BUREAU OF RECLAMATION

Quality of Water
Colorado River Basin

Progress Report No. 27

U.S. Department of the Interior

September 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 Photo – Lake Powell Reservoir on the Colorado River.

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Acronyms and Abbreviations

Af	acre feet
ACEC	Area of critical environmental concern
AIS	Aquatic Invasive Species
AMD	acid mine drainage
ARC	Application Review Committee
BLM	Bureau of Land Management
BSP	Basin State Program
CFS	Cubic feet per second
CRB	Colorado River Basin
CWP	Colorado Parks and Wildlife
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FLPMA	Federal Land Management Policy Act of 1976
FAR	Federal Accomplishment Report
FOA	Funding Opportunity Announcement
Forum	Colorado River Basin Salinity Control Forum
FWS	Fish and Wildlife Service
GLCA	Glen Canyon Recreation Area
Mg/L	Milligram per Liter
Maf	million acre feet
MWD	Metropolitan Water District
NEPA	National Environmental Policy Act
NPS	National Park Service
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PPM	Parts per Million
Reclamation	Bureau of Reclamation
Review	2020 Review, Water Quality Standards for Salinity, Colorado River System
RFP	Request for Proposal
SCP	Colorado River Basin Salinity Control Program
Secretary	Secretary of the Interior
TDS	Total Dissolved Solids (salinity)
TMDL	Total Maximum Daily Load
UCRB	Upper Colorado River Basin
UDAF	Utah Department of Agriculture and Food
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USGS	U.S. Geological Survey
WMIDD	Wellton-Mohawk Irrigation & Drainage District

Contents

Tables

Figures

Appendices

Appendix

Summary

The Colorado River and its tributaries provide water to about 35 - 40 million people and irrigation water to nearly 4.5 million acres of land in the United States (Moving Forward, 2015). The river also serves about 3.3 million people and 500,000 acres in Mexico (Cohen, 2011). The effect of salinity is a major concern in both the United States and Mexico. Salinity damages in the United States are presently estimated to be about $354 million per year at 2020 salinity concentrations. This biennial report on the quality of water in the Colorado River Basin is required by Public Laws 84-485, 87-483, and the Colorado River Basin Salinity Control Act (Salinity Control Act) (Public Law 93-320, as amended by Public Laws 98-569, 104-20, 104-127, and 106-459).

The Salinity Control Act authorizes the Secretaries of the U.S. Department of the Interior (Interior) and U.S. Department of Agriculture (USDA) to enhance and protect the quality of water available in the Colorado River for use in the United States and the Republic of Mexico.

Salinity damages to water pipes

Salinity damages to crop production

Title I of the Salinity Control Act authorized the construction and operation of a desalting plant, brine discharge canal, and other features to enable the United States to deliver water to Mexico having an average salinity no greater than 115 parts per million (ppm) plus or minus 30 ppm over the annual average salinity of the Colorado River at Imperial Dam. The Title I program (administered by the Bureau of Reclamation [Reclamation]) continues to meet the requirements of Minute No. 242 of the International Boundary and Water Commission, United States and Mexico. Title II of the Salinity Control Act authorizes the Secretary of the Interior (Secretary) and the Secretary of Agriculture to implement a broad range of specific and general salinity control measures in an ongoing effort to prevent further degradation of water quality to meet the objectives and standards set by the Clean Water Act.

In 1995, Public Law 104-20 authorized an entirely new way of implementing salinity control. Reclamation's Basinwide Salinity Control Program opened the program to competition through a "Request for Proposal" process, which greatly reduced the cost of salinity control by selecting the most cost-effective projects. However, the price of salinity control is expected to increase in the future as the more cost-effective projects are completed.

The Colorado River Basin Salinity Control Forum (Forum) in accordance with the requirements of the Clean Water Act, prepared the "2020 Review, Water Quality Standards for Salinity, Colorado River System" (Review). The Review reported the Forum would pursue a salinity control program designed to remove at least 1.7 million tons of salt annually by the year 2040 to minimize downstream economic damages while the Upper Basin States continue to develop their Compact apportioned water supplies. The Review shows that the Colorado River Basin Salinity Control Program (Program) is currently controlling over 1,218,000 tons of salt annually. In order to meet the 1.7 million tons of salt removal under the plan of implementation, it will be necessary to fund and build potential new measures that ensure the removal of an additional 482,000 tons by 2040. The Forum stated that in order to achieve this level of salt reduction, the federal departments and agencies would require the following capital funding: Reclamation's Basinwide program maintains an annual target of 9,250 tons/year of additional control at increasing cost due to inflation and increased cost per ton of controls. NRCS funding follows the agency's 3-year funding plan for 2020-2022 with 2022 funding levels ($15.7 million) maintained through 2040. Beginning in 2005, the BLM began a comprehensive program to minimize the salt loading from BLM lands in the Colorado River basin. BLM salinity funding from Congress began in FY 2006.

With the reported existing salt controlled, and assuming no reduction of the existing salinity control projects, then nearly 24,000 tons of new or additional controls will need to be implemented each year to meet the Program goal. This Program goal is the combined target for the participating agencies within Interior and USDA.

Upper Colorado River Basin regularly experiences significant year to year hydrologic variability, but overall is still in drought conditions. During the 22-year period beginning in water year 2000 and ending in water year 2021, the unregulated inflow to Lake Powell, which is a good measure of hydrologic conditions in the Colorado River Basin, was above average in only 4 out of the 22 years. The period 2000 through 2021 is the lowest 22-year period since the closure of Glen Canyon Dam in 1963, with an average unregulated inflow of 8.46 maf, or 88% of the 30-year average (1991-2020). (For comparison, the 1991-2020 total water year average is 9.60 maf.) The unregulated inflow during the 2000-2021 period has ranged from a low of 2.64 maf (24% of average) in water year 2002 to a high of 15.97 maf (147% of average) in water year 2011. In water year 2021 unregulated inflow volume to Lake Powell was 3.50 maf (36% of average), the second driest year on record with 2002 having the lowest inflow since Glen Canyon Dam was built. However, one wet year can significantly increase total system reservoir storage, just as persistent dry years can draw down the system storage.

Salinity concentration has varied during this time period (with a downward trend) but has not exceeded the numeric salinity criteria on the Colorado River below Hoover Dam, Parker Dam and at Imperial Dam; 723, 747 & 879 mg/L respectively. Reclamation's future salinity modeling scenarios indicate that the numeric salinity criteria should be maintained over the next three years even with additional years of drought. The numeric salinity criteria could have been exceeded in 2007 without the salinity control program and other salt reductions.

Reclamation prepared this report in cooperation with State water resource agencies and other Federal agencies involved in the Salinity Control Program. This Progress Report 27 is the latest in a series of biennial reports that commenced in 1963.

The authorization for these reports and the legal aspects can be found in Chapter 1 of prior Progress Reports http://www.usbr.gov/uc/progact/salinity/pdfs/PR24final.pdf.

Chapter 1 – Salinity Conditions

Causes of Salinity

Within the Colorado River basin there are geologic formations and soils containing elevated salt concentrations. This salt may become mobilized into the Colorado River watershed from natural erosion or human activities. From 1940 to 1972, an annual average of approximately 9.8 million tons of salt was carried down the river measured at the U.S. Geological Survey (USGS) gauge below Hoover Dam. From 1973 to the present, an annual average load of approximately 7.3 million tons of salt have been measured in the river at this gage. The trend of the salinity, both load and concentration, below Hoover is seen in figure 1 below. The flow of the river dilutes the salt, and depending upon the quantity of flow, salinity concentration can be relatively dilute or concentrated. Since climatic conditions directly affect the flow in the river, salinity in any one year may double (or halve) due to extremes in runoff. Because this natural variability is virtually uncontrollable, the seven Basin States adopted a non-degradation water quality standard in 1972.

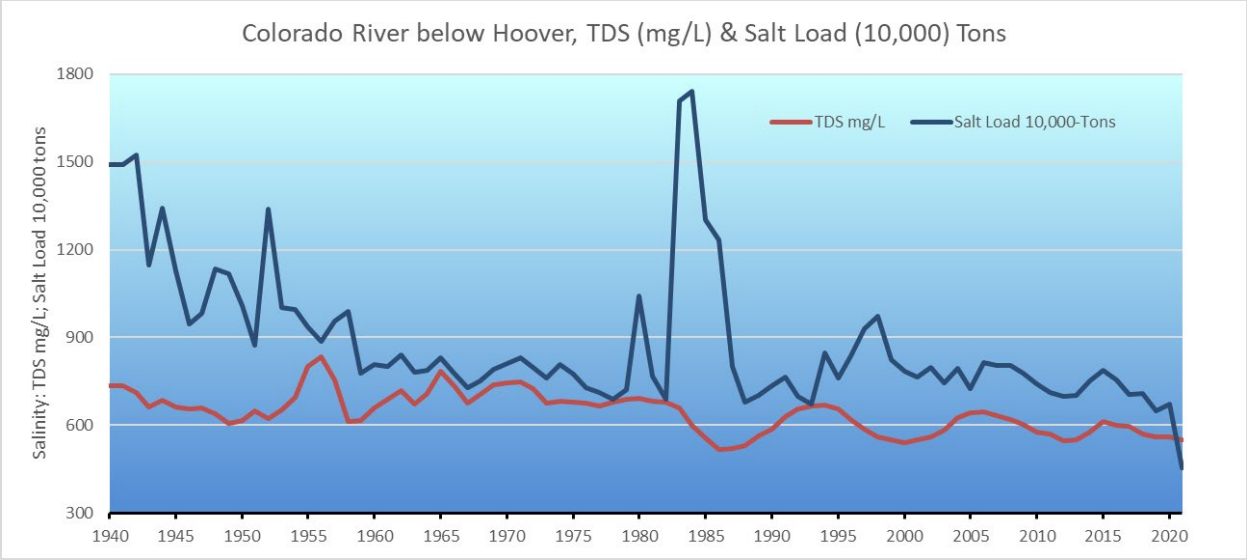

Figure 1 - Colorado River Salinity below Hoover Dam, USGS Gage.

Nearly half of the salinity concentration in the Colorado River System is from natural sources. Saline springs, erosion of saline geologic formations, and runoff all contribute to this background salinity. The EPA (EPA, 1971) estimated the natural salinity in the Lower Colorado River at Imperial Dam to be 334 milligrams per liter (mg/L). Irrigation, reservoir evaporation, and municipal and industrial (M&I) sources make up the balance of the salinity in the Colorado River Basin. Figure 2 shows the relative amount each source contributes to the salinity of the Colorado River, as estimated by the Environmental Protection Agency (EPA) in 1973. Table 1, on the following page, quantifies the salinity from several of the known sources.

Salinity of the Colorado River has increased due to the development of water resources in two major ways: (1) the addition of salts from water use and (2) the consumption (depletion) of water. The combined effects of water use and consumption have had a significant impact on salinity in the Colorado River Basin. The basin-wide drought, since 2000, has also had an influence on the present salinity of the Colorado River.

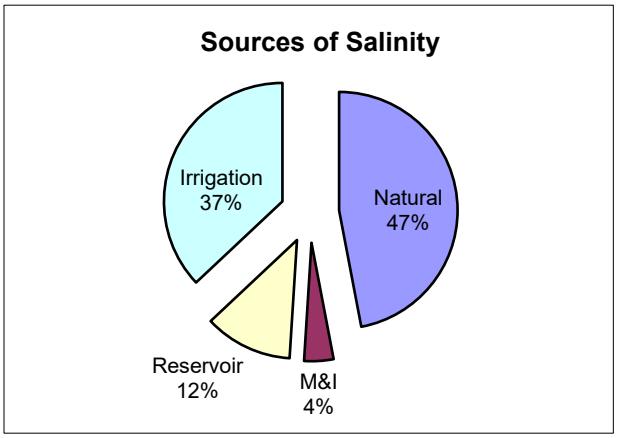

Figure 2 - Salinity Sources.

Table 1 – 1971 Quantified Sources of Salt Loading

Source	Type of Source	Salt Loading (tons per year)
Paradox Springs	Springs / point	205,000
Dotsero Springs	Springs / point	182,600
Glenwood Springs	Springs / point	335,000
Steamboat Springs	Springs / point	8,500
Pagosa Springs	Springs / point	7,300
Sinbad Valley	Springs / point	6,500
Meeker Dome	Springs / point	57,000
Other minor springs in the Upper Basin	Springs / point	19,600
Blue Springs	Springs / point	550,000
La Verkin Springs	Springs / point	109,000
Grand Valley	Irrigation / non-point	580,000
Big Sandy	Irrigation / non-point	164,000
Uncompahgre Project	Irrigation / non-point	360,000
McElmo Creek	Irrigation / non-point	119,000
Price-San Rafael	Irrigation / non-point	258,000
Uinta Basin	mostly irrigation / non-	240,000
Dirty Devil River Area	Irrigation / non-point	150,000
Price-San Rafael Area	Irrigation / non-point	172,000
Other, non-regulated areas	Various	5,200,000
Total		8,724,000

Values listed are pre salinity control project loading

Any potential health concerns from the salinity levels in the Colorado River have previously been addressed in the health section of Progress Report 21
http://www.usbr.gov/uc/progact/salinity/pdfs/PR21.pdf

Economic Effects of Salinity

Salinity related damages are primarily economical and due to reduced agricultural crop yields, corrosion, and plugging of pipes and water fixtures in housing and industry. Figure 3 breaks down the percentage of total damages estimated at 2020 with 1.21 million tons of salt controlled. The seven Basin States have agreed to limit this impact and adopted numeric criteria, which require that salinity concentrations not increase (from the 1972 levels) due to future water development. Salinity levels measured in the river may be low or high due to hydrologic conditions, but the goal of the Water Quality Criteria for the Colorado River Basin and the Salinity Control Program is to offset (eliminate/reduce) the salinity effects of additional water development.

Reclamation has developed an economic model that calculates damages for a given level of salt. The Salinity Economic Impact Model (SEIM) estimates the quantitative damages that are incurred in the metropolitan and agricultural areas in the lower Colorado Basin that receive Colorado River water. The model estimates the impacts from salinity levels greater than 500 mg/L TDS on household water using appliances, damages in the commercial sector, industrial sector, water utilities, and agricultural crop revenues. It also estimates the additional costs related to meeting statewide water quality standards for ground water and recycled water use in the Colorado River service area. The SEIM was last run for the 2020 Review and results and information on the SIEM can be found at http://www.coloradoriversalinity.org/documents.php?ctgy=Reviews.

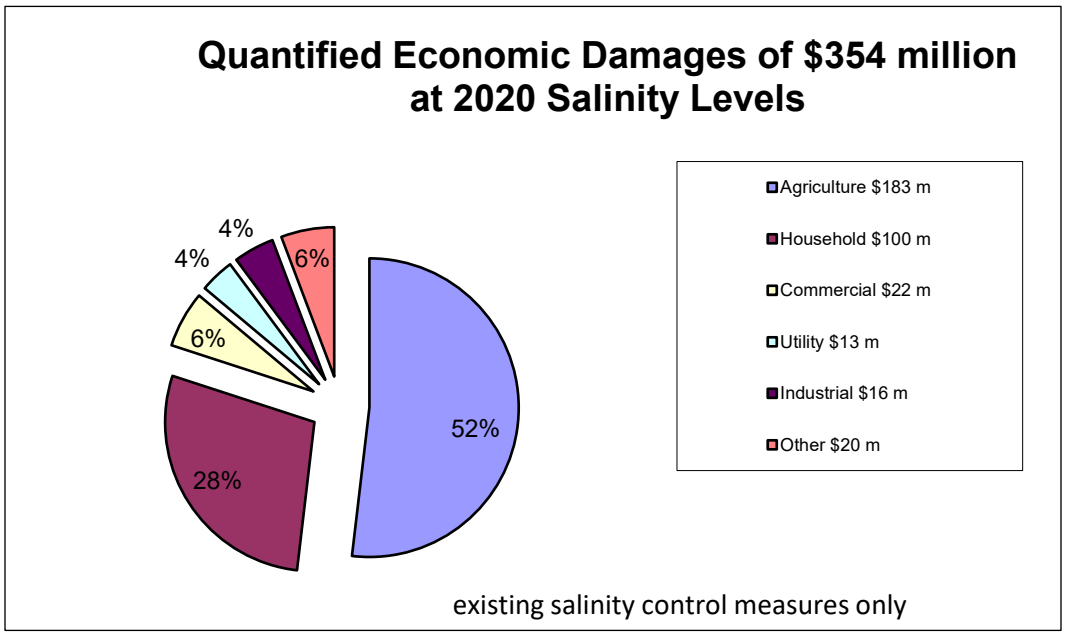

Figure 3 - Salinity Damages.

Historical Salinity Conditions

Salinity in the Colorado River is monitored at 20 key stations throughout the Colorado River Basin. A map of station location is presented in Appendix A. Salt loads and concentrations are calculated from daily conductivity and flow records using methods developed jointly between Reclamation and USGS (Liebermann et al., 1986), Appendix B shows the historical annual streamflow, and salinity concentrations from 1940 through 2021. Monthly and annual salinity and flow data may be obtained by request from Reclamation, Salt Lake City, Utah or by going to Reclamation's Upper Colorado Regional Office Salinity Program web page; http://www.usbr.gov/uc/progact/salinity/index.html.

The salinity of the 3 lower basin numeric criteria locations (Hoover, Parker and Imperial Dams) since 1940 is shown in Figure 4. As Figure 4 shows, the last time the TDS exceeded or reached the salinity criteria at any of the numeric criteria locations, was in 1972 – the year that the salinity standard was established for the Colorado River.

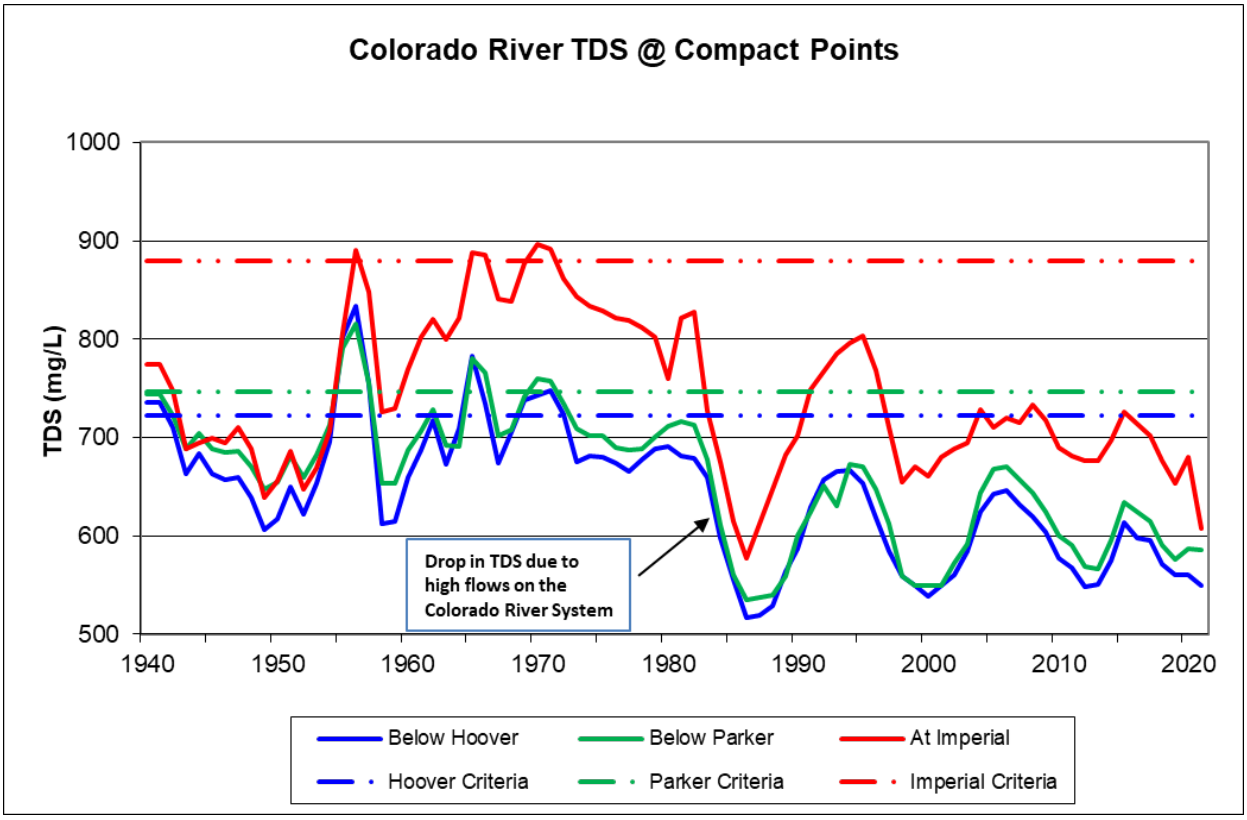

Figure 4 - Colorado River Numeric Criteria Locations and Values.

Factors Influencing Salinity

Stream flow, reservoir storage, water resource development, salinity control, climatic conditions, and natural runoff directly influence salinity in the Colorado River Basin. Before water development, the salinity of spring runoff was often below 200 mg/L throughout the Colorado River Basin. However, salinity in the lower mainstem was often well above 1,000 mg/L during the low flow months (most of the year) since no reservoirs existed to catch and store the spring runoff.

Streamflow

Streamflow directly influences salinity. For the most part, higher flows (or reservoir releases) dilute salt concentration. The left graph in Figure 5 shows streamflow at two key points in the mainstem over the last 50 years. In 1983, Lake Powell (Glen Canyon Dam) filled for the first time and spilled.

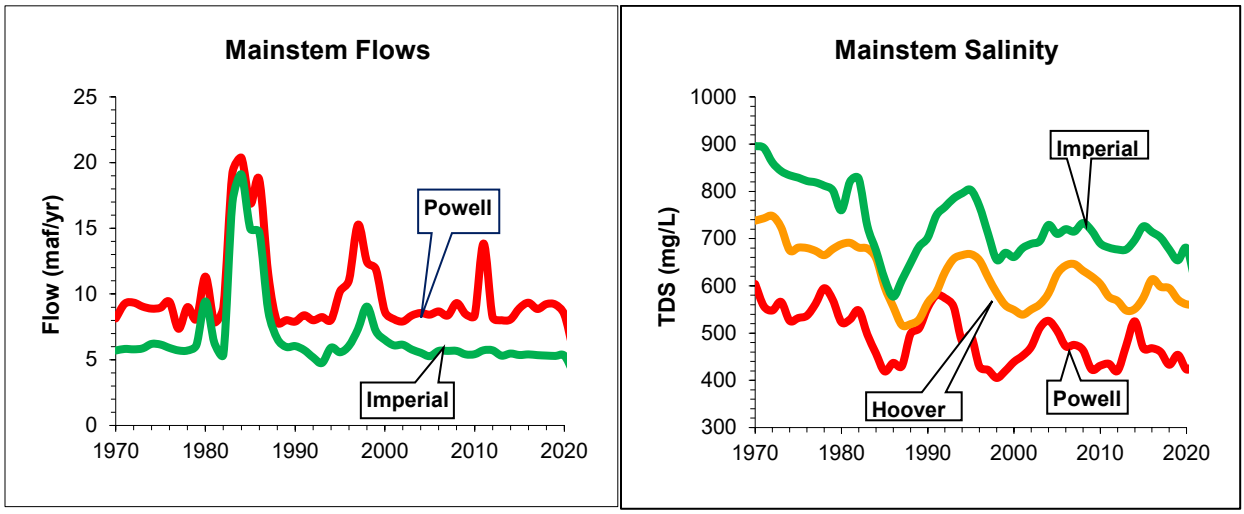

Figure 5 - Colorado River Flow and TDS at Lees Ferry, below Hoover and at Imperial USGS gages.

This spill went through Lake Mead (Hoover Dam) and on downstream through Imperial Dam. In 1983 and on through 1987, flows in the system were again extremely high and sustained, reducing salinity to historic lows. As shown in the right graph of Figure 5, returning to average flows in the system after 1987 returned the salinity in the reservoir system to moderate levels.

Reservoir Storage

The Colorado River Storage Project Reservoirs produce not only major hydrologic modifications downstream, but they also significantly alter the salinity variability of the downstream river. The overall long term salinity effects of the reservoirs are beneficial and have greatly reduced the salinity peaks and annual fluctuation (Figure 6). The high concentration low flow waters are mixed with low concentration spring runoff, reducing the month-to-month variation in salinity below dams (Mueller et al., 1988). At Glen Canyon Dam, the pre and post dam peak monthly

salinity has been reduced by nearly 600 mg/L, with a pre dam range of 1,106 mg/L and a post dam range of 694 mg/L. Similar effects can be seen below Flaming Gorge, Navajo, and Hoover Dams, greatly improving the quality of water during the summer, fall and winter.

Large reservoirs like Lake Powell selectively route less saline water while holding more saline waters during low inflow periods. The poorer quality waters are then slowly released after the inflows have begun to increase, which helps to prevent exceeding the salinity criteria during drought years. The large reservoirs selectively retain higher salinity winter inflows in the bottom of the pool and route lower salinity overflow density currents from the spring runoff. The seasonal and long-term effects of this selective retention and routing of salt are shown below Glen Canyon Dam in Figure 6.

