RECLAMATION

Managing Water in the West

QUALITY OF WATER

COLORADO RIVER BASIN

Progress Report No. 22

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region

2005

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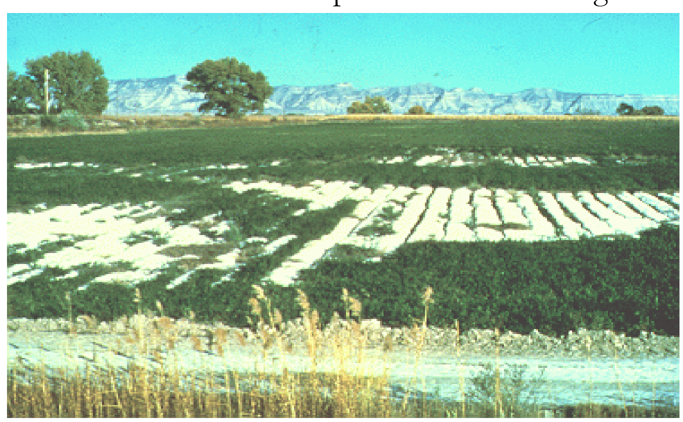
SUMMARY

The Colorado River and its tributaries provide municipal and industrial water to about 33 million people and irrigation water to nearly 4 million acres of land in the United States. The river also serves about 3 million people and 500,000 acres in Mexico. The effect of salinity is a major concern in both the United States and Mexico. Salinity damages in the United States are presently about $306 million per year at 2004 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).

Salinity damages to municipal water pipe.

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.

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.



Salinity damages to crop production.

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

The Colorado River Basin Salinity Control Forum (Forum) in accordance with the requirements of the Clean Water Act, prepared the 2002 *Review, Water Quality Standards for Salinity, Colorado River System* (Review). The Review reported that by 2025 a target of 1.8 million tons per year of salt will need to be diverted from entering the Colorado River in

order to meet the water quality standards in the Lower Basin, below Lees Ferry, AZ. The combined Reclamation, USDA & BLM salinity reduction reported for 2004 shows that the Colorado River Basin Salinity Control Program (Program) has controlled over 1,072,000 tons of salt per year. In order to meet the 1.8 million tons of salt per year goal, it will be necessary to fund and implement potential new measures which ensure the removal of an additional 728,000 tons by 2025. 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 appropriation - $10.5 million per year (bringing the total Reclamation program with cost-sharing to $15 million per year); and USDA EQIP appropriation - $13.8 million per year (bringing the total on-farm program to $19.7 million per year with Basin states parallel program). Beginning in 2005, 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 35,000 tons of new controls will need to be implemented each year to maintain the standards with increased future water development. This Program goal is the combined target for the participating agencies within Interior and USDA. The participating agencies reported to the Colorado River Basin Salinity Control Advisory Council, showing that the agencies efforts have been able to exceed the program's target over the past several years.

Colorado River flows have averaged only about 50% over the five years of drought from 1999-2004. Salinity increased significantly during this period, 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 short term future salinity modeling scenarios indicate that the numeric salinity criteria should be maintained even with an additional 1-2 years of drought. However, the uncertainty of the prediction is within reach of the salinity criteria. The salinity criteria could have been exceeded in 2003 or 2004 without the salinity control program and other salt reductions. Nevertheless, salinity damages are still very high at the 2004 salinity levels. This is the first observation of this level of reservoir draw down. This drought is providing new data, which will eventually reduce the uncertainty in salinity forecasting. For example, it was not obvious in 2002 that an additional 2 years of drought would not cause exceedance of the criteria.

Other Colorado River Basin water quality issues of concern include reservoir eutrophication and algae impacts to drinking water treatment; natural bromide in the water and formation of potentially toxic or carcinogenic trihalomethanes (THM) with chlorination or ozonation during water treatment; selenium and trace elements from irrigation return flows and their impacts to endangered species; contaminants such as ammonium perchlorate into Lake Mead; ammonium, trace elements, and radiologicals from the Atlas Uranium Tailings on the Colorado River at Moab, Utah; and salinity, eutrophication, agro-chemicals, and selenium at the Salton Sea.

Chapter 1 - INTRODUCTION

The Bureau of Reclamation (Reclamation) of the U.S. Department of the Interior prepared this report in cooperation with State water resource agencies and other Federal agencies involved in the Colorado River Basin Salinity Control Program (Salinity Control Program). This Progress Report is the latest in a series of biennial reports that commenced in 1963.

AUTHORIZATION FOR REPORT

The directive for preparing this report is contained in four separate public laws.

Public Law 84-485 states:

> Section 15 –"The Secretary of the Interior is directed to continue studies and make a report to the Congress and to the States of the Colorado River Basin on the quality of water of the Colorado River,"
>
> Section 5c – "All revenues collected in connection with the operation of the Colorado storage project and participating projects shall be credited to the Basin Fund, and shall be available, without further appropriation, for (1) defraying the costs of operation, maintenance, & replacement of, and emergency expenditures for, all facilities ...". The ongoing water quality monitoring, studies, and report are considered part of the normal operation of the project and are funded by the Basin Fund."

Public Law 87-483 states:

> Section 15 - "The Secretary of the Interior is directed to continue his studies of the quality of water of the Colorado River System, to appraise its suitability for municipal, domestic, and industrial use and for irrigation in the various areas in the United States in which it is used or proposed to be used, to estimate the effect of additional developments involving its storage and use (whether heretofore authorized or contemplated for authorization) on the remaining water available for use in the United States, to study all possible means of improving the quality of such water and of alleviating the ill effects of water of poor quality, and to report the results of his studies and estimates to the 87th Congress and every 2 years thereafter."

Public Law 87-590 states that January 3 would be the submission date for the report.

Public Law 93-320 states:

> "Commencing on January 1, 1975, and every 2 years thereafter, the Secretary shall submit, simultaneously, to the President, the Congress, and the Advisory Council created in Section 204(a) of this title, a report on the Colorado River salinity control program authorized by this title covering the progress of investigations, planning, and construction of salinity control units for the previous fiscal year; the effectiveness of such units; anticipated work needed to be accomplished in the future to meet the objectives of this title, with emphasis on the needs during the 5 years immediately following the date of each report; and any special problems that may be

impeding progress in attaining an effective salinity control program. Said report may be included in the biennial report on the quality of water of the Colorado River Basin prepared by the Secretary pursuant to section 15 of the Colorado River Storage Project Act (70 Stat. 111; 43 U.S.C. 602n), section 15 of the Navajo Indian Irrigation Project and the initial stage of the San Juan-Chama Project Act (76 Stat. 102), and section 6 of the Fryingpan-Arkansas Project Act (76 Stat. 393)."

LEGAL ASPECTS

Water Quantity

Colorado River water was apportioned by the Colorado River Compact of 1922, the Boulder Canyon Project Act of 1928, the Water Treaty of 1944, the Upper Colorado River Basin Compact of 1948, and the United States Supreme Court (*Arizona* v. *California et al*., 1963).

The Colorado River Compact divided the Colorado River Basin between the Upper and Lower Basins at Lee Ferry (just below the confluence of the Paria River), apportioning to each use of 7.5 million acre-feet (maf) annually. In addition to this apportionment, the Lower Basin was given the right to increase its beneficial consumptive use by 1 maf per year. The compact also contains provisions governing exportation of Colorado River water. The Water Treaty of 1944 obligates the United States to deliver to Mexico 1.5 maf of Colorado River water annually, absent treaty surplus or shortage conditions.

Upper Colorado Use - The Upper Colorado River Basin Compact of 1948 divided and apportioned the water apportioned to the Upper Colorado River Basin by the Colorado River Compact, allocating to **Arizona** 50,000 acre-feet annually, with the remaining water allocated to Upper Colorado River Basin States as follows:

- **Colorado** 51.75 percent
- **New Mexico** 11.25 percent
- **Utah** 23 percent
- **Wyoming** 14 percent

Lower Colorado Use - States of the Lower Colorado River Basin did not agree to a compact for the apportionment of waters in the Lower Colorado River Basin; in the absence of such a compact Congress, through Secretarial contracts authorized by the Boulder Canyon Project Act, allocated water from the mainstem of the Colorado River below Lee Ferry among California, Nevada, and Arizona, and the Gila River between Arizona and New Mexico. This apportionment was upheld by the Supreme Court, in 1963, in the case of Arizona v. California.

As confirmed by the U.S. Supreme Court in 1963, from the mainstem of the Colorado River (i.e., The Lower Basin):

- **Nevada** was apportioned 300,000 acre-feet annually and 4 percent of surplus water available,
- **Arizona** was apportioned 2,800,000 acre-feet annually and 46 percent of surplus water available,
- **California** was apportioned 4,400,000 acre-feet annually and 50 percent of surplus water available.

Water Quality

Although a number of water-quality-related legislative actions have been taken on the State and Federal levels, several Federal acts are of special significance to the Colorado River Basin: the Water Quality Act of 1965 and related amendments, the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), commonly referred to as the Clean Water Act and related amendments, and the Colorado River Basin Salinity Control Act (Salinity Control Act) of 1974 as amended. Also, central to water quality issues are agreements with Mexico on Colorado River System waters entering that country.

The Water Quality Act of 1965 (Public Law 89-234) amended the Federal Water Pollution Control Act and established a Federal Water Pollution Control Administration (now Environmental Protection Agency [EPA]). Among other provisions, it required States to adopt water quality criteria for interstate waters inside their boundaries. The seven Basin States initially developed water quality standards that did not include numeric salinity criteria for the Colorado River primarily because of technical constraints. In 1972, the Basin States agreed to a policy that called for the maintenance of salinity concentrations in the Lower Colorado River System at or below existing levels, while the Upper Colorado River Basin States continued to develop their compact-apportioned waters. The Basin States suggested that Reclamation should have primary responsibility for investigating, planning, and implementing the proposed Salinity Control Program.

The enactment of the Federal Water Pollution Control Act Amendments of 1972 affected salinity control, in that it was interpreted by EPA to require numerical standards for salinity in the Colorado River. In response, the Basin States founded the Colorado River Basin Salinity Control Forum (Forum) to develop water quality standards, including numeric salinity criteria and a basinwide plan of implementation for salinity control. The Basin States held public meetings on the proposed standards as required by the enacting legislation. The Forum recommended that the individual Basin States adopt the report, *Water Quality Standards for Salinity, Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System*. The proposed water quality standards called for maintenance of flow-weighted annual averaged total dissolved solids concentrations of 723 milligrams per liter (mg/L) below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam. Included in the plan of implementation were four salinity control units and possibly additional units, the application of effluent limitations, industrial use of saline water, and future studies. The standards are to be reviewed at 3-year intervals. All of the Basin States adopted the 1975 Forum-recommended standards. EPA approved the standards.

The Salinity Control Act of 1974 (Public Law 93-320) provided the means to comply with the United States' obligations to Mexico under Minute No. 242 of the International Boundary and Water Commission, United States and Mexico, which included, as a major feature, a desalting plant and brine discharge canal for treatment of WMID drainage water. These facilities enable the United States to deliver water to Mexico having an average salinity of 115 parts per million (ppm) plus or minus 30 ppm (United States' count) over the annual average salinity of the Colorado River at Imperial Dam. The act also authorized construction of 4 salinity control units and the expedited planning of 12 other salinity control projects above Imperial Dam as part of the basinwide salinity control plan.

In 1978, the Forum reviewed the salinity standards and recommended continuing construction of units identified in the 1974 act, placing of effluent limitations on industrial and municipal discharges, and reduction of the salt-loading effects of irrigation return flows. The review also called for the inclusion of water quality management plans to comply with section 208 of the Clean Water Act. It also contemplated the use of saline water for industrial purposes and future salinity control.

Public Law 98-569, signed October 30, 1984, amended Public Law 93-320. The amendments to the Salinity Control Act authorized the U.S. Department of Agriculture (USDA) Colorado River Salinity Control Program. The amendments also authorized two new units for construction under the Reclamation program.

In 1993, the Dept. of Interior Inspector General concluded that the lengthy congressional authorization process for Reclamation projects was impeding the implementation of cost-effective measures. Consequently, a public review of the program was conducted in 1994. In 1995, Public Law 104-20 authorized Reclamation to implement a basinwide approach to salinity control and to manage its implementation. Reclamation completed solicitations in 1996, 1997, 1998, 2001, and 2004 in which Reclamation requests proposals, ranks the proposals based on their cost and performance risk factors, and awards funds to the most highly ranked projects. The awards from the first three solicitations consumed the available appropriation ceiling of $75 million authorized by Congress to test the new program.

In 1996, Public Law 104-127 significantly changed the authorities provided to USDA. Rather than carry out a separate salinity control program, the Secretary of Agriculture was directed to carry out salinity control measures in the Colorado River Basin as part of the Environmental Quality Incentives Program established under the Food Security Act of 1985. Public Law 104-127 also authorized the Secretary of Agriculture to cost share salinity control activities from the basin funds in lieu of repayment. Cost sharing has been implemented for both USDA and Reclamation programs. Under this new authority, each dollar appropriated by the Congress is matched by $0.43 in cost sharing from the basin funds.

In 2000, Public Law 106-459 amended the Colorado River Basin Salinity Control Act to increase the appropriation ceiling for Reclamation's basinwide approach by $100 million ($175 million total). This appropriation authority will allow Reclamation to continue to request new proposals under its Basinwide Salinity Control Program. In 2002, Public Law 107-171, Title II, Subtitle D reauthorized the USDA's Environmental Quality Incentives Program (under which the Secretary of Agriculture carries out salinity control measures).

Nothing in this report is intended to interpret the provisions of applicable federal law including, but not limited to, The Colorado River Compact (42 Stat. 171), The Upper Colorado River Basin Compact (63 Stat. 31), The Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219), the United States/Mexico agreement in Minute No. 242 of August 30, 1973, (Treaty Series 7708; 24 UST 1968), the 1964 Decree entered by the Supreme Court of the United States in Arizona v. California et al. (376 U.S. 340), as amended and supplemented, The Boulder Canyon Project Act (45 Stat. 1057), The Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), The Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620), The Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501), The Colorado River Basin Salinity Control Act (88 Stat. 266; 43 U.S.C. 1571), The Hoover Power Plant Act of 1984 (98 Stat. 1333), The Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600), or The Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669).

CHAPTER 2 - SALINITY CONDITIONS

CAUSES OF SALINITY

The Colorado River System is naturally very saline. At the USGS gauge below Hoover Dam, between 1940 and 1979 an average of approximately 9.4 million tons of salt were carried down the river every year. Since 1980, on average, approximately 8.7 million tons of salts have been measured in the river each year, with the trend going down (see Figure 2, page 10). The flow of the river dilutes this salt, and depending upon the quantity of flow, salinity 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.

