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14 **SUPERIOR COURT OF THE STATE OF CALIFORNIA**
15 **FOR THE COUNTY OF ORANGE, CIVIL COMPLEX CENTER**

16 MOJAVE PISTACHIOS, LLC; et al., Plaintiffs,
17 v.

18 INDIAN WELLS VALLEY WATER
19 DISTRICT; et al., Defendants.

20 INDIAN WELLS VALLEY WATER
21 DISTRICT, Cross-Complainant,

22 v.
23 ALL PERSONS WHO CLAIM A RIGHT TO
EXTRACT GROUNDWATER, et al., Cross-
24 Defendants.

25 SEARLES VALLEY MINERALS INC., Cross-
Complainant,

26 v.
27 ALL PERSONS WHO CLAIM A RIGHT TO
28 EXTRACT GROUNDWATER, et al., Cross-
Defendants.

Case No. 30-2021-01187275-CU-OR-CJC
Related to: 30-2021-01187589-CU-WM-CXC;
30-2021-01188089-CU-WM-CXC

Assigned For All Purposes To:
The Hon. William D. Claster, Dept. CX101

**UNITED STATES' NOTICE OF SERVICE
OF EXPERT REPORT OF SEAN A.
MCKENNA, PH.D.**

Action Filed: November 19, 2019
Phase 2 Trial Date: June 1, 2026

1 Pursuant to the First Amended Case Management Order dated March 18, 2025, the United
2 States hereby provides the expert report of Sean A. McKenna Ph.D., relevant to the Phase 2 trial
3 on the Indian Wells Valley Water District's cross-complaint for a comprehensive groundwater
4 adjudication. Dr. McKenna's report is attached hereto as **Exhibit 1**.

5 A link to a OneDrive site containing the materials referenced in Dr. McKenna's report is
6 being e-mailed to counsel for those parties who gave notice of intent to participate in the Phase 2
7 trial. Any other party may request a link by contacting undersigned counsel for the United States.

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9
10 Respectfully submitted this 15 day of August 2025,

11
12 ADAM R.F. GUSTAFSON
Assistant Attorney General
Environment and Natural Resources Division

13 /s/ Alexa V. Penalosa

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EXHIBIT 1



Expert Report of Sean A. McKenna, PhD

In the matter of:

Mojave Pistachios, LLC, et al.

vs.

Indian Wells Valley Water District, et al.

Case Number: 30-2021-01187275-CU-OR-CJC

August 2025

A handwritten signature in blue ink, appearing to read "Sean A. McKenna", is written over a horizontal line.

Sean A. McKenna, PhD

Executive Director, Division of Hydrologic Sciences

[Desert Research Institute](#)

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1 INTRODUCTION

The US Department of Justice retained me to provide expert testimony in the matter of *Mojave Pistachios, LLC, et al. vs. Indian Wells Valley Water District, et al.*, Superior Court of the State of California for the County of Orange. I was asked to provide an opinion on the safe yield of the Indian Wells Valley groundwater basin (California Department of Water Resources [DWR] Basin No. 118) and to evaluate the groundwater model created for the 2025 Groundwater Sustainability Plan (GSP) for the Indian Wells Valley.

My opinions are as follows:

1. A terminal basin conceptual model adequately represents the Indian Wells Valley (IWW) groundwater system. As in a closed basin conceptual model, in a terminal basin, the vast majority of pre-development discharge is through evapotranspiration (ET). Inter-basin flow can contribute to recharge, but there are not significant amounts of inter-basin flow contributing to discharge from the IWW.
2. To avoid lowering the groundwater level, the safe yield cannot be more than the recharge that IWW receives; safe yield must be less than recharge if transpiration from vegetation is considered. 7650 acre-feet/year (AFY) is a reasonable estimate of the recharge and is consistent with estimates of the pre-development discharge in IWW.
3. Other potential sources of recharge including leakage from the LA aqueduct, irrigation leachate, and leakage from community water systems are not credible sources of recharge.
4. The groundwater flow model developed for the 2025 GSP well represents the hydrogeological framework of IWW and is consistent with the available geological, borehole and geophysical data.
5. The calibrated model, when using a long-term average natural recharge rate of 7650 AFY, is able to well represent both steady state and transient water levels recorded over a 100-year period.
6. The model results support the conclusion that 7650 AFY is a reasonable estimate of the long-term average natural recharge.

2 QUALIFICATIONS AND EXPERIENCE

I am the Executive Director of the Division of Hydrologic Sciences at the Desert Research Institute, part of the Nevada System of Higher Education. I have a BA degree in geology from Carleton College, an MS in hydrology/hydrogeology from the University of Nevada, Reno and a PhD in Geological Engineering from the Colorado School of Mines. My work experience prior to my graduate degrees was at an international consulting firm as an engineering geologist designing, installing and testing groundwater wells, and conducting engineering analysis of soils and rock materials for building foundations, roadways and dams. I have been engaged in groundwater research for nearly 40 years, beginning with geophysical surveys to map water quality for my undergraduate thesis.

My PhD work focused on numerical modeling of groundwater flow and solute transport and statistical techniques for modeling heterogeneous aquifers. I continued and expanded this area of work for nearly 19 years at Sandia National Laboratories in Albuquerque, NM, including development and calibration of groundwater models for the WIPP and Yucca Mountain nuclear waste repository programs. I moved to Europe 2012 and joined IBM Research, leading a team of scientists and engineers in applying machine learning and numerical modeling techniques to create solutions for global customers in the Energy Environment, and Utilities business area. I started in my present position at DRI in 2020. I was named the Joe Clark Guild Endowed Chair in Hydrology in 2023.

I have taught graduate level courses in environmental science, petroleum engineering, hydrogeology, and civil engineering as an adjunct or visiting professor at New Mexico Tech, the University of Texas, Austin, the National University of Singapore, and the University of New Mexico. I have also taught short courses on probabilistic performance assessment of geologic nuclear fuel repositories for national programs in Japan and Taiwan, as well as for the International Atomic Energy Agency. I have published over 100 peer reviewed papers and obtained 14 patents that together have been cited several thousand times. I led a joint Sandia and US EPA team in developing open-source water quality event detection software, CANARY, that was awarded a 2010 R&D100 Award and in 2016 I was named the International Association of Mathematical Geosciences Distinguished Lecturer.

I have provided expert opinion in one case in 2024 for the law firm Robins Borghei. The case involved groundwater contamination in the Central Valley of California. I provided both written and oral evidentiary testimony on hydrogeologic conditions, transport of contaminants in groundwater, and degradation processes of contaminants as part of the legal proceedings.

For a complete statement of qualifications and list of publications, see my Curriculum Vitae. Included as Exhibit A to this report. DRI is being compensated at a rate of \$324/hour for my work and testimony.

3 INTRODUCTION TO GROUNDWATER AND GROUNDWATER MODELING

Groundwater resides in subsurface materials known as aquifers, moving through the pore spaces and fractures in soil, sediment, and rock. At the basin scale, the direction of groundwater flow is governed by differences in hydraulic head — water moves from areas of high head (high potential energy, or upgradient) to areas of low head (downgradient). This movement is typically slow, and often on the order of inches to feet per day, depending on the ability of the aquifer materials to transmit fluid. This ability may be referred to as permeability, hydraulic conductivity, or transmissivity. In general, flow rates will be slower through fine-grained materials, such as silts and clays with smaller pore spaces between particles and faster through coarse-grained materials, such as sands and gravels with larger pore spaces. Aquifer materials may also be described in terms of the capacity to store and release water, which in general is also a function of the pore spaces between particles. Both hydraulic conductivity and storage properties can be reduced by compaction or cementation, which reduces total pore space and the connectivity between pore spaces.

The behavior of groundwater systems is fundamentally governed by the principle of mass balance: inflow equals outflow plus any change in storage. Inflows to the groundwater system include natural recharge from precipitation and surface water infiltration, while outflows occur via evapotranspiration (ET), discharge to streams and springs, and groundwater extraction through pumping. When outflows exceed inflows over time, groundwater levels decline, reflecting a reduction in stored volume of groundwater. In an undisturbed (i.e., pre-development) groundwater basin, the long-term average inflows can be considered to be equal to the long-term

average outflows, meaning that on average, groundwater levels are stable and there is no change in storage.

Groundwater models are tools used to simulate the movement and distribution of groundwater within an aquifer system. These models are based on well-established physical principles, including conservation of mass and Darcy's Law, which describes how water flows through porous media. In practical terms, a groundwater model represents the subsurface as a three-dimensional grid of cells or elements. Each cell has defined properties that represent the aquifer materials, such as hydraulic conductivity and storage parameters. Mass balance is maintained within each cell and the model calculates how water moves between cells over time.

Groundwater models are constrained by boundary conditions, which allow for the simulation of inflows and outflows of groundwater from the model. Boundary conditions can be classified into three groups: specified flow, specified head, or head-dependent. A specified flow boundary requires the modeler to define the amount of flow into or out of the model at a given location. This is the type of boundary condition that is typically used to simulate recharge, meaning that the modeler must determine the amount of recharge to apply to a model – it is not determined by the model. Similarly, a specified head boundary requires the modeler to assign a water level at a given location. Specified head boundaries are often used to represent features like lakes, large rivers, or regional groundwater levels that are relatively stable. Finally, a head-dependent boundary allows the modeler to simulate changes in flow depending on the groundwater level in the model. These types of boundaries are used to simulate features such as surface water features which are in communication with the water table, or ET, where the rate of discharge is a function of the water level.