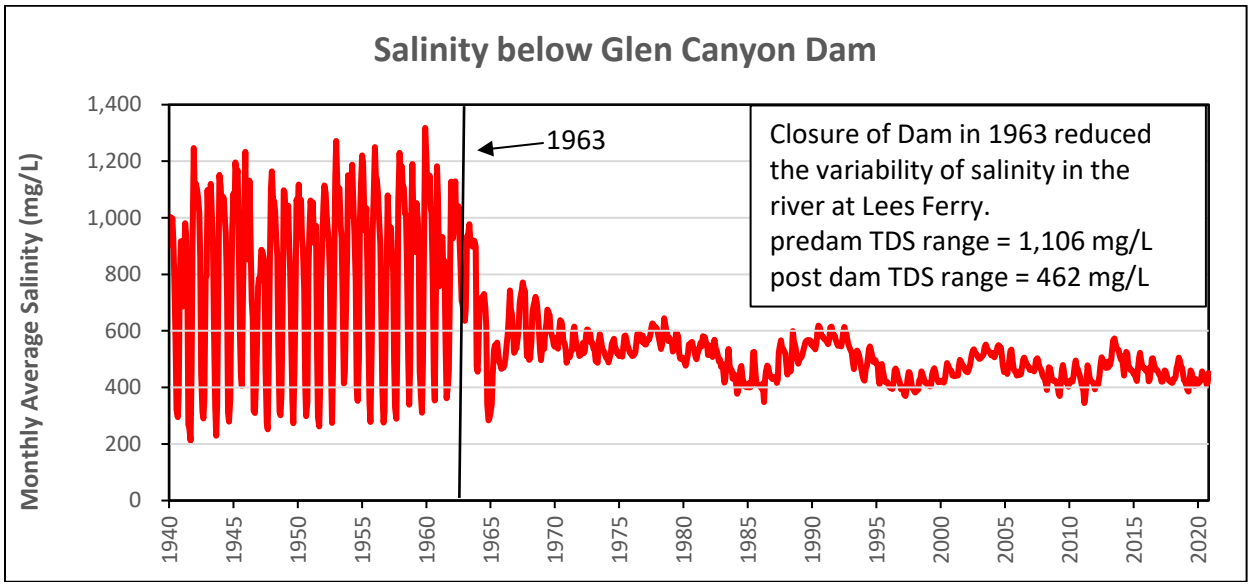

Figure 6 – Reduction in the Range of Salinity below Glen Canyon Dam, at Lees Ferry USGS gage.

Figure 7 further displays this retention. Figure 7 is a 56-year depth vs. time profile of salinity in the forebay of Glen Canyon Dam and is an illustrated history of the salinity. The Y (vertical) axis is depth in the water column and the X axis is time in years. The color scale is the change in salinity with the blues being lower TDS water and the brown color being higher TDS water.

Increasing the resolution from Figure 7 to a 20-year view, Figure 8, it is easier to see that during the drought of the last 20 years as the elevation of the reservoir declines, as in 2005, 2014 & 2021, higher TDS water concentrations increase and get entrained into the penstock withdrawal zone. During wet years with higher inflows, as in 2011, 2017 & 2019 the fresher water mixes with the higher TDS water around the penstock elevations and reduces the level of salinity in the outflow waters.

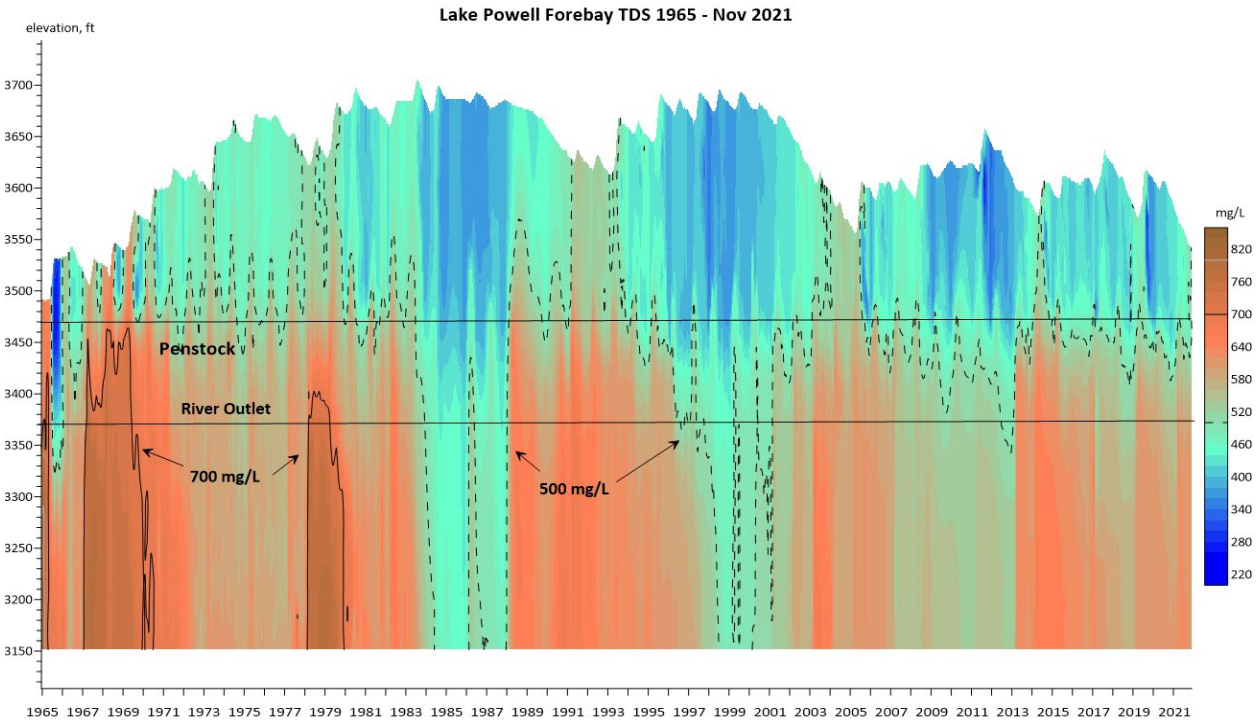

Figure 7- Lake Powell Forebay TDS from 1965 – 2021, change in TDS as Reservoir volume changes, (UCB BOR Data).

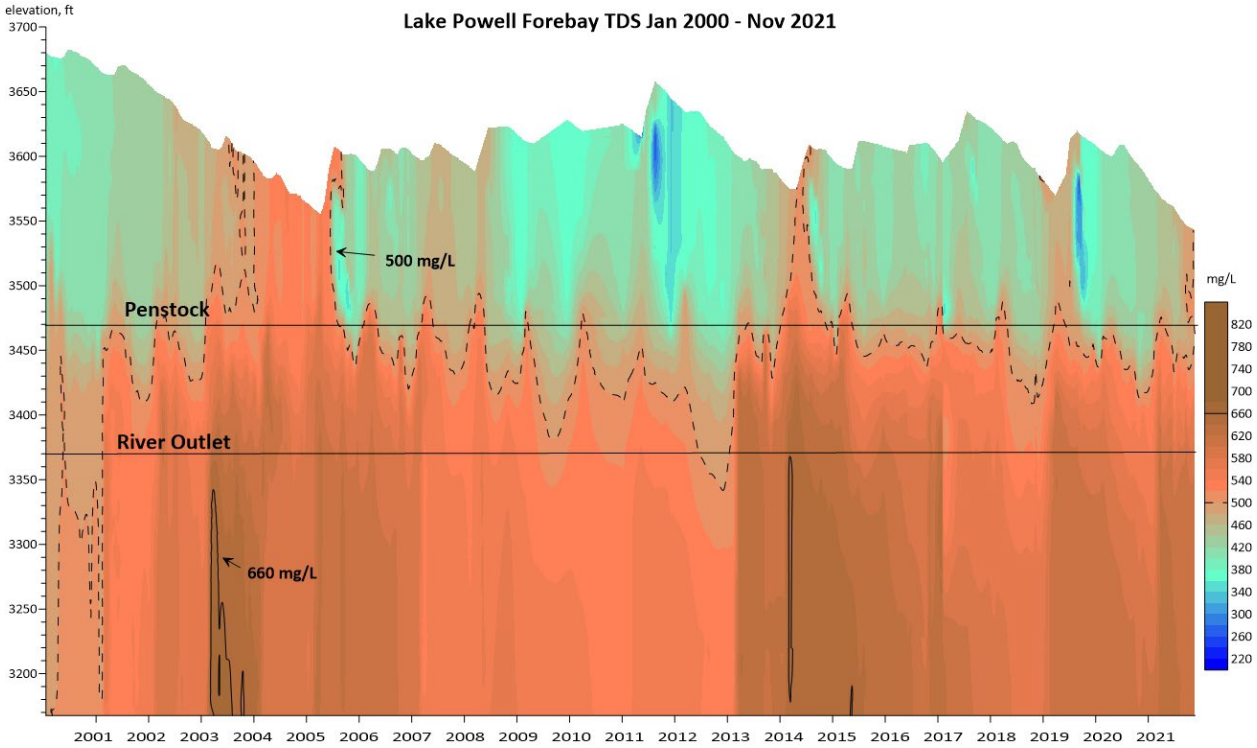

Figure 8 – Lake Powell Forebay TDS Level increases as Reservoir surface elevation decreases (UCB BOR Data).

Figures 6 - 9 illustrate that because of Glen Canyon Dam Lake Powell can selectively retain higher salinity water during drier years of drought, and then routes it out with the increased mixing and shorter hydraulic retention times of wetter cycles. During these wetter cycles there is a significant mixing and dilution of these previously stored salts. Generally, there is an inverse relationship between salt load and concentration as can be seen in figures 9 & 10. When flows are high salt concentration generally goes down due to dilution, and loads go up with more water carrying the salt equating to a higher amount of salt being moved.

There are 4 periods or trends, with regards to salt loads and concentration, which can be seen in the Colorado River salinity for the inflow to and outflow from Lake Powell shown in Figures 9 & 10 (yellow dash trend lines are the outflow and the green dash trend lines are the inflow). The overall inflow (red lines) in Figures 9 & 10 is calculated from the salinity at the inflow stations to Lake Powell, Colorado River at Cisco, Green River at Green River, UT, San Rafael River near Green River and San Juan River near Bluff. The overall outflow (blue line) comes from the salinity at Lees Ferry.

The 4 periods begin with the pre dam period, 1950 – 1964. The average salinity concentration in the river was increasing with divergence between the average annual inflow and outflow TDS concentrations while the salt loading was seen to be on a decreasing trend. This difference between outflow and inflow may be impacted by the beginning hydraulic conditions, since the actual annual levels appear to track each other closely.

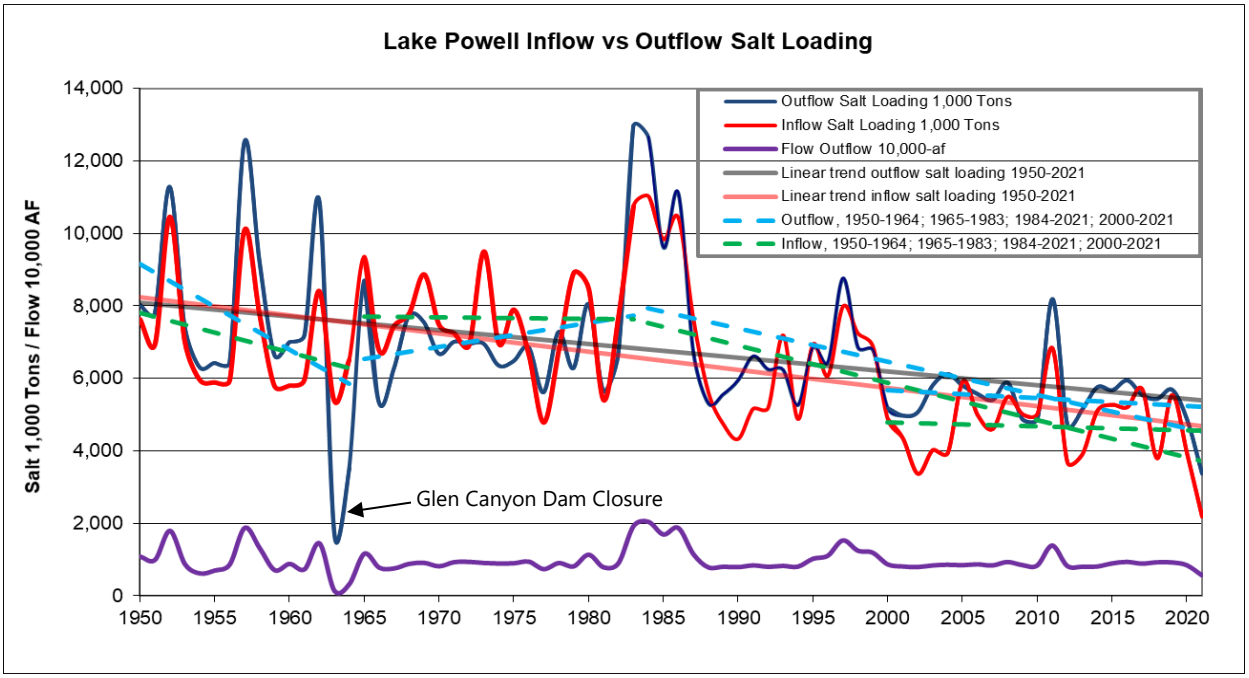

Figure 9 – Four Periods of change in Lake Powell Inflow and Outflow Salt Loading and Flow.

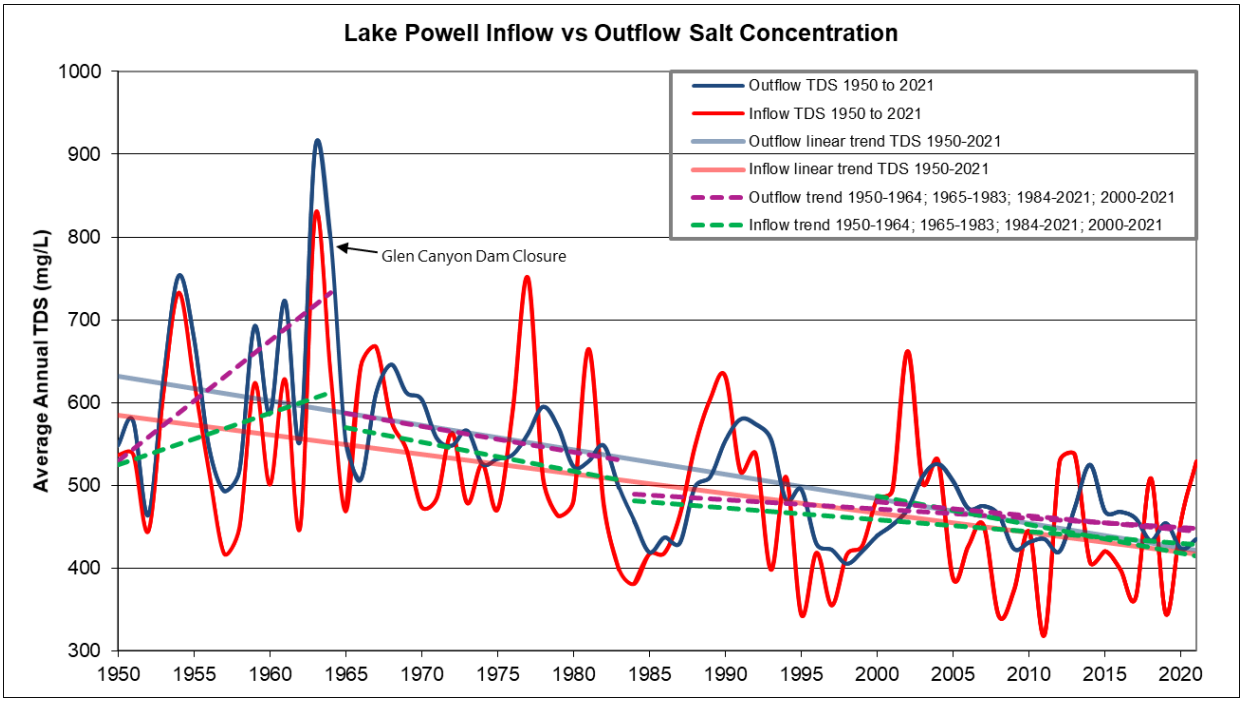

Figure 10 – Four Periods of change in Lake Powell Inflow and Outflow TDS.

Next there was the dam filling period where Lake Powell and the Upper Basin reservoirs were completed and filling, 1965-1983. The average annual salinity during this time decreased with a convergence occurring between the inflow and outflow concentrations. The salt loading converged during this time while the river flow stayed fairly constant, possibly due to the reservoir storing the salinity.

Then there was the period, 1984 to 2021, when the basin hydrology went through both wet and dry periods and the salinity control projects in the upper basin were coming online. The declining trend of the average annual salinity concentration and load during this time is seen to be constant between the inflow and outflow stations. The outflow for both the concentration and loading is seen to be a little higher than that of the inflow, possibly due to the release of some of the stored salt from the reservoir.

The last period, since 2000, covers the basinwide drought. The trend shows that the inflow TDS has declined, while the outflow TDS from Lake Powell has stayed constant with the 1983 to present TDS trend. The salinity loading during this time is shown to be slightly increasing possibly due to the higher than average flows in 2011.

Lake Powell (and other reservoirs in the basin) went through an initial filling salt leach out which actually began with temporary water retention behind the coffer dam during construction in the mid 1950's. Long-term linear regression trend lines on the inflow and outflow salinity concentrations at Lake Powell indicate that internal salt leaching seems to have declined to a

minimum by the mid-1990's suggesting a long-term salinity leach out which is approaching a dynamic equilibrium (Figures 9 & 10, red and blue trend line). Overall, there is seen to be a decreasing trend of salt concentration and loading in the Colorado River.

The natural variation in salinity as well as the agricultural sources, energy development, and the municipal and industrial use impacts on salinity have been discussed in a prior Progress Report 24 http://www.usbr.gov/uc/progact/salinity/pdfs/PR24final.pdf

Future Water Development

Tables 2 and 3 summarize projected future total depletions by water uses that are input into Reclamation's Colorado River System Simulation (CRSS) model. The schedules presented below were used in the CRSS modeling in support of the 2020 Review.

Table 2 summarizes the projected future depletions by water uses in the Upper Colorado River Basin as adopted for planning purposes by the Upper Colorado River Commission. Figure 11 illustrates the historical annual consumptive use by water uses in the Upper Basin as reported in Reclamation's Colorado River System Consumptive Uses and Losses Reports (CUL), and the projected future total depletions from the CRSS model.

The annual depletions for the Lower Colorado River Basin shown in Table 3 include only depletions resulting from the use of water from the mainstem of the Lower Colorado River. Reclamation's CRSS model does not model or include as input consumptive uses made from tributaries to the Colorado River within the Lower Colorado River Basin. More detailed data on historical Colorado River Basin consumptive uses and losses (including tributary uses in the Lower Basin and reservoir evaporation losses) may be found in Reclamation's *Colorado River System Consumptive Uses and Losses Reports* or on the web at: https://www.usbr.gov/uc/DocLibrary/reports.html

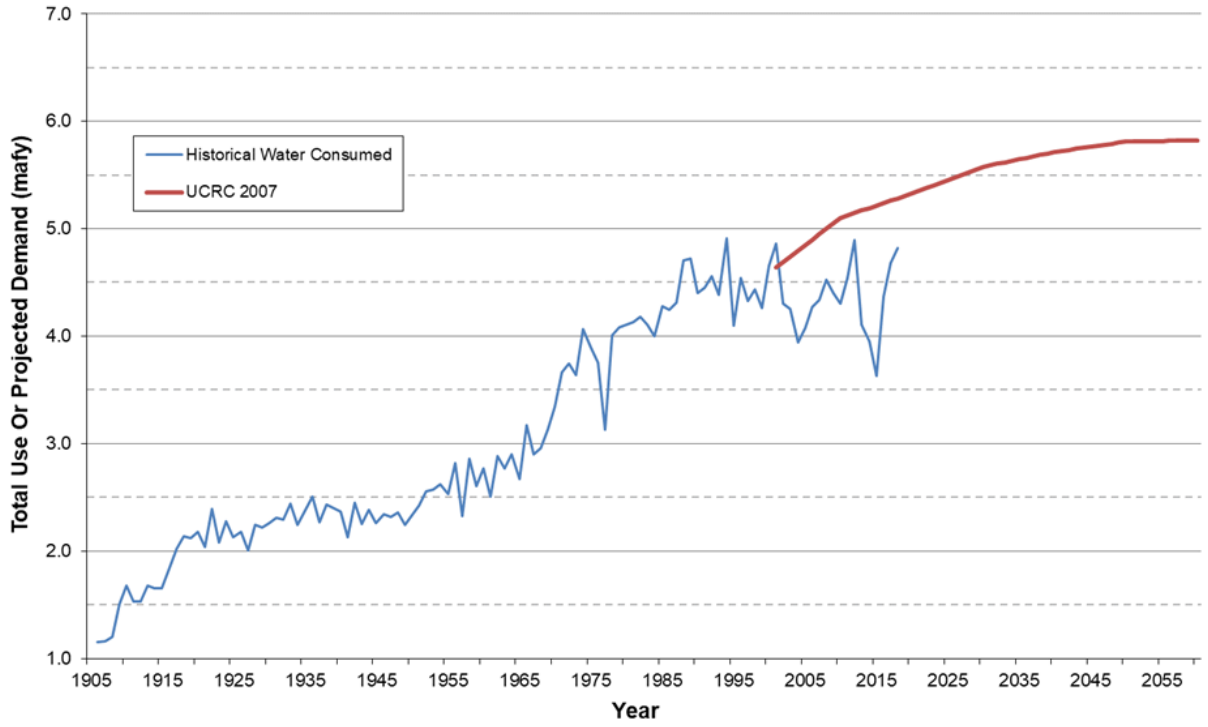

Figure 11 – Upper Basin Annual Consumptive Use and Projected Demands, includes CRSP Reservoir Evaporation. Model data from 2007, last time model was run, and Demands from 2020 Review.

Table 2 - Upper Basin Total Projected Depletion Demand Scenarios (1000 af/yr)

UPPER BASIN	2020	2030	2040	2050	2060
Arizona					
Total scheduled depletion	50	50	50	50	50
State share of 2007 Hydro-Det Amount (6.01 maf)	50	50	50	50	50
Remaining available	0	0	0	0	0
Percent of State share available	0	0	0	0	0
Colorado					
Total scheduled depletions	2,842	2,891	2,919	2,955	2,955
Critical Period CRSP Shared Evap. (% of 0.25 maf)	129	129	129	129	129
Total	2,971	3,020	3,048	3,084	3,084
State share of 2007 Hydro-Det Amount (6.01 maf)	3,084	3,084	3,084	3,084	3,084
Remaining available	113	64	36	0	0
Percent of State share available	4	2	1	0	0

New Mexico					
Total scheduled depletions	608	635	642	642	642
Critical Period CRSP Shared Evap. (% of 0.25 maf)	28	28	28	28	28
Total	636	663	670	670	670
State share of 2007 Hydro-Det Amount (6.01 maf)	670	670	670	670	670
Remaining available	34	7	0	0	0
Percent of State share available	5	1	0	0	0
Utah					
Total scheduled depletions	955	1,032	1,118	1,163	1,163
Critical Period CRSP Shared Evap. (% of 0.25 maf)	58	58	58	58	58
Total	1,013	1,090	1,176	1,221	1,221
State share of 2007 Hydro-Det Amount (6.01 maf)	1,371	1,371	1,371	1,371	1,371
Remaining available	358	281	195	150	150
Percent of State share available	26	20	14	11	11
Wyoming					
Total scheduled depletions	621	719	735	750	763
Critical Period CRSP Shared Evap. (% of 0.25 maf)	35	35	35	35	35
Total	656	754	770	785	798
State share of 2007 Hydro-Det Amount (6.01 maf)	834	834	834	834	834
Remaining available	178	80	64	49	36
Percent of State share available	21	10	8	6	4

Note 1: This depletion schedule does not attempt to interpret the Colorado River Compact, the Upper Colorado River Basin Compact, or any other element of the "Law of the River." This schedule should not be construed as an acceptance of any assumption that limits the Upper Colorado River Basin's depletion.

Note 2: This depletion schedule is for planning purposes only. This estimate does not constitute an endorsement of the Bureau of Reclamations 2007 Hydrologic Determination and should not be construed as in any way limiting the Upper Division States use of Colorado River water in accordance with the commission's resolution of 6/5/06.

Note 3: "Shared CRSP Evap." refers to the total and individual state portions of evaporation from the major Reservoirs constructed under the Colorado River Storage Project Act. These projects include Flaming Gorge, the Aspinall Unit Reservoirs and Glen Canyon.

