Mojave Basin Area Watermaster

Appendix D

Este Subarea

Water Supply Update

Prepared by:

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February 28, 2024

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MEMORANDUM

To: Mojave Basin Area Watermaster

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

Date: February 28, 2024

Re: **Water Supply Update for Este Subarea**

This memorandum updates the estimates of groundwater production and supply for the Este Subarea of the Mojave River Groundwater Basin. Sources of water supply to the subarea were previously evaluated by Wagner & Bonsignore (WBE) as part of a water budget for the years 1995 to 2014, summarized in a draft January 20, 2016 memorandum. An updated water supply evaluation through 2020 was also prepared and submitted to Watermaster in a June 19, 2020 draft memorandum.

The purpose of the current evaluation and memorandum is to provide Watermaster with an update on the state of knowledge about available groundwater supply for the Este Subarea to develop an updated Production Safe Yield (PSY). The current evaluation was limited to review of available reports and data; no field studies or modeling were performed. The current update relies largely on the prior WBE studies (2016 and 2020 draft memorandums) and on the data and findings presented in a U.S. Geological Survey hydrogeologic study and groundwater model for the Lucerne Valley (Stamos and others, 2022).

The location of the Este Subarea with respect to other subareas of the Mojave River Area is shown on Figure 1. The Este Subarea consists of Fifteenmile Valley to the west and the Lucerne Valley to the east, separated by the northwest-trending Helendale fault. Water supply for the Este Subarea is obtained entirely from groundwater, pumped from aquifers within the subarea. No subsurface inflow from other subareas has been documented and there are no additional surface deliveries of water from outside the Este Subarea, with the exception of treated wastewater deliveries from the Big Bear Area Regional Wastewater Agency (BBARWA). Direct infiltration of the small amount of annual precipitation to the ground is considered to be negligible (USGS; various studies). Potential sources of groundwater recharge and supply to the subarea, shown on Figure 1, have been identified by various previous studies to include:

- Natural recharge from surface water runoff at the base of the mountain front bounding the southern margin of the subarea, also referred to as mountain-front recharge;

