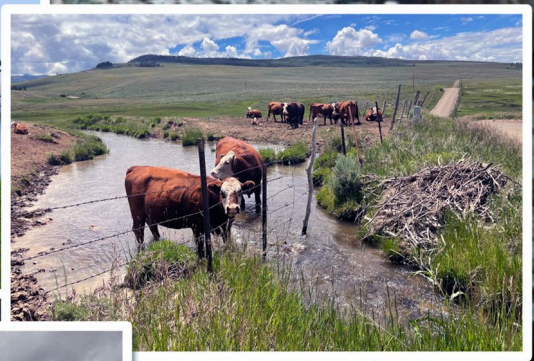
BUREAU OF RECLAMATION

Consumptive Uses and Losses: Provisional Estimate

Arizona Portion of the Upper Colorado River Basin
Calendar Year 2022
Interior Region 7: Upper Colorado Basin



U.S. Department of the Interior

October 2023

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover photos: background photo of a scenic view of creek near Inscription House, Arizona on the Navajo Nation. Inset photos from left to right:

1. Traditional Navajo hogan on the Navajo Nation at Sanostee, New Mexico
2. Center pivot irrigating alfalfa crop, Utah.
3. Cattle drink and cool off in an irrigation ditch in Gunnison County, Colorado.
4. Potash evaporation ponds in Moab, Utah.
5. Azotea tunnel outlet, New Mexico. (Reclamation photo by T. Ross Reeve)
6. Many Farms Lake and Diversion Dam on the Navajo Nation, Arizona

Consumptive Uses and Losses Provisional Estimate

Arizona Portion of the Upper Colorado River Basin

Calendar Year 2022

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U.S. Department of the Interior October **2023**

Acronyms and Abbreviations

°F	degrees Fahrenheit
af	acre feet
BIA	Bureau of Indian Affairs
GCNRA	Glen Canyon National Recreation Area
Gcpd	gallons per capita per day
NOAA	National Oceanic and Atmospheric Administration
NTUA	Navajo Tribal Utility Authority
Reclamation	Bureau of Reclamation
SCS	Soil Conservation Service
TR21	Irrigation Water Requirements Technical Release No. 21 (SCS 1970).
USDA	United States Department of Agriculture
WOM	Water Operations and Maintenance Department

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1.0 Introduction

1.1 Summary

Based upon data made available for preparation of this document, the total consumptive use and loss value for the Arizona portion of the Upper Colorado River Basin for calendar year 2022 was 11,580 acre-feet (af) (±924 af). The Bureau of Reclamation (Reclamation) prepares this estimate annually, final annual values for consumptive uses and losses for the northern Arizona portion of the Colorado River basin are published in the 5-year summary documents for the Upper Colorado River Basin.

