



SUPPLY & DEMAND

2025



METHODS APPENDIX

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1 INTRODUCTION

This methods appendix serves as a companion document to the 2025 Supply and Demand Reports (SDRs): Aravaipa Canyon, Bill Williams, Bonita Creek, Coconino Plateau, Dripping Spring Wash, Duncan Valley, Hualapai Valley, Little Colorado River Plateau, Morenci, Sacramento Valley, Safford, Salt River, and San Simon Wash. This document provides an overview of the methods used to develop the data presented in the SDRs, with the intent of providing explanation and transparency. As indicated in each SDR, these assessments are high-level analyses and often focus on areas with extremely limited available data. Estimates were used where reported data were unavailable or unreliable, and in some cases creating estimates based on minimal data proved challenging. These results should be read as broad estimates.

For each basin, ADWR created baseline estimates of past water use and then used those estimates to create several projection scenarios. The specific methods used in the 2025 SDRs are noted in tables in Section 2.

2 BASELINE ESTIMATES

2.1 AGRICULTURAL DEMAND

Several methodologies were utilized to produce the agricultural water use estimates in the 2025 SDRs. The methods applied in each basin vary and depend on the types of data sources that are available. Reported or field verified data was prioritized. In instances where data was either unavailable or where data was outdated, a combination of moving averages and satellite-based estimates were utilized to complete the data record.

Table 1. Methods Applied by Basin – Agricultural Water Use Estimates

Basin	Reported Data	USGS Field Verified Data	Open ET Water Duty Estimates	Surface Water Diversion Estimates	No Agriculture Present
Aravaipa Canyon			X		
Bill Williams		X*	X		
Bonita Creek					X
Coconino Plateau					X
Dripping Springs Wash					X
Duncan Valley			X	X	
Hualapai Valley		X			
Little Colorado River Plateau	X**		X		
Morenci					X
Sacramento Valley		X			
Safford		X*	X	X	
Salt River					X
San Simon Wash			X		

**Recent field verified data (less than 10 years old) was available only for certain subbasins within the Bill Williams and Safford Basins. OpenET water duty estimates were used for the remaining subbasins.*

***Reported data was available only within the Joseph City INA for the Little Colorado River Basin. OpenET water duty estimates were used for the rest of the Basin.*

2.1.1 Reported Data

Within Active Management Areas (AMAs) and Irrigation Non-Expansion Areas (INAs), agricultural irrigation of two or more acres is required to be reported to the department through annual water use reports. The only AMA or INA covered in the 2025 Supply and Demand Reports is the Joseph City INA within the Little Colorado River Groundwater Basin. For the baseline years 1990-2017, irrigation withdrawals for the Joseph City INA were already included in USGS estimates used for the Little Colorado River Basin. For the years 2018-2023, water withdrawal volumes from annual reports were aggregated for all applicable water rights in the INA. A three-year average was used to estimate agricultural withdrawals in 2024 as reported data was not yet available at the time of the baseline data development.

2.1.2 USGS Data

Arizona does not require metering and reporting of groundwater pumping in areas outside of the AMAs and INAs. To quantify irrigation withdrawals in non-AMA/INA groundwater basins, estimates from the US Geological Survey (USGS) were used where available. For the baseline years 1991-2018, the USGS has estimated total groundwater withdrawals for irrigation in each Arizona groundwater basin. The USGS also produces annual field verified data for certain groundwater basins. The field verified data includes additional information on the location and size of fields, irrigation types, crop types, and field-by-field estimated consumptive use (CU) and irrigation withdrawals. Field verified data was used preferentially over the 1991-2018 estimates where available. In years with missing data, ADWR estimated the total irrigation withdrawals by taking a three-year average. Section 2.5.3 provides additional detail regarding the USGS estimation methodology.

2.1.3 OpenET Water Duty Estimates

For some groundwater basins, no agricultural water use data was available other than the USGS 1991-2018 basin-wide estimates. To estimate the agricultural water use in these basins for more recent years, OpenET was used. OpenET is an open-source platform that uses satellite-based evapotranspiration (ET) data to estimate the consumptive use of agriculture. ADWR combined ET data retrieved from the OpenET Application Programming Interface (API) with effective precipitation data and irrigation type, extent, and activity data, which were determined using satellite imagery, to produce a water duty estimate. In the 2025 SDRs, the OpenET water duty tool was used to produce agricultural water use estimates for the entire Aravaipa Canyon, Duncan Valley and San Simon Wash Basins and for parts of the Bill Williams, Little Colorado River, and Safford Basins.

2.1.4 Surface Water Diversions for Agriculture

In certain regions, surface water diversions make up a significant portion of total agricultural water usage. For the 2025 Supply and Demand Reports, this applies to the Duncan Valley Basin and the Gila Valley and San Carlos Subbasins of Safford. All of the aforementioned basins use Gila River water for irrigation.

For these basins/subbasins, data on total surface water diversions from the Gila River was gathered from the Office of the Gila Water Commissioner (Gila River Commissioner, n.d.). Surface water use from the Gila River was reported by point of diversion, allowing ADWR staff to assign water use to each applicable basin. The estimated surface water diversion for each basin was used in combination with either the USGS-estimated groundwater withdrawal (see 2.1.2 USGS Data) or OpenET water use (see 2.1.3 OpenET Water Duty Estimates) estimate from each year to produce an estimate for the total agricultural water use.

2.2 INDUSTRIAL DEMAND

Table 2. Industrial Water Uses by Basin

Basin	Dairies	Feedlots	Grazing	Mining	Sand and Gravel	Power Plants	Turf	Other
Aravaipa Canyon			X		X			
Bill Williams			X	X	X	X	X	
Bonita Creek			X					
Coconino Plateau			X	X	X	X	X	
Dripping Springs Wash			X					
Duncan Valley	X		X		X		X	
Hualapai Valley			X		X	X	X	
Little Colorado River Plateau		X	X	X	X	X	X	X
Morenci			X	X	X		X	
Sacramento Valley			X	X	X	X	X	X
Safford			X	X	X		X	X
Salt River			X	X	X		X	
San Simon Wash			X				X	

2.2.1 Dairy

The Duncan Valley Basin is the only basin in the 2025 SDRs that has water demands related to dairies. Headcounts were used to estimate dairy water demand values. Water use was considered for both lactating and dry cows, each of which were assigned different values for estimating consumptive water needs based on literature reviews (Becker, 2024; Himmelmann, H. & Amaral-Phillips, D., n.d.). Estimates for additional water uses, such as dust suppression and miscellaneous farm use, were also identified from literature reviews (Alberta Ministry of Agriculture and Irrigation, n.d.; Governor’s Agricultural Best Management Practices Committee, 2015; Davis & Watts, 2016; Broom, 2019;). The final estimate for cattle consumptive use and miscellaneous farm use was an average from the literature (Table 3). Dust can be a significant issue in Arizona, so the high-end value from literature was used (Table 3). Values for consumptive needs, dust suppression, and miscellaneous farm uses were added to create a total daily water use per cattle based on life stage and total annual water use across the dairy.

Table 3. Daily water demand volumes for different life stages of cattle at Arizona dairies.

	Lactating Cows	Dry Cows
Water consumption	13	22
Dust suppression	6	6
Miscellaneous farm use	7	7

All values in gallons per animal per day.

Potential future improvements include adding variance in water needs for temperature and climate and getting direct water use data from dairies of similar size.

2.2.2 Feedlots

Water use estimates for swine feedlots considered the headcount per facility, the life stages of the animals, and the type of cleaning system used. Water consumption values were estimated for each life stage and were derived from literature (Guthrie, 2011). Cooling needs were derived from literature and are temperature dependent (Matlock et al., 2011). Cleaning needs are dependent on the type of facility. For facilities using a flush manure removal system, the values in Table 5 were applied (Jones, D. & Collins E., 2019). Facilities without a defined cleaning system were assigned a generic cleaning value, shown in Table 6 (Van Kempen, 2003). Total water use was calculated by multiplying water consumption, cleaning, and cooling needs by the applicable headcount for each facility and scaling the volume to an annual estimate.

Table 4. Daily water consumption volumes for hogs.

	Sows/Gestating	Nursery Pigs	Growing Pigs	Finishing Pigs
Water consumption	4.5	.7	1.5	4

All values in gallons per animal per day

Table 5. Water requirements for flush system manure removal.

	Manure removal – flush system
Sow and litter	70
Nursery/growing	8
Finishing	30
Gestation	100

All values are in gallons per building per day.

Table 6. Cooling and cleaning needs for hog feedlots.

	All Swine
Cooling needs	6 gallons/pig/day over 80°F
Cleaning needs	.81 gallons/pig

2.2.3 Grazing

ADWR estimated water demands for grazing by calculating the maximum number of animals authorized to graze per basin and then estimating the water needs per grazing animal. The Bureau of Land Management (BLM) allotments and the Arizona State Land Department (ASLD) leases were used to determine the maximum number of animals authorized to graze in the basins of interest (ASLD, n.d.; BLM, n.d.). ADWR assumes that the maximum number of grazing animals per lease/allotment is present year-round.

Since grazing allotments and leases do not perfectly conform to groundwater basins, grazing animals were proportioned based on the number of stock ponds and BLM land improvements present on each allotment/lease (BLM, n.d.; ADWR, 2023).

$$\# \text{ Animals per Well or Improvement} = \frac{(\text{Total \# Animals on Allotment or Lease})}{(\text{Total \# Wells and Improvements on Allotment or Lease})}$$

Since BLM and ASLD allotments and leases are infrequently updated, with typical lease terms of 10 years (pers. comm., D. Whitbeck, Dec. 2022), the method assumes that historical use is the same as present-day use. Additional assumptions include that grazing animals are evenly distributed among wells and stock ponds and that all grazing animals are cattle.

Grazing demands were also estimated for the Native American tribes that overlap the basins of study. Grazing demands within the Navajo Nation considered both the livestock that is actively managed by the tribe as well as the feral horses that graze within the basin but are not managed. To estimate the water demands for managed grazing, estimated headcounts of animals were taken from the US Bureau of Reclamation’s Consumptive Uses and Losses reports. Reports were not available for all years. Years without data from an annual report were filled in by extrapolating data by applying rolling averages. Estimated headcounts of animals were multiplied by the annual water demand volume for the applicable species to generate a total water estimate, see Table 7 (Rasby & Walz, 2011; Ivey, n.d.; USBR, n.d.). To estimate the water used by feral horses in the basin, headcounts were estimated using various reports and were multiplied by the annual water demand for horses listed in Table 7. (Navajo Nation Office of the President, 2024). In Native American reservations other than the Navajo Nation, headcounts for grazing animals were estimated by multiplying the proportion of the reservation that falls within a basin by the estimated cattle inventory (Drugova, T. et al., 2020). Headcounts were multiplied by the annual water demand volume for cattle to generate a total water use estimate.

Table 7. Annual water demand volumes for grazing livestock in Arizona.

	Cattle	Horses	Sheep	Goats
Water consumption	5482	3559	730	730

All values in gallons per animal per year.

2.2.4 Mining

Metal Mining

Arizona’s most commonly mined metals are copper, gold, silver, molybdenum, and lead (AZGS, n.d.-a). Due to the limitations of publicly available mining data, accurately estimating water use can be problematic. Therefore, broad estimates are used in these analyses.

The main assumption of this methodology is that the mass of mined ore corresponds to the total volume of water consumed within a mine, as illustrated in the following calculation:

$$\text{Water Consumption} = \text{Extracted Ore (Tons)} \times \text{Water Use Intensity Coefficient} \left(\frac{\text{AF}}{\text{Ton}} \right)$$

Reports from the Arizona Department of Mine and Mineral Resources (ADM MR) and USGS were analyzed to determine the total production of individual mines (AZGS, n.d.-b; USGS, n.d.-c). If data were unavailable for a specific year, historical trends and statewide production records were used to estimate production.

Production values were converted into extracted ore estimates by applying the reported ore grade of the mine. If an ore grade was unavailable for a specific mine, average ore values for the extracted mineral were used (Calvo et al., 2016).

Water use intensity coefficients were sourced from peer-reviewed publications and, where possible, assumed water reuse and recycling at mines (Singh, 2010; Gunson, 2013). The coefficients were multiplied by the corresponding extracted ore estimates to produce a final water use estimate for each mine.

The estimates produced by this method are high-level, due to the limited nature of available data. This method does not include water use for domestic purposes, environmental remediation, waste management, or dust suppression. Broad changes and improvements to this methodology may be considered for future SDRs.

2.2.5 Power Generation

Water use estimates for power generation were calculated with the following equation:

$$\text{Total Water Consumption} = \text{Water Use Intensity} \times \text{Net Generation (MWH)}$$

where $\text{Water Use Intensity} = \left(\frac{\text{Gallons}}{\text{Megawatt-hour (MWH)}} \right)$

Water use intensity coefficients were derived from a variety of sources, including AMA annual reporting data, Arizona Public Service (APS) metrics (Pinnacle West Capital Corporation, 2023), Certificate of Environmental Compliance (CEC) data, and peer-reviewed literature (Frisvold, 2013). A single water use coefficient was established for each fuel type, and a weighted average of the applicable fuel type coefficients was taken for power plants that use a mix of fuel types.

Net generation data were collected for 2001-2024 from the U.S. Energy Information Administration's (US EIA's) Electricity Data Browser (US EIA, 2024d). Any missing data were filled in with the average of the three preceding years' net generation. A linear regression of the available data was created to estimate generation values for the years before data were available, and generation values were extrapolated. The generation estimates were cross-referenced with ancillary data to confirm that the estimates were reasonable. Water use intensity coefficients were multiplied by net generation estimates to produce final water use estimates.

Final water use estimates reflect only water consumed within the power generation process and do not capture site-specific factors that may contribute to total water use. These include, but are not limited to, the consideration of on-site domestic use, water treatment facilities, or water for hazard mitigation and waste processing. This methodology did not consider differences in the efficiency of cooling processes, whether due to environmental or technological factors unless site-specific data were available. Future estimates can be improved by considering the differences between individual power plants and technologies.

2.2.6 Sand and Gravel

To estimate water use, internet searches were used to identify the year each sand and gravel facility opened. ASMI active mines lists, and internet searches were then used to determine what types of aggregates each facility process. Staff used Texas data on sand and gravel water needs across different aggregate types to estimate water use for each facility (Reedy & Scanlon, 2022).

This method assumes that Texas and Arizona sand and gravel facilities use similar amounts of water and that water use has not changed at sand and gravel facilities over time. This method could be improved by incorporating more Arizona data, better understanding the relationship between the size of an operation and its water use, and better-identifying facilities based on whether they wash their materials on-site.

2.2.7 Turf

In this study, turf refers to any area of irrigated landscaping that is not part of a private residence. Irrigated landscaping may include grass, trees, gardens, low water-use plants, ground cover, artificial water bodies, synthetic turf, or any mix thereof. The scope of the estimations and the methods used to calculate turf water use in the SDRs are not congruent with the methodology described within the Management Plans. As such, these estimations should be considered independently from the reported data from the AMAs.

The general methodology for calculating turf demand within the SDRs was based on the following:

Total Water Use = Total Water Duty * Acreage

To determine currently irrigated acreage within each basin, a combination of color infrared imagery, vegetation indices, and high-resolution National Agricultural Imagery Program (NAIP) images were analyzed to determine the extent and type of landscaping present. To determine historically irrigated acreage, the Historical Imagery tool on Google Earth was used to approximate the presence and activity of turf facilities over the baseline period. From the imagery analysis, the total turf acreage was split into five broad categories that best captured the types of landscaping in the basins: overseeded grass, non-overseeded grass, sparse or seasonal grass, water surface area, and synthetic turf.

Crop coefficient (K_c) values were developed for each turf category except for water surface area and each were developed to be specific to the climate zone that the turf facilities are located in. To determine the climate zone of each turf category, the identified acreage was overlaid with the 2023 USDA Plant Hardiness Zone Map (USDA, 2023). K_c values were calculated for each climate zone for overseeded, non-overseeded, and sparse or seasonal grass. For synthetic turf, an artificial crop coefficient (K_{ac}) was assigned for each climate zone that considers the need of watering for cooling purposes; in this study, cooling was only assumed to be necessary in months when the average high temperature exceeded 80 F. To create basin level coefficients, the assigned K_c and K_{ac} values for each turf category were scaled proportionally according to the amount of acreage within each climate zone.

K_c and K_{ac} values were multiplied by reference ET, which is defined as the volume of water that evaporates from well-irrigated grass, to produce consumptive use (CU) estimates. Reference ET values were sourced from AZMET (University of Arizona, n.d.-a). Since station data is not available for all locations, data from the nearest station with the most similar climate was applied. See the below equation for the CU calculation:

$$CU = K_c * ET_{os}$$

$$\text{or } CU = K_{ac} * ET_{os}$$

Where, $CU = \text{Consumptive use}$

$K_c = \text{Crop coefficient,}$

$K_{ac} = \text{Artificial crop coefficient}$

$ET_{os} = \text{Reference ET}$

The CU values were converted into total water duties by incorporating irrigation efficiency and effective precipitation data. Irrigation efficiency (IE) was held constant between turf categories and basins but was assumed to increase at a consistent rate over the baseline period from 75% to 77.5%, this increase reflects IE assumptions from the 2nd and 5th Management Plans for the Prescott AMA. Effective precipitation was incorporated into the water duties for overseeded, non-overseeded, and sparse or seasonal grass facilities, however, no effective precipitation was considered for synthetic turf. To calculate effective precipitation, precipitation data were compiled from 1990-2024 and averaged to produce a single basin estimate of precipitation for each year (PRISM Climate Group, 2024). Precipitation estimates were then converted into effective precipitation values using the following formula:

$$\text{Effective Precipitation} = (\text{Precipitation (mm)} - 5) \times .75$$

The resulting effective precipitation values were built into the total water duty for overseeded, non-overseeded, and sparse or seasonal grass using the following equation:

$$\text{Total Water Duty (Turf)} = \frac{CU - \text{Effective Precipitation}}{\text{Irrigation Efficiency}}$$

The total water duty for synthetic turf water was calculated using the following equation:

$$\text{Total Water Duty (Synthetic)} = \frac{CU}{\text{Irrigation Efficiency}}$$

The total water duty for water surface area was not calculated but was assumed to follow the duty defined within the 5th Management Plans.

Total water duties for each turf category were multiplied by the acreage of the same category to produce water use estimates. Water use estimates for all categories of turf were summed at the basin level to produce the final turf water use estimates.

This methodology is built on general turf irrigation data and does not consider site or location -specific factors that may contribute to overall water use, such as leaching needs or synthetic turf cleaning. This method also assumes that irrigation is inherently dependent on the precipitation received; actual irrigation practices may vary and may not be fully accounted for by this method. Furthermore, this method relies on satellite imagery to locate turf facilities, determine extent, and categorize landscape type. Spatial resolution has become a limiting factor for applying this methodology for less recent years. Future studies hope to build upon this methodology to create increasingly robust and regionally applicable analysis methods.

2.2.8 Other

Greenhouses

In the context of this report, greenhouses refer only to commercial or industrial facilities; residential or community greenhouses are included within the municipal sector. To estimate greenhouse water use, the following equation was utilized:

$$\text{Greenhouse Withdrawal} = \left(\frac{\text{Irrigation Requirement}}{\text{Acre}} \times \text{Acres} \right) \times \text{Greenhouse Efficiency}$$

Census of Agriculture reports and individual facility websites were reviewed to determine the types of crops grown within each facility (USDA, 2019). Irrigation requirements for the identified crop types are sourced from the Fifth Management Plan for the initial AMA with the most comparable environment (ADWR, 2022).

Greenhouse facility acreage was estimated using high-resolution satellite imagery. The extent was measured and tracked within the baseline period, 1990-2024. Where image resolution was a limiting factor in determining the extent, alternative data sources such as news articles, parcel data, and facility website information were reviewed.

Irrigation requirements were multiplied by the total acreage to produce a water use estimate reflecting an assumption of open-field cultivation. An efficiency rate was then applied to convert this estimate from an open-field estimate to a greenhouse estimate. The applied efficiency rate was derived from peer-reviewed literature and facility-reported data and assumes increased efficiency due to reduced evapotranspiration, high IE systems, increased crop density, and decreased crop cycle lengths (O'Connor & Mehta, 2016).

This methodology makes broad assumptions of water use based on the spatial extent of facilities. It does not consider the percentage of each facility being actively cultivated at a time and cannot determine the precise crop mix within a facility. In addition, water uses beyond the irrigation of crops were not included in this method. Future estimates can be refined with the inclusion of more detailed site data.

Compressor Stations

ArcGIS Pro was used to map compressor stations in the groundwater basins of interest (Natural Gas Compressor Stations, 2022). U.S. Environmental Protection Agency (US EPA) Envirofacts were then used to identify the year each compressor station of interest opened (US EPA, n.d.). A median annual water use was

calculated from compressor stations in AMAs and applied for each year the station was open during the baseline period.

This method assumes water use has not changed substantially over time, that high water use outliers from AMA data are outliers and do not represent standard practice, and that compressor stations within AMAs operate similarly to those outside AMAs. Improvements could include understanding the cause of outliers in AMA data, identifying water use data for specific compressor stations of interest, and understanding how water use technology has changed over time at compressor stations.

Oil and Gas Production Wells

A small amount of oil and gas production wells exist in the northeastern portion of the state. To estimate the water that is used in the production of oil and gas, reported production volume data from the Arizona Geological Survey was multiplied by a water intensity coefficient (Rauzi, 2010).

To convert produced oil into estimated water use, the following equation was used:

$$Water\ Used\ (AF) = \frac{(Oil(Bbl) * 1.71) * 42}{325851}$$

Where, *Bbl* = barrel

Per A.R.S. §12-7-101, one barrel of oil is equivalent to 42 US gallons. In addition to this, the equation assumes that for each barrel of oil produced, 1.71 barrels of water are consumed (Ali & Kumar, 2017).