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

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

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

Hydrogeologic Setting

Geologic Units and Aquifers

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

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

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

Faulting

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

Groundwater Conditions

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

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

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

Water Supply

Mountain-Front (Natural) Recharge

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

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

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

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

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

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

BBARWA Return Flows

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

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

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

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

Irrigation Returns

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

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

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

Water Supply Summary

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

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

Consumptive Use and Outflows

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

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

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

Change in Storage

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

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

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

Discussion and Conclusions

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

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

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

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

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

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

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

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

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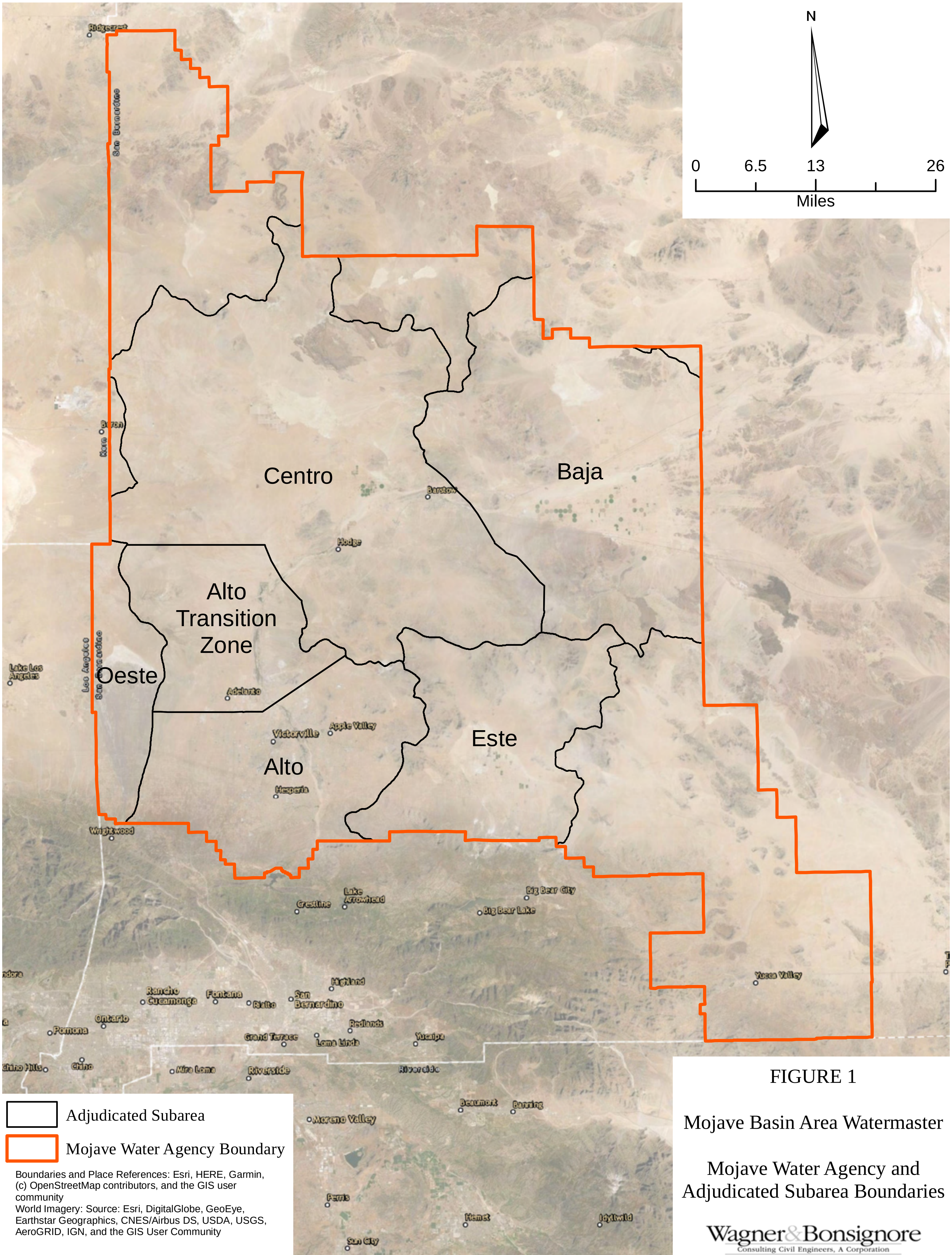