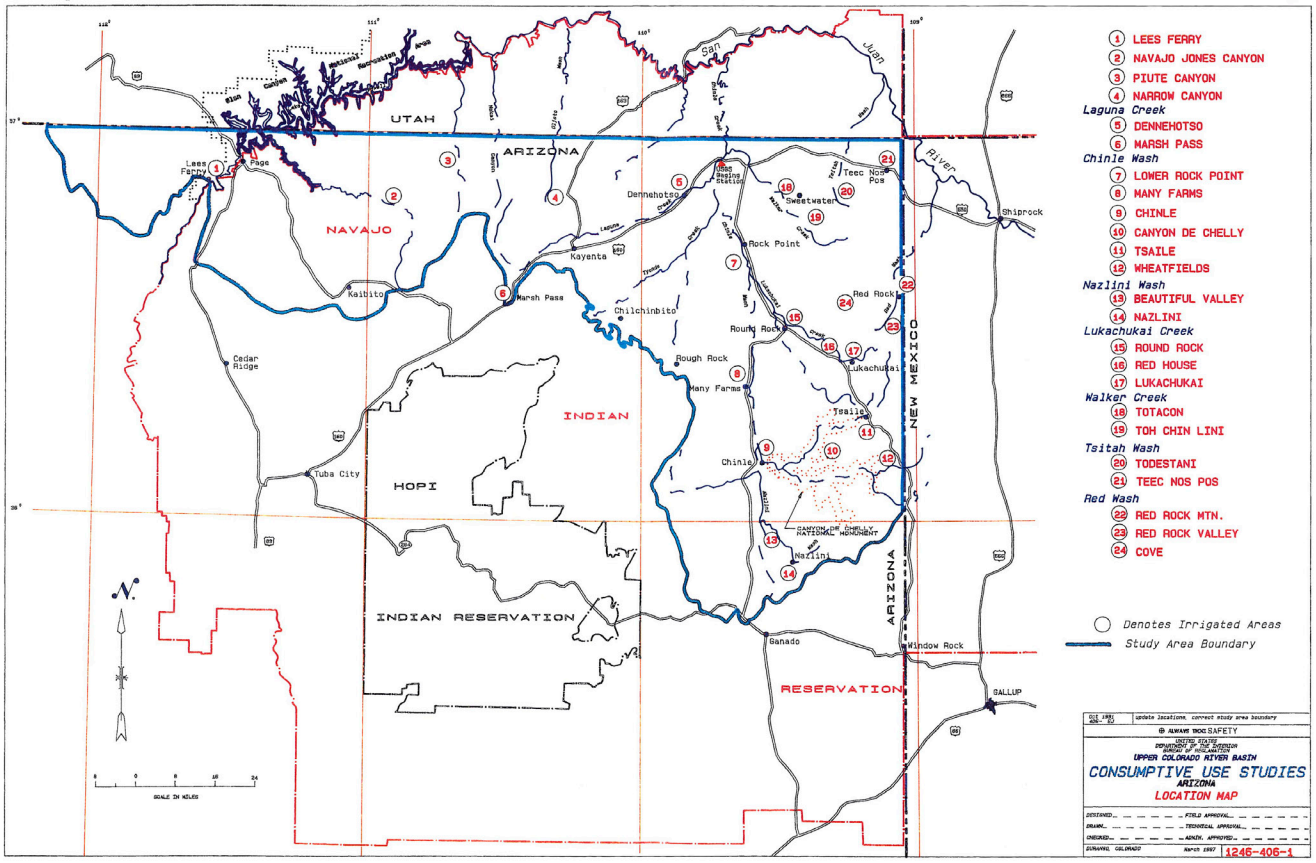

Figure 1. Study area boundary and the various irrigated areas.

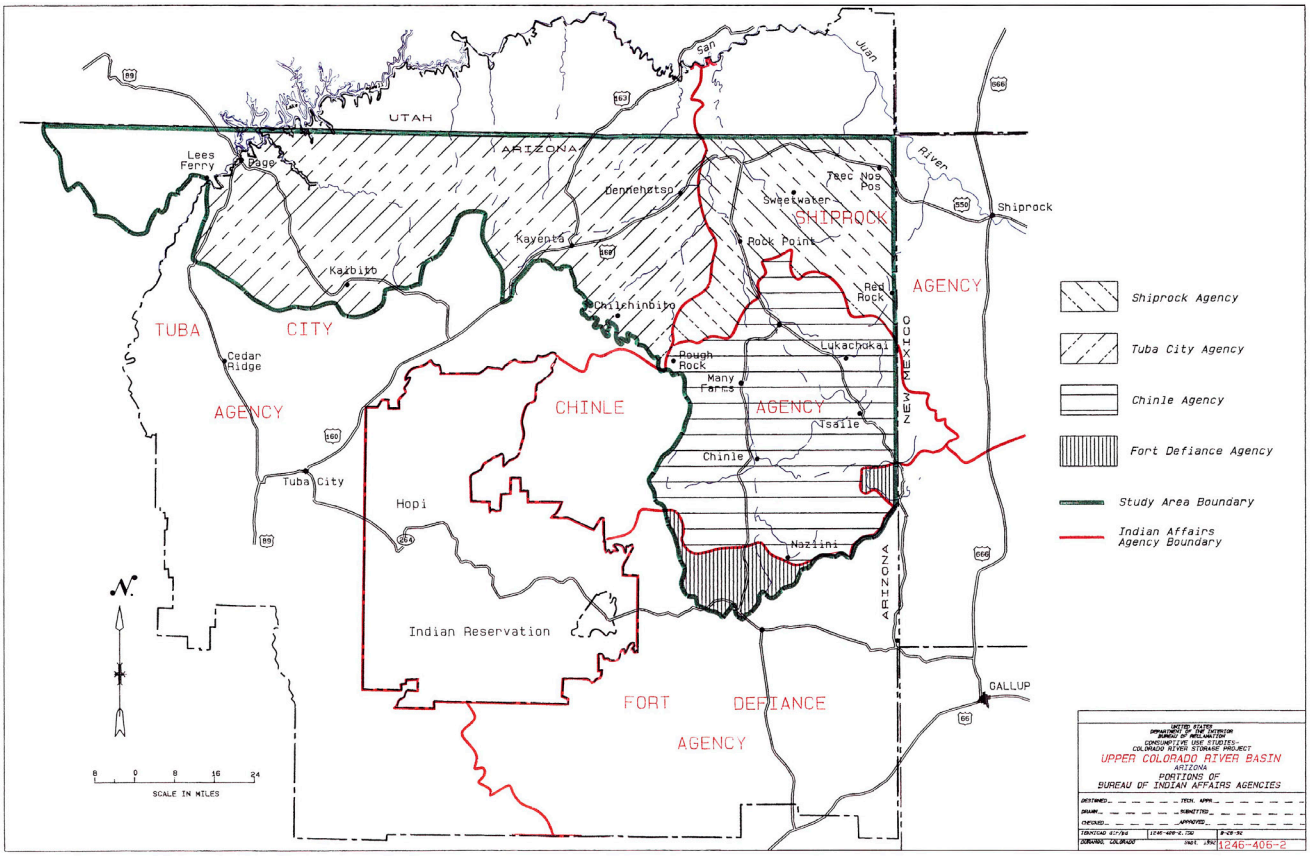

Figure 2. Study area boundary and the Bureau of Indian Affairs agency boundary.

1.2 Study Area Description

The Arizona portion of the Upper Colorado River Basin covers approximately 6,900 square miles in the north-east corner of Arizona, as shown in the Figure 1 and Figure 2 location maps. This report is a subset of the Colorado River Consumptive Use Report. The climate of the 5,900 square mile area to the west of the Chuska and Carrizo Mountains is largely arid to semiarid, with mean annual precipitation ranging from 6 to 12 inches and with summertime temperatures often reaching 100 degrees Fahrenheit (°F). The potential evaporation rate is high and exceeds mean annual precipitation, with gross lake evaporation values of up to 55 inches per year or more. Elevations in the western portion range from 3,200 feet on the Colorado River at Lee Ferry to over 8,000 feet on the northern edge of the Black Mesa and across the Zilnez and Skeleton Mesas, back down to 5,280 feet in the Chinle Valley, and back up to about 6,500 feet on the western edge of the Chuska Mountains. Much of the western part of the study area is starkly beautiful southwestern desert country with mesas and canyons intertwined across a pastoral landscape. By contrast, the eastern 1,000 square miles is largely mountainous, with elevations rising to nearly 10,000 feet and mean annual precipitation reaching 30 inches. The mountainous land responds with grass meadows interspersed with conifer forest of mostly ponderosa pine.