To convert produced gas into estimated water use, the following equation was used:

$$Water\ Used\ (AF) = \frac{Gas\ (MCF) * \frac{1.038\ MMBtu}{MCF}}{325851}$$

Where, *MCF* = thousand cubic feet

And, *MMBtu* = million British thermal units

Production volumes are provided in MCF unit and were converted to MMBtu. This equation assumes that for each MMBtu of gas extracted, 1 gallon of water is consumed (Mielke, 2010).

Reported data was not available for all years during the baseline period. The available reported data was extrapolated through running averages to fill in data gaps.

Proving Grounds

Site-specific data was provided to the department for the following years: 2012, 2013, 2014, 2015, and 2016. This data is inclusive of water uses for employee consumption, sanitary purposes, landscaping, fire protection, dust suppression, vehicle test event operations, and road maintenance. For years when the facility was operational, but data was not provided, a running average was used to extrapolate the data.

Manufacturing

Chemical Manufacturing

The Sacramento Basin was the only basin in the 2025 SDRs with demands related to chemical manufacturing. Due to lack of site-specific data, water use was estimated by converting the estimated energy consumption of the facility into water use. Total energy consumption for all chemical manufacturing plants and the total number of establishments was provided in a manufacturing survey from the US EIA, allowing for an average energy use per facility value to be derived (US EIA, 2018). The average energy use value was then converted into water use using an estimated energy-water ratio (Rao et. al, 2017). The estimated water use was applied every year in which the facility was operational. This method is generic and

does not consider the specific type of chemical that is being produced or the specific production process utilized by each individual facility.

Timber and Glulam Production

To estimate the water usage of glulam production facilities, industry averages were applied. Production was estimated using the total reported glulam production at a national scale and dividing it by the number of operational facilities (Bowers et. al, 2017; APA, 2020). A water use intensity coefficient was multiplied by the production value to produce a total water use estimate for glulam facilities. This method assumes that glulam facilities across the country have comparable production processes and capacity, and that they use similar amounts of water.

Water use for timber production was estimated following similar methodology as glulam production. Timber production was estimated using reported profits from facilities, the types of commodities produced, and the average price per commodity produced (Dun & Bradstreet, n.d.; Fortune Business Insights, 2025). A water use intensity coefficient was then multiplied by the estimated production value to produce a total water use estimate for the timber production.

Meat Processing

Water usage at meat processing plants was estimated by multiplying the number of animals processed in a facility by the average water use per head of animal. The production capacity of facilities was estimated using data from an USDA report (Saitone, T., et al., 2023). Water use intensity coefficients for processing were dependent on the type of animal and included water use for cooling, cleaning, and waste conveyance purposes (Food Northwest, n.d.).

Steel Manufacturing

There is one steel manufacturing facility present in the 2025 SDRs. To estimate the water use of the facility, estimated production values were pulled from news articles (ACA, 2022c; Manufacturing Net, 2008). The estimated production values were multiplied by a water use intensity coefficient to estimate the total water use at the facility (World Steel Association, 2020).

Manufactured Homes

Water demand for the production of manufactured homes was estimated based on the size of the manufacturing facility. Google Earth Imagery was used to calculate the approximate square footage of a facility. This area was multiplied by a water intensity per unit area value from an US EIA study of large commercial buildings (US EIA, 2012). This method is generic and can be improved in future analyses with the inclusion of site-specific data.

Papermills

The Little Colorado River Plateau Basin is the only basin with water demands related to a paper mill for the 2025 SDRs. Water consumption at the paper mill in the basin was estimated by multiplying the reported water use per unit of product produced by the reported annual production of paper at the facility (Catalyst Paper, 2015). Rolling averages were used to extrapolate data for years without reported data.

2.3 MUNICIPAL DEMAND

Table 8. Municipal Water Uses by Basin

Basin	Residential Provider	Residential Non-Provider	Non-Residential	Lost & Unaccounted for
Aravaipa Canyon		X		
Bonita Creek		X		
Bill Williams	X	X	X	X
Coconino Plateau	X	X	X	X
Dripping Springs Wash		X		
Duncan Valley	X	X	X	X
Hualapai Valley	X	X	X	X
Lower Colorado River Plateau	X	X	X	X
Morenci	X	X	X	X
Sacramento Valley	X	X	X	X
Safford	X	X	X	X
Salt River	X	X	X	X
San Simon Wash	X	X	X	X

2.3.1 Residential Provider

For the purposes of the SDRs, residential provider use is defined as the water used for residential purposes (i.e., drinking, cooking, cleaning, bathing, landscaping) supplied by a municipal provider, Community Water System (CWS), or water district. Residential provider use was calculated as follows:

$$\text{Residential Provider Use} = \text{Provider Service Population} \times \text{Gallons Per Capita Per Day (GPCD)}$$

The provider service population was estimated using the annual reports of CWSs in the basin. If CWS reports were unavailable or were determined to have poor data quality, alternative data sources were used. These include Arizona Corporation Commission (ACC) annual reports, USCB people per household unit (PPHU) statistics, and Arizona Department of Environmental Quality (ADEQ) system data from the Safe Drinking Water Database.

To produce historical population estimates for each system, the current population was scaled back to 1990 according to the Arizona Commerce Authority's (ACA) Office of Economic Opportunity's population growth rate statistics. Historical populations were calculated using the following equation:

$$\text{Population}_{n-1} = \frac{\text{Population}_n}{(1 + \text{Population Growth Rate}_{n-1})}, \text{ where } n = \text{Year}$$

Regional gallons per capita per day (GPCD) rates were developed from CWS annual reports, using available data for residential deliveries from 2006-2023, as illustrated in the equation below. The resulting GPCD rates were averaged within the basin to derive a regional GPCD rate for each year.

$$\text{GPCD}_n = \frac{\text{Volume of Residential Deliveries}_n}{\text{Service Population of Municipal Provider}_n}, \text{ where } n = \text{Year}$$

The yearly average GPCD rates were used to create a linear regression for each basin where data were available. For years within the data range (2006-2023), the regression was used to interpolate GPCD values. Interpolation was done to reduce the impact of years within the data range where data quality was poor.

For years outside the data range (1990-2005, 2024), linear regression was used to extrapolate GPCD values. While extrapolation of data beyond the data range can introduce uncertainty into an analysis, the trends in the calculated GPCD rates were comparable to trends found in recorded data of other regions within Arizona (City of Phoenix, n.d.).

2.3.2 Residential Non-Provider

Residential non-provider use is defined as water consumed for domestic purposes that is self-supplied and is not provided by a municipality, CWS, or water district. Total basin populations were estimated with census block group data and were adjusted to consider population clusters, available demographic data, domestic wells, and residential infrastructure presence.

To derive the residential non-provider population, the residential provider population (see Section 2.3.1) was subtracted from the total residential population of each basin, as shown below:

$$\begin{aligned} & \text{Residential Non – Provider Use} \\ & = (\text{Total Residential Population} – \text{Residential Provider Population}) \times \text{GPCD} \end{aligned}$$

A water use estimate was then calculated by applying a regional GPCD rate (see Section 2.3.1) to the estimated non-provider population.

To produce historical estimates, the residential non-provider population was scaled back to 1990 according to the ACA’s Office of Economic Opportunity’s population growth rate statistics (ACA, 2022a) (see Section 2.3.1 for equation).

2.3.3 Non-Residential

Non-residential use was delineated into two categories for this study: water delivered by CWSs for commercial, institutional, or transient uses and water delivered by non-community water systems (NTNC).

Water delivery data from CWS annual reports were compiled and reviewed to isolate deliveries for non-residential uses. Non-residential deliveries considered under other sectors, such as industrial turf irrigation or agricultural water, were excluded. A non-residential GPCD was developed as follows:

$$\text{Non – Residential GPCD} = \frac{\text{Non – Residential Water Deliveries}}{\text{Water Provider Population}}$$

The calculated non-residential GPCDs were averaged into two rates: one rate to represent providers that have high water-intensity facilities, such as medical care facilities or hotels, and a second rate to represent providers that service low water-intensity facilities, such as office buildings or retail stores. The resulting non-residential GPCD rates were consistent with comparable facilities’ data (Energy Star, 2012).

GPCDs were applied to water provider populations to develop a water use estimate based on the types of facilities present within the service area boundaries. Historical estimates were generated by holding the non-residential GPCDs constant over time and using the historical provider population estimates (see Section 2.3.1).

NTNC use was categorized by general type: schools, recreational facilities, service stops or rest areas, and other/miscellaneous. Water use intensity per user was estimated using proxy AMA or CWS data, Third Management Plans water-use models from the initial AMAs (ADWR, 1999), and US EPA end-use water ratios (US EPA, n.d.). Estimates of the populations served by the water systems were developed using data from ADEQ’s Safe Drinking Water Information System (SDWIS; ADEQ, 2023a), facility websites, and transit records (ADOT, 2013; ADOT, 2017). The estimated populations were applied to the appropriate water use intensity value to estimate water use. Historical estimates were developed by adjusting the present-day population using population change statistics (ACA, 2022a).

The methodologies assume that facilities of a similar type use comparable amounts of water. Unless data were available on a site-specific basis, generalizations were made that may not fully capture water use or may artificially inflate water use for some facilities. In addition, while these methods have attempted to capture service populations as accurately as possible, the seasonal nature of specific populations and water uses may lead to inaccuracies in some population estimates. Future assessments may work to address these uncertainties and improve understanding of non-residential use statewide.

2.3.4 Lost & Unaccounted For

Lost and unaccounted for (L&U) water refers to the volume of water lost within a water delivery system between the point of withdrawal or diversion and the point of delivery. For this study, all public municipal water systems were considered to have some level of L&U water.

To determine L&U volumes within a basin, regional L&U rates were developed using data from CWS annual reports. For the 2025 studies, one L&U rate were deployed for the basins from the NPA National Statistics, for the Aravaipa Canyon, Bill Williams, Bonita Creek, Coconino Plateau, Dripping Springs Wash, Duncan Valley, Hualapai Valley, Little Colorado River Plateau, Morenci, Sacramento Valley, Safford, Salt River, and San Simon Wash. L&U rates were calculated as follows:

$$\text{Lost \& Unaccounted for} = \frac{\text{System Supply} - \text{Delivered Water}}{\text{System Supply}}$$

L&U rates within each region were averaged to develop a singular regional rate. Regional rates were held constant within the baseline period (1990-2024) and were applied to public water system demands to produce a single L&U estimate for each basin, according to the equation below.

$$\text{L\&U Volume} = \text{L\&U Rate} \times (\text{Residential Provider Demand} + \text{Non-Residential Demand})$$

This methodology assumes that systems within a given region are likely to have similar percentages of L&U water. In addition, this methodology is limited by the availability and quality of system data. Developing a more robust dataset and refining this methodology will contribute to more accurate and regionally specific estimates for future studies.

2.4 Other Demand

Other demand is considered to be any water demand that does not fit solely within the confines of a preexisting demand sector. In the 2025 SDRs, other demand includes environmental demands and the multi-sectoral consumptive uses of the Colorado River.

2.4.1 Environmental

Environmental water demand is defined as consumption by native plants (i.e., riparian evapotranspiration) and intentional groundwater withdrawals or surface water diversions for defined areas such as preserves, catchments, wildlife areas, and wildfires.

Table 9. Environmental Water Use by Basin

Basin	Environmental
Aravaipa Canyon	X
Bill Williams	X
Bonita Creek	X
Coconino Plateau	X
Dripping Springs Wash	X
Duncan Valley	X
Hualapai Valley	X
Little Colorado River Plateau	X
Morenci	X
Sacramento Valley	X
Safford	X
Salt River	X
San Simon Wash	X

Evapotranspiration

To estimate the total water requirement of riparian plants, consumptive use (CU) values were multiplied by the total acreage of riparian habitat, see equation below.

$$Total\ Water\ Requirement = CU * Acreage$$

Riparian acreage was estimated using the National Wetland Inventory produced by the US Fish and Wildlife Service. Acreage was broadly split into two categories, high water use acres and low water use acres, depending on the types and density of the vegetation present.

Consumptive use values were derived from literature and assume that high water use stretches of riparian habitat will contain predominately cottonwood-willow forests and low water use riparian habitat will contain a mixture of cottonwood and willow trees, mesquites, and grasses (USGS, 2005; USGS, 2020; NDA, n.d.).

Table 10. Consumptive Use in Feet

High Water Use	3.16
Low Water Use	1.74

Effective precipitation was not considered in the calculations of riparian water use in this assessment. As such, the values presented should be viewed as an estimated total water requirement that includes water from any available water source including precipitation events, groundwater, and surface water sources.

This method is not site or location-specific and does not consider differences in the composition of riparian habitat between basins. Future assessments can improve upon this methodology to produce more regionally specific estimates.

2.4.2 Colorado River – Consumptive Use

Two basins in the 2025 SDRs had consumptive uses of Colorado River water, the Little Colorado River Plateau Basin and the Bill Williams Basin.

A portion of the Little Colorado River Plateau Basin is located within the Upper Basin of the Colorado River. To estimate the quantity of Upper Colorado River water that is used annually to meet demands, ADWR staff referenced the US Bureau of Reclamation's Consumptive Use and Losses: Provisional Estimate, Arizona Portion of the Upper Colorado River Basin reports (USBR, 2023). Consumptive use values for surface water diverted directly from the Colorado River were considered to be Colorado River demand. For years in which data was unavailable, rolling averages were used to extrapolate data.

The Bill Williams Basin falls within the Lower Basin of the Colorado River. To estimate the consumptive use of Lower Colorado River water, ADWR staff referenced the US Bureau of Reclamation's Colorado River Accounting and Water Use Reports (USBR, n.d.-b). Consumptive use values for water users in the Bill Williams basin were compiled to produce a basin estimate for Colorado River water use. In older USBR reports, consumptive use values were not provided. To estimate consumptive use, an average consumptive use to total diversion ratio was used to convert diversions to consumptive use.

2.5 Supply

2.5.1 Surface Water

Estimating the surface water supply volumes assumed a water budget containing inflows and outflows to determine an overall remainder considered "supply" for human use. Streamflow was considered for inflows, and evapotranspiration and infiltration were outflows.

Stream Identification/Classification

Important stream reaches were identified and classified using GIS layer data from AZGS (ASLD and AZGS, 2020) and The Nature Conservancy (The Nature Conservancy, 2021). The GIS layers labeled streams by name and their flow frequency (perennial, intermittent, ephemeral). Other selection criteria for streams included nearby streamgages with recorded streamflow, the presence of effluent discharge in the stream, diversions or structures present in aerial imagery indicating water uses, or the existence of instream surface water filings.

Streamflow

To estimate the amount of streamflow for each basin analyzed this year, streamgage data were analyzed from the USGS streamgage networks. The USGS streamgage data were determined using the USGS streamgage website, known as the National Water Dashboard, which gave real-time data for streamflow (USGS, 2024b). A list of streamgages located in the targeted basins is provided in Table 11. Time-series data of daily mean streamflow for each streamgage was obtained from the USGS website, which was then converted into AF per year based on days of streamflow. This allowed for a more representative value when streamflow was measured on only certain days of the year.

Table 11. Locations of applicable USGS streamgages for the 2025 SDRs.

Basin	Streamgage Name	Latitude, Longitude	Begin Date	End Date
*! Aravaipa Canyon	Aravaipa Creek (09473000)	32.844233, -110.6301	1931-05-01	present
Bill Williams				
Alamo Reservoir Subbasin	Big Sandy River (09424450)	34.462517, -113.624377	1966-03-29	present
	Santa Maria River (09424900)	34.305854, -113.347144	1966-04-18	present
Burro Creek Subbasin	Burro Creek (09424447)	34.541684, -113.445205	1980-07-25	present
Clara Peak Subbasin	Bill Williams River (09426620)	34.262515, -114.027721	1988-10-01	present
	Bill Williams River (09426000)	34.230854, -113.608819	1939-12-01	present
Santa Maria Subbasin	Upper Little Sycamore Wash (09424580)	34.570739, -113.067561	2016-08-23	2025-06-24
	Little Sycamore Wash (09424600)	34.549167, -113.057778	2016-08-23	present
*! Skull Valley Subbasin	Santa Maria River (09424900)	34.305854, -113.347144	1966-04-18	present
Bonita Creek	Bonita Creek (09447800)	32.955618, -109.531188	1981-08-01	present
Coconino Plateau	Little Colorado River (09402000)	35.926382, -111.567368	1947-06-01	present
	Cataract Creek (09404104)	35.804444, -112.426389	2008-12-11	present
	Havasu Creek (09404115)	36.305816, -112.761305	1995-10-01	present
	Pump House Wash Spring (09403013)	36.078594, -112.126003	1995-06-22	present
Dripping Spring Wash	Gila River (09469500)	33.169505, -110.531211	1899-07-11	present
Duncan Valley	Gila River (09439000)	32.724444, -109.099167	2003-10-01	present
	Gila River (09442000)	32.965278, -109.308611	1987-10-01	present
*! Hualapai Valley	Truxton Wash (09404343)	35.384162, -113.657719	1993-10-08	2025-01-31
	Spencer Creek (09404222)	35.7999, -113.65535	1998-03-27	present
Little Colorado River Plateau	Chinle Creek (09379025)	36.155, -109.5375	1999-11-05	present
	Chinle Creek (09379200)	36.943891, -109.710668	1964-10-01	present
	Little Colorado River (09383400)	34.016714, -109.457313	1960-08-01	present
	Little Colorado River (09384000)	34.314486, -109.362315	1940-04-01	present
	Little Colorado River (09385700)	34.450593, -109.36232	1985-03-01	present
	Little Colorado River (09386030)	34.583646, -109.407047	1975-10-01	present
	Little Colorado River (09386300)	34.604754, -109.489273	1998-09-11	present
	Little Colorado River (09394500)	34.782808, -110.044284	1905-03-16	present
	Little Colorado River (09397000)	34.897804, -110.163177	1905-03-17	present
	Little Colorado River (09397300)	34.901137, -110.255401	1970-03-01	2023-08-17
	Little Colorado River (09400350)	35.011688, -110.651244	2001-12-13	present
	Chevelon Canyon (09397500)	34.63642, -110.714296	1947-05-01	present
	Chevelon Creek (09398000)	34.926413, -110.531518	1906-01-01	present
	Jacks Canyon Creek (09399400)	34.921411, -110.797636	1969-10-01	present
	Show Low Creek (09390500)	34.179488, -109.987886	1953-05-01	present
	Puerco River (09396100)	35.182246, -109.447051	1973-02-07	2023-03-23
	Newman Canyon (09400815)	35.054944, -111.489222	2014-08-22	present
	Moenkopi Wash (09401260)	36.104993, -111.201807	1976-07-01	present
	Pasture Canyon Spring (09401265)	36.171583, -111.201444	2004-08-10	2025-01-05
Morenci	Blue River (09444200)	33.290895, -109.196183	1998-10-01	present
	San Francisco River (09444500)	33.049508, -109.295905	1910-10-23	present

	Eagle Creek (09447000)	33.064506, -109.442298	1944-04-01	present
*! Sacramento Valley	Big Sandy River (09424450)	34.462517, -113.624377	1966-03-29	present
Safford				
San Carlos Valley Subbasin	San Carlos River (09468500)	33.296447, -110.451488	1987-10-01	present
	Gila River (09466500)	33.185613, -110.22009	1987-10-01	present
Gila Valley Subbasin	Gila River (09448500)	32.868397, -109.511186	1987-10-01	present
*! San Simon Valley Subbasin	Gila River (09448500)	32.868397, -109.511186	1987-10-01	present
Salt River				
Salt River Lakes Subbasin	Salt River (09498500)	33.619495, -110.921504	1987-10-01	present
	South Fork Parker Creek (09498503)	33.79727, -110.960395	1987-10-01	present
Salt River Canyon Subbasin	Cherry Creek (09497980)	33.827826, -110.856227	1987-10-01	present
	Carrizo Creek (09496500)	33.985881, -110.280942	1987-10-01	present
	Salt River (09497500)	33.798106, -110.499829	1987-10-01	present
	Cibecue Creek (09497800)	33.843105, -110.557609	1987-10-01	present
White River Subbasin	White River (09494000)	33.736441, -110.166767	1987-10-01	present
Black River Subbasin	Black River (09489500)	33.47672, -109.763977	1987-10-01	present
	Black River (09490500)	33.712829, -110.211767	1987-10-01	present
San Simon Wash	Vamori Wash (09535300)	31.951111, -112.347222	1972-02-01	present

**For the missing years between 1990 and 2024, historical precipitation data are being used to establish trends over time and apply that to unaccounted historical surface water volumes.*

**! Signifies that the streamgage selected is outside of the basins boundaries as the basin did not have a streamgage inside.*

Drainage Area Ratio (DAR) Method

To estimate the amount of streamflow for the entire basin, the Drainage Area Ratio (DAR) method was used (Levin & Farmer, 2020). This method relates the size of the drainage area to streamflow at a nearby gaged site (USGS, 2015; USGS, 2020). Streamflow at an ungaged site can be estimated if the drainage area of that site is known, using the following equation:

$$\hat{Q}_u = Q_i \left(\frac{A_u}{A_i} \right)$$

Where Q_u = streamflow at the ungaged site; Q_i = streamflow at the gaged/index site; A_u = drainage area of the ungaged site; A_i = drainage area of the gaged/index site.

Drainage areas for both the gaged and ungaged sites were obtained using StreamStats (Figure 1; USGS, n.d.-a; USGS, n.d.-b). To determine only the amount of streamflow within a given basin, drainage areas were chosen in StreamStats at the furthest downstream and upstream points along main streams within the basin (Table 12).

For this method, the drainage basin delineation process in StreamStats was assumed to be accurate, that all appropriate rivers and streams within a basin were accounted for in the delineation process, that drainage basin areas were an appropriate measure to estimate streamflow, and that the nearby streamgages represented the same conditions as the ungaged sites.

Table 12. Drainage area details from StreamStats.

