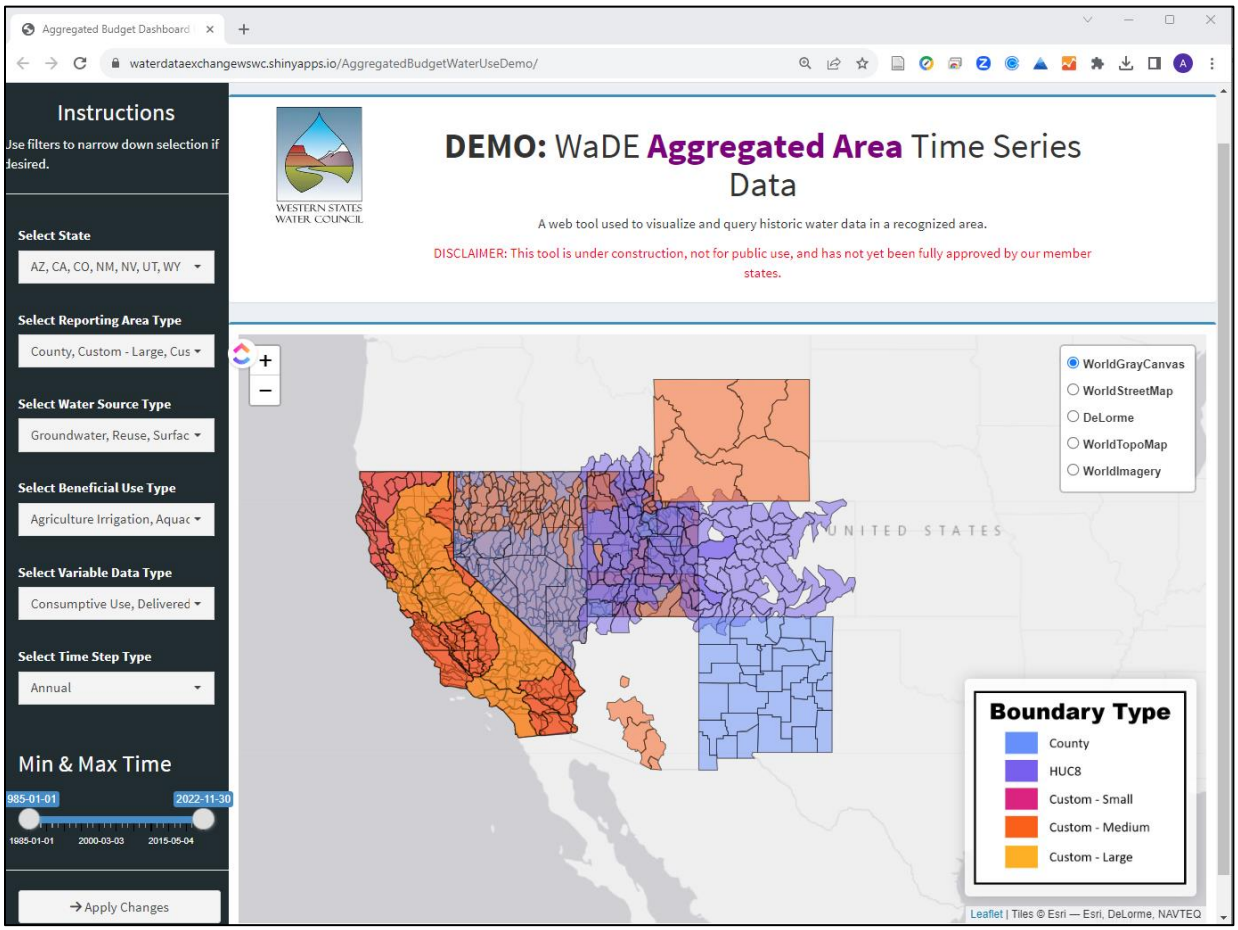
Report on the Availability of Aggregated Water Use Data in the Colorado River Basin States