Except for Page, Arizona; a small area around Lee Ferry; and a portion of the Paria Plateau administered by the Bureau of Land Management; the study area lies entirely within the Navajo Nation. According to 2020 United States Census data, 56,233 persons were living within that portion of the Navajo Nation, and of these 42,477 resided within the Upper Colorado River Basin.

The largest cities are Page and Kayenta, with 2020 United States Census populations of 7,551 and 5,634, respectively. Other major communities and their populations include Dennehotso (717), Kaibeto (1,755), Chinle (4,291), LeChee (1,435), Lukachukai (1,774), Many Farms (867), Rock Point (529), Teec Nos Pos (798), and Tsaile (1,345). Subsistence in the region is derived principally from livestock grazing, farming, tourist-related industries, employment at the Navajo Generating Station (NGS), which has been decommissioned and shutdown, it now consumes less than 1 percent of the water used or lost in the study area on average every year, well down from historic usage of approximately 61 percent in 2019. Agriculture accounts for about 25 percent of the total water use; municipal and industrial about 43 percent; recreation, fish and wildlife, about 11 percent; and reservoir evaporation, about 21 percent in an average year.

1.3 Authority

This report was prepared in compliance with Public Law 90-537, Section 601 (b)(1), dated September 30, 1968, which directs the Secretary of the Interior to "make reports as to the annual consumptive uses and losses of water from the Colorado River System. . . starting on October 1, 1970. Such reports shall include a detailed breakdown of the beneficial consumptive use of water on a state-by-state basis." Additionally, this report is in compliance with Section 49 of the Navajo Project Participation Agreement dated September 30, 1969, which states in part: "The Secretary of the Interior further agrees to make the reports required by Section 601 (b)(1) of Public Law 90-537 as they pertain to Arizona's Upper Basin uses annually rather than every five years. Within fifteen days following the completion of said reports, the Secretary of the Interior shall furnish copies of such reports to the Co-Tenants, the Navajo Tribe, each of the Upper Basin States, and the Upper Colorado River Commission."

2.0 Consumptive Uses

Estimates of uncertainty in the data are presented as a percent of the consumptive use value, noted in the individual consumptive use sections presented below. The total degree of uncertainty is computed by taking the square root of the sum of the individual uncertainties squared; known as the quadratic sum. This method and nomenclature is used throughout this report. This method was used because a simple sum does not account for the partial cancellation of errors occurring when calculating the total uncertainty derived from individual values that are random and independent of each other. Estimations of uncertainty were based upon a reasonable estimate of error due to lack of necessary information required to precisely calculate error. The combining of estimates of uncertainty does not imply an equivalence of uncertainty from sector to sector.

2.1 Agricultural Consumptive Uses

Agricultural consumptive use is divided into three categories:

- **Irrigation use** includes all use related to irrigating crops including the incidental losses
- **Stock pond use** is the evaporation that occurs from stock ponds
- **Livestock use** is the water consumed by livestock

2.1.1 Irrigation Uses

Within the Arizona portion of the Upper Colorado River Basin, historically 23 irrigated areas were scattered across the Navajo Nation plus a small amount of land near Lee Ferry irrigated by the National Park Service. Currently, only 16 irrigated areas are in production. An accurate assessment of consumptive use on the irrigated land is difficult due to poor quality of information, such as the exact number of acres under irrigation, the cropping pattern for each irrigated area, site climatological conditions, and the amount of water actually diverted. In many cases, during the latter part of the irrigation season, farmers have to rely on dry land farming since there is little water available in the streams. This means that the crops do not receive their full water requirement.

For this report, the U.S. Department of Agriculture (USDA), Soil Conservation Service's (SCS) Modified Blaney-Criddle evapotranspiration, without an elevation adjustment, estimation formula was used for computing irrigated crop consumptive use. This model, along with appropriate crop-growth stage coefficients and the method for computing effective precipitation, is described in SCS (1970). Information required for applying this model includes mean monthly temperature and monthly total precipitation values, growing season data for each crop type, and the total number of acres planted by crop at each site. No climatological data exists for the irrigation sites other than Teec Nos Pos, Canyon de Chelly, Lukachukai, Betatakin, and Lee Ferry. Where no data exists, values must be generated from data collected at surrounding established weather stations. Growing season dates depend largely on the judgment of the local inhabitants and are, therefore, not known. Although data are available from the National Agricultural Statistics Service and the Cropland Data Layer, with values for irrigated acres, it is unclear if these values represent actual acres currently under irrigation.

The crop acreage used to estimate consumptive use by irrigated crops for the year 2022 is shown in Table 1. These values were estimated from previous direct field examination by a party composed of representatives from the State of Arizona and the Navajo Nation. It has been some time since these acreage numbers were updated by Navajo Nation representatives, other than to indicate that the acreages vary minimally from year to year. Due to the rehabilitation of the Many Farms Dam, a substantial reduction in irrigated acreage for this area was realized in 2006. Navajo Nation representatives indicate that the Many Farms area will return slowly to its historic average acreage (590 acres) as the dam refills. An estimated 5% increase in irrigated acreage is assumed annually until the full acreage is attained.