Table 3 - Lower Basin Depletion Projections (1000 af/yr)

LOWER MAINSTEM	2020	2030	2040	2050	2060
Nevada					
Southern Nevada Water Authority	287	287	287	287	287
Laughlin Area	4	4	4	4	4
Mohave Steam Plant	0	0	0	0	0
Fort Mohave Indian Reservation	9	9	9	9	9
Total	300	300	300	300	300
Arizona					
Lake Mead NRA	1	1	1	1	1
Marble Canyon Co	0	0	0	0	0
Fort Mohave Indian Reservation	73	73	73	73	73
Mohave Valley I&D District	24	24	25	25	25
Havasu NWR	5	5	5	5	5
Lake Havasu City & Other Users	32	35	39	44	47
Central Arizona Project	1372	1362	1351	1346	1343
Parker & Other Users	10	10	10	10	10
Cibola & Imperial NWR	4	4	4	4	4
Cibola Valley I&DD	8	8	8	8	8
Colorado River Indian Reservation	463	463	463	463	463
Gila Gravity Main Canal	774	770	776	776	776
Gila & Yuma Users	15	15	15	15	15
Fort Yuma Reservation	1	1	1	1	1
Other Users	20	29	29	29	29
Total	2800	2800	2800	2800	2800
California					
Fort Mohave Indian Reservation	9	9	9	9	9
City of Needles	1	1	1	1	1
Havasu NWR	0	0	0	0	0
Chemehuevi Indian Reservation	8	8	8	8	8
Other Users & misc. present rights	2	2	2	2	2
Metropolitan Water District	847	854	854	854	854
Colorado River Indian Reservation	39	39	39	39	39
Palo Verde Irrigation District	366	366	366	366	366
Imperial Irrigation District	2645	2608	2608	2611	2611
Coachella Valley Water District	429	459	459	456	456
All American Canal (Yuma Project)	54	54	54	54	54
Total	4400	4400	4400	4400	4400

Unassigned					
Phreatophytes & Native Vegetation	632	632	632	632	632
Yuma Desalting Plant	109	109	109	109	109
Total	741	741	741	741	741

Note: In the LC Basin, depletions are from mainstem diversions of the Colorado River only. Does not include depletions from diversions of Colorado River tributaries or evaporation from mainstem reservoirs. The Figures represent measured diversions less measured and estimated, unmeasured return flow that can be assigned to a specific project.

Compliance with the Salinity Standards

Reclamation and the Basin States analyzed the effects on the salinity of the river for the 2020 Review. As part of the triennial review process, Reclamation used the Colorado River Simulation System (CRSS) river system model to evaluate whether sufficient salinity control measures are in place to offset the effects of development. The information provided in the next two sections of the report was used to evaluate compliance with the water quality standards.

In response to the Clean Water Act, the States have adopted water quality (salinity) criteria for the Colorado River Basin and the Environmental Protection Agency (EPA) has approved them at all three locations in the Lower Colorado River Basin. The standards call for maintenance of flow-weighted average annual salinity concentrations (numeric criteria) in the lower mainstem of the Colorado River and a plan of implementation for future controls.

The water quality standards are based on the *Water Quality Standards for Salinity, Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System,* prepared by the Colorado River Basin Salinity Control Forum, June 1975. The document was adopted by each of the Basin States and approved by EPA. A summary of the report follows:

The numeric criteria for the Colorado River System are to be established at levels corresponding to the flow-weighted average annual concentrations in the lower mainstem during calendar year 1972. The flow-weighted average annual salinity for the year 1972 was used. Reclamation determined these values from daily flow and salinity data collected by the USGS and Reclamation. Based on this analysis, the numeric criteria are 723 mg/L below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam.

It should be recognized that the river system is subject to highly variable annual flow. The frequency, duration, and availability of carryover storage greatly affect the salinity of the lower mainstem; and, therefore, it is probable that salinity levels will exceed the numeric criteria in some years and be well below the criteria in others. However, under the above assumptions, the average salinity will be maintained at or below 1972 levels.

Periodic increases above the criteria as a result of reservoir conditions or periods of below normal long-time average annual flow also will be in conformance with the standards. With satisfactory reservoir conditions and when river flows return to the long-time average annual flow or above, concentrations are expected to be at or below the criteria level.

The standards provide for temporary increases above the 1972 levels if control measures are included in the plan. Should water development projects be completed before control measures, temporary increases above the criteria could result and these will be in conformance with the standard. With completion of control projects, those now in the plan or those to be added subsequently, salinity would return to or below the criteria level.

The goal of the Salinity Control Program is to maintain the flow-weighted average annual salinity at or below the numeric criteria of the salinity standards. The Program is not, however, intended to counteract the salinity fluctuations that are a result of the highly variable flows caused by climatic conditions, precipitation, snowmelt, and other natural factors.

Salinity Control

Existing salinity control measures prevent nearly 1.22 million tons of salt per year from reaching the river. In 2021 the Salinity Control Program for Reclamation has controlled approximately 550,000 tons of salt, while the NRCS program has reduced around 610,000 tons of salt, and the BLM has controlled an estimated 14,000 tons of salt per year from entering the Colorado River. In the 2020 Review it was determined that salinity control units will need to prevent nearly 1.70 million tons of salt per year from entering the Colorado River by 2040, in order to meet the standard and keep the economic damages minimized. To reach this objective, as shown in Table 4, the Salinity Control Program needs to implement 480,000 tons of new controls beyond the existing 1,220,000 tons of salinity control presently in place (2020) as reported by Reclamation, NRCS & BLM. On average about 24,000 tons per year of new salinity control measures must be added each year if the program is to meet the cumulative target of 1,700,000 tons per year by 2040, assuming no degradation of existing salinity projects. However, due to expected funding limitations in future years, more tons of salt should be controlled sooner than later.

To achieve this goal, a variety of salinity control methods are being investigated and constructed. Saline springs and seeps may be collected for disposal by evaporation, industrial use, or deep-well injection. Other methods include both on-farm and off-farm delivery system and irrigation improvements, which reduce the loss of water and reduce salt pickup by improving irrigation practices and by lining canals, laterals, and ditches.

Table 4 - Salinity Control Requirements and Needs Through 2040

Measures in place (2020)	1,220,000 tons
Plan of Implementation Salt to Control by 2040)	1,700,000 tons
Annual Plan of Implementation Target [a]	24,000 tons

a. This value is the amount of salt required on an annual basis to meet the potential available salt to control over the next 20 years.

Chapter 2 – Title I Salinity Control Program

The Salinity Control Act, as amended, authorized the Secretary of the Interior (Secretary) to proceed with a program of works of improvement for the enhancement and protection of the quality of water available in the Colorado River for use in the United States and the Republic of Mexico. Title I enables the United States to comply with its obligation under the agreement with Mexico of August 30, 1973 (Minute No. 242 of the International Boundary and Water Commission, United States and Mexico [Minute No. 242]), which was concluded pursuant to the Treaty of February 3, 1944 (TS 994).

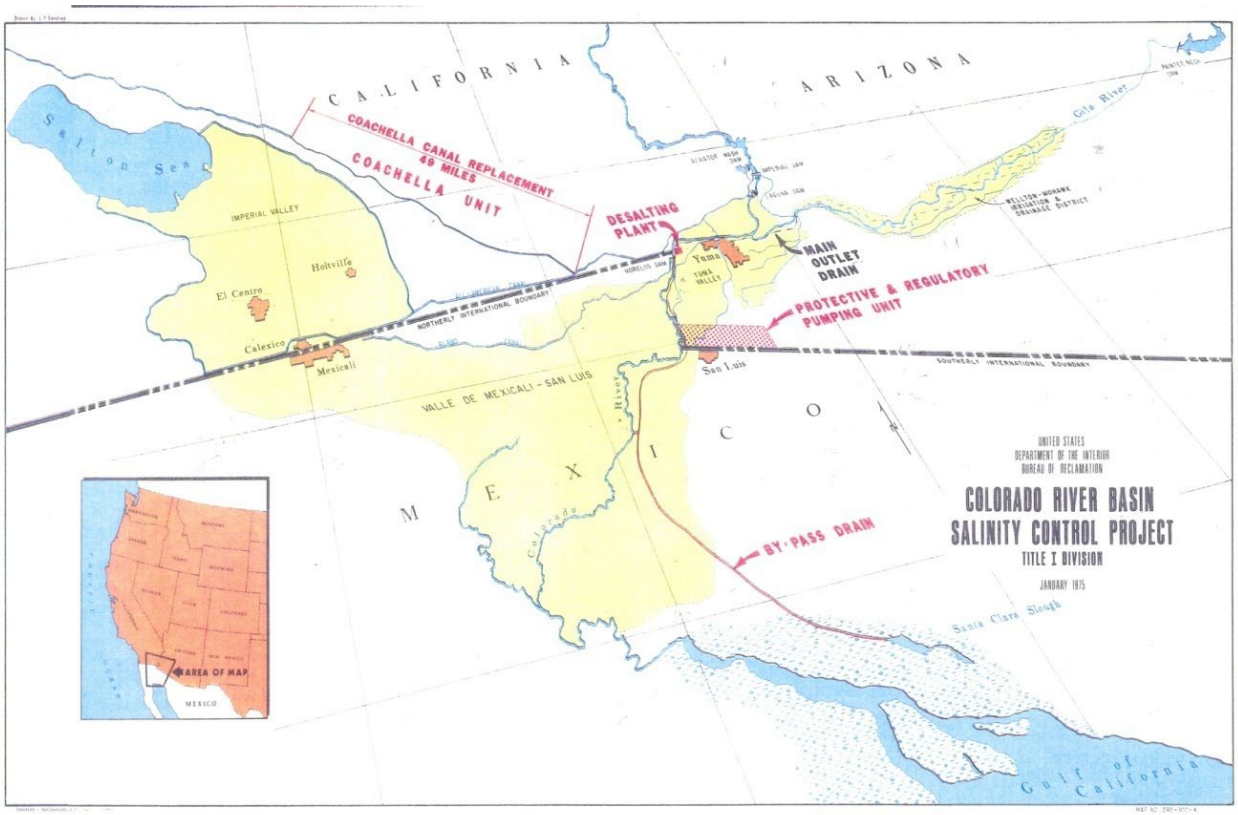

Figure 12 - Title I Salinity Control Projects.

These facilities enable the United States to deliver water to Mexico with an average annual salinity concentration no greater than 115 parts per million (ppm) plus or minus 30 ppm (United States count) over the average annual salinity concentration of the Colorado River water at Imperial Dam.

The background and history of the Title I projects (Coachella Canal Lining, Protective and Regulatory pumping, Yuma Desalting Plant, Wellton-Mohawk Irrigation & Drainage District) can be found in Progress Report 22, chapter 4 at;
http://www.usbr.gov/uc/progact/salinity/pdfs/PR22.pdf

Updates for the Title I Projects since last Progress Report:

USGS Estimation of Dissolved-Solids Concentrations Using Continuous Water-Quality Monitoring and Regression Models

The USGS published a final Report for the Estimation of Dissolved-Solids Concentrations Using Continuous Water-Quality Monitoring and Regression Models at Four Sites in the Yuma Area, Arizona and California, January 2017 through March 2019. Scientific Investigations Report 2021-5080. Here is the link to the report https://doi.org/10.3133/sir20215080.

The USGS currently has an agreement with the Bureau of Reclamation (Reclamation) to demonstrate the ability of the USGS to serve online real-time continuous computed dissolved-solids concentrations and real-time measured specific conductance. Continuous, real-time, specific conductance and water temperature is currently being monitored by the USGS at 4 sites: 1) The Colorado River above Imperial Dam (09429490), 2) Colorado River below Cooper Wasteway (09522005), 3) 242 Lateral above Main Drain at Arizona-Sonora Boundary (09534550), and 4) Yuma Main Drain above Arizona-Sonora Boundary (09534000; fig. 1). Discrete water samples are being collected during the monitoring period for major constituents at each of the 4 sites. The major constituents of bicarbonate, calcium, carbonate, chloride, fluoride, magnesium, nitrate, potassium, silicon dioxide, sodium, and sulfate are being summed to compute dissolved-solids concentration.

Reclamation currently has a 5-year Interagency with the USGS. Continuous real-time specific conductance will continue to be collected, reviewed, and published by the USGS from October 2020 through September 2025. Concurrently, monthly major constituent sample will be collected, analyzed, reviewed, and published at the 4 sites from October 2020 through September 2025. Specific conductance-dissolved solids regression models will be maintained for each site and available online.

Unmeasured Flow Meters (UMF) Salinity Investigation Project

An interagency agreement has been signed with the USGS to cover the portion of work the USGS will be doing. YAO is preparing to consult with the Quechan Tribe regarding the well sites that will be located on Tribal land. Well drilling is tentatively scheduled to start in February 2022.

242 Well Field Expansion Project

The 242 Well Field Expansion Project is substantially complete, water has been flowing since 12-16-2020 to the Colorado River. The Yuma Mesa Conduit Extension Project is substantially complete and is in the process of "transfer to plant" signatories as of 11-11-2021. Water has been flowing to the 242 Lateral canal since 10-19-2021.

Coachella Canal

No new activity.

Protective and Regulatory Pumping

No new activity.

Yuma Desalting Plant

No new activity.

Wellton-Mohawk Irrigation and Drainage District (WMIDD)

Total crop acres have remained relatively stable since the early 1970's because more acreage is double-cropped than when the program was initiated. In particular, more vegetable crops are being grown in the district than in the past, with lettuce (iceberg and romaine) now the major crop. Irrigation efficiency levels and return flow levels for 1991-2019 (latest data available) are shown in Table 5. Efficiency values do not include a leaching fraction.

With the use of monthly groundwater table monitoring using observation well measurements as well as input from land users, WMIDD is able to maintain a drainage-pumping program that sufficiently maintains the agriculture root zone. Land users continue to maintain water efficient farming techniques with the use of sprinkler, drip, dead level, high heads, and short runs.

Table 5 - WMIDD Irrigation Efficiency

Year	Drainage Return Flow (acre-feet)	Irrigation Efficiency, %
1991	144,900	68.8
1992	116,200	70.4
1993	8,970	68.8
1994	49,820	65.4
1995	121,500	64.3
1996	119,600	60.4
1997	91,695	62.2
1998	98,972	61.9
1999	94,869	63.0
2000	110,287	59.7
2001	107,908	60.9
2002	119,410	61.2
2003	116,477	57.8
2004	106,002	63.3
2005	110,770	64.6
2006	103,810	62.3
2007	112,910	62.6
2008	120,190	63.0
2009	105,482	62.7
2010	111,170	66.1
2011	108,140	64.9
2012	115,630	64.1
2013	107,860	67.5
2014	111,390	64.6
2015	106,170	63.9
2016	99,130	67.6
2017	101,064	66.6
2018	104,209	69.9
2019	98,205	62.3

(note: data provided by WMIDD)

Chapter 3 - Title II Salinity Control Program

Title II of the Salinity Control Act authorizes the Secretary of the Interior (Secretary) and the Secretary of Agriculture to implement a broad range of specific and general salinity control measures in an ongoing effort to prevent further degradation of water quality in the Colorado River Basin. In order to accomplish this goal salinity control projects have been in various areas of the upper Colorado River watershed shown on the map below (Figure 13). To date the NRCS, Reclamation and BLM have controlled 1.2 million tons of salt annually and with current funding levels project to keep a total of 1.7 million tons of salt annually out of the Colorado River by 2040. The current plan of implementation (Review) has a combined NRCS, Reclamation and BLM goal of controlling 62,400 tons of salt annually through 2023. These federal agencies are required to work together under the Salinity Control Act, as amended; with Reclamation being the lead federal agency. The Salinity Control Act also calls for periodic reports on this effort. The report is to include the effectiveness of the units, anticipated work to be accomplished to meet the objectives of Title II with emphasis on the needs during the 5 years immediately following the date of each report, and any special problems that may be impeding an effective salinity control program. Title II also provides that this report may be included in the biennial Quality of Water Colorado River Basin, Progress Report. New activities since the last progress report as well as ongoing and active projects are listed in this chapter. The following updated agency information comes from information provided by the BLM, NRCS and Reclamation found in the 2021 Federal Accomplishment Report (FAR).

Bureau of Land Management (BLM)

The BLM administers about 53 million acres of public land within the Colorado River Basin (CRB) and is required to reduce salt transport from these lands under the CRB Salinity Control Act of 1974 (as amended). In Fiscal Year (FY) 2021, the BLM allocated $2 million to salinity control projects in four states and the BLM National Operations Center (NOC).

Program Administration

The BLM's Aquatic Habitat Management Program fosters a watershed approach to improve water quality on public lands in support of the agency's multiple use and sustained yield mandate.

The Aquatic Habitat Management Program coordinates activities within the BLM to achieve the following objectives of the CRB Salinity Control Program: (1) reduce salt and sediment transport; (2) develop additional capabilities to quantify and report the effectiveness of salinity and sediment control activities; (3) strengthen partnerships and increase collaboration with federal partners, states, and stakeholders; (4) improve availability and access to monitoring data; and (5) enhance and maintain technical expertise and project management capabilities.

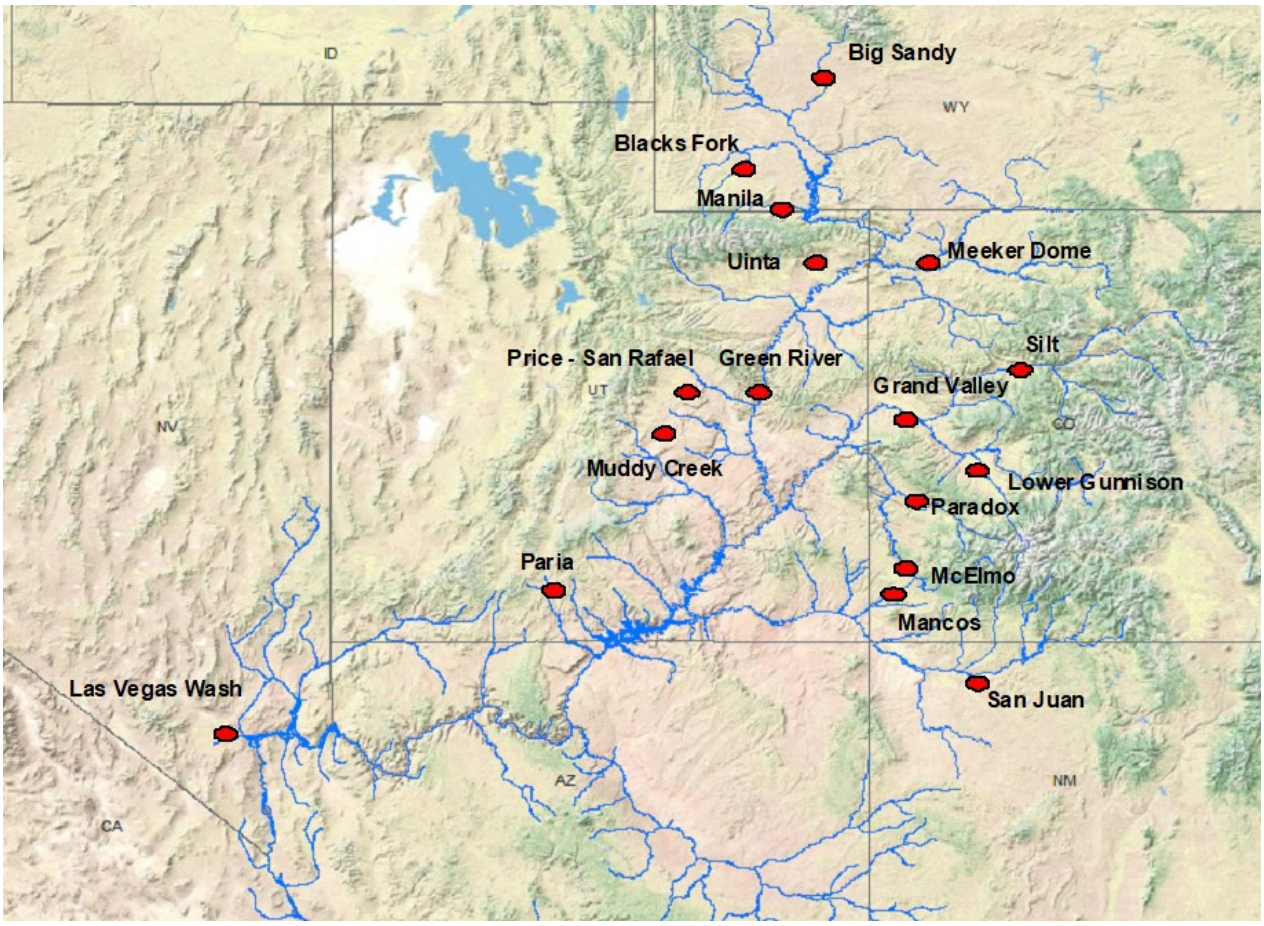

Figure 13 - Title II Salinity Control Projects.

Since 2015, the BLM has allocated an average of $1.7 million per year to the CRB Salinity Control Program (Figure 14) and estimates that salinity control measures implemented with these funds have prevented over 225,000 tons of salt from reaching the Colorado River and its tributaries (Table 6).

FY21 CRB Salinity Control Program Funding Allocation and Accomplishments
FY21 projects and funding are summarized in Table 7, and FY21 program activities are highlighted below. Estimates of salt retained from FY21 projects will be reported in FY22.

Table 6. Estimates of salt retained on BLM-administered lands within the CRB from projects receiving congressionally directed salinity control funding for the period FY15 – FY20

State	Estimated Salt Retained		
	FY15 to FY19 (tons)	FY20 (tons)	Cumulative Total (tons)
AZ	11,537	0	11,537
CO	6,000	308	6,308
NM	84,734	17,680	102,414
UT	38,630	5,441	44,071
WY	57,881	4,713	62,594
Total	**198,782**	**28,142**	**226,924**

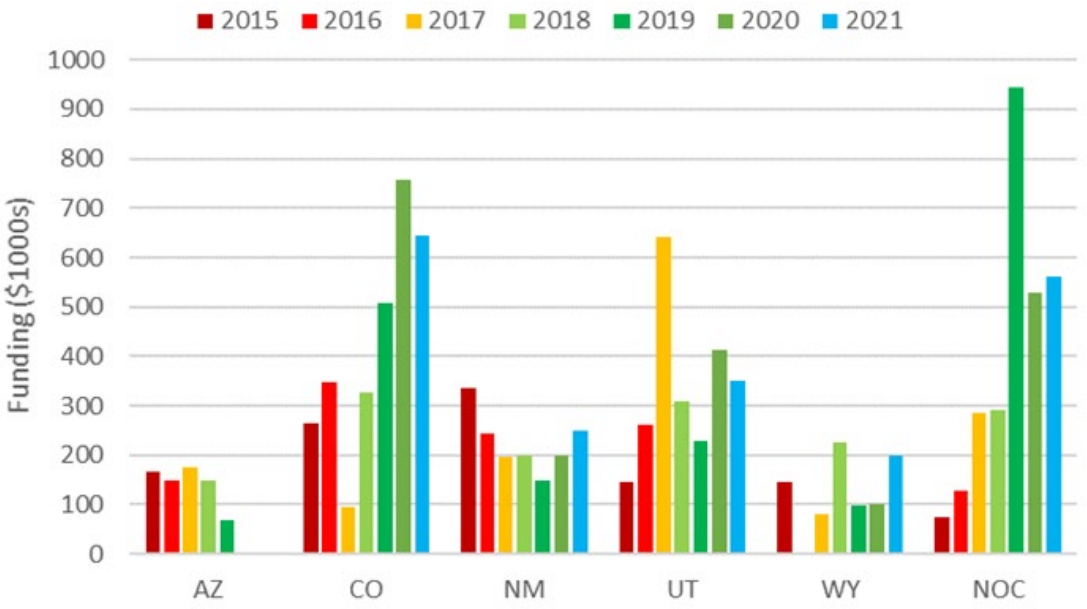

Figure 14 - BLM Funding for salinity control.

Table 7. FY21 allocation of CRB Salinity Control Program funding for each state or center

Project	Activity	Collaborators	Funding ($)
National Operations Center			
Enhancement of APEX model	MD	TX A&M University, CO State University	400,000
Informational management system	MD	TX A&M University, CO State University	160,000
Colorado			
SC in the Dry Creek Travel Management Area	SC	-	225,000
Dolores River restoration project	SC	Dolores River Restoration Partnership	25,000
Monitoring salt loading from the Pine Gulch fire	AM	USGS	150,000
Zone L geomorphic salinity analysis	AM	USGS	95,000
Effects of base-level lowering on salinity and sediment near Rangely	AM	USGS	90,000
Erosion rates in Zone L of the Grand Junction Travel Management Plan	AM	-	60,000
New Mexico			
San Juan River watershed restoration	SC	NM Youth Conservation Corps	150,000
San Juan River watershed vegetation management	SC	Southwest Conservation Corps, San Juan Fishing Guides Association	100,000
Utah			
Grand Staircase-Escalante National Monument salinity control	SC	U.S. Forest Service	100,000
St. George Field Office salinity control	SC	-	100,000
Kanab Field Office salinity control	SC	-	80,000
Salinity loads in the Upper CRB	AM	USGS, Upper CRB Salinity Forum	37,750
San Juan River salinity and sediment monitoring	AM	USGS, UT Dept of Environmental Quality	23,000
Paria River District water quality inventory and monitoring	AM	UT Division of Water Quality, UT State University	10,000

Wyoming			
New Fork restoration and river access	SC	WY Game and Fish Dept., Trout Unlimited, BOR, and others	75,000
LaBarge Watershed restoration project	SC	-	50,000
Muddy Creek Watershed habitat improvement	SC	WY Game and Fish Dept., Trout Unlimited, FWS, USGS	50,000
Savery Creek stabilization project	SC	WY Game and Fish Dept, Trout Unlimited	25,000
Total			**2,005,750**

(SC = Salinity control; MD = Model development and support; and AM = Assessment and monitoring).