November 2023

Western States Water Council (WSWC)

Water Data Exchange (WaDE) Program

Adel Abdallah: WaDE Program Manager
Ryan James: WaDE Data Analyst / Hydroinformatics Specialist



Executive Summary

The Colorado River Basin is a critical resource to its seven basin states (i.e., Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming), providing water supply for agriculture, hydropower, recreation, fish and wildlife habitat, and about 35 and 40 million people.[1] The Basin has been under a prolonged drought since 2000, highlighting the need for water data sharing and improving water budgeting estimates. Each state in the Colorado River Basin administers its own water rights and water use. Each state develops water accounting and budget models to determine in-state water use planning within and outside the Colorado River Basin. However, state water budget data is made publicly available in different formats and terminology, which makes regional analysis challenging, as highlighted by the previous Sandia National Lab study.[2] Thus, the WSWC Water Data Exchange (WaDE) Program has been on a mission since 2011 to transform western water planning, management, and policy by sharing state water data.[3] The WaDE goal is to make water rights and water use information more Findable, Accessible, Interoperable, and Reusable (FAIR) based on a common format and terminology and through an Application Programming Interface (API). In parallel with the states' efforts, the Bureau of Reclamation collects, models, and reports data on water use in the Upper and Lower Colorado River Basins for compact administration. Such reports are prepared in consultation with the States of the lower Basin individually and with the Upper Colorado River Commission.[4] The United States Geological Survey (USGS) has collected, modeled, and published water use data for major use categories in the U.S. since 1950 at the county level. In November 2023, the USGS re-published an analysis of national water use estimates from 2000 through 2020 into monthly estimates for HUC 12 watersheds for the three largest categories in the United States: self-supplied thermoelectric power generation, self-supplied irrigation, and public supply.[5]

This report summarizes the availability of data for aggregated or summary water use in the Colorado River Basin States made available through WaDE; identifies gaps within the currently available water data and improvements that could be made to fill in data gaps; and

[1] Colorado River Basin https://www.usbr.gov/ColoradoRiverBasin
[2] Mapping water availability, projected use, and cost in the western United States: https://doi.org/10.1088/1748-9326/9/6/064009
[3] WaDE: https://westernstateswater.org/wade
[4] Comparison of U.S. Geological Survey and Bureau of Reclamation water-use reporting in the Colorado River Basin, 2018 https://doi.org/10.3133/sir20185021
[5] Water Use in the United States: https://www.usgs.gov/mission-areas/water-resources/science/water-use-united-states

presents comparison insights on data availability, used time steps and range of covered years, reported parameters and methods used to estimate water use that the Colorado Basin States can use. The aggregate data represent water budget estimates at a boundary such as Hydrologic Unit Code (HUC), River Basin, or County.

During 2022-2023, the WaDE team worked on making machine-readable aggregate water use and budget data for the Colorado River Basin States to FAIR by sharing them publicly through the WaDE Data System. Each state's data is imported into the WaDE centralized database hosted in Microsoft Azure SQL Server. Water budget data mentioned here refers to model summaries of annual estimates for these components: demand, supply, withdrawal, delivered, and consumptive use within defined administrative areas such as Hydrologic Units (HUCs) or counties. Western water laws and water rights are based on reasonable beneficial use, and most owners or managers irrigating lands in the West do not directly measure consumptive use, which is a critical element of water budgeting. Consumptive use includes evaporation, transpiration, and other irrecoverable water losses not available for immediate use. Evapotranspiration (ET) from crops that consume water often serves as a useful proxy for consumptive water use on irrigated lands because it is easier to measure using satellite-based remote sensing.