Table 1.Total Irrigated Acreage, 2022

Project	Corn (acres)	Alfalfa (acres)	Grass pasture (acres)	Spring grains (acres)	Small vegetables (acres)	Orchard (acres)	Total (acres)
Chinle Agency							
Canyon de Chelly	0.36	0.00	0.00	3.03	2.26	0.00	5.65
Lukachukai	39.09	7.69	0.00	7.50	5.98	2.07	62.33
Many Farms	235.99	39.37	145.72	3.84	39.37	0.00	464.30
Nazlini	0.00	0.00	0.00	0.00	1.79	0.74	2.53
Rough Rock	30.00	0.00	11.87	0.00	12.43	0.00	54.30
Tsaile	23.72	5.27	15.67	5.73	5.42	0.00	55.81
Wheatfields	0.00	60.80	0.00	0.00	0.00	0.00	60.80
TOTAL	**329.16**	**113.13**	**173.26**	**20.10**	**67.25**	**2.81**	**705.72**
Shiprock Agency							
Red Rock Valley	26.22	0.00	10.19	5.12	10.22	0.00	51.75
Teec Nos Pos	20.00	0.00	0.00	0.00	3.67	0.00	23.67
Toh Chin Lini	0.00	0.00	0.00	0.00	3.90	13.67	17.57
Totacon	0.00	0.00	0.00	0.00	1.00	0.00	1.00
TOTAL	**46.22**	**0.00**	**10.19**	**5.12**	**18.79**	**13.67**	**93.99**
Western Navajo Agency							
Dennehotso	1.82	0.00	38.70	0.00	0.00	0.00	40.52
Lees Ferry	0.00	0.00	1.00	0.00	0.00	2.00	3.00
Marsh Pass	7.02	3.31	0.00	0.00	1.99	0.00	12.32
Navajo Canyon	0.00	0.00	0.00	0.00	0.00	3.50	3.50
Paiute Canyon	2.64	0.00	0.00	0.00	3.86	0.00	6.50
TOTAL	**11.48**	**3.31**	**39.70**	**0.00**	**5.85**	**5.50**	**65.84**
GRAND TOTAL	**386.86**	**116.44**	**223.15**	**25.22**	**91.89**	**21.98**	**865.55**

Several factors complicate irrigation consumptive use modeling. For example, the Modified Blaney-Criddle computer program used to model consumptive use assumes a full water supply. If shortages exist, as they often do in this semiarid study area, adjustments must be made. These adjustments are complicated because some of the projects have no storage water and may only have a reliable irrigation water supply during spring runoff. After spring runoff, farming becomes essentially dry land until rains in July and August provide intermittent flows for irrigation. Finally, no ditch diversion records are available to help estimate irrigation water supplies and shortages.

A full irrigation supply seldom exists at many of the projects. Generally, a full supply is available for Lee Ferry, Navajo Canyon, Tsaile, and Wheatfields projects as there is both or either adequate stream flows or available storage water. It would require approximately 12.67 inches of precipitation to provide 100 percent of the irrigation requirement. Precipitation in the area averages approximately 10.4 inches per year using meteorological data provided by the National Weather Service (NWS) Cooperative Observer Program (COOP) network stations Betatakin (AZ0750) and Canyon De Chelly (AZ1248) 1971-2021. In years with average precipitation, it is estimated that Chinle Wash provides approximately 75 percent of the irrigation requirement. The percent of crop water requirement met was computed as a ratio of annual precipitation to 12.67 inches. These values are found in Table 2.

To determine the amount of crop consumptive use, the percentage of crop water requirement met was multiplied by the total net crop water requirement. Incidental irrigation losses, evaporation, and phreatophyte consumptive use along supply canals are estimated to be 5 percent of the consumptive use of the irrigated area and are added to the crop consumptive use value to develop a total consumptive use value.

A portion of the water used for irrigation at these sites may not be contributing to the Colorado River System since evaporation rates in the area are high and the nature of most of the drainage enhances evapotranspiration. A good example of such a drainage is Chinle Wash, which becomes wide and sandy and is lined with willows, cottonwoods, and other phreatophytes after leaving Canyon de Chelly.

The uncertainties in the irrigation consumptive use values displayed in Table 2 are very large—estimated as 40 percent of the total consumptive use. This estimate of possible error only reflects the uncertainty of consumptive use and does not account for any possible errors in the acreage estimates. The effective consumptive use for irrigation for 2022 was estimated to equal 1,567 acre-feet. Including 5 percent for incidental losses, the irrigation related consumptive use is 1,645 (±374) acre-feet.