Groundwater models are calibrated to observed (i.e., measured) water levels and flows. Calibration is the process of iteratively modifying aquifer properties, such as hydraulic conductivity and specific storage, such that the model is able to closely simulate observed water levels or flows. The difference between simulated and observed water levels or flows is known as model error. All models have error. The allowable amount of error is a function of the range of observed values that the model is attempting to simulate, referred to as 'relative error'. For example, in a model simulating a watershed with a range of observed heads of 10 ft, an error of 10 ft would be very large (i.e., 100% relative error), but for a model simulating a range of

observed heads of 500 ft, a 10 ft error would be minimal (2% relative error). While absolute error is also important, relative error provides a metric that scales to an individual model. There is no universally accepted value for an acceptable relative error in a model, though generally a relative error of less than 5% is considered very well calibrated.

Groundwater models can be developed as ‘steady-state’ or ‘transient’ models. A steady-state model does not include a time component, and is developed to simulate a long-term equilibrium condition, typically the pre-development condition, under which groundwater levels and inflows and outflows to the groundwater system are constant. When pumping is included in steady-state model, the resulting simulated water levels represent a condition in which the simulated wells have been pumping at a constant rate for a long enough time to achieve an equilibrium condition in the basin (i.e., where groundwater level drawdown has stabilized). Transient models are used to simulate changes in the groundwater system that occur over shorter time scales and are not part of an equilibrium state.

Broadly speaking, aquifer properties in a basin can be expected to remain constant on the time scale of human development of the basin, meaning that, if the physical properties are defined appropriately (i.e., parameterized), it should be possible to develop both a well-calibrated steady-state model representing pre-development conditions in a basin and a transient model representing pumping over time using the same estimated aquifer properties in both models.

4 HYDROGEOLOGY OF INDIAN WELLS VALLEY

The geologic structure of any basin exerts control on the flow of groundwater through the basin. In this report the hydrogeology of IWV is examined with a focus on recharge and discharge. This section is a summary of the 2025 GSP (Rybarski and Bacon, 2025) that is also included here as Exhibit B.

4.1 Geologic Structure

Understanding the geologic structure of a groundwater basin is essential for interpreting how groundwater moves and is stored. The arrangement, orientation, and composition of geologic units determine the shape of the aquifer system and the pathways available for groundwater flow. Before evaluating the hydrogeology of the basin, it is necessary to establish

this structural framework, as it provides the physical context within which all groundwater processes occur.

4.2 Basin Extent

The extent of IWV groundwater basin has been defined by the California Department of Water Resources' Groundwater Sustainability Agencies (GSA) state-wide mapping project based on the distribution of sedimentary valley fill (Figure 1) – effectively, it is defined by the surface extent of non-bedrock materials theoretically capable of transmitting recoverable groundwater, and does not consider the thickness or water content of these materials. The base of the aquifer or valley fill can be considered the depth at which meaningful recovery of groundwater is no longer feasible or practical due to very low permeabilities in the geologic materials and the cost required to pump at deeper depths. The depth of the base of the aquifer can be approximated using the unconsolidated (i.e., loose/uncemented) sedimentary thickness dataset of the U.S. Geological Survey (USGS) National Crustal Model (NCM), derived from the results of gravity surveys (Shah and Boyd, 2018). This unconsolidated sedimentary thickness has been confirmed using reported lithologies from deep well logs throughout Indian Wells Valley (Rybarski & Bacon, 2025; Figure 2).

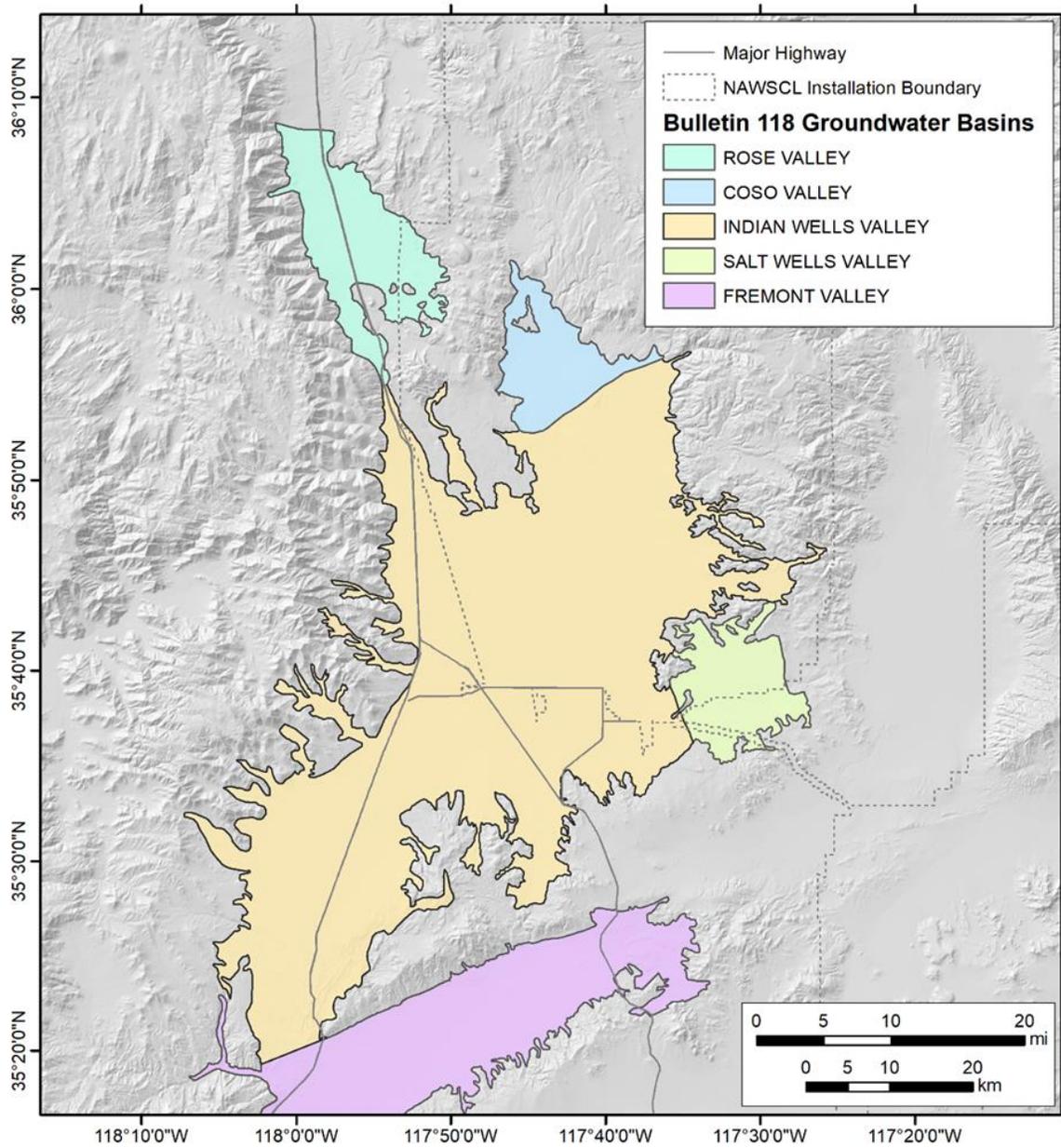


Figure 1. Map showing the Groundwater Sustainability Agencies (GSAs) Bulletin 118 Indian Wells Valley groundwater basin and adjacent basins. From Rybarski & Bacon (2025).