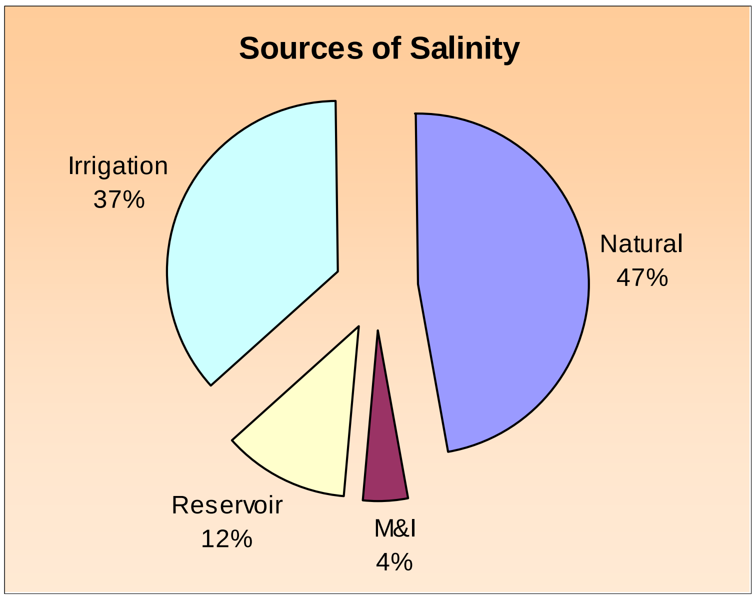


Figure 1 - Sources of Salinity

Nearly half of the salinity in the Colorado River System is from natural sources. Saline springs, erosion of saline geologic formations, and runoff all contribute to this background salinity. Irrigation, reservoir evaporation, and municipal and industrial (M&I) sources make up the balance of the salinity problem in the Colorado River Basin. Figure 1 shows the relative amounts each source contributes to the salinity problem. The Environmental Protection Agency (EPA, 1971) estimated that the natural salinity in the Lower Colorado River at Imperial Dam, was 334 milligrams per liter (mg/L). In 2004, the average annual flow weighted salinity at Imperial Dam was reported to be about 706 mg/L, a 372 mg/L increase over the estimated natural salinity. Table 1 on the following page quantifies several of these known sources.

Salinity of the Colorado River has been increased by 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 1999, has also had an influence on the present salinity of the Colorado River.

Current information indicates that the present salt levels in the Colorado River system have few if any negative health effects for EPA's primary drinking water standards (see Progress Report 21, Health section). However, the EPA secondary drinking water standards are 500 mg/L for TDS (salinity), and 250 mg/L for sulfate. A regression of sulfate versus TDS

Table 1 - Quantified Sources of Salt Loading

Source	Type of Source	Salt Loading (tons per year)
Paradox Springs	Springs	205,000 [1] (Preproject)
Dotsero Springs	Springs	182,600
Glenwood Springs	Springs	335,000
Steamboat Springs	Springs	8,500
Pagosa Springs	Springs	7,300
Sinbad Valley	Springs	6,500
Meeker Dome	Springs	57,000 [1]
Other minor springs in the Upper Basin	Springs	19,600
Blue Springs (Little Colorado River in Grand Canyon)	Springs	550,000
La Verkin Springs (Virgin River inflow into Lake Mead)	Springs	109,000
Grand Valley	Irrigation	580,000
Big Sandy	irrigation	164,000
Uncompahgre Project	irrigation	360,000 [1]
McElmo Creek	irrigation	119,000
Price-San Rafael	irrigation	258,000 [1]
Uinta Basin	mostly irrigation	240,000
Dirty Devil River Area	non-point	150,000
Price-San Rafael Area	non-point	172,000 [1]
Other, non regulated areas	various	5,200,000
Total		8,724,000

Note: [1]- Sources significantly reduced by salinity control projects

shows that sulfate exceeds 250 mg/L when the TDS exceeds 612 mg/L below Hoover Dam. During dry cycles the secondary drinking water standards for TDS and sulfate are exceeded at many places in the Colorado River in both the Upper and Lower Basins, including the three salinity criteria sites.

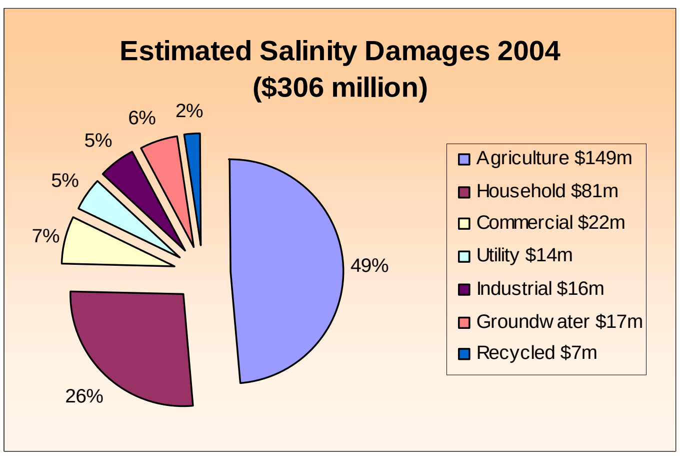


Figure 2 – Percentage of Salinity Damages

The primary negative impact of the salt concentration is seen as economic. Present economic damages using the 2004 salinity levels at Imperial Dam have been modeled between $306 and $312 million per year depending on the conditions used. Projected 2025 salinity levels show damage estimates increasing to $471 million per year without additional WQIP projects being implemented. With additional WQIP projects implemented, the annual damages decline by $76 million or approximately $187 per ton of salt removed. Salinity related damages are primarily due to reduced agricultural crop yields, corrosion, and plugging of pipes and water fixtures. Figure 2 breaks down the percentage of total damages. 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 climatic conditions, but the goal of the Water Quality Criteria for the Colorado River Basin and the Colorado River Basin Salinity Control Program (Salinity Control Program) is to offset (eliminate) the salinity effects of additional water development.

HISTORIC SALINITY CONDITIONS

Salinity in the Colorado River is monitored at 20 key stations throughout the Colorado River Basin (See 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). Historical streamflow, and salinity concentrations from January 1941 to present are included in graphical form in Appendix A. 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.

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 any 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, and release this fresher water later through the year.

Streamflow

Streamflow directly influences salinity. For the most part, higher flows (or reservoir releases) dilute salinity. The top graph in Figure 3 shows streamflow at two key points in the mainstem. In 1980,

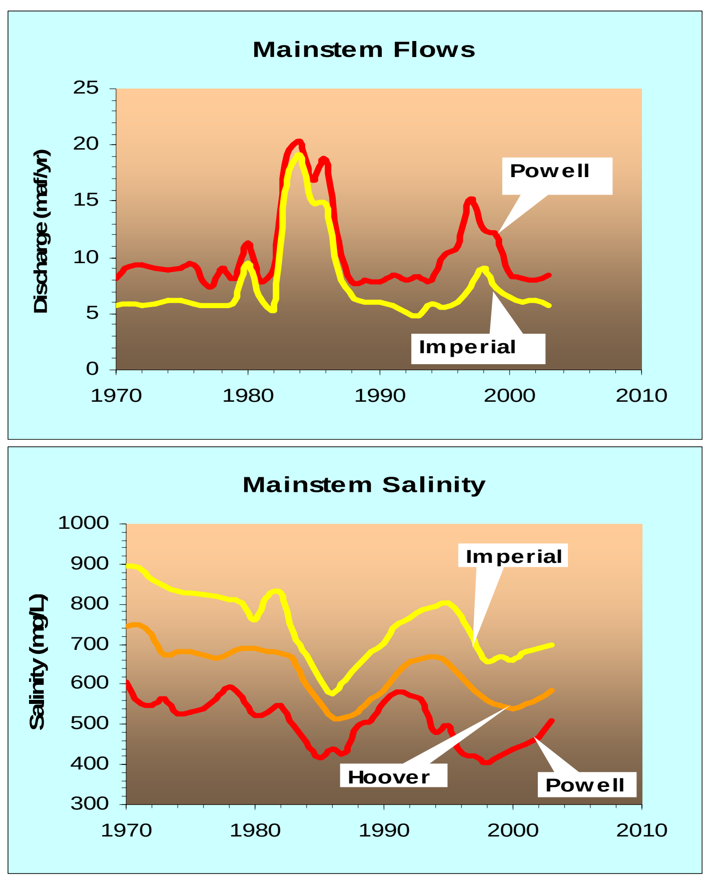


Figure3 - Mainstem Flow and Salinity.

Lake Powell (Glen Canyon Dam) filled for the first time and spilled.

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 bottom graph of Figure 3 (above), relatively low flows in the system after 1987 returned the salinity in the reservoir system to more normal levels. Figure 4 shows the salinity concentration below Glen Canyon Dam, from 1941 to 2004.

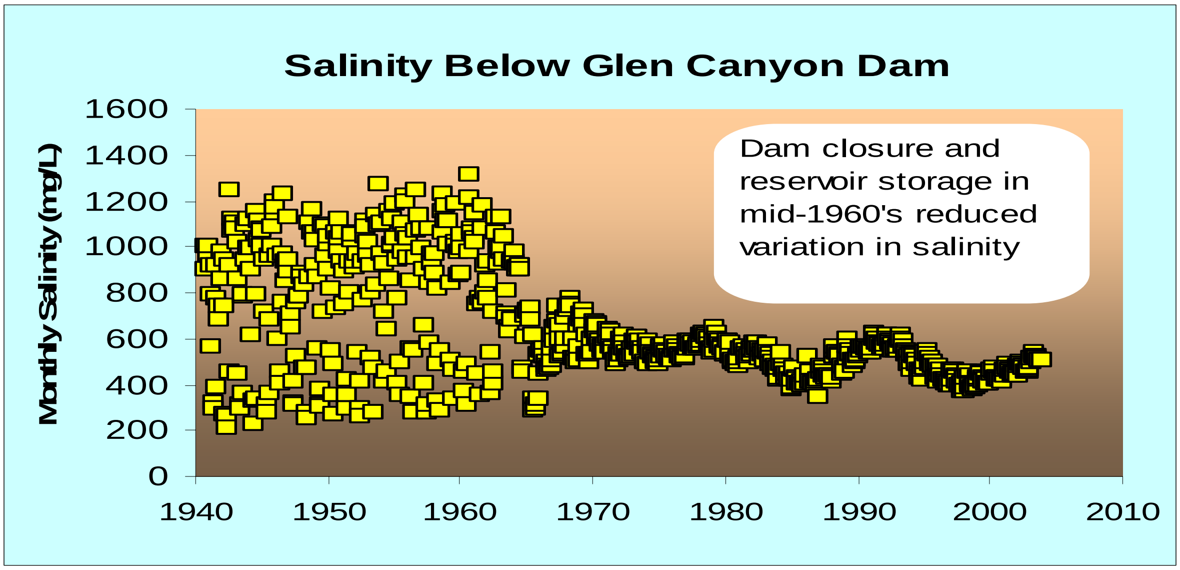


Figure 4 - Effects of Glen Canyon Dam on Colorado River Salinity at Lees Ferry.

Reservoir Storage

The Colorado River Storage Project Reservoirs produce not only major hydrologic modifications downstream, but they also significantly alter salinity cycles. The overall long term salinity affects of the Reservoirs are beneficial and have greatly reduced the salinity peaks (Figures 4 & 5). When Lakes Powell and Mead are full they can contain over 50 million acre-feet of water. On average Lakes Powell and Mead contain more than 3 years the volume of the mean annual flow in the river. During a drought the inflow to Lake Powell can drop to well below 5 million acre-feet. The hydraulic retention time of the combined volumes of Lakes Powell and Mead during a drought can approach ten times the inflow to Lake Powell. Therefore, it can take several years of drought for salinity to peak below Hoover Dam following the initiation of a drought in the Upper Basin. For example, the salinity below Hoover Dam did not peak until 1994 during the drought of 1990-1992 in the Upper Colorado River Basin.

Water storage has greatly reduced extensive seasonal changes in salinity. As shown in Figure 4, completion of Glen Canyon Dam in the mid 1960's greatly reduced the peak monthly salinities observed below the dam. The high concentration low flow waters are mixed with low concentration spring runoff, reducing the month-to-month variation in salinity below the dam from 299 mg/L to 72 mg/L (Mueller et al., 1988). The pre and post dam peak monthly salinity has been reduced by nearly 600 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.

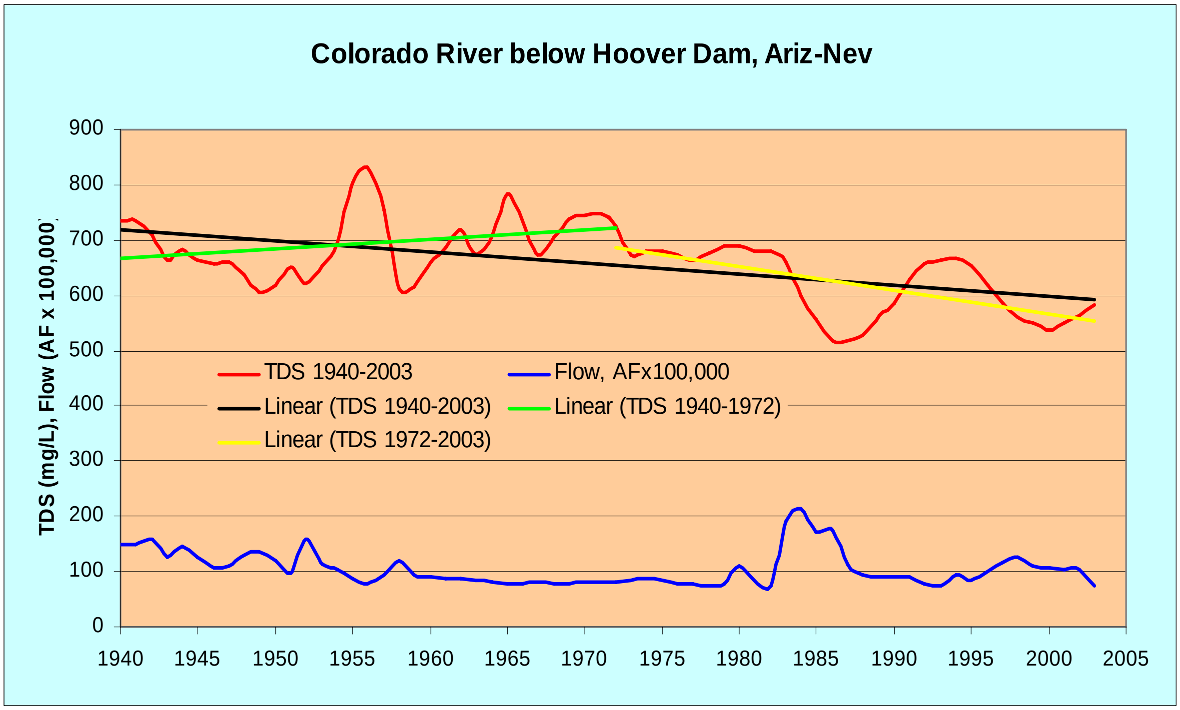


Figure 5 - Graph of Flow and Salt, with Short and Long Term Trend Lines, Illustrating the Change in Salinity over Time below Hoover Dam.

Reservoir Initial Filling Salt leaching impacts to Salinity

During the initial filling of about 30 million acre feet of storage in the Upper Basin from 1963-1973, the effects were an overall increase in salinity. Initial filling of the reservoirs in the Upper Basin had three major impacts on salinity in the Colorado River

1. The storage in the Upper Basin resulted in reduced flow in the Lower Basin (Table 2), which increased salinity in the Lower Basin by reducing dilution of approximately 1 – 1.4 million tons of salt entering the system between Glen Canyon Dam and below Hoover Dam with only about 0.75 million ac-ft of water with a mean salinity of about 1,300 mg/L. Reductions in flow appear to increase downstream salinity concentrations.