Table 2. Net Consumptive Use Values, 2022

Project	Crop water requirement (in)	Total irrigated (acres)	Total water required (af)	Crop water requirement met (%)	Crop water requirement met (af)	Total consumptive use (af)[1]
Chinle Agency						
Canyon de Chelly	25.91	5.65	12	82%	10	10.5
Lukachukai	27.01	62.33	140	82%	115	120.6
Many Farms	26.86	464.30	1039	82%	851	893.3
Nazlini	24.20	2.53	5	82%	4	4.4
Rough Rock	21.61	54.30	98	100%	98	102.7
Tsaile	27.42	55.81	128	82%	104	109.6
Wheatfields	34.92	60.80	177	82%	145	152.1
TOTAL	**187.93**	**705.72**	**1599**		**1327**	**1,393.1**
Shiprock Agency						
Red Rock Valley	29.53	51.75	127	69%	88	92.9
Teec Nos Pos	33.07	23.67	65	57%	37	39.1
Toh Chin Lini	39.12	17.57	57	29%	16	17.2
Totacon	26.55	1.00	2	29%	0.6	0.7
TOTAL	**128.27**	**93.99**	**252**		**143**	**149.8**
Western Navajo Agency						
Dennehotso	35.48	40.52	120	41%	49	51.5
Lee Ferry	42.31	3.00	11	100%	11	11.1
Marsh Pass	20.39	12.32	21	92%	19	20.1
Navajo Canyon	36.42	3.50	11	100%	11	11.2
Paiute Canyon	23.91	6.50	13	61%	8	8.3
TOTAL	**158.50**	**65.84**	**175**		**97**	**102.2**
GRAND TOTAL	**474.70**	**865.55**	**2026**		**1,567**	**1,645.1**

[1] Total includes 5% addition for incidental losses.

2.1.2 Stock Pond Evaporation

Stock pond consumptive use is assumed to be from the evaporation from area stock ponds. It is also assumed that any consumptive use by natural vegetation prior to the construction of the stock ponds is limited to precipitation, which is subtracted from the evaporation losses.

A compilation of the stock ponds in the study area, including their locations and the water surface areas when ponds are full, was obtained from Bureau of Indian Affairs (BIA) (1985) and are shown in Table 3. For average year conditions, the stock pond evaporative surface area was estimated as one-third of the water surface area that occurs when the ponds are full. The surface area used was computed by multiplying the percentage of water supply available (the ratio of the current year precipitation to the average annual precipitation) by the average water surface area. These values are found in Table 3.

Table 3. Stock Pond Evaporation, 2022

County	Surface area full (acres)	Surface area used (acres)	Water supply available (%)	Lake evaporation (inches)	Precipitation (inches)	Net evaporation (inches)	Net evaporation (acre-feet)
Coconino	80	27	100%	57	15.46	41.54	92.3
Navajo	40	13	100%	55	11.75	43.26	48.1
Apache	646	215	100%	53	8.80	44.20	792.7
Total	**766**	**255**					**933.1**

This method of evaporation estimation was used because continuous useful water level records for all stock ponds from which surface area could be accurately computed were not available. Another factor complicating the estimating procedure is that evaporation rates are not known at the individual stock ponds. For this report, the Evaporation Atlas for the Contiguous 48 United States (National Oceanic and Atmospheric Administration [NOAA] 1982) was used to determine the amount of lake evaporation. It was assumed that any consumptive use by natural vegetation prior to construction of the stock ponds is limited to precipitation which is subtracted from reservoir evaporation losses.

The computed values for stock pond evaporation for calendar year 2022 are shown in table 3. The total evaporative losses in 2022 are 933 (±240) acre-feet with the stock pond evaporation uncertainty being estimated as 30 percent.

2.1.3 Livestock Water

The source of most livestock water in the study area is from wells, with windmill-operated pumps developed and maintained by Navajo Water Operations and Maintenance, and water collected in small surface ponds. The estimated number of livestock in the area was estimated based on previous livestock tallies and current-year estimates from the USDA National Agriculture Statistics Service (NASS). It was estimated that horses and cattle consume 12 gallons per day; sheep and goats consume 2 gallons per day.

The number of animals for the Upper Colorado portion of each district is shown in Table 4. The computed value for livestock consumptive use is 717 acre-feet. The uncertainty in this number is estimated as 30 percent of the total or ±192 acre-feet.

Table 4. Number of Livestock, 2022

Agency	Cattle	Horses	Sheep	Goats
Western Navajo District No. 1	0	0	624	0
Western Navajo District No. 2	2,058	53	1,447	2,623
Western Navajo District No. 8	11,322	2,385	17,843	11,559
Shiprock District No. 9	1,177	0	4,883	4,669
Chinle District No. 10	4,937	1,296	8,574	4,396
Chinle District No. 11	3,232	469	3,986	3,632
Shiprock District No. 12	9,268	1,727	14,703	7,725
Fort Defiance District No. 17	0	146	1,214	1,377
Fort Defiance District No. 18	0	235	908	0
TOTAL	**31,994**	**6,311**	**54,182**	**35,981**

2.1.4 Total Agricultural Consumptive Use

The total agricultural consumptive use is the sum of the individual components discussed in the previous sections (Table 5). Agricultural water consumption represents approximately 28 percent of the total use in the study area.

Table 5. Total Agricultural Consumptive Use, 2022

Category	Consumptive use (acre-feet)	Estimated uncertainty ± (acre-feet)
Irrigation	1,645	374
Stock Ponds	933	240
Livestock	717	192
TOTAL	3,295	484

2.2 Municipal and Industrial Consumptive Use

Municipal and industrial consumptive use is divided into three categories: mineral resources, thermal electric power, and other. Mineral resources consumptive use includes water used for mineral production. No mineral resources consumptive use is reported in the study area. Thermal electric power consumptive use includes the water used at the power plants, and that used to transport material to the power plant (such as a coal slurry pipeline). Other consumptive use includes urban, rural, and industrial uses.

