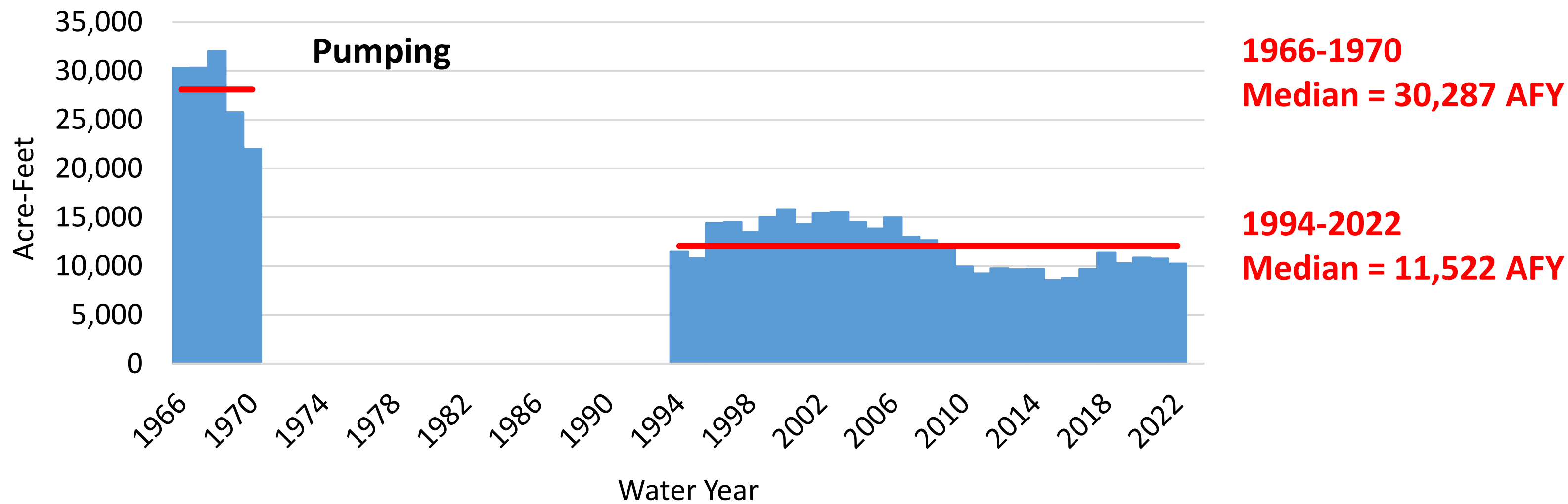
Transition Zone Production Wells
WY 1994 - 2022

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





AFY: Acre-Feet per Year

aquilogic, Inc.

BHFS- GSWC Mojave

Average Annual Stream Transition Zone Recharge and Pumping

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

FENNEMORE.

Derek Hoffman
Director
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March 15, 2024

VIA EMAIL/ahostetter@mojavewater.org

Andrea Hostetter
Watermaster Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307-4377

Re: **Mojave Watermaster March 27, 2024 Meeting: Comments on PSY Update and 2024-25 FPA Watermaster Proposal**

Dear Ms. Hostetter:

This firm represents Mitsubishi Cement Corporation ("Mitsubishi"), Robertson's Ready Mix, Ltd. ("Robertson's"), and CalPortland Company ("CalPortland"). Collectively, these parties have facilities located throughout the Mojave Basin Area within the Este, Centro, Alto, and Baja Subareas.

The Mojave Basin Watermaster Engineer released on February 28, 2024, its (1) Recommendation for Free Production Allowance for Water Year 2024-25 ("FPA Recommendation WY 2024-2025") and (2) Production Safe Yield & Consumptive Use Update ("PSY Update"). We provide these comments for the Watermaster's consideration of these items at the scheduled March 27, 2024 public hearing, and we request these comments be included in the record.

I. PRODUCTION SAFE YIELD FOR ESTE DOES NOT APPEAR TO SELECT THE HIGHEST AVERAGE ANNUAL AMOUNT OR ACCOUNT FOR INCREASES IN STORAGE AS REQUIRED BY THE JUDGMENT

In 2023, the Court directed the Watermaster to re-evaluate Production Safe Yield ("PSY") for each Subarea, and to incorporate the updated PSY estimates into any Rampdown recommendations for Free Production Allowance for Water Year 2024-2025.

The Judgment defines Production Safe Yield as:

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

(Judgment, paragraph II.A.4.aa, emphasis added.)

In the recently released FPA Recommendation WY 2024-2025, the Watermaster Engineer notes that Este PSY "has an average 5,108 acre feet for the past 5 years and 6,582 acre feet for the 20 year base period (2001-2022)."[1] In the Watermaster PSY Update, Verified Production is estimated to "range from 4,029 to 4,304 AFY during the last five water years."[2]

The current Watermaster Engineer recommendations for the Este Subarea: (1) do not utilize the highest average Annual Amount; (2) should explain how the recommendations are representative of the long-term average; and (3) ignore or fail to account for many recent years of stable water levels reported by the Watermaster demonstrating that current pumping levels will not result in a long-term net reduction of groundwater in storage. In short, to the extent the Watermaster Engineer will utilize data presented in its PSY Update to propose Rampdown, the PSY should be at least 6,582 AFY (the higher supported figure cited by the Watermaster Engineer in the PSY Update), and likely higher given the sustained levels of verified production in Este that do not risk loss of groundwater in storage.

A. **The Watermaster Engineer Appears to Select the Lowest Average Annual Amount it Analyzes as Opposed to the Highest Average as Required by the Judgment**

In the Watermaster's FPA Recommendation WY 2024-2025, the Watermaster Engineer states:

> Assuming limited or no change in storage the PSY for Este is about equal to the pumping, or about an average 5,108 acre feet for the past 5 years and 6,582 acre feet for the 20 year base period (2001-2022). Assuming water levels indicate lack of storage change during the past 20 plus years, the PSY might be as high as 6,582 acre feet.

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[1] Watermaster Recommendation for Free Production Allowance for Water Year 2024-25, February 28, 2024 https://mojavewater.granicus.com/MetaViewer.php?view_id=2&clip_id=1336&meta_id=107551#page=4

[2] Watermaster Production Safe Yield and Consumptive Use Update, Water Supply Update for Este Subarea, February 28, 2024 https://www.mojavewater.org/wp-content/uploads/2024/02/20240222-PSY-and-CU-Update-2024.pdf#page=53

(FPA Recommendation WY 2024-2025, pg. 4.)[3]

Without explanation, the Watermaster proposes utilizing a 5,108 AFY value for Este PSY:

> We recommend the **smaller** value as more representative of the present conditions, but note this is subject to continuing investigation (PSY Update, Appendix D).

(FPA Recommendation WY 2024-2025, pg. 4., emphasis added.)[4]

The Watermaster Engineer's recommendation does not adhere to the Judgment's requirements defining PSY. The Watermaster is required to utilize the **highest** average Annual Amount of water that can be produced.

The Watermaster Engineer's analysis should have analyzed whether 5,108 AFY, 6,582 AFY, or possibly an even higher figure, is the highest average in accordance with the PSY definition under the Judgment. Instead, the Watermaster Engineer's PSY Update presents only these two options for Este and acknowledges that further investigation is required due to data gaps in the Este Subbarea.

B. **The Watermaster Engineer Should Explain how its Recommendations are Based Upon Representative Long-Term Averages as Mandated by the PSY Definition**

FPA Recommendation WY 2024-2025 notes:

> Assuming limited or no change in storage the PSY for Este is about equal to the pumping, or about an average 5,108 acre feet for the past 5 years and 6,582 acre feet for the 20 year base period (2001-2022).

(FPA Recommendation WY 2024-2025, pg. 4.)[5]

The definition of PSY requires PSY to consider a sequence of years that is representative of long-term averages. (Judgment, paragraph II.A.4.aa.)

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[3] Watermaster Recommendation for Free Production Allowance for Water Year 2024-25, February 28, 2024 https://mojavewater.granicus.com/MetaViewer.php?view_id=2&clip_id=1336&meta_id=107551#page=4
[4] Watermaster Recommendation for Free Production Allowance for Water Year 2024-25, February 28, 2024 https://mojavewater.granicus.com/MetaViewer.php?view_id=2&clip_id=1336&meta_id=107551#page=4
[5] Watermaster Recommendation for Free Production Allowance for Water Year 2024-25, February 28, 2024 https://mojavewater.granicus.com/MetaViewer.php?view_id=2&clip_id=1336&meta_id=107551#page=4

The Watermaster Engineer should explain: (1) whether and how 2017-2022 is representative of long-term averages[6]; (2) whether any five-year period can be considered a long-term representative value under the Judgment; and (3) whether and how the 2001-2022 period is less representative of long-term averages compared to 2017-2022.

This issue is further compounded when reviewing the draft WY 2022-2023 Annual Report. The Annual Report notes that "PSY is based on long term average water supply (1931-1990)" and that "[t]ime is an important consideration in the relationship between FPA, PSY and sustainability."[7] These statements appear to be inconsistent with the Este PSY Update analysis that does not address the existing baseline period 1931-1990.

The Watermaster Engineer may have good reasoning for why certain time periods serve as better long-term averages as compared to others, but that analysis needs to be conducted and made available to the Parties and the Court to ensure the Judgment is being applied correctly.

C. **The Current Recommendation for Este PSY Overlooks Increases in Storage and Stable Water Levels**

The PSY definition in the Judgment requires that the value selected for a Subarea does not result in a net reduction of groundwater in storage in the Subarea.

The Watermaster Engineer notes for the Este Subarea that "UMBM indicates a loss of storage of 191 acre feet per year for the 70 year model period of record, but an increase of 134 acre feet per year in the 20 year base period (2001-2022)."[8] Additionally, the Watermaster Engineer notes "In general, the historical water levels shown on the hydrograph (Figure 4) are relatively stable, or are only changing at a small rate."[9] The Change in Storage Analysis in the PSY Update report, however, does not refer to or appear to account for this increase.[10]

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[6] See Watermaster Production Safe Yield and Consumptive Use Update, Water Supply Update for Este Subarea, February 28, 2024 at 54-55, which indicates the Watermaster Engineer analyzed 2017-2022 for a Base Period analysis. It is not clear how the Watermaster analyzed 2001-2022 as compared to 2017-2022, https://www.mojavewater.org/wp-content/uploads/2024/02/20240222-PSY-and-CU-Update-2024.pdf#page=54

[7] Watermaster Draft Water Year 2022-2023 Annual Report, pg. 38.

[8] Watermaster Production Safe Yield and Consumptive Use Update, Water Supply Update for Este Subarea, February 28, 2024 https://www.mojavewater.org/wp-content/uploads/2024/02/20240222-PSY-and-CU-Update-2024.pdf#page=54

[9] Watermaster Production Safe Yield and Consumptive Use Update, Water Supply Update for Este Subarea, February 28, 2024 https://www.mojavewater.org/wp-content/uploads/2024/02/20240222-PSY-and-CU-Update-2024.pdf#page=53

[10] Watermaster Production Safe Yield and Consumptive Use Update, Water Supply Update for Este Subarea, February 28, 2024 https://www.mojavewater.org/wp-content/uploads/2024/02/20240222-PSY-and-CU-Update-2024.pdf#page=54

To the extent the Watermaster Engineer will utilize data presented in its PSY Update to propose Rampdown, the PSY should be at least 6,582 AFY, and likely higher given the sustained levels of verified production in Este that do not risk loss of groundwater in storage and, to the contrary, demonstrate increases in groundwater in storage over the past 20 years.