The available aggregate water budget data for the seven Colorado River Basin States is accessible through a prototype application[6] and the WaDE API.[7]

- The demand component includes total requested water amounts such as water rights.
- The supply component represents estimated water availability in streams or reservoirs based on precipitation.
- The withdrawal component includes water diverted, extracted, or removed from surface water or groundwater sources.
- The delivered or applied component includes water that is conveyed to users through a municipal distribution system or put on a field for crop growth. Delivered or applied is

[6] WaDE Aggregated Area Time Series Data Prototype Application https://waterdataexchangewswc.shinyapps.io/AggregatedBudgetWaterUseDemo
[7] Aggregate Water Budget Time Series Data API: https://api.westernstateswater.org/api-reference/aggregate-water-budget-time-series-data

mostly the same as withdrawal minus carriage and evaporative losses through canals and distribution systems.

Availability of data, comparison insights, data gaps, and potential improvements

- The seven Colorado River Basin States have a mix of annual water budget estimates for one or many of these components: demand, supply, withdrawal, delivered, and consumptive use. Each state has its own methods of estimating or modeling water budgets and may not make all of them publicly available.
- Water budget and use data are summarized in different hydrologic units or administrative areas for a period ranging from 1985-2022. The availability of annual estimates increased after the 2000s.
- Consumptive use estimates for agriculture irrigation are only available in California, Utah, and Wyoming and overlap for the period of 2005-2016.
- Colorado has only model results of available water supplies in streams and reservoirs. New Mexico only has withdrawal data for 2015 and 2017.
- Surface water is not included in Nevada water withdrawal data for its groundwater hydrographic basins.
- Both California and Utah estimate consumptive use for a mix of surface and groundwater sources. Wyoming estimates consumptive use separately for surface water and groundwater. Consumptive use estimates using remote sensing require identifying the water source type for each irrigated field. Therefore, connecting irrigated fields with their points of diversion (e.g., well or canal headgate) is the biggest next step consumptive use modeling.
- WaDE has streamlined accessibility to water budget data for the Colorado River Basin States. However, the spatial scales, limited availability of water budget components, and different time frames and methods used to estimate water use make it difficult to view estimated regional water use across the Colorado Basin States.
- Modeling the water budget in an area involves collecting various data on water sources and uses, which is a time-consuming process. California and Utah have documented their process through dedicated web pages and manuals, which can be of help to the other

states. The California Department of Water Resources (DWR) has documented its process in a "Handbook for Water Budget Development."[8] Utah has a Water Budget webpage with documentation of used methods and available data.[9]

- The Utah Division of Water Resources adopted the WaDE data structure for sharing all their water budget data, river basins, and water budget components, in one file for all years.[10]
- The biggest data availability gap and opportunity for improvement is the consumptive use of data in machine-readable formats for Arizona, Colorado, Nevada, and New Mexico. The advent of OpenET with historical satellite remote-sensing evapotranspiration data for irrigated fields across the Western U.S. has substantially reduced the technical and cost barriers to adopting such technology. Evapotranspiration is used as a key proxy measure in estimating consumptive use across the western United States.[11] However, policy change is needed to adopt OpenET models, especially in interstate river basin compact administration.
- The biggest policy breakthrough was announced on June 14, 2022, by the Upper Colorado River Commission states in adopting one of the OpenET models as a uniform and consistent method to estimate consumptive use for their states. The model is called Google **E**arth **E**ngine implementation of the **M**apping **E**vapotranspiration at high **R**esolution with **I**nternalized **C**alibration model (eeMETRIC).[12] On the other hand, the Bureau of Reclamation will use another OpenET model to estimate consumptive use in the Lower Colorado River Basin states[13]. The model is used by USGS and is called the **Op**erational **S**implified **S**urface **E**nergy **B**alance (SSEBop). The official adoption of eeMETRIC and SSEBop models in the Colorado River Basin to estimate consumptive use is expected to be a game-changer in improving consumptive use estimates across the Basin States and also be a reference to other western river basins. Historically the Blaney-Criddle method was used beforehand to estimate consumptive use, but was highlighted as an outdated method.