Basin	Stream	Drainage Basin Area ⁱ (mi ²)		Index Streamgage ⁱⁱ
	Upstream	Downstream		
Aravaipa Canyon	Aravaipa Canyon	4.09	533.04	USGS 09473000, ARAVAIPA CREEK NEAR MAMMOTH, AZ
	Booger Canyon Stream	0.22	5.55	
	Fourmile Creek	0.61	26.34	
	Kennedy Falls Wash	0.48	4.69	
	Parsons Canyon Stream	1.19	8.9	
	Sheep Wash	0.04	10.11	
	Rattlesnake Creek	1.48	47.27	
	Telegraph Wash	0.7	4.08	
	Turkey Creek	0.69	21.94	
	Virgus Canyon	0.99	14.79	
Bill Williams				USGS 09424450, BIG SANDY RIVER NEAR WIKIEUP, AZ
Alamo Reservoir Subbasin	Burro Creek	15.85	32.68	
	Graveyard Wash	7.17	26.01	
	Groom Spring Wash	0.93	14.17	
	Rupley Wash	0.96	56.49	
	Bullard Wash	8.74	226.59	USGS 09424900, SANTA MARIA RIVER NEAR BAGDAD, AZ
	Miller Wash	4	6.22	
	Date Creek	115.19	149.12	
Burro Creek Subbasin	Adobe Creek	31.16	34.38	USGS 09424447, BURRO CREEK AT OLD USE 93 BRIDGE NEAR BAGDAD, AZ
	Black Canyon	16.22	51.79	
	Boulder Creek	0.14	149.66	
	Cold Spring Canyon	0.21	7.44	
	Conger Creek	0.88	30.17	
	Contreras Wash	1.87	5.94	
	Francis Creek	3.09	149.02	
	Kaiser Spring Canyon	4.43	9.53	
	Scratch Canyon	2.29	0.75	
	Pine Creek	6.64	37.66	
Clara Peak Subbasin	Mississippi Wash	0.82	8.88	USGS 09426650, BILL WILLIAMS RIVER AT PARKER, AZ
	Mohave Wash	216.74	263.28	
Santa Maria Subbasin	Bland Creek	0.3	18.32	USGS 09424600, LITTLE SYCAMORE WASH NEAR BAGDAD, AZ
	Cottonwood Canyon	6.58	53.85	
	Date Creek	36.54	97.42	
	Kirkland Creek	34.21	95.24	
	Little Shipp Creek	0.97	26.68	
	Peoples Canyon	2.93	10.13	
	Placeritas Creek	0.78	18.13	
	South Fork Santa Maria River	0.36	86.17	
	Sycamore Creek	0.8	236.97	

	Waterman Creek	28.75	46.43	USGS 09424900, SANTA MARIA RIVER NEAR BAGDAD, AZ
	Wood Creek	0.21	9.78	
Skull Valley Subbasin	Ash Creek	0.21	8.23	
	Copper Basin Wash	0.51	28.96	
	Finch Wash	2.15	9.16	
	Kirkland Creek	0.96	310.11	
	Logan Wash	0.88	2.3	
	Miller Creek	0.46	13.74	
	Model Creek	0.27	14.21	
	Poplar Wash	0.29	12.32	
	Sheppard Wash	0.6	10.38	
	Skull Valley Wash	0.84	151.61	
	Tonto Wash	1.14	42.53	
	Woosley Wash	0.5	57.6	
Bonita Creek	Ash Creek	1.28	110.93	USGS 09447800, BONITA CREEK NEAR MORENCI, AZ
	Midnight Creek	0.48	11.98	
	Ninemile Creek	0.75	25.18	
	Sevenmile Creek	0.4	4.83	
Coconino Plateau	Coconino Wash	0.55	319.91	USGS 09404115, HAVASU CREEK ABOVE THE MOUTH, NEAR SUPAI, AZ
	Heather Wash	1.17	80.37	
	Little Coyote Canyon	0.63	139.64	
	Monument Wash	1.13	95.14	
	Sandstone Wash	0.96	93.93	
	Cedar Wash	13.02	458.6	USGS 09402000, LITTLE COLORADO RIVER NEAR CAMERON, AZ
	Lee Canyon	0.87	633.29	
	Miller Wash	1.22	207.99	
	Red Horse Wash	1.34	433	
	Tappan Wash	16.46	557.21	
Dripping Spring Wash	Ash Creek	1.04	57.27	USGS 09469500 GILA RIVER BELOW COOLIDGE DAM, AZ
	Deer Creek	0.53	57.68	
	Dripping Spring Wash	0.93	117.31	
	Garden Creek	0.73	49.53	
	Mescal Creek	0.8	13.29	
	Silver Creek	0.81	27.06	
Duncan Valley	Bitter Creek	0.12	8.97	USGS 09439000, GILA RIVER AT DUNCAN, AZ USGS 09442000, GILA RIVER NEAR CLIFTON, AZ
	Burro Wash	1.11	132.13	
	Rainville Wash	0.41	10.35	
	Sand Wash	0.11	11.01	
	Sanders Wash	0.15	12.55	
	Apache Creek	0.31	27.35	
	Cold Creek	0.15	26.62	
	Cottonwood Creek	0.68	14.73	
	Greaser Wash	0.21	6.69	

	Kaywood Wash	0.2	4.16	
	Soapbox Canyon	0.29	10.41	
	Wampoo Wash	0.37	4.47	
	Willow Creek	0.22	5.75	
Hualapai Valley	Hualapai Wash	1.04	133.35	USGS 09404222, SPENCER CREEK NEAR PEACH SPRINGS, AZ
	White Elephant Wash	0.15	13.61	USGS 09404343, TRUXTON WASH NEAR VALENTINE, AZ
	Cane Spring Wash	0.28	7.89	
	Frees Wash	0.5	268.27	
	Vock Wash	0.34	2.56	
Little Colorado River Plateau	Canyon de Chelly	193.4	335.1	USGS 09379200, CHINLE CREEK NEAR MEXICAN WATER, AZ
	Canyon del Muerto	0.05	164.93	
	Laguna Creek	25.52	504.59	
	Lukachukai Creek	10.31	445.19	
	Nazlini Creek	3.23	724.44	USGS 09384000, LITTLE COLORADO RIVER ABV LYMAN LAKE NR ST. JOHNS, AZ
	Auger Creek	0.4	11.26	
	Coyote Creek	3.01	179.78	
	Nutrioso Creek	8.2	163.24	
	Paddy Creek	1.46	5.84	
	Water Canyon Creek	2.2	12.76	
	Hall Creek	0.46	22.77	USGS 09383400, LITTLE COLORADO RIVER AT GREER, AZ
	Lee Valley Creek	1.09	2.25	
	Brown Creek	8.51	60.46	USGS 09394500, LITTLE COLORADO RIVER AT WOODRUFF, AZ
	Silver Creek	75.56	882.12	
	Anderson Canyon/Draw	19.58	48.92	USGS 09402000, LITTLE COLORADO RIVER NEAR CAMERON, AZ
	Ball Court Wash	0.09	7.94	
	Citadel Wash	0.33	70.08	
	Deadman Wash	0.28	137.71	
	Walnut Creek	1.64	152.76	
	Yaeger Canyon	10.12	37.08	
	Pueblo Colorado Wash	242.5	1270.76	USGS 09400350, LITTLECOLORADO RIVER NEAR WINSLOW, AZ
	Billy Creek	1.16	27.86	USGS 09390500, SHOW LOW CREEK NEAR LAKESIDE, AZ
	Porter Creek	34.1	39.23	
Morenci	Bush Creek	0.55	118.29	USGS 09444200, BLUE RIVER NEAR CLIFTON, AZ
	Campbell Blue Creek	0.41	69.6	
	Clear Creek	0.23	14.38	
	Coal Creek	4.07	24.72	
	Coleman Creek	0.47	20.77	
	Dry Prong Creek	0.68	45.56	
	Foot Creek	1.33	20.24	
	Grant Creek	1.2	19.81	
	Jackson Creek	0.3	6.29	
	K P Creek	0.88	18.92	

	Little Blue Creek	0.86	58.24	
	Little Creek	0.19	3.87	
	Pace Creek	0.15	8.95	
	Pigeon Creek	1.1	64.83	
	Pipestem Creek	0.32	6.36	
	Raspberry Creek	0.37	10.6	
	Romero Creek	0.41	7.59	
	Rousensock Creek	0.85	16.39	
	Sardine Creek	0.8	14.87	
	Sheep Wash	0.81	385.5	
	Stone Creek	0.22	10.35	
	Strayhorse Creek	0.69	29.12	
	Turkey Creek	0.22	5.22	
	Willow Creek	0.8	160.92	
Sacramento Valley	Cow Creek	1.1	18.17	USGS 09424450, BIG SANDY RIVER NEAR WIKIEUP, AZ
	Sacramento Wash	1.3	1331.77	
	Walnut Creek	1.59	61	
Safford				USGS 09448500, GILA RIVER AT HEAD OF SAFFORD VALLEY, NR SOLOMON
Gila Valley Subbasin	Ash Creek	2	29.16	
	Black Rock Wash	2.76	100.26	
	Goodwin Wash	2.72	87.42	
	Oak Draw	0.99	26.8	
	Slick Rock Wash	1.03	86.39	
	Underwood Wash	1.5	99.65	
San Carlos Valley Subbasin	Fivemile Wash	0.99	9.42	USGS 09466500, GILA RIVER AT CALVA, AZ
	Salt Creek	1.57	39.53	
	Ash Creek	3.73	62.59	USGS 09468500, SAN CARLOS RIVER NEAR PERIDOT, AZ
	Blue River	2.17	88.48	
	Ramboz Wash	0.97	40.5	
	Ranch Creek	0.86	99.79	
	Sevenmile Wash	1.07	253.14	
San Simon Valley Subbasin	Cave Creek	1.52	51.72	USGS 09448500, GILA RIVER AT HEAD OF SAFFORD VALLEY, NR SOLOMON
	East Turkey Creek	1.05	20.84	
	Gold Gulch	1.36	152.65	
	Happy Camp Wash	1.01	43.36	
	Hot Well Draw	4.48	188.75	
	San Simon River	428.82	1708.91	
	Whitlock Wash	2.18	60.86	
Salt River				USGS 09489500, BLACK RVR BLW PUMPING PLANT, NR POINT OF PINES, AZ
Black River Subbasin	Bear Wallow Creek	1.89	23.78	
	Beaver Creek	1.01	63	
	Big Bonito Creek	3.06	221.29	
	Fish Creek	2.52	25.6	

	Little Bonito Creek	1.07	38.79	USGS 09490500, BLACK RIVER NEAR FORT APACHE, AZ
	Pacheta Creek	1.98	30.1	
	Reservation Creek	1.68	25.68	
	Tonto Creek	1.29	60.21	
	Corn Creek	1.51	19.41	
	Sweater Creek	0.92	10.6	
	Burnt Corral Creek	3.95	14.34	
	Poker Gap Creek	0.61	3.66	
	Unnamed near Sawbuck Tank	1.49	4.93	
	Unnamed above Pumping Station Tank	3.13	5.1	
Salt River Canyon Subbasin	Corduroy Creek	4.75	212.36	USGS 09496500, CARRIZO CREEK NEAR SHOW LOW, AZ
	Crouch Creek	1.35	16.8	USGS 09497980, CHERRY CREEK NEAR GLOBE, AZ
	Ash Creek	1.73	30.36	USGS 09497500, SALT RIVER NEAR CHRYSOTILE, AZ
	Canyon Creek	4.6	317.83	
	Ellison Creek	1.55	18.74	
	Gentry Creek	2.13	12.23	
	Oak Creek	1.4	39.96	
	Rockhouse Creek	1.52	18.48	
	Unnamed Stream near Shorty Camp	0.07	0.39	
	Hess Creek/Canyon	0.43	42.98	
	Unnamed Stream near Willow Spring	0.07	1.13	
	Unnamed Stream near No Name Spring	0.08	0.79	
	Unnamed Stream under Haystack Road	0.07	0.47	
	Unnamed Stream right of Haystack Road	0.06	0.41	
	Unnamed Stream near Brushy Spring 1	0.09	0.31	
	Unnamed Stream near Brushy Spring 2	0.13	1.75	
	Unnamed Stream near Brushy Spring 3	0.1	0.17	
	Sedal Canyon	0.3	11.43	
	Unnamed Stream off Sedal Canyon	0.13	0.23	
Salt River Lakes Subbasin	Campaign Creek	1.54	33.41	USGS 09498500, SALT RIVER NEAR ROOSEVELT, AZ
	Connor Wash	1.21	20.95	
	Coon Creek	2.35	14.63	
	La Barge Creek	0.6	40.94	
	Pinal Creek	2.22	199.88	
	Pine Creek	1.59	35.65	
	Pinto Creek	2	185.14	
	Salome Creek	0.74	104.86	
White River Subbasin	Bog Creek	0.44	29.86	USGS 09494000, WHITE RIVER NEAR FORT APACHE, AZ
	Deep Creek	1.74	9.24	
	Diamond Creek	1.9	69.5	
	Gooseberry Creek	1.78	38.74	
	Horseshoe Creek	2.32	13.44	

	Little Diamond Creek	0.65	22.46	
	Ord Creek	0.46	12.82	
	Paradise Creek	0.86	16.14	
	Rock Creek	0.91	21.72	
	Trout Creek	0.45	153.4	
	Soldier Creek	1.23	6.21	
	Ruins Tank	6.97	17.04	
	ADWR_1	0.14	0.59	
	ADWR_2	0.29	0.5	
	ADWR_3	1.52	2.28	
	ADWR_4	0.18	0.37	
	ADWR_5	0.53	2.19	
	ADWR_6	1.33	2.06	
	ADWR_7	1.87	5.94	
	ADWR_8	0.44	1.32	
	ADWR_9	0.1	0.17	
	ADWR_10	1.31	6.27	
	ADWR_11	0.74	1.88	
	ADWR_12	0.26	0.55	
San Simon Wash	Chukut Kuk Wash	0.29	153.27	USGS 09535300, VAMORI WASH AT KOM VO, AZ
	Hickiwan Wash	1.15	136.49	
	San Simon Wash	0.72	1917.54	
	Sells Wash	0.74	182.18	

ⁱⁱⁱ Drainage basin area delineated by StreamStats.

ⁱⁱⁱⁱ For the missing years between 1990 and 2024, historical precipitation data are used to establish trends over time and apply that to unaccounted historical surface water volumes.

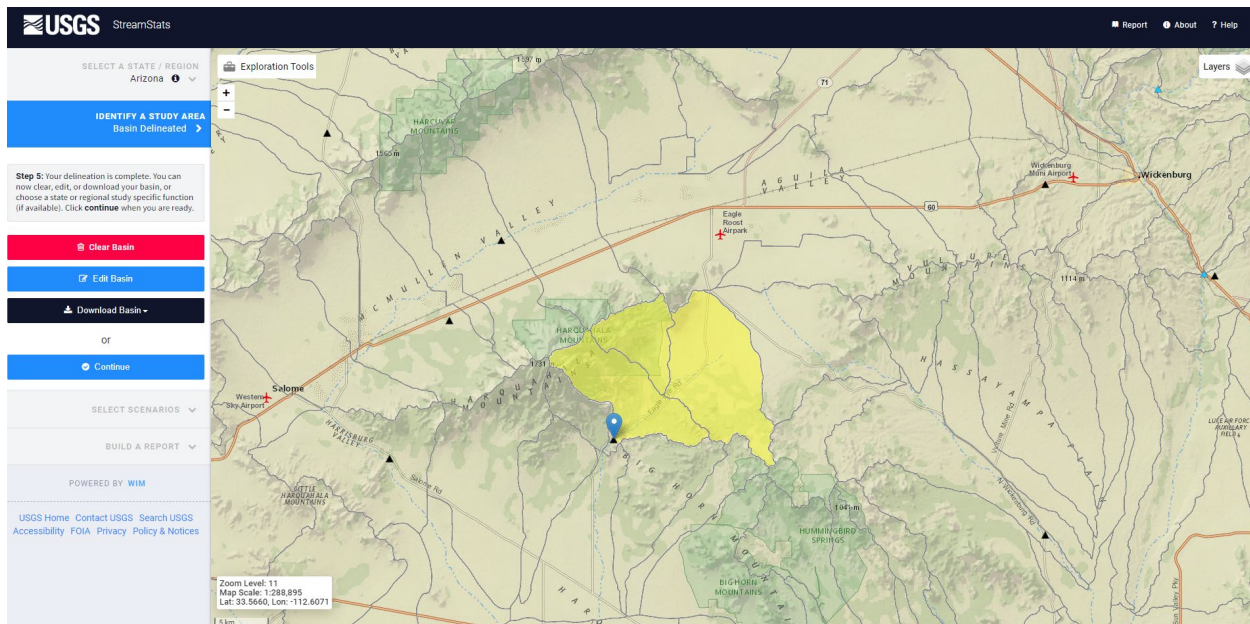


Figure 1. Example showing the drainage basin delineation in the StreamStats program.

Precipitation

The University of Arizona’s SnowView data (University of Arizona, 2024) was used to calculate the total annual accumulation of precipitation (PPT) or snow water equivalent (SWE) in a basin by determining the daily positive change and summing it by the calendar year. The data is based on a gridded model, which results in interpolation of the data. The data is also provided as one average number per day per basin, so there is also loss of spatial variation with this method.

Evapotranspiration

The method for determining evapotranspiration is thoroughly described within Section 2.4.1. Evapotranspiration is considered an outflow in all the surface water volume estimations, with the volume of that outflow depending on the infiltration rates and the overall volumes of surface water diverted.

Infiltration

This method for determining infiltration is similar and complementary to the method used to determine streamflow infiltration in Section 2.5.2. A published rate of infiltration (USDA NRCS, 2008) was applied to the volume of streamflow estimated for each basin based on storm duration and the soil type in and near the stream. From the MCFCD DDM, these storm durations determine the infiltration amount per storm event time.

Surface Water Rights

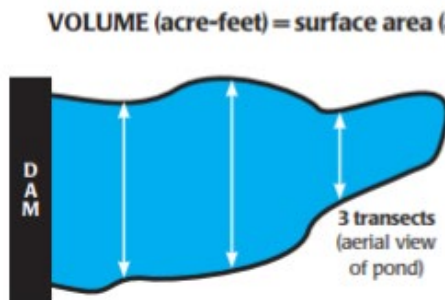
Although Arizona surface water rights were ultimately not used to estimate volumes in the targeted basins, the rights were a key component to understanding expected volumes of surface water in each basin. Surface water rights were evaluated by reviewing ADWR Surface Water GIS layers and documents filed in the ADWR Adjudications section from users claiming a surface water right in each basin. Decisions in the General Stream Adjudications may affect the legal character and availability of surface water and certain underground water (subflow). The information in this appendix and report is provided with the understanding that certain information contained in the report is subject to change based on decisions of the court.

Reservoirs and Diversions

The number of instream reservoirs for each basin was counted using an ADWR Surface Water division GIS Reservoir layer. The reservoirs and their depths were then queried to determine the average reservoir depth for all small reservoirs in Arizona, while removing large outlier reservoirs.

Small reservoir volumes were estimated using a pond volume formula from Nebraska Game and Parks, shown below.

The formula for calculating a pond's **volume** is **surface area (acres) x average depth (feet)**. Average pond depth can be estimated by measuring the depth of the water in a number of places throughout the pond, adding these measures together to get a total, and then dividing the total by the number of measurements. Several transects should be established across the pond (from one side straight across to the other side). Depth measurements should be taken/recorded every 40 feet with an electronic depth finder or a weight attached to a string marked in feet.



EXAMPLE: forty measurements were taken while conducting three transects across the surface of a .75 acre pond; average depth calculated to be 4 feet; therefore, $.75 \times 4 = 3$ acre-feet

NOTE: Average depth can be estimated by multiplying the maximum depth by 0.4

The total volume of small reservoirs in each basin was found by multiplying 0.4 by the average depth of reservoirs in the basin and then multiplying by total surface area of reservoirs in the basin:

$$\text{Total Average Volume (AF)} = 0.4 * \text{Average Depth of Reservoirs in Feet for Arizona} * \text{Total Small Reservoir Area in Acres}$$

Larger reservoirs may have historic inflow data recorded for certain years. Historic inflow data was used to estimate the volume of water diverted into these larger reservoirs, with any data gaps filled using a ratio between the average usable volume of the reservoir and the inflow volume for any given year.

The total volume of reservoirs added to agricultural diversion volumes provide the amount of surface water currently diverted for water use. Agricultural diversion volumes were obtained from the results of the demand assessments.

Colorado River Disclaimer

While Colorado River water is subject to a different legal framework, the term "surface water" necessarily encompasses Colorado River water, including Central Arizona Project ("CAP") water. Therefore, Colorado River water, including CAP water, is incorporated in the estimates of available surface water supplies. The availability of Colorado River water in Arizona will be subject to operations to be determined by the Secretary of the Interior in an ongoing federal process. While significant uncertainty surrounds the reliability of Colorado River water supplies, particularly on the mainstem of the Colorado River in the Lower Basin, this report assumes that Non-Indian Agricultural (NIA) Priority CAP water will generally not be available during the analysis period, but that all other Colorado River water and CAP water will be available.

Subflow Disclaimer

For this report, all subflow was accounted for as groundwater in storage. “Subflow” is subterranean or underground water, usually found bordering or beneath a stream, which is considered part of the surface stream and subject to the same laws and rules as other types of surface water, unlike groundwater. ADWR recognizes the extensive and complex interactions between surface water and groundwater. Although some of the estimated water in storage may be legally classified as “subflow zone,” ADWR did not differentiate subflow from groundwater in storage. ADWR also did not determine whether wells outside the subflow zone withdraw water from the subflow zone. Since the characteristics of subflow zone delineation are subject to change based on the adjudication of streams, ADWR considered subflow zones as part of the basin-fill aquifer to accurately determine the overall hydrogeological status of the basin, allowing ADWR to complete a water budget analysis.