II. CONCLUSION

On behalf of our clients, we reserve all rights to comment further on these pending items, including commenting on any proposals for the other Subareas.

We request that the Watermaster Engineer address the issues raised in this letter and conform its analysis to the Judgment requirements. Additionally given the extent of these questions raised, we request that the Watermaster extend the comment period for FPA recommendations such that further review and analysis of the PSY Update and FPA Recommendation WY 2024-2025 can occur. Only once the PSY is properly determined can Free Production Allowance recommendations be properly considered and analyzed.

Sincerely,

Fennemore LLP

/s/ Derek Hoffman

Derek Hoffman
Director

DHOF/mrh

State of California – Natural Resources Agency
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Inland Deserts Region
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www.wildlife.ca.gov

March 19, 2024

Mojave Basin Area Watermaster
Mojave Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307-4377

Subject: Updates to Production Safe Yield and Free Production Allowance for Water Year 2024-2025

Dear Watermaster Board Members,

The California Department of Fish and Wildlife (CDFW) has reviewed the Watermaster's recommendation for free production allowance (FPA) for Water Year (WY) 2024-2025 as presented at the February 28, 2024, Watermaster Board (Board) meeting and further described in the February 28, 2024, "Production Safe Yield & Consumptive Use Update" (2024 PSY Update) and draft "30th Annual Report of the Mojave Basin Area Watermaster" (Watermaster's 30th Annual Report). CDFW hereby submits its comments to the Board regarding FPA and the recently completed 2024 PSY Update in advance of the Board's March public hearing to receive comments and adopt the proposed FPA for WY 2024-2025.

As noted in my remarks to the Board in February and in our comment letter dated February 20, 2024, CDFW is concerned that implementation of the Watermaster's new approach to determining PSY and the resulting increases in FPA for the Alto and Centro Subareas is premature. Specifically, CDFW notes that that the increase in FPA in Alto is reliant on complex modeling outputs (and the underlying model assumptions), as well as significant imported artificial recharge in the future, rather than observed trends reflected in the ground and surface water monitoring network. CDFW believes that a more cautious "wait and see" approach is warranted given the sensitive fish and wildlife resources at risk. CDFW recommends that the artificial recharge prescribed by the Watermaster be applied first, followed by monitoring to verify the projected modeling results before FPA is increased. CDFW has additional concerns with the new PSY recommendations explained further below.

CDFW ROLE

CDFW is the trustee agency for the state's fish and wildlife resources and is a party to the Judgment After Trial, dated January 10, 1996 (Judgment). In addition, CDFW is a landowner in two of the five subareas in the Judgment, the Baja and Alto Subareas. In the Baja Subarea, CDFW owns the Camp Cady Wildlife Area (Camp Cady), and in the Alto Subarea, CDFW owns the Mojave Narrows Regional Park and Mojave River Fish Hatchery. Exhibit H of the Judgment, Biological Resource Mitigation, states that the physical solution was developed in consideration of the water needs of public trust resources and seeks to achieve certain minimum groundwater table standards necessary to maintain sensitive riparian resources and species associated with the Mojave River system.

COMMENTS AND RECOMMENDATIONS

CDFW met with the Watermaster Engineer and staff on March 11, 2024, to discuss questions pertaining to the 2024 PSY update and related topics and has subsequently requested additional materials and information. CDFW staff appreciate that the Watermaster has been responsive, yet significant questions remain that are unlikely to be fully resolved before the June Court date to set FPA for WY 2024-2025.

CDFW acknowledges that there have been substantial advances in the tools and datasets available to model and monitor groundwater systems in the nearly 30 years since the Judgment was implemented and is supportive of using these resources to improve our understanding of water in the Mojave Basin; However, CDFW also believes that critical decisions on water management should be weighted towards observed real-world data over modeled outcomes.

In the Alto Subarea, CDFW understands that the proposed increase in FPA is based on a modeled scenario of holding production at 2020 levels[1,2] and the annual import of 17,500 acre-feet of artificial recharge for 20 years. CDFW agrees that the Watermaster's modeled response to such imported water indicates potential benefits to fish and wildlife resources but believes that it is prudent to monitor the results of this action before increasing production. Such an approach would be consistent with Mr. Wagner's May 2023 declaration to the Court in which he recommended holding FPA in the Alto subarea at 50% for five years. Additionally, the Watermaster's 30th Annual Report for the current year states that:

> We note that variability showing lower lows and lower highs is an indication of extractions exceeding recharge over time. Water levels in the western portion of Alto in the regional aquifer exhibit declines consistent with locally heavy pumping and limited local recharge… Continued pumping in depleted areas of the regional system may result in long-term local negative impacts such as declining yields and water quality problems. Water levels in near river wells, particularly in the south part of Alto, experienced a trend of decline for 7 years consistent with limited recharge due to drier than average conditions… Continuation of dry conditions will result in water level declines

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[1] Mojave Water Agency Watermaster, 2024 PSY Update (February 24, 2024), Appendix A, Alto & Centro Subarea Water Supply Update, p. 3 and Table 2.
[2] Mojave Water Agency Watermaster, 2024 PSY Update (February 24, 2024), Appendix G, Upper Mojave River Basin Groundwater Model, p. 4.

(Watermaster's 30th Annual Report, pp. 27-28).

As indicated in this discussion, water levels in the Alto Subarea are still influenced by locally heavy pumping and the hydrographs for many wells do not indicate the levels of stability that would warrant increased production at this time. Further, the modeled scenario of artificial recharge in the Alto Subarea assumes that additional "wet water" is imported annually, which differs from other forms of replacement water such as unused FPA, claim program, and pre-stored water. Appendix G of the 2024 PSY Update notes the assumption that "17,500 [acre-feet] imported water was delivered at the Deep Creek (directly to the river) site and spread over a three month period from June to August" (Appendix G, p. 4). Monitoring of this approach is needed to ensure the desired results are achieved.

In the Baja Subarea, the Watermaster has set PSY equal to production based on the observation that "in some wells the decline has stopped or is reversing."[3] CDFW notes that in the contemporary PSY calculation,[4] the surface water inflow to the Baja Subarea has been reduced significantly and agrees this is consistent with observed measurements. Therefore, as with last year, CDFW agrees that based on the proposed PSY, further ramp down of FPA is not prescribed for WY 2024-2025. CDFW is concerned, however, that groundwater levels in portions of the Baja Subarea, particularly below the Waterman Fault at the CDFW Camp Cady/ Exhibit H riparian habitat areas, are now at such a low depth that the natural establishment of native riparian vegetation is not occurring. CDFW encourages the Watermaster to continue investigating why the surface water inflow to the Baja Subarea has been so dramatically reduced in the last 30 years, in addition to possible remedies to this lost inflow and storage.

Additionally, CDFW takes issue with the significant 51% reduction in water use allocated to riparian vegetation (i.e., phreatophyes) in the proposed PSY table. The original 2,000 acre-foot per year value was the result of a thorough investigation published by the U.S. Geological Survey[5] and was later validated in 2011 by Utah State University and the U.S. Bureau of Reclamation.[6] CDFW finds that this reduction in groundwater allocation effectively incentivizes the loss of riparian habitat resulting from

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[3] Mojave Water Agency Watermaster, *Draft Thirtieth Annual Report of the Mojave Basin Area Watermaster*, Water Year 2022-23 (February 28, 2024), 28.
[4] Mojave Water Agency Watermaster, 2024 PSY Update, February 24, 2024, Appendix E, *Baja Supply Update*, Table 2 [Table 5-1 (Based on 2001-2020)].
[5] U.S. Department of the Interior, U.S. Geological Survey, "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California," by Lines, G and Bilhorn, T, *Water-Resources Investigations Report 96-4241*. U.S. Geological Survey, (Sacramento, CA: 1996).
[6] USU and US Bureau of Reclamation, "Evapotranspiration Water Use Analysis of Saltcedar and Other Vegetation in the Mojave River Floodplain, 2007 and 2010," *Mojave Water Agency Water Supply Management Study*, Phase 1 Report, (2011).

groundwater depletion and the lowering groundwater table that has occurred since the implementation of the physical solution.

CDFW appreciates the opportunity to communicate its concerns regarding the integration of the 2024 PSY Update into the FPA recommendations for WY 2024-2025. In summary, 1) CDFW respectfully urges the Watermaster to proceed with the importation of water proposed in the Alto Subarea while holding FPA at current levels, until such time that real-world monitoring data indicates that future changes in production are warranted; 2) CDFW agrees that based on the proposed PSY in the Baja Subarea, reducing FPA is not indicated for the coming water year, but CDFW remains concerned about the reduced inflow and cumulative loss in storage; and 3) CDFW believes that reducing the allocation of water to riparian vegetation in the Baja Subarea PSY calculation sets a poor precedent when the intent of the physical solution was to consider the water needs of public trust resources. CDFW will be attending the March 27, 2024, Board meeting when the Board will hear additional comments and vote on its FPA recommendation to the Court.

Sincerely,

DocuSigned by:
Aaron Johnson
6477ACD4E0DE4DB...

Aaron Johnson
Senior Environmental Scientist
Inland Deserts Region

ec:

CDFW

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March 27, 2024

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VIA EMAIL TO: WATERMASTER@MOJAVEWATER.ORG

Board of Directors
Mojave Basin Area Watermaster
Mojave Water Agency
13846 Conference Center Drive
Apple Valley, CA 92307-4377

RE: Agenda Items 7 & 9 - Comments on Watermaster's Production Safe Yield Update (February 2024), proposed recommendation for Free Production Allowance for Water Year 2024-25, Watermaster Annual Report for Water Year 2022-23

Dear Board of Directors:

This letter follows my letter dated February 28, 2024 on behalf of Golden State Water Company (GSWC) related to the Mojave Basin Area (Basin) Watermaster's evaluation and update of the Production Safe Yield (PSY) for each Subarea of the Basin—specifically Watermaster's estimate of flow across the Transition Zone. GSWC is a party to the Mojave Basin Judgment and a producer in three of the Mojave Basin Subareas—Alto, Este, and Centro.

Despite the significant concerns raised by my February 28, 2024 letter, which included a technical analysis by aquilogic, Inc. regarding the accuracy of the Watermaster's calculation of flow across the Transition Zone, and the potential resulting impacts on Watermaster's calculation of the Production Safe Yield and Free Production Allowances for each Subarea, to date, GSWC has not received any response from the Watermaster.[1]

At the Watermaster's February 28 meeting, the Watermaster Engineer's presentation[2] included some information not previously shared that may represent an attempt to assess streamflow losses (i.e., groundwater recharge) in the Transition Zone, although the purpose is unclear.[3] To the extent that this information implies that most streamflow loss between the Lower Narrows gage and the Barstow gage

[1] The minutes of the Watermaster's February 28, 2024 meeting reflect Director Limbaugh's direction to the Mojave Water Agency or the Wastermaster to respond to GSWC February 28, 2024 comment letter.

[2] Watermaster Agenda, February 28, 2024, Item 7 Presentation: Production Safe Yield Update and Proposed Free Production Allowance (2024-2025), available at:
https://mojavewater.granicus.com/MetaViewer.php?view_id=2&clip_id=1336&meta_id=107549

[3] Watermaster Agenda, February 28, 2024, Item 7 Presentation: Production Safe Yield Update and Proposed Free Production Allowance (2024-2025), slides 24 and 25. The March 27, 2024 presentation on the same topic does not include this information. (See generally, Watermaster Agenda, March 27, 2024, Item 7 Presentation: Production Safe Yield Update and Proposed Free Production Allowance (2024-2025).)

occurs in the downstream half of the Centro Subarea, it contradicts the analysis conducted by aquilogic, which points to the conclusion that most streamflow loss between the Lower Narrows gage and the Barstow gage may occur in the Transition Zone—before it reaches the Centro Subarea. Given that groundwater extraction patterns, and perhaps other factors, have changed over the last 50+ years, this apparent contradiction can only be resolved through further, in-depth analysis, preferably with a well-calibrated groundwater flow model, which to date has not occurred.