FIGURE 1

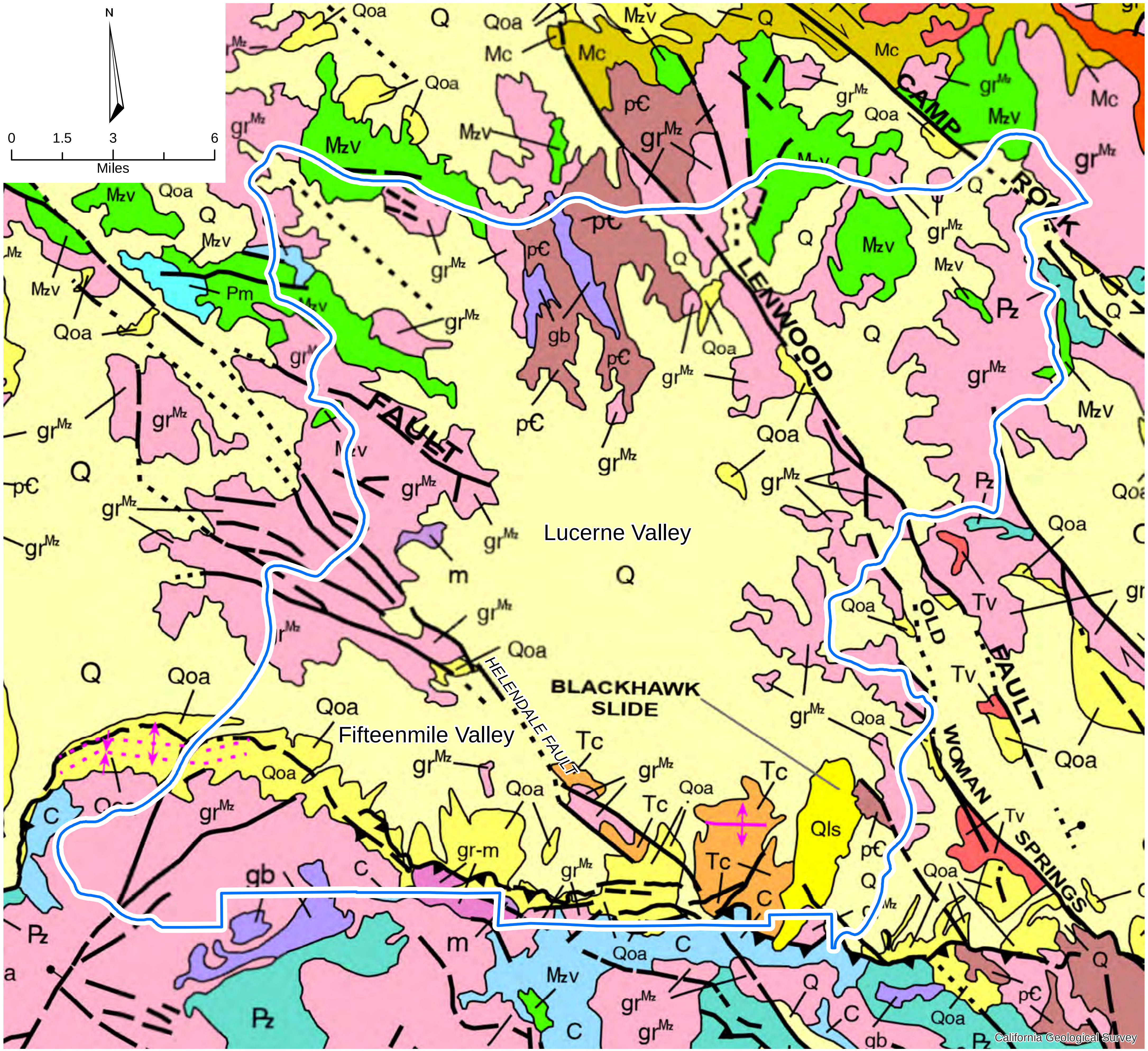
Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

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



Adjudicated Subarea

Q; Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast

Qls; Selected large landslides, such as the Blackhawk Slide on the north side of San Gabriel Mountains; early to late Quaternary

Qoa; Older alluvium, lake, playa, and terrace deposits

Qv, Qv?; Quaternary volcanic flow rocks; minor pyroclastic deposits

Tc; Undivided Tertiary sandstone, shale, conglomerate, breccia, and ancient lake deposits

Mc; Sandstone, shale, conglomerate, and fanglomerate; moderately to well consolidated

Tv; Tertiary volcanic flow rocks; minor pyroclastic deposits

gr-m; Granitic and metamorphic rocks, mostly gneiss and other metamorphic rocks injected by granitic rocks. Mesozoic to Precambrian

Mzv; Undivided Mesozoic volcanic and metavolcanic rocks. Andesite and rhyolite flow rocks, greenstone, volcanic breccia and other pyroclastic rocks; in part strongly metamorphosed. Includes volcanic rocks of Franciscan Complex: basaltic pillow lava, diabase

grMz, grMz?; Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite

gb; Gabbro and dark dioritic rocks; chiefly Mesozoic

Pz; Undivided Paleozoic metasedimentary rocks. Includes slate, sandstone, shale, chert, conglomerate, limestone, dolomite, marble, phyllite, schist, hornfels, and quartzite

Pm; Shale, conglomerate, limestone and dolomite, sandstone, slate, hornfels, quartzite; minor pyroclastic rocks

C; Shale, sandstone, conglomerate, limestone, dolomite, chert, hornfels, marble, quartzite; in part pyroclastic rocks

m; Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble

pC; Conglomerate, shale, sandstone, limestone, dolomite, marble, gneiss, hornfels, and quartzite; may be Paleozoic in part

FIGURE 2

Mojave Basin Area Watermaster

Regional Geology
Este Subarea

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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

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

June 2020

Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/NWIS,
DWR Bulletin 84 1967
Date: February 2023
Mojave Water Agency
Water Resources Department