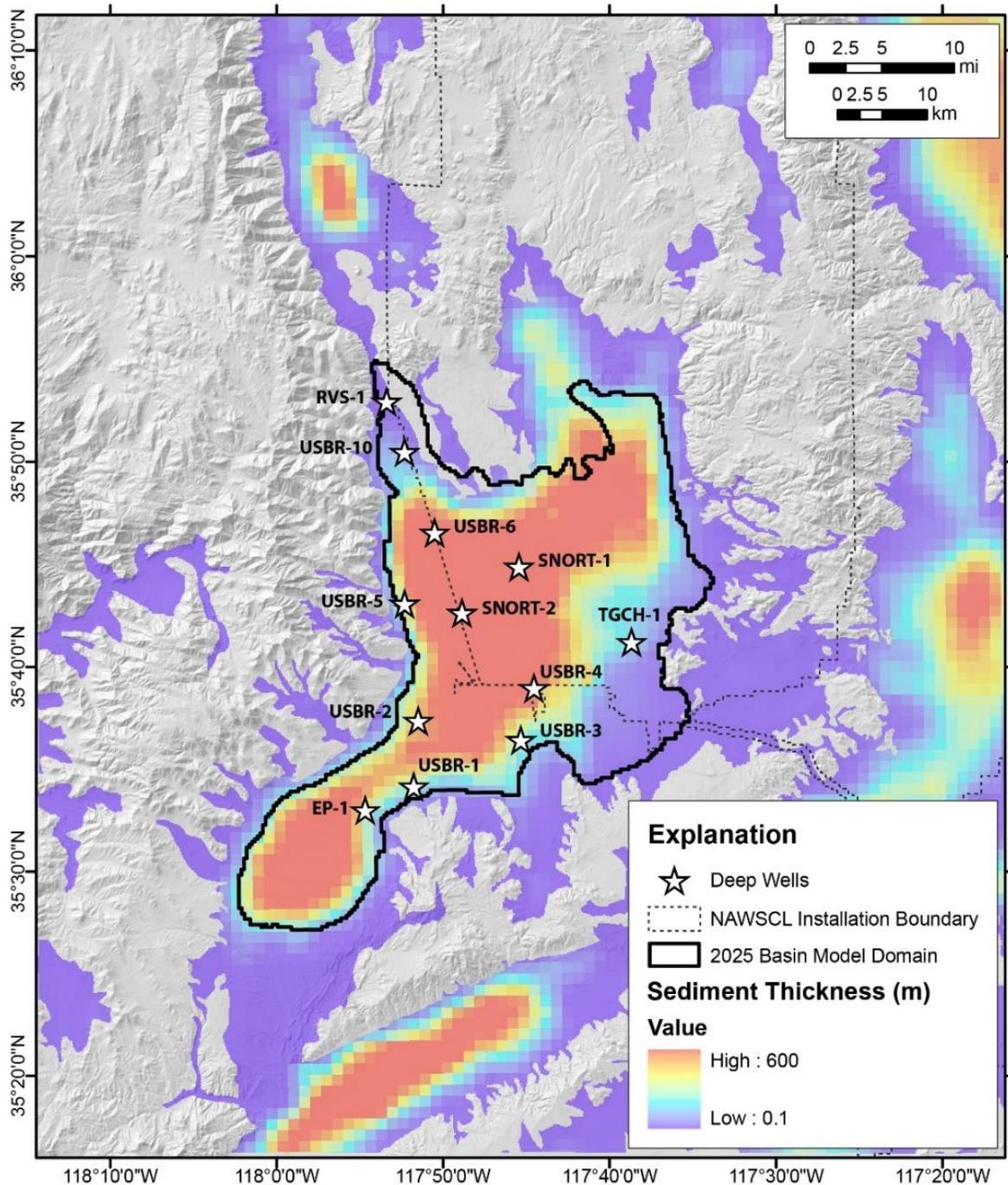


Figure 2. Map showing the 2025 Basin Model domain in relation to the National Crustal Model unconsolidated sedimentary thickness (Shah and Boyd, 2018). Also shown are deep wells used to confirm unconsolidated sedimentary thickness. From Rybarski & Bacon (2025).

4.3 Faults

The IWV is one of the most seismically active regions in California where the M7.1 Ridgecrest earthquake struck the area as recently as July 2019. Within the IWV groundwater basin, groundwater flow is structurally controlled by numerous faults that cross the valley, which commonly act as barriers to horizontal and sometimes vertical flow. A fault is a fracture or zone of fractures in the Earth's crust along which there has been surface displacement of sedimentary fill or rock on either side during large earthquakes. Faults can influence groundwater flow in various ways, depending on their geologic characteristics and history. Mapped surface traces of faults within the IWV watershed are shown in Figure 3.

In some cases, faults act as conduits, enhancing groundwater flow by creating open, connected fractures. However, faults can also act as barriers to groundwater movement. It should be noted here that the use of the word ‘barrier’ in reference to a fault does not mean that no water can flow through it, but rather that it is much less permeable than the surrounding materials. This typically occurs when fault movement grinds the rock into fine material known as fault gouge, which can reduce permeability and hence reduce groundwater flow compared to materials further away from the fault zone. Additionally, faults can juxtapose geologic materials with differing permeability — for example, placing low-permeability bedrock against a high-permeability aquifer composed of sands and gravels — effectively impeding lateral groundwater flow across the fault. Faults which act as a barrier perpendicular to the local direction of groundwater can often be identified by measurements of groundwater elevation on either side of the fault that can show a steep drop in water levels relative to the gradient observed away from the fault (Figure 4). In some cases, these water level drops can help to identify the location of buried or partially buried fault zones. Geophysical surveys are often used to identify buried or partially buried (concealed) faults, as well as geologic material type.

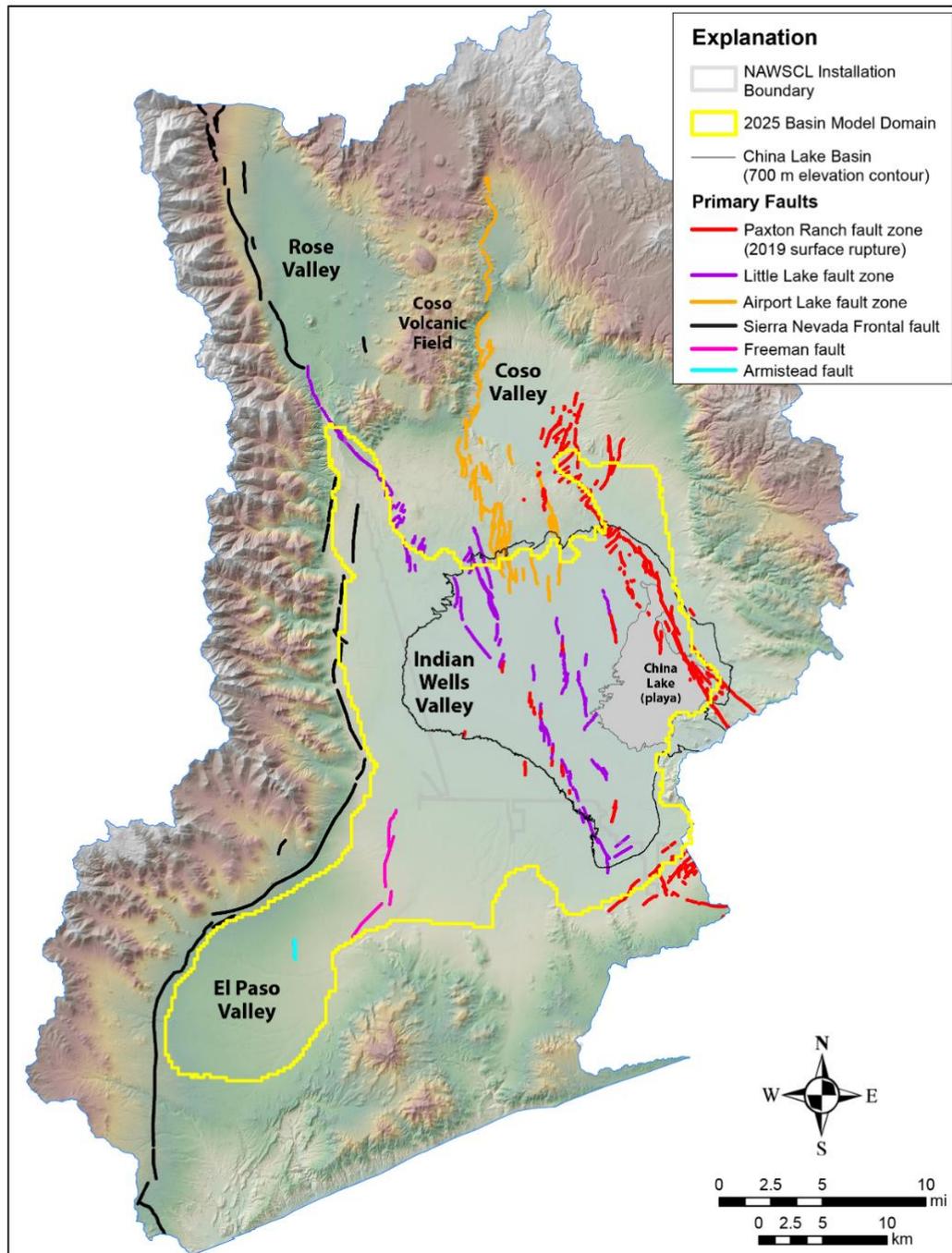


Figure 3. Primary fault zones mapped at the land surface within the IWW watershed. Locations of surface faults from U.S. Geological Survey and California Geological Survey fault hazards mapping programs (CGS, 2010; DuRoss et al., 2020; Ponti et al., 2020; USGS, 2020). From Rybarski & Bacon (2025).

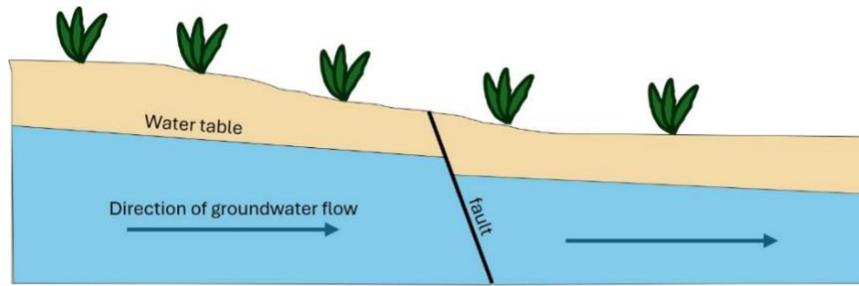


Figure 4. Diagram showing a decrease in groundwater levels on either side of a fault acting as a barrier to flow.