2.5.2 Groundwater

Groundwater

The total amount of inflows to and outflows from an aquifer each year are referred to in these reports as Annual Groundwater. This is distinct from the volume of groundwater available in storage. The Annual Groundwater sources include streamflow infiltration, incidental recharge, mountain-front recharge, and inter-basin underflow.

Streamflow Infiltration

Streamflow infiltration refers to the water from a stream that infiltrates into the ground but does not fully recharge the local aquifer system. The volume of streamflow infiltration is considered available to be consumed through evapotranspiration. Any water remaining afterward is assumed to recharge the aquifer.

Infiltration rates for ephemeral/intermittent streams were calculated based on the soil type in and near the stream and standard storm duration. These rates were applied to the volume of streamflow estimated for each basin (USDA NRCS, 2008) (see 2.5.1 Surface Water).

Perennial streams underwent a different process to attain infiltration rates. Perennial streams utilized a published average infiltration rate of 8.5% and was applied to the volume of streamflow estimated for each basin (Phoenix AMA model, ADWR 2024c).

$$\text{Perennial Infiltration Rate} = \text{Total Perennial Streamflow Volume} * 8.5\%$$

Google Earth Pro was used to collect the average stream width by attaining multiple measurements of the stream’s width within the basin’s boundary. ArcGIS Pro was used to create a buffer for the streams, dependent on the attained stream width, to determine the soil type in and near the stream. The buffer was intersected with a shapefile of soil types from the Soil Survey Geographic Database (Soil Survey Staff, 2016). The result was a new shapefile that only included the soil information within the buffer area. To account for missing information, the available soil information was assumed to represent the remaining unknown area within the basin. Infiltration rates for each soil type were applied to the proportion of soils in the buffer area to create an aggregate infiltration rate (USDA NRCS, 2008). ArcGIS Pro Mountain Front Recharge layers were clipped out from stream flow infiltration. This process separated out streams and portions of streams that are a part of mountain front recharge. For basins in mountainous regions, stream selection depended on the alluvial outcrops from the Geologic Map of Arizona (AZGS, 2024).

Baseflow

Baseflow was determined for gaged streams using the USGS Hydrologic Toolbox in GIS, aggregated by year and checked for gaps. Gaps were filled using the average baseflow index for the streamgage, drainage basin areas, the USGS Streamstats website, and precipitation data from PRISM.

Underflow (Groundwater Inflow/Outflow)

Inter-basin underflow volumes were based on USGS predevelopment maps (Anderson et al., 1992), literature estimates (Tillman et al., 2011), and ADWR Hydrology division groundwater flow model estimates. The pre-development groundwater flow system was characterized by steady-state conditions when there was a long-term balance between aquifer inflow and outflow. Before anthropogenic influences, groundwater levels and aquifer storage remained relatively constant. Inflows to the aquifer system generally consisted of recharge from ephemeral streams and precipitation events. Underflow estimates from the groundwater flow models provided data for the basins.

Mountain-Front Recharge

Initially, a regression equation based on alluvial basins in southern Arizona was developed to calculate mountain-front recharge based on average annual precipitation and the basin area (Anderson et al., 1992). The equation below was derived from Wilson & Guan, 2004 and Tillman et al., 2011.

$$\text{Mountain - front Recharge} = 10^{-1.4}(A(P - 8))^{0.98}$$

Where, A = total area of the basin in acres and P = average annual precipitation in inches.

The equation is not adjusted for variations in geology, vegetation, or other factors, and is only as accurate as the water-budget components in Anderson (1992) and the precipitation values estimated above (Anderson et al., 1992). Only precipitation greater than eight inches contributes to recharge, reflecting water lost to soil and evapotranspiration; greater precipitation values are typically found in mountainous areas (Donovan et al., 2009). However, this method may lead to underestimating mountain-front recharge by potentially excluding precipitation from lower-elevation valleys and alluvial fans, where mountainous precipitation collects before recharging (Donovan et al., 2009). Another limitation of this method is that only direct recharge is calculated and does not include indirect recharge from the mountain block (Wilson & Guan, 2004).

The mountain-front recharge estimates for the 2025 SDRs, including perennial infiltration and recharge, were calculated using precipitation data, model data, scientific literature values, and a water budget accounting for different groundwater inflows/outflows that affected the mountain-front recharge volume:

$$\text{Mountain Front Recharge} + \text{Perennial Infiltration/Recharge} = \text{Evapotranspiration (Stream ET)} + \text{Baseflow} + \text{Underflow Out} - \text{Ephemeral/Intermittent Streambed Recharge} - \text{Underflow In}$$

Perennial infiltration and recharge were then deducted to determine the final mountain-front recharge volume, assuming a constant 8.5% perennial infiltration rate, based on a percentage provided in the Phoenix AMA model (ADWR 2024c).

$$\text{Perennial Infiltration/Recharge} = \text{Perennial Streamflow} * 0.085$$

$$\text{Mountain-Front Recharge (Without Perennial/Infiltration/Recharge)} = \text{Mountain Front Recharge} + \text{Perennial Infiltration/Recharge} - \text{Perennial Infiltration/Recharge}$$

Artificial Recharge

Artificial recharge to aquifers occurs in Active Management Areas through the utilization of recharge basins and effluent discharge to replenish aquifer resources. AMA artificial recharge data was queried from ADWR's database and then compared to any effluent recharge volumes provided by ADEQ, if provided.

Groundwater Storage

Non-Model Method

The non-model method was based on Ivanich & Conway (2009), and was used for the Aravaipa Canyon, Bill Williams, Dripping Springs Wash, Duncan Valley, Little Colorado River Plateau, Safford, Salt River, and San Simon Wash because there were no recent storage estimates or no hydrologic models were available for these basins. The Bonita Creek, Coconino Plateau, and Morenci basins did not undergo this method due to a lack of well measurements within aquifer boundaries for these basins. Four raster surfaces were needed for the calculation: water level elevation, depth-to-bedrock, land surface elevation, and bedrock elevation (Figure 2). These surfaces and maximum depths were used to find the top and bottom of the saturated zone so that a volume of saturated material could be calculated. This method aimed to determine the amount of water in storage available for use, not the total volume of water underground. Therefore, the saturated volume was multiplied by a specific yield value, not porosity (Figure 2).

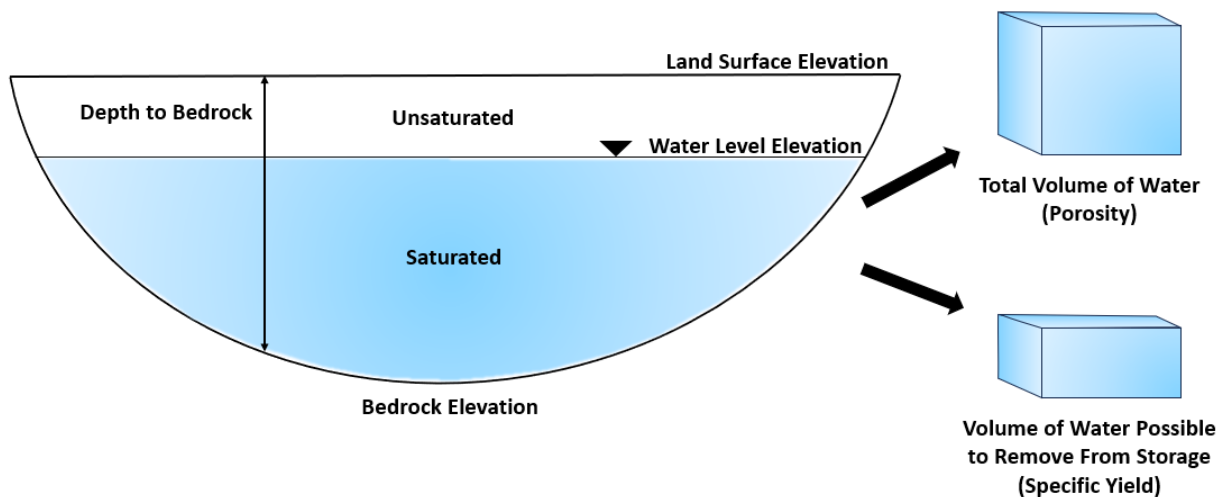


Figure 2. Simple diagram of an alluvial basin depicting important terms used in the 2025 Supply and Demand Report Methods Appendix.

Average Well Depth

The ADWR Wells55 Registry database and PowerBI were used to determine average and median well depths for exempt and non-exempt wells in the groundwater basin of interest. Wells that were inactive, with incomplete/incorrect reporting, or major outliers were filtered out. The average well depths were used during groundwater storage analysis to determine the storage volumes at each of the depths.

Water Level Elevation Surface

Water level elevation data collected during the most recent water year with a sufficient distribution of data points were compiled from the ADWR Groundwater Site Inventory (GWSI) database. This method assumes that the water level data were collected contemporaneously and represent a single snapshot in time. To ensure representation of the static water level, values taken during pumping, recent pumping, or nearby pumping were removed. A hydrograph of each well was reviewed to determine whether any measured value was anomalous. A conservative approach was taken, and no anomalous wells were removed until a water-level surface was created. If unusual patterns, such as bullseyes, were observed on the surface, the wells near those features were further reviewed and removed if necessary.

Wells that fell outside the footprint of the alluvial aquifer system were also removed. This was determined by comparing the well location to the area's geology (Richard et al., 2000, Map 35; AZGS n.d.-a, n.d.-b, and 2024). In general, wells overlying igneous, metamorphic, and sedimentary rock were removed from the analysis.

With the remaining data points, raster surfaces of the water table were generated using the Inverse Distance Weighted (IDW) and Spline geoprocessing tools in ArcGIS Pro until a surface consistent with previous studies was generated. The surfaces were analyzed using the Geostatistical Wizard in ArcGIS Pro, and the surfaces with the smallest root-mean-square error (RMSE) were chosen. In every case, this was the surface generated with the Spline tool on default settings. All surfaces were clipped to the extent of the aquifer system and resampled to 500- by 500-meter resolution. The water level elevation surface was used as the top of the saturated zone when estimating the amount of water in storage available for use.

Depth-to-Bedrock Surface

The Topo to Raster geoprocessing tool in ArcGIS Pro was used to convert the contours to a surface. All surfaces were resampled to 500- by 500-meter resolution. The depth-to-bedrock surfaces were then used to determine the bedrock elevation and the elevations of the maximum depths.

Land Surface Elevation (DEM)

The USGS 1/3 arc-second Digital Elevation Model (DEM) with 10-meter resolution was used for the land surface elevation. After the units were converted from meters to feet, the raster was reprojected to the same map projection as the water level and depth-to-bedrock surfaces (NAD 1983 UTM Zone 12N) and resampled to 500- by 500-meter resolution. This surface was used to determine the bedrock elevation.

Bedrock Elevation Surface

The land surface elevation and depth-to-bedrock raster surfaces were clipped to the same extent. Using the Raster Calculator geoprocessing tool, depth-to-bedrock was subtracted from the land surface elevation, resulting in the elevation of the bedrock. This surface and a set maximum depth were used as the bottom of the saturated zone when estimating the amount of water in storage available for use.

The average well depth was one of the maximum depths used with the bedrock elevation surface. This was calculated by taking the average of the well depths between upper and lower limits, which were used to eliminate any outliers that could skew the result.

Converting Surfaces to Cell-by-Cell Data

Using the Raster Calculator geoprocessing tool, the bedrock elevation surface was divided by the water level elevation surface. If the bedrock elevation was greater than the water level elevation, the resulting value would be greater than one. This generally occurs in mountainous regions or in areas near the fringes of the basins, which were not incorporated in the water level elevation interpolation. Any water in the mountainous region was not considered part of the regional aquifer system. If the bedrock elevation was less than the water level elevation, the resulting value would be less than one. This value represents an area where there is saturated material. The Contour geoprocessing tool was used to add contours to this new surface. The "1" contour represents the furthest extent of saturated material. A shapefile was created from the "1" contour line and was used as the extent and spatial reference when creating a grid layer.

All four surfaces (water level elevation, depth-to-bedrock, land surface elevation, and bedrock elevation) were clipped to the same extent as the outer boundary of the grid. The Extract Multi Values to Point tool was used to add the information from the four surfaces to the layer of points generated with the grid. The point data were exported to Excel for the final steps of the calculation.

Water Available in Storage Calculation

Two different maximum depth scenarios were used to represent the amount of available water stored underground: average well depth and a standard depth of 1000 feet. In Excel, the depth-to-bedrock was

adjusted based on these maximum depths. If the maximum depth was greater than the depth-to-bedrock, the depth for that cell was not changed.

Once the depth-to-bedrock for each cell was adjusted based on the maximum depth, the value was subtracted from the land surface elevation, resulting in a modified bedrock elevation. The saturated thickness was calculated by subtracting the modified bedrock elevation from the water level elevation. The cell size was multiplied by the saturated thickness to determine the volume of saturated material. A range of specific yield values found in the literature or based on well log information were multiplied by the saturated volume, resulting in a range of estimates of the amount of water in storage available for use. The supplies and demands estimated in this assessment were used to determine the storage value for each baseline year (1990-2024).

Several assumptions had to be made to perform this calculation. The first assumption was that the specific yield values accurately represent the entire basin. While a single specific yield value was used for the entire basin, there is much variability in the specific yield throughout the basin; the value could be higher or lower depending on the subsurface material present in a particular basin area. The water level surfaces generated from the well measurement data were also assumed to be accurate. However, the interpolated surface is a prediction based on nearby data points. This prediction is less certain in areas with few data points. Additionally, this assessment does not account for subsidence or the permanent loss of aquifer storage if the amount of water calculated is taken out of the basin.

Model Method

Storage was calculated using model data provided by the Hydrology division of ADWR. Initial storage was calculated for the beginning of the model year. The change in storage was then used to estimate following years. The yearly model inflows (supply) and outflows (demand) were used to estimate the groundwater storage in 1989, prior to the start of the assessment interval in 1990, and then Supply and Demand net totals were used to determine the storage value for 1990-2024.

Report and Dashboard Volume

From the range of volumes calculated, only one volume of water in storage (available for use) was chosen for each basin to use in the report and dashboard. To reflect the current infrastructure, the average well depth was chosen as the maximum depth (Figure 3). Since all new or existing drilled wells cannot be assumed to be deepened to 1000 feet, the volume in storage up to 1000 feet could be unattainable in many cases.

For the non-model basins, a conservative literature value of specific yield in the range of 0.1-0.15 was chosen. Aquifer tests are not within the scope of this study, which could be used to determine a more accurate value. Robust specific yield information could substantially improve these estimates in the future.

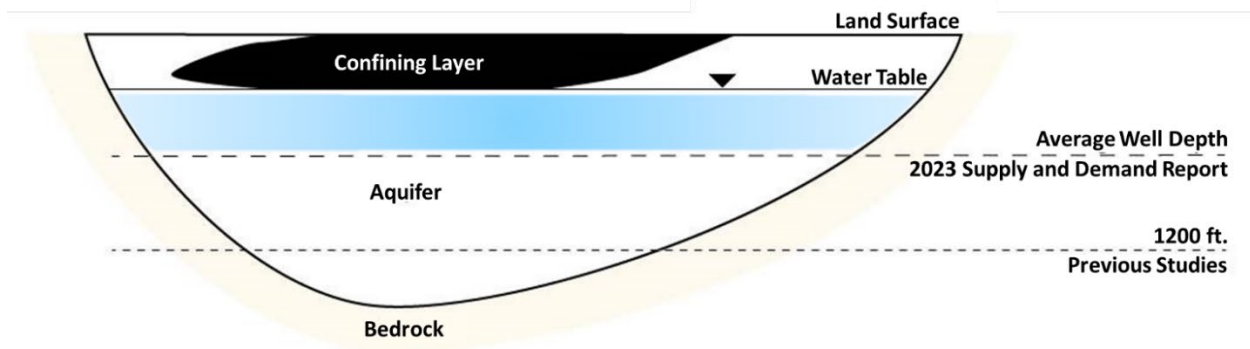


Figure 3. Diagram of a typical Basin and Range aquifer, not to scale. This diagram does not represent the actual geology of any of the basins studied in 2025 and is only for illustrative purposes. The dashed lines indicate different depths used to calculate storage, which can make a significant difference for estimating the amount of water. The blue shaded area is the saturated volume calculated for the 2025 SDRs.

2.5.3 Effluent

To estimate effluent, ADWR worked with ADEQ to develop an effluent data-sharing agreement. ADEQ provided Aquifer Protection Permits (APPs) (ADEQ, 2025a) and effluent data from wastewater treatment plants or any wastewater facilities with APPs (ADEQ, 2025b) to ADWR. The APPs are required permits in the State of Arizona “for owners or operators of facilities that discharge a pollutant directly to an aquifer or to a land surface or vadose zone where there is reasonable probability that the pollutant will reach an aquifer pursuant to A.R.S. § 49-241 (ADEQ, 2023). The permits include facility descriptions, discharging facilities, treatment technologies, sampling requirements, and reporting requirements which produce qualitative and quantitative data sets for ADEQ.

The estimation method utilized the amount of effluent produced (AF) per wastewater treatment plant in every basin as indicated in the permits. The Excel datasheets provided categorized the types of use for effluent volumes produced at each wastewater treatment plant (i.e. reuse, evaporation ponds, land application/discharge).

From the effluent data provided, the three main effluent volume categories are:

1. Discharge (pursuant to Arizona Pollution Discharge Elimination System (AZPDES)): This refers to effluent being discharged for land application purposes and can end up in numerous areas such as washes, rivers, streams, and runoff basins.
2. Reuse: The most common examples of effluent reuse include land applications such as landscape watering and agricultural irrigation. This effluent category was the only one reported in the 2025 SDRs, since the only effluent volumes considered for water supply were the effluent volumes already being allocated to reuse.
3. Evaporation and Drying Beds: This refers to effluent captured on-site at the wastewater treatment plant and is contained in a lined evaporating pond or drying bed. Since the effluent cannot infiltrate, it evaporates over time, and the remaining sludge waste is gathered and sent to a landfill. Therefore, although produced as effluent, evaporation and drying beds are not considered a current supply source.
4. CWS Annual Reports provided data for years without reported data from ADEQ. These reports include volumes and types of water used, including effluent production and reuse (ADWR, 2024a).

2.5.4 Incidental Recharge

Agricultural

This study followed the same method used in *Overdraft, Safe-Yield, and The Management Goals of Arizona's Active Management Areas* (ADWR, 2022b). Agricultural incidental recharge was calculated as follows:

$$\text{Agricultural Incidental Recharge} = \text{Water Withdrawn for Agriculture} \times (\% \text{ Irrigation Application Loss} + \% \text{ Transmission Loss})$$

Where, $\% \text{ Irrigation Application Loss} = 100\% - \% \text{ Irrigation Efficiency}$

$$\% \text{ Transmission Loss} = (\% \text{ Lost \& Unaccounted For} - (\% \text{ Evaporation} * \% \text{ Lost \& Unaccounted For}))$$

First, incidental recharge was calculated using USGS data for agricultural groundwater withdrawal. For the most recent years (2015-2023), incidental recharge was calculated by aggregating values from each field (Table 13). For earlier years (2006-2014), incidental recharge was calculated as a weighted average based on the irrigation system (Table 13).

Average irrigation system efficiencies and best judgment were used to estimate incidental recharge for gap years when no USGS IE estimates were available.

To estimate incidental recharge for years before 2006, irrigation efficiencies were adjusted based on the percentages of irrigation system types in Arizona from the 1990, 1995, 2000, 2005, and 2010 *Estimated Use of Water in the United States* reports (Solley et al., 1993; Solley et al., 1998; Hutson et al., 2004; Kenny et al.; 2009; Maupin et al., 2014).

Table 13. Years for which each basin has field-level agricultural information provided by USGS (marked with “X”). Note that there is no agricultural demand in the Bonita Creek, Coconino Plateau, Dripping Springs Wash, Morenci, and Salt River basins.

Year	Basin							
	Aravaipa Canyon	Bill Williams	Duncan Valley	Hualapai Valley INA	Little Colorado River	Sacramento Valley	Safford	San Simon Wash
2006								
2007			X				X	
2008					X			
2009			X				X	
2010								
2011					X			
2012								
2013			X				X	
2014							X*	
2015				X		X	X*	
2016				X		X	X*	
2017				X		X	X*	
2018				X		X	X*	
2019		X*		X		X		
2020				X		X		
2021								
2022				X		X	X*	
2023				X		X	X*	
2024								

* USGS data only available for a specific subbasin (Skull Valley in Bill Williams, San Simon Valley in Safford)

Industrial

The only industrial demand with assumed potential for substantial incidental recharge is turf, which can be calculated similarly to agricultural incidental recharge:

$$Turf\ Incidental\ Recharge = Water\ Withdrawn\ for\ Turf \times \% \ Application\ and\ System\ Loss$$

Where % Application and System Loss = % Total System Loss - % Evaporation Loss

County-level system loss data were obtained from the National Water Information System (NWIS, n.d.), and, because of the nature of turf sprinkler systems, 50% of the water lost was assumed to evaporate. The remaining 50% of the water lost was assumed to recharge the aquifer. The resulting percentage was multiplied by the estimated water withdrawn for turf (see Section 2.2.7) to determine the amount of incidental recharge due to turf.

Municipal

Municipal incidental recharge has two components: L&U water and water recharging from septic tanks.

Percentages of L&U water were calculated based on CWS data for residential provider and non-residential water uses (see Section 2.3.4). These percentages were applied to the total public water system usage to determine the volume of L&U water. All L&U water was assumed to recharge.