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

FIGURE 4

Este Subarea Hydrographs 2023

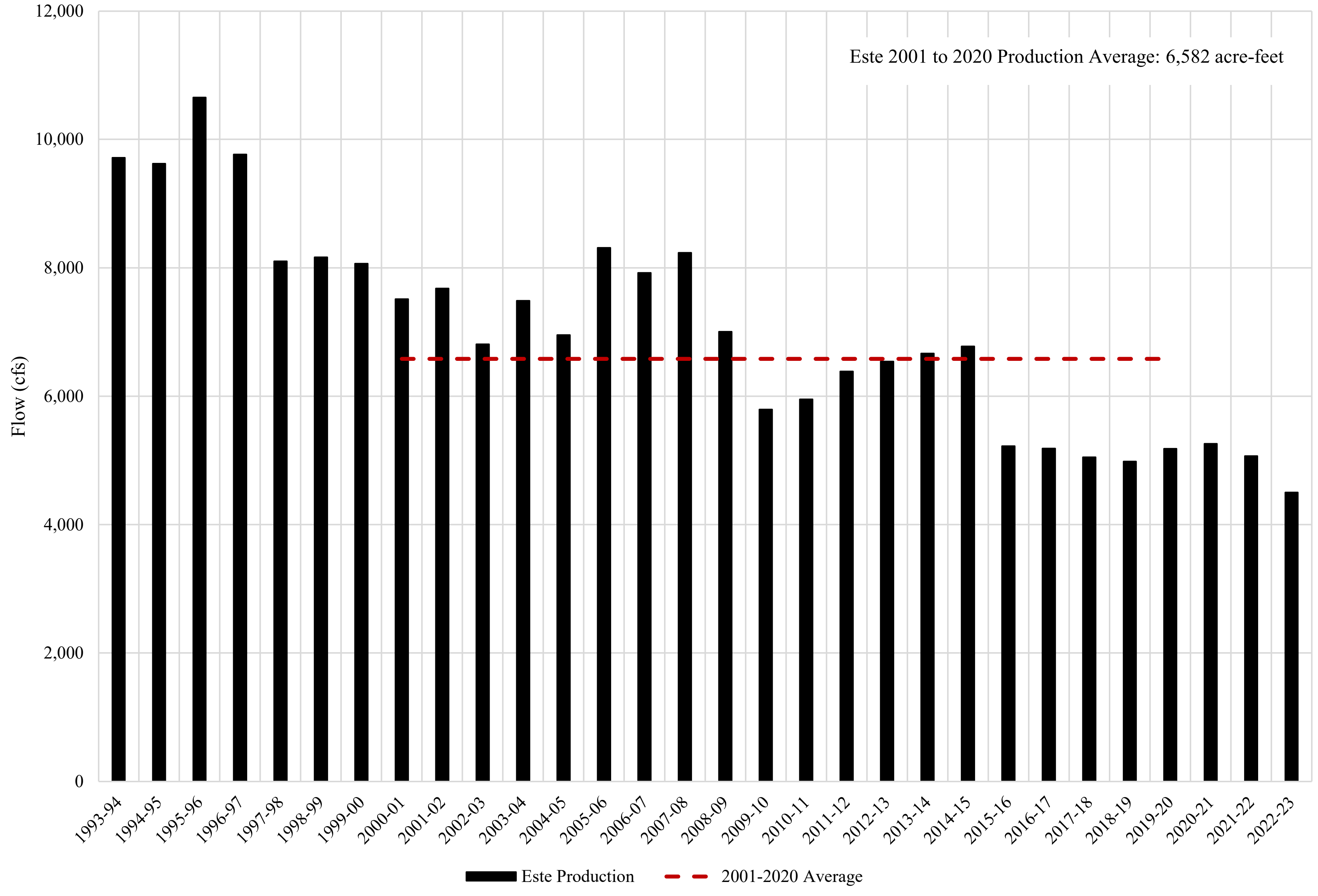
- Recent record
- Long-term record (begins ~1950 to ~ 1980)
- Very long-term record (begins ~1920)

0 1 2 4
Miles

N

FIGURE 4

Figure 5
Este Production
1993 to 2023



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