2.2.1 Thermal Electric Power

Thermal electric power consumptive use includes the water used in the power plant and the water used to transport material to the plant.

2.2.2 Navajo Generating Station

The water used by the Navajo Generating Station (NGS) is pumped directly from Lake Powell and comprises approximately less than 2 percent of the total consumption in the study area. Since all NGS water use is metered, this quantity is among those most precisely known, with the maximum uncertainty in the metered quantities believed to be less than 3 percent. The actual quantity consumed, along with the estimated uncertainty for the calendar year 2022, was 208 (±6) acre-feet. During the Retirement Period of the Navajo Generating Station (which began on December 23, 2019 and continues through December 22, 2024), the water usage will be no more than 1,500 acre-feet per calendar year.

2.2.3 Other

The other consumptive use category includes the remaining use by urban, rural, and industries.

2.2.3.1 *Page, Arizona and Vicinity*

City of Page, Arizona. The City of Page pumps its domestic water directly from Lake Powell. The water pumped is metered, and the uncertainty of the pumped quantities was assumed to be less than 3 percent. A portion of the water pumped and treated by the City of Page is supplied to the community of Le Chee on the Navajo Nation and is accounted for separately. The quantity supplied to the City of Page and its associated uncertainty for the calendar year 2022 was 2,219 (±67) acre-feet. Water returning to the waste water treatment plant is metered as well. The waste water for the City of Page is treated and is either evaporated from lined ponds or applied to the golf course, with a portion being returned to the Colorado River. The return flow is estimated to be 1,446 acre-feet. The net consumptive use is estimated to be 773 acre-feet (±79).

Le Chee. The community of Le Chee is supplied and metered by the City of Page. Total water supplied for 2022 was 94 (±3) acre-feet. The uncertainty was estimated to be 3 percent.

Greenhaven Water Company. The Greenhaven Water Company derives its domestic water supply from wells. Well pumping records are available. According to these records, the total water pumped for 2022 was 121 (±8) acre-feet. The uncertainty was estimated to be 7 percent.

Arizona Department of Transportation Housing. The Arizona Department of Transportation operates a housing, maintenance, and administrative facility located on US Hwy 89, north of Page, Arizona. This facility is supplied from wells that have no meters installed. It is estimated that the total water pumped for 2022 was 7 acre-feet with an uncertainty of 30 percent of this value or ±2 acre-feet.

2.2.3.1.1 Navajo Nation

Community Water Systems. 1980 statistics from the Division of Community Development of the Navajo Nation reveal that various community water systems served 26,086, or about 83 percent of the 31,429 people residing within the study area at that time. These 1980 statistics have not been updated; therefore, the same percentage (83 percent) was applied to the 2022 Navajo Nation population projection calculated using the 2020 United States Census data. This resulted in an estimate of 35,664 out of 42,969 people being served by community water systems in 2022. These systems include those operated by the Navajo Tribal Utility Authority (NTUA), the BIA, and the Water Operations and Maintenance Department of the Navajo Nation, and some privately developed community water systems.

Table 6 shows the source of water and estimated population served by each source of water for people living on the Navajo Nation during 2022. All of the communities obtain their water supply from ground water.

Table 6. Domestic Water Sources, 2022

Source	Percentage of population served	Number of population served[1]
Community Water Systems	83	35,664
Navajo Tribal Utility Authority	[2](60)	21,398
Bureau of Indian Affairs	[2](25)	8,916
Navajo Water Operations and Maintenance Department	[2](13)	4,636
Private	[2](2)	713
Individual Wells	17	7,305
TOTAL	**100**	**42,969**

[1] Total population within the Upper Colorado River Basin portion of the Navajo Nation, estimated from 2020 US Census.

[2] These numbers are a percentage of the Community Water Systems.

Navajo Tribal Utility Authority Water Systems. The cities and surrounding communities of Oak Springs, Red Valley, Sweetwater, Chinle, Rough Rock, Round Rock, Rock Point, Wheatfields, Lukachukai, Kayenta, Chilchinbeto, Dennehotso, and Kaibeto derive most of their domestic water supply from wells operated by the Navajo Tribal Utility Authority (NTUA). Well pumping records are available. According to these records, the total water pumped for 2022 was 1,596 acre-feet with an uncertainty estimated to be 7 percent of this value or ±113 acre-feet.

The NTUA manages the raw waste water contained in individual septic tanks, evaporation ponds, and wastewater treatment plans for the cities of Chinle and Kayenta. Very little water, if any, is returned to the ground water system through leakage from the evaporation ponds, but there are losses from the main collection system. Effluent from the Chinle and Kayenta waste water treatment plants is metered. Under normal conditions, the effluent returns to the Colorado River System and is subtracted from the pumping totals to determine a net consumptive use. For 2022, Chinle's treatment plant effluent was 13.6 (±1.0) acre-feet, and Kayenta's effluent was 9.7 (±0.7) acre-feet. An estimated uncertainty of 7 percent was used for the effluent of these two plants. The total effluent of 23.3 acre-feet is subtracted from the NTUA pumping total of 1,619 acre-feet to arrive at a net consumptive use of 1,596 (±113) acre-feet.

Bureau of Indian Affairs Water Systems. Wells developed and operated by the BIA serve numerous Navajo communities. These systems also serve BIA schools, hospitals, agency offices, and some housing on the Navajo Nation. Metered records for total amounts of water pumped from BIA wells were available for a portion of the Shiprock Agency, the Western Navajo Agency, and the Chinle Agency. Figure 2 shows the agency boundaries within the Upper Colorado River Basin. The uncertainty was estimated to be about 7 percent for all three agencies.