---

[8] California Water Budget Handbook: https://data.cnra.ca.gov/dataset/water-budget-handbook
[9] Utah Water Budget: https://dwre-utahdnr.opendata.arcgis.com/pages/water-budget
[10] Download Utah Water Budget Data: https://dwre-utahdnr.opendata.arcgis.com/pages/water-budget-data
[11] OpenET: https://openetdata.org
[12] Resolution of the Upper Colorado River Commission – Consumptive Use: http://www.ucrcommission.com/wp-content/uploads/2022/07/2022-06-14-Resolution-Consumptive-Use-Measurement.pdf
[13] Personal communication October 30, 2023: Research and Modeling Group Chief, Bureau of Reclamation, Upper Colorado Basin Region.

- The Secretary of the Interior annually provides detailed and accurate records of diversions, return flows, and consumptive use of water diverted from the mainstream of the Colorado River below Lee Ferry (lower Colorado River) through the "Water Accounting Reports."[14]
- The new USGS irrigation monthly consumptive water use analysis for the 2000-2022 period by HUC12 is based on a national Landsat-based irrigation dataset and using the SSEBop OpenET model.[15] This new data and software product is expected to be a valuable resource to the western states and may inform their water budget modeling.

Overview

The Colorado River Basin is a critical resource to its seven basin states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, providing water supply for agriculture, hydropower, recreation, fish and wildlife habitat, and about 35 and 40 million people.[16] The Basin has been under a prolonged drought since 2000, highlighting the importance of water data sharing and improving water budgeting estimates. Each Colorado River Basin state administers its water rights and water use. The Colorado Basin states also develop water accounting and budget models to inform in-state water planning purposes within and outside the Colorado River Basin. However, state water budget data is made publicly available in different formats and terminology, which makes regional analysis challenging, as highlighted by the previous Sandia National Lab study.[17]

The WaDE Data System is designed to streamline data access of Western States' time series water data for aggregated water budget components, including water supply, demand, withdrawal, delivered water, and consumptive use. WaDE includes a centralized SQL Server Database hosted in Microsoft Azure and an Application Programming Interface (API) for data access, all of which are built on a common data dictionary with consistent metadata and terminology describing water use data. The WaDE goal is to make water rights and water use information more Findable, Accessible, Interoperable, and Reusable (FAIR) based on a common format and terminology and through an API.

---

[14] Lower Colorado Rive Water Accounting Reports: https://www.usbr.gov/lc/region/g4000/wtracct.html
[15] USGS HUC 12 irrigation water use dataset: https://www.usgs.gov/data/irrigation-water-use-reanalysis-2000-20-period-huc12-month-and-year-conterminous-united-states
[16] Colorado River Basin https://www.usbr.gov/ColoradoRiverBasin
[17] Mapping water availability, projected use and cost in the western United States: https://doi.org/10.1088/1748-9326/9/6/064009

The following section summarizes the availability of data for aggregated water use in the Colorado River Basin States made available through WaDE; identifies gaps within the currently available water data and improvements that could be made to fill in data gaps; and presents comparison insights on data availability, used time steps and range of covered years, reported parameters and methods used to estimate water use that the Colorado Basin States can use.

Availability, gaps, and comparison of aggregated water use and budget data in the Colorado River Basin States made available through WaDE

The following writeup summarizes aggregated water use data within WaDE and the source methodology from seven Colorado River Basin states. Aggregated water use data are model summaries of the water budget in one year over a geospatial area. Water budgets within a basin have historically been categorized by both withdrawals (i.e., how much water was taken from a stream, spring, or reservoir) and consumptive use (i.e., how much water was depleted through use). The data availability can be visualized through this interactive prototype application (Figure 1 and Figure 2). Tables 1 & and 2 below summarize the noted data type and weblinks to the states' methodology pages and the WaDE GitHub page describing how the data was mapped into WaDE. Finally, the report provides a high-level narrative summary of the water budget estimate methodology and data availability of each of the seven states.