Accordingly, GSWC reiterates is prior request that the Watermaster consider and respond to its comments and recommendations, inclusive of those contained in the aquilogic memorandum, before completing its update of PSY for each Subarea and before issuing its Free Production Allowance for Water Year 2024-25 and Annual Report for 2023-24. In addition, should the recommended analysis show the need for additional subsurface and surface monitoring to evaluate hydrogeologic conditions with the Transition Zone, especially at the Centro Subarea boundary, GSWC asks Watermaster to commit to install, operate, and maintain appropriate monitoring equipment to address data gaps.

If helpful, GSWC would be pleased to discuss its concerns in more detail with Watermaster Staff and Engineer.

Respectfully,

Stephanie Osler Hastings

cc: Leland McElhaney, Brunick, McElhaney & Kennedy
Robert Wagner, Watermaster Engineer
Toby Moore, Golden State Water Co.
Bob Abrams, aquilogic, Inc.

City of Hesperia

March 27, 2024

Watermaster c/o
MOVAJE WATER AGENCY
13846 Conference Center Drive
Apple Valley, CA 92307

Subject: Mojave River Basin – Alto Subarea
Free Production Allowance (FPA) for Water Year 2024-25

Ladies and Gentlemen,

For Water Year 2024-25, WM recommends that the Court increase the Alto Subarea FPA from 50.4% to 53.3%. The City requests that WM change the proposed recommendation to rescind last year's rampdown and return the Alto Subarea FPA to 55%.

1. **2022-23 Record Water Delivery Year** - rainfall, both local precipitation and runoff from the San Bernardino Mountains, together with imported water deliveries provided about 305% of the 60-year base period flow at Deep Creek. In addition, for calendar year 2023, MWA delivered nearly 100,000 acre feet of imported water to the region. Cumulative Alto Subarea storage increased by nearly 184,000 acre feet.

2. **Ongoing Analyses** – MWA is preparing a series of geologic, modeling, and return flow studies. MWA began evaluating the feasibility of groundwater banking. Geotechnical and geohydrology investigations in the upper Alto Subarea continue and will characterize the subsurface infiltration rates, subsurface hydrogeologic zones and properties, groundwater levels, hydraulic properties and alluvial sediments of the aquifer as well as identify favorable areas for recharge facilities and will assist to assess the regional suitability of projects.

   Regarding return flow, WM continues to rely on a 2018 Water Consumptive Use Study that requires an update. The City agreed to assist WM to assemble return flow data to improve consumptive use estimates. In addition, WM has acknowledged that agricultural use is the primary to consumption use. In the Alto Subarea, agriculture uses have essentially disappeared. Results of these studies will provide greater data and enhanced knowledge of the aquifer.

3. **Water Management** – VVRWA has constructed two sub-regional wastewater treatment plants that provide recycled water supplies to meet irrigation demands resulting in demand reductions and Alto Subarea recharge. In addition, the City is looking into opportunities with other agencies for planning recharge basin projects. Basins will provide MWA water recharge opportunities.

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Again, the City requests that WM revised its recommendation to rescind last year's FPA rampdown and consider the arguments presented above prior to recommending any future rampdowns. Thank you for your consideration. If you have any questions or require additional information, please contact me at csanchez@cityofhesperia.us or by phone at 760-947-1059.

Sincerely,

Cassandra Sanchez, City Engineer

cc. Rachel Molina, City Manager
Michael Thornton, Consulting Engineer

MOJAVE BASIN AREA
WATERMASTER
FOR
CITY OF BARSTOW, ET AL, VS. CITY OF ADELANTO, ET AL,
CASE NO. 208568 - RIVERSIDE COUNTY SUPERIOR COURT

April 1, 2024

Mr. Aaron Johnson
Senior Environmental Scientist
Inland Deserts Region
California Department of Fish and Wildlife
Sent via Email Aaron.Johnson@wildlife.ca.gov

Re: California Department of Fish and Wildlife (Department) Comments to Watermaster

Dear Mr. Johnson:

Thank you for letter of March 19th 2024 regarding Updates to Production Safe Yield and Free Production Allowance for 2024-25. We appreciate your comments and the cooperation between the Watermaster and the Department to manage the Mojave Basin Area water resources.

The Watermaster incorporated the Upper Mojave Basin Model into the analysis of the Alto Subarea water supply conditions. The results of the model are similar to our previous method for evaluating the Alto subarea. In 2023 while we were still in the process of updating the model we indicated that FPA for Alto should be 50% of BAP. We also reported that our expectation for Alto ultimately would be that FPA would be within a range of 50% to 55% of the BAP. After evaluating the water resources and selecting a recent and representative Base Hydrologic period (2001-2020), we concluded that 53.3% was the appropriate level for Alto FPA. That calculation results in Alto producers purchasing between 16,000 and 17,500 acre-feet per year, depending on pumping and transfers of FPA and Carryover.

As part of the evaluation, we modeled a future condition of recharging the annual deficit of 17,500 acre-feet per year. The results of the modeling indicate a substantial increase in flow through the Lower Narrows (9,000 acre-feet per year), which will benefit habitat as well as support water levels in the Transition Zone and support increased flow downstream from future storms. We note that the PSY and FPA are independent of the amount of the annual deficit, rather the deficit is a result of the PSY/FPA calculation.

Regarding the selected months and duration for modeled recharge, we can't know in advance when water will be available for importation and recharge. We selected the months to model when the river channel is normally dry to maximize recharge. In 2023 for example, MWA was able to purchase for release to Alto about 85,013 acre-feet of supplemental water during the year. As noted, we do not control the availability or timing for supplemental water.

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Regarding the Baja subarea, measuring inflow and outflow is challenging. Also, the over pumping since at least 1940 has significantly reduced water levels. However, as we have reported, the reduction in pumping in recent years has resulted in water levels stabilizing. The Department has raised issues with the calculations for water supply for Baja under the two hydrologic base periods identified; 1931-1990 (Judgment), and 2001-2020, as used for Alto and Centro subareas. As we discussed in our March 11, 2024 meeting, we will address the Department's concerns in the coming months. We note that the recommendation for Baja is based on our assessment of water levels in Baja.

We estimated the use of water for phreatophytes at Camp Cady to update, to the extent possible, the actual amount of water consumed by phreatophytes. The value of 2,000 acre-feet, has been acknowledged in the Baja water balance calculations since at least 1996. This value was the result of a 1995 joint report by USGS and the CDFW (Lines and Bilhorn). Our calculation based on use of remote sensing algorithms doesn't change the amount of water actually consumed by riparian vegetation, merely allows an accounting for the water use.

We will reach out to you to schedule a follow up meeting in advance of the June hearing date to discuss your specific questions regarding the data sources you have questioned.

Sincerely,

Robert C. Wagner, P.E.
Watermaster Engineer

CC:

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MEMORANDUM

To: Mr. Lee McElhaney
Attorney, Mojave Basin Area Watermaster
Brunick, McElhaney & Kennedy
lmcelhaney@bmklawplc.com

From: Robert Wagner, P.E., A. Leonardo Urrego-Vallowe

Date: April 12, 2024

Re: **Response to comments on Transition Zone Water Balance memorandum, dated February 28, 2024.**

This memorandum responds to comments on the Mojave Basin Area Watermaster's update to the Production Safe Yield (PSY) for the Alto and Centro subareas that was presented by Watermaster Engineer to the Watermaster Board on January 24, 2024 and on the Watermaster memorandum titled "Production Safe Yield & Consumptive Use Update" dated February 28, 2024.

The comments Ms. Stephanie Hastings, Attorney transmitted on behalf of Golden State Water Company (GSWC) highlight the importance of accuracy in the calculation of the Free Production Allowance (FPA) as required by the Judgment. The comments indicated that GSWC has concerns that the calculation of the of PSY and FPA do not accurately represent observed conditions in the Centro subarea. Watermaster understands that GSWC concern is based on decline in groundwater levels in its wells within the Centro subarea, water quality impacts associated with this decline and the operational costs associated with these issues.

The comments included a technical analysis prepared by Aquilogic titled "Progress Report and Mojave Basin Transition Zone Water Budget" (referred to as the "aquilogic memorandum"). The aquilogic memorandum concludes that Watermaster has overestimated the streamflow recharge into the Centro subarea because the Watermaster incorrectly assumed that all inflows into the Transition Zone (TZ) are equal to the inflows to the Centro subarea. The aquilogic memorandum states that Watermaster assumption of the change in storage for the TZ is zero may be incorrect given that there is no direct measurement of stream flows at the upstream boundary of the Centro subarea.

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The aquilogic memorandum explains that the USGS Wild Crossing gage was in operation for a relatively short period of time (March 1966 to September 1970). A stream flow analysis of the Wild Crossing gage relative to the Lower Narrows gage during the period of record indicated that most of the Mojave River recharge occurred along the TZ rather than within the Centro subarea and therefore, the assumption regarding the change in storage for the TZ appears to be incorrect.

In addition, the aquilogic memorandum states that "the Wild Crossing gage was discontinued because of unstable controls and changing stage-discharge relations that did not allow for acceptable discharge records." Watermaster does not believe the data recorded at the Wild Crossing gage is representative enough to include in the current calculation of return flows into the TZ and neither in the calculation of the PSY and FPA. This is because stream flows at the Wild Crossing gage were recorded for a short period of time (only four complete water years) and because operations at this gage were discontinued due to inaccuracy issues as mentioned in the aquilogic memorandum.

Watermaster assumption of no change in storage for the TZ is supported by the consistent decrease in groundwater pumping within the TZ. Historic groundwater production in the TZ is shown below (**Figure 1**). The average pumping between 1951-2020 and 2001-2020 declined about 40.7%.