National Operations Center

The BLM NOC is collaborating with Texas A&M University to develop an Agricultural Policy/Environmental eXtender (APEX) model to quantify sediment and salt transport from nonpoint sources on BLM-administered lands to the Colorado River. This is a multi-year project. In FY21, work focused on integrating surface-subsurface watershed modeling, wildfire impact assessment, salt transport modeling, groundwater refinement, snowmelt-streamflow assessment, and wind erosion.

Work continued to link the APEX model to a MODFLOW groundwater flow model using a single modeling code. The current APEX model's snowmelt routine was revised to capture the snowmelt contributions to runoff. A manuscript titled “The Impact of Rainfall Distribution Methods on Streamflow throughout Multiple Elevations in the Rocky Mountains using the APEX model—Price River Watershed, Utah” has been submitted for publication.

Landscape wind erosion was integrated into the APEX model to simulate wind-driven sediment transport and dust emission for rangelands, which is a major contributor to salt transport. A manuscript titled, “Modeling landscape wind erosion processes on rangelands using the APEX model” is being prepared for publication.

The integrated APEX-MODFLOW watershed model was tested through applications to three watersheds: the Animas River, the Price River, and the Middle Bosque River watersheds (Figure 15). Results were compared to monthly streamflow and groundwater level data and simulated cell-by-cell recharge rates and groundwater-surface water exchange rates were assessed.

Work continued to compile vegetation, soil, climate, land use, and hydrologic data for the six priority watersheds (Upper Green, Price, White, Animas, Dolores, and Gunnison River) identified by the Salinity Work Group, Science Team, and Forum. Quantification of sediment and salt loading from fire events continued. Over 5,000 events occurring since 1974 were evaluated to better understand their impact on sediment and salt transport.

Approximately 100 fire events impacting greater than 10,000 acres within the Upper CRB have been selected for further analysis due to the availability of cloud-free LandSat 7 data within the 1-month pre- and post-fire period. Burn severity indices were evaluated in 30m x 30m pixels using leaf area index. The post-fire leaf area index illustrates the extent of biomass loss, which has serious implications to surface runoff processes, and salt and sediment loads to streams.

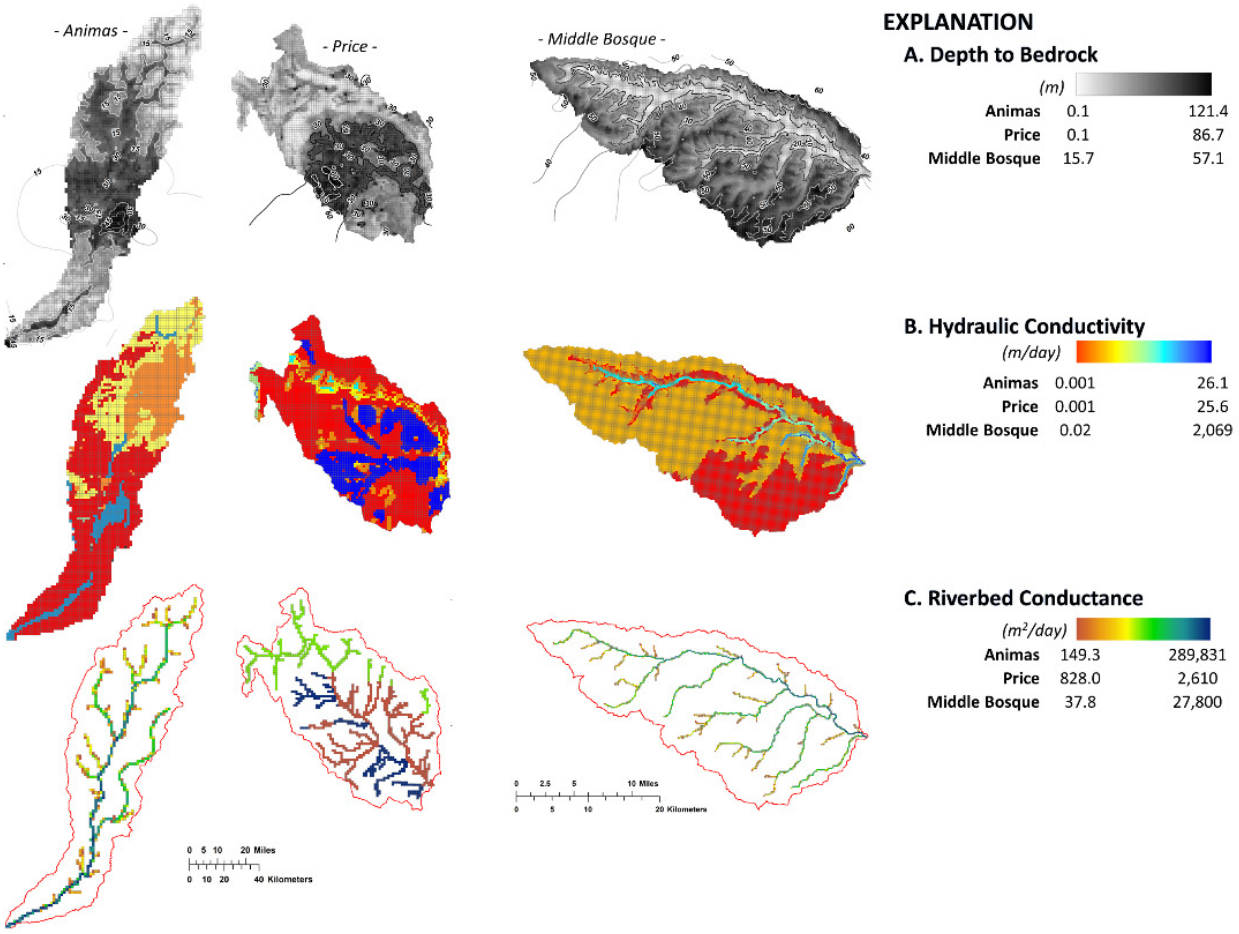

Figure 15. Maps showing (A) depth to bedrock (m), (B) hydraulic conductivity (m/day), and (C) riverbed conductance (m2/day) for the Animas River, Price River, and Middle Bosque River watersheds.

Colorado

Zone L Geomorphic Salinity Analysis: The BLM collaborated with the USGS to conduct field work and develop models to identify relationships between watershed characteristics and areas of high erosion in Grand Valley, located in western Colorado. These data will be used to identify areas for erosion control. The USGS completed the project and presented preliminary results in May 2021; the final report is expected to be released in fall 2021.

Erosion rates in Zone L of the Grand Junction Travel Management Plan: Over 500 upland sites in western Colorado were sampled for soils, vegetation, and geomorphic inputs into the Rangeland Hydrology Erosion Model (RHEM) (Figure 16).

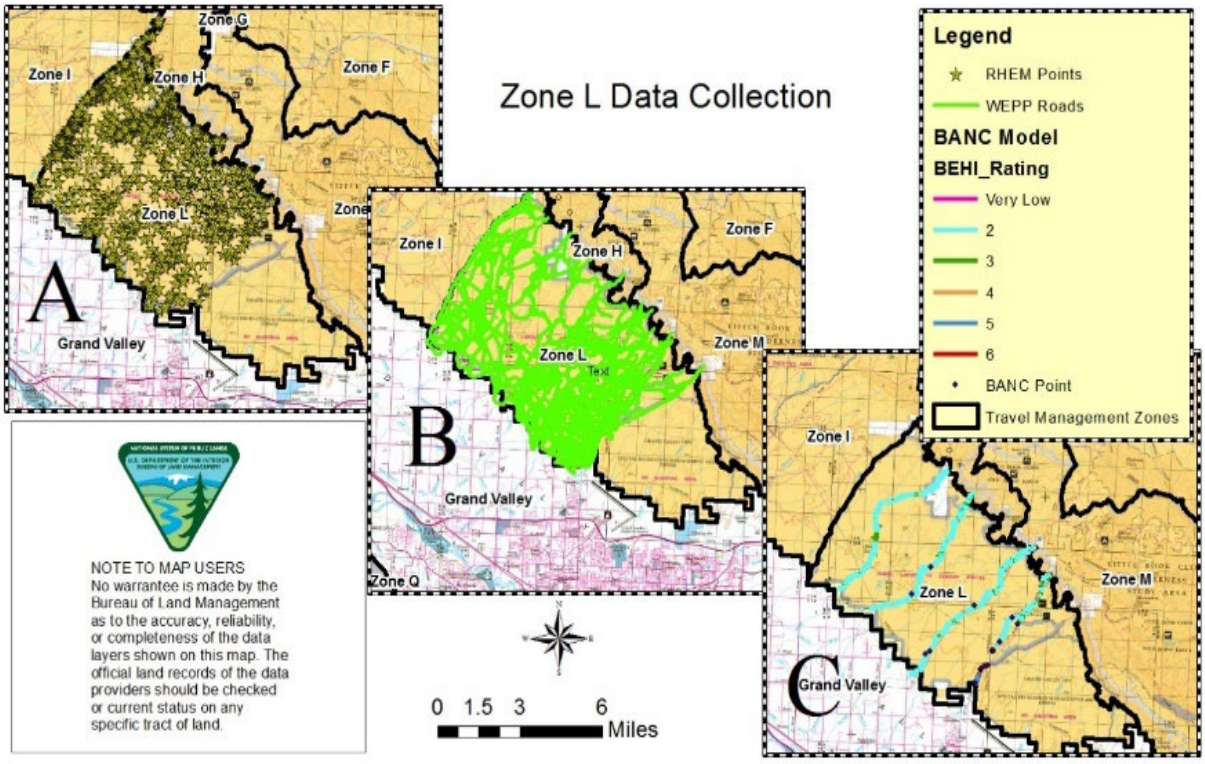

Figure 16. Vicinity map of ongoing work in Zone L Off-Highway Vehicle area.

All transportation routes were surveyed, and the data were used to run the Water Erosion Prediction Project Road (WEPP Road) model to calculate erosion from the current set of routes. Monitoring Salt Loading from the Pine Gulch Fire: The Pine Gulch Fire burned 138,680 acres northwest of Grand Junction in the fall of 2020. There are 15,799 acres of saline soils directly in the burn area and 148,533 acres downstream of the fire. Post fire modeling by the DOI Burned Area Emergency Response (BAER) team indicated that there will be a 2-to-3-fold increase in erosion and flow in the 1 to 7 years after the fire. Data collection will occur at existing and new USGS streamgages to characterize changes in water-quality downstream from the Pine Gulch Fire. Discrete water-quality sampling will occur in the Colorado River, Roan Creek, Big Salt Wash, and Salt Creek. In FY21, two monitoring locations were installed on Roan Creek and on Big Salt Wash. Crest gages were installed at 10 locations and two sediment fences have been installed (Figure 17). These data will be used to validate the models used by DOI BAER teams.

Deer Creek Retention Dam Repair: Work began in FY19 to repair and stabilize the Deer Creek Retention dam, located about 6 miles upstream of the Colorado River in Horseshoe Canyon. The dam was built by the BLM to control sediment and to provide water for grazing. The soils around the dam and 22-acre pond have a moderate salinity content and are highly erodible. In

FY20, earth work to repair erosional features and stabilize overflow channels was completed and temporary steel-jack fence was placed in late FY21. The BLM estimates that the dam and sediment filled pond had the potential to deliver 314,627 and 2,347,704 pounds of salt, respectively to the Colorado River prior to the repair.

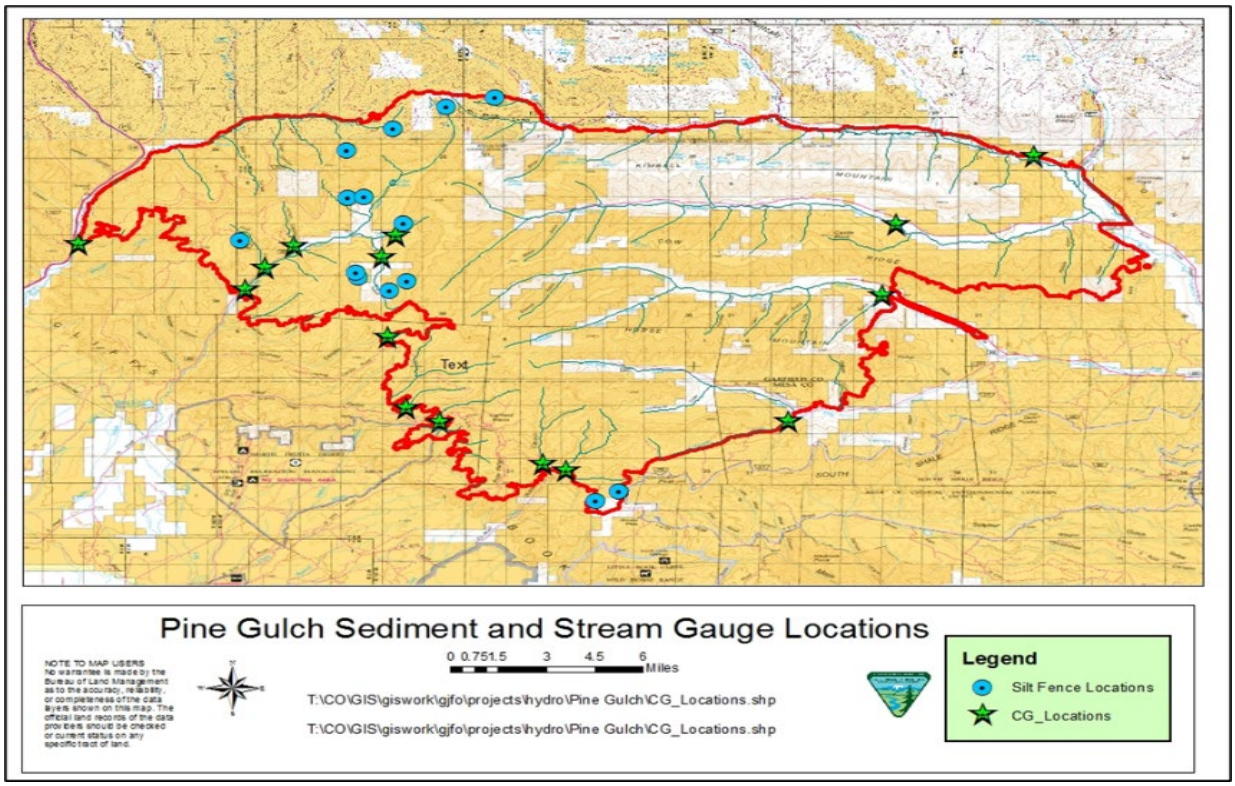

Figure 17- Pine Gulch sediment fence and stream gage locations.

New Mexico

San Juan River watershed vegetation management and restoration: In FY21, work continued to reduce salt and sediment transport to the San Juan River. In late FY21, the BLM began work with a partner through Restore New Mexico to implement aerial treatments that will reduce sagebrush and increase native grass cover on approximately 6,590 acres. A series of sediment fences will be constructed in an adjacent wash that is eroding and widening, along with planting and bank stabilization. The BLM is also collaborating with the San Juan Soil and Water Conservation District to expand previous work to control salt cedar and Russian olive in riparian areas to reduce salt and sediment transport in ephemeral and perennial stream systems in the San Juan River watershed.

Utah

Grand Staircase-Escalante National Monument / Kanab Field Office salinity control: The BLM continued to repair and maintain salinity control structures in the sub-watersheds of the Paria River, Kanab Creek, Buckskin Gulch, and Upper Johnson Wash, which drain into the Colorado

River. In FY21, nineteen salinity control structures ranging in size from 0.03 to 0.4 acres were cleaned out across the Monument (Figure 18), and two sediment dikes were repaired.

Figure 18-Farnsworth Reservoir in the Kanab Creek watershed before (left) and after (right) sediment removal.

The Telegraph Head Cut Repair project is a multi-year project to stabilize head cutting in Telegraph Flat on the southern border of the Monument. FY21 monitoring of the main head cut repair indicated that the repair was able to withstand monsoonal storms that occurred in July and August 2021 in southern Utah.

Paria River District water quality inventory and monitoring: The BLM has contracted with RedFish Environmental to conduct inventory and monitoring in the Paria and Escalante Rivers to better understand salinity loads. Baseline water quality sampling was performed by field crews in FY21. Final data and results will be provided to the BLM in October 2021.

St. George Field Office salinity control: The BLM repaired approximately 11 salt and sediment control structures in the Hurricane Fault Work Area within the Gould Wash and Fort Pearce watersheds, which drain directly into the Virgin River, a tributary to the Colorado River.

San Juan River salinity and sediment monitoring: The BLM partnered with the USGS to collect sediment and streamflow data at the San Juan River stream gage near Bluff, UT. The San Juan River is a major source of sediment in the Upper CRB. All data were input into the National Water Information System for real-time conditions to benefit multiple interests, including the Utah Department of Environmental Quality and the BLM's salinity control and modeling programs, as well as to increase understanding of the effects of the Gold King Mine release on the San Juan River and Lake Powell.

Salinity loads in the Upper CRB: The BLM is collaborating with the USGS on a multi-year project to better understand how high-flow events affect salinity in the Upper CRB. Automated water sampling equipment were installed at USGS streamgages located on the San Rafael River

near Green River and Dirty Devil above Poison Springs Wash. Successful sampling of high flow events occurred in the summer of 2021 and are being analyzed by the USGS. Data collection will continue through November 2022. These data will be used to validate models to quantify the effectiveness of salinity control activities.

Wyoming

New Fork restoration and river access: The lower New Fork River flows through an area of high-density natural gas fields downstream from the confluence with the East Fork River. In FY21, approximately 3,500 ft of streambank were stabilized near a boating access ramp and well site. Erosion control work will continue along 1.3 miles of the river in FY23.

LaBarge Watershed restoration project: The BLM is addressing accelerated erosion in the Big Piney-LaBarge project area, which is located within a 100-year-old oil and gas field containing more than 1,500 wells, a livestock grazing area, and a popular recreation area. The project area includes the Dry Piney Creek, Dry Basin Draw, and Birch Creek watersheds, tributaries to the Upper Green River. In FY21, funding was added to an existing contract with Jackola for engineering services to support the Tank Battery and Calpet Road Culvert Projects in the Birch Creek watershed, the restoration plan for erosion and incised channels in the Bird Draw sub-watershed, and the development of a monitoring and maintenance schedule and database to track restoration activities. The Tank Battery Culvert Project addresses three misaligned culverts that cross an ephemeral channel in the Birch Creek watershed; the Calpet Road Culverts Project addresses a misaligned culvert on Birch Creek and a plugged upstream culvert, to prevent catastrophic collapse of sediment and salt into the Birch Creek channel (Figure 19).

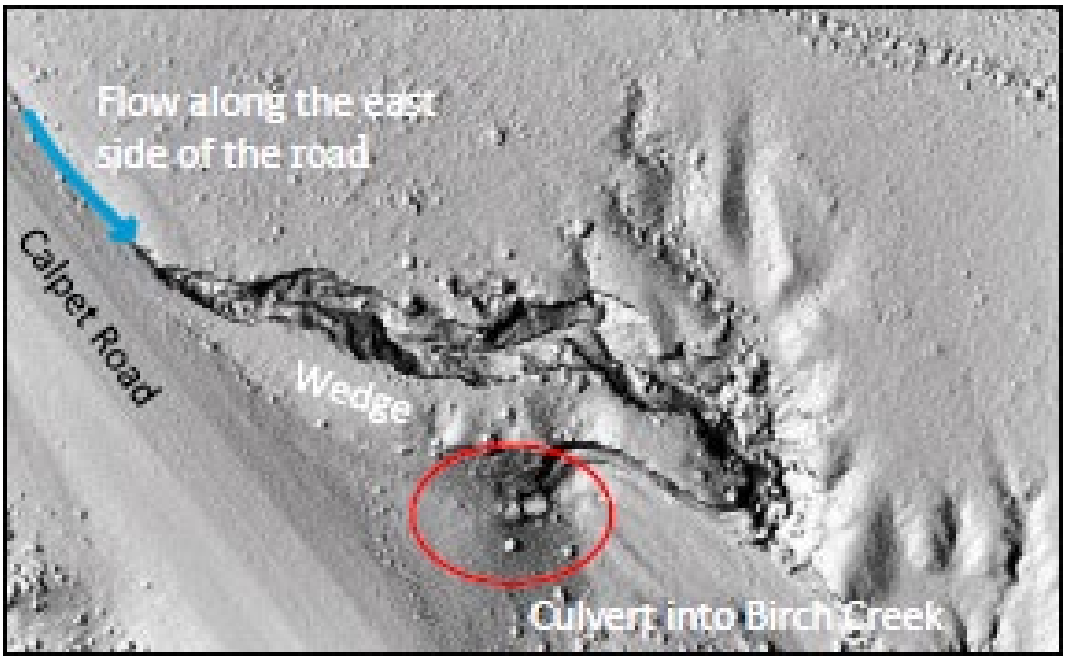

Figure 19. Calpet Road Culverts at Birch Creek.

Figure 20. Littlefield Creek restoration project. Photo taken summer 2021.

Muddy Creek Watershed habitat improvement: Preparations began for the Littlefield Creek restoration project, a cooperative effort by the BLM, Wyoming Game and Fish Department, Trout Unlimited, FWS, and the USGS (Figure 20). Littlefield Creek is a tributary to Muddy Creek, a major tributary to the Little Snake River and has experienced increased sediment loading over time. A USGS study will determine sources of sediment to Littlefield Creek and the removal of a fish barrier will reconnect the incised channel to its historic floodplain. This work will decrease streambank erosion, elevate the water table, expand the riparian area, and increase stream connectivity for native fishes. This project is expected to be completed in FY22.

Savery Creek stabilization project: The BLM continued a multi-year cooperative effort with Wyoming Game and Fish Department and Trout Unlimited to reduce in-channel erosion and sediment and salt loading along approximately four miles of Savery Creek below High Savery Reservoir. Savery Creek is a major tributary to the Little Snake. This project implements natural channel design techniques on target reaches that exhibit unstable channel characteristics. Phase 2 of this four-phase project was completed in fall 2020 and Phase 3 will begin in September 2021.

Summary

In FY21, the BLM continued to construct, maintain, and repair salinity and sediment and control structures, identify saline soils, and support projects that will improve the effectiveness of salinity control activities in the Colorado River Basin. Figure 21 summarizes the percentage of FY21 funding allocated toward these activities.

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

The NRCS of the USDA conducts CRBSC activities primarily under the authorities of the Environmental Quality Incentives Program (EQIP). EQIP was authorized by the 1985 Food Security Act (1985 Farm Bill) but received its first appropriation with passage of PL104-127, Federal Agricultural Improvement Act of 1996, a.k.a. “1996 Farm Bill.”

EQIP has been reauthorized four times; (1) PL 107-171, The Farm Security and Rural Investment Act of 2002, (2) PL 110-246, The Food, Conservation, and Energy Act of 2008, and

most recently (3) PL 113-79, The Agricultural Act of 2014, and most recently (4) PL 115-334, The Agriculture Improvement Act of 2018 (4) PL 115-334 enacted on December 20, 2018.

Through EQIP, NRCS offers voluntary technical and financial assistance to agricultural producers, including Native American tribes, to assist decision-makers to install conservation practices that correct environmental problems and that meet their environmental goals. Within the twelve salinity project areas, producers may be offered additional financial incentives and technical assistance to implement salinity control measures with the primary goal of reducing offsite and downstream damages to the Colorado River and its tributaries and to replace wildlife habit impacted as a result of the salinity measures.

Following fund allocations to the NRCS Salinity Control Program for FY2021. At present NRCS leadership teams in Colorado, Utah, and Wyoming anticipate obligating the majority of the funds allocated to Salinity EQIP in FY2021 as follows:

Allocation	
Colorado -	$6,500,000
Utah -	$4,000,000
Wyoming -	$250,000
Totals	$10,754,000

Program History

Progress in implementing the various projects is controlled primarily by annual federal appropriations. The Salinity Control Act provides funds for additional implementation from the Basin States Salinity Program. From the 1970s through 1986, the Agricultural Conservation Program (ACP) administered by the Agricultural Stabilization and Conservation Service (ASCS) provided financial assistance (cost share) to land users through long term agreements (LTAs) and the Soil Conservation Service (SCS) provided the technical assistance to plan, design, and certify practice implementation. From 1987 through 1996, the Colorado River Salinity Control Program (CRSCP) received dedicated annual funding, again with the ASCS administering the financial assistance and SCS providing the technical assistance. In 1995, Public Law 103-354 authorized the reorganization of several agencies of USDA. The ASCS was reorganized as the Farm Service Agency. The SCS was reorganized as the NRCS. Financial administration of the CRSCP was transferred to the NRCS where it has remained to the present.