2. The initial filling of reservoirs in the Upper Basin resulted in a salt leach out of the newly inundated lands.

3. The addition of storage in the Upper Basin resulted in changes in irrigation practices which increased irrigation efficiency. Much of the current salinity control in the Upper Basin is based on the now proven fact that increased irrigation efficiency decreases salt loading (Butler, 2001).

Table 2 - Hydrology and Salt at Grand Canyon and Virgin River Streamflow Gages

		1940 - 1962	1963 - 1972	1973 - 2004
Colorado R @ Grand Canyon	Salt (mg/L)	618	697	550
	Flow (1000 ac-ft/yr)	12,267	8,015	10,872
Virgin River @ Littlefield	Salt (mg/L)	1,741	1,750	1,654
	Flow (1000 ac-ft/yr)	171	142	181

There were numerous large and small reservoirs that went through initial filling in the Colorado River Basin in the 1960-1980's. Many of the smaller reservoirs should have had less overall salinity impact than Flaming Gorge or Lake Powell. However, many of the smaller reservoirs were built in Cretaceous geology with higher potential for salt leaching. The initial filling and leach out of salts from these reservoirs contributed to the declining salinity from the mid 1970's – 1990's, as discussed later.

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 help keep from exceeding the salinity criteria during the drought years. The inflows to Lake Powell were again high in 1993, and the salinity downstream below Hoover Dam began to decrease after 1994. When Lakes Powell and Mead are only about half full, and the Lake Powell inflow is 150% or more than average, then the hydraulic retention time is much smaller (<2 years), and the downstream dilutions in salinity may be seen in less time. It is interesting to note the decline in salinity seen in the longer term trend line below Hoover Dam (Figure 5) from the early 1990's to 2003 is about equal to the estimated salinity reductions produced by the salinity control program. In the early to mid-1990's, major portions of the Salinity Control Program started to come online, preventing about 355,000 tons of salt from entering the river system each year. These salinity program salt reductions decreased salinity by about 28 mg/L and helped keep the salinity criteria from being exceeded in 1994. This suggests that without the salinity control program these continued salinity declines may not be appropriately projected into the future.

It is postulated that salt leaching from Lake Powell and Flaming Gorge Reservoir alone temporarily increased salinity from the mid 1960's through the initial filling and salinity peak in 1972. This salt leaching plus the reduced downstream dilution due to retention of water in the upstream reservoirs was at least one factor in the salinity peak concentrations in the lower basin from 1968-1972 (see Figures 3, 5, 6 & 7).

An illustration of the impacts of salt leaching associated with initial filling of reservoirs from the mid 1960's to present is shown in Figure 6 below. Figure 6 depicts the salinity downstream from Flaming Gorge Reservoir (Greendale) on the Green River in Utah and Wyoming. Bolke and Waddel (1975) and Bolke (1979) of the U.S. Geological Survey reported the flow weighted annual Total Dissolved Solids (TDS) below Flaming Gorge Dam increased from 386 mg/L to 512 mg/L pre to post Flaming Gorge Dam up to 1975. The increased salt loading was primarily in the form of sulfates from internal loading of 1,947,000 metric tons (2,144,000 tons) for the period 1963-1975 (Bolke, 1979). Therefore, the average salt loading from Flaming Gorge Reservoir salt leaching during initial filling from 1963-1975 was approximately 170,000 tons/year. An update of this estimate indicates that the TDS below Flaming Gorge Dam at the Greendale Station averaged 460 mg/L from 1993 through 2003. This would amount to about a 70,000 ton/year decrease in salt loading below Flaming Gorge Dam.

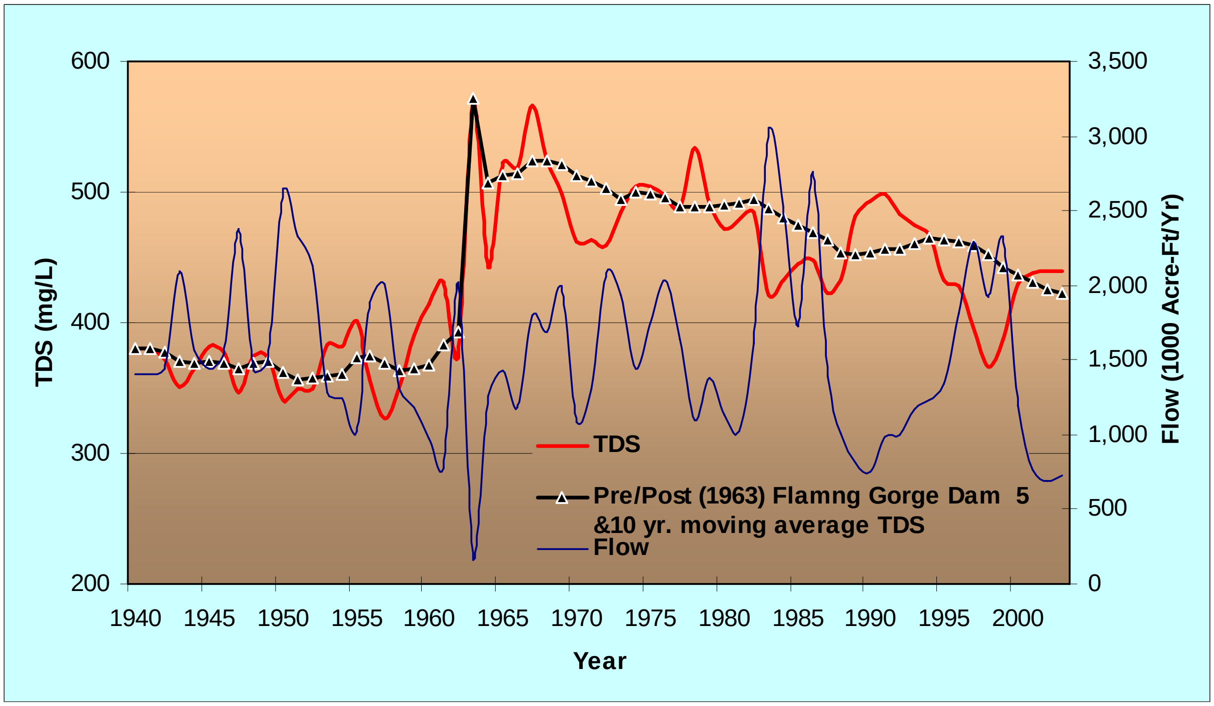


Figure 6 - Green River below Flaming Gorge Reservoir, Flow and Salt over Time

Both Flaming Gorge and Lake Powell 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 affects of this selective retention and routing of salt has already been shown below Glen Canyon Dam in Figure 4. Figure 7 further displays this retention. A long- term depth versus time profile of salinity in front of Glen Canyon Dam on Lake Powell is a pictured history of salinity. The Y (vertical) axis is depth in the water column, and the X axis is time in years. The color scale demonstrates changes in salinity.

Two things are effectively demonstrated by this graphic: 1) Glen Canyon Dam selectively retains higher TDS water, especially during initial years of drought, and then routes those waters later usually during wetter cycles. 2) Lake Powell has selectively retained higher salinity water during drier years, and then routed it with the increased mixing and shorter hydraulic retention times of wetter cycles as seen particularly in 1983 (Figure 7). During these wetter cycles there is a significant mixing and dilution of these previously stored salts.

Lake Powell also 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. An immediate increase in salinity occurs with water storage as has been shown at Flaming Gorge Reservoir. 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 (Figure 8).

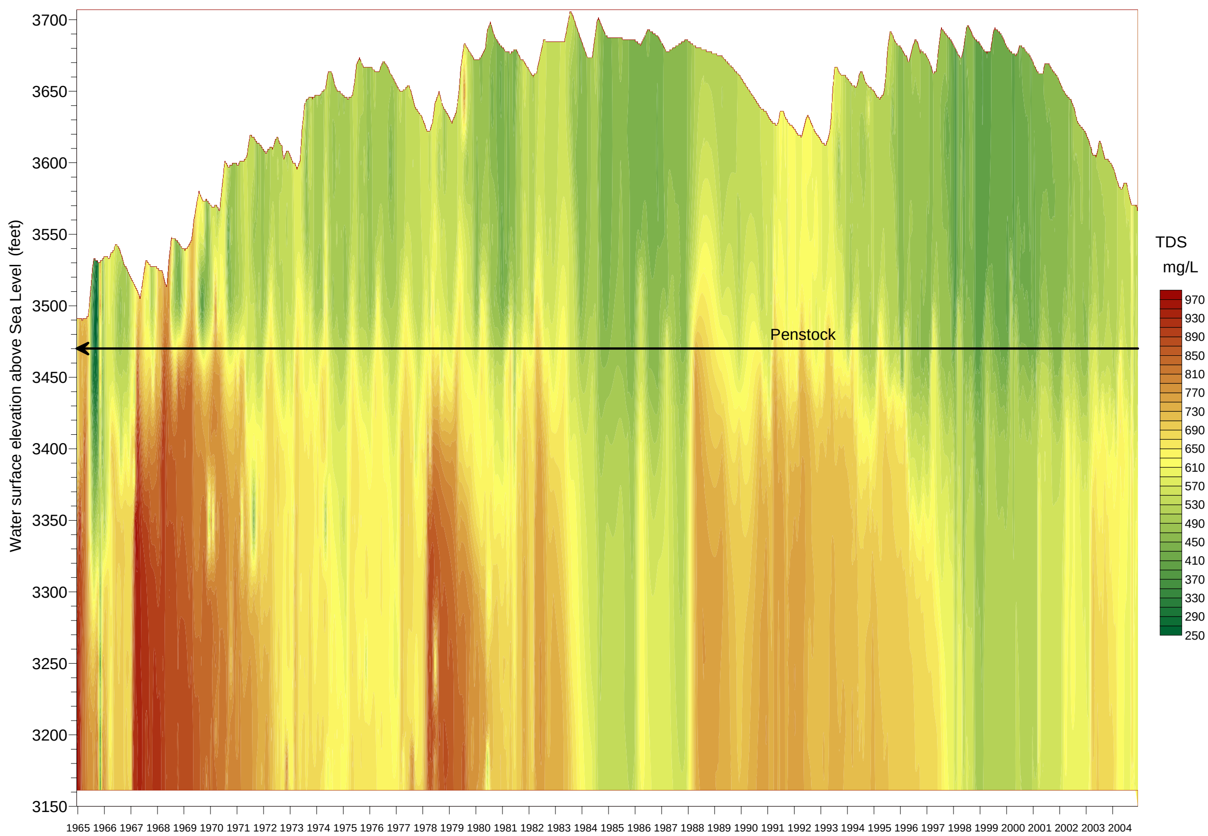


Figure 7- Lake Powell Forebay, Dec 1964 to Dec 2004 Salinity Concentration, mg/L

SALINITY TREND STUDIES

Over a century of water resource use and development has had some serious negative impacts on the water quality. Although peak salinities have been greatly reduced, the average annual salinities have more than doubled from natural historic levels estimated to be about 334 mg/L at Imperial Dam.

When the Salinity Forum established the salinity criteria goal to not exceed the 1972 levels, it was not obvious that this could be achieved given projected future water development within the basin. Figure 5 (page 11) indicates that long term average salinity below Hoover Dam has declined since 1940. The salinity control program can account for much, but not all of this salinity decline after the wet cycle from 1983-86. Flushing of salt during that wet cycle has also had an impact on salinity concentrations, as well as the reservoirs ability to retain and route saline water throughout the years.

Figure 8 is an analysis of salt inflow and outflow for Lake Powell from 1950-2002. Trend lines indicate that the inflow was generally within 3-4 % of outflow prior to the coffer dam in about 1956. From 1956-1992 Lake Powell leached salt. After 1992 this leaching appears to have come to a new dynamic equilibrium. Lake Powell is the largest, but is only one of many dams built in the upper basin from the 1950's through about 1987. Each of these reservoirs also experienced a leach out period. Flaming Gorge Reservoir experienced a similar leach out contributing near 400,000 tons of salt per year during early initial filling.

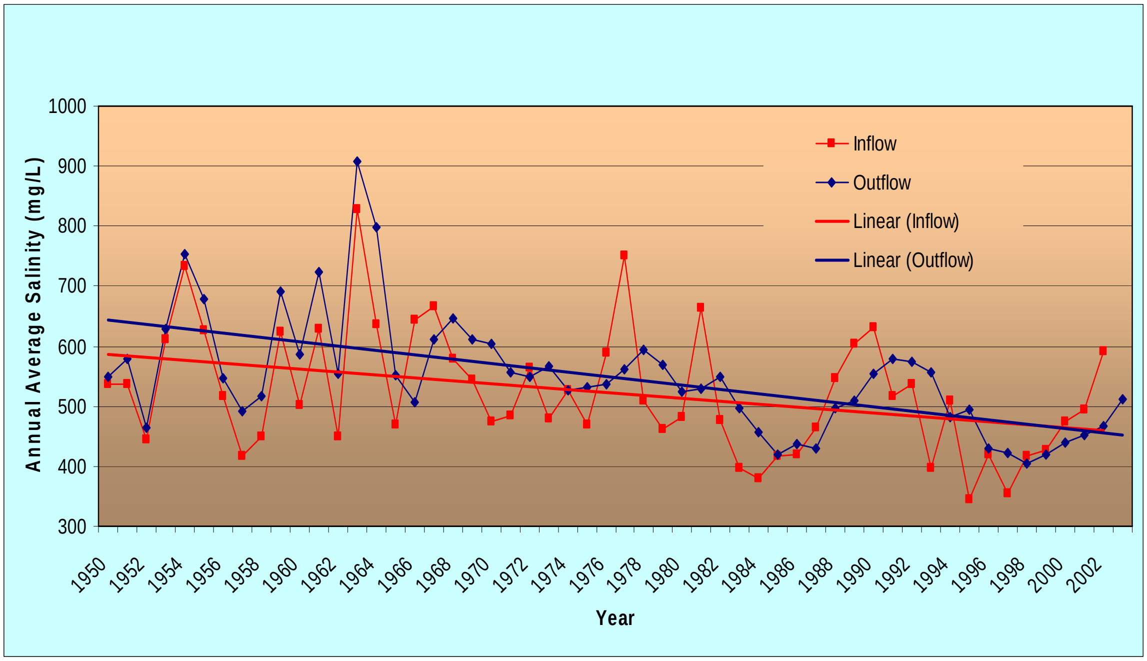


Figure 8 - Lake Powell Inflow and Outflow Salt Concentration, mg/L

Figure 9- "Bathtub ring" on Lake Powell

NATURAL VARIATION IN SALINITY

Although seasonal swings in salinity have been greatly reduced, annual fluctuations in salinity are still observed. Natural climatic variations in rainfall and snowmelt runoff continue to cause large year-to-year differences in both flow and salinity and in some cases nearly doubling the salinity in the river.