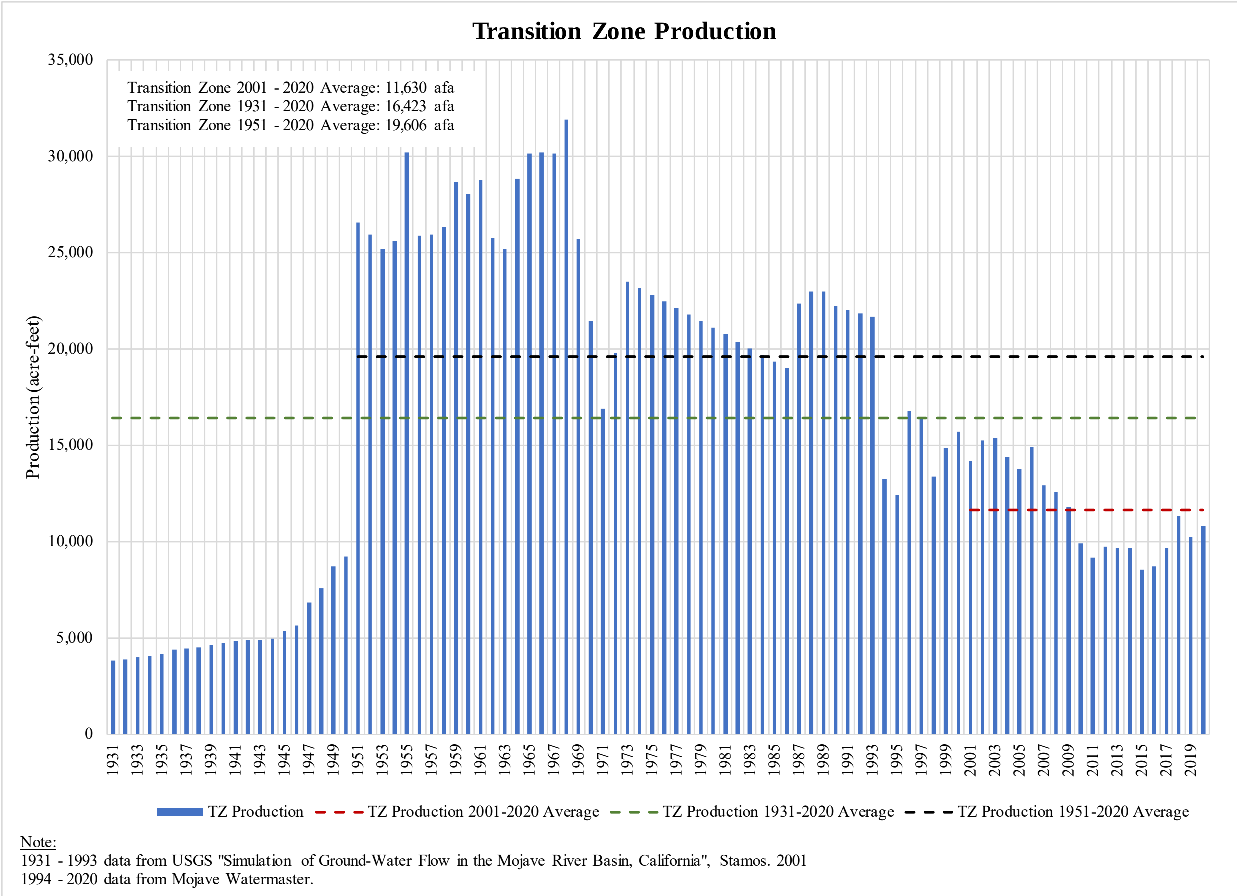


Figure 1. Historic groundwater pumping in the Transition Zone.

In September 2022, USGS initiated operations of the streamflow gage #10262000 Mojave River near Hodge. In water year (WY) 2023, total annual stream flow at the Lower Narrows was 96,606 acre-feet (AF) and total stream flow at the Hodge gage was 84,351 AF. The difference between these two gages was about 12,203 AF. Total discharge from VVWRA into the Mojave River was 14,274 AF. Neglecting stream flow losses due to evaporation, net stream change between Lower Narrows and the Hodge gage was about 24% (or 26,529 AF during 2023). The reach between the Lower Narrows gage and the Hodge gage is nearly 23.5 miles; and the distance between the Lower Narrows gage and the Helendale Fault is about 13 miles. Hence, we expect that only 13% (or 14,675 AF) of the net stream change would have occurred along the TZ. This is consistent with the historical record of losses between Lower Narrows and the Helendale Fault.

As explained in the Watermaster Annual Report for Water Year 2022-23 (Annual Report), the elements of use from the TZ are: 1) Groundwater extractions (pumping), and 2) Consumptive use by native vegetation (phreatophytes). The verified production during WY 2023 was 10,039 AF. Total consumptive use for phreatophytes was calculated to be about 5,702 AF. Return flows from pumping during 2023 was 3,180 AF. Thus, total use from the TZ during WY 2023 was 12,561 AF (production plus phreatophytes use minus return flows) which is close to the net change in stream flows in the TZ estimated above (14,675 AF). In other words, the net streamflow loss is accounted for by the groundwater pumping, return flow and water demand for phreatophytes.

We prepared an estimated surface water balance for the TZ for WY 2023 for purposes of calculating the outflow to Centro subarea for WY 2023 as shown on **Table 1**.

Table 1. Transition Zone Water Balance for WY 2023 (all values are provided in units of AF).

WATER SUPPLY	
Surface Water Inflow	
Lower Narrows	96,606
VVWRA	14,274
Ungaged (Runoff from Precipitation)	745
Subsurface Inflow	2,000
Return Flow from Production [1]	3,180
Imports	0
Total Inflows	116,806
CONSUMPTIVE USE AND OUTFLOW	
Surface Water Outflow	
Gaged	0
Ungaged	99,064
Subsurface Outflow	2,000
Production	10,039
Phreatophytes	5,702
Imports	0
Total Outflows	116,806
Notes: [1] Return flows are calculated as total production (10,039 AF) minus consumptive use (6,859 AF).	

Hydrographs showing historical groundwater levels within the TZ (Figure 3-13 of the Annual Report) indicate that groundwater levels have been stable for most of the wells since at least 1993. This supports our assumption that average change in storage in the TZ historically has been nearly zero. If a positive change in groundwater storage had occurred as suggested by Aquilogic, we would expect to see evidence of an increase in the groundwater elevations.

Watermaster also understands the concern presented on behalf of GSWC regarding the declining water levels in the Centro subarea and the impacts to the GSWC operations and facilities.

Watermaster is implementing groundwater modeling tools to improve the understanding of water supply, use and disposal for the Centro subarea. Watermaster has developed a groundwater model for the Alto subarea and used model outputs to update PSY and FPA for the Alto subarea as described in the Watermaster memorandum. Watermaster is in the process of extending the model to include Centro and the other subareas and future PSY and FPA updates will incorporate output from model results.

According to the aquilogic memorandum, average annual streamflow between the Lower Narrows and Wild Crossing gage was decreased by approximately 51,500 AFY (acre-feet per year) during WY 1966 to 1970. This would suggest that about 51,500 AFY is net recharge into the TZ via percolation. However, the historic pumping during the 1960s was remarkably higher than present conditions (see **Figure 1**). Historic production in the TZ, during the five years evaluated by Aquilogic is summarized in **Table 2**. Average total pumping in the TZ during the 1966-70 period was 27,885 AF.

Table 2. Historical groundwater pumping in the Transition Zone during WY 1966-1970

WY	Total Pumping
1966	30,208
1967	30,138
1968	31,893
1969	25,727
1970	21,460
Average 1966-70	27,885

Watermaster expects that losses from the surface water supply within the TZ correspond to pumping rather than recharge. As noted on the Watermaster memorandum, we updated the hydrologic base period for purposes of establishing PSY for Alto and Centro; the average pumping in the TZ during the updated hydrologic base period (2001-2020) was 11,630 AF. Total verified production during 2023 was 10,039 AF. Therefore, the average pumping of the base period and the pumping during 2023 were roughly 60% lower than the average total pumping during the 1966-70 period.

A historic aerial imagery comparison between 1969 and 2022 is provided in **Figure 2** (1969 aerial imagery) and **Figure 3** (2022). The 1969 aerial imagery shows the extent of agricultural development along the Mojave River between the Helendale Fault and the Hodge gage, including the vicinity of the Wild Crossing gage (near Indian Trail). The 1969 aerial imagery indicates the significant irrigation within the area of interest. The 2022 aerial imagery evidences the change in land use with most irrigation areas being fallowed over time. The change in groundwater pumping since the 1960s has changed the behavior of the river relative to recharge within the TZ.

Watermaster concludes that the decrease in annual stream flows during 1966-1970 between the Lower Narrows and the Wild Crossing gage was likely due to the high groundwater extractions downstream of the TZ rather than significant net stream recharge within the TZ.

Total annual stream flow at the Mojave River at Barstow gage was 8,687 AF during WY 2023 (as reported on the Annual Report). The net stream change between the Hodge gage and the Barstow gage was 75,664 AF during WY 2023 (i.e., difference between 84,351 and 8,687 AF). The distance between the Hodge gage and the Barstow gage is nearly 12 miles. Watermaster estimates that groundwater recharge from surface supply between these gages was about 90% of the total flow at Hodge.

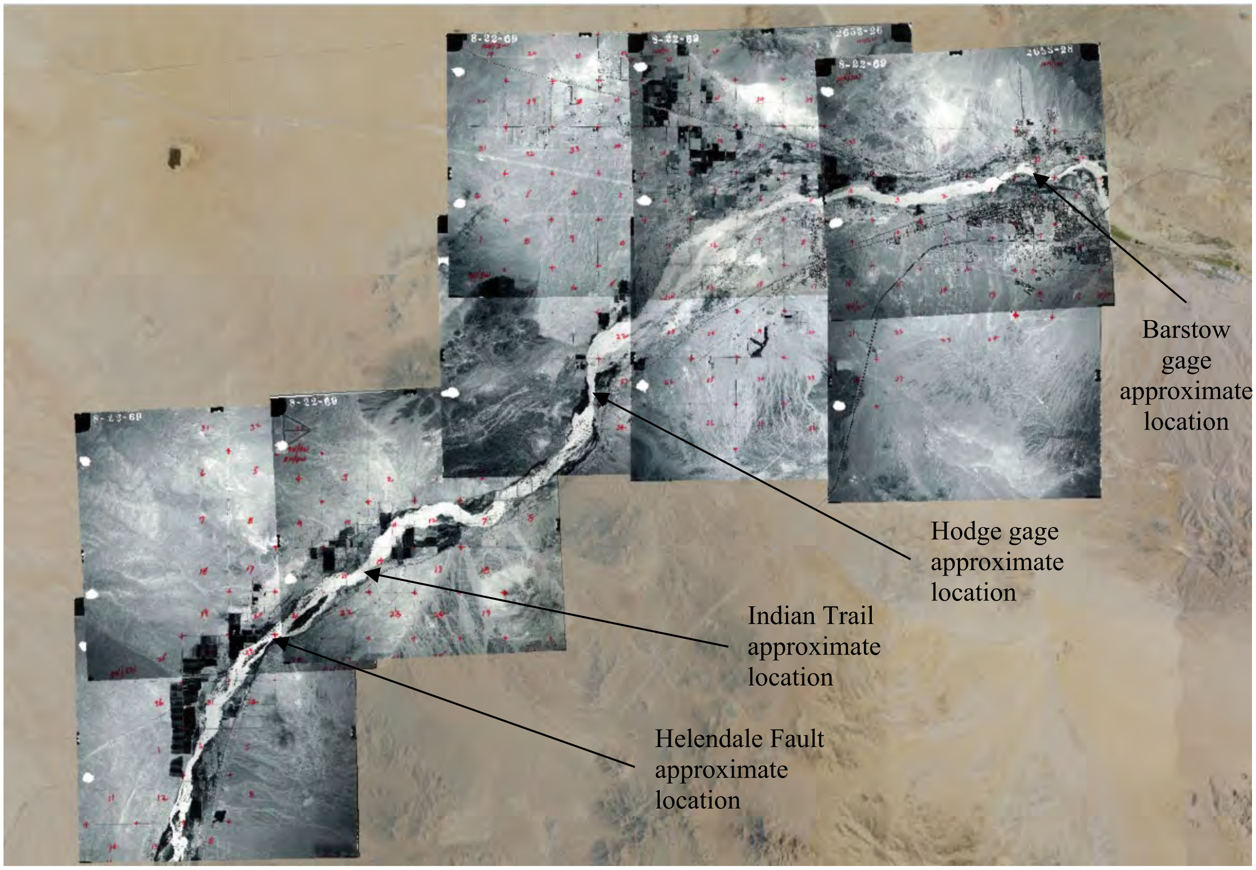


Figure 2. Aerial imagery of the area of interest taken in 1969 with the 2022 background image.