The Federal Agricultural Improvement and Reform Act (FAIRA) of 1996 (Public Law 104127) combined four existing programs including the CRBSCP into the newly authorized EQIP. Since the 1996, EQIP has been reauthorized through five consecutive farm bills and is currently authorized through FY 2023.

In FY 1997, Reclamation began on-farm cost sharing from the Basin States funds that would parallel and supplement the EQIP.

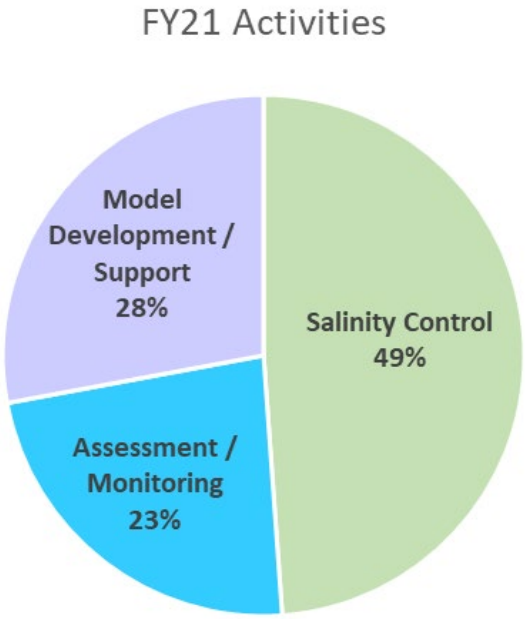

Figure 21. Percentage of FY21 funding allocated towards salinity control, assessment and monitoring, and model development and support activities.

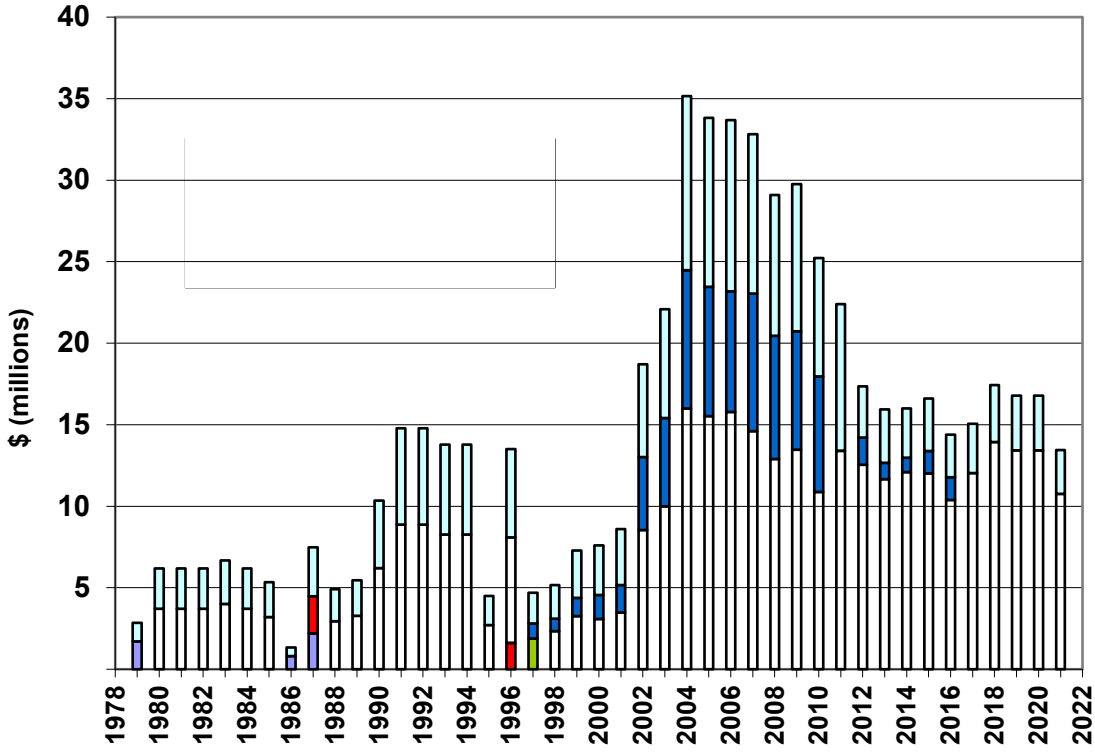

Figure 22 - On-farm / near farm Allocations.

Monitoring and Evaluation

NRCS personnel from project and area offices monitor and evaluate the effectiveness and quantity of salinity control, wildlife habitat, and economic trends in order to improve overall performance and management of the program. The program continues to function effectively and economically, though the nominal cost per ton of salt control is escalating in some areas. Monitoring and Evaluation Reports for FY 2019 can be found at: www.nrcs.usda.gov/wps/portal/nrcs/detail/co/programs/landscape/?cid=nrcs144p2_062765

Status of Planning and Implementation

USDA-NRCS continues to provide technical and financial assistance to landowners and operators to implement on-farm salinity control measures in twelve approved project areas in three Upper Basin states. Contract obligation figures reported are tentative as contracting is not complete for FY2021. Data are not yet available to update this section of the report to show FY2021 achievements. The locations of the following activities can be found in Figure 13.

Grand Valley, Colorado

Implementation has been underway in this unit since 1979 and NRCS considers that the salt control measures of the project have been successfully completed as planned. In 2010, a status report was compiled from field visits and observations. The report indicated that at least 12,000 irrigated acres are no longer in agricultural production. Of the remaining 44,700 acres still in production, 42,435 acres or 95 percent had received varying levels of treatment. This unit has been designated as complete, but additional implementation continues at a reduced rated. No new contracts were obligated in FY2021.

Lower Gunnison Basin, Colorado

This project, which began in 1988, encompasses the irrigated farmland in the Gunnison and Uncompahgre River valleys. With the expansion into the upper headwaters of the Uncompahgre River in 2010, implementation continues in Delta, Montrose, and Ouray Counties. Nearly 70 percent of the salt control goal has been achieved.

Interest remains high in the project area particularly in those service areas that were awarded Reclamation grants for irrigation infra-structure improvements. In 2021 about $3.6M of EQIP was obligated into 46 new contracts to control an additional 2,898 tons of salt on 2,252 acres. There were three new wildlife habitat contracts obligated on 167 acres in 2021.

Mancos Valley, Colorado

This project, near the town of Mancos, Colorado, was initiated and approved for funding and implementation by USDA-NRCS in April 2004. In 2021 three new EQIP contract were developed for $78,040 to control 49 tons of salt on 62 acres. There was one new wildlife habitat contract obligated on 3 acres in 2021.

McElmo Creek, Colorado

Implementation was initiated in this unit in 1990. In 2021 14 new contracts were developed for $429,917 to control 162 tons of salt on 220 acres.

Silt, Colorado

The Silt Project, authorized in 2006, is Colorado's newest project. In 2021, two new contracts were developed for $39,343 to control 9 tons of salt on 90 acres.

Green River, Utah

There were no new contracts in the project area in 2020.

Manila-Washam, Utah

In 2021, 3 new contracts were obligated for $280,118. When implemented, these measures will control about 188 tons on 147 acres.

Muddy Creek, Utah

In 2021, 4 new contracts were obligated for $204,093. When implemented these projects will control 163 tons on 118 acres. The canals and appurtenant delivery systems to Muddy Creek are currently being piped through various State, Local, and Federal funding sources. Interest for on-farm improvements in Muddy Creek is strong and completion of improvements to the delivery system is expected to facilitate a rapid conversion of the entire unit from flood to sprinkler irrigation. NRCS anticipates completion of the majority of the work in the Muddy Creek Unit within the next five years.

Price-San Rafael, Utah

In 2021, 7 new contracts were obligated for a sum of about $440,121. When implemented, these measures will control about 202 tons on 73 acres. There were three new wildlife habitat contracts obligated on 32 acres in 2021.

Uintah Basin, Utah

Implementation began in this unit in 1980. The original salt control goal was reached several years ago but about 60,000 acres might still be improved. Producer participation has exceeded the original projections. In 2021, 38 new contracts were obligated for a sum of about $2.5M. When implemented, these measures will control about 624 tons on 809 acres. There were five new wildlife habitat contracts obligated on 294 acres in 2021.

Big Sandy River, Wyoming

Implementation has been underway in this unit since 1988. Approximately 13,800 acres of the planned 15,700 acres have been treated (88 percent) and about 71 percent of the salt control goal has been reached. No new contracts were obligated in the Big Sandy Unit. Remaining untreated acres are largely controlled by producers not interested in implementing salinity controls, so salinity funds were not allocated to the Big Sandy Unit in 2021.

Henrys Fork (of the Green River), Wyoming

The Henrys Fork Project was officially adopted with the issuance of the Record of Decision, June, 2013. In 2021, one new contract was obligated in the Henrys Fork Project Area for a cost of $171,556 that will control 187 tons of salt on 400 acres.

San Juan Basin, New Mexico and Arizona

The San Juan River Dineh Water Users, Inc. (SJRDWU, Inc.) provides irrigation water to Navajo Nation farmers along the San Juan River from Farmington past Ship Rock, New Mexico. The SJRDWU, Inc. has been aggressive in seeking funding to upgrade its delivery system. While NRCS has never designated this area a salinity control project there is hope that the improvement of delivery infrastructure will spur on-farm irrigation improvements.

Areas Beyond Current Project Boundaries

Even though some relatively high salt loading basins exist in both Colorado and New Mexico, local sponsors have not yet been inclined to pursue a salinity project designation.

NRCS continues to have success in funding salinity control practices outside of its five designated project areas but within the Colorado River Basin (known as Tier II projects). In 2021 Colorado NRCS obligated two Tier II contracts on 99 acres to control 182 tons of salt at a cost of $129,363. In 2021 Utah NRCS obligated two Tier II contracts on 141 acres at a cost of $280,602. Wyoming NRCS obligated no Tier II contracts in FY2021.

The Agricultural Improvement Act of 2018 (PL 115-334) authorizes NRCS to undertake irrigation conveyance improvements in partnership with Water Management Entities (WME). The first WME contracts were obligated in FY2021. Colorado NRCS obligated 5 WME contracts in Fy2021 for a cost of $1 million to control 385 tons. Utah NRCS obligated no WME contracts in FY2021. Wyoming NRCS obligated no WME contracts in FY2021.

TDS Forecast Modeling

The Water Operations Group of Reclamation publishes a 24-month forecast for Lake Powell. This forecast includes a minimum, most likely, and maximum hydrology scenarios for the upcoming 24-months. The three scenarios (min, most, and max) are published in January, April, August, and October. The remaining months consist of a most likely hydrology scenario. However, in response to DROA (Drought Response Operations Agreement), the modeling efforts have increased, and the three scenarios mentioned above (min, most, max) are published monthly.

The Water Quality Group takes the forecasts and uses them to run the 2-dimensional model, CE-QUAL-W2. This model is used to forecast temperature, TDS, and occasionally DO (Dissolved Oxygen). In FY 2021 (WY 2021), the model has been run each month with version 4.1 and the standardized Meteorological data file has been updated with each run. The various regressions (EC to TDS) used for the inflows to Lake Powell have also been updated from the most recent water samples sent to the lab. The resulting modeled TDS of the Glen Canyon Dam (GCD) discharge water is provided to the Lower Colorado region to be used as input for their water quality modeling of Lake Mead.

Table 8 - Implementation Status (October 1, 2020)

			Irrigated Acres	Treated Acres	EIS Goal (tons)	On-Farm Controls (tons)	Off-Farm Controls (tons)	[1]Total Tons Controlled	Indexed Initial Cost ($/ton)	Nominal 2020 Cost ($/ton)
Colorado	Grand Valley	1977	44,600	43,449	132,000	137,597	7,134	144,731	55	90
	Lower Gunnison	1982	171,000	73,991	186,000	105,018	23,006	128,024	92	205
	McElmo Creek	1989	29,000	18,970	46,000	29,226	2,895	32,121	105	184
	Mancos Valley	2004	11,700	3,093	11,940	2,574	2,113	4,687	71	608
	Silt	2005	7,400	1,862	3,990	1,497	914	2,411	98	473
Utah	Uintah Basin	1982	226,000	162,451	140,500	142,990	9,957	152,947	187	282
	Price-San Rafael	1997	66,000	38,468	146,900	92,455	1,553	94,008	38	57
	Manila-Washam	2005	8,000	4,076	17,430	8,693	0	8,693	56	0
	Muddy Creek	2004	6,000	1,343	11,677	1,779	6	1,785	101	116
	Green River	2009	2,600	929	6,540	2,860	0	2,860	110	0
Wyoming	Big Sandy River	1988	18,000	13,933	83,700	58,654	114	58,768	42	0
	Henrys Fork	2013	20,700	345	6,540	277	0	277	249	115
Tier II	(all)		0	1,029	0	7,667	1,075	7,568	0	0

Bureau of Reclamation - Colorado River Basin Salinity Control Program

Colorado River Simulation System (CRSS)

In FY 2021 Reclamation supported the salinity workgroup at meetings in February, June, and September in preparation for the 2023 Triennial Review. Reclamation preformed additional work to advance the salinity modeling capabilities of the CRSS model which is used to investigate control scenarios for the salinity workgroup. The model's layout of upper basin water users was revised in February 2021. Additional improvements are required to enable and verify modeling of salinity in the new layout. Reclamation initiated this process and expects to have a working model by end of calendar year 2021.

Reclamation reviewed and approved a USGS SLOAD update to the historical record for salinity load and concentration that extends the record through calendar year 2020. This flow and salinity concentration record comprises the USGS 20-gauge monitoring network including the 3 numeric criteria locations, below Hoover and Parker Dams, and above Imperial Dam USGS gages. Reclamation used SLOAD and other data sources to develop a natural flow and salt record at the monitoring locations that extends through calendar year 2019. This record will be used as input to in the CRSS model for the 2023 Triennial Review.

Economic Impacts Model

Reclamation maintains a Salinity Economic Impact Model (SEIM) that is used to estimate monetary damages due to salinity in Colorado River water. Damages are estimated in the metropolitan and agricultural areas that receive Colorado River water and presents costs in seven economic sectors including residential, agricultural, commercial, industrial, water and wastewater utilities, groundwater and recycled water use. Economic damages are based on total dissolved solids (TDS) levels greater than 500 mg/L, the Environmental Protection Agency's secondary safe water drinking standard for TDS.

Previously the SEIM was run out of the Reclamation Denver Technical Service Center, now it is run out of the UCB Water Quality Group remote office located at the University of Colorado CADSWES in Boulder, Colorado. The input data includes water supply, water use, demographic data, and other data pertaining to each region in the lower Colorado Basin. In FY 2021, Reclamation initiated a plan to update input data in cooperation with the SEIM committee, a group of state and agency representatives. Monthly meetings of the committee were held to monitor progress of members obtaining relevant data updates. The model is also being extended through 2045. A release of the revamped model is expected to take place in 2021. This SEIM version will be used for the 2023 Triennial Review to estimate quantified damages in the Lower Colorado River Basin.

Science Team

To further improve and expand our knowledge of salinity control methods, data, and modeling within the Colorado River basin, the Salinity Science Team was created. This team incorporates technical experts and coordinators from each Federal agency (Reclamation, USDA, NRCS, BLM, and the USGS) that provides salinity data and/or modeling and the Forum's Executive Director.
The following are some of the topics that were addressed by the Science Team during meeting held on May 2021:

1. Funding/contract update of approved Research, Studies, and Investigations (SIRs)

2. Review of SIR proposals for funding and recommending to the Advisory Council's Technical Advisory Group (TAG) which proposals should receive funding.

   a. SIR 2021-01 Colorado River Indian Tribe Lands, AZ, USGS Salinity Sampling

   b. SIR 2021-02 Squaw Gulch, CO, USGS Salinity Sampling

3. Update on Pah Tempe Study. This is an ongoing study regarding a potential salinity control project at the saline Pah Temp Springs. These springs flow into the Virgin River which is in southwest UT near St George, and is a tributary to the Colorado River flowing into Lake Mead. The springs discharge up to 100,000 tons of salt into the Virgin River annually.

Basin-wide Salinity Control Program (Basin-wide Program)

Notice of Funding Opportunity (NOFO) 2022

New applications to reduce salinity contributions to the Colorado River will be solicited through a FOA for both the Basinwide Program and Basin States Program (BSP). The NOFO is projected to be released sometime in 2022.

Uintah Basin, Utah

Ashley Upper and Highline Canals Rehabilitation Project: This project is located in Uintah County in the vicinity of Vernal, Utah. It was selected from the applications received in the 2015 Funding Opportunity Announcement (FOA) and was submitted by the Ashley Upper Irrigation Company in conjunction with the Ashley Highline Irrigation Company. A cooperative agreement was executed in September of 2016 for $3,514,847 as a 25 percent Federal cost share. This project will replace approximately 21.9 miles of earthen canal and laterals with irrigation pipe resulting in the annual reduction of 2,713 reportable tons of salt in the Colorado River at an anticipated cost of approximately $54.00 per ton of salt. The project began construction in the fall of 2020 and is scheduled to be completed in the spring of 2023.

Gunnison Basin, Colorado

Clipper Center Lateral Pipeline Project: Selected under the 2015 FOA, the Crawford Clipper Ditch Company was awarded a $3.15 million cooperative grant to pipe approximately 4.3 miles of existing, unlined earthen irrigation canals located near Crawford, Colorado and along Cottonwood Creek, a tributary to the Gunnison River. This will result in an annual salt load reduction of approximately 2,606 tons to the Colorado River, at a cost effectiveness of $50.43 per ton. The piping project will consist of buried PVC and HDPE pipe. The cooperative agreement was executed in March 2016, and construction began in 2018. The pipeline was completed in the spring of 2020, and the habitat mitigation was completed in the summer of 2020. The Crawford Clipper Ditch Company requested and was granted a modification to use the remaining funds to pipe 2400 ft of the Clipper West lateral, to be completed by Spring 2022.

UVWUA Phase 9 – ESL: As a result of the 2015 FOA, the UVWUA was selected to be awarded a $5.4 million cooperative agreement for Phase 9 of the ESL. This phase involves piping or abandoning an additional 21.6 miles of laterals off the Selig and East Canals, resulting in an expected annual salt reduction of 6,030 tons, at a cost effectiveness of $37.07 per ton. A portion of the project is funded by the USDA, NRCS, through the RCPP. The cooperative agreement was executed in September 2017. Construction began in 2018 and the first and second phases of the project was completed. The last phase of the project was completed in the summer of 2021.

Gould Canal Improvement Project A: Selected under the 2017 FOA, Gould Canal A was awarded a $4,294,027 cooperative grant for four stages of work. “Section 1” will be piping approximately 1.17 miles of existing open earth irrigation canal with buried HP Storm or similar pipe. “Upper Tunnel” consists of slip liner construction for the upper tunnel. “Section 3” includes lining approximately 1.41 miles of unlined canal with 30 mil PVC membrane with shotcrete cover. “Section 4” consists of lining approximately 0.76 miles of unlined canal downstream of Section 3 using the same method. All four section will be responsible for controlling approximately 3,137 tons of salt annually. Fruitland Irrigation Company requested and received a modification to change a portion of sections 3 and 4 from a lined canal to a pipeline. Construction of the pipeline is scheduled to begin in the fall of 2020. The project is expected to be completed by the spring of 2023.

Gould Canal Improvement Project B: Selected under the 2017 FOA, Gould Canal B was awarded a $3,545,246 cooperative grant for three stages of work. “Lower Tunnel” consists of slip liner construction for the lower tunnel. Section 2 includes lining approximately 2.10 miles of unlined irrigation canal with 30 mil PVC membrane with shotcrete cover. Section 5 consists of lining roughly 2.30 miles of unlined canal using the same methods as Section 2. These improvements will control 2,564 tons of salt annually. Fruitland Irrigation Company requested and received a modification to change a portion of section 2 from a lined canal to a pipeline. Construction of the pipeline is scheduled to begin in the fall of 2020. The project is expected to be completed by the spring of 2023.

Upper Stewart Ditch: Selected in the 2017 FOA, the Upper Stewart project near Paonia, CO, was selected to be awarded a $2,507,561 cooperative agreement for piping approximately 2.6 miles of existing earthen irrigation canal. The pipe will consist of buried PVC pipe. This

project will control 1,622 tons of salt annually with 20 acres of potential on farm improvements. Construction is scheduled to begin in November 2020 and was completed in the spring of 2021. Habitat mitigation expected to be completed by the end of April 2023.

UVWUA Phase 10: As a result of the 2019 FOA, the UVWUA was selected to be awarded a $5.1 million cooperative agreement for Phase 10. This phase involves piping or abandoning an additional 19.2 miles of laterals off the Ironstone, M&D, Selig and East Canal systems, resulting in an expected annual salt reduction of 3,501 tons, at a cost effectiveness of $55.12 per ton. The cooperative agreement was executed in August 2020. Construction will begin in the winter of 2021 and will be completed in the winter of 2024.

Needle Rock Ditch: Selected in the 2019 FOA, the Needle Rock Ditch Piping Project near Crawford, CO, was selected to be awarded a $4,238,228 cooperative agreement for piping approximately 6.7 miles of existing earthen irrigation canals and laterals. The pipeline will consist of buried PVC pipe. This project will control 2,952 tons of salt annually. Construction is scheduled to begin in November 2022 and expected to be completed by the end of April 2023.

Tuner/Lone Cabin Ditch: Selected in the 2019 FOA, the Turner and Lone Cabin Ditch project near Paonia, CO, was selected to be awarded a $6,195,859 cooperative agreement for piping approximately 25 miles of existing earthen irrigation canals and laterals. The pipe will consist of buried pipe. This project will control 3,398 tons of salt annually. Construction is scheduled to begin in November 2022 and expected to be completed by December 2024.

Grandview Canal: Selected in the 2019 FOA, the GCIC Upper, Middle, and Lower pipeline project near Crawford, CO, was selected to be awarded a $6,360,984 cooperative agreement for piping approximately 4.1 miles of existing earthen irrigation canal. The pipe will consist of buried pipe. This project will control 3,553 tons of salt annually. Construction is scheduled to begin in fall of 2022 and expected to be completed by March 2024.

Grand Valley, Colorado

Grand Valley Irrigation Company (GVIC) 550 Salinity Control Program: Selected under the 2019 FOA, the GVIC was awarded a $1.2 million cooperative grant to line approximately 1.0 mile of their main irrigation canal within the Grand Valley. This will result in a salt load reduction of approximately 743 tons annually at a cost effectiveness of $62.70 per ton. The canal lining will consist of a 30-mil PVC membrane with 3-4 inches of shotcrete cover. The cooperative agreement was executed in July 2020. Construction is scheduled to begin November 2021 and completed in March 2024.

Grand Valley Water Users Association (GVWUA) Government Highline Canal – Reach 1A Lower: Selected under the 2019 FOA, the GVWUA was awarded a $476 million cooperative grant to line approximately 1.2 miles of their main irrigation canal within the Grand Valley. This will result in a salt load reduction of approximately 3,083 tons annually at a cost effectiveness of $57.75 per ton. The canal lining will consist of a 30-mil PVC membrane with 3-4 inches of shotcrete cover. The cooperative agreement was executed in June 2020, and construction began in November of 2020. And is scheduled to be completed by March 2024.

Mancos, Colorado

Webber Ditch Piping Project: Selected under the 2019 FOA, the Webber Ditch Company was awarded a $3.3 million cooperative grant for piping approximately 4.24 miles of existing earthen irrigation canal. The pipeline will consist of buried PVC pipe. This will result in a salt load reduction of approximately 2,066 tons annually at a cost effectiveness of $59.99 per ton. The cooperative agreement was executed in July 2020. Construction is scheduled to begin in November 2021 and to be completed in April 2024.

New Mexico

San Juan Dineh Water Users: Reclamation's Upper Colorado Region's Salinity Control Program entered into a cooperative agreement with the San Juan River Dineh Water Users (SWDWU) for financial assistance. The SJRDWU's proposal, replacing earthen ditches and canals with enclosed piping and habitat replacement, will reduce the salt load of the Colorado River above Imperial Dam. The water user's proposal plans on converting fifteen secondary laterals into underground pressurized pipelines.

The project will be divided into two areas. The first area located in Shiprock Chapter is served by Hogback Canal and located west of the Hogback monocline. The 26-mile-long Hogback Canal diverts from the San Juan River at the Hogback Diversion and serves 8,830 acres. The project will convert 14 ditches into underground pressurized pipeline serving approximately 240 farmers on 2,077 acres. The total length of the new pipeline is 156,246 ft.

The second area located in Nenahnezad Chapter is served by Fruitland Canal and located east of Hogback monocline. The 22-mile-long Fruitland Canal diverts water from the San Juan River at Fruitland Diversion and serves 2,224 acres. The project will convert Yellowman Lateral from an earthen ditch into an underground pipeline. Yellowman Lateral serves about 35 farmers on 386 acres. The total length of the new pipeline is approximately 26,671 ft.