A study by the Central Arizona Governments (CAG) estimated that 20 percent of households in Gila County have septic tanks (CAG, 2020). The basins studied during the 2025 Assessment were assumed to have a similar percentage of septic tanks. The total non-provider water demand was multiplied by 20 percent to estimate the water sent to septic tanks (see equation below). Based on a USGS study in Mohave County, Arizona, 80% of water sent to septic tanks recharges the aquifer (Garner & Truini, 2011). The amount of water sent to septic tanks was multiplied by 80% to determine the amount of septic tank incidental recharge (see equation below).

$$\text{Septic Tank Incidental Recharge} = \text{Non - Provider Water Use} \times \% \text{ Households} \times \% \text{ Recharge}$$

Where *Non-Provider Water Use* = *Estimated Demand Volume* (Section 2.3.2)

% Households = *Percentage of Households with Septic Tanks*

% Recharge = *The Amount of Water in Septic Tanks that Recharges the Aquifer.*

2.5.5 Transportation Water

Certain basins have been identified in A.R.S. Title 45, Chapter 2, Article 8.16 as basins from which groundwater may be withdrawn for transportation to an AMA. Where such transportation has been authorized, that groundwater is referred to as "Transportation Water". No basins in the 2025 SDRs were identified as having transportation water.

2.5.6 Moved Water

Any water that crosses basin boundaries through artificial means and that does not fall under the Transportation Water definition is referred to as "Moved Water" in this report. Moved Water includes groundwater that is transported between basins that are not AMAs, pursuant to A.R.S. Title 45, Chapter 2, Article 8. Four groundwater basins in the 2025 SDRs were identified to have moved water, with the Bill Williams Basin importing water, the Little Colorado River Plateau Basin exporting water, and the Salt River Basin (Black River subbasin) exporting water to the Morenci Basin.

Exported transported water from the Big Sandy Basin to the Bill Williams Basin is used for mining purposes at the Bagdad Mine. ADWR estimated that transportation water is equivalent to the volume of water used by the mine. For more information on how mining water use is calculated, see Section 2.2.4.

Transportation water exported from the Little Colorado River Plateau Basin into the Verde and Tonto basins was estimated using reported CWS data from the annual reports of the City of Payson. Due to Payson's location on the boundary of the Verde River and Tonto Creek basins, the volume of water sent to each basin was assumed to be equal to the proportion of the total population of Payson that resides in each basin.

The Morenci Basin imports water from the Salt River Basin for use at the Morenci mine. Annual reports submitted by the Gila River Commissioner were used to estimate the volume of water (Gila River Commissioner, n.d.). For years where reported data was unavailable, 1990-1997, ADWR estimated diversions from the Black River using reported data from 1998-2002.

3 PROJECTION SCENARIO ESTIMATES

Projection scenarios were created from the baseline datasets according to the following categories:

- Status quo: baseline volumes were carried forward through the projection period
- Growth: volumes were assumed to increase within specific parameters through the projection period
- Conservation: volumes were assumed to be influenced by specific conservation practices through the projection period
- Technology: volumes were assumed to be influenced by technological advancements through the projection period
- Climate: three climate scenarios were projected; a low emissions scenario following a one-degree Fahrenheit temperature increase in the mean annual temperature, a medium emissions scenario following a five-degree Fahrenheit temperature increase in the mean annual temperature, and a high emissions scenario following a ten-degree Fahrenheit temperature increase in the mean annual temperature (Frankson et al., 2022)

These scenarios were evaluated for applicability for a given sector, subsector, water supply, and basin, with some scenarios removed where applicability was limited. Every category includes a status quo projection.

3.1 AGRICULTURAL

Growth

Agricultural Growth projections were based on the amount of potentially available farmland in each basin, using State Land agricultural leases and private land zoned as rural agricultural land. State land was considered as potentially available if the land was not used for grazing, not already leased, not in an AMA, INA, incorporated city or Community Water System (CWS) service area, and was distant from mountain ranges. County zoning and State Land lease types are assumed not to change over time and publicly owned land will not be converted from grazing to agricultural use.

A growth rate was calculated from trends in USGS historical agricultural acreage data for the basin. For basins where USGS data was not available, the trend in OpenET-estimated consumptive use was used instead. For positive growth rates, acreage was assumed to continue growing at a constant linear rate until either the end of the projection scenario (2075) or all available land was occupied. For negative growth rates, an exponential decrease was assumed, with acreage decreasing by a constant percentage each year. This was assumed to be more realistic than a linear decreasing trend, which would result in a projection of zero acreage in some groundwater basins. For both positive and negative growth, irrigation withdrawals were assumed to change proportionally to irrigated acreage. Under this assumption, irrigation efficiency and consumptive use per acre remain constant. A five-year average of past irrigation withdrawals was used as a starting point for the growth projection.

Conservation

Agricultural Conservation projections were based on achieving 80% or greater irrigation efficiencies on agricultural lands. For a given basin, the recent field-level data was adjusted where each field's IE was set to the larger of 80% or its actual IE. The resulting irrigation allotment for each field was:

$$\text{Annual Allotment} = \text{Baseline Irrigation Withdrawal} * \frac{\text{Baseline IE}}{\text{Conservation IE}}$$

where

$$\text{Conservation IE} = \max(0.80, \text{Baseline IE})$$

For each year of field-level USGS or OpenET data, these field-by-field annual allotments were summed and an impact ratio was calculated:

$$\% \text{ Impact} = \frac{\textit{Total Allotment under Conservation Scenario}}{\textit{Total Baseline Irrigation Withdrawal}} - 1$$

This impact ratio was calculated for each year that data was available in the past five years and then averaged. The average impact ratio was applied to the five-year average baseline irrigation withdrawal to calculate the final projected irrigation withdrawal under the Conservation scenario.

It was assumed that any conservation measures would require a five-year time period to be fully implemented. Therefore, the projected irrigation withdrawal calculated above was applied to the years 2030 to 2075 (the final year of the projections). To project the years 2026-2029, a linear interpolation was used.

Technology

Agricultural Technology projections were based on two assumptions: 1) that any acres producing cotton or alfalfa using flood irrigation would transition to gravity micro-irrigation, which would result in a 33% reduction in water consumption, and 2) that improvements made to sprinkler and center pivot systems would result in a 5% reduction in water consumption. This projection scenario does not consider the price of adopting new technologies and assumes that temperature, precipitation, and evapotranspiration remain constant.

For a given basin, projected field-by-field irrigation withdrawals were calculated using recent USGS field-level data, which includes irrigation system types as well as irrigation withdrawal estimates. For basins lacking USGS data, satellite imagery was used to determine irrigation system types. For each sprinkler irrigated field, the baseline irrigation withdrawal was reduced by 5% to get the projected irrigation withdrawal. For each flood irrigated field with crop type identified as alfalfa or cotton, the baseline irrigation withdrawal was reduced by 33%. For basins lacking crop type data, GIS data from the USDA Cropland Data Layer (USDA, 2021) was used to estimate the percentage of alfalfa and cotton among all crops by acreage. This percentage was multiplied by 33% to calculate an average water savings applied to all flood-irrigated fields in the basin.

As in the Conservation scenario, the projected irrigation withdrawals after savings were summed for each year of field-level USGS or OpenET data. The impact ratio was calculated as:

$$\% \text{ Impact} = \frac{\textit{Total Allotment under Technology Scenario}}{\textit{Total Baseline Irrigation Withdrawal}} - 1$$

This impact ratio was calculated for each year that data was available in the past five years and then averaged. The average impact ratio was applied to the five-year average baseline irrigation withdrawal to calculate the final projected irrigation withdrawal under the Technology scenario.

It was assumed that technology measures would be implemented at a constant linear rate and the final projected irrigation withdrawal would be achieved in the year 2075. This results in a projection where 2% of the final water savings are realized each year.

Climate

Agricultural Climate projections assume that higher temperatures will increase total irrigation demands. To calculate the difference in required irrigation from baseline temperatures to the temperatures in the low,

medium, and high emissions climate scenarios, the modified Blaney Criddle equation shown below was used. The equation allows for the magnitude of difference in ET to be calculated at different temperatures.

$$ET = .457T + 8.128$$

Where *ET* = *Evapotranspiration* and *T* = *Temperature (in Celsius)*

To determine the difference in ET, a baseline ET was established for each basin. Climate data were compiled as temperature raster layers for each year from 1990-2024 (PRISM Climate Group, 2025). The raster layers were spatially joined to a shapefile of agricultural fields using GIS software to determine the average temperature at each field. To calculate the projected ET for each field, one-degree Fahrenheit was added to the baseline temperature for the low emissions scenario, five-degrees Fahrenheit were added in the medium emissions scenario, and ten-degrees Fahrenheit were added in the high emissions scenario. Using the baseline and projection ET values, a percent change value was calculated for all fields for each climate scenario.

This Climate projection assumes that irrigation will increase proportionally to the rate of increase in ET. The average baseline irrigation withdrawals from the last five years were increased proportionally to the percent change in ET to estimate projected withdrawals in 2075. Irrigation volumes from 2026 to 2075 were estimated assuming a constant rate of change from present day irrigation volumes to the projected irrigation withdrawals in each climate scenario.

The results of the Climate scenario were compared with literature values to ensure estimated irrigation withdrawals were reasonable. A study from Arizona State University suggests major crops could require increased irrigation of 2.6% per every degree Celsius of warming, or 1.4% per every degree Fahrenheit of warming (Berardy & Chester, 2017). The projected irrigation withdrawals were comparable to the findings of the Arizona State University study.

The Climate methodology is not crop-specific and only provides a general estimate of irrigation needs under increased temperatures. Depending on differences in crop response to heat stress, variations in local conditions, and other site-specific factors, actual irrigation under increased temperatures may vary.

3.2 INDUSTRIAL

Industrial projections were split into subsectors and developed for dairy, feedlot, mining, power production, and turf subsectors. Projections were not developed for grazing, sand and gravel, or other industrial demands due to low volumes or the limited expected impact of a given scenario on that subsector.

3.2.1 Dairies

Climate

In the methods for estimating water use in dairies under different climate scenarios, three emissions models were applied: low, medium, and high. The low emissions scenario, with a one-degree Fahrenheit increase over baseline, reflects minimal changes in water consumption across dairy operations, as the slight warming would have little impact on the drinking water needs. The medium emissions scenario, representing a five-degree Fahrenheit rise, accounts for increased water demand, particularly for lactating cows, which are sensitive to temperature increases. The high emissions scenario, with a ten-degree Fahrenheit increase, projects significant rises in water consumption across all cattle life stages, driven by heat stress.

Conservation

Water use estimates were calculated based on dairy cattle numbers from the last five years of available data to create a five-year average per basin, which was held constant for each projection year. These estimates were used to calculate water use in the projection years.

Estimated conservation water use values were integrated over a five-year adoption period, using the water use estimated for 2024 as a baseline. The lower conservation water use values were fully applied in 2028 and subsequent years, based on the Arizona Department of Water Resources' (ADWR) Agricultural Management Area (AMA) conservation plans.

3.2.2 Feedlots

Climate

Feedlot Climate projections were developed by identifying consumptive water use coefficients from literature for feedlot cattle and hogs as temperature increases (U.S. Climate Data, n.d.; Guthrie, 2011; Rasby & Walz, 2011; Meehan, Stokka, & Mostrom, 2021).

The drinking water use coefficients were applied based on temperature changes, assuming a one-degree Fahrenheit increase, while dust suppression and miscellaneous water needs were held constant across temperature shifts. This year, three climate scenarios were considered: a low emissions scenario with a one-degree Fahrenheit warming, a medium emissions scenario with a five-degree Fahrenheit warming, and a high emissions scenario with a ten-degree Fahrenheit warming. All scenarios assume no changes in precipitation and assess the impact on feedlot water consumption. For each projection year, the total temperature change was divided by the number of years in the projection period to determine annual water use values. These were then multiplied by the appropriate water use coefficients. Feedlot cattle and hog numbers, calculated as a five-year average from the most recent data, were held constant across the projection period. Estimated water use was applied to these figures to calculate annual water consumption for each year of the projection.

Additional literature values were identified for dust suppression at cattle feedlots (Governor's Agricultural Best Management Practices Committee, 2015), and for miscellaneous water use at cattle and hog feedlots (Alberta Ministry of Agriculture and Irrigation, n.d.; Matlock et al., 2011; Davis & Watts, 2016; Broom, 2019). No dust suppression water use values were identified for hog feedlots, because hog farms may use oil for dust suppression as a BMP. The dust suppression value used for cattle feedlots was the high-end value identified from the literature because Arizona has an arid climate and no known conservation programs for rural feedlots. The miscellaneous water use value was an average taken from available literature values for cattle and a value specifically identified from literature for hogs.

This method assumes that water use scales equivalently for all temperatures above 90 degrees Fahrenheit, that water use scales equivalently for all humidities and precipitation patterns, that cattle and hog weights are distributed evenly across feedlots, that temperature increases linearly over time, and that temperature increases at the same rate across the entire state. Potential improvements for future analyses may include incorporating urban heat island effects and local changes in precipitation and humidity values into water use needs.

Conservation

Feedlot Conservation projections were developed using average literature values for water consumption and miscellaneous water needs for cattle and hogs, and dust suppression water needs for cattle (Alberta Ministry of Agriculture and Irrigation, n.d.; Parish & Rhinehart, n.d.; Guthrie, 2011; Matlock et al., 2011; Rasby & Walz, 2011; Governor's Agricultural Best Management Practices Committee, 2015; Davis & Watts, 2016; Spencer et al., 2017; Broom, 2019; Mullenix & Brantley, 2019; Meehan, Stokka, & Mostrom, 2021; Ontario Ministry of Agriculture, Food, and Rural Affairs, 2023). No dust suppression water use values were identified for hog feedlots, because hog farms may use oil for dust suppression as a BMP.

The last five years of feedlot data were used to calculate a five-year average in cattle and hog numbers per basin, which were held constant for every year in the projection. Water use estimates were applied to the cattle and hog numbers to calculate an estimated water use for each projection year.

Estimated conservation water use values were incorporated over a five-year adoption period, using the water use estimated for 2024 as a starting point. Lower conservation water use values were fully applied in 2028 and all subsequent years.

This method assumes all feedlots can successfully implement conservation programs, that conservation programs achieve similar reductions in water use, and that cattle and hog weights are distributed evenly across facilities. Potential improvements for future analyses may include incorporating information on the latest conservation technologies, improving estimates on the conservation that can be achieved with a given technology, and incorporating variation in how successfully conservation programs are implemented.

3.2.3 Power Generation

Climate

Power generation Climate projections were developed considering four factors: increased consumer demand, reduced power plant generating efficiency, decreased transmission capacity, and increased generation curtailments of thermoelectric power plants. All listed factors are expected to result in a net deficit in power production if current generation patterns are maintained. It is assumed that additional power will need to be generated to compensate for the increased demand and reduced power supply.

Additional consumer demand for power was estimated using data from the Intergovernmental Panel on Climate Change's (IPCC's) Fourth Climate Assessment, which considers the increased need for cooling as temperatures rise (US EPA, 2017). Loss of power plant efficiency, generation curtailment rates, and transmission efficiency decreases were each estimated using peer-reviewed literature data (Bartos, 2016; Henry, 2016; Coffel, 2021). Impacts of all variables were assumed to increase at a consistent rate throughout the projection period, and all were assumed to be cumulative. According to the equation below, the total impact was quantified for each year within the projection period as a deficit.

$$\text{Annual Generation Deficit (MWH)} = \frac{\text{Total Generation Deficit (MWH)}}{\text{Years in Projection}}$$

Additional power produced to meet the deficit was assumed to be generated by existing power plants in each basin. As such, this assumes no power plant decommissions or construction will occur, and it holds the energy mix constant for each basin with present-day values.

Additional power needs were added to the 2024 baseline generation rates to produce annual generation estimates for the projection period; 2024 generation rates were used as the starting point for the projections as opposed to a five-year average due to recent changes in power plant operation in multiple basins. Estimated generation values were converted to water demand estimates using the same methodology within the baseline data (see Section 2.2.5).

Growth

Power generation Growth projections were developed by considering population growth estimates, the generation potential of power plants, and the addition of currently planned and permitted power plants. This scenario only considers growth in the context of the groundwater basins studied; external influences and impacts from larger power grids are not considered due to the inherent complexity of regional power markets.

Capacity factors were calculated for each power plant to determine the growth potential for power production in each basin. Capacity factors were calculated using generation data from the US EIA and reported nameplate capacity data, which defines a power plant's maximum potential energy output (US EIA, 2023a).

$$\text{Capacity Factor} = \frac{\text{Actual Energy Production (MWH)}}{\text{Nameplate Capacity (MW)} \times \text{Time (Hours)}}$$

Thermoelectric power plants in each basin were compared against national average capacity factors for their given fuel type (US EIA, 2023c; US EIA, 2023d). Solar power plants were compared against state average capacity factors rather than national averages due to Arizona's difference in solar potential compared to other states (US EIA, 2019). Power plants determined to be at or above average capacity factors were excluded from modification within the Growth scenario under the assumption that no further growth could be sustained. Power plants operating below average capacity factors were modified within the scenario.

For power plants included within the scenario, 2024 generation output was modified yearly to correspond to estimated population growth; as this scenario is partially dependent on population, 2024 generation values were selected over a five-year average. Population growth estimates were derived from the medium series population projections from the ACA Office of Economic Opportunity (ACA, 2022b). Growth was sustained in this pattern until a power plant hit the average capacity factor threshold. Once the average capacity factor threshold was met, generation was held constant for the remainder of the scenario.

In addition to currently operating power plants, this scenario considers adding power plants within the planning and permitting process (ACC, n.d.). Power plants were included in this scenario if they met set criteria that indicated that construction was both likely and feasible. Criteria evaluated include the presence of a submitted project map, an approved certificate of environmental compatibility, approval from BLM, ASLD, or any applicable counties, and finally, the ability for the project to be operational within the next 10 years. Nameplate capacity and operation dates were determined from approved certificate of environmental compliance reports and were used to simulate power generation within this scenario. All new power plants had sustained growth in this scenario either until they met their fuel type's average capacity factor or until the projection period's end.

The combined generation estimates from all power plants, current and projected, were converted into water use estimates using the same methodology as used within the baseline estimates (see Section 2.2.5). No power plants were assumed to be decommissioned within the projection period, and no changes in water use intensity were assumed to occur throughout the projection period.

Technology

Power plant Technology projections were developed by considering the implementation of technology that influences total power demand and alters the existing power infrastructure in each basin. On the consumer side, an increase in energy efficiency and the rising demand for electric vehicles (EVs) were considered. From the utility perspective, cooling technology for power plants, the shift from traditional fossil fuels to renewables, and the increased efficiency requirements of transmission and distribution systems were accounted for.

To quantify how consumer energy efficiency would change over the scenario, projections from the US EIA for residential and commercial energy use were reviewed to determine total potential efficiency gains (US EIA, 2023). Increases in energy efficiency were assumed to occur at a consistent rate for the duration of the projection period. The adoption of EVs was modeled after a modified Euroelectric study scenario, and consistent rates of EV adoption within the projection were assumed (Euroelectric, 2018).

Shifts in technology on the utility side were quantified in two separate phases: one dedicated to generation technology and the other to transmission and distribution technology. Regarding the first phase, this scenario shifts the energy mix of all the basins and the water intensity of generation for all types of power plants. The transition from fossil fuels to renewables was modeled on the de-carbonization plans of three major Arizona electrical utilities: APS, Salt River Project (SRP), and Tucson Electric Power (TEP) (APS, 2020; SRP, 2023; TEP, 2023). Each utility's actions were assumed to influence state policies and consumer expectations, resulting in a broader transition to renewable energy at a state level.

This scenario considers explicitly two goals: by 2050, all basins are simulated to have at least 65% of energy produced from renewable sources, and by 2075, 90% of energy is projected to be generated from renewable sources. The 2050 goal in this scenario was set using the median 2035 renewable energy goal of APS, SRP, and TEP. The 2075 goal was likewise set using the defined goals of APS, SRP, and TEP. However, it applies the minimum renewable energy goal from 2050 as the goal for 2075. The transition to renewables also includes phasing out coal: in this scenario, coal will be phased out entirely by 2050 (Executive Order 14057, 2021).

Implementing alternative cooling technologies for power plants, such as dry or hybrid cooling, was accounted for in this scenario through modifications to the water intensity coefficients. The adoption of and efficiency of alternative cooling technologies was based on available data from APS and only considers presently available technologies (APS, 2020). The decrease in water consumption per megawatt-hour (MWH) of power generated was assumed to be linear throughout the projection period.

The secondary utility phase dedicated to transmission and distribution efficiency was quantified using policy recommendations from the U.S. Department of Energy (US DOE; US DOE, 2023). Implementation of higher efficiency distribution transformers was assumed to occur at a consistent rate for the entire duration of the projection period.

Estimated generation values were projected starting from reported 2024 generation values; 2024 generation values were used as the starting point for the projection as opposed to a five-year average due to recent changes in power plant operation in several basins.

Estimated generation values consider the combined impact of the change in consumer demand and the increased efficiency of transmission and distribution systems. The generation estimates were multiplied by the modified water use intensity coefficients to produce final water use estimates according to the equation below.

$$\text{Estimated Water Consumption} = \text{Water Use Intensity} \left(\frac{\text{Gallons}}{\text{MWH}} \right) \times \text{Projected Generation (MWH)}$$

3.2.4 Turf

Climate

Turf Climate projections were developed based on estimated increases in evapotranspiration rates that are projected to occur with higher temperatures. For a description of how ET increases were calculated, see Section 3.1.

It was assumed that irrigation of turf facilities would increase proportionally to the rate of increase in ET. The total rate of increase in ET was applied to 2024 irrigation withdrawals to project turf water use in 2075. Linear interpolation was used to estimate the irrigation withdrawals between 2025 and 2075.

This method adjusts irrigation volumes based on changes in plant water needs. Due to this, no differences in water use for artificial water bodies or synthetic turf were considered in this method. Future assessments can expand the Climate projections to consider increased water needs for artificial water bodies and synthetic turf for evaporation replenishment and cooling purposes.

Conservation

The turf Conservation projections estimated water use for turf facilities, assuming that IE would be increased from 77.5% to 80% for facilities that have overseeded or non-overseeded grass. IE for sparse or seasonal grass was not altered from baseline estimation methods; water surface area and artificial turf estimates were also unchanged in this projection scenario.