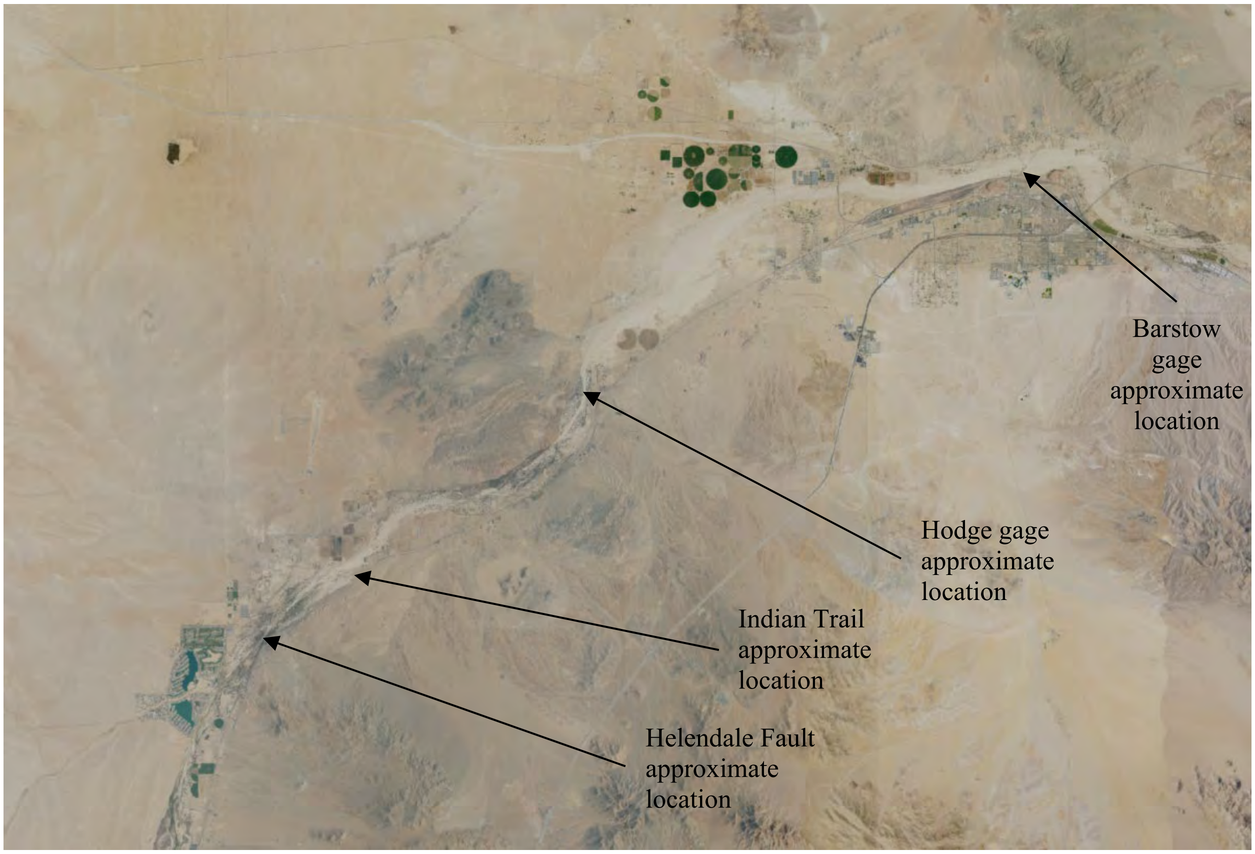


Figure 3. Aerial imagery of the area of interest taken in 2022.

Attached to this memorandum is the excerpts from "Exhibit A, Area of Influence of the Mohave River and it's 20 subareas" prepared by Edward Fitzgerald Dibble, Consulting Engineer (Dibble, 1973) showing the total annual extractions as reported by the Mojave Water Agency. Section 8 of the excerpts corresponds to the area between the Helendale Fault and Lenwood (Centro subarea). Total annual production for Section 8 during the years 1951 to 1973 is summarized in **Table 3**.

Table 3. Total annual extractions within Section 8 for the years 1951-1973.

Year	Total Production	Year	Total Production
1951	8,686	1963	8,344
1952	9,002	1964	8,648
1953	10,105	1965	7,458
1954	10,547	1966	7,327
1955	10,338	1967	8,638
1956	11,600	1968	11,437
1957	9,868	1969	7,873
1958	10,108	1970	8,888
1959	10,485	1971	7,408
1960	12,911	1972	6,197
1961	12,028	1973	5,389
1962	11,983	Average 1951-73	9,359

The output from the groundwater flow model by the USGS (Stamos, 2001) provides simulated streamflow at various locations of the Mojave River (see **Figure 4**). The long-term flow average at Vista Road (at Helendale) is the approximate discharge from the TZ. The 1951-1999 average of 35,819 AF is close to the total average surface flow to Centro subarea (37,205AF) for the 1991-2023 period.[1] Average annual surface outflow from Alto to Centro during 1936-61 was estimated to be 35,500 AF (California Department of Water Resources, 1967). Thus, surface flows from the TZ into Centro subarea, as estimated at Helendale Fault have not changed significantly.

Figure 5 shows the long-term average discharge at Lower Narrows (USGS gage) plus the discharge from VVWRA to be 49,028 AF for the period 1951 to 1990 (VVWRA data started in 1986). The recent long-term average of 1991 to 2023 was 48,899 AF. Therefore, long-term inflow to the TZ has also been historically consistent.

[1] Calculated from the water balance at the TZ to be the average surface outflow (34,900 AF for 1991-2023) plus the average makeup purchases (2,305 AF for 1995-2023).

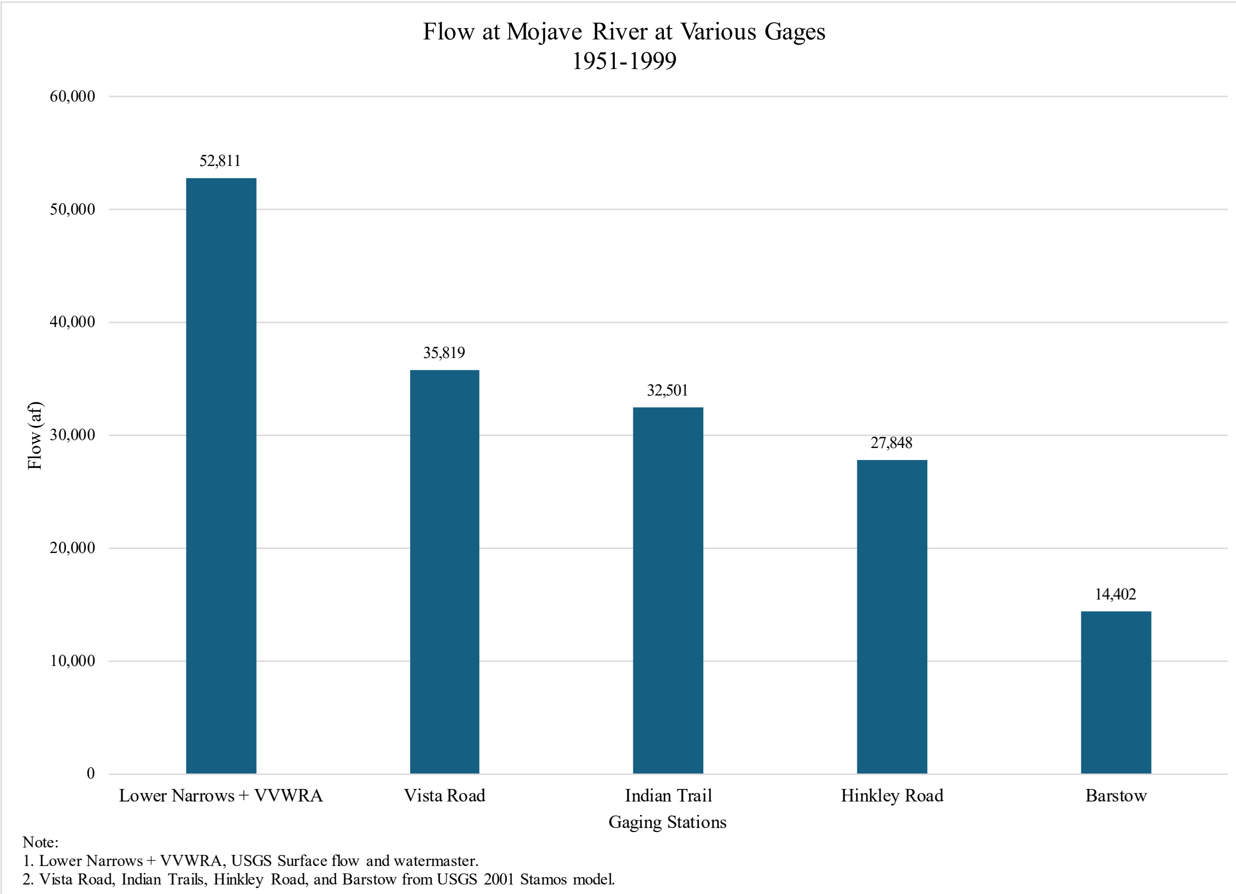


Figure 4. Simulated long-term average stream flows at the Mojave River from the USGS model.