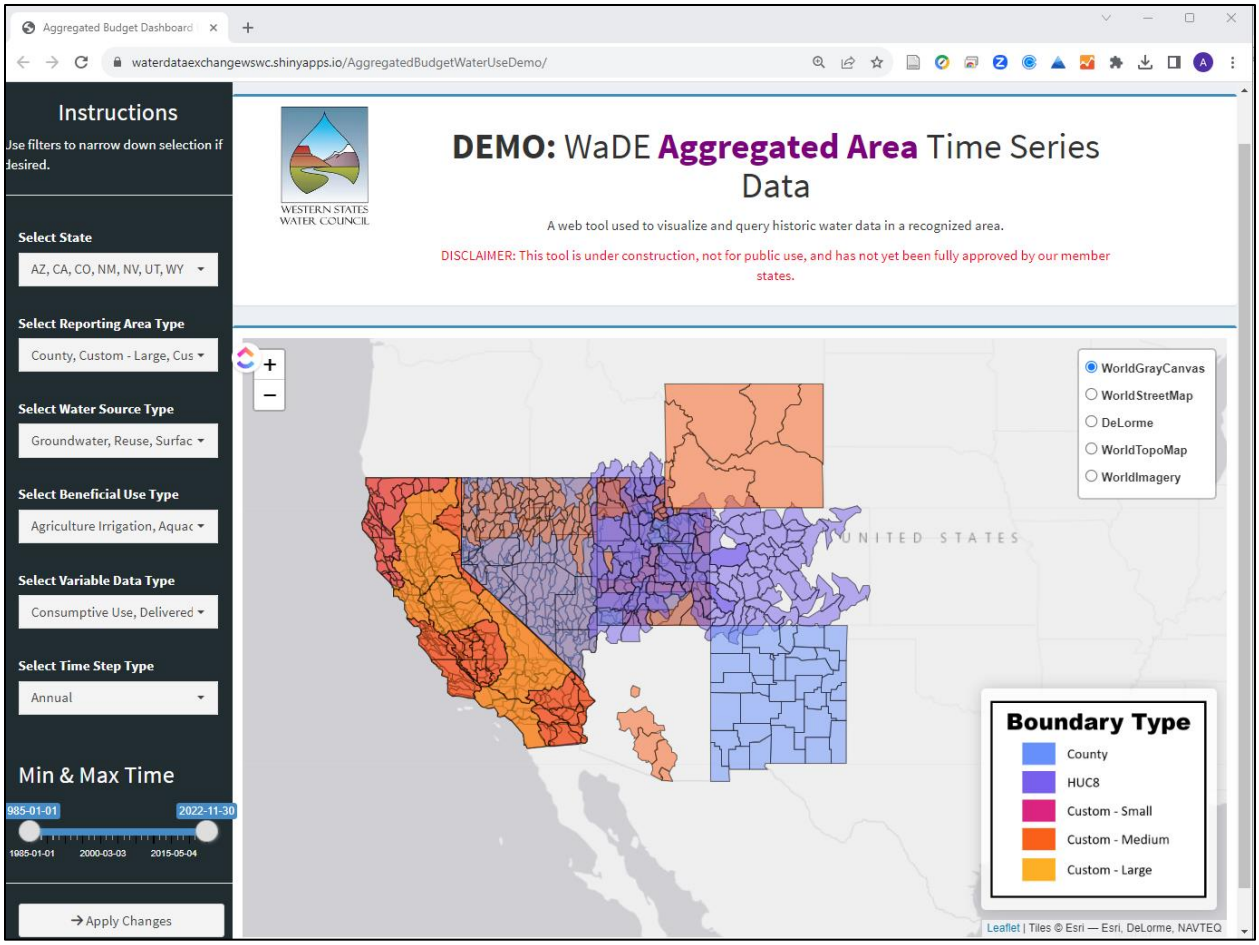


Figure 1: Screenshot of the WaDE Aggregated Area Time Series Prototype RShiny Application https://waterdataexchangewswc.shinyapps.io/AggregatedBudgetWaterUseDemo