Overall, the two sub-projects in Shiprock and Nenahnezad Chapters will total 2,463 acres and convert 182,917 feet of open ditches into underground pressurized pipelines.

San Juan Dineh Waters Users completed the follow as of August 31, 2020:

Completed Projects:

- Habitat Mitigation project. The SJRDWU completed the habitat mitigation project which restored flow from the San Juan River to a historic secondary channel. The project also installed electromagnetic fish antennas for Reclamation used to monitor endangered fish. Construction was completed in November 2018. SJRDWU was able to remove the illegal diversion installed in the habitat mitigation channel in 2020. Water is now flowing the full length of the channel.

- Little Mesa laterals was completed and commissioned in April 2019. The SJRDWU completed installation of the Little Mesa turnout. Pipelines which replace existing earthen ditches. The SJRDWU installed 8,285 ft of PVC pipe, completed four road crossing, installed 20 turnouts, and demolished all ditches. The pipeline was commissioned in early April.

- H-58/59 laterals was completed and commissioned in June 2019. On June 26, 2019, SJRDWU hosted local vendors to demonstrate irrigation sprinklers and gated pipe to approximately 50 farmers. The demonstration included strategies on how to irrigate with pressurized water, sprinkler demonstration, and how gated pipes work. The demonstration was given on a farm served by the recently completed H58/59 pipeline. The pressure at the farm was 50 psi.
- H-54 lateral was completed and commissioned in April 2020. SJRDWU installed 20,305 ft of pipeline.

- H-41 and H-44 lateral was completed in June 2020. The SJRDWU installed approximately 28,217 ft of pipelines and several turnouts. The pipeline was connected to an existing pipeline and will be commissioned in July 2020.

- H-46 lateral was completed and commissioned in April 2020. SJRDWU installed approximately 20,480 ft of pipeline.

- H-52 Lateral was completed and commissioned in April 2021. SJRDWU installed approximately 16,111 ft of pipeline.

Unfinished Projects

Yellowman Later construction began. The SJRDWU unloaded PVC purchased by the Navajo Nation for Yellowman Lateral and stored it securely in a yard located at Nenahnezad Chapter. As of this date, SJRDWU installed approximated 21,069 ft of pipeline. Construction on Yellowman Lateral is scheduled to resume in November 2021 and completed by April 2022. Four utility crossings remain to be completed.

H-53 Lateral. A design has been completed for H-53 lateral. The total length of lateral designed is 22,445 ft. As of August 31st, 2021, SJRDWU has installed approximately 1,249 ft of pipeline. The H-53 lateral is scheduled to be completed by April 2022. H-53 lateral includes 70 field turnouts and 9 road crossings.

H-50 Lateral. A design has been completed for H-50 lateral. The total length of lateral designed is 5,262 ft. As of August 31st, 2021, SJRDWU has installed approximately 100 ft of pipeline. The H-50 lateral is scheduled to be completed by April 2022. H-50 lateral includes 16 field turnouts.

#9 Ditch Lateral. A design has been completed for #9 Ditch lateral. The total length of lateral designed is 18,3912 ft. As of August 31st, 2021, SJRDWU has not started construction on the #9 Ditch Lateral, with construction to begin in November 2021 that will include 42 field turnouts and ten road crossings. The #9 Ditch lateral is scheduled to be completed by April 2022.

San Juan Dineh Water Users – Shiprock Later Conversion Phase II: Selected in the 2019 FOA, a cooperative agreement with the San Juan Dineh Water Users in the amount of $1.2M has been awarded that will control 751 tons of salt annually with a cost effectiveness of $60.64 per ton. The proposed project is to convert 15 laterals from earthen ditches into underground pressurized pipelines and to convert two sections of the Hogback Canal into a pipeline resulting in the elimination of a sluiceway that discharges flow back to the San Juan River via an artificial earthen channel. Overall, the proposed project will convert 6,393 ft of main canal into a pipeline, 47,110 ft of earthen laterals into underground pressurized pipeline, and eliminate a 2,770 ft of earthen sluiceway channel. Total areas served by the proposed project is 1,405 acres.

Basin States Program (BSP)

Public Law 110-246 amended the Act creating the BSP to be implemented by the Secretary of the Interior through Reclamation. Section 205(f) of the Act was amended to provide that cost share obligations be met through an up-front cost share from the Basin Funds. The amendment also authorizes Reclamation to expend the required cost share funds through the BSP for salinity control activities established under Section 202(a)(7) of the Act.

Reclamation has determined that agencies within the upper Basin states to be appropriate partners and has executed cooperative agreements to utilize the services of these state agencies to assist in seeking and funding cost-effective activities to reduce salinity in the Colorado River system. Activities will also benefit the upper Basin states by improving water management and increasing irrigation efficiencies.

Utah Department of Agriculture and Food (UDAF)

UDAF closed the Rock Point Irrigation Company contract on November 2, 2020. The company was in litigation with the contractor for minor cleanup and system leaks but certified that the system was functioning and would hold the state of Utah and Bureau of Reclamation harmless.

This was the last implementation project given to UDAF from Reclamation.

UDAF, at the direction of the Advisory Council and Reclamation, continues to employ the Uintah basin salinity coordinator using BSP funds. The work of the coordinator has benefited the salinity control program by creating interest and participation in the program. Because of the competitive nature of the FOA process and minimal salt loading in some of the salinity project areas, other funding has been necessary to reduce the cost per ton. The Coordinator has been effective in finding local funding from diverse sources to help fund projects. This has been a challenge to bring diverse funding sources together and make them fit into the salinity control

program. Through his efforts several PL-566 watershed projects are moving forward that have significant salinity control. UDAF feels that using BSP funds for this position has greatly benefited the salinity control program in the Uintah Basin area and other salinity control areas.

During the past year UDAF has been working with Reclamation and the basin states to determine how the states can move the salinity control program forward without administering construction projects. After several months of work, tasks were developed that would help the program and can be conducted by the states. These tasks were documented in new agreements with the states and Reclamation. The new agreement with UDAF has been signed and becomes effective October 1, 2021.

Colorado Department of Agriculture - Colorado State Conservation Board (CSCB)

The Colorado Department of Agriculture continues to employ a full-time salinity program field coordinator. The position is funded by the Basin States Program and makes it possible for the State to give input on salinity projects in the State's portion of the Colorado River Watershed.

The coordinator has now begun working with potential applicants for the next FOA. The coordinator has also been responding to a wide variety of other inquiries concerning irrigation improvements. Some of the proposed projects may become candidates for the next Reclamation salinity FOA. Others may be a better fit for NRCS funding or other sources of funding. The coordinator tries to engage at least briefly with all who seek his assistance, knowing that doing so creates a good reputation for his position. This reputation may yield more FOA applications in the long run.

The coordinator was extensively involved in helping Lateral Ditch ML47 successfully complete its piping project. This was the last remaining BSP pass off project. The ML47 project was completed and operational in April of 2021

The Coronavirus has restricted the coordinator's travel for the past several months. This has decreased his ability to promote interest in the next Reclamation salinity FOA. However, his travel restrictions have eased, and he has been able to resume making site visits.

Progress: BSP Projects:

The following BSP projects are currently being administered by the Colorado Department of Agriculture and conservation districts.

Ward B. Studt Headgate 275 Grand Valley Salinity Project Area ($85,875). The NEPA and design work are completed. The project is available to go to construction in the fall of 2020, but it is unclear if the owners will do so.

Wyoming Water Development Commission (WWDC)

The WWDC provides state funding through grants and loans for water studies, master plans, and construction projects across Wyoming. WWDC project funding is provided to a public entity for projects including, but limited to, transmission pipelines, storage, reservoirs, irrigation

improvements, canal to pipe conversions, and system improvements. Day-to-day operations are managed by the Wyoming Water Development Office (WWDO) staff. The WWDO construction division administered the construction and study components of the Wyoming BSP program.

At this time no Basin State programs in Wyoming have been delayed or canceled over the past year.

Reclamation Notice of Financial Opportunity (NOFO) 2022

Applications to reduce salinity contributions to the Colorado River will be solicited through a NOFO for both the Basin-wide Program and Basin States Program (BSP). The NOFO is estimated to be released later in 2022.

Ongoing projects from past Funding Opportunity Announcement's (FOA now NOFO's).
In the **2017 FOA**, 4 projects were selected and are being administered by Reclamation.

Muddy Creek Irrigation Company Piping Project Phase III: This project was selected from the 2017 FOA. A cooperative agreement was executed in September 2018 for the amount of $4,583,000. This project, located in Emery County, will replace approximately 37.5 miles of earthen canals with a pressurized pipeline system resulting in the annual reduction of 3,010 reportable tons of salt in the Colorado River, and enabling 3,310 acres of potential on-farm work. This project is in the pre-construction phase with construction expected to begin in the fall of 2021.

Root and Ratliff Salinity Pipeline Project: Selected in the 2017 FOA, the Root & Ratliff ditch Company was awarded a $3.6 million cooperative agreement to pipe approximately 5.5 miles of their main irrigation canal, located near Mancos, Colorado. This will result in a salt load reduction of approximately 2,347 tons annually at a cost effectiveness of $58.21 per ton. Construction began in the summer of 2021 and the project is expected to be completed by the spring of 2022.

Shinn Park/Waterdog Lateral Salinity Reduction Project: Selected in the 2017 FOA, the Bostwick Park Water Conservancy District was awarded a $4.1 million cooperative agreement to pipe approximately 7.8 miles of unlined irrigation canals, located near Montrose, Colorado. This will result in a salt load reduction of approximately 3,304 tons annually at a cost effectiveness of $47.51 per ton. Construction is scheduled to begin in the fall of 2021 and the project is expected to be completed by the September of 2023.

Jerdan, West, Hamilton Laterals Pipeline Project: Selected in the 2017 FOA, the Crawford Clipper Ditch Company near Crawford, CO, was selected to be awarded a $3,997,208.60 cooperative agreement for piping approximately 6.7 miles of existing earthen irrigation canal. The pipe will consist of buried PVC pipe. This project will control 2,584 tons of salt annually with 20 acres of potential on farm improvements. Construction is scheduled to begin in November 2022 and expected to be completed by the end of December 2022.

In the **2019 FOA**, 3 projects were selected and are being administered by Reclamation.

Interstate Canal Salinity Reduction project: This project was selected from the 2019 FOA. A cooperative agreement was executed in September 2020 for the amount of $5,284,119. This project, located in Southwestern WY, adjacent to the WY-UT border near McKinnon, WY, will replace approximately 13.1 miles of an unlined earthen canal with a pressurized HDPE pipeline system resulting in the annual reduction of 2,295 reportable tons of salt in the Colorado River. This project is in the pre-construction phase.

Pilot Rock Ditch Piping Project: This project was selected from the 2019 FOA. A cooperative agreement was executed in June 2020 for $940,401. This project, located near Crawford CO. The Pilot Rock Ditch company will replace approximately 1.5 miles of an unlined earthen canal with a pressurized pipeline system resulting in the annual reduction of 665 reportable tons of salt in the Colorado River. This project is in the pre-construction phase with construction expected to begin in the summer of 2022.

Short Ditch Extension Piping: This project was selected from the 2019 FOA. A cooperative agreement was executed in July 2020 for $548,687. This project, located near Hotchkiss CO. The Short Ditch Extension Company will replace approximately 1.1 miles of an unlined earthen canal with a pressurized pipeline system resulting in the annual reduction of 419 reportable tons of salt in the Colorado River. This project is in the pre-construction phase with construction expected to begin in the summer of 2022.

Paradox Valley Unit (PVU), Colorado

The Paradox Valley Unit was authorized for investigation and construction by the Salinity Control Act. The unit is located in southwestern Colorado along the Dolores River in the Paradox Valley, formed by a collapsed salt dome (Figure 23). Groundwater in the valley comes into contact with the top of the salt formation where it becomes nearly saturated with sodium chloride. This project intercepts extremely saline brine (260,000 mg/l total dissolved solids) before it reaches the Dolores River and disposes of the brine by deep well injection. The project historically intercepted and disposed of 95,000+ tons of salt annually (Figure 24).

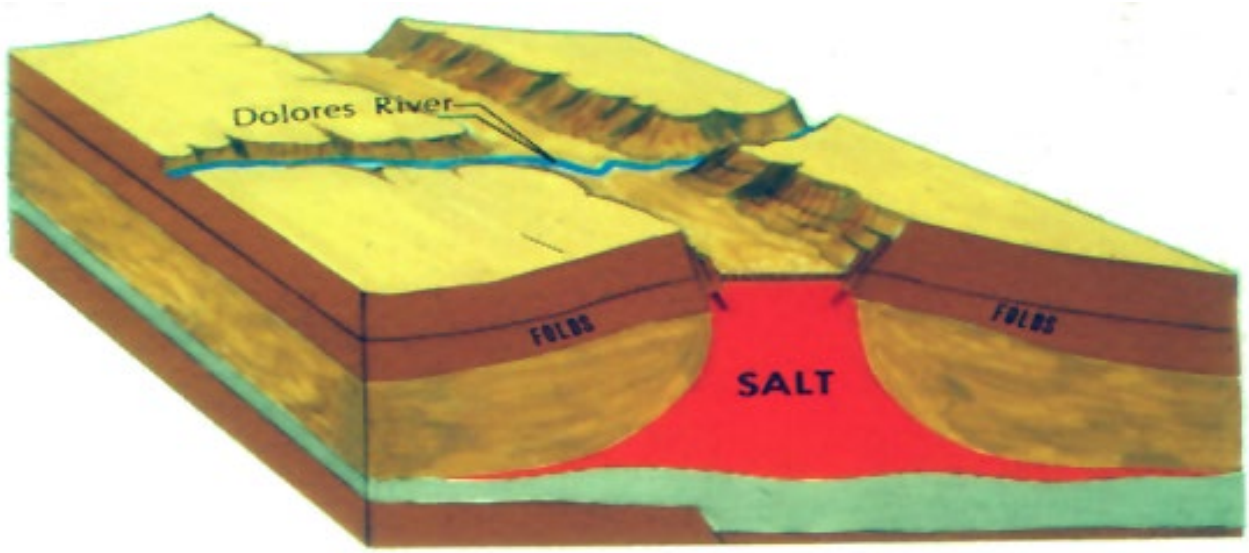

Figure 23 – Paradox Valley Geology.

Induced seismicity and the pressure necessary to inject the brine into the disposal formation at 14,000' have been the limiting factors of the project. The injection pressure has been substantially reduced following injection rate reductions in 2013 and 2017, and seismicity is now the main concern.

PVU operations were suspended on March 4, 2019, after a M4.5 earthquake occurred approximately 1.5 km SW of the injection well. The well remained shut in until April 21, 2020, resulting in the longest shut down since full time operation of the unit began in 1996.

A thirty-nine-day injection test at a reduced injection rate was conducted form April 21, 2020 to May 29, 2020 to determine injection well performance after the extended shut-in since March 2019. The test results showed little change to the well performance since the well was shut in on March 4, 2019.

Following the thirty-nine-day injection test, Reclamation made the decision to remain shut down and allow the injection formation pressure to further dissipate to potentially extend the service life of the well. After further consideration, Reclamation elected to evaluate the potential risk associated with future induced seismicity through a formal seismic risk analysis. The risk analysis is currently underway and is expected to be completed by mid-2023.

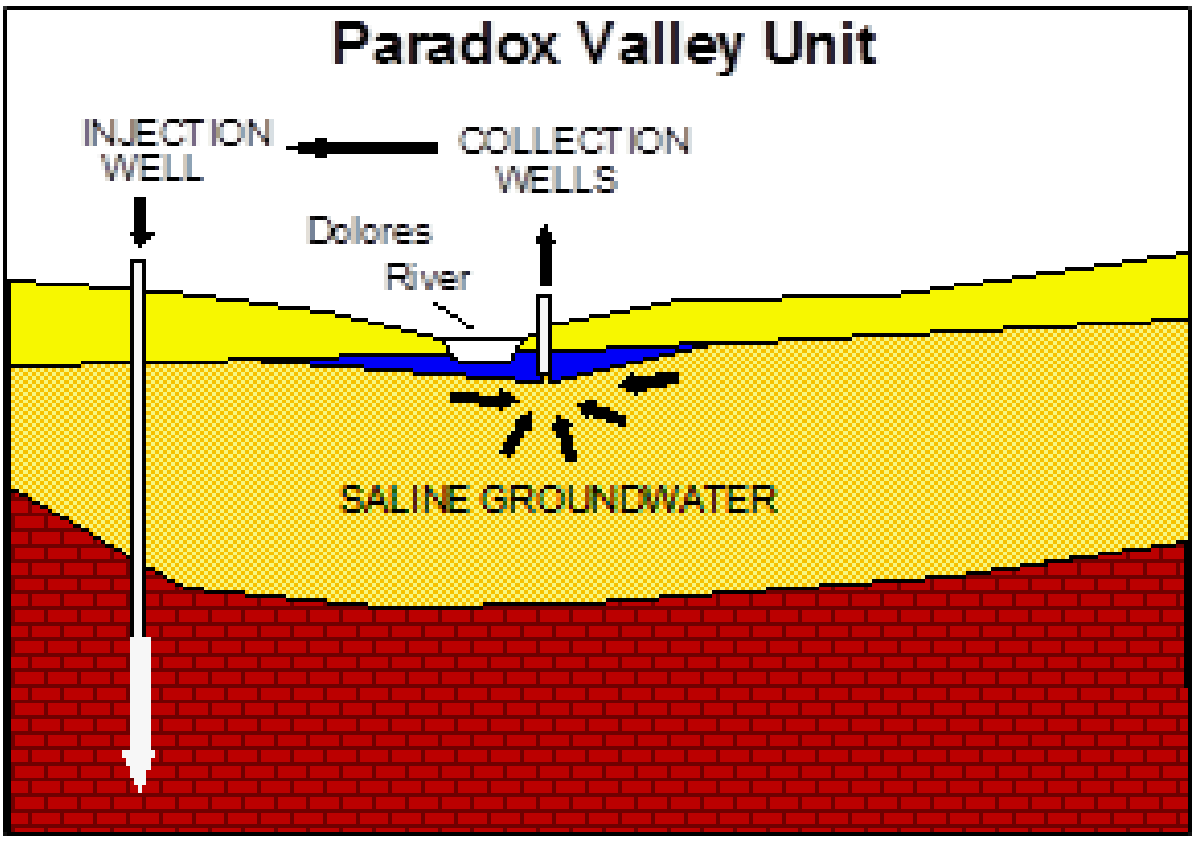

Figure 24- Schematic of Paradox Project.

PVU EIS

Reclamation released a Final Environmental Impact Statement (FEIS) on December 11, 2020. The FEIS evaluated brine disposal alternatives to replace the existing brine injection well of the Paradox Valley Unit. Reclamation identified "no action" as the preferred alternative. The no action alternative includes continued operation of the PVU until it becomes no longer feasible to operate.

Table 9 - Paradox Well Injection History

Injection Period	Days of Operation	Pressure Start	High Pressure During Period	Injection Period Net Pressure Change	Tons of Salt[1] Injected	Estimated Tons of Salt[2] Entering the River	No. of Induced Seismic Events ≥ 0.5	Maximum Magnitude of Induced Seismic Events
Jan-May '02	148	1609	4432		52,860	8,945	19	2.7
June-Dec '02	178	929	4593	161	58,953	11,021	38	3.3
Jan-May '03	144	1172	4627	34	53,173	19,545	31	2.4
June-Dec '03	184	1154	4675	48	59,530	12,592	120	2.6
Jan-May '04	140	1201	4640	-35	51,449	21,828	45	2.9
June-Dec '04	160	1091	4541	-99	51,589	8,129	57	3.9
Jan-May '05	140	1038	4736	195	55,024	18,194	52	2.8
June-Dec '05	148	1203	4750	14	46,551	40,762	57	2.9
Jan-June '06	138	375	4680	-70	44,779	53,893	10[3]	2.4
July-Dec '06	162	1084	4797	117	56,920	22,840	16[3]	1.9
Jan-June '07	159	1066	4796	-1	56,068	22,792	6[3]	2.2
July-Dec '07	163	1232	4712	-84	57,395	12,752	26	2.9
Jan-June '08	160	1152	4813	101	54,720	20,936	21	1.3
July-Dec '08	162	1263	4822	9	56,734	17,105	30	2.1
Jan-Mar '09	84	1246	4756	-66	29,163	22,353	13	2.6
Apr-Sept '09	160	1157	4891	135	55,083	17,892	42	2.7
Oct '09-Mar '10	153	970	4930	39	51,589	32,739	40	2.9
Apr '10-Sep '10	162	1347	4990	60	55,747	20,522	25	2.7
Oct '10-Mar '11	161	1378	5000	10	55,501	23,410	246	2.9
Apr '11-Sep '11	158	1276	5102	102	54,422	15,388	77	2.7
Oct '11-Mar '12	162	1282	5115	6	56,531	21,808	33	2.5
Apr '12-Sep '12	161	1417	5108	-7	55,605	6,392	32	2.1
Oct '12-Mar '13	97	3149	5120	12	34,409	6,331	32	4.4
Apr '13-Sep '13	162	498	4770	-350	45,769	13,099	11	1.8
Oct'13-Mar '14	181	4059	4788	18	52,194	5,873	11	1.7
Apr '14-Sep '14	182	4658	4758	-30	50,539	2,460	5	2.3
Oct '14-Mar '15	181	4550	4758	0	50,305	22,856	9	1.1
Apr '15-Sep '15	182	4483	4791	33	50,396	7,935	11	1.6
Oct '15-Mar '16	180	4581	4758	-33	50,100	24,041	26	2.1

Apr ‘16-Sep '16	182	4633	4789	31	50,748	9,941	17	1.4
Oct ‘16-Mar '17	161	4749	4803	14	44,955	27,652	32	2.9
Apr ‘17-Sep '17	175	1511	4669	-134	46,215	11,548	50	2.6
Oct ‘17-Mar '18	181	4674	4749	80	47,750	35,791	34	2.9
Apr ‘18-Sep '18	179	4710	4814	65	46,764	12,985	29	1.8
Oct ‘18-Mar '19	154	4704	4788	-26	40,567	20,917	196	4.5
Apr ‘19-Sep '19	0	1336	1336	-3452	0	29,435	154	3.0
Oct ‘19-Mar '20	0	49	49	-1287	0	37,212	46	2.5
Apr ‘20-Sep '20	39	0	3573	3524	6,650	23,089	37	3.1
Oct ’20-Mar ‘21	0	0	0	-3573	0	30,074	101	3.9

1 Tons of salt injected based on 260,000 mg/L. Brine concentration varies slightly due to seasonal and environmental fluctuations.

2 Tons of salt entering the river based on regression equations (Ken Watts, USGS Administrative Report – “Estimates of Dissolved Solids Load of the Dolores River in Paradox Valley, Montrose County, CO, 1988-2009, August 5, 2010”). The 2010 FAR contained erroneous estimated tons of salt entering the river.

3 Seismic data for 2006 and the first half of 2007 is incomplete due to seismic network problems.

Colorado River Basin Salinity Control Program Summary Data

The following tables summarize the salinity control program and funding using the latest available data from the 2020 Review.

Table 10 – Summary of Federal Salinity Control Programs (2020)

Salinity Unit		Tons / Year Removed
MEASURES IN PLACE		
Ashley Valley WWTP	1/	9,100
Meeker Dome		48,000
Las Vegas Wash Pitman		3,800
Grand Valley (stage 1 & 2)		122,300
Paradox Valley	2/	0
Lower Gunnison Winter Water (USBR)		41,400
San Juan		52,700
Blacks Fork		1,100
Paria		1,800
Grand Valley		160,300
Price-San Rafael		161,500
Uinta Basin		212,700
Big Sandy River		71,400
Lower Gunnison		214,600
Dolores (McElmo Ck)		56,500
Henry"s Fork, WY		500
Mancos		6,100
Muddy Creek		2,700
Manila		23,300
Silt		2,600
Green River		2,700
Tier 2	3/	8,300
BOR/NRCS/BSP Subtotal		**1,203,400**
MEASURES IN PLACE BY BLM		
Nonpoint Sources	4/	0
BLM Well-Plugging		14,600
Measures in Place Total		**1,218,000**
GOALS TO REACH TARGET		
Reclamation (Basinwide Program)		27,800
NRCS Program (EQIP)		30,100
BSP		4,500
2021 & 2022 Annual Goal		**62,400**
Target Total (Measures in Place + Goals)		1,342,800
Target by 2023	5/	**1,330,400**

1/ Off-farm projects funded by the BSP

2/ Paradox injection well shut down in 2020; assumed continuation of well or alternative control beginning in 2021

3/ Measures in areas outside approved projects.