4.4 Fine-Grained Materials

Much of the valley fill in the IWV groundwater basin consists of sands and gravels associated with long-term deposition of alluvial fans sourced from the steep mountain ranges that bound the valley. During colder and wetter climatic episodes in the past (i.e., glaciations), lakes formed in IWV. China Lake playa is currently the dry lakebed of the most recent ancient deep lake that has come and gone during geologic time. Groundwater flow rates in the north-central sector of IWV in the vicinity of China Lake playa are significantly lower than in other parts of the basin due to the presence of a large and thick, low-permeability, fine-grained layer colloquially referred to as the ‘clay’ unit. This clay unit is the result of deep-water deposition of fine-grained sediments in an ancient lake that acts like a plug to groundwater flow in the middle of the valley. The depth of the clay layer also varies across the valley as a result of long-term tectonic activity that has faulted and warped the clay layer. While the presence of this clay layer has been known for some time from a few deep well logs, newly collected Airborne Electromagnetic (AEM) geophysical survey data of Behroozmand et al. (2018) was recently used and integrated with deep well logs and fault mapping to more accurately define its spatial extent (Figure 5) and 3-dimensional geometry at depth (Figure 6).

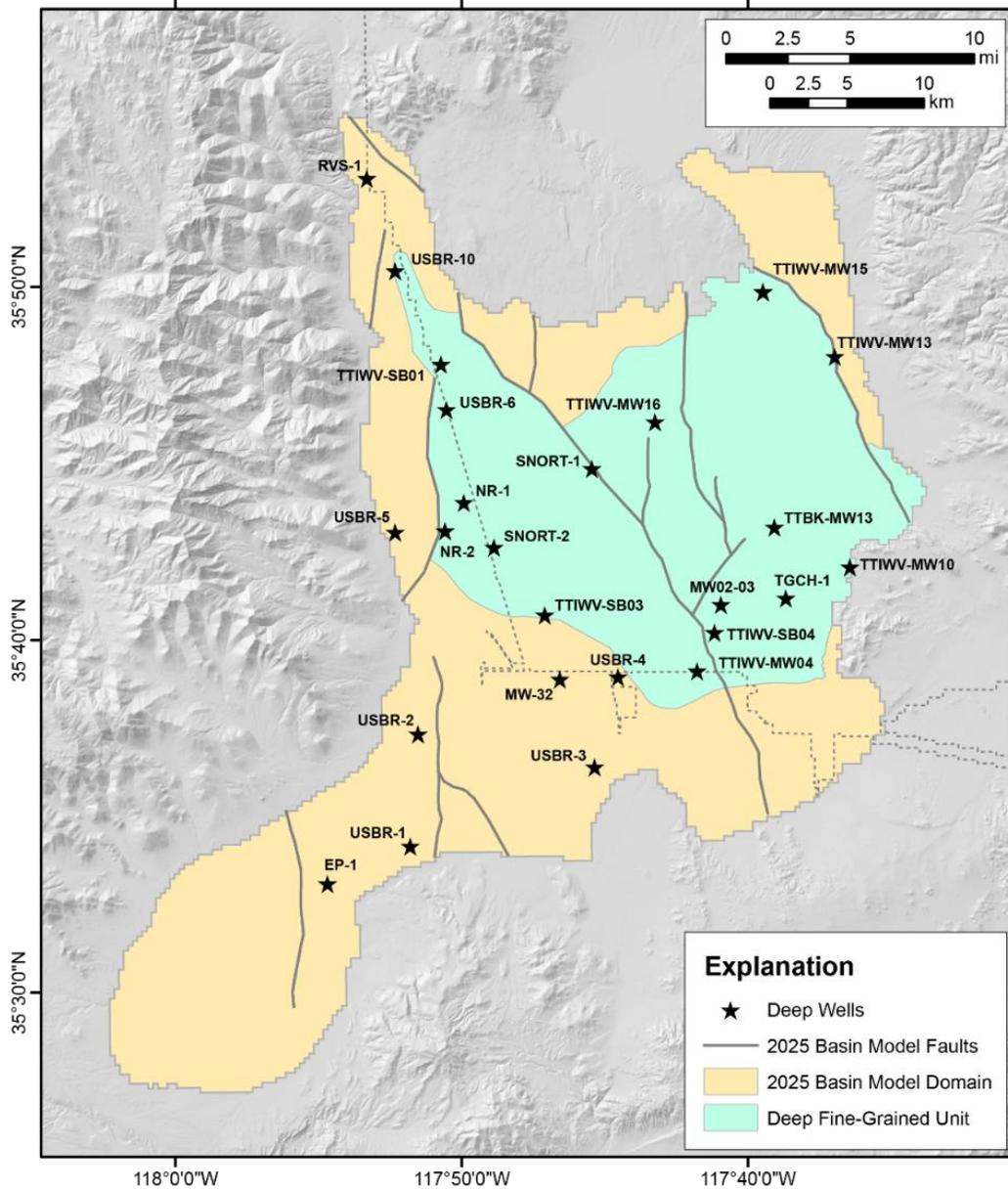


Figure 5. Map showing the lateral extent of the deep fine-grained “clay” unit within the 2025 Basin Model domain. Also shown is the location of deep wells used to confirm the presence and lateral extent of the deep fine-grained unit.

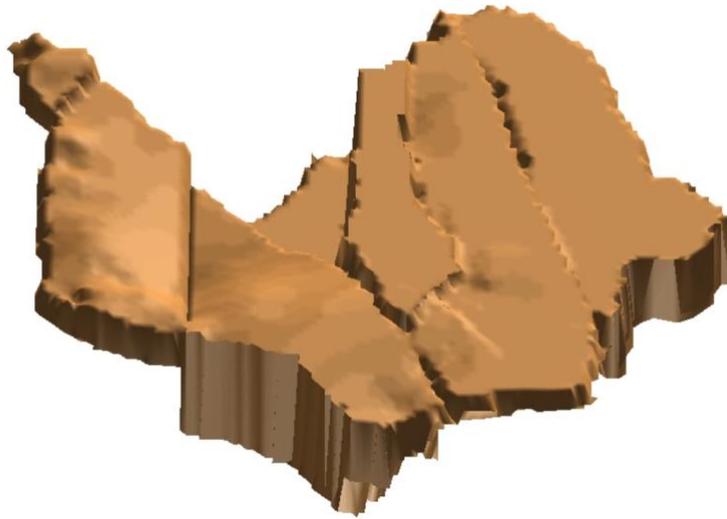


Figure 6. Three-dimensional representation of the clay unit, shown in map view in Figure 5, with an applied vertical exaggeration to show depth and offsets along faults.

4.5 Indian Wells Valley Hydrogeology

In general, groundwater that recharges the basin flows across IWV from west to east, ultimately discharging as: (1) evapotranspiration (ET) from groundwater dependent vegetation (phreatophyte) and bare soil evaporation (E) in areas within and encompassing China Lake playa and termed the “discharge area”, and (2) via underflow to the adjoining Salt Wells Valley, east and downgradient of IWV (Figure 7). Flow paths and flow rates are controlled by local head gradients and by the hydraulic conductivity of the material through which groundwater flows. Many faults within the IWV basin act as barriers to flow. The most hydraulically significant of these faults is the Little Lake fault (Figure 3) that crosses near the center of the basin, trending northwest to southeast, and effectively compartmentalizes the ET discharge zone from the areas of the basin where the majority of pumping has occurred. This compartmentalization means that there is a notable time lag between drawdowns in the pumping areas and a reduction in outflows in the ET discharge zone.

Sources of natural groundwater recharge in IWV include mountain block/mountain front recharge from the surrounding ranges, as well as some component of underflow (i.e., leakage) originating from Rose Valley that is adjacent to and north of IWV. The elevations of the southern

Sierra Nevada mountains in IWV are much lower compared to other parts of the mountain range to the north (e.g., the high Sierras in Owens Valley, town of Mammoth Lakes, and Mono Lake basin). Therefore, IWV receives less precipitation and hence less recharge compared to other valleys to the north that receive substantially more precipitation in the form of large annual snowpacks. Due to smaller and inconsistent annual snowpack in IWV, there are no perennial streams, which is in sharp contrast to all the other valleys along the eastern Sierra Nevada north of IWV that do contain perennial streams supported by snowmelt runoff. For perspective, the source of water conveyed by the L.A. Aqueduct is snowmelt runoff in Mono Lake basin and Owens Valley. As a result, IWV receives significantly less groundwater recharge compared to all other valleys to the north along the entire Sierra Nevada and is characterized as a semi-arid to arid valley at the transition between the Great Basin and Mojave Desert.

The hydrogeologic framework of a basin can be evaluated in part through development of a flow budget. A groundwater flow budget is an accounting of all the water entering, leaving, and being stored within a defined groundwater system. It is based on the principle of conservation of mass: over time, the amount of water flowing into the system must equal the amount flowing out, plus or minus any change in storage. Understanding the flow budget is essential for evaluating how the aquifer responds to natural conditions and human activities, and for assessing the long-term sustainability of groundwater use.