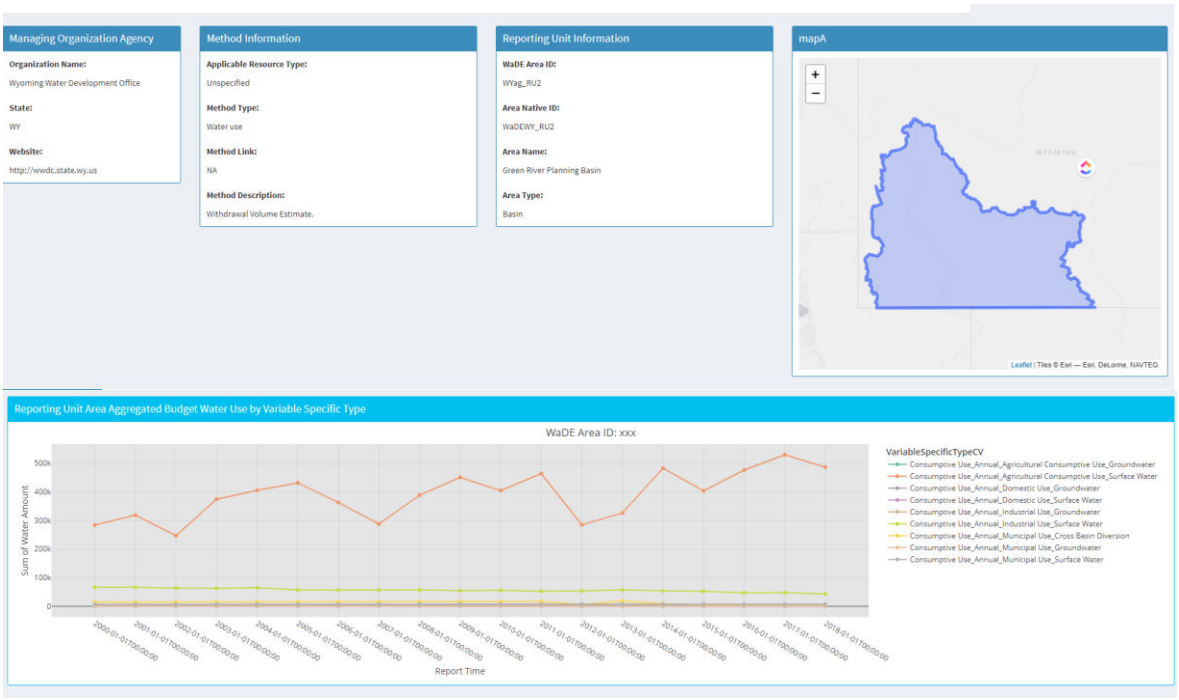


Figure 2: Screenshot of the landing page showing historical consumptive water use in Green River Planning, Wyoming. https://waterdataexchangewswc.shinyapps.io/AggregatedBudgetLandingPadgeDemo/?SQPInput=WYag_RU2

Table 1: Aggregate water use and budget components, methods, data source, and WaDE data mapping process for the Colorado River Basin states