4/ BLM non-point source are estimates of implementation

5/ Based on the 2020 Triennial Review Plan

Table 11 – Summary of Colorado River Basin Salinity Control Program Appropriations and Cost Share from the Basin Funds 2010 thru 2020

Total Program ($1,000)

Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Subtotal
Grand Valley O&M	766	1,030	967	1,133	1,414	1,685	1,734	1116	1,812	1197	1,849	14,702
Paradox Valley O&M	2,823	2,745	2,427	2,344	2,632	2,681	3,733	3,329	3,059	4,241	2,854	32,868
Lower Gunnison O&M	0	0	0	0	0	0	0	0	0	0	0	0
McElmo Creek (Dolores) O&M	473	344	336	394	335	402	321	434	524	687	566	4,816
USBR Basinwide Program	6,704	8,493	8,298	8,679	7,015	7,293	9,391	8,547	10,374	8,381	10,305	93,480
Subtotal (USBR Program)	10,766	12,612	12,028	12,550	11,396	12,062	15,178	13,427	15,769	14,506	15,573	145,867
USDA Program	14,583	16,382	15,485	13,354	14,488	15,226	11,791	15,319	17,618	16,320	16,377	166,944
BLM (no Basin Funds)	800	800	800	800	800	800	800	1,000	1,700	1,700	1,700	11,700
Total	26,149	29,794	28,313	26,704	26,684	28,088	27,769	29,746	35,087	32,526	33,650	324,511

Appropriations Expended ($1,000)

Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Subtotal
Grand Valley O&M	766	1,030	967	1,133	1,414	1,685	1,734	1,116	1,278	1,197	2,348	14,668
Paradox Valley O&M	2,823	2,745	2,427	2,343	2,626	2,681	3,733	3,329	2,875	4,241	3,992	33,815
Lower Gunnison O&M	0	0	0	0	0	0	0	0	0	0	0	0
McElmo Creek (Dolores) O&M	473	344	336	394	335	403	321	434	337	686	502	4,565
USBR Basin-wide Program	6,704	8,473	8,298	8,679	7,015	7,293	9,391	8,547	10,883	8,381	10,000	93,664
Subtotal (USBR Program)	10,766	12,592	12,028	12,549	11,390	12,062	15,179	13,426	15,373	14,505	16,842	146,712
USDA Program	14,583	16,382	15,485	13,354	14,488	15,226	11,791	15,319	17,082	15,767	16,377	165,854
Total	25,349	28,974	27,513	25,903	25,878	27,288	26,970	28,745	32,455	30,272	33,219	312,566

Upper Basin Fund Cost Share Payments ($1,000) 2010-2020

Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Subtotal
Grand Valley O&M	38	52	48	57	71	94	119	74	91	60	92	796
Paradox Valley O&M	141	137	121	117	132	213	189	166	153	212	143	1,724
Lower Gunnison O&M	0	0	0	0	0	0	0	0	0	0	0	0
McElmo Creek (Dolores) O&M	30	22	22	25	21	44	31	28	30	44	36	333
USBR Basinwide Program	431	546	533	558	451	640	583	650	700	539	662	6,293
Subtotal (USBR Program)	640	757	724	757	675	991	922	918	974	855	933	9,146
USDA Projects	1,289	802	862	931	1,603	1,009	1,005	778	897	1,049	1,053	11,278
Total Payment	1,929	1,559	1,586	1,688	2,278	2,000	1,927	1,696	1,871	1,904	1,986	20,424

Lower Basin Fund Cost Share Payments ($1,000)

Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Subtotal
Grand Valley O&M	217	292	274	321	401	477	641	418	513	339	524	4,417
Paradox Valley O&M	800	778	688	664	746	760	1,072	943	867	1,202	809	9,329
Lower Gunnison O&M	0	0	0	0	0	0	0	0	0	0	0	0
McElmo Creek (Dolores) O&M	172	126	122	144	122	147	176	158	191	250	206	1,814
USBR Basinwide Program	2,442	3,094	3,023	3,161	2,555	2,657	3,305	3,684	3,779	3,053	3,754	34,507
Subtotal (USBR Program)	3,631	4,290	4,107	4,290	3,824	4,041	5,194	5,203	5,350	4,844	5,293	50,067
USDA BSP	1,844	9,949	8,909	8,171	4,315	4,291	5,859	4,694	5,269	6,181	1,258	60,740
Total	5,475	14,239	13,016	12,461	8,139	8,332	11,053	9,897	10,619	11,025	6,551	110,807

Chapter 4 – Additional Water Quality Issues

Dreissenid Mussels in the Upper Colorado River Basin

Continued monitoring for quagga and zebra mussels continue in the Colorado River Basin (CRB). No new waters have been found to contain these aquatic invasive species above Lake Powell in the basin. Other waters in the Upper Colorado River Basin, outside of the CRB, have not been found to contain any new populations of these mussels. New methods of decontamination are being implemented such as dip tanks for boats on trailers for boats leaving Lake Powell. One is located near the Wahweap marina near the dam. Another is being constructed, with the help of Reclamation funding, up-lake for the Bullfrog marina area. Figure 23 shows the Lake Powell Wahweap State line dip tank. This decontamination method is more efficient than the portable trailer based hot water sprays in general use for boat decontamination.

Figure 25 – Boat Decontamination Dip Tank.

Figure 26 - Decontamination Dip Tank at Stateline Launch Ramp Lake Powell, UT (UCR BOR photo).

Water Quality Issues Related to Drought Conditions

With the CRB in continued drought conditions, water quality issues related to the lower water levels of reservoirs, specifically related to dissolved oxygen and the temperature, becomes more pronounced.

Using Lake Powell as an example, temperature of the penstock water generally stays within a 8 degree range through the year. Historically, the reservoir mixing in early winter is generally only to the penstock and doesn't mix into the deeper water below the penstock. As the reservoir elevation lowers the mixing in the winter goes into the deeper and cooler water which begins to warm this water. Figure 24 shows the temperature in Lake Powell forebay from Jan 2000 – Dec 2021. It can be seen that when the elevation of the reservoir decreases the warmer water above the penstock elevation goes deeper into the reservoir, which then increases the temperature of the water discharged. Figure 25 shows how the temperature might increase in the penstock discharge water using CEQUAL W2 modeling. This warmer water discharged from the dam may have a negative effect on the fishery below the dam. Not only may this negatively impact the sport fishery, it may allow for other non-native fish to inhabit and thrive below the dam. These fish may then have a negative impact on the endangered fish in the Colorado River as they consume younger and smaller fish.

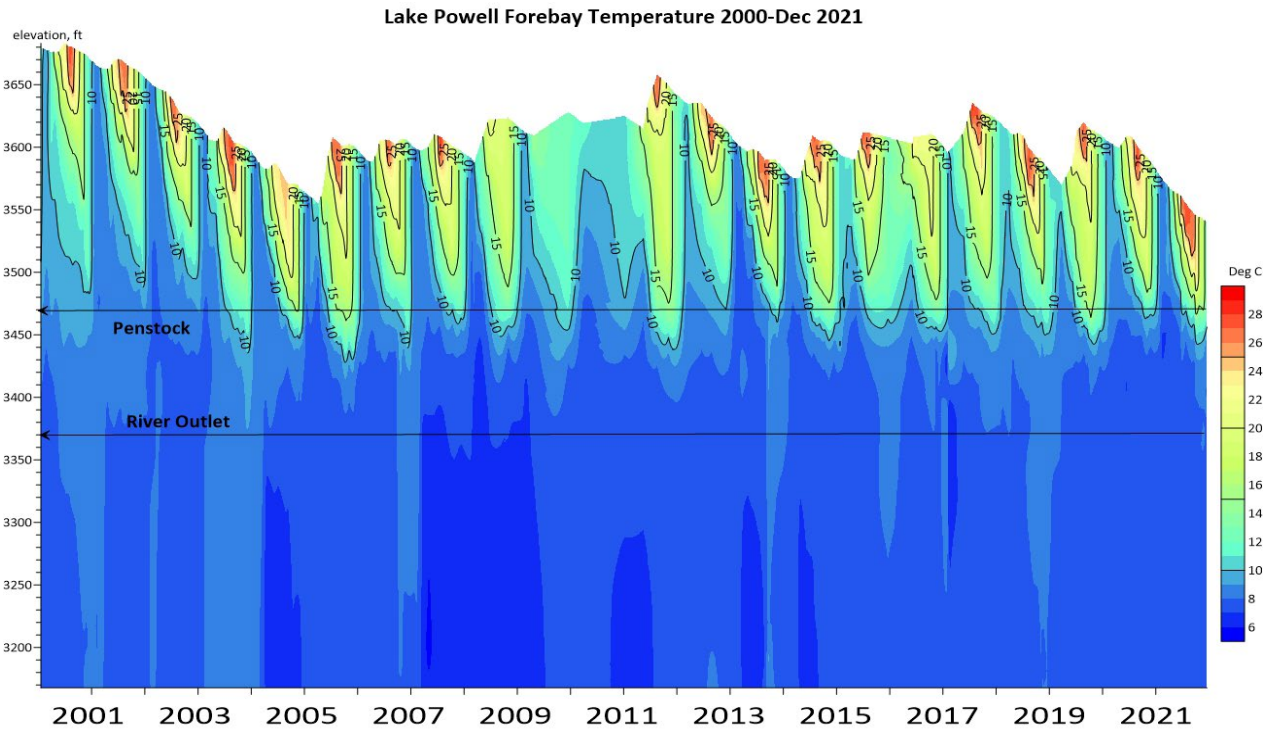

Figure 27 – Annual change in the temperature at Lake Powell Forebay Jan 2000 - Dec 2021 (UCB BOR Data).

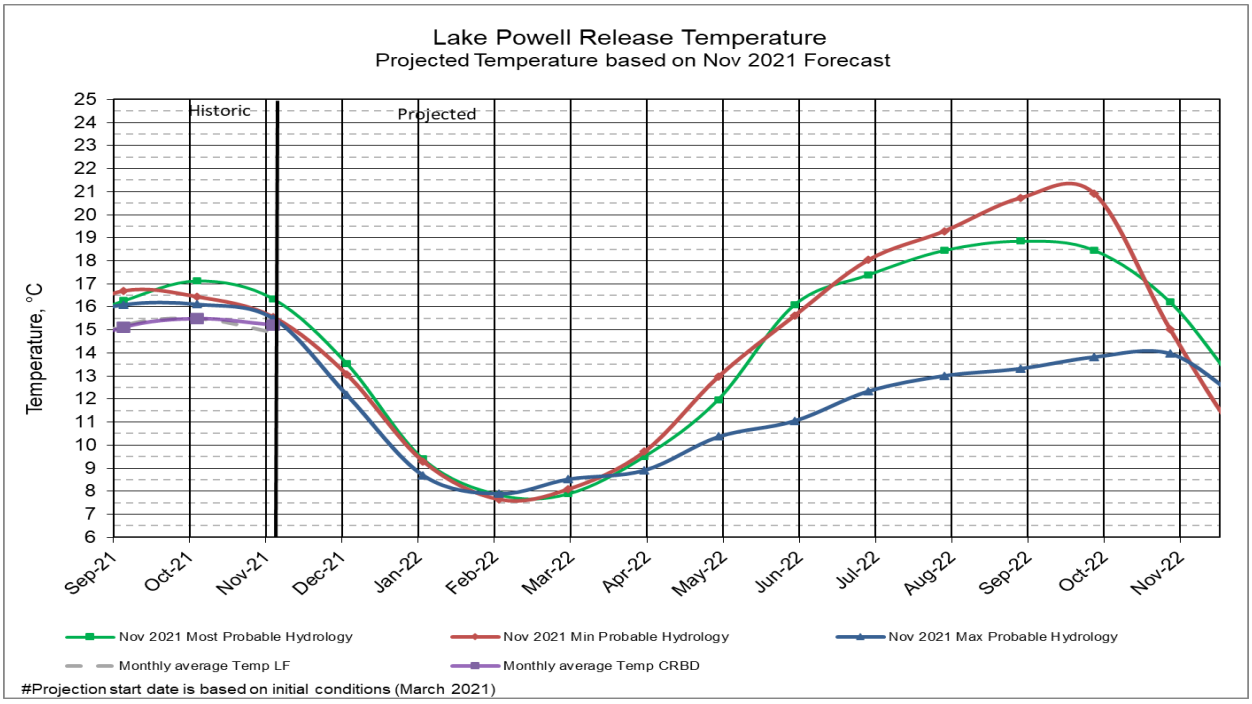

Figure 28- Projected Lake Powell Discharge Temperature change with lowering Reservoir elevation (UCB BOR model run).

In Fig 28, the CEQUAL W2 model shows the temperature is projected to increase about 2 deg C, using the projected two-year hydrology from Nov 2021, as the water level of the reservoir drops to record low elevations. This is for both projected most probable and minimum probable hydrology, green and red line. The maximum projected hydrology, the blue line, shows a lower high temperature as the elevation of the reservoir would increase and there would be an increase in the spring cold water inflow volume.

Levels of dissolved oxygen are mostly impacted by temperature and the biological and chemical activities in the reservoir. Warmer water will hold less oxygen than colder water, everything else being equal. Biological activities such as organic matter decomposition, removes oxygen from water as well as chemical reactions in the water. As the water elevation decreases sediment which was eroded from the surrounding landscape is exposed throughout the reservoir which was previously inundated. This sediment becomes available for resuspension from heavy rains, such as the monsoonal rains Lake Powell tends to get latter in the summer. Figure 26 shows a cut in the shoreline in Cha bay on the San Juan Arm of Lake Powell. This beach was fully covered with sand until heavy monsoonal rains cut this channel (10-15’ deep) through the middle of the beach. Considering the large surface area of Lake Powell and the many embayments, the amount of resuspended sediment entering the reservoir could be excessive under the right conditions. This suspended sediment increases biological and chemical activity which increases the oxygen demand in the water system reducing the dissolved oxygen level. From the late summer heavy monsoonal rains in 2021 which cut through and resuspended sediment reservoir wide, a low dissolved oxygen plume of water became established throughout the reservoir, seen in Figure 27, just above the penstock elevation. This hypoxic plume of water was not very thick and ended up mixing enough that the discharge water from Lake Powell didn’t get to levels which could have had an impact on the fishery below the dam.

Figure 29- Monsoonal Rain Sediment cut in Cha Canyon, San Juan Arm Lake Powell. (UCB BOR photo)

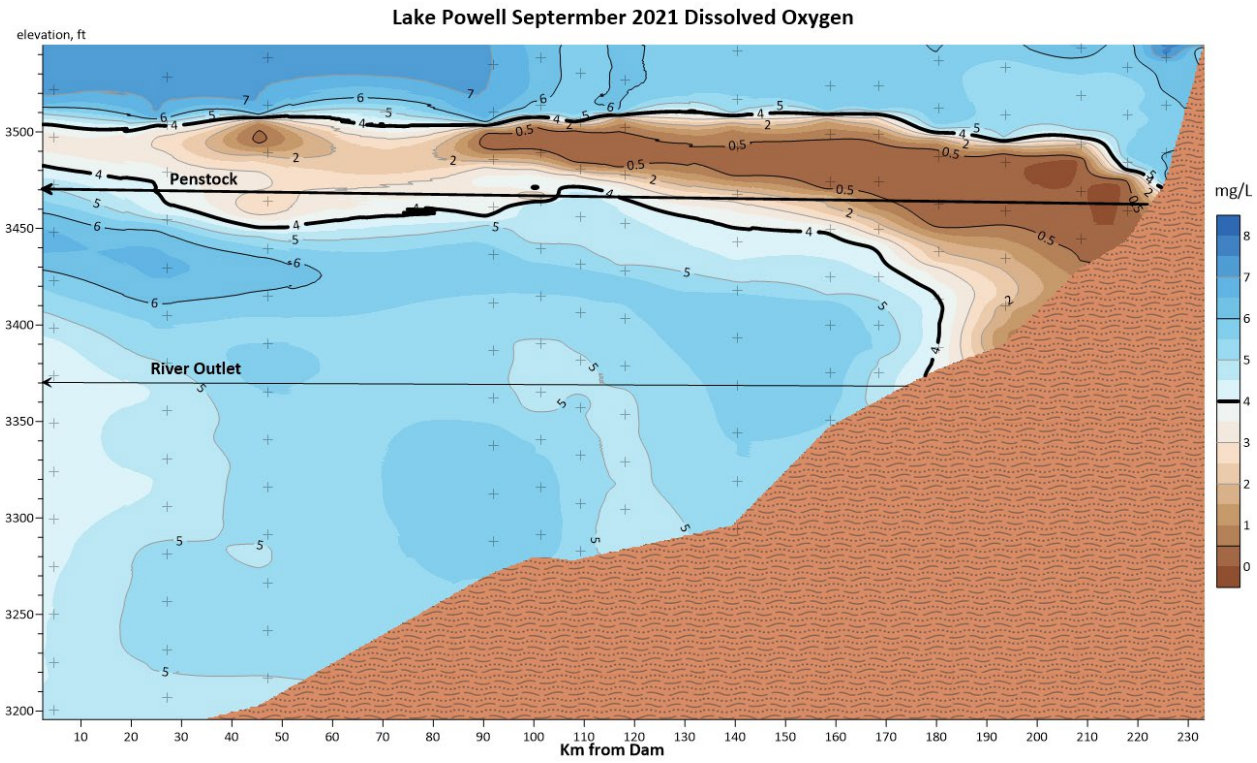

Figure 30 - Lake Powell Monsoonal Rain caused Reservoir wide Low Dissolved Oxygen Plume, Sept 2021(UCB BOR data).

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Appendix A

Salinity Control Monitoring Stations

Colorado River Basin Monitoring Stations

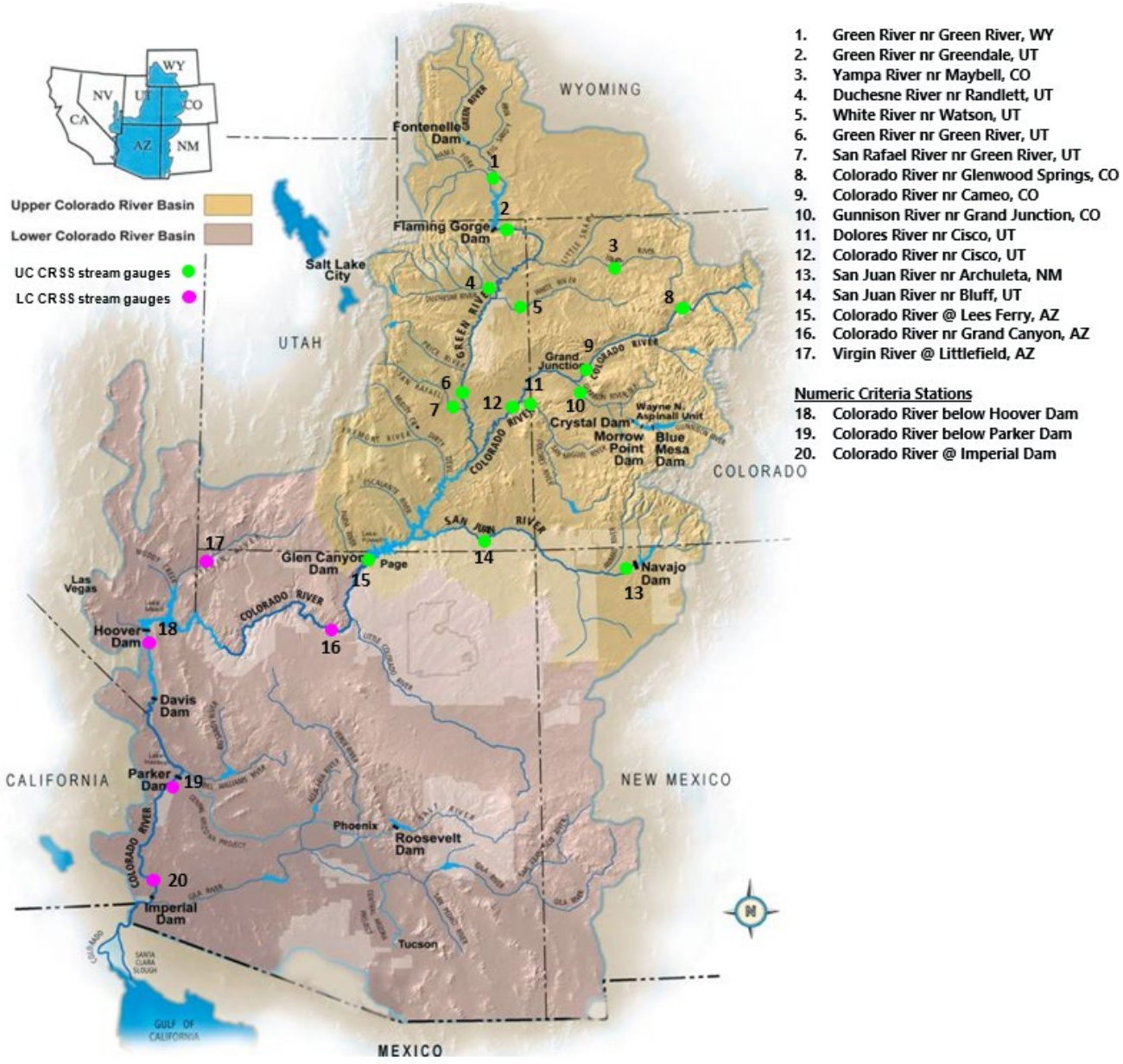

Figure A-1 - Colorado River Basin 20 Stream Gage Locations.

Table A1 - Characteristics of the 20 Salinity Streamflow-gaging Stations in the Colorado River Basin

U.S. Geological Survey streamflow-gaging station number	U.S. Geological Survey streamflow-gaging station name	Site short name	Latitude, in decimal degrees	Longitude, in decimal degrees	Elevation, in feet above sea level	Drainage area, in square miles
09217000	Green River near Green River WY	GRWY	39.5589	-107.2909	5,760	4,556
09234500	Green River near Greendale, UT	GDALE	39.2391	-108.2662	4,814	7,986
09251000	Yampa River near Maybell, CO	YAMPA	38.9833	-108.4506	4,628	7,923
09302000	Duchesne River near Randlett, UT	DUCH	38.7972	-109.1951	4,165	4,580
09306500	White River near Watson, UT	WHITE	38.8105	-109.2934	4,090	24,100
09315000	Green River at Green River, UT	GRUT	41.5164	-109.4490	6,060	14,000
09328500	San Rafael River near Green River, UT	SANRAF	40.9083	-109.4229	5,594	19,350
09071750	Colorado River above Glenwood Springs, CO	GLEN	40.5027	-108.0334	5,900	3,383
09095500	Colorado River near Cameo, CO	CAMEO	40.2103	-109.7814	4,756	3,790
09152500	Gunnison River near Grand Junction, CO	GUNN	39.9789	-109.1787	4,947	4,020
09180000	Dolores River near Cisco, UT	DOLOR	38.9861	-110.1512	4,040	44,850
09180500	Colorado River near Cisco, UT	CISCO	38.8583	-110.3701	4,190	1,628
09355500	San Juan River near Archuleta, NM	ARCH	36.8019	-107.6986	5,653	3,260
09379500	San Juan River near Bluff, UT	BLUFF	37.1469	-109.8648	4,048	23,000
09380000	Colorado River at Lees Ferry, AZ	LEES	36.8647	-111.5882	3,106	111,800
09402500	Colorado River near Grand Canyon, AZ	GRCAN	36.1014	-112.0863	2,419	141,600
09415000	Virgin River at Littlefield, AZ	VIRGIN	36.8916	-113.9244	1,764	5,090
09421500	Colorado River below Hoover Dam, AZ-NV	HOOVER	36.0153	-114.7386	675	171,700
09427520	Colorado River below Parker Dam, AZ-CA	PARKER	34.2956	-114.1402	301	182,700
09429490	Colorado River above Imperial Dam, AZ-CA	IMPER	32.8837	-114.4674	183	188,500

[Latitude and Longitude datum: NAD83; Elevation datum: NGVD29.]