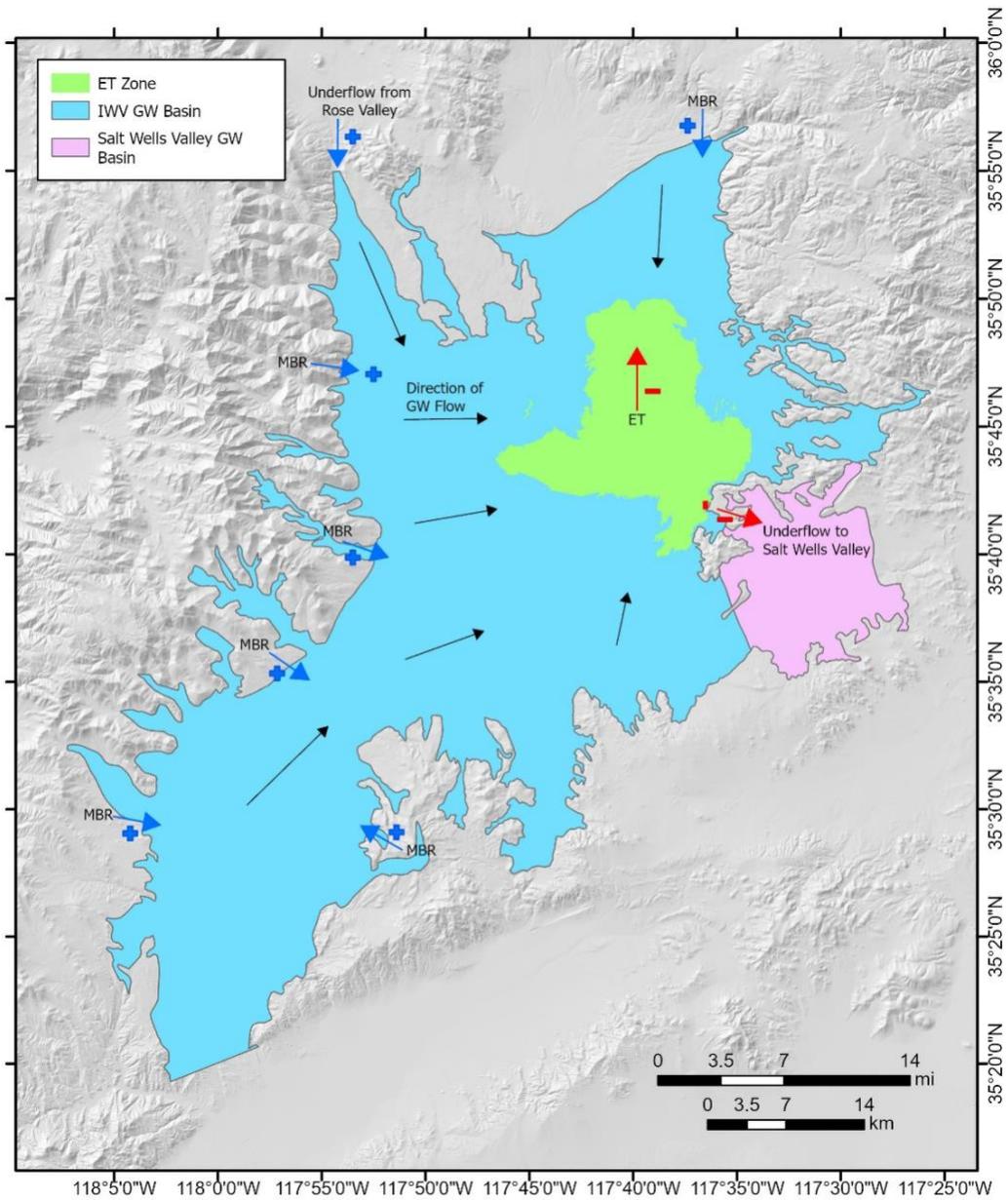


Figure 7. Conceptual flow diagram of Indian Wells Valley. Blue arrows indicate sources of recharge (mountain block/front recharge (MBR) and underflow from Rose Valley). Red arrows indicate components of discharge (evapotranspiration (ET) and underflow to Salt Wells Valley). Black arrows indicate the general direction of groundwater flow.

5 BASIS OF OPINIONS

5.1 Opinion 1: Terminal Basin

All recharge entering IWV begins as mountain front recharge, some of which collects in Rose Valley and then enters IWV as underflow (McGraw, et al., 2016, Pohlmann et al., 2020, and Rybarski and Bacon, 2025). There is no compelling evidence for significant direct mountain front recharge coming into the IWV from outside of the watershed; underflow from Rose Valley is included as mountain front recharge. There is a relatively small amount of flow out of the basin into the Salt Wells Valley, but otherwise the IWV groundwater system operates as a terminal basin, i.e., one with little or no outflow. The implication of a terminal basin is that natural (pre-development) discharge is solely, or in the case of IWV, mainly, accommodated through ET.

5.2 Opinion 2: Safe Yield

For the purposes of adjudication, safe yield has been defined as “*the maximum quantity of water which can be withdrawn annually via pumping from a groundwater basin as a whole based on long-term conditions in the basin without causing an undesirable result. Undesirable result is the gradual lowering of the groundwater level resulting eventually in depletion of a supply intended to last perpetually*” (Highberger, 2024). In this report, I address lowering of the water level.

5.2.1 Recharge

Pre-development groundwater flow in large basins operates on long time scales with travel times for water to go from recharge to discharge zones being on the order of thousands of years. Aquifers act as a low-pass filter by smoothing out annual fluctuations in natural recharge and discharge into an equilibrium state that changes very slowly. The earliest existing measurements of the IWV groundwater system are just over 100 years old and natural conditions measured then will not have changed significantly unless altered by faster acting stresses on the aquifer such as pumping.

It is not possible to directly measure mountain block/mountain front recharge in a basin and numerous ways to estimate recharge have been developed (Markovich et al., 2019). Common methods for estimating recharge include numerical modeling and the use of empirical

relationships to relate precipitation rates to recharge at watershed scales. In 2016, a 2-dimensional numerical model was developed and used to test recharge rates using measured aquifer properties for IWV (McGraw et al., 2016). Recharge rates were adjusted with the goal of finding the rate that resulted in simulated water levels which most closely matched those measured during the pre-development period in 1920-21. This analysis estimated a recharge rate of 7,650 acre-feet per year (AFY) for the IWV groundwater basin, which was applied in a groundwater model developed for the U.S. Navy to use for water resources management (McGraw et al., 2016).

The Indian Wells valley groundwater sustainability plan models in both 2020 and 2025 use the recharge estimate from the McGraw et al., (2016) report. That report reviews two different techniques for estimating recharge in arid basins: Anderson et al, (1992) and Epstein et al., (2010) and applies them to IWV. To better understand these techniques, I used them to recalculate recharge in IWV. These techniques are of similar form in that both calculate the volume of precipitation between different precipitation contours and then apply a coefficient that defines the fraction of the precipitation volume that becomes recharge. The precipitation contours are typically controlled by different elevation bands within the basin (see Figure 3 in McGraw et al., 2016). Both techniques used here were developed for arid basins in the southwestern US and remove areas of the basin with precipitation less than eight inches in a single year. Less than eight inches per year may contribute to changes in soil moisture and/or be lost as ET, but does not infiltrate into the groundwater table (Anderson et al., 1992). Removing years with less than eight inches of precipitation from the analysis led to improved recharge estimates (Anderson, et al., 1992). McGraw et al. (2016) developed the precipitation volumes for each elevation band using precipitation data from PRISM for the 30-year period: 1981-2010, and the same are used here with results presented in Tables 1 and 2. The recharge estimates I calculate are different from those of McGraw et al. (2016) for reasons discussed below.

Anderson et al. (1992) examined 72 sedimentary basin groundwater systems, mainly in AZ and including several in CA, NM, and NV. These basins are all in arid settings, and similar to IWV, have thick sedimentary sequences with pre-development ground recharge and discharge being quite small compared to the amount of groundwater storage in the basins. Anderson et al

(1992) developed a regression model to estimate the amount of mountain front recharge in a basin as a function of precipitation and then applied and calibrated this equation using water budgets in the basins and region they were studying. The regression fit is shown in Figure 13 B of Anderson et al. (1992) and the resulting equation is: $\log_{10}(Q_{rech}) = 0.98(\log_{10}(P)) - 1.40$ where Q_{rech} is the average annual mountain front recharge, and P is the total annual volume of precipitation for areas where the average annual amount of precipitation is > 8 inches.

The results of using this equation are presented in McGraw et al., (2016) in Table 1 and result in an estimated average recharge of 4085 ac-ft/yr. Recalculations done here using the areas in Table 1 of McGraw et al (2016) are presented in Table 1.

Table 1. Calculation of IWV mountain front recharge using Anderson et al., 1992 equation.

Precipitation contours (in)			(ft)	Area	Area	Precip	log10	log10	Q rech
Lower	Upper	MidPt	MidPt	(m2)	(Acres)	(AFY)	Precip	Qrech	(AFY)
8	10	9	0.75	489,270,865	120,901	90,676	4.96	3.46	2873
10	12	11	0.92	379,661,834	93,816	85,998	4.93	3.44	2728
12	14	13	1.08	128,722,738	31,808	34,459	4.54	3.05	1113
14	16	15	1.25	30,445,006	7,523	9,404	3.97	2.49	312
16	18	17	1.42	22,945,598	5,670	8,032	3.90	2.43	267
18	20	19	1.58	12,466,326	3,080	4,877	3.69	2.21	164
20	22	21	1.75	317,513	78	137	2.14	0.69	5
22	24	23	1.92						
				Total	262,878	233,584			7462

There are several differences between Table 1 of this report and Table 1 of McGraw et al., (2016). The first is the lower and upper bounds on the amount of precipitation appears to have a typographical error in McGraw et al. (2016) where “10” was entered instead of “16” as the lower bound of the precipitation in the 5th row of the table. That error was carried through the calculation of the precipitation midpoint to be 14 instead of 17 inches and into the volume of precipitation and recharge. Additionally, the total area in acres shown in Table 1 of McGraw et al. (2016) is not equal to the sum of the numbers in the rows above it. That sum is recalculated here for a total area of 262,878 acres (1064 km²). Using the Anderson et al. (1992) equation and these updated numbers as shown in Table 3, the estimated annual recharge into IWV is 7462 AFY.