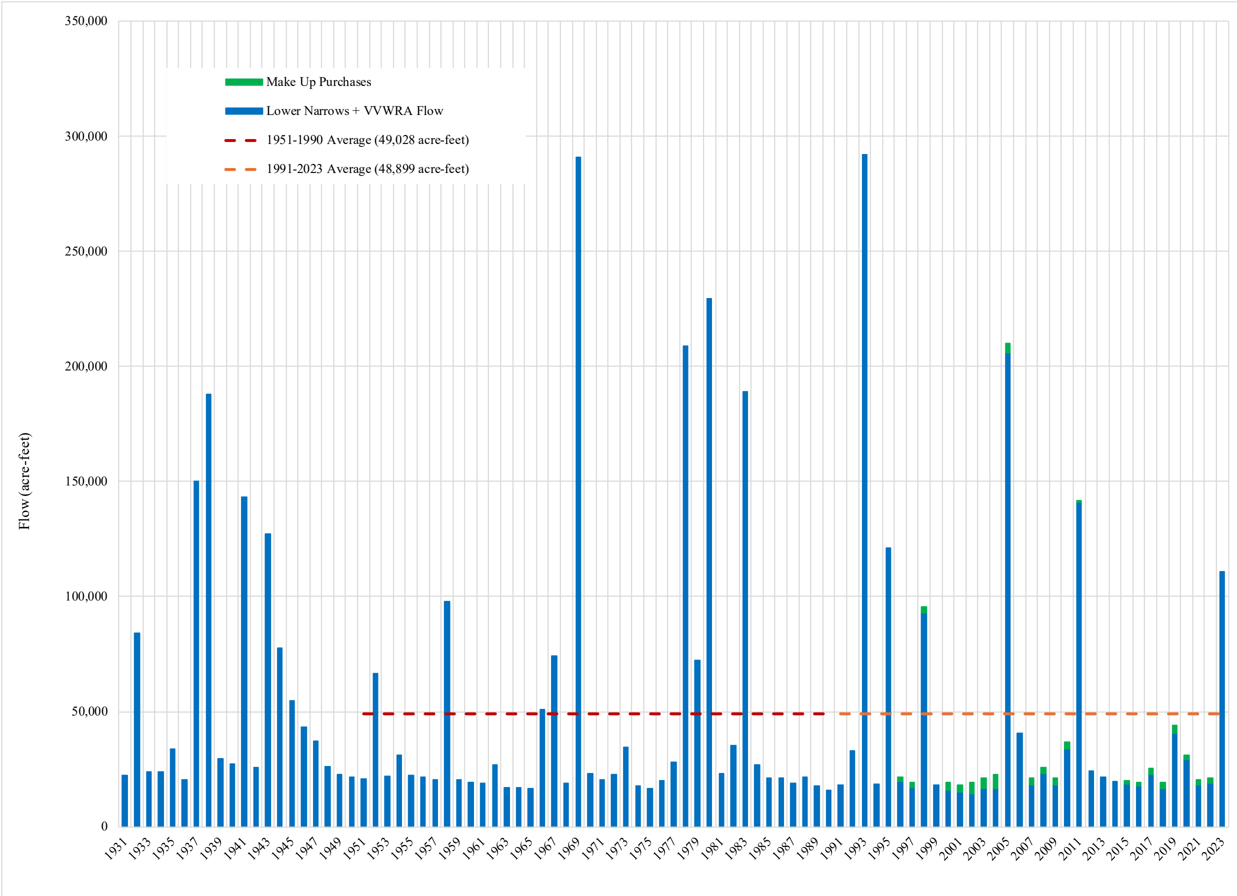


Figure 5. Total stream flows at Lower Narrows + VVWRA

In addition, the net change in simulated average stream flows between the reach of the Lower Narrows and the Vista Road (at Helendale) was 16,992 AF (difference between 52,811 and 35,819 AF from **Figure 4**). According to the historical groundwater production in the TZ shown on **Figure 1**, the average pumping during the period of 1951-1999 was 22,940 AF. Irrigation return flows to the TZ are in the order of 50-percent of the pumping.[2] Thus, we expect that average consumptive use from 1951-1999 to be about 11,470 AF. The USGS study by Lines and Bilhorn reported that the consumptive use by riparian vegetation was estimated to be about 6,000 AF along the TZ and this amount is representative of "normal" hydrologic conditions along the Mojave River (Lines & Bilhorn, 1996). The net change in stream flows along the TZ (16,992 AF) can be attributed to consumptive use by phreatophytes (6,000 AF) and consumptive use by pumping (11,470) rather than groundwater recharge from stream flows.

[2] From Hardt (1971) page 48, and Stamos (2001) page 32.

Requirements from the Judgment

The Judgment states that Alto subarea producers have a surface and subsurface flow obligation to the Transition Zone consisting of 21,000 AF of surface base flow (excluding storm flow) and 2,000 AF of subsurface flow. The obligation is calculated annually and maintained by assessing the Alto producers a Make Up Obligation based on a calculation outlined in Exhibit G, of the Judgment and included in the Watermaster Annual Reports as Tables 4-2 and 4-3. Exhibit G (e) provides “Alto Subarea Producers--an average Annual combined Subsurface Flow and Base Flow of 23,000 acre-feet per Year to the Transition Zone. For the purposes of Paragraph 6 of this Exhibit G, the Subsurface Flow component shall be deemed to be 2,000 acre-feet per Year. In any Year Alto Subarea Producers shall have an obligation to provide to the Transition Zone a minimum combined Subsurface Flow and Base Flow….” The Alto subarea obligation to the Transition Zone has been met every year.

Closing

Brownstein Hyatt Farber Schreck, LLP provided comments on behalf of Golden State Water Company suggesting that Watermaster assumption of the change in storage for the TZ is zero may be incorrect. Brownstein included a technical analysis prepared by Aquilogic which concluded that Watermaster has overestimated the streamflow recharge into the Centro subarea because the Watermaster incorrectly assumed that all inflows into the TZ are equal to the inflows to the Centro subarea.

In response to the comments provided by Brownstein, Watermaster evaluated the historical data to support our assumption that the average change in storage within the TZ has been nearly zero. Watermaster concludes that loss in stream flows observed along the TZ during the 1960s was attributed to consumptive uses in the TZ rather than groundwater recharge from stream flows.

Measured water levels in the TZ (Figure 3-13 of the Annual Report) have been historically stable which supports the accuracy of Watermaster assumption of no change in storage in the TZ. The historic decline in pumping and the change in the land use in the TZ since the 1960s has contributed to the water level stability observed in the TZ. The analysis of long-term historical data suggests that surface inflows (including VVWRA discharges) to the TZ and surface outflows from the TZ into Centro subarea have not changed significantly over time.

Enclosures:

Excerpts from “Exhibit A, Area of Influence of the Mohave River and it’s 20 subareas” prepared by Edward Fitzgerald Dibble, Consulting Engineer (1973).

References

California Department of Water Resources. (1967). *Bulletin No. 84 Mojave River Ground Water Basins Investigation.* California Department of Water Resources.

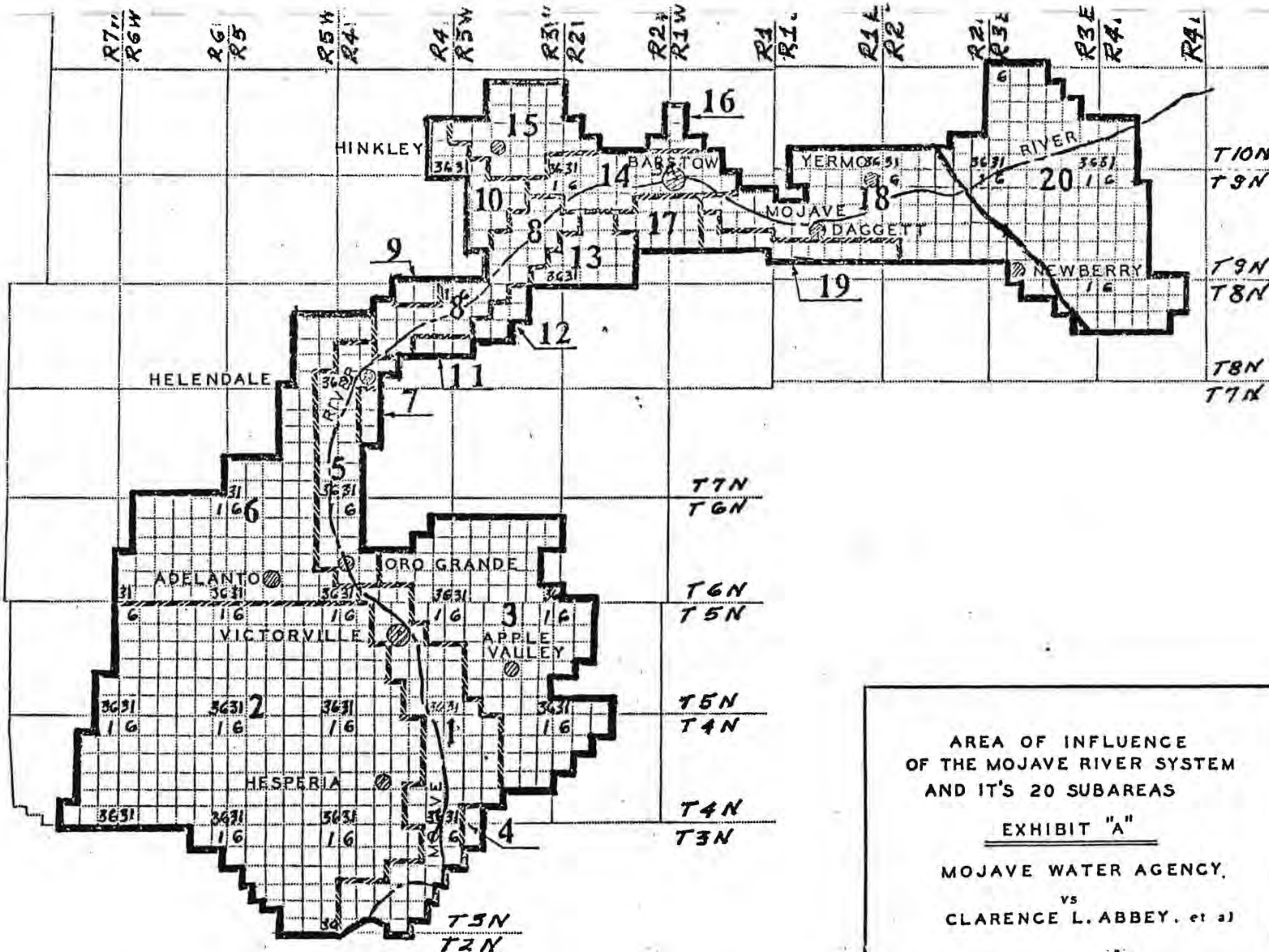
Dibble, E. F. (1973). *Water Production Verification Program.*

Hardt, W. F. (1971). *Hydrologic analysis of Mojave River Basin, California, using electric analog model.* USGS.

Lines, G. C., & Bilhorn, T. W. (1996). *Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California.* U.S. Geological Survey.

Stamos, C. L. (2001). *Simulation of ground-water flow in the Mojave River Basin, California.* United States Geological Survey.

ENCLOSURES



AREA OF INFLUENCE
OF THE MOJAVE RIVER SYSTEM
AND IT'S 20 SUBAREAS

EXHIBIT "A"

MOJAVE WATER AGENCY,
vs
CLARENCE L. ABBEY, et al

SUB AREA	NO. OF WELLS	NO. OF OWNERS	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	PRODUCTION RIGHTS 5-YR AVG	PRODUCTION RIGHTS MAX YR	PRODUCTION RIGHTS LMTD
	3	2	6,663	6,761	6,759	6,757	6,755	6,733	6,508	7,166	6,194	5,223	4,262	3,292	2,128	1,579	1,040	6,760	6,760	6,760
01	270	111	63,811	75,566	73,380	72,052	69,953	59,626	59,716	65,291	68,316	69,382	67,135	66,847	69,601	69,945	71,383	103,720	118,109	20,246
02	22	8	1,780	2,273	2,932	1,711	1,613	816	960	1,292	1,500	1,611	2,156	1,916	2,475	3,170	3,342	4,090	5,809	1,481
03	67	41	2,244	3,146	4,456	4,547	4,201	3,610	5,135	5,058	5,082	5,063	5,304	4,039	3,268	3,573	3,811	6,725	6,781	2,734
05	246	78	26,129	25,549	24,827	25,452	29,081	25,293	25,503	26,019	28,475	27,945	28,657	25,656	25,119	28,808	30,081	38,472	44,510	8,342
06	6	4	306	281	255	242	291	512	379	257	105	84	127	103	61	49	22	356	613	285
08	146	53	8,686	9,002	10,105	10,547	10,338	11,600	9,868	10,108	10,485	12,911	12,028	11,983	8,344	8,648	7,458	15,506	19,919	5,814
10	3	2	0	0	0	0	3	4	8	11	10	12	18	16	21	33	22	22	33	0
13	10	4	159	156	166	158	201	202	193	193	203	203	206	293	669	705	652	525	736	1
14	171	86	16,350	16,455	17,125	18,176	18,138	17,983	17,874	18,139	18,349	17,807	18,278	18,461	18,042	18,394	19,008	25,004	29,547	6,608
15	148	61	13,523	13,601	15,506	13,779	13,210	11,537	11,097	10,117	11,203	9,995	10,044	9,290	8,750	8,270	6,989	17,166	20,770	8,440
16	4	1	15	20	25	30	35	45	46	43	40	42	40	53	49	64	34	49	64	1
17	2	2	24	29	29	34	39	43	26	21	32	0	0	0	0	0	0	26	32	26
18	172	79	11,022	12,193	14,419	15,920	16,902	13,511	14,166	16,629	18,729	19,436	20,226	20,524	21,305	24,633	20,622	26,576	32,352	3,506
TOTALS	1,270	532	150,712	165,032	169,984	169,405	170,760	151,515	151,479	160,344	168,723	169,714	168,481	162,473	159,832	167,871	164,464	244,997	288,035	64,244