The BIA systems include sewage disposal units terminating in lined evaporation ponds with very little or no return water returning to the ground water system. Undoubtedly, some losses occur in distribution, but insufficient data currently exist to estimate these losses. The losses are probably less than the uncertainties for each of the reported values.

The BIA well data available for the Shiprock Agency include: Cove, Red Rock, and Teec Nos Pos. Total consumptive use values are 11 (±1) acre-feet.

Pumping records for the Western Navajo Agency include data for these schools: Chilchinbeto Day School, Dennehotso Boarding School, Kaibeto Boarding School, and Kayenta Boarding School. Total consumptive use for the Western Navajo Agency was 172 (±12) acre-feet.

Well pumping records for the Chinle Agency include data for the following schools: Cottonwood Day School, Lukachukai School, and Rock Point School. Rough Rock School maintains its own records, but the data was included with the Chinle Agency data. Total consumptive use for the Chinle Agency was 69 (±5) acre-feet.

Navajo Water Operations and Maintenance Department Water Systems. Water use in 2022 by the Navajo Water Operations and Maintenance Department (WOM) service areas was based on an assumed consumption rate of 110 gallons per capita per day (gpcd). For a 2022 estimated service area population of 4,636, the estimated annual water use was 571 (±171) acre-feet. The uncertainty is estimated as 30 percent of the total.

Private Water Systems. The estimated 2022 population served by private water systems on the Navajo Nation was 713. Assuming a consumptive use rate of 110 gallons per capita per day (gcpd), the annual water use for 2022 was 88 (±26) acre-feet. The uncertainty is estimated as 30 percent of the total.

Individual Wells. According to census data from the Navajo Nation's Division of Community Development, approximately 17 percent of the study area's population on the reservation (about 7,305 persons in 2022) receives a domestic water supply from individual wells. A consumptive use of 110 gpcd was derived as being a reasonable water use rate. Based on these figures, the annual consumptive use was 900 (±270) acre-feet for 2022.

2.2.4 Total Municipal and Industrial Consumptive Use

The total municipal and industrial consumptive use is the sum of the individual components discussed in the previous sections (Table 7). Municipal and industrial water consumption, including the Navajo Generating Station, represents approximately 40 percent of the total use in the study area.

Table 7. Total Municipal and Industrial Consumptive Use, 2022

User	Consumptive use (af)	Estimated uncertainty ± (af)
Thermal electric power		
Navajo Generating Station	208	9
Other		
Page, Arizona and vicinity		
City of Page	773	79
Le Chee	94	3
Greenhaven Water Company	121	8
Arizona Department of Transportation	7	2
Navajo Indian Reservation		
Community Water Systems		
Navajo Tribal Utility Authority Water Systems	1,596	113
Bureau of Indian Affairs Water Systems	252	13
Navajo Water Operations and Maintenance Department	571	171
Private Water Systems	88	26
Individual Wells	900	270
TOTAL	**4,610**	**350**

It is questionable whether all the water pumped from wells should be considered a depletion to the Colorado River System; however, it is assumed that 100 percent of the water pumped is considered lost to the system. It is proposed that a future joint study be completed by Reclamation, the State of Arizona, and the Navajo Nation to estimate what percentage of water pumped could actually be attributed to the Colorado River System and thus would have affected the river flows for a particular year.

2.3 Recreation, Fish, and Wildlife

The recreation, fish, and wildlife consumptive uses include evaporation from reservoirs used exclusively for fish and wildlife purposes as well as acreages irrigated for wildlife feeding. Consumptive use related to recreation at Glen Canyon National Recreation Area (GCNRA) is also addressed.

2.3.1 Glen Canyon National Recreation Area

Colorado River water is used by the GCNRA at Wahweap and Lee Ferry. The recreational area at Wahweap also gets its water supply from a series of wells on the shore of Lake Powell. This water was used for domestic purposes at the campgrounds, picnic areas, and trailer parks. It was also used to irrigate approximately 60 acres of Bermuda grass and cottonwood trees. The domestic waste water is treated and the effluent is allowed to evaporate from two lined evaporation ponds with a total surface area of 16.7 acres. Pumping records for both Wahweap Marina, and Lee Ferry show 205 (±6) acre-feet of water withdrawn during 2022. The uncertainty is estimated at 3 percent.

Based on estimates of evaporation and consumptive use by the plants, there is some water which is unaccounted for and is assumed to be leakage from the delivery system, the evaporation pond, or deep percolation from irrigation application. However, since these water losses are difficult to quantify and verify, the losses were charged as consumptive uses. Therefore, net consumptive use of water is estimated to be equal to the quantity of water pumped.

2.3.2 Fish and Wildlife and Reservoir Evaporation

A listing of the reservoirs in the study area, including their locations and normal water surface areas, was obtained from BIA (1985) and are shown in Table 8.

Table 8. Recreation, Fish and Wildlife Reservoir Evaporation, 2022

Reservoir	Surface acres full (acres)	Surface area used (acres)	Lake evaporation (inches)	Net precipitation (inches)	Net evaporation (inches)	Net evaporation (acre-feet)
Tsaile	260	260	35	10.37	24.63	533.7
Wheatfields	272	272	32	10.37	21.63	490.3
TOTAL	**532**	**532**				**1,024**

Efforts are made to maintain a nearly full condition and to minimize water surface fluctuations in reservoirs managed for a fishery. Under average operating conditions, the water surface area of a reservoir used primarily for fishing is assumed to be equal to a normal water surface area. It is assumed that, in 2022, these reservoirs filled in the spring and were maintained at the normal pool level.