Table 3 in McGraw et al. (2016) shows the results of another method for calculating mountain front recharge for IWV. These calculations were done using the bootstrap brute-force recharge model (BBRM) developed by Epstein et al., (2010). Similar to other recharge estimation techniques, BBRM relates recharge to precipitation and accounts for increasing precipitation and recharge with increasing elevation. The recalculation of recharge from Table 3 in McGraw et al., (2016) is shown here in Table 2. The average recharge using the BBRM the method is 8745 ac-ft/yr compared to 9265 ac-ft/yr estimated by McGraw et al. (2016). The difference appears to be from an error in the application of the recharge coefficients to the precipitation volumes.

Table 2. Calculation of IWV mountain front recharge using BBRM method of Epstein et al. (2010).

Precipitation contour (in)			(ft)	Area	Precip	Recharge	Recharge
Lower	Upper	Midpt.	Midpt.	(acres)	Volume (AF)	Coeff.	(AFY)
8	10	9	0.75	120,901	90,676	0.019	1722.8
10	12	11	0.92	93,816	85,998	0.049	4213.9
12	14	13	1.08	31,808	34,459	0.049	1688.5
14	16	15	1.25	7,523	9,404	0.049	460.8
16	18	17	1.42	5,670	8,032	0.049	393.6
18	20	19	1.58	3,080	4,877	0.049	239.0
20	22	21	1.75	78	137	0.195	26.8
			Total	262,878	233,584		8745

Additionally, McGraw et al. (2016) developed a groundwater flow model and adjusted the spatial distribution and magnitude of recharge to calibrate the model to available water level data. From their report: “Using the groundwater model developed for this study as the primary basis for the spatial distribution of recharge, the best estimates are 1,500 afy, 2,100 afy, 2,400 afy, and 1,600 afy for the Sierra Nevada North, Sierra Nevada South, Rose Valley, and Coso/Argus Ranges, respectively. The addition of 50 afy from the El Paso Mountains is added from estimates presented by Brown and Caldwell (2009) and Todd Engineers (2014). The total volume of mountain block recharge is 7,700 afy.” (The actual sum is 7650 and was rounded to 7700). It was not possible to access the model used in these calculations, and therefore, no additional calculations using the model were made.

As a check of the estimated recharge for consistency with what would be expected in an arid basin, mountain front recharge in Owens Valley (OV), the next basin to the north of IWV, is examined and used to estimate recharge in IWV. OV is the primary source of water for the city of Los Angeles through long-term water transfer from OV to southern California by the Los Angeles Department of Water and Power (LADWP). As such, the OV hydrologic system is one of the most highly studied and monitored arid basins in the world. The OV watershed contains higher peaks than that of IWV including the highest peak in the Sierra, Mount Whitney. These higher elevations result in perennial streams fed by the consistent snowpack that provide water to OV. In contrast, IWV has much less high elevation terrain and does not accumulate nearly as much snowpack as OV with the result being that there are no perennial streams flowing into IWV.

To compare the difference in precipitation between OV and IWV, the area of the mountain watersheds for each valley that received more than eight inches of precipitation in each water year was calculated from 1896 through 2015 using PRISM data (Figure 8). The average annual area receiving greater than eight inches of precipitation per year in IWV is 964 km² (238,210 acres) as calculated for the 120-year record. OV has a long-term average of 4840 km² (1.2M acres). For each year in the record, the calculated areas were used with the PRISM precipitation data to calculate total precipitation volume in each basin (lower image, Figure 8). The long-term average volumes for OV and IWV are 1,685,600 ac-ft/yr in OV and 225,740 ac-ft/yr, respectively. Using the average areas and precipitation volumes, the areas receiving greater than inches/year in OV receive 16.9 inches/year and those in IWV receive 11.4 inches/year. Given that OV receives roughly 1.5 times the amount of precipitation each year, the amount of recharge per unit area in OV will also be larger than that in IWV.

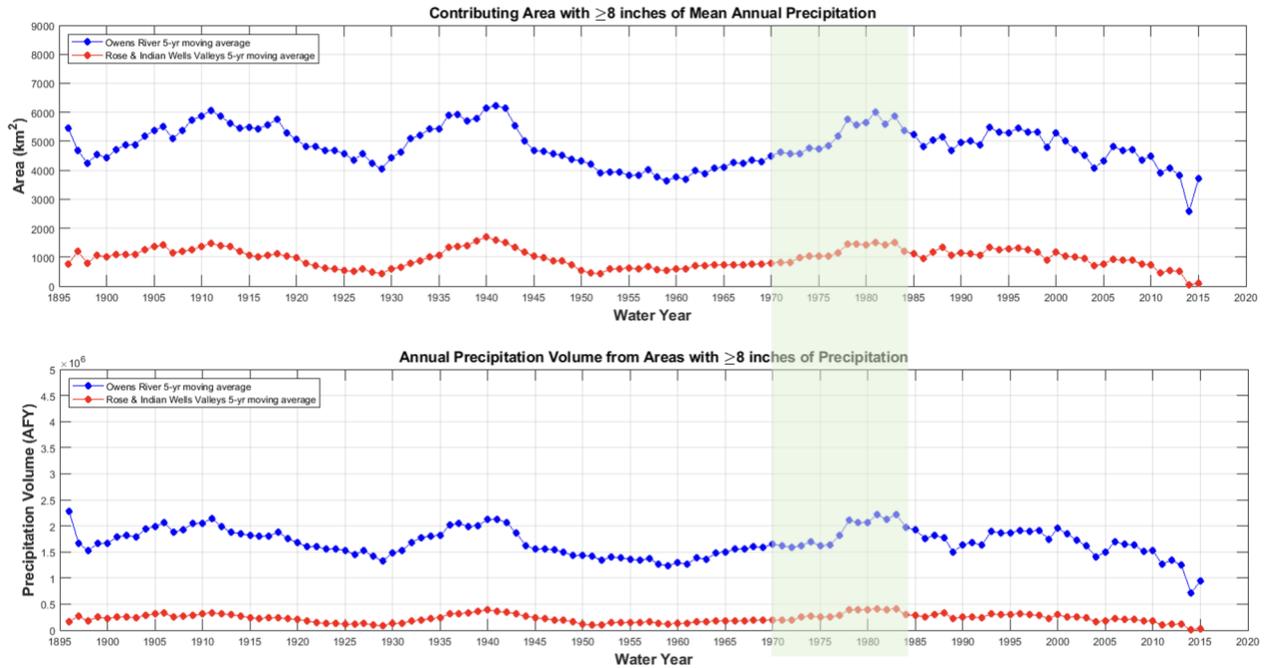


Figure 8. Annual watershed areas receiving >8 inches of precipitation (top plot) and annual precipitation volume (bottom) for both Owens and Indian Wells Valleys. The values shown are a five-year running average. The 1970-1984 water years are highlighted in green.

Extensive work by the USGS in partnership with LADWP (Danskin, 1998) to understand the hydrologic system in OV resulted in development of a detailed water budget. This work includes estimation of mountain front recharge in OV that is distinct and separate from recharge coming from the perennial streams. The estimated mountain block recharge from the areas excluding the perennial streams was calculated for two periods: 1963-1969 and 1970-1984 and in both cases the recharge was estimated at 26,000 ac-ft/yr with lower and upper bounds of 15,000 and 35,000 ac-ft/yr (see Table 10, Danskin, 1998). Here, data from the longer period (water years: 1970-1984) are used in a comparison.

Relative to the 120-year averages, the 1970-1984 period was somewhat wetter in both basins with an average precipitation of 17.4 and 12.6 inches per year in OV and IWV, respectively, in the areas receiving greater than eight inches annually. The minimum, maximum and mean precipitation volume for the areas receiving greater than eight inches annually in both basins are determined from the five-year running averages (Figure 8) for the period 1970-1984. These resulting volumes are used with the minimum, maximum and average estimated amounts

of mountain front recharge from Danskin (1998) to calculate a set of recharge/precipitation ratios for OV (Table 3). These ratios are dimensionless (Volume per year / Volume per year) and define the fraction of precipitation above eight inches per year that becomes mountain block recharge in OV.

Table 3. Calculation of Recharge/Precipitation ratios for Owens Valley for the period 1970-1984.

	Precipitation volume (AFY)	Mountain-front recharge (AFY)	Recharge/Precipitation ratio
Minimum	1,590,260	15,000	0.0094
Maximum	2,219,228	35,000	0.0158
Average	1,854,124	26,000	0.0140

Application of the Recharge/Precipitation ratios calculated for OV to the precipitation volumes in IWV for the same 1970-1984 period provide recharge estimates for IWV (Table 4).