IE was increased for overseeded grass and non-overseeded grass following the same timeframe. Current IE, 77.5%, was maintained for 2025-2027. In 2028, improvements to infrastructure were assumed to have started and IE goals would have been partially achieved. Full achievement of IE goals was assumed to be achieved in 2029. IE was held constant at 80% for 2029-2075.

The modified IE values were used to produce water use estimates were produced using the methodology described in Section 2.2.7. No changes were assumed to be made to the spatial extent of turf facilities during calculations.

Technology

The turf Technology scenario estimates water use under the assumption that eligible areas of turf will be converted to synthetic turf. Turf that was considered to be eligible within this scenario was any area of actively irrigated natural turf that was being used for the sole purpose of athletics. Athletic fields were only considered if they were for a defined sport and did not include multi-purpose fields. Examples of facilities included within these criteria are football fields, baseball diamonds, and softball diamonds.

This scenario assumed that 50% of eligible acres would be converted to synthetic turf over the course of the projection period. Conversion of natural turf to synthetic turf was assumed to be linear over this time period.

3.3 MUNICIPAL

3.3.1 Residential Provider

Growth

Residential provider Growth projections were developed using population projections from the ACA Office of Economic Opportunity (ACA, 2022b). The medium series was assumed to represent the most likely outcome of growth for the basins analyzed.

To calculate future residential provider populations, the following equation was used:

$$Population_n = Population_{n-1} + (Population_{n-1} \times Growth\ Rate), \text{ where } n = Year$$

The applied equation assumes that a population for a given year is dependent on the population of the year prior. Due to this relationship, the 2024 population was used as the starting point for the projection rather than a five-year average.

Population estimates were produced for 2024-2060 using growth rates from the ACA. Since the ACA only projects population through 2060, a rolling five-year average was used to produce growth rate estimates for 2061-2075. Populations were then calculated for 2061-2075 using the estimated population growth rates and growth equation. Water use estimates were developed from the population projections using the same methodology as the baseline data.

This method makes assumptions regarding population growth based on current demographics and historical patterns. Socio-economic, political, and environmental factors are not considered and can potentially impact projected results significantly.

Climate

Residential provider Climate projections were developed under three climate scenarios: a low-emission scenario, a moderate-emission scenario, and a high-emission scenario, each projecting different levels of temperature and evapotranspiration increase. Under these scenarios, it was assumed that residential provider water use would increase due to higher CU requirements for landscaping. To determine the volume of residential provider water use dedicated to outdoor purposes, an indoor threshold GPCD was developed using aggregate residential end-use water data, assuming the use of all major water-consuming fixtures (DeOreo et al., 2016). The set threshold was held constant for all basins and was compared to the regional

GPCDs calculated in the baseline data. Water use within the set threshold was assumed to be indoor water use, and water use exceeding the threshold was assumed to be outdoors.

Basins with low or decreased GPCDs, such as San Simon Wash, did not exceed the threshold and were assumed to have minimal outdoor water use. Aravaipa Canyon, Bill Williams, Bonita Creek, Coconino Plateau, Dripping Springs Wash, Duncan Valley, Hualapai Valley, Little Colorado River Plateau, Sacramento Valley, Safford, and Salt River have higher GPCDs and, consequently, were all assumed to have some volume of outdoor water use. These results were cross-referenced with satellite imagery to verify that these assumptions appeared to correspond with actual landscaping practices.

Outdoor water use was assumed to correspond to the evapotranspiration rate in each basin, meaning higher temperatures would lead to increased application rates for landscape irrigation water. A rate of evapotranspiration increase was calculated for each basin using predicted evapotranspiration values, according to the method described for agriculture climate projections (see Section 3.1).

An irrigation estimate was produced for 2075 by applying the calculated evaporation increase rate to baseline 2024 outdoor water use estimates. 2024 was used as the starting point for the projection rather than a five-year average due to the general stability in municipal water use year over year.

This calculation assumes outdoor water use will increase at the same rate as evapotranspiration in each basin. Outdoor water use estimates were linearly interpolated for years between 2024 and 2075. These values were added to the indoor water use estimates from the baseline data to produce final residential provider estimates for the Climate projection scenario.

Conservation

Residential provider Conservation projections were developed by assuming the voluntary installation of WaterSense fixtures by residents to increase water efficiency. WaterSense fixture installations were set at 0% at the beginning of the projection scenario. Fixture installations were assumed to occur consistently throughout the projection period until full implementation, as defined by this projection scenario, is achieved in 2075.

To quantify the conservation potential of this projection scenario, total water savings were calculated at a household level. Savings were calculated with the expectation that every household in all basins would install WaterSense toilets and showerheads. An additional 50% of households in the Bill Williams, Hualapai Valley, Sacramento Valley, Duncan Valley, San Simon Wash, Morenci, Coconino Plateau, Little Colorado River Plateau, Safford and Salt River basins were also assumed to install WaterSense irrigation controllers in this projection scenario; this assumption was made for these basins due to the significant amount of outdoor water use, which was estimated using the percentage of landscape irrigated from sampled residential areas within each basin (see Section 2.3.1).

Water savings were scaled to a basin level by multiplying household savings under full implementation by the number of households in each basin. Calculated savings were subtracted from the 2024 estimated demand to produce a final Conservation projection scenario estimate for 2075. The 2024 estimated demand was used as the starting point for the projection rather than a five-year average due to the general stability in municipal water use trends year to year. As implementation was projected consistently, water use estimates between 2024 and 2075 were interpolated linearly.

Technology

Residential provider Technology projections were based on the anticipated voluntary adoption of water monitoring technologies, such as advanced metering infrastructure (AMI) or home-based devices, with active leak detection and customer response. At the onset of the scenario, device installation was assumed to be at 0%, with gradual implementation beginning in 2028 and ultimately reaching full adoption by 2075.

Water savings were evaluated at the household level, with each household expected to conserve approximately 14,000 gallons annually through the use of home-based or AMI devices (Flume Utility and Business Solutions, 2022). These per-household savings were then scaled up to the basin level by multiplying the average household savings by the total number of households in each basin. The total projected savings were deducted from the estimated demand for 2024 to generate the final Technology projection for 2075. The 2024 demand estimate was selected as the baseline, due to the stability observed in municipal water use trends. Water use between 2024 and 2075 was projected using linear interpolation, accounting for the phased adoption of AMI technology starting in 2028.

3.3.2 Residential Non-Provider

Growth

Residential non-provider Growth projections were assumed to follow the same trends in population growth as the residential provider population. As such, non-provider populations were projected using the same methods (see Section 3.3.1).

Climate

Residential non-provider Climate projections were developed in the same manner as residential provider use (see Section 3.3.1).

Conservation

Residential non-provider Conservation projections were developed by assuming that residents who self-supply their water would implement conservation measures to the same extent and at the same rate as residents who live in the service area of municipal providers. Given this assumption, the methodology described in the residential provider section (see Section 3.3.1).

Technology

Residential non-provider Technology projections were developed in the same manner as residential provider use (see Section 3.3.1).

3.3.3 Non-Residential

Growth

Non-residential Growth projections were developed by assuming that non-residential water use is dependent on the residential population within the area (see Section 2.3.1). The calculation for estimating water use was modified from the residential growth equation as shown below:

$$\text{Non-Residential Demand}_n = \text{Non-Residential Demand}_{n-1} + (\text{Non-Residential Demand}_{n-1} \times \text{Population Growth Rate}), \text{ where } n = \text{Year}$$

The applied equation assumes that water use for a given year depends on the prior year's water use. Due to this relationship, the 2024 water demand was used as the starting point for the projection rather than a five-year average.

The Growth projection scenario was only applied to basins with existing non-residential demand. Basins without current non-residential demand (Aravaipa Canyon, Bonita Creek, and Dripping Springs Wash) were assumed to continue to have no non-residential demand throughout the projection period.

Climate

Qualitative analysis of the 2025 SDR basins indicated that climate was unlikely to have a significant impact on non-residential water use. Non-residential water use was held constant at 2024 values for the duration of the projection.

Conservation

Qualitative analysis of the 2025 SDR basins indicated that conservation was unlikely to have a significant impact on non-residential water use. Non-residential water use was held constant at 2024 values for the duration of the projection.

Technology

Qualitative analysis of the 2025 SDR basins indicated that technology was unlikely to have a significant impact on non-residential water use. Non-residential water use was held constant at 2024 values for the duration of the projection.

3.3.4 Lost & Unaccounted For Water

Growth

L&U Growth projections were calculated using the same methods as in the baseline data (see Section 2.3.4). L&U rates were assumed to remain constant throughout the projection period.

Climate

L&U Climate projections were calculated using the same methods as in the baseline data (see Section 2.3.4). L&U rates were assumed to remain constant throughout the projection period.

Conservation

L&U Conservation projections were calculated by assuming L&U water would be reduced in each basin as improvements are made to water infrastructure and delivery systems. In this projection scenario, two L&U rates were deployed: one modeled after basins that fell under the AMA requirements, and a separate L&U goal rate for the remaining basins based on the NPA National Statistics.

L&U was assumed to be reduced in this projection scenario for all public water systems within the same timeframe. Current L&U was held constant for users for 2024-2026. In 2027, improvements to infrastructure were assumed to have started and a partial achievement of L&U goals would have been met. Full achievement of L&U goals was assumed to be achieved in 2028. Once the L&U goal rate was achieved, the rate was held constant for the remainder of the projection period, 2028-2075.

L&U rates were converted to water use estimates for all years and applicable municipal sectors using the same methodology applied within baseline data (see Section 2.3.4).

Technology

L&U Technology projections were calculated using the same methods as in the baseline data (see Section 2.3.4). L&U rates were assumed to remain constant throughout the projection period.

3.4 OTHER DEMAND

3.4.1 Environmental

Evapotranspiration

Climate

In the environmental Climate projections, the CU of riparian plants and the total acreage of riparian habitat were assumed to change in response to increased temperatures and higher ET rates. The rate of increase for ET was calculated using the methods described in Section 3.1.

Consumptive use values were altered using the rate of increase in ET. CU was increased at a consistent rate over the projection period until the full projected increase was reached for the year 2075.

Habitat transition was represented in this method by altering the total acreage of riparian areas as well as the breakdown between high water use areas and low water use areas. As ET rates increase, it was assumed that higher water use riparian areas would transition to lower water use areas and lower water use areas

would transition to xeric or non-riparian habitat. The transition rate for riparian habitat was set to be proportional to the rate of ET increase.

The altered CU and acreage data were used to calculate total riparian water use for each year within the projection period using the same formula described in Section 2.3.1.

3.5 SUPPLY

3.5.1 Surface Water

Status Quo

The last 5 years of streamflow volumes were averaged, and the resulting average volume was assumed to remain constant until 2075.

3.5.2 Effluent

Status Quo

The last 5 years of effluent use volumes were averaged, and the resulting average volume was assumed to remain constant until 2075.

Growth

Effluent Growth projections were developed based on the assumption that population growth and development in municipal service areas will be positively correlated with future effluent volumes. Population projections were calculated using projections from the ACA Office of Economic Opportunity (ACA, 2022b). An average of the most recent 5 years of available effluent data, 2020-2024, was used to calculate the first year of projected effluent volumes, 2025, by applying the appropriate percent change from the population data.

3.5.3 Groundwater

Incidental Recharge

Climate

Incidental recharge climate projections were developed by adjusting the evaporation percentage used to calculate incidental recharge in relation to a one-degree Fahrenheit, five-degree Fahrenheit, and ten-degree Fahrenheit increase in average temperature over 50 years. This method uses the rate of evaporation increases calculated in Section 3.1 and assumes that the rate of evaporation would increase linearly with temperature. The same equations used in the baseline estimates were used in the projection calculations (see Section 2.5.3).

The agricultural incidental recharge climate projection used the climate-projected agricultural data for the withdrawal numbers. The percentage of evaporation was increased from 2025-2075, while L&U and IE were kept constant at a rate equal to the last year of the baseline period.

$$\begin{aligned} \text{Agricultural Incidental Recharge} \\ &= \text{Water Withdrawn for Agriculture} * (\% \text{ Irrigation Application Loss} \\ &+ \% \text{ Transmission Loss}) \end{aligned}$$

where

$$\begin{aligned} \% \text{ Irrigation Application Loss} &= 100\% - \% \text{ Irrigation Efficiency and } \% \text{ Transmission Loss} \\ &= (\% \text{ Lost \& Unaccounted For} - (\% \text{ Evaporation} * \% \text{ Lost \& Unaccounted For})). \end{aligned}$$

The industrial incidental recharge climate projection used the climate-projected turf data for the withdrawal numbers. The percentage of evaporation was increased, and the percentage of total water loss was kept constant at the same rate as the baseline period.

$$\text{Turf Incidental Recharge} = \text{Water Withdrawn for Turf} * \% \text{ Application and System Loss}$$

Where % Application and System Loss = % Total System Loss - % Evaporation Loss.

This method assumes that temperature is the only change impacting the evaporation rate. A potential improvement for future analyses may be to better characterize the impacts of the other factors involved in the evaporation rate.

Non-Climate

With the exception of agricultural incidental recharge, impacts due to changes in conservation, growth, and technology were assumed to be insignificant for incidental recharge projections. The same equations used in the baseline estimates were used in the projection calculations.

Under the Technology and Conservation projection scenarios for agricultural incidental recharge, application loss was recalculated with the projected efficiencies, and the incidental recharge percentages were changed accordingly. The technology IEs were calculated by dividing the projected withdrawal by the volume of water needed to meet CU. In some cases, the IE was limited to 95% to reflect a realistic maximum efficiency that could be reached (Howell, 2003; see Section 3.3). The conservation IEs were adjusted to reflect the change in minimum IE to 80% (see Section 3.3). Incidental recharge was calculated by multiplying the new incidental recharge percentages by the projected agricultural withdrawal volumes.

Industrial, septic, and growth-projected agricultural incidental recharge were calculated by applying the last year of baseline incidental recharge percentages to the projected demand water-use values. L&U incidental recharge was equal to the projected L&U volumes. The total municipal incidental recharge adds the septic incidental recharge and L&U volumes together.

3.5.4 Moved Water

To estimate the volume of moved water in the projection scenarios, it was assumed that the ratio of moved water used compared to all other sources would be equivalent to the average of the five most recent years. The ratio of moved water was multiplied by the demand volumes projected under the various scenarios to produce an estimate of moved water for each year. In all projection scenarios, the volume of moved water was not allowed to exceed maximum volumes set by applicable water rights settlements or surface water allocations.

4 ACRONYMS AND DEFINITIONS

Acronyms

Acre-Foot	AF
Arizona Commerce Authority	ACA
Arizona Department of Agriculture	AZDA
Arizona Department of Corrections, Rehabilitation, and Reentry	ADCRR
Arizona Department of Environmental Quality	ADEQ
Arizona Department of Mines and Mineral Resources	ADMMR
Arizona Department of Water Resources	ADWR
Active Management Area	AMA
Advanced Meter Infrastructure	AIM
Arizona Pollution Discharge Elimination System	AZPDES
Aquifer Protection Permit	APP
Arizona Revised Statutes	A.R.S.
Arizona State Land Department	ASLD
Bureau of Land Management	BLM
Central Arizona Project	CAP
Community Water System	CWS
Consumptive Use	CU
Drainage Area Ratio	DAR
Gallons Per Capita per Day	GPCD
Irrigation Efficiency	IE
Irrigation Non-Expansion Area	INA
National Interagency Fire Center	NIFC
Non-Transient, Non-Community Water System	NTNC
People Per Household Unit	PPHU
Supply and Demand Report	SDR
Transient, Non-Community Water System	NC
United States Department of Agriculture	USDA
United States Energy Information Administration	US EIA
United States Geological Survey	USGS

Definitions

Acre-foot	The amount of water it takes to cover one acre of land to the depth of one foot, approximately 325,851 gallons
Active Management Area	A geographic area that has been designated pursuant to A.R.S. § 45-411 as requiring active management of groundwater or, in the case of the Santa Cruz AMA, active management of any water, other than stored water, withdrawn from a well. Subsequent active management areas may be designated through local initiative or by the Director of ADWR
Advanced Meter Infrastructure	A comprehensive system incorporating metering devices, communication networks, and data management platforms designed for utilities to remotely allow real-time acquisition of customer water usage data.
Agricultural Water Use	The water applied to two or more acres of land to produce plants, or parts of plants, for sale for human consumption or use as feed for livestock, range livestock, or poultry.
Aquifer	A geologic formation that contains sufficient saturated materials to store water and transmit water in useable quantities to a well.
Aquifer Recharge	Water added to the aquifer through seepage and infiltration, either naturally or artificially. Water may be stored artificially (recharged) pursuant to a permit issued under A.R.S. § 45-831.01, the Underground Water Storage, Savings and Replenishment Program.
Aquifer Storage	Water stored underground, either naturally or artificially. Water may be stored artificially (recharged) pursuant to a permit issued under A.R.S. § 45-831.01, the Underground Water Storage, Savings and Replenishment Program.
Baseflow	The part of a stream discharge that is not attributable to direct runoff from precipitation or melting snow. The stream is sustained by groundwater discharge and may be considered as normal day-to-day flow during most of the year
Baseline	A starting dataset, survey, or study to which future datasets, surveys, and studies can be compared.
Capacity Factor	The unitless ratio of the electrical energy produced by a generating unit in a given period of time compared to the electrical energy that could have been produced at continuous full power operation during the same period.
Census Blocks	A geographic area bounded by visible and invisible features shown on a map prepared by the U.S. Census Bureau (USCB). A block is the smallest geographic area for which the Census Bureau tabulates decennial census data.

Community Water System (CWS)	A public water system, as defined in A.R.S. § 49-352(B), that serves at least fifteen service connections used by year-round residents of the area served by the system or that regularly serves at least twenty-five year-round residents. A person is a year-round resident of the area served by a system if that system serves the person's primary residence with water.
Confined Aquifer	An aquifer that is sandwiched between two layers of relatively impermeable materials
Consumptive Use (CU)	The part of the water demand that becomes unavailable for future use because the water is evaporated or consumed by the use. Consumptive use also refers to diversions from the mainstream of the Colorado River minus the returns.
Domestic Use	Uses related to the supply, service, and activities of households and private residences that include the application of water to less than two acres of land to produce plants or part of plants for sale or human consumption or for use as feed for livestock, range livestock, or poultry.
Dairy Operation	A facility that houses an average of 100 or more lactating cows per day during a calendar year as calculated in section 6-2102.
Domestic Well	A small-capacity water production well typically used to provide water for domestic purposes.
Drought	A sustained natural reduction in precipitation that results in negative impacts to the environment and human activity
Effluent	Water that has been collected in a sanitary sewer for subsequent treatment in a facility that is regulated pursuant to Title 49, Chapter 2. Such water remains effluent until it acquires the characteristics of groundwater or surface water.
Ephemeral Stream	A stream or part of a stream that flows only in direct response to precipitation; it receives little or no water from springs, melting snow, or other sources; its channel is always above the water table.
Evapotranspiration	Loss of water from the land through transpiration of plants and evaporation from the soil and surface water bodies.
Groundwater	<p>Water under the surface of the earth regardless of the geologic structure in which water is stored or travels. Groundwater does not include water flowing in underground streams with ascertainable beds and banks.</p> <p>The Maricopa County Superior Court will likely draw legal distinctions between groundwater and surface water as part of the general stream adjudications proceedings. Such legal distinctions may differ from traditional hydrologic characterizations of groundwater and surface water and may affect ADWR's classification of available water in future reports.</p>

Groundwater Basin	An area which may be designated to enclose a relatively hydrologically distinct body or related bodies of groundwater which shall be described horizontally by surface description.
Groundwater Flow Model	A digital computer model that calculates a hydraulic head field for the modeling domain using numerical methods to arrive at an approximate solution to the differential equation of groundwater flow.
Incidental Recharge	The percolation of water to the water table after the water has been used. Components of incidental recharge include recharge that occurs from septic tanks, turf watering and effluent discharge.
Industrial Demand	Water used by an industrial facility, such as a golf-course, dairy, feedlot, power plant, mine, or paper mill.
Industrial Demand Reuse	A water supply source used to meet industrial demand and later reused for a secondary beneficial use.
Inflow	All water that enters a hydrologic system. Examples include mountain-front and stream channel recharge, artificial and incidental recharge and baseflow and underflow into a system.
Land Subsidence	The lowering of the land-surface from changes that take place underground.
Lost and Unaccounted For Water (L&U)	The total quantity of water from any source that enters a water distribution system during a calendar year minus the total quantity of deliveries of water from the water distribution system during the calendar year.
Municipal Demand	All non-agricultural and non-industrial uses of water supplied by a city, town, private water company, irrigation district, domestic water improvement district, water cooperative, or private domestic well.
Municipal Provider	A city, town, private water company or irrigation district that supplies water for municipal use.
Natural Gas Pipeline Compressor Station	An industrial facility placed along a natural gas pipeline designed to recompress natural gas so that it flows more efficiently through the pipeline
Non-Public Water System	Water systems that serve less than 15 service connections or 25 people.
Non-Residential Use	Municipal water use that is not used for residential purposes. This may include commercial, institutional, recreational, or transitory uses.

Non-Transient Non-Community Water System	A water system that serves 15 or more service connections that are used by the same persons for at least six months per year or serves the same 25 or more persons for at least six months per year. These systems are not the primary source of water for consumers and typically include schools, hospitals, and places of work.
Outflow	All water that leaves a hydrologic system. Examples include cultural water demand, phreatophyte use and underflow and baseflow out of the system
Overdraft	A term signifying that more groundwater is being pumped than the amount of water naturally or incidentally recharged to the aquifer.
Overseeded Area	For a calendar year, an area of land planted with any cool-season grass species that grows over a dormant warm-season grass species during the fall-winter period.
People Per Household Unit	A measure obtained by dividing the number of people residing in housing units by the number of housing units.
Perennial Stream	A stream or part of a stream with surface flow throughout the year, drying only during periods of drought.
Porosity	A value between zero and one represents the amount of pore (or empty) space within a material. If the material is saturated, the porosity represents the total amount of water contained in the material. Porosity comprises Specific Yield and Specific Retention, which are also explained in this table.
Public Water System	Pursuant to A.R.S. § 49-352(B), a water system that: (a) Provides water for human consumption through pipes or other constructed conveyances. (b) Has at least fifteen service connections or regularly serves an average of at least twenty-five persons daily for at least sixty days a year.
Residential Use; Non-Provider	Residential use not supplied by a municipal provider.
Residential Use; Provider	Residential use supplied by a municipal provider.
Sand and gravel facility	A facility that produces sand and gravel and that uses more than 100 ac-ft of water from any source per calendar year. For purposes of this definition, the annual water use shall include all water used by the facility regardless of the nature of the use.
Saturated Thickness	The difference between the top and bottom elevations of an aquifer. Typically, the elevation of the bedrock subtracted from the elevation of the water table.