This method of evaporation estimation was used because continuous useful water level records for all reservoirs from which surface area could be accurately computed were not available. Another factor complicating the estimating procedure is that evaporation rates are not known at the individual reservoirs.

For this report, NOAA (1982) was used to determine the amount of lake evaporation at each reservoir location. It was assumed that any consumptive use by natural vegetation prior to construction of the reservoirs is limited to precipitation which is subtracted from reservoir evaporation losses.

The computed values for reservoir evaporation for calendar year 2022 are shown in Table 8. The total evaporative losses in 2022 are 1,229 (±307) acre-feet with the reservoir evaporation uncertainty being estimated as 30 percent.

2.3.3 Total Recreation, Fish and Wildlife

The total recreation, fish and wildlife consumptive use, displayed in Table 9, is the sum of the individual components discussed in the previous sections. Recreation, fish, and wildlife water consumption represents approximately 11 percent of the total use in the study area.

Table 9. Total Recreation, Fish and Wildlife Consumptive Use, 2022

User	Consumptive use (acre-feet)	Estimated uncertainty (acre-feet)
Glen Canyon National Recreation Area	205	6
Reservoir Evaporation	1,024	307
TOTAL	**1,229**	**307**

2.4 Irrigation Reservoir Evaporation

Reservoir evaporation losses make up about 21 percent of the total water uses and losses in the study area. Reservoir data in the study area, including their locations and normal water surface areas, was obtained BIA (1985) and is shown in Table 10. These reservoirs are used primarily for irrigation.

Table 10. Reservoir Evaporation, 2022

Reservoir	Surface acres full (acres)	Surface acres used (acres)	Water supply available (%)	Lake evaporation (inches)	Net precipitation (inches)	Net evaporation (inches)	Net evaporation (acre-feet)
Many Farms	1,800	554	100%	56	10.37	45.63	2,108.4
Marsh Pass	40	20	100%	40	13.60	26.40	44.0
Round Rock	83	41	100%	57	8.80	48.20	166.6
Walker Creek	30	13	89%	59	7.23	51.77	57.9
Others	38	19	100%	55	11.01	43.99	69.6
TOTAL	**1,991**	**648**					**2,446.5**

Reservoirs used primarily for irrigation experience large fluctuations in water levels and, correspondingly, large variations in surface area. Reservoir level records and elevation- area curves were available at Many Farms, but not for the remaining reservoirs in Table 10. For the reservoirs with no records from which surface area could be accurately computed, the average evaporative surface area was estimated as one-half the water surface area of a full reservoir. The surface area used was computed by multiplying the percentage of water supply available (the ratio of the current year precipitation to the average annual precipitation) by the average evaporative surface area.

Another factor complicating the estimating procedure is that evaporation rates are not known at the individual reservoirs. For this report, NOAA (1982), was used to determine the amount of lake evaporation at each reservoir location. It was assumed that any consumptive use by natural vegetation prior to construction of the reservoirs is limited to precipitation which is subtracted from reservoir evaporation losses. The computed values for reservoir evaporation for 2021 are shown in Table 10. The total evaporative losses in 2022 are 2,447 (±635) acre-feet with the reservoir evaporation uncertainty being estimated as 30 percent of the total evaporation.

3.0 Conclusions

This report assesses the total consumptive use of the Arizona portion of the Upper Colorado River surface water systems, depletion of ground water, and evaporative losses. Clearly, the amounts of water used by the Navajo Generating Station, City of Page, and GCNRA at Wahweap and Lee Ferry are direct depletions of water from the Upper Colorado River System. However, the situation is not as clear for other consumptive uses and losses in other sections of the study area. For example, the source of water used by the Navajo Nation for domestic and

municipal purposes is from wells, some exceeding 1,000 feet in depth. For our purposes here, it is considered to be consumed and a depletion to the Colorado River System. But this may not actually result in a reduction of Colorado River stream flows in the same year that the withdrawal occurs, or at all. There is little knowledge or information about ground water movement and, therefore, subsurface flow rates in the study area may not be accurate descriptions of the effects on river flows.

Although the water diverted for agricultural purposes is considered as consumptive use in this report, a portion of the remaining surface water on the Navajo Nation, excess to needs, does evaporate before reaching the Colorado River. No attempt has been made for this report to quantify these losses.

Uncertainties in estimating uses and losses exist, and the degree of variation in the figures is presented. Fortunately, the areas with the highest degree of uncertainty account for only a small percentage of the total consumptive use. Use by the Navajo Generating Station is the most accurately monitored. The total annual value for estimated consumptive use of water within the Arizona portion of the Upper Colorado River Basin for 2022 was 11,580 acre-feet, as shown in Table 11.

Table 11. Consumptive Use for Arizona Portion of Upper Colorado River Basin for 2022

Use category	Total consumptive use (acre-feet)	Uncertainty	Percent of total
Agriculture	3,295	484	28.45%
Municipal and Industrial	4,610	350	39.81%
Recreation, Fish, and Wildlife	1,229	307	10.61%
Reservoir Evaporation	2,447	635	21.13%
TOTAL	**11,580**	**924**	**100%**

4.0 References

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