Even with the tempering effects of reservoir storage in the river system, natural variations in runoff and flows in the Colorado River Basin will continue to cause salinity to vary significantly. The water quality standards require that the flow-weighted average annual salinity will not rise above the 1972 levels using a long-term mean water supply of 15 maf (2002 Review). This means that depending on the hydrology (drought conditions) that salinities may actually increase above the numeric criteria and it is not a violation of the standards, but is due to natural variations in the hydrologic conditions. Even with full compliance with the standards, the actual salinities at Imperial Dam (and elsewhere in the Colorado River Basin) will continue to fluctuate with hydrologic conditions in the future. The Salinity Control Program is designed to offset the effects of development, even as salinity varies from year to year in response to the climatic and hydrologic conditions. Assuming continued salinity control and full compliance with the standards, the potential range of annual salinities that might be observed in the future at Imperial Dam is quite wide. With Colorado River basin reservoir storage tempering the natural variability of the system, the range between the high and low salinity values at Imperial Dam has dropped to a monthly average of about 480 mg/L and an annual average around 266 mg/L since 1973.

AGRICULTURAL SOURCES OF SALINITY

Irrigated agriculture is the largest user of water in the Colorado River Basin and a major contributor to the salinity of the system. Iorns (Iorns et al., 1965) found that irrigated lands in the Upper Colorado River Basin contributed about 3.4 million tons of salt per year (37 percent of the salinity of the river). Irrigation increases salinity by consuming water (evapo transpiration) and by dissolving salts found in the underlying saline soils and geologic formations, usually marine (Mancos) shale.

Deep percolation mobilizes the salts found naturally in the soils, especially if the lands are over irrigated. Through salinity control practices, these contributions to the river system can be reduced significantly, helping maximize the future beneficial uses of the river.

Irrigation development in the Upper Colorado River Basin took place gradually from the beginning of settlement in about 1860, but was hastened by the purchase of tribal lands in the late 1800's and early 1900's. About 800,000 acres were being irrigated by 1905. Between 1905 and 1920, the development of irrigated land increased at a rapid rate, and by 1920, nearly 1.4 million acres were being irrigated. The *Upper Colorado Region Comprehensive Framework Study, June 1971,* reported that more than 1.6 million acres were in irrigation in 1965. Since that time, development of new agricultural lands has leveled off because of physical, environmental, and economic limitations. Reclamation's latest *Colorado River System Consumptive Uses and Losses Report 1996-2000* estimated that 1.5 million acres were irrigated in the Upper Colorado River Basin in 2000.

Irrigation development in the Lower Colorado River Basin began at about the same time as in the Upper Colorado River Basin, but was slow due to the difficulty of diverting water from the Colorado River with its widely fluctuating flows. Development of the Gila area began in 1875 and the Palo Verde area in 1879. Construction of the Boulder Canyon Project in the 1930's, and other downstream projects, has provided for a continued expansion of the irrigated area. In 1970, an additional 21,800 acres were irrigated by private pumping either directly from the Colorado River or from wells in the flood plain. In 1980, nearly 400,000 acres were being irrigated along the Colorado River mainstem. In 2000, total irrigated lands for the entire Lower Colorado River Basin were about 1.4 million acres.

Reclamation and the U.S. Geological Survey (USGS) continuously monitor the flow and salinity of the river system through a network of 20 gauging stations (See Appendix A, Fig. A1). Reclamation evaluates the data collected to determine if sufficient salinity control is in place to offset the impact of water development. In 2004, the actual salinity in the Colorado River was below the numeric criteria at the established monitoring stations. However, as the impacts of recent and future basin developments work their way through the hydrologic system, salinity would increase without salinity control to prevent further degradation of the river system.

UPPER BASIN IRRIGATION

Many subbasins experienced significant changes in irrigation following development of available reservoir storage. Once late season irrigation supplies were assured, less water was applied during the snowmelt runoff, and overall irrigation efficiency increased. Based on results from the Reed Wash study (Reclamation, 1982) the Colorado River Basin salinity control program has depended on improved irrigation efficiency to decrease human-induced salt loading. Providing guaranteed late season water supplies from reservoir storage was not provided through the Colorado River Basin Salinity Control Program. Examining water and salt loading relationships in these subbasins where reservoir storage was developed strongly suggests that storage did increase irrigation efficiency, and additionally decreased salt loading. The impacts from these subbasins that have increased irrigation efficiency not resulting from the salinity control program have not been directly incorporated in the Colorado River Simulation System (CRSS). The relationships between natural and irrigation induced salt loading have changed, and are being reexamined for modeling purposes.

WATER USE BY AGRICULTURE & MUNICIPAL & INDUSTRIAL USERS

Salinity levels are directly influenced by depletion (consumption) of water flowing in the river system and salt loading. Agriculture increases salinity by consuming water through evapotranspiration and leaching salts from saline soils. Municipal and industrial (M&I) use increases salinity by the consumption of the water, thus reducing the dilution of salts in the river or by disposal on land. These two types of uses are critical in predicting future salinity levels in the basin.

Reclamation continues to monitor water use and adjusts their future salinity control needs as water development plans may be postponed, delayed, or canceled. The depletion schedules used to project salinity conditions have been updated so that the implementation needs for the Salinity Control Program can be planned to offset the impacts of additional water development.

The large amounts of water use once forecasted for steam power generation, coal gasification, oil shale, and mineral development have not yet occurred. The few coal-fired power plants that have been constructed recently have obtained their water from existing agricultural rights rather than from developing additional water. This conversion of use reduces the salt loading to the Colorado River by eliminating the pickup of salt from canal seepage and on farm deep percolation.

Most of the irrigation projects that deplete water and increase salt pickup to the river were in place before 1965. Moreover, like the newly inundated soils in reservoirs, newly irrigated lands are subject to a leach-out period. In cases where lands with poor drainage stored salt, these areas were taken out of production. In addition, irrigation practices changed significantly with the introduction of canal and lateral lining, sprinkling systems, gated pipe, trickle systems and tile drains (initial operation of tile drains increase salt loading, which decreases after time). These changes have resulted in reduced return flows and salt pickup.

FUTURE WATER DEVELOPMENT

Tables 3 and 4 (below), summarize the projected depletions used by Reclamation to evaluate the effects of water use and depletions for this progress report. These water use estimates were compiled as the first step in the evaluation process. Table 3 summarizes the estimated depletion of water through full basin development for the mainstem Upper Colorado River Basin. The projections were made in consultation with individual States within the Colorado River Basin and the Upper Colorado River Commission; however, the States do not necessarily concur with the projections adopted by Reclamation for planning purposes.

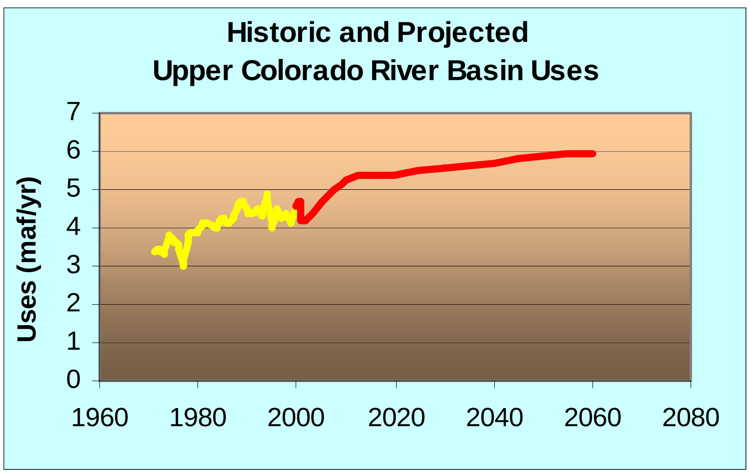


Figure 10 - Historic and Projected Water Uses.

The Upper Colorado River Basin Compact provides that the States of Arizona, Colorado, New Mexico, Utah, and Wyoming will share in the consumptive use of water available in the Upper Colorado River Basin in the following proportions: Arizona, 50,000 acre-feet; Colorado, 51.75 percent of the remainder; New Mexico, 11.25 percent of the remainder; Utah, 23.00 percent of the remainder; and Wyoming, 14.00 percent of the remainder. Each Upper Colorado River Basin State is charged a proportionate share of the total evaporation. Figure 10 illustrates the historic Upper Basin States usage of the Colorado River water and their projected future river water use.

The depletions for the Lower Colorado River shown in Table 4 include only mainstem use of the Colorado River in the Lower Colorado River Basin. Reclamation's river simulation model does not model consumptive uses of the Lower Colorado River Basin tributaries.

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

UPPER BASIN	2010	2020	2030	2040	2050	2060
Arizona						
Total scheduled depletion	50	50	50	50	50	50
State share of 6.0 maf	50	50	50	50	50	50
Remaining available	0	0	0	0	0	0
Percent of State share available	0	0	0	0	0	0
Colorado						
Total scheduled depletions	2,580	2,626	2,675	2,703	2,776	2,784
Evaporation storage units	295	295	295	295	295	295
Total	2,875	2,921	2,970	2,998	3,071	3,079
State share of 6.0 maf	3,079	3,079	3,079	3,079	3,079	3,079
Remaining available	204	158	109	81	8	0
Percent of State share available	7	5	4	3	0	0
New Mexico						
Total scheduled depletions	548	589	604	605	605	605
Navajo Reservoir evaporation	28	28	28	28	28	28
Evaporation storage units	58	58	58	58	58	58
Total	634	675	690	691	691	691
State share of 6.0 maf	669	669	669	669	669	669
Remaining available	35	-6	-21	-22	-22	-22
Percent of State share available	5	-1	-3	-3	-3	-3
Utah						
Total scheduled depletions	1009	1055	1129	1177	1207	1230
Evaporation storage units	120	120	120	120	120	120
Total	1129	1175	1249	1297	1327	1350
State share of 6.0 maf	1369	1369	1369	1369	1369	1369
Remaining available	240	194	120	72	42	19
Percent of State share available	18	14	9	5	3	1
Wyoming						
Total scheduled depletions	517	535	571	615	687	760
Evaporation storage units	73	73	73	73	73	73
Total	590	608	644	688	760	833
State share of 6.0 maf	833	833	833	833	833	833
Remaining available	244	225	189	145	74	0
Percent of State share available	29	27	23	17	9	0

Note: Evaporation from storage units - Estimates for evaporation from Lake Powell, Wayne N. Aspinall Unit, and Flaming Gorge Reservoirs are allocated as described in Article V of the Upper Colorado River Compact.

New Mexico will use more than their share of water if the future projected use is met

Fixed inflow values are used for the tributaries. Colorado River Basin use data (including tributary use) may be found in Reclamation's *Colorado River System Consumptive Uses and Losses Reports* or on the web at www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html

Table 4 - Lower Basin Depletion Projections (1000 af/yr)

LOWER MAINSTEM	2010	2020	2030	2040	2050	2060
Nevada						
Robert B. Griffith Water Project	264	264	280	280	280	280
Other users above Hoover Dam	7	7	7	7	7	7
Southern California Edison	16	16	0	0	0	0
Ft. Mohave Indian Reservation	9	9	9	9	9	9
Laughlin and users below Hoover Dam	4	4	4	4	4	4
Total	300	300	300	300	300	300
Arizona						
Imperial Wildlife Refuge	10	9	10	10	10	10
Lake Havasu Wildlife Refuge	5	5	5	5	5	5
Fort Mohave Indian Reservation	73	73	73	73	73	73
City of Kingman	0	0	0	0	0	0
Mohave Valley I&D District	23	17	17	17	17	17
Bullhead City and other M&I	4	5	6	6	6	6
Cibola Valley I&DD, Parker and others	24	27	30	32	34	34
Lake Havasu I&D District	13	12	12	12	12	12
Central Arizona Project	1425	1419	1406	1398	1395	1395
Colorado River Indian Reservation	414	463	463	463	463	463
Cibola Wildlife Refuge	8	8	16	16	16	16
Gila Project	505	477	476	476	476	476
City of Yuma	27	30	35	41	41	41
Yuma Project - Valley Division	248	234	229	229	230	230
Cocopah Indian Reservation	12	12	12	12	12	12
Other users below Imperial Dam	9	9	10	10	10	10
Total	2800	2800	2800	2800	2800	2800
California						
City of Needles	1	1	1	1	1	1
Metropolitan Water District	855	852	852	852	802	802
Fort Mohave Indian Reservation	12	12	12	12	12	12
Chemehuevi Indian Reservation	5	8	8	8	8	8
Colorado River Indian Reservation	19	39	39	39	39	39
Palo Verde Irrigation District	373	366	366	366	366	366
Yuma Project Reservation Division	47	54	54	54	54	54
Imperial Irrigation District	2711	2641	2611	2611	2661	2661
Coachella Valley Water District	376	426	456	456	456	456
Other uses Davis to Parker Dam	1	1	1	1	1	1
Other uses below Imperial Dam	0	0	0	0	0	0
Total	4400	4400	4400	4400	4400	4400
Unassigned						
Fish, wildlife, and recreation	515	515	515	515	515	515
Yuma Desalting Plant	120	120	52	52	52	52
Total	635	635	567	567	567	567

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 conducted salt-routing studies for the *2002 Triennial Review of the Water Quality Standards for Salinity, Colorado River Basin*. As part of the triennial review process, Reclamation used a spreadsheet format and will use a model of the river system 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 the Bureau of 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 will prevent over a million tons of salt per year from reaching the river. By 2004 the salinity control program for Reclamation has controlled an estimated 569,000 tons of salt, while the USDA NRCS (NRCS) program has reduced an estimated 405,000 tons of salt, and the BLM has controlled an estimated 98,000 tons of salt per year from entering the Colorado River (Figure 11). According to the Colorado River Salinity Control Forum, salinity control units will need to prevent nearly 1.8 million tons of salt per year from entering the Colorado River by 2025. To reach this objective, as shown in Table 5, the program needs to implement 728,000 tons of new controls beyond the existing 1,072,000 tons of salinity control presently in place (2004) as reported by Reclamation, USDA & BLM. About 35,000 tons per year of new salinity control measures must be added each year if the program is to meet the cumulative target of 1,800,000 tons per year by 2025.

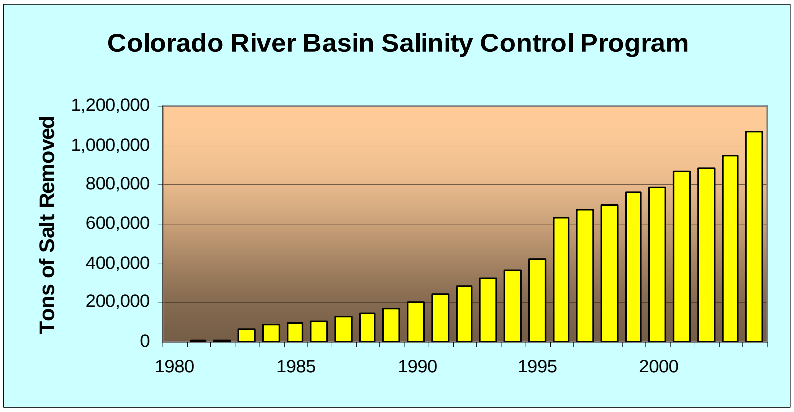


Figure 11 – 2004 Est. Salinity Control Progress; BOR, NRCS & BLM

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. See Progress Report #21 for a more detailed description of each salinity control project and the salinity controlled by Reclamation, NRCS and BLM.