Table 4. Annual recharge volumes for Indian Wells Valley calculated using the Recharge/Precipitation ratios calculated for Owens Valley.

	Precipitation volume (AFY)	Recharge/Precipitation ratio	Mountain-front recharge (AFY)
Minimum	193,820	0.0094	1828.2
Maximum	402,975	0.0158	6355.4
Average	304,932	0.0140	4276.0

The range of calculated recharge values for IWV is below the currently used value of 7650 AFY. These calculations can be done in reverse to determine the volume of annual precipitation needed in IWV to create an average of 7650 AFY of recharge using the average Recharge/Precipitation ratio from Table 4: $7650/0.014 = 546,429$ ac-ft. Examination of the annual precipitation volumes shows that only 14 years within the 120-year record (11.7%) exceeded this volume. It would take a consistent amount of precipitation well above the 120-year average to sustain 7650 AFY of recharge in IWV. The IWV recharge estimates in Table 4 assume that the fraction of precipitation that becomes recharge in OV is the same in IWV. However, IWV is lower in elevation and drier and warmer than OV and, for a given volume of precipitation, mountain front recharge will be lower in IWV. These results indicate that calculation of the recharge to precipitation ratio for OV applied to the IWV recharge into IWV cannot be more than 6355 AFY and more likely is near 4300 AFY.

5.2.2 Discharge

The terminal basin conceptual model for arid basins with no perennial stream or spring flow dictates that the only, or the main, pre-development mechanism for groundwater discharge is ET. Under predevelopment conditions the groundwater system in the IWV basin was at an equilibrium state, and the long-term natural recharge and discharge were equal. The principle of mass balance dictates that if present day discharge exceeds the rate of recharge, storage will decline, meaning that groundwater levels will decline.

The magnitude of groundwater level decline will differ depending on where the development occurs (see Bredehoeft, 2002). In the IWV, natural recharge and discharge in the China Lake playa area are compartmentalized by the deep clay layer and faults that cross the valley. In particular, these faults act as barriers to flow. Therefore, even if pumping is limited to or equal to the rate of natural recharge, a reduction in groundwater levels will be focused around pumping centers and will likely continue until the basin reaches a new equilibrium state. Until this equilibrium state is reached, the total discharge in the basin will be equal to the pumping rate plus any natural discharge from groundwater dependent vegetation and bare soil evaporation. In this scenario, discharge will exceed recharge, and the difference will be taken from aquifer storage, resulting in water-level declines.

Over time, these water-level declines will result in a reduction of discharge to the ET zone, which in turn will adversely impact the groundwater dependent vegetation community in the basin. The groundwater dependent vegetation in IWV basin primarily occurs in the form of extensive vegetated dune areas that have wide significance for the ecology and cultural history of the region. Adverse impact to the vegetated dune areas also has the potential to significantly impact air quality in the valley and region because the groundwater dependent vegetation currently stabilizes the dune sands and prevents the sand from being transported during high wind events. A loss of groundwater dependent vegetation resulting in the destabilization of dunes will result in the potential for excessive sand transport and dust emission across China Lake playa, which in turn will cause the degradation of visibility and air quality (Lancaster et al., 2019; Lancaster et al., 2022).

Identified points of natural discharge from IWV include evapotranspiration/evaporation from phreatophytes and bare soil, and a small amount of subsurface outflow to the adjoining Salt

Wells Valley. Beginning in 1921, pumping began and has also become a significant component of discharge. Current methods for estimating ET often rely on remote sensing (satellite) data, which have only been available since the 1980s. Pohlmann et al. (2020) used a technique developed by Beamer et al. (2013) to estimate ET in IWV. Figure 28 of Pohlmann et al. (2020) shows annual ET estimates using the Beamer et al. (2013) method for the period 1997 through 2008. These estimates range from nearly 5000 AFY to below 3500 AFY with an average value near 4000 AFY. The only other natural discharge is outflow to Salt Wells Valley which has been estimated to be between 0 and 200 AFY (McGraw, et al., 2016).

A common method for deriving rates of groundwater recharge relies on the principle of mass balance – in a groundwater system under equilibrium conditions (i.e., no change in storage), the inflows must equal the outflows (e.g., Markovich, 2019). While measurements of pre-development discharge do not exist, groundwater levels near the phreatophyte and bare soil ET zones have been largely buffered from the extensive drawdowns seen elsewhere in the basin due to bounding faults and the deep clay layer in the vicinity of the ET zones. Additionally, mapped ET zones dating to 1912 show little difference in extent from those observed today. McGraw (2016) updated vegetation mapping based on a 2013 California vegetation map (Menke et al., 2013) and a geomorphic map of the area (Bacon et al., 2015). A comparison of the Lee (1912) and McGraw et al. (2016) maps showed that the major difference was the addition of greasewood in the 2016 map, in areas that were previously mapped as containing pickleweed and salt grass. Root depths of pickleweed and salt grass are typically limited to 10 feet or less (Kunkel and Chase, 1969), while greasewood rooting depths have been reported up to 57 ft (Meinzer, 1927). This suggests that declining water levels are simply resulting in the replacement of vegetation with varieties better adapted to deeper groundwater levels rather than the loss of total vegetation. Therefore, while pre-development recharge cannot be determined based on observed rates of present-day discharge, I believe the rates (3,500-5000 AFY) reported in Pohlmann et al., (2020) are near the minimum value for natural recharge in the basin.

The question arises as to whether these rates are representative of the pre-development groundwater system, or has pumping in IWV impacted these rates? Since the pre-development period, groundwater pumping has become the dominant source of discharge from the basin. This discharge has potentially influenced the amount of ET leaving the basin by lowering

groundwater levels below the playa and impacting nearby vegetation. The lower ET discharge values from Pohlmann et al. (2020) may reflect these changes.

However, groundwater pumping may not yet be having a strong impact on the eastern portion of the IWV basin including the playa and vegetation zones due to NW-SE trending faults acting as flow barriers and limiting most of the pumping drawdown to the west side of the basin. Figure 17 in McGraw et al. (2016) shows observed groundwater levels in or near the playa rising by several feet over a 40-year period between 1952 and 1994. If groundwater levels on the east side of the basin in the predominant area of vegetation are relatively unchanged by pumping, then the lower values of discharge in Pohlmann et al. (2020) are indicative of pre-development discharges from the basin.

5.2.3 Summary

Three different calculations of natural IWV recharge are completed here, two of them result in recharge values: 7462 and 4276 AFY, that are below the currently used 7650 AFY and the third, 8745 AFY, is 14% above the current value. In a pre-development, closed-basin groundwater system at an equilibrium state, the discharge from the basin will be due to ET and must be equal to the recharge. Direct measurements of discharge are difficult to obtain, but a satellite-based estimation indicate an average discharge rate of approximately 4000 AFY. Given the results of previous work and the calculations done here, 7650 AFY is a reasonable estimate of the annual recharge in IWV and while the amount could be slightly higher, there is strong evidence that the recharge could be considerably lower.

5.3 Opinion 3: Other Sources of Recharge

There are several other possible sources of recharge to the IWV groundwater system. These are mainly outside of natural recharge processes, and several are relatively recent additions to the hydrologic system within the valley that were not occurring under pre-development conditions. These include: 1) geothermal leakage, 2) leakage from the LA Aqueduct, 3) irrigation return flows, 4) leakage from water distribution systems, and 5) percolation from rainfall in the lower parts of the basin.

Geothermal Leakage

Bean (1989) suggested the possibility of leakage from a deep geothermal system with an inflow rate of less than 100 AFY. However, the value is irrelevant as a separate, direct source of recharge because Bean (1989) also states that this flow would enter Indian Wells Valley as underflow from the Coso geothermal area. Including geothermal leakage as recharge is redundant because the groundwater would have originated as mountain block or mountain front recharge in the first place, which is already considered in the estimation of mountain-front recharge entering Indian Wells Valley.

Leakage from the LA Aqueduct

It is a near certainty that some leakage from the aqueduct does occur, but the rate of resultant recharge, if any, has not been studied in a meaningful way. Bean (1989) suggested a leakage rate of 900 AFY, but a more recent study (Todd Engineers, 2014) considered it to be negligible. There is no compelling evidence of water leakage of a volume that would create significant recharge to the groundwater system.

Irrigation Return Flows

In agricultural areas it is common practice to irrigate with a greater amount of water than will be taken up by crops, with the explicit intention of flushing salts from the soil. Ultimately, upon reaching the water table, this excess will become groundwater recharge. However, given the depth to the water table below the agricultural areas in IWV (greater than 200 ft), infiltration to the water table can be expected to take many decades. Assuming an infiltration rate of 1.64 ft/yr (Izbicki et al., 2000), and assuming that no clay layers impede infiltration, it would take approximately 122 years for agricultural return flows to reach the water table at a depth of 200 feet. Well logs and analysis of AEM data confirm the presence of fine-grained layers throughout much of the basin. As infiltrating water encounters these layers, flow will be impeded and infiltration will take longer. Regardless, 122 years is longer than this area has been irrigated, and therefore this source of recharge should not be included in present-day water budget accounting.