State	State Component	State Definitions	State Data Link	WaDE Data Mapping Description
AZ	Supply, Demand	**Supply**: the sources of water available for use by a certain sector. Also referred to as "type". Sources include groundwater, CAP, surface water, reclaimed, recovered water of various types, etc. **Demand:** The end use of supplied water, beyond the categories of agriculture, industrial, and municipal. Demands include exempt and non-exempt irrigation, water losses, large provider residential and non-residential deliveries, urban irrigation, golf courses, HOAs, mining, etc.	[AZ State Link]	[AZ WaDE Link]
CA	Depletion, Applied Water use	**Depletion**—The quantity of water consumed within a service area and no longer available as a source of supply. Depletion includes evaporation, evapotranspiration, and outflow to a salt sink. **Applied Water Use**—The total amount of water diverted from any source and applied to meet the uses of urban and agricultural sectors and dedicated to the environment, including water applied for groundwater recharge. Applied water is the quantity of water delivered to the intake to a city water system, a factory, or a farm headgate, either directly or by incidental flows to a marsh or wetland for wildlife areas. For existing instream use, applied water is the portion of the streamflow dedicated to instream use or reserved under the federal or State Wild and Scenic Rivers acts, or the flow needed to meet required standards in the Sacramento-San Joaquin Delta. Applied water includes consumptive use, reuse, and outflows. Applied water includes all sources of supply (surface water, groundwater, reuse, and recycled water).	[C.A. State Link]	[C.A. WaDE Link]
CO	Forecasted Runoff, Reservoir Storage	**Forecasted Runoff** or **Reservoir Storage** entries are considered "Component types", but no definition is given to what those are.	[C.O. State Link]	[C.O. WaDE Link]
NM	Withdrawal	**Withdrawal**: The quantity of calculated, metered, or estimated water taken from a surface water or groundwater source.	[N.M. State Link]	[N.M. WaDE Link]
NV	Withdrawal	**Withdrawal**: Water diverted from the ground or diverted from a surface water source for use. It may be Consumptively or Non-consumptively used, beneficially or nonbeneficially used, or returned in part for reuse.	[N.V. State Link]	[N.V. WaDE Link]
UT	Withdrawal, Consumptive Use	**Withdrawal**: Quantity of water diverted for Municipal and Industrial uses. **Consumptive Use**: portion of water withdrawn from a surface or groundwater source that is consumed by particular use(s) and does not return to a natural water source or another body of water.	[U.T. State Link]	[U.T. WaDE Link]
WY	Consumptive Use	**Consumptive Use**: Consumptive water use is a specific subset of water use that refers to the permanent removal of water from a hydrologic system. Crop evapotranspiration, reservoir evaporation losses, and water evaporated out of a cooling tower are examples of consumptive use. In this document, consumptive water use is defined as the volume of water diverted minus the volume of water returned.	[W.Y. State Link]	[W.Y. WaDE Link]

Table 2: Comparison of data availability, gaps, used time steps and range of covered years and reported parameters for aggregate water use and budget data available in WaDE for the Colorado River Basin states

State	State parameter	Spatial Scope	Water Source Type	Water Use Category	Start Year	End Year
AZ	Supply Demand	Active Management Areas	Surface Water, Surface Water and or Groundwater	Agriculture Irrigation, Commercial/Industrial, Other Public Supply, Agriculture Irrigation, Commercial/Industrial	1985	2018
CA	Depletion Applied Water Use	Detailed Analysis Unit by County (DAUCO), Planning Area (P.A.), Hydrologic Region (H.R.)	Surface Water and or Groundwater	Agriculture Irrigation, In-stream Flow, and Public Supply Agriculture Irrigation, In-stream Flow, and Public Supply	2002	2016
CO	Forecasted Runoff Reservoir Storage	Hydrologic Unit Codes (HUC 8)	Surface Water	Unspecified	2010	2022
NM	Withdrawal	County	Surface water, and Groundwater	Agriculture Irrigation, Commercial/Industrial, Domestic Livestock, Mining, Municipal, Irrigation, Reservoir Storage	1990	2015
NV	Withdrawal	Hydrographic Basins	Groundwater	Agriculture Irrigation, Commercial/Industrial, Domestic In-stream Flow, Livestock, Mining, Other, Public Supply, Recreation	2015	2017
UT	Withdrawal Consumptive Use	Count and sub-area watershed Consumptive Use	Surface Water, Groundwater Surface Water and or Groundwater	Agriculture Irrigation, Municipal Irrigation, Public Supply	2005	2019
WY	Consumptive Use	Consumptive Use	Groundwater, Surface Water	Public Supply, Agriculture Irrigation, Commercial/Industrial, Domestic	2000	2018

Arizona

The 1980 Arizona Groundwater Code recognized the need to aggressively manage the state's finite groundwater resources to support the growing population and economy. Areas with heavy reliance on groundwater were identified and designated as Active Management Areas (AMAs) (e.g., Prescott, Phoenix, Pinal, Tucson, and Santa Cruz). The AMAs were established to provide long-term management and conservation of their limited groundwater supplies. Within AMAs, the Arizona Department of Water Resources administers state laws, develops and implements groundwater management plans, explores ways of augmenting water supplies to meet future needs, and works to develop public policy to promote efficient use and an equitable allocation of available water supplies.