Saturated Volume	The saturated thickness multiplied by the area of the aquifer. This volume includes the aquifer material and the water filling its pores.
Surface Water	<p>The waters of all sources, flowing in streams, canyons, ravines, or other natural channels, or in definite underground channels, or in definite underground channels, whether perennial or intermittent, floodwater, wastewater or surplus water, and of lakes, ponds, and springs on the surface.</p> <p>The Maricopa County Superior Court will likely draw legal distinctions between groundwater and surface water as part of the general stream adjudications proceedings. Such legal distinctions may differ from traditional hydrologic characterizations of groundwater and surface water and may affect ADWR's classification of available water in future reports.</p>
Transient, Non-Community Water System	A water system that serves 15 or more service connections but does not serve 15 or more service connections that are used by the same persons for more than six months per year. Alternatively, may refer to a system that serves an average of at least 25 persons per day for at least 60 days per year, but does not serve the same 25 persons for more than six months per year. Examples include rest stops, campgrounds, lodging, or restaurants.
Treated Wastewater	Water that has been collected in a sanitary sewer for subsequent treatment in a facility that is regulated as a sewage system, disposal plant or wastewater treatment facility.
Turf Acres	An area of irrigated landscaping that is not part of a private residence. May include grass, ground cover, trees, gardens, low water use landscaping, or ornamental water surface area.
Water Table	The top of the water surface in the saturated part of a non-confined aquifer.
Well	A well is a manufactured opening in the earth through which water may be withdrawn or obtained from beneath the surface of the earth. Wells exempted pursuant to A.R.S. § 45-591.01 are not included in this definition for purposes of this report.

5 SOURCES

1. Alberta Ministry of Agriculture and Irrigation. (n.d.). Average Daily and Annual Water Requirements. Alberta Ministry of Agriculture and Irrigation.
https://www.agric.gov.ab.ca/app19/calc/livestock/waterreq_dataentry1.jsp
2. A.L., Bush. (2001). Construction Materials: Lightweight Aggregates, Encyclopedia of Materials: Science and Technology. <https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/scorias#:~:text=In%20the%20USA%20deposits%20of,deposits%20of%20scoria%20or%20cinder.>
3. Anderson, T. W. et al. (1992). Geohydrology and Water Resources of Alluvial Basins in South-Central Arizona and Parts of Adjacent States. United States Geological Survey.
<https://pubs.er.usgs.gov/publication/pp1406B>
4. Arizona Commerce Authority (ACA). (2022a). Population Estimates. Arizona Commerce Authority.
<https://www.azcommerce.com/oeo/population/population-estimates/>
5. ACA. (2022b). Population Projections. Arizona Commerce Authority.
<https://www.azcommerce.com/oeo/population/population-projections/>
6. ACA. (2022c). Nucor Announces \$100 Million Steel Production Facility Expansion in Kingman.
<https://www.azcommerce.com/news-events/news/2022/8/nucor-announces-100-million-steel-production-facility-expansion-in-kingman/>
7. Arizona Corporation Commission (ACC). (n.d.). Arizona Power Plant and Transmission Line Siting Committee. Arizona Corporation Commission.
<https://www.azcc.gov/arizona-power-plant>
8. ADEQ. (2023). Safe Drinking Water Database [Dataset].
https://azsdwis.azdeq.gov/DWW_EXT/
9. ADEQ. (2024a). Safe Drinking Water Database.
https://azsdwis.azdeq.gov/DWW_EXT/
10. ADEQ. (2024b). Aquifer Protection Permit No. P-100333, Place ID 927, LTF 103377, Minor Amendment.
https://static.azdeq.gov/wqd/pinyonplain/2024_indpermit.pdf
11. ADEQ (2025a). Aquifer Protection Permits (APPs) from 1990 to 2024. Filtered for 2025 Basins. [Internal].
12. ADEQ (2025b). Effluent data for APP facilities from 1990 to 2024. Filtered for 2025 Basins. [Internal database and dataset].
13. ADWR. (1999). Third Management Plan for Phoenix Active Management Area.
https://infoshare.azwater.gov/docushare/dsweb/Get/Document-10007/PhoenixAMA_3MP.pdf
14. ADWR. (2009-2010). Arizona Water Atlas, Volumes 1-8.
<https://infoshare.azwater.gov/docushare/dsweb/View/Collection-19396>
15. ADWR. (2022a). Fifth Management Plan Phoenix Active Management Area.
<https://www.azwater.gov/sites/default/files/media/Phx5MP.pdf>
16. ADWR. (2022b). Overdraft, Safe-Yield, and The Management Goals of Arizona's Active Management Areas. Arizona Department of Water Resources.
<https://www.azwater.gov/ama/management-plans>
17. ADWR. (2024a). Community Water System (CWS) Database and Map [Map].
<https://azwatermaps.azwater.gov/cws>
18. ADWR. (2024b). Well Registry in Arizona (Wells 55) [Map].
<http://azwatermaps.azwater.gov/wellreg>
19. ADWR. (2024c). ADWR Developed Groundwater Models.
<https://www.azwater.gov/hydrology/groundwater-modeling/adwr-models>
20. Arizona Geological Society (AZGS). (n.d.-a). AZGS Library [dataset].
<https://library.azgs.arizona.edu/>
21. AZGS. (n.d.-b). Mining in Arizona. The University of Arizona.
<https://azgs.arizona.edu/minerals/mining-arizona>
22. AZGS. (2024). Geologic Map of Arizona.
<https://geomapaz.azgs.arizona.edu/>

23. Ali, B. & Kumar, A. (2017). Life cycle water demand coefficients for crude oil production from five North American locations.
<https://www.sciencedirect.com/science/article/abs/pii/S0043135417305523>
24. APA – The Engineered Wood Association. (n.d.). Manufacturer Directory.
<https://www.apawood.org/manufacturer-directory?c=2>
25. Arizona Public Service. (2020). Integrated Resource Plan.
<https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Doing-business-with-us/Resource-Planning-and-Management/2020IntegratedResourcePlan062620.ashx?la=en&hash=24B8E082028B6DD7338D1E8DA41A1563>
26. Arizona State Land Division (ASLD). (n.d.). ASLD Parcel Viewer [Map].
<http://gis.azland.gov/webapps/parcel/>
27. ASLD and AZGS. (2020). Streams-Ephemeral and Perennial [Dataset]. Downloaded on January 18, 2023.
<https://azgeo.az.gov>
28. Arizona Water Settlements Act, Pub. L. No. 108–541, 118 Stat. 3478 (2004).
<https://www.congress.gov/108/plaws/publ451/PLAW-108publ451.pdf>
29. Barlow, P.M. et al. (2022). U.S. Geological Survey Hydrologic Toolbox — A graphical and mapping interface for analysis of hydrologic data: U.S. Geological Survey Techniques and Methods, book 4, chap. D3, 23 p.
<https://doi.org/10.3133/tm4D3>
30. Bartos, M., Chester, M., Johnson, N., Gorman, B., Eisenberg, D., Linkov, I., & Bates, M. (2016). Impacts of rising air temperatures on electric transmission ampacity and peak electricity load in the United States. *Environmental Research Letters*, 11.
<https://iopscience.iop.org/article/10.1088/1748-9326/11/11/114008/meta#:~:text=As%20atmospheric%20carbon%20concentrations%20increase,and%20increasing%20peak%20electricity%20load>
31. Beagles et. al. (2024). Arizona’s Forest Products Industry and Timber Harvest, 2021. Forest Industry Research Program, University of Montana.
<https://www.bber.umt.edu/pubs/forest/fidacs/AZ2021%20Tables.pdf>
32. Becker, C. (2024). The Value of Water. Penn State Extension.
<https://extension.psu.edu/the-value-of-water>
33. Becker, R. (2014). Water Use and Conservation in Manufacturing: Evidence from U.S. Microdata.
<https://www.worldbank.org/content/dam/Worldbank/Feature%20Story/SDN/Water/events/IWREC2014-Session2A-Water-Use-Manufacturing-RandyBecker-Sept8.pdf>
34. Benjamin, C. (2022). Is Artificial Turf a Beneficial Water Conservation Tool in the West? *Western Resource Advocates*.
https://westernresourceadvocates.org/wpcontent/uploads/2023/01/2022_WRA_Artificial_Turf_Report.pdf
35. Berardy, A., & Chester, M. (2017). Climate Change Vulnerability in the Food, Energy, and Water Nexus: Concerns for Agricultural Production in Arizona and its Urban Export Supply. *Environmental Research Letters* 12 03004.
<https://iopscience.iop.org/article/10.1088/1748-9326/aa5e6d/meta>
36. Bergna, D., et al. (2020). Effect of Some Process Parameters on the Main Properties of Activated Carbon Produced from Peat in a Lab-Scaled Process. *Waste Biomass Valor*.
<https://doi.org/10.1007/s12649-019-00584-2>
37. Bowers, T. et al. (2017). Cradle-to-Gate Life-Cycle Impact Analysis of Glued-Laminated (Glulam) Timber: Environmental Impacts from Glulam Produced in the US Pacific Northwest and Southeast.
<https://corrim.org/wp-content/uploads/2018/03/cradle-to-gate-impact-analysis-glulam-pnw-se.pdf>
38. Broom, D. (2019.). Land and Water Usage in Beef Production Systems. *Animals*, 9(6), 286.
<https://doi.org/10.3390/ani9060286>
39. Brown, P. (2003a). Turfgrass Consumptive Use Values for the Phoenix Area. University of Arizona.
<https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1314.pdf>

40. Brown, P. (2003b). Turfgrass Consumptive Use Values for the Tucson Area. University of Arizona. <https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1313.pdf>
41. Brown, P., & Jones, C. (2004). Turfgrass Consumptive Use: Payson, AZ. University of Arizona. <https://cales.arizona.edu/research/dirt/az1355.pdf>
42. Brown, P., & Albrecht, W. (2005). Turfgrass Consumptive Use: Flagstaff, Arizona. University of Arizona. <https://repository.arizona.edu/handle/10150/146426>
43. Brown, P., & Schalau, J. (2005). Turfgrass Consumptive Use: Prescott, Arizona. University of Arizona. <https://repository.arizona.edu/handle/10150/144808>
44. Brown, P. (2008). Water Use of Turfgrass Mohave County, Arizona. University of Arizona. <https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1447.pdf>
45. Brown, P., & Whitlark, B. (2020, June 22). University of Arizona Expanded Analysis Turf Water Duties: Scientific Input. https://www.azwater.gov/sites/default/files/media/2020-06-22_Turf_Breakout.pdf
46. BLM. (n.d.). Rangeland Administration System Reports: Allotment Information. <https://reports.blm.gov/reports/ras/>
47. Calvo, G., Mudd, G., Valero, A., & Valero, A. (2016). Decreasing Ore Grades in Global Metallic Mining: A Theoretical Issue or a Global Reality? *Resources*, 5(4), 36. <https://doi.org/10.3390/resources5040036>
48. Catalyst Paper. (2015). Our Mills: Snowflake, Arizona. https://web.archive.org/web/20150710180436/http://www.catalystpaper.com/sites/default/files/CATP_6394_Catalyst-Snowflake_factsheet_WEB_0.pdf
49. Central Arizona Governments (CAG). (2020). Gila County Septic Use Study. <http://www.cagaz.org/Departments/208/files/CAGGilaSepticUseStudyFINAL.pdf>
50. Coffel, E., & Mankin, J. (2021). Thermal power generation is disadvantaged in a warming world. *Environmental Research Letters*, 16(2). <https://doi.org/10.1088/1748-9326/abd4a8>
51. Condenzo, T., et al. (2023). Possible Alternatives for Using Kraft Lignin as Activated Carbon in Pulp Mills – A Review. *Nordic Pulp & Paper Research Journal* 38(2). [10.1515/npprj-2022-0099](https://doi.org/10.1515/npprj-2022-0099)
52. Cornell University. (2024). Northeast Region Certified Crop Adviser (NRCCA) Study Resources. <https://nrcca.cals.cornell.edu/soil/CA2/CA0211.1.php>
53. Data Basin. (n.d.). Arizona Mineral Resources [Map]. <https://databasin.org/datasets/cd24daae6e6642e2b2ae880356bcba04/>
54. Davis, R., & Watts, P. (2016). Water Requirements. In *Feedlot Design and Construction*. https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/feedlot-design-manual/04-water-requirements-2016_04_01.pdf
55. DeCook, K.J., & Fazzolare, R.A. (1977). Resource Information Applied to Water Sources and Discharged at Existing and Potential Power Plant Sites in Arizona and the Southwest: Project Completion Report. University of Arizona. <https://repository.arizona.edu/handle/10150/305449>
56. DeOreo, W., Mayer, P., Dziegielewski, B., & Kiefer, J. (2016). Residential End Uses of Water, Version 2 [Executive Report]. Water Research Foundation. https://www.circleofblue.org/wp-content/uploads/2016/04/WRF_REU2016.pdf
57. Donovan, D., Katzer, T., & Brothers, K. (2009). Review of Ground-Water Recharge Estimates in Nevada with an Analysis of Geologic Control on the Recharge Process. Southern Nevada Water Authority. <https://aquaterranova.files.wordpress.com/2014/09/2009-review-of-ground-water-recharge-estimates.pdf>
58. Drugova, T., Curtis, K., & Kim, M-K. (2020). Impacts of Drought on Tribal Economies in Arizona. Utah State University Applied Economies Extension. <https://extension.usu.edu/apec/research/impacts-of-drought-on-tribal-economies-in-arizona>
59. Dun & Bradstreet. (n-d). Manufacturing Companies in Eagar, Arizona, United States of America. <https://www.dnb.com/business-directory/company-information.manufacturing.us.arizona.eagar.html>

60. Energy Star. (2012). Data Trends: Water Use Tracking.
https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Water_20121002.pdf
61. Esri, USDA, NRCS, (2024). SSURGO Downloader.
<https://www.arcgis.com/apps/View/index.html?appid=cdc49bd63ea54dd2977f3f2853e07fff>
62. Essuah, E.Y., & Buah, W.K. (2019). Effects of Steam Dosage on the Qualities of Activated Carbon Developed from Coconut Shells in Ghana. International Journal of Mining Science.
<http://dx.doi.org/10.20431/2454-9460.0504002>
63. Euroelectric. (2018). Decarbonisation pathways.
<https://www.euroelectric.org/wp-content/uploads/2024/06/decarbonisation-pathways-all-slideslinks-29112018.pdf>
64. Executive Order 14057, Federal Register Volume 86, No. 236 (2021).
<https://www.govinfo.gov/content/pkg/FR-2021-12-13/pdf/2021-27114.pdf>
65. FCA US, LLC. (2016). [Personal Communication].
66. Fedrow, D. M. (2019). Water Use in Confined Animal Feeding Operations (CAFOs) in Minnesota: Who's Keeping Track? [Master's Thesis, University of Montana].
<https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=12430&context=etd>
67. Flume Utility and Business Solutions. (2022). City of Goodyear: Empowering Residents with Flume to Reduce Residential Water Use by 14%. Flume, Inc.
<https://ssusa.s3.amazonaws.com/c/308481883/media/41756525dae1791a803875081689189/Goodyear%20Case%20Study%20-%20Flume.pdf>
68. Fortune Business Insights. (2025). Utility Poles Market Size, Share & Industry Analysis, By Material (Steel, Concrete, Composite, and Wood), By Pole Size (Below 40 ft, Between 40 ft and 70 ft, and Above 70 ft), By Application (Transmission Line, Distribution Line, Telecommunication, and Others), and Regional Forecast, 2025-2032. <https://www.fortunebusinessinsights.com/utility-poles-market-107107>
69. Frankson, R., Kunkel, K., Stevens, L., Easterling, D., Brown, T., Selover, N., & Saffel, E. (2022). Arizona State Climate Summary 2022 (Technical Report NESDIS 150-AZ). National Oceanic and Atmospheric Association.
<https://statesummaries.ncics.org/chapter/az/>
70. Frisvold, G., & Marquez, T. (2013). Water Requirements for Large-Scale Solar Energy Projects in the West. Journal of Contemporary Water Research & Education, 151(1), 106–116.
<https://doi.org/10.1111/j.1936-704X.2013.03156.x>
71. Food and Agriculture Organization of the United Nations (FAO). (2024). Annex 2 Infiltration Rate and Infiltration Test. <https://www.fao.org/4/s8684e/s8684e0a.htm>
72. Food Northwest. (n.a.). Meat and Poultry Processing.
https://www.foodnorthwest.org/index.php?option=com_content&view=article&id=83%3Awater-and-wastewater-use-in-the-food-processing-industry&catid=20%3Asite-content&limitstart=2&id=83:water-and-wastewater-use-in-the-food-processing-industry#:~:text=Beef%20processing%20water%20usage%2C%20primarily,pound%20of%20processed%20hamburger%20meat
73. Freeport-McMoRan. (2019). Building on Strength: 2019 Water Report.
<https://www.fcx.com/sites/fcx/files/documents/sustainability/2019-water-report.pdf>
74. Freeport-McMoRan. (2023). The Value of Copper: 2023 Annual Report on Sustainability.
<https://fcx.com/sites/fcx/files/documents/sustainability/2023-annual-report-on-sustainability.pdf>
75. Gillespie, J.B. and Bentley, C.B. (1971). Geohydrology of Hualapai and Sacramento Valleys, Mohave County. Water Supply Paper 1899-H, U.S. Geological Survey, Arizona State Land Department.
<https://pubs.usgs.gov/publication/wsp1899H>
76. Heindl, L.A. and McCullough, R.A. (1961). Geology and the Availability of Water in the Lower Bonita Creek Area, Graham County, Arizona. Geological Survey Water-Supply Paper 1589, U.S. Geological Survey, City of Safford.
<https://pubs.usgs.gov/wsp/1589/report.pdf>
77. Gila River Commissioner. (n-d). Annual Reports.
<https://www.gilawater.org/annual-reports>

78. Governor's Agricultural Best Management Practices Committee. (2015). Guide to Agricultural PM10 Best Management Practices.
<https://agriculture.az.gov/sites/default/files/Feedlot%20PM10%20Best%20Management%20Practices%20Guide%20-%20AZ%20Dept%20of%20Ag.pdf>
79. Gunson, A. (2013). Quantifying, reducing, and improving mine water use [Ph.D. Dissertation, University of British Columbia].
<https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0071942>
80. Guthrie, T. (2011). Water needs of pigs. Michigan State University Extension.
https://www.canr.msu.edu/news/water_needs_of_pigs
81. Henry, C., & Pratson, L. (2016). Effects of Environmental Temperature Change on the Efficiency of Coal- and Natural Gas-Fired Power Plants. *Environmental Science and Technology*, 50(17), 9764–9772.
<https://doi.org/10.1021/acs.est.6b01503>
82. Himmelmann, H. & Amaral-Phillips, D. (n.d.). Water Needs for the Dairy Herd. University of Kentucky, Department of Animal & Food Sciences.
<https://afs.ca.uky.edu/content/water-needs-dairy-herd>
- Hite, K., et. Al. (2025). Management of the Colorado River: Water Allocations, Drought, and the Federal Role.
<https://www.congress.gov/crs-product/R45546>
83. Holstein Foundation. (n.d.). Milking and Lactation.
https://www.holsteinfoundation.org/pdf_doc/workbooks/Milking_Lactation_Workbook.pdf
84. Howard, J. (2021). BlockGroup 2020 [Map]. Maricopa Association of Governments.
<https://geodata-azmag.opendata.arcgis.com/datasets/AZMAG::blockgroup-2020/explore?location=34.069173%2C-111.914702%2C7.50>
85. Hutson, S., Barber, N., Kenny, J., Linsey, K., Lumia, D., & Maupin, M. (2004). Estimated Use of Water in the United States in 2000 (Circular 1268). United States Geological Survey.
<https://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf>
86. Ivanich, P.A. and Conway, B.D., (2009). Preliminary estimate of groundwater in storage for the Hualapai Valley groundwater basin, Mohave County, Arizona. Arizona Department of Water Resources, Hydrology Division.
87. Ivey, J. (n-d). Equine Welfare Series, Water: The Most Essential Nutrient. University of Tennessee, Department of Animal Science.
<https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/SP794.pdf>
88. Jackson, W. and Summers, P. (1988). Bill Williams River Field Assessment: Hydrology, Hydrogeology, and Geomorphology. U.S. Bureau of Land Management.
https://upload.wikimedia.org/wikipedia/commons/1/14/Bill_Williams_River_field_assessment_-_hydrology%2C_hydrogeology%2C_and_geomorphology_%28IA_billwilliamsrive00jack%29.pdf
89. Johnson, A. (1967). Specific Yield—Compilation of Specific Yields for Various Materials (1662-D). United States Geological Survey.
<https://pubs.usgs.gov/wsp/1662d/report.pdf>
90. Jones, D., & Collins, E. (2019). Recirculation Systems for Manure Removal. Swine Extension.
<https://swine.extension.org/recirculation-systems-for-manure-removal/>
91. Kayenta Mine Permit Renewal Environmental Assessment. (2011).
https://web.archive.org/web/20130215124306/http://www.wrcc.osmre.gov/Current_Initiatives/Kayenta_Mine/Renewal/EA-SecD.pdf
92. Kenny, J., Barber, N., Hutson, S., Linsey, K., Lovelace, J., & Maupin, M. (2009). Estimated Use of Water in the United States in 2005 (Circular 1344). United States Geological Survey.
<https://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>
93. Lacroix, K. et. al. (2016). Wet Water and Paper Water in the Upper Gila River Watershed. University of Arizona, Water Resources Research Center.
<https://wrrc.arizona.edu/publication/wet-water-and-paper-water-upper-gila-river-watershed>
94. Levin, S., & Farmer, W. (2020). Evaluation of Uncertainty Intervals for Daily, Statistically Derived Streamflow Estimates at Ungaged Basins across the Continental U.S. *Water*, 12(5).
<https://doi.org/10.3390/w12051390>