SUB AREA	NO. OF WELLS	NO. OF OWNERS	1966	1967	1968	1969	1970	1971	1972	1973
	3	2	0	1,488	2,522	4,218	0	0	0	
01	270	111	70,664	70,216	67,863	74,099	57,929	54,773	51,042	58,316
02	22	8	3,799	3,749	4,438	4,246	4,733	4,369	4,855	5,563
03	67	41	3,257	3,145	4,011	3,270	4,075	4,011	4,450	4,606
05	246	78	30,210	30,088	31,696	25,477	21,617	17,020	19,629	22,763
06	6	4	21	196	302	257	275	219	161	122
08	146	53	7,327	8,638	11,437	7,873	8,888	7,408	6,197	5,389
10	3	2	22	27	22	32	24	24	18	16
13	10	4	536	501	477	547	465	419	324	388
14	171	86	20,106	20,506	20,763	17,275	19,168	23,447	25,779	23,605
15	148	61	6,810	6,619	6,054	5,720	6,185	5,269	4,511	4,654
16	4	1	41	43	60	62	87	78	68	55
17	2	2	0	0	0	0	0	0	0	
18	172	79	20,910	21,741	21,104	19,320	24,017	25,150	25,301	24,930
TOTALS	1,270	532	163,703	166,957	170,749	162,396	147,463	142,187	142,335	150,407

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mr. Aaron Johnson
Senior Environmental Scientist
California Department of Fish and Wildlife

From: Robert Wagner, P.E., A. Leonardo Urrego-Vallowe

Date: April 16, 2024

Re: **Response to questions regarding well H1-2, PSY calculation and Alto model**

Thank you for providing the questions on Well H-1, PSY calculations and modeling output to the Mojave Watermaster. Please see below the responses to reach of the items prior to our call. We will discuss these during our call schedule for tomorrow April 17, 2024.

1. **Exhibit H, H-2:** Regarding the well H1-2 which was moved after storm damage. Please see attached existing layouts. We will discuss this during our call.
   a. Can you please provide a copy of the report that you noted that correlates the new H1-2 well to the old H1-2 dataset? Exhibit H contains a maximum depth of 7 feet in this well and we would like to see the details of how the max depth now in use by the Watermaster was determined. When I plot the data from USGS using the same datum (NAVD88) for both wells there appear to be some discrepancy (attached).
   b. What is the new well H1-2 riverbed elevation that's used to calculate the minus 7 feet trigger?
   c. We would like to have the Exhibit H-2 wells specifically identified in future ARs with the maximum depth indicated.

2. **Alto PSY and imported water:**
   a. Has the 17,500 af of proposed imported water been purchased for WY2024-25 at this time? This needs further discussion. As of this time, we believe that we have taken 19,494 af that has already been delivered.
   b. Will the 17,500 af of supplemental water be pre-purchased each year? No. It depends on DWR allocations, Replacement Water Assessments and basin conditions. On average, we expect 17,500 acre feet to be delivered and recharged.
   c. Will the PSY be adjusted if the annual 17,500 af isn't available? PSY is not dependent on the importation of water as it is based on natural water supply and other inputs. Free

Production Allowance (FPA) is set accordingly, and approved by the Court; it is FPA that results in a deficit/surplus that requires importing supplemental water.

d. Will the 17,500 af of proposed imported water be "wet water" as assumed in the model, or will unused FPA, claim program, or pre-stored water get applied to that deficit going forward? The producers that over pump their FPA will be assessed a Replacement Water Assessment. It is expected to generate up to between 16,000 and 17,500 acre feet per year, based on transfers of carryover and FPA between parties. When water is available for import, depending on allocations, MWA will use the funds to import water as envisioned by the Judgment. While obligations can be satisfied in multiple ways, imported must still be purchased and recharge to arrest overdraft and manage the basin.

3. **Alto Mountain Front Recharge (MFR):**
   a. Can you explain the basis of the 8,511 af used in the new Table 5-1 proposed PSY inflow for Alto, relative to the 7,409 af from the model (Full Simulated Water Budge table in the Feb 28 presentation page 7, column C) and the USGS 7,000 af noted in the 10.29.2021 Wood URMB project completion report section 2.5.1? The 8,511 af includes runoff, subsurface flow, ungagged inflow, deep percolation precipitation; this is modeled output, including output from the USGS Basin Characterization Model and Modflow. The 7,401 af is from an earlier version of the model. The adjustment was made for calibration. The new value (8,511 af) involves the BCM.
   b. What are the hydrological components of the MFR? What causes a difference in these values that results the total value ranging from 7,000 af to 8,511 af? See (a). above.

4. **Alto/TZ Outflow to Centro:** Can you please break down the components of the 36,725 af of surface water inflow to Centro in the new Table 5-1 proposed PSY calculation, the values of each component, and how those values are obtained from the inflow and/or outflow values given in the table for the of the TZ? We calculated flows from Alto at the Helendale fault based on a water balance shown on Table 5-1.

5. **Baja PSY calculations (Table 5-1 2001-2020):**
   a. Where does the 952 af of surface water inflow from Kane Wash, Boom Creek and other washes (footnote 3) in the previous Table 5-1 end up in the proposed new PSY calculation for Baja? Previous estimates for Kane Wash and Boom Creek are included as ungagged inflow in the current evaluation.
   b. Can you explain why the new proposed Baja subsurface inflow is 1,751 af, taken from Stamos 2001 Figure 34 with a base period of 1931-1990, is used in the proposed new 2001-2020 PSY? Why has this increased from the previous PSY value of 1,581 af, also taken from Stamos 2001? Under the current conditions we ignore the 170 af of discharge from Baja previously estimated by Stamos, 2001.
   c. Which of the ungaged tributaries in Stamos 2001, pages 15-17, sum to the 1,568 af in the proposed new Baja PSY calculation? The 1,568 af is from prorating tributary inflow to the Barstow gage as described by Stamos (page 15).
   d. Where does the MFR occur in Baja (Stamos 2001, Figure 35A?), and how was the 647 af of MFR determined? It came from the model, long-term average and assume constant.
   e. Did your evaluation of ET from phreatophytes at Camp Cady determine how much of the original riparian vegetation at Camp Cady has been lost since the 1996 baseline year study by Lines and Bilhorn, 1996, USGS WRI 96-4241? If so, what percentage of the

original 1,389 acres of Camp Cady phreatophytes has been lost? We evaluated total ET for the 1,389 acres of Camp Cady area for the four years 2019-2022. The 4-year average was 984 acre-feet per year. OpenET captures the variability of ET throughout the year. The long-term water use of 2,000 AFY estimated by Lines and Bilhorn (1996) derived from a different methodology. Water use from phreatophytes varied by more than 50% between our estimate and the 1996 study. Our study is based on a water balance that uses satellite images and an energy equation.

f. Table 3 in the 2.28.2024 Updated PSY and CU report indicates that the annual total ET for the Baja riparian zone ranged from approximately 695 to 1276 af. Was any of this variation due to a difference in the riparian vegetation area? In other words, does the variation reflect growth in the riparian vegetation? Our study was focused on water use by the riparian vegetation but not evaluation of plant growth or changes in plant density.

MOJAVE BASIN AREA WATERMASTER
FOR
CITY OF BARSTOW, ET AL, VS. CITY OF ADELANTO, ET AL,
CASE NO. 208568 - RIVERSIDE COUNTY SUPERIOR COURT

MEMORANDUM

Date: March 24, 2010

To: Watermaster

From: Robert C. Wagner, Watermaster Engineer

Re: Report on Upper Narrows Exhibit H Well

At the January 2010 Watermaster meeting Mr. Bilhorn, on behalf of the Department of Fish and Game indicated to Watermaster that the water level in the Upper Narrows monitoring well, used for monitoring compliance with Exhibit H, was greater than 7 feet below ground surface.

Staff indicated that it would investigate the water level and report back to Watermaster after meeting with Mr. Bilhorn. Staff believes the reason for the appearance that the water level is below the indicated target is due to the ground surface elevation of the well with respect to the current surface water level in the river channel.

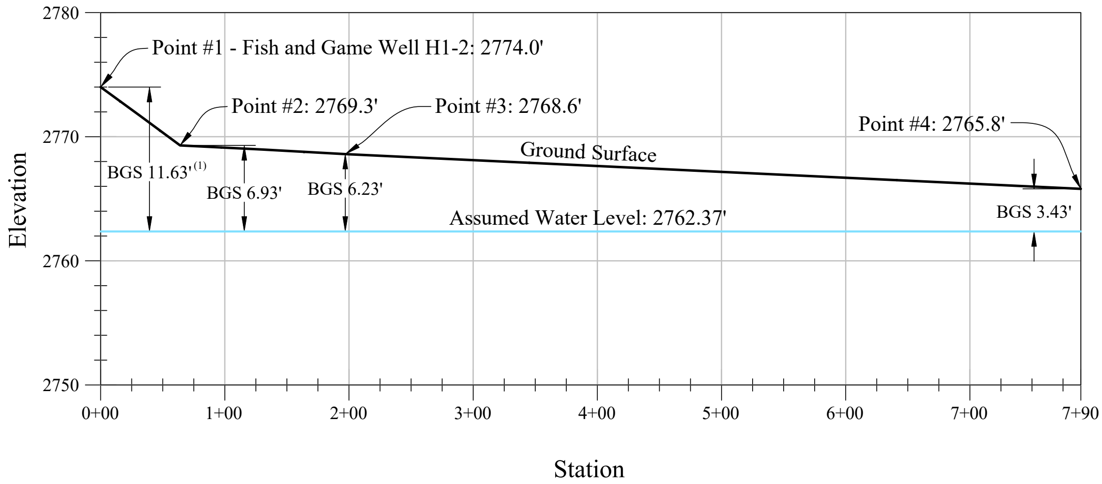
The well that is now used to measure compliance (H1-2) is located above the floor of the riparian habitat area. Thus, a measured depth to water of more than 7 feet is not reflecting the conditions in the riparian habitat protection area.

Ground surface measurements taken on February 12, 2010 along a transect from the monitoring well location to the flowing water surface in the river (the river was flowing on the date of the measurement) show the indicated water level is within 7 feet of the surface. The indicated water level is projected from the depth to water in the monitoring well and adjusted for the changes in the ground surface elevation along the transect. The water surface and ground surface are shown on the figure attached.

Although the water level is currently indicated to be within 7 feet of the ground surface it is apparent that near the boundary of the habitat protection area, the water level approaches the 7 foot trigger depth. This is a result of the ground surface elevation rising when moving in a direction away from the river channel (west in this case) but also is an indication of potential problems in the future. One of Mr. Bilhorn's concerns is the need to maintain and support the habitat conditions existing during the 1986-1990 base period.

22450 Headquarters Drive • Apple Valley, California 92307-4304
(760) 946-7000 • 1-800-254-4242 • FAX (760) 240-2642 • E-Mail: Watermaster@mojavewater.org

My discussion with Mr. Bilhorn included the suggestion that a program to monitor the health of the habitat and develop a better indicator of long-term habitat sustainability should be developed and presented to Watermaster. Such a program might involve additional monitoring wells to indicate changes in water level, re-affirmation of the appropriate location and base line ground surface elevation within the habitat areas, and ground surveys to establish base line plant health. The ground surveys could be tasked to a local university graduate student program. We will continue discussions with DFG and report back to Watermaster.