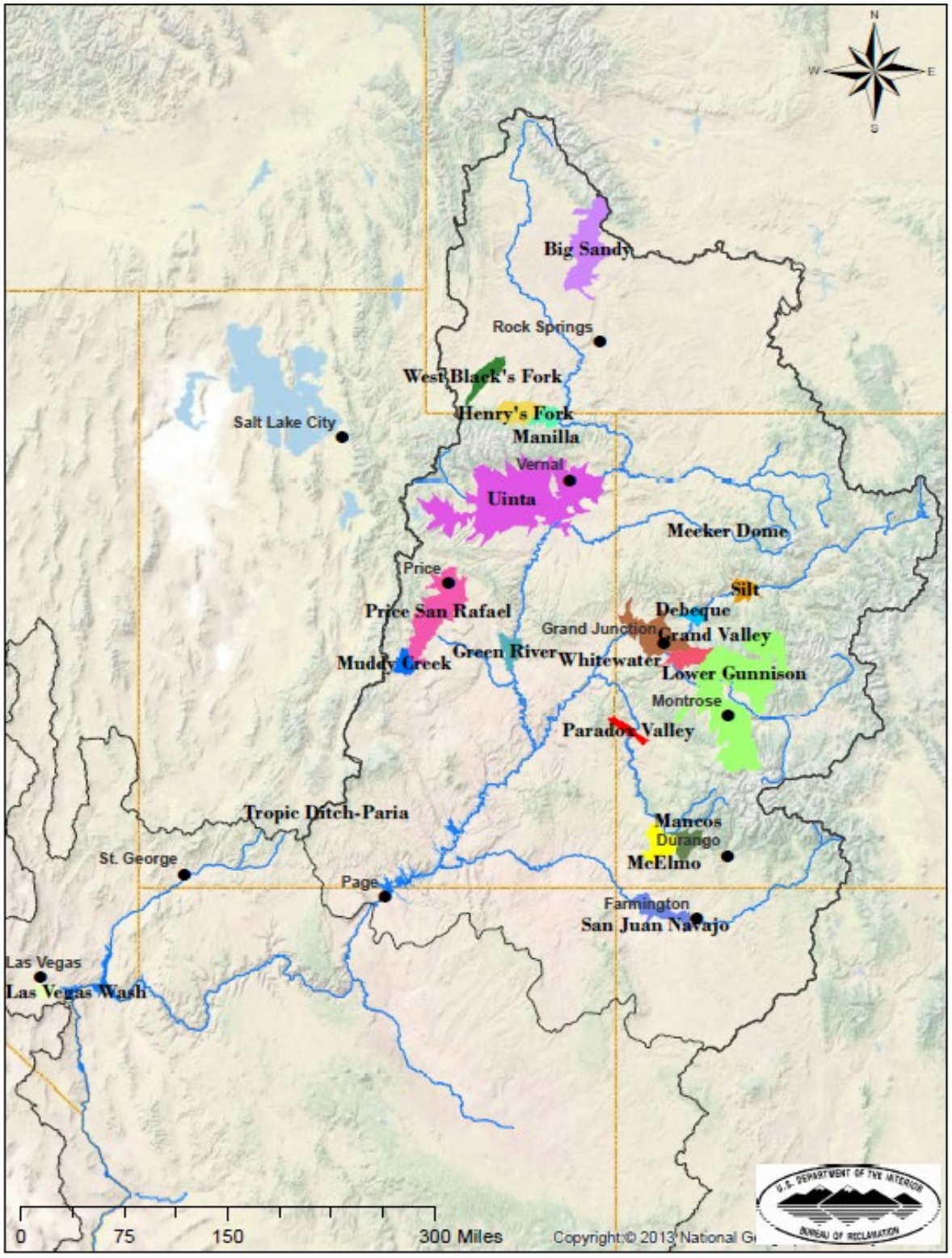

Figure A-2 – Salinity Project Locations.

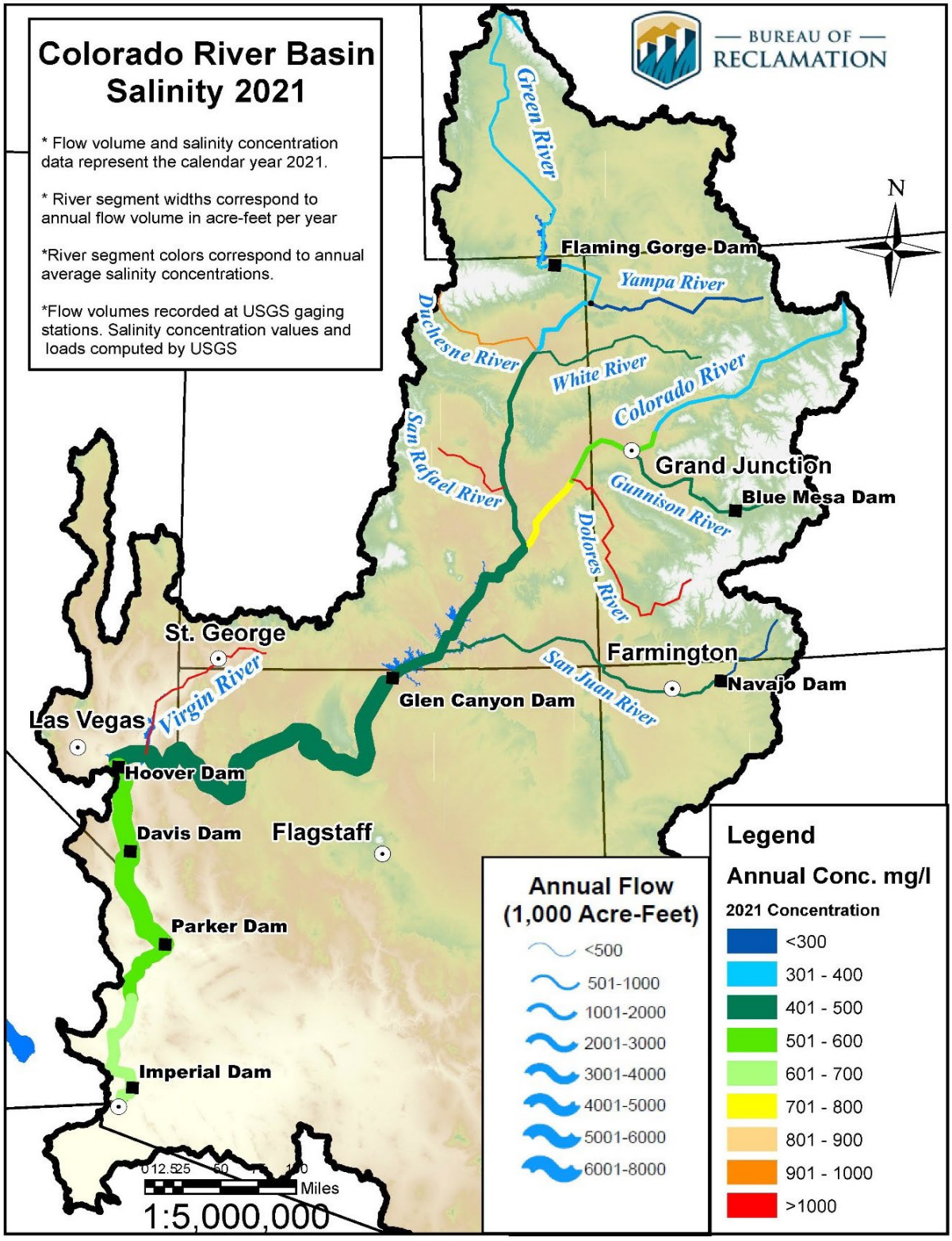

Figure A-3 - Colorado River Flow and Salinity (UCB BOR – Jeremiah Drewel).

APPENDIX B

20 Station Flow and Salinity

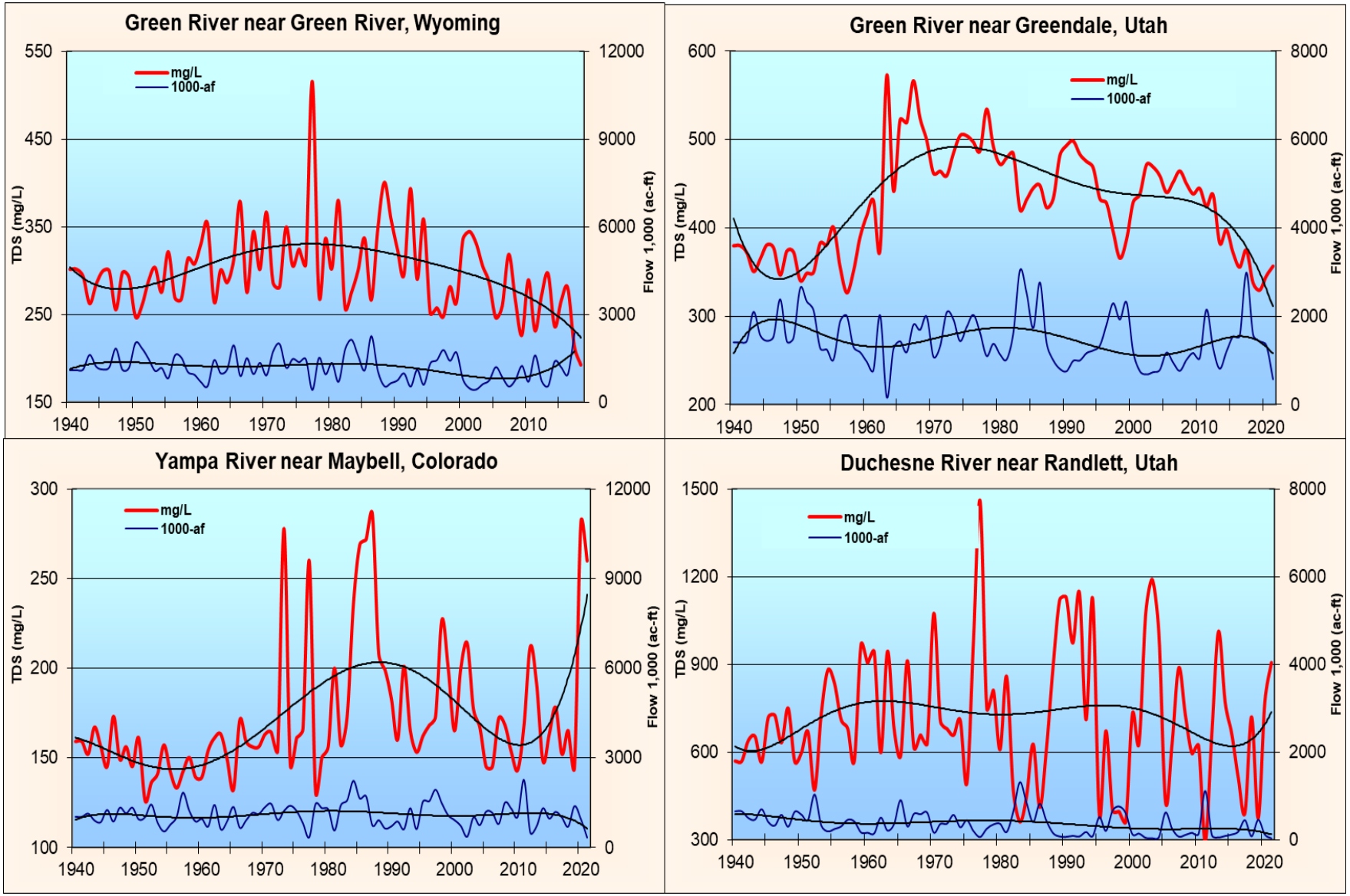

Figure B-1 - Flow and TDS over Time for Sites 1-4.

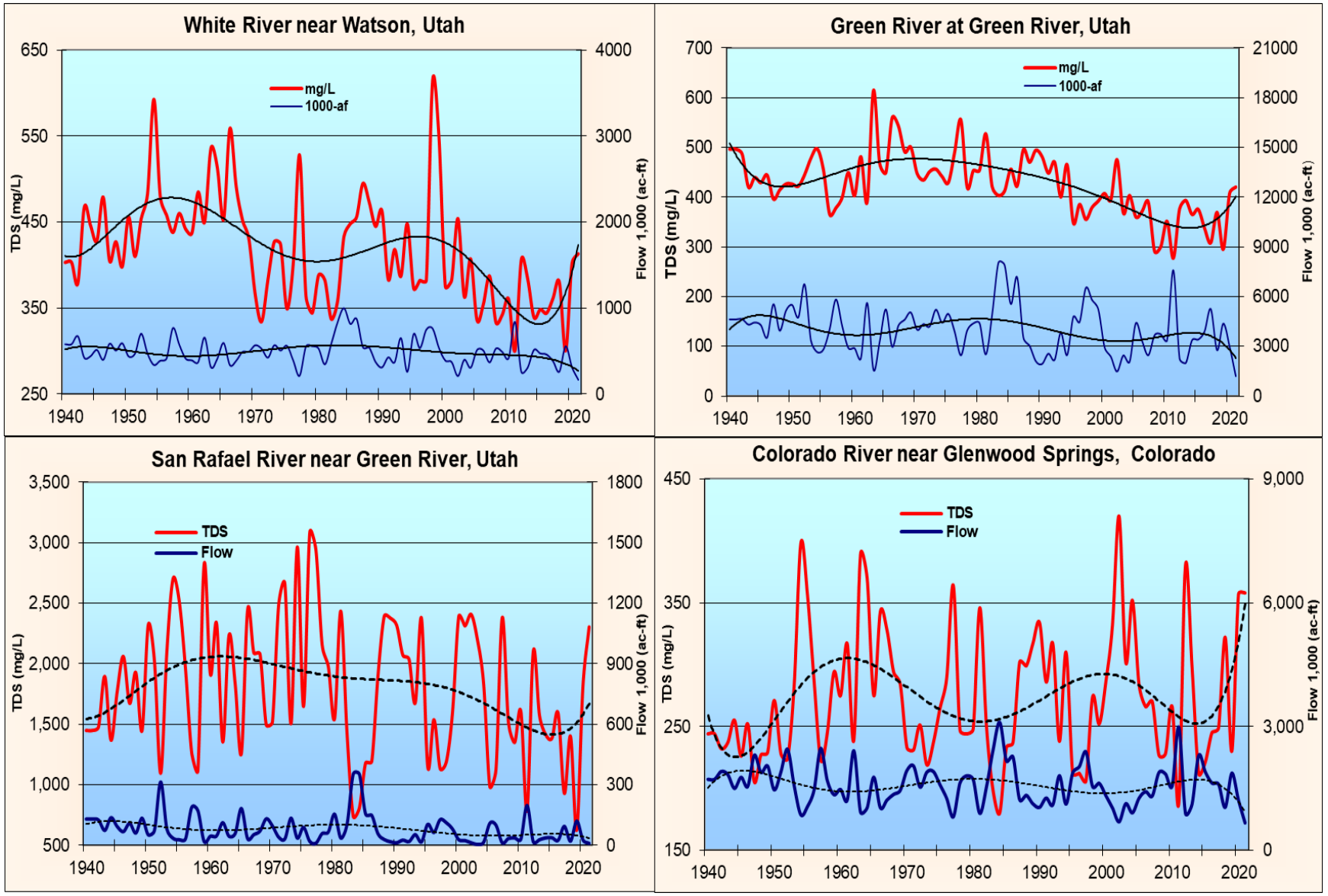

Figure B-2 - Flow and TDS over Time for Sites 5-8.

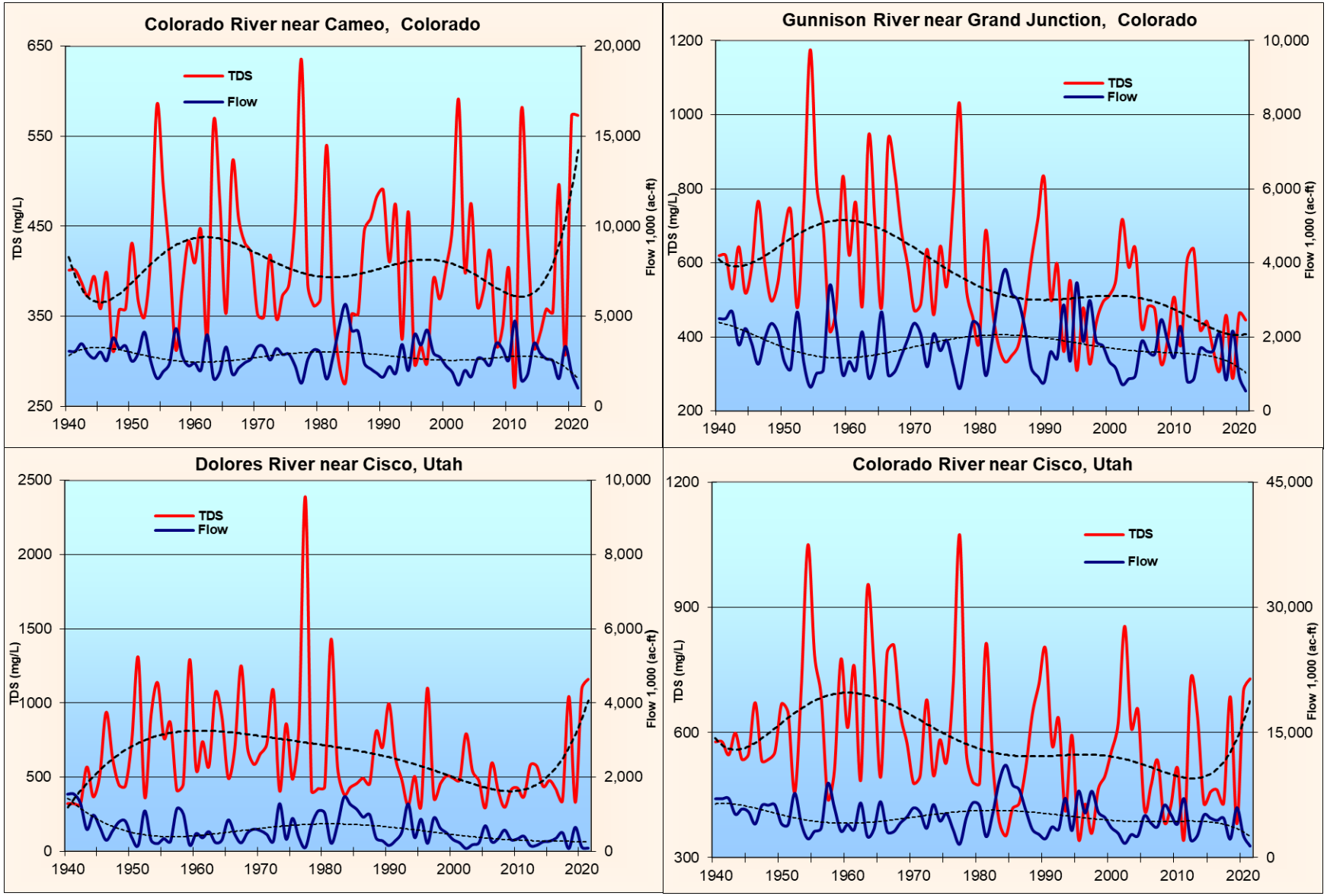

Figure B-3 - Flow and TDS over Time for Sites 9-12.

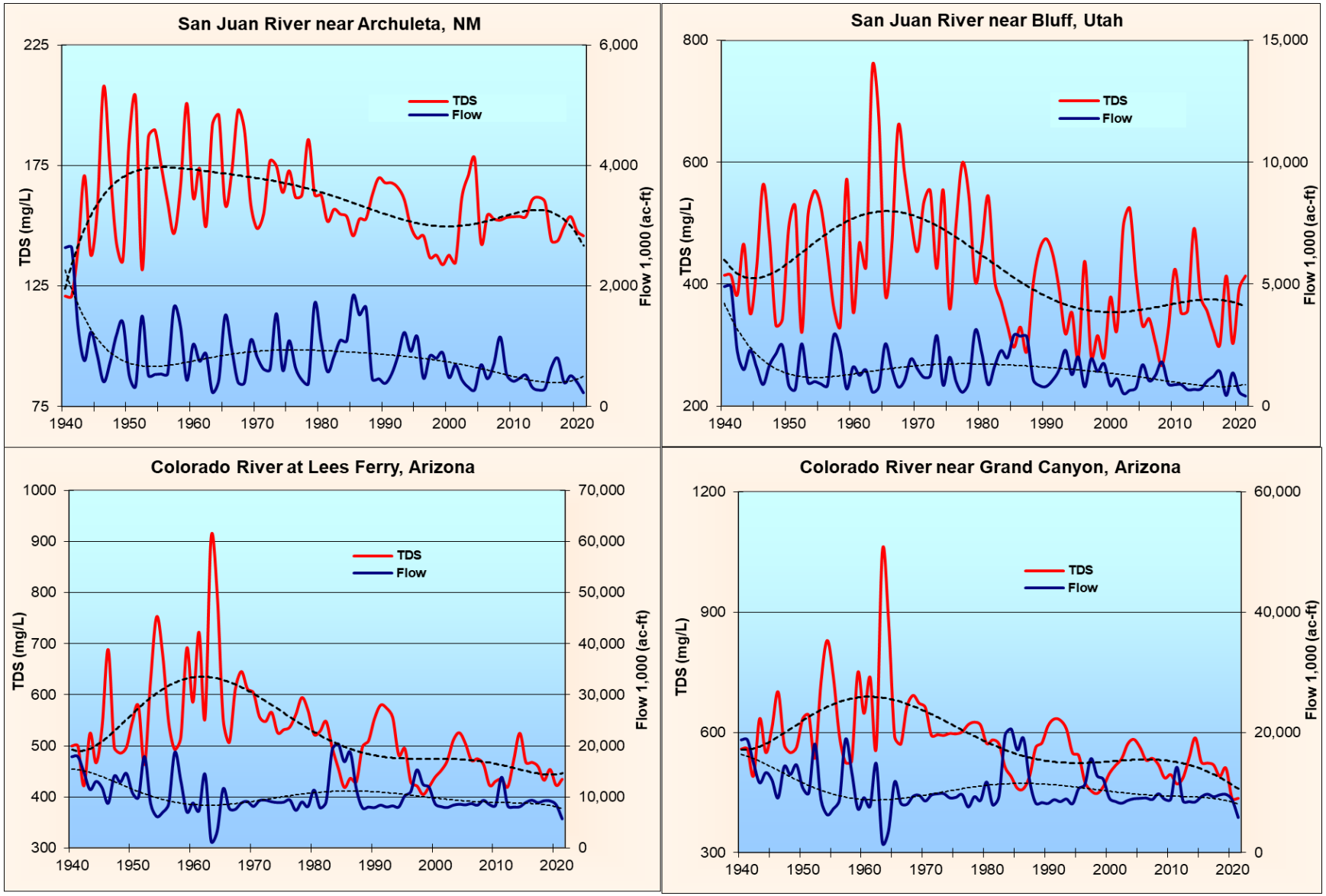

Figure B-4 - Flow and TDS over Time for Sites 13-16.

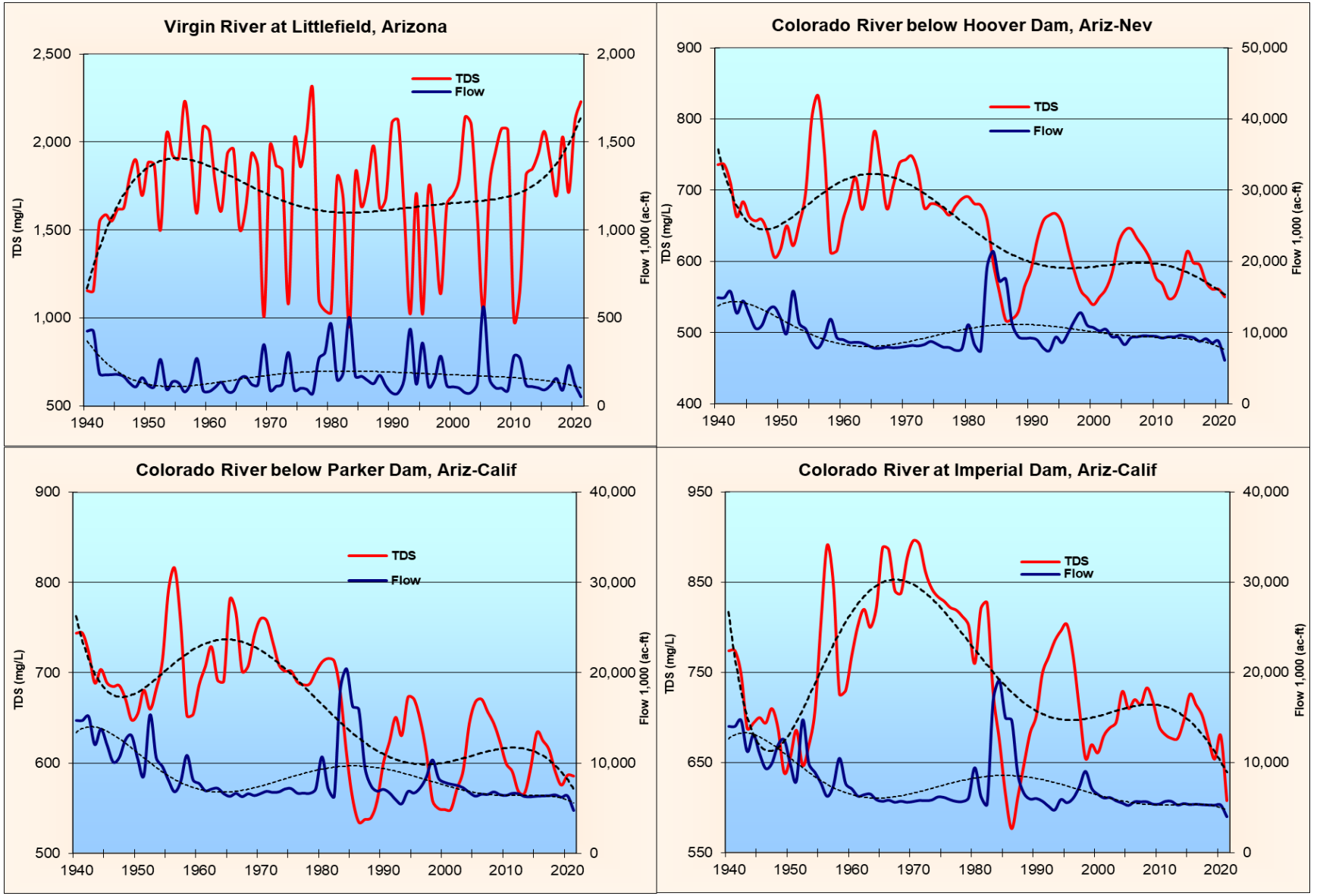

Figure B-5 - Flow and TDS over Time for Sites 17-20.