Table 5 - Salinity Control Requirements and Needs

Salinity control needs (2020)	1,800,000 tons
Measures in place (2004)	- 1,072,000 tons
Plan of Implementation Target	728,000 tons

CHAPTER 3 - SALINITY MODELING

ECONOMIC SALINITY DAMAGE MODEL

The Lower Colorado Salinity Damage Model estimates the economic damages from salinity levels above 500 mg/L TDS. The model estimates damages based on agricultural and municipal and industrial water (M&I) use as well as local and regional water quality requirements within the Lower Colorado River Basin. Agricultural damages are based on the changes in gross crop values due to changes in crop yield brought on by different salinity levels. For M&I water use, house holds, commercial, industrial, and water utility damages are estimated for the major urban areas in the Lower Colorado River basin. For local or regional water quality requirements, costs associated with treating recycled water or maintaining ground water quality based on changes in Colorado River salinity levels are estimated. Figure 2 (page 8) shows the breakdown of the salinity costs between the various categories. Using the present salinity at Imperial dam, it is estimated that the economic costs to the water users will be between $305 - $312 million dollars per year. Figure 12 shows how the increase of salinity impacts the cost to various categories.

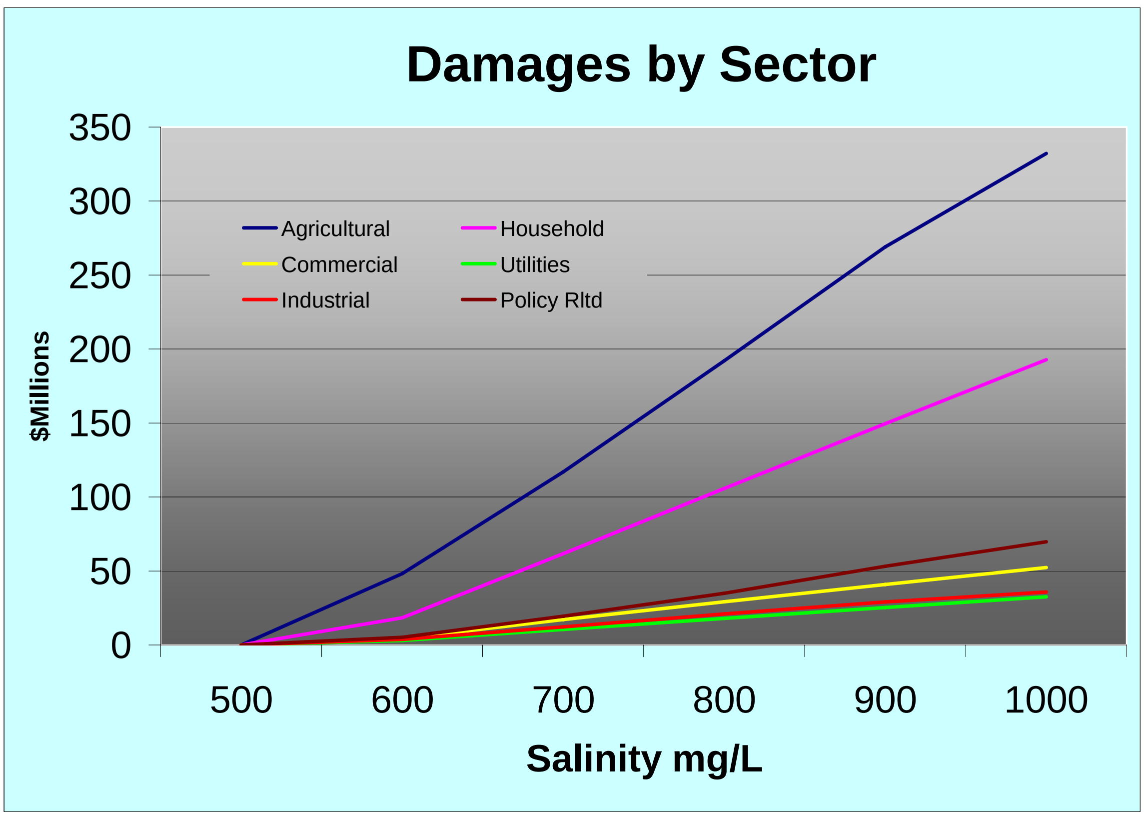


Figure 12 – Economic Model Damages Caused by Increase in Salinity

COLORADO RIVER SIMULATION SYSTEM

The CRSS model was developed to simulate long-term salinity conditions given future development of water, with and without various levels of salinity control. The model is a long-term planning tool designed to look out 30 to 50 years into the future. The CRSS is a group of programs that are collectively used to evaluate the impact of water development and salinity control on the Colorado River.

Salinity Model Verification

During the last 6 years Reclamation has critically investigated the data and methodologies used within CRSS and these efforts have resulted in an updated version of CRSS. The model updates include improvements to both the input data and submodels used by CRSS. However, additional critical investigations of sub-basin water and salt relationships will be continuing over the next several years.

The original CRSS included a submodel developed by the USGS (Mueller and Osen, 1988) that computed natural salt as a function of natural flow. This submodel was based on data from 1941-1983 and could not easily be updated with recent data. Reclamation took the need to update the submodel based on current data as an opportunity to incorporate improvements from recent research that use nonparametric regression methods (Prairie et al., 2005). The improved submodel is based on data from the more recent period 1971-1995. Considering the need to periodically update the regressions the improved submodel can easily be updated as the historic record is extended. The submodel includes the ability to capture nonlinear relationships between natural flow and natural salt that could not be captured with the previous version. These nonlinear relationships were observed in the historic record.

The verification of the updated CRSS is shown in Figure 13. For comparison the Figure includes the historic salinity concentration, numeric criteria at Imperial Dam (879 mg/L), and the result of the CRSS model before the updates were applied. Figure 13 demonstrates the updated CRSS model is capable of recreating the salinities that occurred from 1971 until 1995. Assuming the relationship between flow and salinity will remain similar in the next 20 years the model can be used with confidence to project a similar natural flow and salt relationship in the future.

Future Salinity Projections

The verified CRSS model provides long-term (20 years in the future) simulations of salinity concentration below Hoover, Parker and at Imperial Dam. These are the three locations where the salinity criteria designates numeric criterion that are to be maintained.

For these recent studies the CRSS model was used with 90 years of natural flow data to simulate the range of possible salinities based on the historic flows observed in the Colorado River Basin from 1906-1995. Figure 14 displays the results from the CRSS model on the Colorado River at Imperial Dam. The plot demonstrates the range of possible salinity that may be seen in the future given the current conditions and overlaying the variations of natural flow along with the projected future depletions and salinity control levels. The results from the model are displayed as exceedance lines. The exceedance percentage for each line represents the probability that the concentration will be less than or equal to this value. The graph indicates in 2025 the projected salinity levels can be equal to or below 779 mg/L at

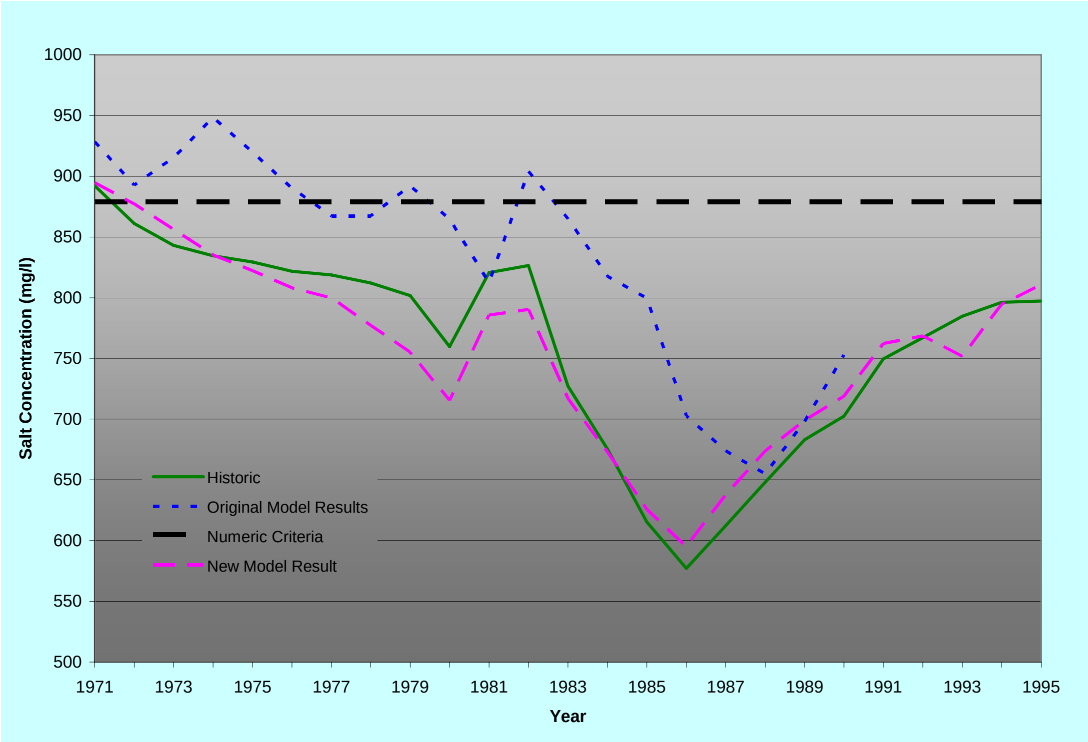


Figure 13 - Calibration of CRSS 1971-1995 for Colorado River at Imperial Dam**.**

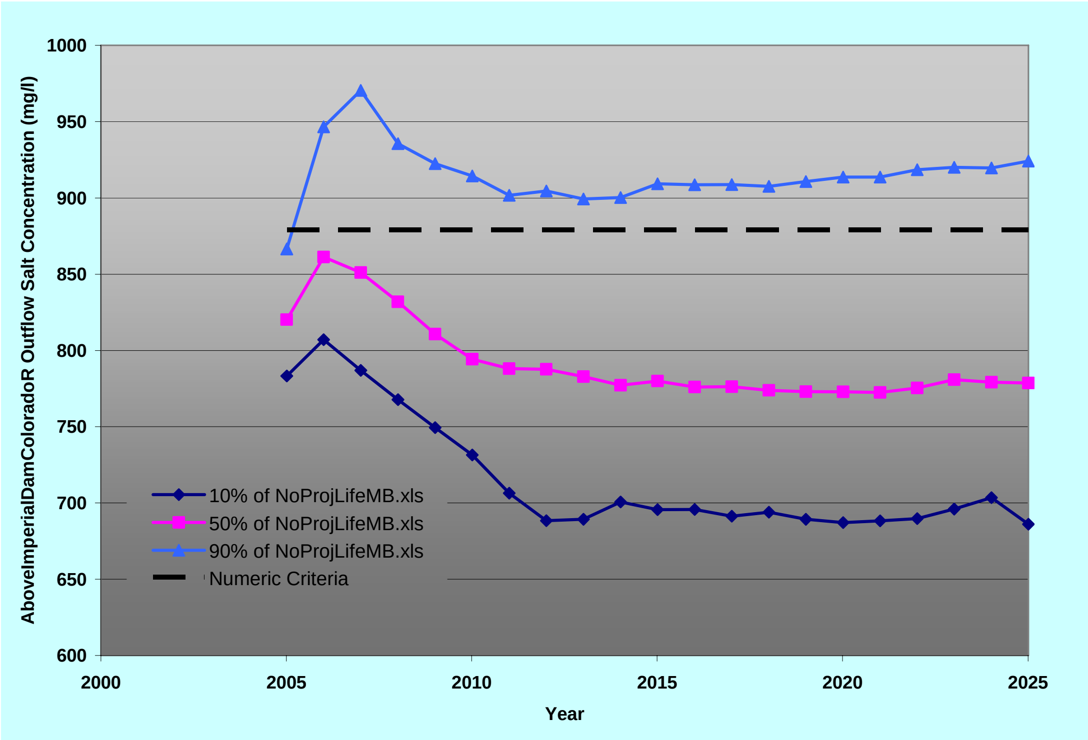


Figure 14 - Future Salinity Concentration for Colorado River at Imperial Dam.

Imperial Dam fifty percent of the time. Ninety percent of the time the projected salinity concentration should be less than or equal to 924 mg/L.

Based on these recent CRSS model results, Table 6 indicates the probability of exceeding the numeric criteria in 2025 for two scenarios. The first scenario, titled "2025 Existing and Potential", maintains the existing salinity control projects at the levels they are currently removing salt and assumes the additional projects that have been approved under that latest RFP shall be built as projected. The second scenario, titled "2025 Existing with Degradation", only includes the salinity control projects built until 2004 and models salinity control projects degrading with age resulting in decreased efficiency. By 2025 under the first scenario salinity control projects are preventing approximately 1.6 million tons per year from entering the Colorado River. Under the second scenario salinity control projects are removing approximately 900,000 tons per year.

Though CRSS model results indicate the numeric criteria will likely not be exceeded in 2025 there is a 34 percent probability it will be exceeded on the Colorado River below Hoover Dam under Scenario 2. Under scenario 1 the CRSS model indicates the average salinity concentration would be approximately 685 mg/L below Hoover Dam, 708 mg/L below Parker Dam and 835 mg/L at Imperial Dam. Though these salinity concentration levels are on average below the numeric criteria, analysis performed with the Economic Damages Model indicated damages resulting from these salinity levels are significant.

Table 6 - Probability of Exceeding Numeric Criteria

		Probability of Exceedance	
	Numeric Criteria	2025 Existing and Potential	2025 Existing with Degradation
Station Name	(mg/L)	(%)	(%)
Colorado River Below Hoover Dam	723	16	34
Colorado River Below Parker Dam	747	16	33
Colorado River at Imperial Dam	879	14	25

CE-QUAL-W2 RESERVOIR MODELING

Since Reclamation is also required to simulate salinity five years into the future (see Chapter 1- Authorizations), another method is being developed that includes more mechanistic models of Lakes Powell and Mead.

Reclamation's Upper Colorado Region has built and is still finalizing calibration and testing of a River Reservoir Model utilizing the Corp of Engineers CE-QUAL-W2 (W2) model. This model will be used to more accurately array near future salinity boundaries to meet the five year forecast requirement to be presented in this report. The model currently includes only Lakes Powell and Mead. The CRSS model is utilized to array the salinity downstream from Hoover Dam in the short term forecast since the downstream reservoirs hydraulic detention times generally do not exceed one to two months.

The W2 reservoir model will be able to give more accurate 1-5 year simulations on a monthly basis than CRSS. W2 is a two dimensional river/reservoir hydrodynamic water quality model that has evolved over a period spanning nearly three decades. The U.S. Army Corp of Engineers (CE or COE), J.E. Edinger and Associates (Edinger), and Dr. Scott Wells at Portland State University working with Mr. Tom Cole (COE) have been the major developers in recent years. All of the above have been helpful and provided some insight on the development of this application.