Notes:
(1) Actual measurement.
BGS = Below Ground Surface.

Upper Narrows Estimated Water Level

Fish and Game Riparian Habitat Area

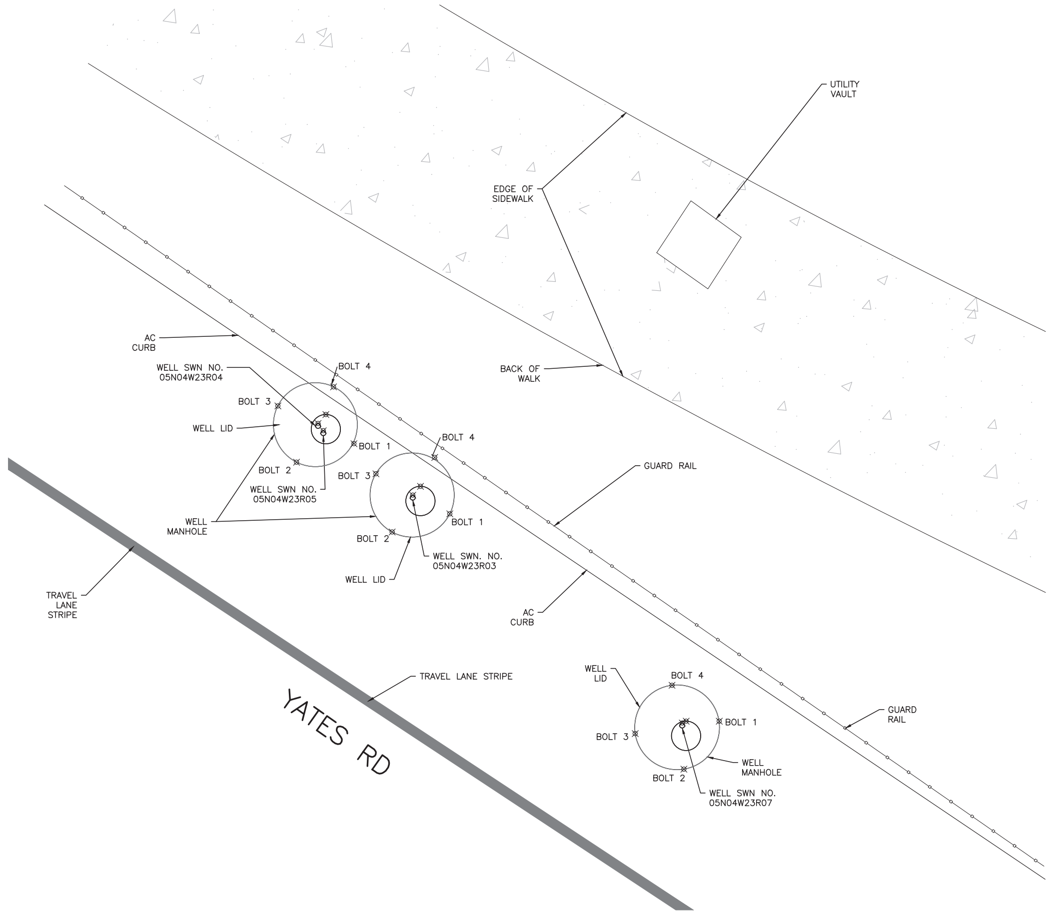
San Bernardino County, California

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Aerial Imagery per U.S. Department of Agriculture (USDA), Aerial Photography Field Office, National Agricultural Inventory Project, flown June 20, 2009.

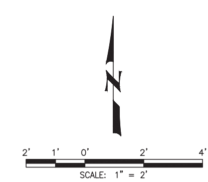
Q:\Drawings\Mojave Water\Transect.dwg

March 2010



COORDINATE TABLE (NAD 83 CALIFORNIA STATE PLANE ZONE 5)

SWN NO.	LOCATION TYPE	NORTHING	EASTING	ELEVATION	LATITUDE	LONGITUDE
05N04W23R03	BOLT 1	2005600.4833'	6784429.5328'	2780.07	N34° 30' 04.3464"	W117° 15' 38.2379"
	BOLT 2	200559.8628'	6784427.5669'	2781.08	N34° 30' 04.3404"	W117° 15' 38.2615"
	BOLT 3	2005601.8489'	6784427.0125'	2781.01	N34° 30' 04.3601"	W117° 15' 38.2679"
	BOLT 4	2005602.4059'	6784429.0180'	2781.03	N34° 30' 04.3654"	W117° 15' 38.2439"
	CASING NORTH POINT	2005601.4209'	6784428.5322'	2780.30	N34° 30' 04.3557"	W117° 15' 38.2498"
	WELL NORTH POINT	2005601.1187'	6784428.2693'	2780.01	N34° 30' 04.3528"	W117° 15' 38.2530"
05N04W23R04	BOLT 1	2005602.8757'	6784426.2633'	2781.02	N34° 30' 04.3703"	W117° 15' 38.2768"
	BOLT 2	2005602.2432'	6784424.3055'	2781.00	N34° 30' 04.3642"	W117° 15' 38.3002"
	BOLT 3	2005604.1644'	6784423.6697'	2780.94	N34° 30' 04.3832"	W117° 15' 38.3076"
	BOLT 4	2005604.8416'	6784425.5676'	2780.93	N34° 30' 04.3895"	W117° 15' 38.2849"
	CASING NORTH POINT	2005603.8701'	6784425.3059'	2780.22	N34° 30' 04.3802"	W117° 15' 38.2881"
	WELL NORTH POINT	2005603.5649'	6784425.0395'	2779.79	N34° 30' 04.3772"	W117° 15' 38.2913"
05N04W23R05	BOLT 1	2005602.8757'	6784426.2633'	2781.02	N34° 30' 04.3703"	W117° 15' 38.2768"
	BOLT 2	2005602.2432'	6784424.3055'	2781.00	N34° 30' 04.3642"	W117° 15' 38.3002"
	BOLT 3	2005604.1644'	6784423.6697'	2780.94	N34° 30' 04.3832"	W117° 15' 38.3076"
	BOLT 4	2005604.8416'	6784425.5676'	2780.93	N34° 30' 04.3895"	W117° 15' 38.2849"
	CASING NORTH POINT	2005603.8701'	6784425.3059'	2780.22	N34° 30' 04.3802"	W117° 15' 38.2881"
	WELL NORTH POINT	2005603.3187'	6784425.2185'	2779.88	N34° 30' 04.3747"	W117° 15' 38.2892"
05N04W23R07	BOLT 1	2005593.4099'	6784438.7226'	2781.29	N34° 30' 04.2757"	W117° 15' 38.1287"
	BOLT 2	2005591.7742'	6784437.5164'	2781.33	N34° 30' 04.2596"	W117° 15' 38.1433"
	BOLT 3	2005592.9873'	6784435.8554'	2781.29	N34° 30' 04.2718"	W117° 15' 38.1630"
	BOLT 4	2005594.6348'	6784437.1112'	2781.25	N34° 30' 04.2880"	W117° 15' 38.1479"
	CASING NORTH POINT	2005593.4113'	6784437.5933'	2781.55	N34° 30' 04.2758"	W117° 15' 38.1422"
	WELL NORTH POINT	2005593.3466'	6784437.4607'	2780.18	N34° 30' 04.2752"	W117° 15' 38.1438"



IN PROGRESS

Know what's below. Call before you dig.

SURVEY MONUMENTATION:

ALL SURVEY MONUMENTS AND MARKERS SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO PROTECT IN PLACE UNTIL SURVEYOR HAS TIED OUT LOCATIONS FOR REPLACEMENT PURSUANT TO BUSINESS AND PROFESSIONS CODE SECTION 8700 TO 8805 (LAND SURVEYOR'S ACT).

UNDERGROUND UTILITIES:

THE LOCATIONS AND EXISTENCE OF UNDERGROUND UTILITIES ARE NOT GUARANTEED. THESE DRAWINGS WERE PREPARED BASED ON SURFACE DATA AND AVAILABLE RECORD INFORMATION AND IT IS POSSIBLE THAT ADDITIONAL UNDERGROUND UTILITIES COULD BE PRESENT THAT ARE NOT SHOWN. THE CONTRACTOR SHALL BE RESPONSIBLE FOR FIELD VERIFICATION OF THE LOCATION AND DEPTH OF EXISTING UNDERGROUND UTILITIES AND SHALL PERFORM POTHOLING AS NECESSARY AT ALL CROSSINGS PRIOR TO COMMENCING CONSTRUCTION. THE CONTRACTOR SHALL BE RESPONSIBLE FOR TAKING ALL PRECAUTIONS NECESSARY TO PROTECT ALL EXISTING UTILITIES AND STRUCTURES FROM DAMAGE DURING THE COURSE OF THE WORK, AND SHALL BE RESPONSIBLE FOR REPAIRING OR REPLACING ANY UTILITIES OR STRUCTURES DAMAGED DURING THE COURSE OF THE WORK.

BENCHMARK AND BASIS OF BEARING

OPUS STATIC GPS OBSERVATION
1" IRON PIPE W/ PLASTIC CAP
BASE POINT COORDINATES:
NORTHING: 2005452.4600'
EASTING: 6784488.8500' - CALIFORNIA STATE PLANE COORDINATE SYSTEM ZONE V NAD 83

ELEVATION: 2784.09' - NAVD 88

DATE	DELTA	REVISION DESCRIPTION	APPROVAL DATE	APPROVAL BY

REGISTERED PROFESSIONAL ENGINEER · E. CARY PACKER · No. C-51752 · CIVIL · STATE OF CALIFORNIA

BRAD S. MERRELL R.C.E. 49423

MERRELL JOHNSON

MERRELL JOHNSON ENGINEERING, INC.
22221 U.S. HIGHWAY 18, APPLE VALLEY, CA 92307
760 240 8000 | MERRELLJOHNSON.COM

JOB TITLE:
WELL SURVEY EXHIBIT
YUCCA LOMA RD
FOR:
MOJAVE WATER AGENCY
F&G 05N04W23R03-R05, R07
WELLS

DRAWN BY: N.G.
DATE: 9/22/23
JOB NO. 2218.077
SHEET 1 OF 1

PROOF OF SERVICE

STATE OF CALIFORNIA }
COUNTY OF SAN BERNARDINO}

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

On May 1, 2024, the document(s) described below were served pursuant to the Mojave Basin Area Watermaster's Rules and Regulations paragraph 8.B.2 which provides for service by electronic mail upon election by the Party or paragraph 10.D, which provides that Watermaster shall mail a postcard describing each document being served, to each Party or its designee according to the official service list, a copy of which is attached hereto, and which shall be maintained by the Mojave Basin Area Watermaster pursuant to Paragraph 37 of the Judgment. Served documents will be posted to and maintained on the Mojave Water Agency's internet website for printing and/or download by Parties wishing to do so.

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

NOTICE OF MOTION AND MOTION TO ADJUST FREE PRODUCTION ALLOWANCE FOR WATER YEAR 2024-2025; MEMORANDUM OF POINTS AND AUTHORITIES AND DECLARATION OF ROBERT C. WAGNER IN SUPPORT THEREOF

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

Executed on May 1, 2024 at Apple Valley, California.

____
Jeffrey D. Ruesch

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Mojave Basin Area Watermaster Service List as of May 01, 2024

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Mojave Basin Area Watermaster Service List as of May 01, 2024

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Mojave Basin Area Watermaster Service List as of May 01, 2024

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