Water Distribution System Leakage

The length of time for any leakage from municipal water distribution systems to infiltrate to the groundwater table is expected to be similar to that of the irrigation return flow infiltration and likewise should not be included in present-day water budget accounting.

Precipitation Within the Groundwater Model Domain

Arid basins in the southwestern US rely on mountain front recharge as the annual rainfall at lower elevations is not enough to recharge the aquifer. Precipitation of less than eight inches per year will either be stored as soil moisture in the shallow subsurface and/or evaporated or transpired back into the atmosphere (see Anderson et al., 1992)

5.4 Opinion 4: Hydrogeological framework of the 2025 GSP Model

The 2025 GSP model update includes an extremely detailed reworking of the groundwater basin margins, the groundwater basin shape and depth, the tectonic framework of the basin and redefined geologic units with their composition and boundaries. A comparison between the 2020 and 2025 GSP models is provided in Exhibit C. In my opinion, this update integrates a complex and expansive data set into a holistic picture of the basin. This work has benefited from data made available relatively recently that have not been used in previous modeling efforts including: the Airborne Electromagnetic (AEM) data, the National Crustal Model (NCM), several deep borehole logs, and additional geophysical data regarding faults in the subsurface. This update provides an excellent and refined picture of the basin and its properties and the geologic basis for the current state of the basin.

As reported in Rybarski and Bacon (2025), defining the edge of the groundwater basin in a large sedimentary basin can be difficult due to thin, but long, lenses of unsaturated sediments near the basin margins as the depth to bedrock declines. The work done for the 2025 GSP model used all available data to better define the margin and this, along with the exclusion of the White Hills units, has decreased the overall area of the basin relative to the 2020 GSP model (Pohlmann et al., 2020). The NCM data were used along with calibration of the groundwater model to revise the depth of the sediments in the basin that led to a considerable reduction (37%) in the basin volume relative to the 2020 GSP model.

Definition of the thickness and locations of the hydrogeologic units and the faults within the basin have strong influence on groundwater flow and hydrologic connections between different parts of the basin. The 2025 GSP model (Rybarski and Bacon, 2025) defines three main hydrogeologic units: the shallow hydrogeologic zone (SHZ), the intermediate hydrogeologic zone (IHZ) and the deep hydrogeologic zone (DHZ). The IHZ is generally considered as the “clay layer” within the basin, whereas the IHZ contains the shallow aquifer that connects to the

discharge zone and the DHZ is where the majority of the pumping is taking place. The AEM data, and borehole logs were used in the 2025 GSP to define the depth and thickness of the clay layer within the basin. While this layer has been represented in different ways in previous models, this is the first time it was explicitly mapped and included as a distinct unit within the numerical model.

The clay unit and other units are shifted, warped and truncated by faults within the basin. Faults are included in the 2025 GSP model using criteria that consider both geomorphic/tectonic attributes of the faults as well as observed groundwater flow and water chemistry indicators. I found this approach to evaluating faults for inclusion in the model to be both more objective and more closely tied to the available data than in any previous modeling studies of the IWV. The 2025 GSP model contains six faults versus the two faults were represented in the 2020 GSP model. The total length of faults in the 2020 GSP model was 38.6 mi (62.1 km) and is just over double that 79.6 mi (128.1 km) in the 2025 GSP. The additional length and locations of fault segments allow for greater fidelity in modeling how faults impact groundwater flow in the groundwater model.

The 2025 GSP model has been constructed in the USGS outflow groundwater modeling software. This is consistent with both the 2016 and 2020 models on which the 2025 model is based. The model is using the correct packages which within MODFLOW including the NWT version that offers improved handling of wetting and drying cells in the upper unconfined layers of the model. Recharge is entered into multiple layers of the model at the mountain fronts using the Well package. Discharge through ET is handled by the Evapotranspiration Segments (ETS) package and the faults are modeled as conductive segments using the Hydrologic Flow Barrier (HBF) package. The use of MODFLOW-NWT and the particular packages highlighted here are done in a manner consistent with the state of practice for modeling groundwater in a basin such as IWV.

5.5 Opinion 5: Calibration of the 2025 GSP Model

The 2025 GSP modeling effort included both a steady-state (pre-development) and a transient component that simulated the entire time period from water year (WY) 1921 to 2022. Steady-state (long-term average) recharge was defined at 7,650 AFY, including mountain block/mountain front recharge in the basin and underflow from Rose Valley. The transient

simulation (WY 1921-2022) recharge was defined such that the average of all simulated years would be equal to 7,650 AFY, but was allowed to fluctuate on a monthly basis to allow for the shorter-term effects of wet or dry periods based on observed precipitation. The locations of applied recharge in the model domain were updated from the previous 2020 GSP model (Pohlmann et al., 2020) to assist in improving model calibration. Hydraulic conductivity and storage values were calibrated within zones defined to represent clay, fractured bedrock, or more permeable aquifer materials, and were based on values appropriate for the material present based on well logs or on measured values where available from aquifer testing. Calibration of the 2025 GSP model was done using a combination of trial-and-error parameter adjustment as well as automated parameter adjustment.

Once calibrated, the aquifer properties, hydrogeologic units, fault locations and conductances and recharge inflows were held constant and used in both simulation periods to compare model outputs to observations. This comparison results in a number of error statistics for both the steady state and transient simulations shown in Tables 5 and 6. The two models are compared to the same historical water levels and the steady state model fit to the data is very good for both models – all relative error statistics are less than one percent. The error statistics for the transient calibration are shown in Table 6. In this case, the set of observed water levels used as targets for calibration of the 2025 model is much larger than that used in 2020. This larger set is used to also used to compare against the 2020 GSP model and the results are used to calculate the error statistics in Table 6. The error statistics for the 2025 transient calibration are greatly improved, generally lower by half or more, than the statistics for the 2020 transient calibration.

The high-quality fit to the data in both steady state and transient models over a 102-year period using the same parameters speaks to the robustness of the calibration for the conditions being simulated. The number of water levels used to calibrate the 2025 transient model is more than three times the number used in the 2020 transient calibration. Additionally, the number of wells from which these water levels are taken is nearly four times (189) larger than it was in 2020 (50). More wells in a model with a smaller surface area and volume creates a denser distribution of the water levels that the model needs to match and generally leads to a more robust calibration.

The 2025 GSP model is well calibrated in both the steady-state (Table 5) and transient (Table 6) components of the model. For the steady state simulations, the error statistics of the 2020 and 2025 models are essentially the same (Table 5) with a slightly larger bias (mean error) from the 2025 model. Error statistics for the transient simulation (Table 6) clearly show that the 2025 model is superior to the 2020 model. The error statistics have all been reduced by a factor of two to three relative to 2020 and all measures of relative error are below three percent, which was not the case for the 2020 GSP model. This means that the updated model, when parametrized with a long-term natural recharge rate of 7650 AFY, is able to simulate observed equilibrium water levels in a pre-development condition, and is able to represent the observed change in water levels as a result of pumping over time.

Table 5. Comparison of steady-state model error statistics for the Updated 2025 Basin Model and the 2020 GSP Model.

	2025 Steady-State Basin Model		2020 Steady-State GSP Model	
	Error (ft)	Relative Error (%)	Error (ft)	Relative Error (%)
Mean Error (ME)	1.44	0.21	-0.13	-0.02
Mean Absolute Error (MAE)	4.63	0.69	4.49	0.67
Root Mean Squared Error (RMSE)	6.66	0.99	5.77	0.86

Table 6. Comparison of transient-historical model error statistics for the Updated 2025 Basin Model and the 2020 GSP Model.

	2025 Basin Model		2020 GSP Model	
	Error (ft)	Relative Error (%)	Error (ft)	Relative Error (%)
Mean Error (ME)	5.94	0.80	16.14	2.18
Mean Absolute Error (MAE)	14.21	1.91	26.44	3.58
Root Mean Squared Error (RMSE)	19.55	2.63	48.75	6.59

5.6 Opinion 6: Model Results

In the basis for Opinion 4, I explained that the model captures the complex hydrogeologic structure of the basin. As explained in the basis for Opinion 5, when the recharge and pumping are then applied to this hydrogeologic framework, resulting errors between the simulated and observed water levels are well within acceptable levels. Therefore, as the model is well-calibrated using the long-term natural recharge rate of 7650 AFY, the model results support the conclusion that 7650 AFY is a reasonable estimate of the recharge.

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1 **PROOF OF SERVICE**

2
3 I, Symone Hetzel, declare I am over the age of eighteen years and not a party to the within
4 action. I am a resident of or employed in the county where the service described below occurred.
5 My business address is 999 18th St., North Terrace, Ste. 600, Denver, Colorado 80202.

6 On August 15, 2025 I served the below listed document:

7 **UNITED STATES' NOTICE OF SERVICE OF EXPERT REPORT OF SEAN A.**
8 **MCKENNA, PH.D.**

9 on all interested parties in this action by uploading to the Case Anywhere website pursuant to the
10 Court Order Authorizing Electronic Service, dated December 2, 2022.

11
12 SEE ATTACHED CASE ANYWHERE SERVICE LIST

13 I declare under penalty of perjury under the laws of the State of California that the above
14 is true and correct. Executed on August 15, 2025, at Denver, CO.

15
16
17 *Symone S. Hetzel*

18 Symone Hetzel

Case Anywhere Electronic Service List

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