Previous versions of the model tended to completely mix each winter, and thus did not maintain the chemical integrity required to make multi-year simulations feasible. This application is a significant test of the capabilities of this model to make multi-year runs on deep, chemically stratified, long hydraulic detention time reservoirs.

Model Calibration

The model was calibrated from 1992-95, and then further verified for a single run from 1990-2002 on each of Lakes Powell and Mead. Ungaged inflows and estimated salt loads had to be simulated multiple times to get the total salt budget correct for the entire time period. In addition to the calibration of salinity at the outflow, temperature was also calibrated at the outflow and at seasonal profiles at individual stations within the reservoir. Similarly salinity was also calibrated seasonally at the individual stations within the reservoir. The model calibration period includes the actual inflow and salt loading from 1990-2002. Table 7 shows that this time period is slightly drier than the long term historical average inflows into Lake Powell. The model was calibrated from January 1, 1990 through December 31, 2002. This period includes two severe droughts and a wet cycle.

The model calibration parameter of greatest interest for this report is the dam release salinity. The model calibration periods illustrated here are comparisons of actual mean annual flow weighted salinity concentrations in mg/L versus the model results (Figures 15 & 16). The differences between the model and the actual data at the higher salinity levels suggest that about 20-30 mg/L of calcite may be precipitating out of the reservoir during these time periods. However, during rapid refilling in wet cycles the salt from the "bathtub ring" around the lake shorelines is added back into the water, offsetting any long term salinity improvement.

Future Salinity Scenarios

The run scenarios generated for future simulations with W2 are illustrated in Table 8. Each run starts with the same initial condition on January 1, 2004, and they remain the same until January 1, 2005. Beginning January 1, 2005 individual 7 year traces begin with 1990 through 2000 as shown in Table 7 (below). The hydrological statistics for each trace are illustrated in Table 8. A summary of the 11 traces run through the W2 model are presented as a flow weighted annual average salinity discharge from the two dams in Figures 17 & 18. As seen in these Figures the W2 model predicts that even if several more years of drought occur, the salinity below Hoover Dam could approach, but does not exceed the salinity criteria of 723 mg/L. This hydrologic sequence of simultaneous drawdown of these two reservoirs is being observed for the first time.

There appears to be other factors reducing the salinity concentrations during this extended drought. The mean annual salinity concentration coming into Lake Powell dropped after the first three years of this drought. This has never been seen before, and was not expected.

Table 7 - Hydrology of the Individual Years Modeled and Percentage of Long Term Averages (either 1964-2002 or 1992-2002).

Actual Lake Powell Inflows (Acre-Feet / Yr.)		
Calendar Year	**Inflow**	**% of Avg.**
1990	5,042,513	45.0%
1991	7,349,138	65.6%
1992	7,099,221	63.4%
1993	13,281,856	118.6%
1994	7,032,423	62.8%
1995	14,862,700	132.7%
1996	10,675,967	95.3%
1997	16,545,283	147.7%
1998	12,788,465	114.2%
1999	11,871,653	106.0%
2000	7,399,821	66.1%
2001	6,471,978	57.8%
2002	3,742,641	33.4%
2004	5,872,567	52.4%
Average	9,551,051	85.3%

NOTE: The periods of 1990-92 (58%) and 2000-02 +04 (52%) are very dry, while the wet period from 1993-99 (112%) is a very wet cycle.

Apparently this occurred because the ground water storage basins (particularly associated with irrigated areas) take 18-36 months to drain out. When a drought extends beyond three years in the Upper Basin two things are believed to happen. First, the saline base flow drops off; and second, many of the Upper Basin irrigation areas do not receive a full water supply. Many of the saline tributaries that begin far from the mainstem have been dry for most of the past two years. Therefore, these tributaries are not delivering normal salt loads to the mainstem. Because of these conditions it is important to extend this W2 database through the 2003-05 years as soon as the data is available.

The results of this study should not be interpreted as a worst case salinity scenario for longer term conditions based on greater water use in the Upper Basin. The long term conditions are modeled with CRSS.

While this array of potential near future scenarios does not show that the salinity criteria should be exceeded in the next few years, it does indicate that a number of future hydrologic scenarios leave salinity near the criteria for several more years to come. Relief from the current high salinity levels will come only after a couple of years of above average hydrology. The measured salinity below Hoover Dam on January 1, 2005 (671 mg/L) is approximately in the middle range of Figure 18, modeled future salinity scenarios.

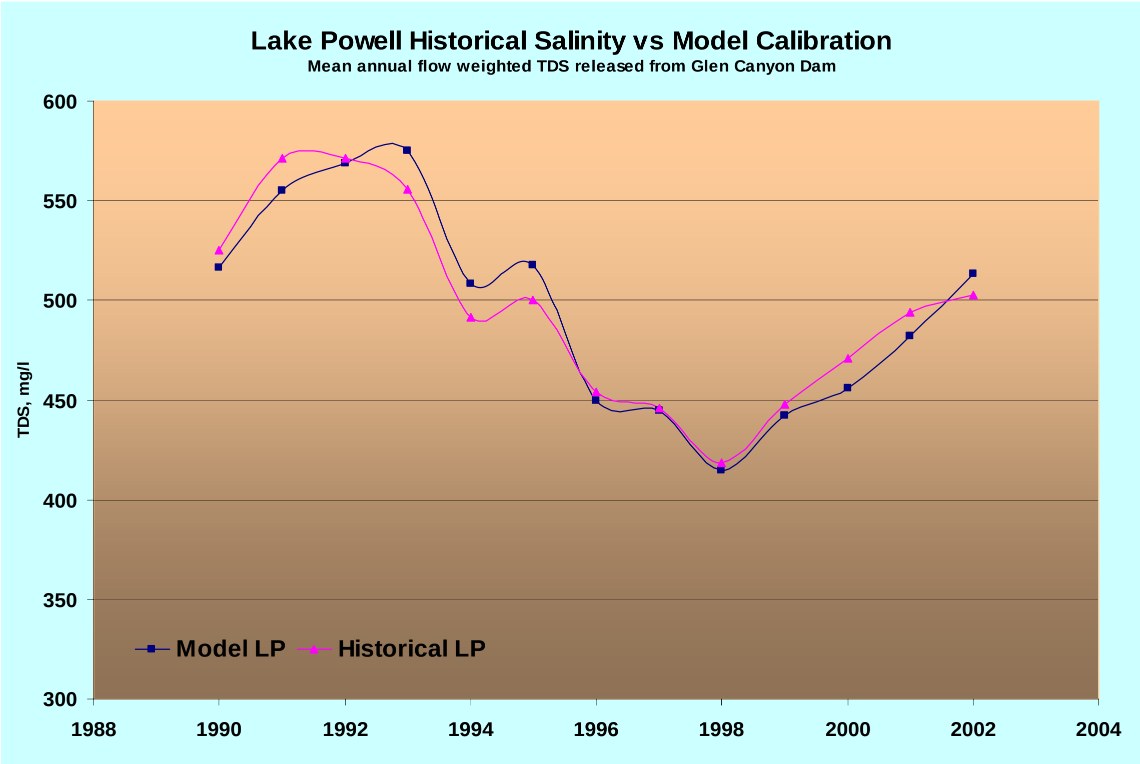


Figure 15- Comparison of the Historical Flow Weighted Annual Average Total Dissolved Solids (TDS or Salinity) Released from Glen Canyon Dam with the Model Calibration.

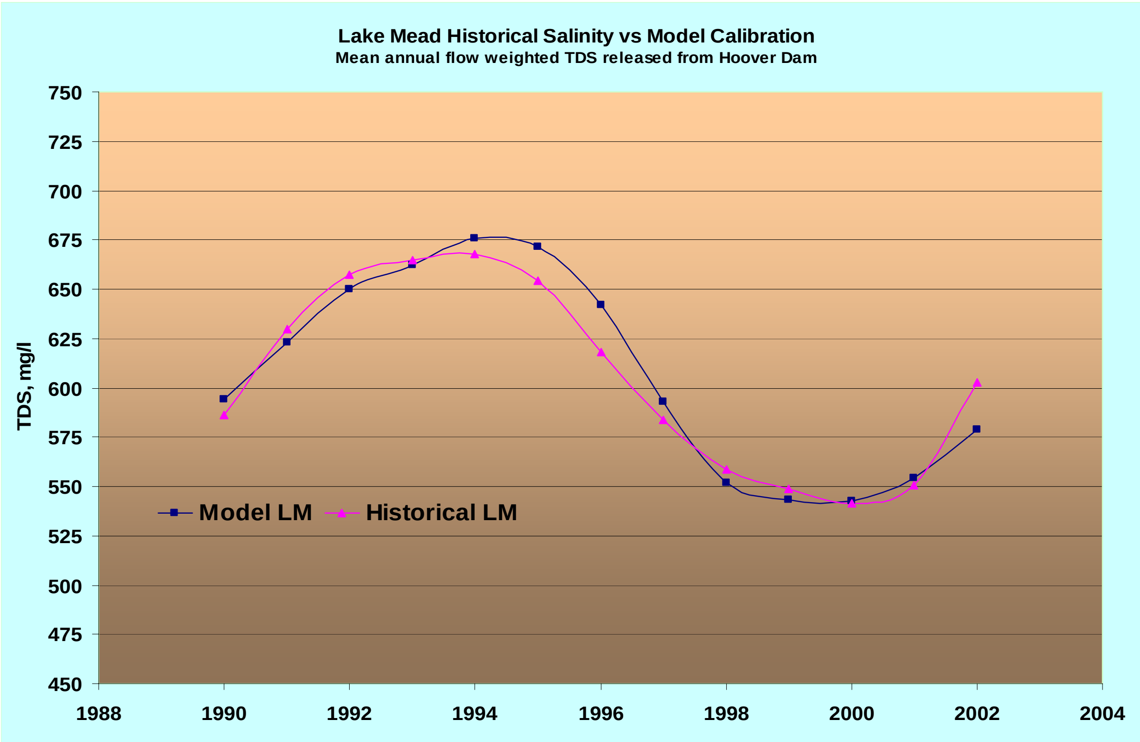


Figure 16- Comparison of the Historical Flow Weighted Annual Average Total Dissolved Solids (TDS or Salinity) Released from Hoover Canyon Dam with the Model Calibration.

Table 8 - Statistical Hydrology for each Trace Arraying Potential Future Salinity Ranges below Glen Canyon and Hoover Dams**.**

Trace	Inflow Ave.	% of Ave.
2004, 1990-1996	8,902,048	79.5%
2004, 1991-1997	10,339,894	92.3%
2004, 1992-1998	11,019,810	98.4%
2004, 1993-1999	11,616,364	103.7%
2004, 1994-2000	10,881,110	97.2%
2004, 1995-2001	10,811,054	96.5%
2004, 1996-2002	9,421,047	84.1%
2004, 1997-2002, 1993	9,746,783	87.0%
2004, 1998-2002, 1993-1994	8,557,675	76.4%
2004, 1999-2002, 1993-1995	8,816,955	78.7%
2004, 2000-2002, 1993-1996	8,667,494	77.4%

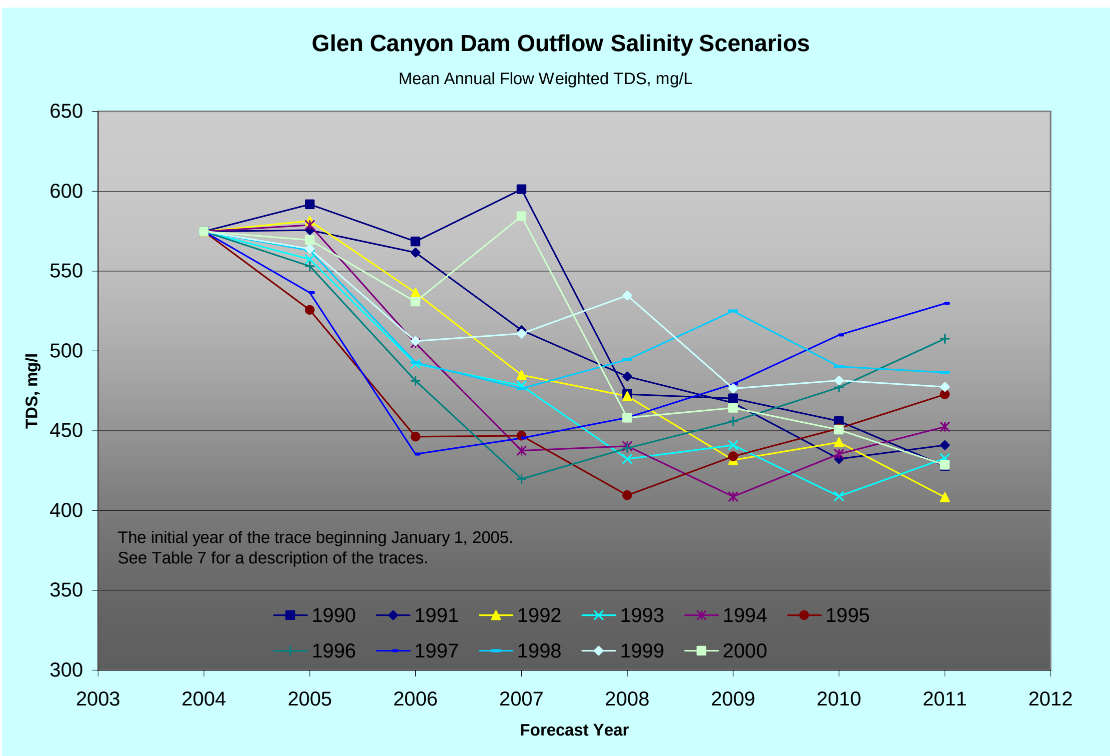


Figure 17- The Array of Potential Future Salinity Concentration Ranges as a Flow Weighted Annual Average Total Dissolved Solids (TDS or salinity) to be Released from Glen Canyon Dam.