California

Department of Water Resources California Water Plan program computes applied, net, and depletion water balances for California. Water balances are simplified water budgets for a water year based on analyses of developed and dedicated water supplies, water uses by sector, water reuses, operational characteristics for an area, and inflows and outflow for a study area that occur above the root zone. Dedicated and developed water supplies include surface water, groundwater, and reused and recycled water. Water uses by sector for these analyses include parameters for agriculture, urban, managed wetlands, Wild and Scenic River annual volumes, minimum required instream flows, and minimum required delta outflow, recognizing that water is often used multiple times and benefits multiple sectors. Water balance is for Detailed Analysis Unit by County (DAUCO), Planning Area (P.A.), and Hydrologic Region (H.R.). Computation and aggregation equations for applied, net, and depletion water balances are included in the Standard Operating Procedures (SOPs) for data management and analyses. Metadata are provided in a .txt file which can be opened by any text editor. Zipped data files are in .CSV format. A data verification file with summary tables is included for each year in PDF format.

Colorado

The Colorado Surface Water Supply Index (SWSI) is used as an indicator of surface water supply conditions in Colorado. It is an indicator of mountain-based water supply conditions in the major river basins and sub-basins of Colorado. Depending on the month,

the volume is a combination of components: streamflow, streamflow forecast, or reservoir storage. The SWSI compares the total volume of water in a basin or sub-basin against the volume available in the same month of historical years. The SWSI scale is from -4 to +4, where -4 indicates severe drought and +4 indicates abundant water supply.

New Mexico

Water Use withdrawal reports are prepared once every five years by the Water Use and Conservation Bureau of the New Mexico Office of the State Engineer. Use reports are used for regional planning and for tracking changes in water use in various categories over time. Water withdrawals in New Mexico counties and river basins are tabulated for nine water use categories: Public Water Supply, Self-Supplied Domestic, Irrigated Agriculture, Self-Supplied Livestock, Self-Supplied Commercial, Self-Supplied Industrial, Self-Supplied Mining, Self-Supplied Power, Reservoir Evaporation.

Nevada

The statewide pumpage inventory datasets include all public groundwater appropriated by permits and certificates issued by the State Engineer, by adjudicated and unadjudicated pre-statutory claims of vested right, and by domestic wells. Data includes existing inventories, self-reported pumpage records from water right owners, duty of water rights, and known irrigated acres. The pumpage amounts are organized by manner of use and presented by hydrographic Basin or by county. Only pumpage amounts of 2015 and 2017 are available at this time. Surface water use is not included in the pumpage amounts. Statewide inventories are only conducted on years in which National Agricultural Imagery Program (NAIP) imagery is available. Pumpage amount data based on the location of the point of diversion of water rights. Data has been normalized to the calendar year and is reported in units of acre/feet. Pumpage represents an estimate of the total amount of groundwater pumped by basin by manner of use in the State of Nevada for a certain calendar year.

Utah

The Utah Division of Water Resources developed a Water Budget Model for State, Basin, and County level water planning purposes. The Water Budget Model assists in better understanding the amount of surface water and groundwater used by major sectors (e.g., municipal and agricultural). Understanding water diversions and depletions (water removed from the system through consumption, evaporation or evapotranspiration), is fundamental to water planning.

Wyoming

Water budget data made available by the Wyoming Water Development Office (WWDO) which was developed by a consultant for the states major basins (HUC8). Water Use data and basin shapefile data were made temporary available to the WSWC staff by the WWDO via email correspondence and shared through Google Drive.