95. Liu, Z., Powers, W. & Mukhtar, S. (2014). A Review of Practices and Technologies for Odor Control in Swine Production Facilities. American Society of Agricultural and Biological Engineers.
<https://krex.k-state.edu/bitstream/handle/2097/18753/ZifeiAppEngAgri2014.pdf?sequence=1>
96. Lorenz, D., & Ziegeweid, J. (2016). Methods to Estimate Historical Daily Streamflow for Ungaged Stream Locations in Minnesota. Scientific Investigations Report. United States Geological Survey.
<https://pubs.usgs.gov/sir/2015/5181/sir20155181.pdf>
97. Manufacturing Net. (2008). Nucor to Start Idled Kingman Steel Plant.
<https://www.manufacturing.net/operations/news/13064183/nucor-to-restart-idled-kingman-steel-plant>
98. Maricopa County Flood Control District (MCFCD). (2009). Drainage Design Manual—Hydrology.
<https://prism.lib.asu.edu/items/46410/view>
99. MCFCD. (2024). ALERT Data Map [Map].
<https://alert.fcd.maricopa.gov/alert/Google/v3/gmap.html>
100. Matlock, M., Thoma, G., Boles, E., Leh, M., Sandefur, H., Bautista, R., & Ulrich, R. (2011). A Life Cycle Analysis of Water Use in U.S. Pork Production. Pork Checkoff, University of Arkansas.
<https://www.porkcdn.com/sites/porkorg/library/2011/06/11-133-matlock-uofark.pdf>
101. Maupin, M., Kenny, J., Hutson, S., Lovelace, J., Barber, N., & Linsey, K. (2014). Estimated Use of Water in the United States in 2010 (Circular 1405). United States Geological Survey.
<https://pubs.usgs.gov/circ/1405/pdf/circ1405.pdf>
102. Meehan, M., Stokka, G., & Mostrom, M. (2021). Livestock Water Requirements. North Dakota State University Extension.
<https://www.ag.ndsu.edu/publications/livestock/livestock-water-requirements>
103. Mielke, E., Anadon, L., & Narayanamurti, V. (2010). Water Consumption of Energy Resource Extraction, Processing, and Conversion.
<https://www.belfercenter.org/publication/water-consumption-energy-resource-extraction-processing-and-conversion>
104. Miller, J. A. (1999) Groundwater Atlas of the United States: Introduction and National Summary. United States Geological Survey.
https://pubs.usgs.gov/ha/ha730/ch_a/index.html
105. Minnesota Asphalt Pavement Association. (2017). Asphalt Plants – Know the Facts.
https://www.asphaltisbest.com/page/asphalt_plants
106. Mullenix, K., & Brantley, E. (2019). Water Requirements of Beef Cattle. Alabama A&M and Auburn Universities Extension.
<https://www.aces.edu/blog/topics/beef/water-requirements-of-beef-cattle/>
107. Nagler, P.L. (2020). Literature-Reviewed Estimates of Riparian Consumptive Water Use in the Drylands of Northeast Arizona, USA.
<https://pubs.usgs.gov/publication/ofr20201129>
108. National Conference of State Legislatures. (2021). State Renewable Portfolio Standards and Goals. National Conference of State Legislatures.
[https://www.ncsl.org/energy/state-renewable-portfolio-standards-and-goals#:~:text=Renewable%20Portfolio%20Standards%20\(RPS\)%20require,production%20and%20encourage%20economic%20development](https://www.ncsl.org/energy/state-renewable-portfolio-standards-and-goals#:~:text=Renewable%20Portfolio%20Standards%20(RPS)%20require,production%20and%20encourage%20economic%20development)
109. National Water Information System (NWIS). (n.d.). Water Use Data for Arizona [dataset].
https://waterdata.usgs.gov/az/nwis/water_use?format=html_table&rdb_compression=file&wu_area=County&wu_year=ALL&wu_county=003%2C012&wu_category=IG&wu_county_nms=Cochise%2BCounty%252C%2BPaz%2BCounty&wu_category_nms=Irrigation%252C%2BGolf%2BCourses
110. Navajo Nation Office of the President. (2024). Navajo Nation faces livestock overpopulation, seeks sustainable solutions.
<https://opvp.navajo-nsn.gov/navajo-nation-faces-livestock-overpopulation-seeks-sustainable-solutions/>
111. Nebraska Department of Agriculture. (n.d.) Water Consumption by Riparian Vegetation.
<https://nda.nebraska.gov/rvmtf/docs/WaterConsumption.pdf>
112. Nebraska Game and Parks (2012). Nebraska Pond Management, Second Edition. Blaser and Eades, Nebraska Game and Parks.

- <https://outdoornebraska.gov/wp-content/uploads/2023/03/nebraska-pond-management-second-edition.pdf>
113. Neuman, S.P. and Adar, E. (1983). Estimation of Recharge in a Small Southern Arizona Basin by Means of Hydrological, Hydrochemical, and Environmental Isotope Data. University of Arizona, UA Campus Repository. <https://repository.arizona.edu/handle/10150/314235>
114. Niemuth, N. (1992). Arizona Copper Reserves (Open-File Report 92-11). Arizona Department of Mines & Mineral Resources. <http://docs.azgs.az.gov/OnlineAccessMineFiles/Pubs/2013-02-0456.pdf>
115. Niemuth, N. (2011). 2010 Arizona Mining Review. <https://azgeology.azgs.arizona.edu/article/minerals-and-mining/2011/09/2010-arizona-mining-review>
116. O'Connor, N., & Mehta, K. (2016). Modes of greenhouse water savings. *Procedia Engineering*, 159, 259–266. <https://doi.org/10.1016/j.proeng.2016.08.172>
117. Ontario Ministry of Agriculture, Food, and Rural Affairs. (2023). Water Requirements of Livestock. Ontario Ministry of Agriculture, Food, and Rural Affairs. <https://files.ontario.ca/omafra-water-requirements-livestock-23-023-en-2023-04-25.pdf>
118. OpenET. (2025). <https://etdata.org/>
119. Painted Desert Tribune. (2016). Copperstate Farms Closes on 40-acre Greenhouse Facility in Snowflake. <https://www.tribunenewsnow.com/articles/news/copperstate-farms-closes-on-40-acre-greenhouse-facility-in-snowflake/>
120. Parish, J., & Rhinehart, J. (n.d.). Beef Cattle Water Requirements and Source Management. Mississippi State University Extension. http://extension.msstate.edu/sites/default/files/publications/publications/P2490_web.pdf
121. Pavlakovich-Kochi, V. (2020). Copper Ore: Arizona's Old Treasure-Today's Top Export. University of Arizona. <https://azmex.eller.arizona.edu/news/2020/03/copper-ore-arizona%E2%80%99s-old-treasure-today%E2%80%99s-topexport#:~:text=Practically%20all%20of%20Arizona's%20exports%20of%20copper%20ore%20go%20to%20Mexico>
122. Pinnacle West Capital Corporation. (n.d.). Metrics and Reporting. Pinnacle West Capital Corporation. <https://www.pinnaclewest.com/corporate-responsibility/metrics-and-reporting/default.aspx>
123. PRISM Climate Group. (2024). 30-Year Normals [dataset] <https://prism.oregonstate.edu/normals/>
124. PRISM Climate Group. (2024). Time Series Values for Individual Locations [dataset]. <https://prism.oregonstate.edu/explorer/>
125. Pool, D.R. et al. (2011). Regional Groundwater-Flow Model of the Redwall-Muav, Coconino, and Alluvial Basin Aquifer Systems of Northern and Central Arizona. Arizona Department of Water Resources, United States Geological Survey, and Yavapai County. <https://pubs.usgs.gov/sir/2010/5180/>
126. Rao, P., Sholes, D., Morrow III, W., & Cresko, J. (2017). Estimating U.S. Manufacturing Water Use. ACEE Summer Study on Energy Efficiency in Industry. https://www.acee.org/files/proceedings/2017/data/polopoly_fs/1.3687919.1501159097!/fileserver/file/790285/filename/0036_0053_000025.pdf
127. Rasby, R., & Walz, T. (2011). Water Requirements of Beef Cattle. University of Nebraska-Lincoln Extension. <https://extensionpublications.unl.edu/assets/pdf/g2060.pdf>
128. Rauzi, S. (2010). Annual Oil, Gas, and Helium Production in Arizona. Arizona Geological Survey. Oil and Gas Publication OG-2. <https://repository.arizona.edu/handle/10150/629469>
129. Reedy, R., & Scanlon, B. (2022). Water Use by the Mining Industry in Texas, Appendix III. Aggregate Mining Industry Water Use Tables. Texas Water Development Board. <https://www.twdb.texas.gov/waterplanning/data/projections/MiningStudy/doc/Final%20TWDB%20Mining%20Water%20Use%20Appendix%20III%20Jun%2015%202022.PDF>

130. Rescorla, D. (2006). Making bacon is a low stress life for pigs. White Mountain Independent. https://www.wmicentral.com/news/snowflake_taylor/making-bacon-is-a-low-stress-life-for-pigs/article_e3959914-f2e7-59c4-b81a-52b33162bc02.html
131. Richard, S., & Kneale, S. (1998). DI-8 Geologic Map of Arizona [Map]. <https://repository.arizona.edu/bitstream/handle/10150/630076/DI8v3Text.pdf?sequence=1&isAllowed=y>
132. Richard, S., Reynolds, S., Spencer, J., & Pearthree, P. (2000). Geologic Map of Arizona [Map]. Arizona Geological Survey. <https://azgs.arizona.edu/photo/geologic-map-arizona>
133. Salt River Project. (2023). SRP's Energy Mix. Salt River Project. <https://blog.srpnet.com/srp-energy-mix-where-your-power-comes-from/>
134. Schaefer, K. et al. (2023). Consolidation and Concentration in U.S. Meat Processing: Updated Measures Using Plant-Level Data. <https://www.usda.gov/sites/default/files/documents/schaefer-et-al-2023.pdf>
135. Schwartz, F., & Zhang, H. (2003). Fundamentals of Ground Water. John Wiley & Sons, Inc.
136. Singh, M. (2010). Water Consumption at Copper Mines in Arizona (Special Report 29). State of Arizona Department of Mines & Mineral Resources. <http://docs.azgs.az.gov/OnlineAccessMineFiles/Pubs/2013-02-0532.pdf>
137. Smalley, R.C. An isotopic and geochemical investigation of the hydrogeologic and geothermal systems in the Safford Basin, Arizona. University of Arizona, UA Campus Repository. <https://repository.arizona.edu/handle/10150/557978?show=full>
138. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture (NRCS, USDA). (2016). Web Soil Survey (STATSGO2). Available online at <http://websoilsurvey.nrcs.usda.gov/>.
139. Solley, W., Pierce, R., & Perlman, H. (1993). Estimated Water Use in the United States in 1990 (Circular 1081). United States Geological Survey. <https://pubs.usgs.gov/circ/1993/1081/report.pdf>
140. Solley, W., Pierce, R., & Perlman, H. (1998). Estimated Use of Water in the United States in 1995 (Circular 1200). United States Geological Survey. <https://pubs.usgs.gov/circ/1998/1200/report.pdf>
141. Spencer, C., Lalman, D., Rolf, M., & Richards, C. (2017). Estimating Water Requirements for Mature Beef Cows. Oklahoma State University Extension. <https://extension.okstate.edu/fact-sheets/estimating-water-requirements-for-mature-beef-cows.html>
142. The Nature Conservancy (TNC). (2021). TNC Arizona Statewide Freshwater Assessment. GIS File Geodatabase. <https://tnc.maps.arcgis.com/home/item.html?id=599888cc2c994b688cc24d88296a92a7>
143. Tillman, F. et al. (2011). Water Availability and Use Pilot: Methods Development for a Regional Assessment of Groundwater Availability, Southwest Alluvial Basins, Arizona (Scientific Investigations Report 2011–5071). United States Geological Survey. https://media.kjzz.gov/s3fs-public/field/docs/2011/09/21/sir2011-5071_text.pdf
144. Towne, D.C. and Freak, M.C. (2001). Ambient Groundwater Quality of the Sacramento Valley Basin: A 1999 Baseline Study. ADEQ Open File Report 01-04, Arizona Department of Environmental Quality. https://static.azdeq.gov/wqd/gw/fs/01-04_SacramentoValleyBasin_ofr.pdf
145. Towne, D.C. (2016). Ambient Groundwater Quality of the Salt River Basin: A 2001–2015 Baseline Study. ADEQ Open File Report 16-01, Arizona Department of Environmental Quality. https://static.azdeq.gov/wqd/gw/fs/16-01_srb_ofr.pdf
146. Truini, M. et al. (2013). Hydrogeologic Framework and Estimates of Groundwater Storage for the Hualapai Valley, Detrital Valley, and Sacramento Valley Basins, Mohave County, Arizona. Scientific Investigations Report 2012-5275, U.S. Geological Survey. <https://pubs.usgs.gov/sir/2012/5275/>
147. Tucson Electric Power. (2023). ESG/Sustainability Performance. Tucson Electric Power. <https://www.tep.com/esg/>
148. USBR. (n.d.-a). Consumptive Uses and Losses: Provisional Estimate, Arizona Portion of the Upper Colorado River Basin Report. <https://www.usbr.gov/uc/DocLibrary/reports.html>

149. USBR (n.d.-b). Lower Colorado River Water Accounting, Water Accounting Reports.
<https://www.usbr.gov/lc/region/g4000/wtracct.html>
150. USCB. (2020). 2020 Census—Census Block Maps [Map].
<https://www.census.gov/geographies/reference-maps/2020/geo/2020-census-block-maps.html>
151. USDA. (1993). Irrigation Water Requirements. In Part 623 National Engineering Handbook.
<https://www.wcc.nrcs.usda.gov/ftpref/wntsc/waterMgt/irrigation/NEH15/ch2.pdf>
152. USDA. (1994). 1992 Census of Agriculture, Arizona: State and County Data.
<https://agcensus.library.cornell.edu/wp-content/uploads/1992-Arizona-1992-01-intro.pdf>
153. USDA. (1999). 1997 Census of Agriculture, Arizona: State and County Data.
<https://agcensus.library.cornell.edu/wp-content/uploads/1997-Arizona-1997-01-full-1.pdf>
154. USDA. (2004). 2002 Census of Agriculture, Arizona: State and County Data.
<https://agcensus.library.cornell.edu/wp-content/uploads/2002-Arizona-01-full.pdf>
155. USDA. (2009). 2007 Census of Agriculture, Arizona: State and County Data.
<https://agcensus.library.cornell.edu/wp-content/uploads/2007-Arizona-azv1.pdf>
156. USDA. (2014). 2012 Census of Agriculture, Arizona: State and County Data.
<https://agcensus.library.cornell.edu/wp-content/uploads/2012-Arizona-azv1.pdf>
157. USDA. (2019). 2017 Census of Agriculture, Arizona: State and County Data.
https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Arizona/azv1.pdf
158. USDA. (2021). 2021 Arizona Cropland Data Layer.
https://www.nass.usda.gov/Research_and_Science/Cropland/metadata/meta.php
159. USDA. (2021). Pinto Valley Mine Final Environmental Impact Statement.
<https://cdxapps.epa.gov/cdx-enepa-ll/public/action/eis/details?eislId=325641>
160. USDA. (2023). 2023 USDA Plant Hardiness Zone. [Map].
<https://planthardiness.ars.usda.gov/>
161. USDA NRCS. (2008). Soil Quality Indicators. United States Department of Agriculture Natural Resource Conservation Service.
<https://www.nrcs.usda.gov/sites/default/files/2022-10/Infiltration.pdf>
162. US DOE. (2023). Energy Conservation Program: Energy Conservation Standards for Distribution Transformers.
<https://www.energy.gov/sites/default/files/2022-12/dt-ecs-nopr.pdf>
163. US Department of the Interior. (n-d). Natural Resources Revenue Data – Greenlee County, Arizona.
<https://archive.revenuedata.doi.gov/archive/case-studies/greenlee/>
164. U.S. Energy Information Administration (US EIA). (n.d.). All energy infrastructure and resources. U.S. Energy Information Administration.
<https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore>
165. US EIA. (2018). 2018 Manufacturing Energy Consumption Survey.
<https://www.eia.gov/consumption/manufacturing/pdf/MECS%202018%20Results%20Flipbook.pdf>
166. US EIA. (2017). 2012 Commercial Building Energy Consumption Survey: Water Consumption in Large Buildings Survey.
<https://www.eia.gov/consumption/commercial/reports/2012/water/#:~:text=Warehouse%20and%20storage%20buildings%20used,exception%20of%20inpatient%20healthcare%20buildings>
167. US EIA. (2023a). Annual Energy Outlook.
https://www.eia.gov/outlooks/aeo/pdf/AEO2023_Narrative.pdf
168. US EIA. (2023b). Electric Power Monthly: Table 6.07.A. Capacity Factors for Utility Scale Generators Primarily Using Fossil Fuels [dataset].
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_6_07_a
169. US EIA. (2023c). Electric Power Monthly: Table 6.07.B. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels [dataset].
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b
170. US EIA. (2025a). Electricity Data Browser [dataset].
<https://www.eia.gov/electricity/data/browser/>

171. US EIA. (2019). Southwestern states have better solar resources and higher solar PV capacity factors. Today in Energy.
<https://www.eia.gov/todayinenergy/detail.php?id=39832>
172. US EIA. (2025b). Natural Gas Gross Withdrawals and Production.
https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm
173. US EIA. (2025c). Crude Oil Production.
https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm
174. United States Environmental Protection Agency (US EPA). (n.d.-a). Envirofacts. U.S. Environmental Protection Agency.
<https://enviro.epa.gov/>
175. US EPA. (n.d.-b). Statistics and Facts: WaterSense & Water Savings. U.S. Environmental Protection Agency.
<https://www.epa.gov/watersense/statistics-and-facts#:~:text=WaterSense%20%26%20Water%20Savings&text=The%20average%20family%20can%20save,home%20with%20WaterSense%20labeled%20models>
176. US EPA. (n.d.-c). WaterSense: Types of Facilities. U.S. Environmental Protection Agency.
<https://www.epa.gov/watersense/types-facilities>
177. US EPA. (2017). Multi-Model Framework for Quantitative Sector Impact Analysis: A Technical Report for the Fourth National Climate Assessment.
https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=OAP&dirEntryId=335095
178. U.S. Fish & Wildlife Services. (2023). National Wetlands Inventory.
<https://www.fws.gov/program/national-wetlands-inventory/data-download>
179. United States Geological Survey (USGS). (n.d.-a). Arizona StreamStats [dataset].
<https://www.usgs.gov/streamstats/arizona-streamstats>
180. USGS. (n.d.-b). StreamStats [dataset].
<https://www.usgs.gov/streamstats>
181. USGS. (n.d.-c). ScienceBase.
<https://www.sciencebase.gov/catalog/>
182. USGS. (1986). Predevelopment Hydrologic Conditions in the Alluvial Basins of Arizona and Adjacent Parts of California and New Mexico. Freethey and Anderson, Hydrologic Atlas 664.
<https://pubs.usgs.gov/publication/ha664>
183. USGS. (2015). Methods to Estimate Historical Daily Streamflow for Ungaged Stream Locations in Minnesota.
<https://pubs.usgs.gov/sir/2015/5181/sir20155181.pdf>
184. USGS. (2017). United States Geological Survey 3D Elevation Program 1/3 Arc-Second Digital Elevation Model. OpenTopography.
<https://portal.opentopography.org/raster?opentopoID=OTNED.012021.4269.1>
185. USGS. (2020). Evaluation of Uncertainty Intervals for Daily, Statistically Derived Streamflow Estimates at Ungaged Basins across the Continental U.S.
<https://www.mdpi.com/2073-4441/12/5/1390>
186. USGS. (2024a). Hydrologic Toolbox Repository.
<https://code.usgs.gov/water/hydrologic-toolbox/-/tree/v1.1.0>
187. USGS. (2024b). National Water Dashboard [Map].
<https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default>
188. USGS. (2024c). National Water Information System: Mapper.
<https://maps.waterdata.usgs.gov/mapper/index.html>
189. University of Arizona. (n.d.-a). AZMET Normal Files [dataset].
<https://cales.arizona.edu/azmet/normals.htm>
190. University of Arizona. (n.d.-b). AZMET Weather Data [dataset].
<https://cales.arizona.edu/azmet/az-data.htm>
191. University of Arizona. (2024). SnowView Precipitation (PPT) and Snow Water Equivalent (SWE). SnowView Map and Database.
<https://snowview.arizona.edu/>

192. University of Minnesota. (n.d.). Water Use in Pulp & Paper Mills. <http://www.mntap.umn.edu/industries/facility/paper/water/#:~:text=Several%20mills%20have%20successfully%20demonstrated,exchange%20within%20its%20bleaching%20system>
193. Van Kempen, T. (2003). Whole Farm Water Use. <https://www.thepigsite.com/articles/whole-farm-water-use>
194. Wilson, J., & Guan, H. (2004). Mountain-Block Hydrology and Mountain-Front Recharge. In Water Science and Application. https://www.researchgate.net/publication/251871304_Mountain-Block_Hydrology_and_Mountain-Front_Recharge
195. World Steel Association. (2020). Water management in the steel industry. <https://worldsteel.org/wp-content/uploads/Water-management-in-the-steel-industry.pdf>