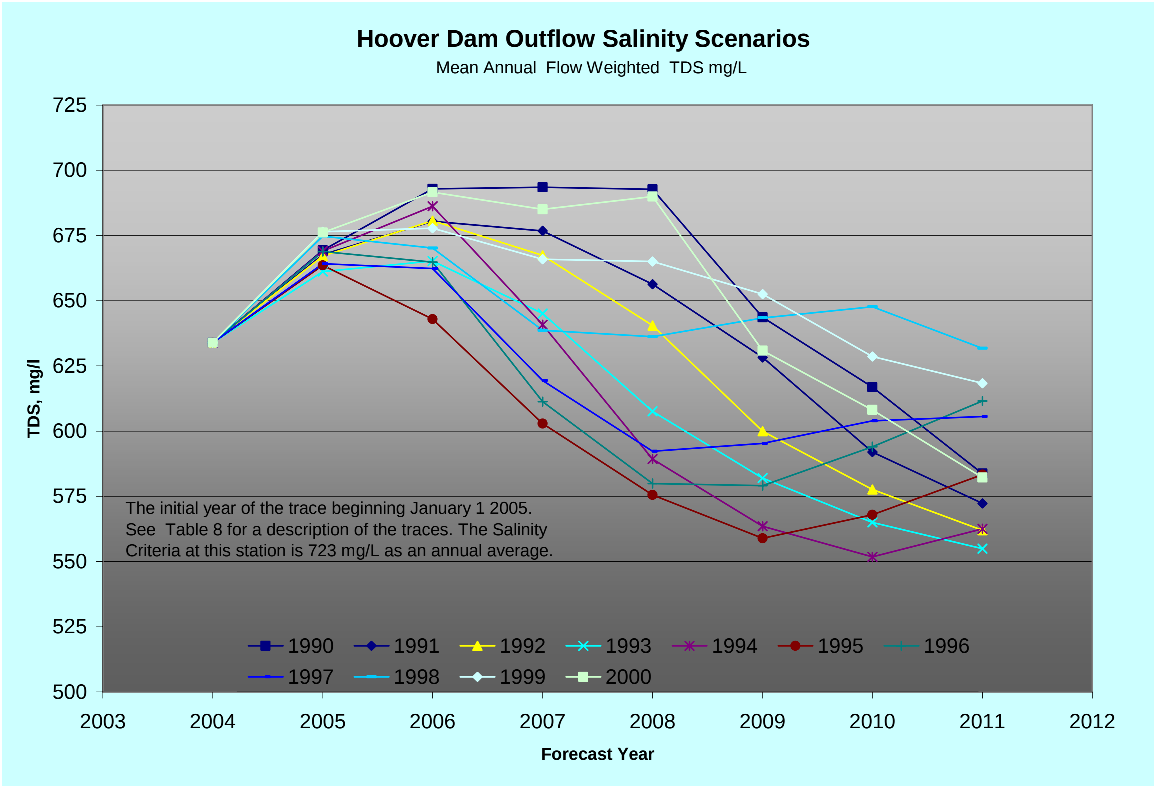


Figure 18 - The Array of Potential Future Salinity Concentration Ranges as a Flow Weighted Annual Average Total Dissolved Solids (TDS or Salinity) to be Released from Hoover Dam.

CHAPTER 4 – TITLE I SALINITY CONTROL PROGRAM

The Colorado River Basin Salinity Control Act (Salinity Control Act), Public Law (PL) 93-320, 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).

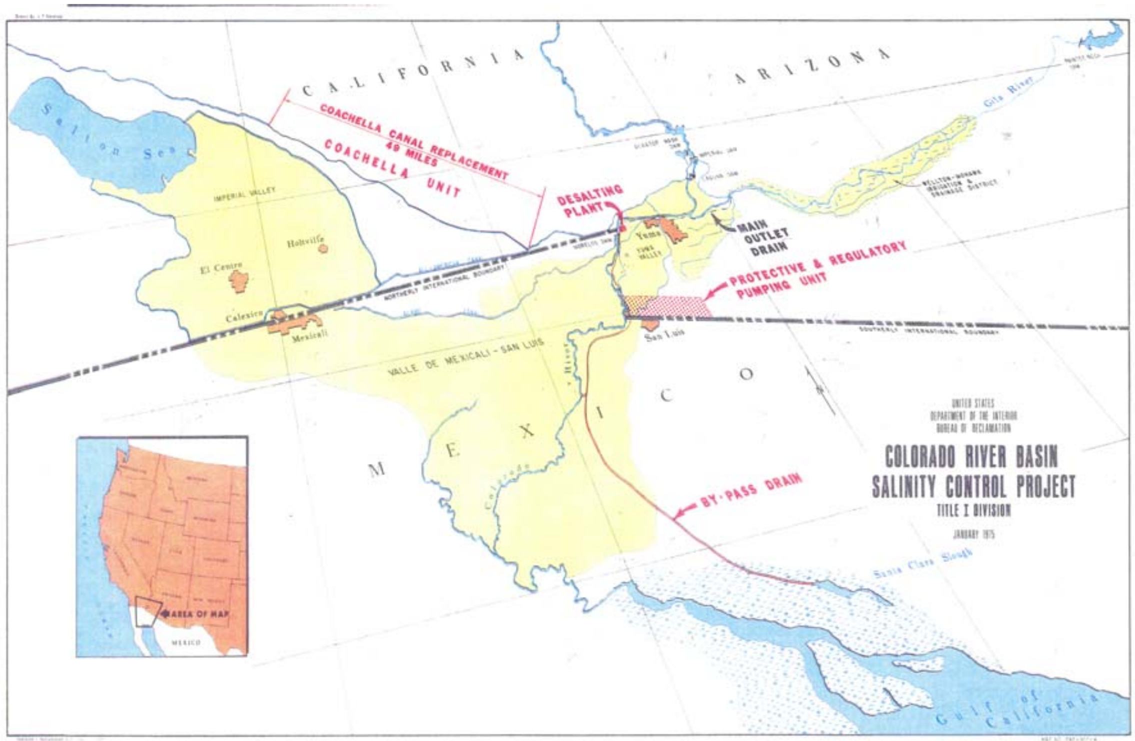


Figure 19 - Map of Title I Projects.

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.

COACHELLA CANAL LINING

To assist in meeting the salinity control objectives of Title I, the Secretary was authorized to construct a concrete-lined parallel canal or to line the unlined initial 49 miles of the

Coachella Canal in place. The act required that a contract be executed with the Coachella Valley Water District for partial repayment of the cost of the work over a 40-year period. Public Law 106-377 – Appendix B amended Public Law 100-675 to provide that during the period of planning, design, and construction of a new lined canal to reduce seepage of water from a portion of the All American Canal and its Coachella Branch, the annual repayment installments will continue to be nonreimbursable. Also, during the period that the San Luis Rey River Indian Water Authority, the City of Escondido, and Vista Irrigation District receive up to 16,000 acre-feet per year of the water conserved by the new lined canals, the annual repayment installments will continue to be nonreimbursable (114 Stat. 1441A-71).

An estimated 141,000 acre-feet of Colorado River water were lost each year through seepage from this reach of the canal. It is estimated that the lined canal paralleling the old unlined canal reduced seepage losses to 9,000 acre-feet per year (af/yr), resulting in an annual savings of 132,000 acre-feet. The seepage losses saved are to be used during an interim period to substitute for the bypassed Wellton-Mohawk Irrigation and Drainage District (District) irrigation drainage waters and for the reject stream from the Yuma Desalting Plant. The interim period began when construction was completed in 1980 and ends the first year that the Secretary delivers less mainstream Colorado River water to California than requested by California agencies and Federal establishments with Colorado River water contracts in California.

PROTECTIVE AND REGULATORY PUMPING

Section 103(a) of Public Law 93-320 authorized the construction, operation, and maintenance of the Protective and Regulatory Pumping Unit (PRPU) by the Bureau of Reclamation (Reclamation) to manage and conserve United States groundwater for the benefit of the United States and for delivery to Mexico in partial satisfaction of the 1944 Treaty. The PRPU is located in a zone 5 miles wide paralleling the Southerly International Boundary between Arizona and Sonora, Mexico.

The PRPU was developed to intercept part of the groundwater underflow that moves southward from the Yuma Mesa in the United States into Mexico. Before the PRPU was constructed, this underflow was increasing because of groundwater pumping in the Sonora Mesa Well Field, immediately south of the Southerly International Boundary in Mexico and located near San Luis, Mexico. The Basin States expressed their concern about the pumping in their July 1973 letter to the President of the United States.

Currently, 21 of the 35 wells in the planned full complement of wells and associated conveyance and energy facilities have been constructed. The wells are connected by a 15.3-mile pipeline and open concrete-lined canal that carries water by gravity across to the Yuma Valley Main Drain where it crosses the Southerly International Boundary.

With 35 wells, the PRPU would be capable of producing about 125,000 acre-feet of water per year. Ultimately, 125,000 acre-feet of water from the PRPU, combined with 15,000 acre-feet of water from the East and West Main Canal Wasteways in the Yuma Valley, would furnish 140,000 acre-feet of Mexico's 1.5-million-acre-foot annual entitlement. The water would be delivered at the Southerly International Boundary near San Luis, Arizona. In addition, 35,000 acre-feet could be withdrawn by private wells and/or Minute No. 242 wells for use on private land to equal the 160,000-acre-foot limit for pumping in the

5-mile zone. Currently, water from the East and West Main Canal Wasteways and the Yuma Valley Main Drain exceed 100,000 af/yr delivered to the Southerly International Boundary.

Should these wasteway and drain flows diminish in the future, wells would be added to the PRPU, as needed, to ensure that approximately 140,000 acre-feet can be delivered at the Southerly International Boundary at all times.

Additionally, as authorized by Title I, approximately 23,500 acres of private, State, and State-leased lands have been acquired within the 5-mile zone. The purpose of these acquisitions is to limit development and thus, limit United States groundwater pumping to 160,000 af/yr, as required by Minute No. 242. The acquisitions were completed in 1984.

Reclamation completed a Resource Management Plan/Environmental Assessment (RMP/EA) for the 5-mile zone in April 2004. This RMP/EA provides direction for future management decisions according to currently recognized standards of proper land and water use and enhances Reclamation's stewardship of the lands and water within the 5-mile zone.

YUMA DESALTING PLANT

The Yuma Desalting Plant (YDP) was built on a 60-acre tract of land 6 miles west of Yuma, Arizona. The purpose of the plant is to recover irrigation drainage water from the Wellton-Mohawk Irrigation and Drainage District (the District) so that it can be returned to the Colorado River and delivered to Mexico in partial satisfaction of the Mexican Water Treaty of 1944.

Figure 20 – Aerial Photo of Yuma Desalting Plant.

The operational design parameters set up for the plant determined that a reverse osmosis membrane desalting process was technically feasible and suitable for the YDP operation. Factors utilized in the plant design were projected volume and salinity of water to be delivered to Mexico at the Northerly International Boundary, the salinity differential required by Minute No. 242, the projected salinity of the Colorado River at Imperial Dam, the volume of the District's drainage water that was expected to be treated, the expected salinity of their drainage water, a number of other factors related to the dilution of return flows below Imperial Dam, as well as plant operational factors.

A study completed in 1978 by the Advisory Committee on Improving Irrigation Efficiency in the District recommended continuation of the on-farm irrigation improvement measures in the district. These improvements were expected to reduce irrigation drain flow to around 108,000 af/yr. In addition, the Colorado River Basin Salinity Control Forum (Forum), representing the Basin States, established a numeric criterion at Imperial Dam of 879 mg/L (ppm). Using the desalting plant design criteria and a projected agricultural drainage flow of 108,000 af/yr from the District at 3,200 ppm and a salinity level of about 840 ppm for flows arriving at Imperial Dam, it was determined that a desalting plant size of 73 million gallons per day would be required to treat the anticipated drainage flow.

The YDP was constructed to produce about 72.4 million gallons of desalinated (product) water per day when operated at full capacity. This would result in a delivery of about 68,500 acre-feet of product water per year. The product water would be blended with untreated drainage water to salvage an estimated 78,000 acre-feet each year for delivery to Mexico. The plant last operated in 1993. Since then, requirements of Minute No. 242 are being met by other means. With the construction of the Bypass Drain, and groundwater drainage management in the Yuma area, the United States has been meeting its salinity control obligations through the bypass of saline agricultural drainage water to the Cienega De Santa Clara Slough in Mexico. Under Minute 242, the bypass water is not charged against Mexico's Treaty entitlement and thus results in releases of a like amount of water from Colorado River storage. Consistent with Title I, this storage release was off-set by the water conserved by lining the first 49 miles of the Coachella Canal until January 1, 2003.

While in ready reserve, the YDP could be placed in full capacity operation within 2-3 years, depending on the availability of funding. When operational, the YDP's concentrate (brine) is sent to the Cienega de Santa Clara Slough (Slough) in Mexico via the Bypass Drain. Due to the unexpected time required for construction, flows of the bypassed WMIDD irrigation drainage expanded the Slough from a relatively small area to several thousand acres of aquatic and wetland environment. Concerns have been raised regarding the effects of reduced flow from YDP operation and the associated high saline brine reject on wetlands in the Cienega that have grown to cover an area of approximately 14,000 acres (the wetlands were approximately 1/100th this size prior to construction of the Bypass Drain).

Increases in water demand in each of the three lower Basin states has intensified the need for more efficient water management of the Colorado River system. This, coupled with the effects of a prolonged drought over the entire Colorado River Basin, has increased interest in replacing and/or recovering bypass flows to Mexico in order to conserve storage in the Colorado River reservoirs.

Among the issues associated with operating the YDP are high costs, time required for reaching operational status, and water supply to the Cienega de Santa Clara Slough. In order to identify the best approach for recovery or replacement of bypass flows at the lowest possible cost, Reclamation began a public process for identifying and evaluating options for replacing or recovering bypass flow to Mexico; maintain the Plant in a "ready-reserve" status and, as funds allow, continue correcting design deficiencies identified during and subsequent to a short, one-third capacity operation some 13 years ago; and initiate a demonstration program to determine the viability of paying holders of Colorado River water delivery contracts to temporarily forbear use of water. It is anticipated that the outcome of one, or a combination, of these items will lead to an action that will meet the competing needs associated with bypass flows to Mexico.

WELLTON-MOHAWK IRRIGATION AND DRAINAGE DISTRICT

To prevent crop damage from high ground water levels, Wellton-Mohawk Irrigation and Drainage District (District) has implemented irrigation drainage pumping of groundwater. This groundwater discharge has relatively high salinity concentrations and caused water quality problems in the river below Imperial Dam. The Title I Program, authorized by section 101(b) of the Salinity Control Act (PL 93-320), has reduced the District's irrigation drainage pumping by removing some lands requiring high water use from irrigation and by increasing irrigation efficiencies.

Acreage Reduction Program

Under this program, the District's irrigable lands were reduced from 75,000 to 65,000 acres. About 6,200 acres of land were purchased from 85 landowners. The remaining 3,800 acres were Federal lands from which irrigable status was withdrawn.

Approximately 4,600 of the irrigable acres purchased were in crop production. As a result of the land purchases, deep percolation was reduced about 29,800 af/yr. This program was completed in 1978.

In addition, the Salt River Pima-Maricopa Indian Community Water Rights Settlement Act of 1988 removed 2,225 acres of land from irrigation as part of an agreement to reduce diversions in the District to make water available to the Pima Maricopa Indian community near Phoenix, Arizona. Approximately 22,000 acre-feet was transferred to the Indian community, reducing drainage flow from the District around 11,000 af/yr and reducing the District's consumptive use entitlement for Colorado River water from 300,000 af/yr to 278,000 af/yr.

In 1993**,** the Gila River flood severely damaged about 3,000 acres of land near the river channel. The District purchased most of this land and, initially, wanted to transfer the water use from this agricultural land to municipal and industrial uses. However, District has since started development of 3,000 acres of additional farmland elsewhere in the district to bring them up to their allotted farmable acreage of about 62,775 acres.

District Irrigation Efficiency Improvement Program

Several entities cooperated on this program, including the District and its farmers, several Government agencies including Reclamation, NRCS, U.S. Salinity Lab, the USDA-Agricultural Research Service and the University of Arizona Cooperative Extension Service. Individual measures are discussed in the following sections.

On-farm Improvements Program

The objective of this program was to increase on-farm irrigation efficiencies by improving on-farm irrigation systems and management practices. NRCS provided design, installation, and management assistance for approximately 48,000 acres of land. Significant accomplishments included lining 263 miles of on-farm canals; leveling 44,415 acres of land; and installing 10 drip irrigation systems and 10,600 on-farm water-control and measurement structures. The Federal government contributed 75 percent of the costs; farmers contributed the remaining 25 percent. The farmers were under contract to maintain specific irrigation efficiency lands for 2 years after the on-farm improvements were installed.

Irrigation Management Services Program

Reclamation provided technical assistance through the Irrigation Management Services (IMS) Program, which, in turn, provided on-farm, field-by-field irrigation scheduling assistance. From 1977 through 1986, irrigation scheduling information was furnished for about 49,000 acres of crops each year. However, the District dropped the irrigation-scheduling program in 1994 as fewer than 4,000 acres were still participating. By this time, technological improvements in irrigation scheduling had made the IMS program obsolete. The District decided that with the few acres participating, the benefits no longer warranted the costs of continuing the program. Farmers participating in the On-farm Improvements Program were required to participate in the IMS Program for two years following installation of on-farm improvements.

Reclamation provided technical expertise, training, and funding for the program. The District provided one employee and office facilities. Reclamation funding for the IMS program ended in 1987.

Research and Demonstration Program

Six projects were funded under this program, which provided information on cultural practices, equipment, and economic considerations that could lead to improved irrigation efficiencies. Projects included monitoring soil salinity, studying emitter clogging in trickle irrigation systems, managing pressure irrigation systems for citrus crops, managing dead-level irrigation, automating surface irrigation, and evaluating alternative irrigation systems. All projects were completed by 1980.

Education and Information Program

The objectives of this program, conducted by the University of Arizona Cooperative Extension Service, were to (1) provide liaison among the various irrigation efficiency programs and (2) educate and encourage growers to adopt recommended irrigation efficiency improvement techniques and practices. Program information was provided through publications, television, and radio. With grower cooperation, field trials were held to demonstrate water management benefits, and field days were conducted on topics such as automated irrigation systems, irrigation scheduling and efficiency, and crop consumptive use. This program was discontinued in the late 1980's.

Results

Before the irrigation efficiency program, the District's irrigation efficiency was 56 percent. While the program was active, overall their irrigation efficiencies exceeded 72 percent, the level estimated to reduce irrigation drainage to 108,000 af/yr. An overall peak irrigation efficiency of 77 percent was reached in 1985, and irrigation drainage dropped from 220,000 acre-feet to a low of 118,500 af/yr. While the program demonstrated an overall positive effect, a cause-and-effect relationship for individual measures cannot be established, because all of the measures are interdependent upon one another and cannot stand alone.

Status

All permanent measures implemented by the District are still in use, although the Federal program has been discontinued. 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. More recent irrigation efficiency levels and return flow levels for 1990-2004 are shown below.

Reclamation believes that the impacts of Gila River flows in 1992, 1993, and 1995 make irrigation efficiency and return flow data from the district questionable for 1992, 1993, 1994, 1995, and 1996. In 1993, the Gila River flood destroyed much of the District's Main Conveyance Channel; so most of the drainage pumping went into the Gila River during 1993 and 1994 until these facilities could be repaired.

Irrigation drainage pumping has varied since 1990 partly due to a change in the cropping (larger acreage in vegetable crops) and partly due to the impacts on the groundwater as a result of Gila River flows through the district. In 1997, the District conducted a test to determine how much pumping of groundwater was needed to maintain existing groundwater levels. The District obtained a surplus water contract for additional Colorado River water to allow them to conduct the test so they could stay within their consumptive use entitlement for calendar year 1997. The testing continued through use of surplus water contracts for calendar years 1998, 1999, and 2000. The district was able to pump only 91,695 acre-feet in 1997, 98,972 acre-feet in 1998, and 94,869 acre-feet in 1999. As a result, these tests indicated that the District was able to pump less than 100,000 acre-feet per year to maintain static groundwater levels for a relatively short period of time.

Reclamation continues to investigate means to reduce irrigation drainage pumping in the District. In 1998, the District paid out their share of this project and requested transfer of title of their project's facilities from the United States government. As part of the title transfer agreement, the District has committed to diligently pursue a goal of permanently reducing irrigation drainage pumping to 108,000 acre-feet or less per year. Their water conservation plan sets a time frame of 5 years to accomplish that goal.

Table 9 – District Pumped Drainage Return Flow

Year	Pumped Drainage Return Flow (acre-feet)	Irrigation Efficiency, % (note: data provided by WMIDD)
1990	138,200	-
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	-
2004	106,002	-

One of the options the District is pursuing is to combine the Gila Project water entitlements. That would allow the District to utilize a portion of the return flows from other districts in the Gila Project. Accounting for Gila Project return flow would allow the District the flexibility at times to avoid pumping solely to meet their consumptive use requirements. This is one option the District may use to pump less than 100,000 acre-feet per year and reduce the obligation of the United States to replace their pumped drainage.

A Yuma Area Water Resource Management Group (YAWRMG) has been developed to look at ways to more effectively manage groundwater resources in the Yuma Area. This includes methods to reduce drainage return flows from the District and other Gila Project and Yuma Project districts. Reduction of drainage pumping could benefit the United States by reducing the U.S. obligation to replace the District's drainage returns. However, it should be noted that significant reductions in drainage return flows to the Cienega de Santa Clara Slough may have impacts on wildlife habitat.

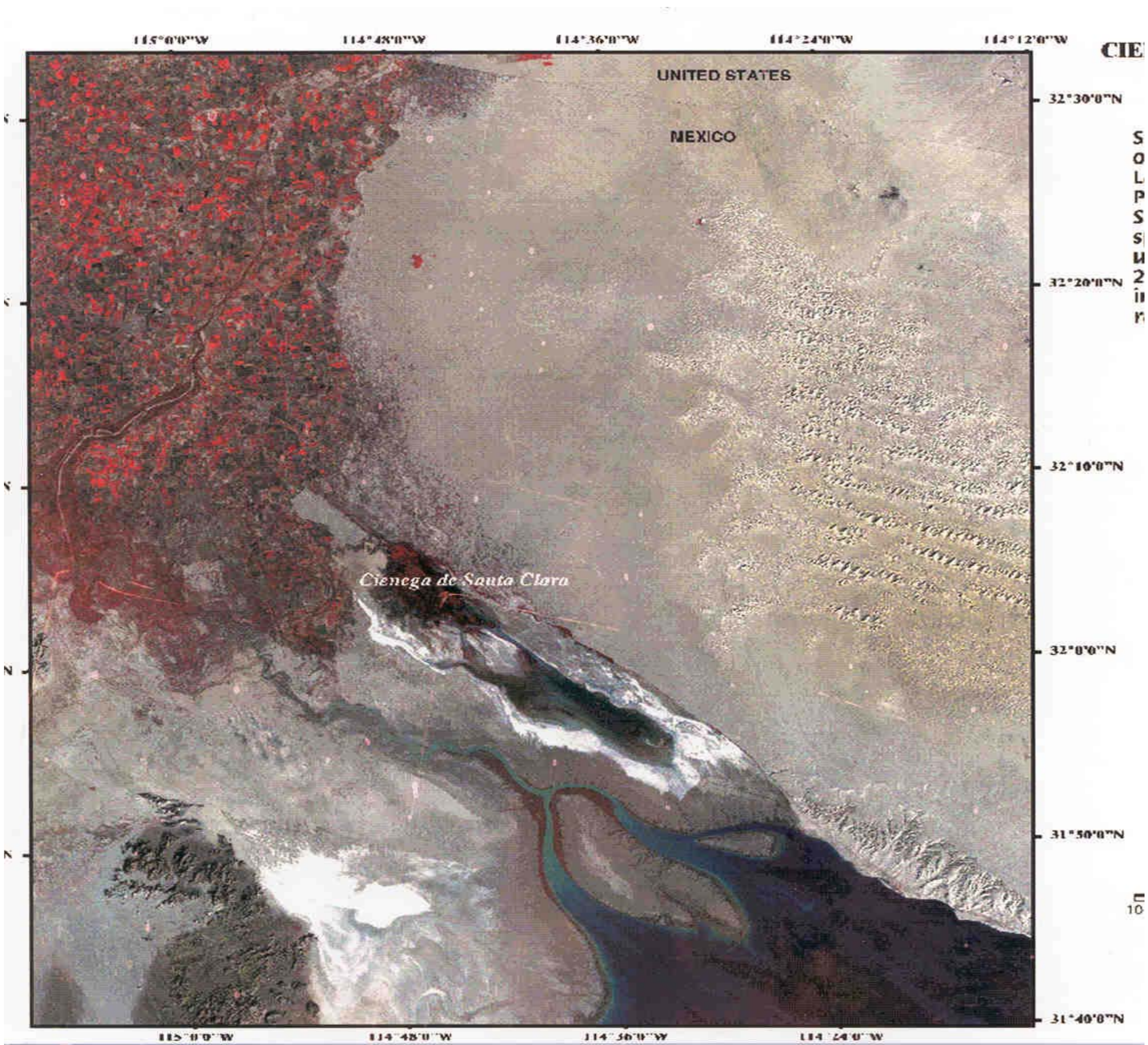


Figure 21 - Satellite photo of Cienega de Santa Clara

CHAPTER 5 – TITLE II SALINITY CONTROL PROGRAM

USDA / NRCS

In 1996, Public Law 104-127 changed the US Department of Agriculture – Natural Resource Conservation Service (NRCS) authorities to conduct on-farm salinity control projects. Colorado River Salinity Control Program (CRSC) activities were transferred to the Environmental Quality Incentives Program (EQIP) established under the Food Security Act of 1985. NRCS administers their CRSC activities through its field offices located in the counties that serve the local agricultural producers.

PL 104-127 also amended the Salinity Control Act to allow Reclamation to provide cost sharing from the Upper Colorado River Basin and Lower Colorado River Basin Development Funds (Basin Funds) to supplement NRCS's on-farm salinity control activities. Through agreements with the individual state administering agencies and NRCS, land treatment contracts to implement salinity control measures are developed and executed with private landowners and groups.

In 2004, an on-farm salinity control implementation project was initiated in the Mancos River Valley in Colorado. Preparations are being made to begin implementation in the Muddy Creek agricultural area near Emery, Utah. Investigations are also underway in at least eight additional agricultural areas.

Table 4 shows the current progress in implementing annual salt control, as well as the cost effectiveness of the control. The NRCS implementation schedule is controlled by annual appropriations. The implementation schedule for NRCS projects is based upon projected salt-load reduction needs, cost-effectiveness analysis, the probability of Federal funding, and the Basin Fund cost sharing capability.

Table 10 - USDA Salinity Control Program Summary

Unit (year Initiated)	Salt Removed Thru FY04 (tons/year)	Potential Salt Removal (tons/year)	Expenditure Thru FY04	[1]Projected Total Cost	[2]Cost Effectiveness Thru FY04 ($/ton)
L. Gunnison, CO (1988)	69,245	186,000	$38,686,632	$103,916,724	46
McElmo Creek, CO (1990)	24,082	46,000	$12,036,480	$22,991,366	41
Uinta Basin, UT (1987)	142,788	140,500	$67,109,572	$67,109,572	39
Grand Valley, CO (1987)	90,425	132,000	$43,117,774	$62,942,175	40
Big Sandy, WY (1988)	42,964	52,900	$13,185,980	$16,235,414	25
Price/San Rafael, UT (1994)	35,441	146,900	$9,731,782	$40,337,428	23
Mancos River, CO (2004)	-	11,900	$0	$4,793,504	-
TOTALS	404,945	716,200	$183,868,220	$318,326,183	38

[1]Projected total costs were estimated using a ratio of existing cost and tons to potential tons.

[2]Cost per ton of applied measures amortized over 25 years at 6.625% interest.

Public Law 98-569 directs the Secretary of Agriculture to carry out a monitoring and evaluation program to evaluate the effectiveness of NRCS's CRSC program. The three general purposes of the M&E effort are to (1) collect salinity control data; (2) evaluate the effect of salinity reduction practices on salt reduction; and (3) verify costs, project effectiveness, economic benefits, and impacts on wildlife habitat.

Monitoring and evaluating NRCS's CRSC program is under way in the seven active project areas in Colorado, Utah and Wyoming. Reports are published annually and can be accessed at www.usbr.gov/uc/progact/salinity/index.hml/

Research is necessary to develop new salinity control technologies. The Agricultural Research Service (ARS), Cooperative Research Service (CRS), and the State Agricultural Experiment Stations conduct research funded from State and Federal sources.

Some of the salinity research activities being conducted by ARS at the U.S. Salinity Laboratory, Riverside, California, and at the Northern Plains Area Natural Resources Research Center, Fort Collins, Colorado, include:

- Suitability of salt-affected water for irrigation reclamation models
- Mobility of potentially toxic trace anions in irrigated root zones
- Field-scale and regional distributions of solute loading to groundwater
- Salt and specific tolerance in crop plants
- Movement of water, salts and agricultural chemicals in the root and vadose zones of salt-affected soils.
- Crop water use from high, saline water tables
- Salt movement under level basin irrigation
- Salinity assessment by rainfall simulation of runoff from rangelands

BLM

The BLM's current strategy is to provide the best management of the basic resource base. Successes with the resource base are designed to translate into improved vegetation cover, better use of onsite precipitation, and stronger plant root systems. In turn, a more stable runoff regime and reduced soil loss should result; thus, benefiting water quality of the Colorado River.

Salt enters the Colorado River and its tributaries from ground-water flows, surface runoff, and from point sources such as saline springs and flowing wells. Dissolution of evaporite deposits in the Upper Colorado River Basin results in highly saline ground water that ultimately contributes the largest amount of salt to the Colorado River System. The natural salt load for the Colorado River at Lees Ferry, Arizona, is estimated to be about 4.4 million tons per year. Contributions from BLM lands are included in this estimate. Surface runoff from BLM-administered lands above Lees Ferry is estimated to contribute about 700,000 tons per year, or about 16 percent. The remaining 3.7 million tons are contributed primarily by ground-water inflow and saline springs, and runoff from other Federal, Tribal, State, and private land.

Planning and Public Involvement

BLM continues to use its land-use planning process, the Resource Management Plan (RMP), as the primary vehicle for carrying forward the solutions to salt-loading problems. In addition to RMPs, in 2003 the BLM created and filled a salinity coordinator position. The salinity coordinator position became permanent at the beginning of January 2005. Budget planning is on-pace to allocate Congressional salinity funds for the 2006 fiscal year through a more accountable tracking method. Longer-term writing and compiling of salinity-control proposals (FY 2007-2009) is also occurring.

The Report to Congress (pursuant to Public Law 106-459) on implementation of the comprehensive program for minimizing salt contributions to the Colorado River from lands administered by the BLM was signed by the Secretary at the beginning of 2005 and transmitted to the Committee on Energy and Natural Resources of the Senate and the Committee on Resources of the House of Representatives.

Nonpoint Source Control

Controlling salinity in rangeland surface runoff is closely related to controlling soil erosion, which is an objective of BLM's Soil, Water, and Air program. Vegetation cover is usually the most important management variable influencing runoff and erosion rates on rangelands. On systematically targeted watersheds, the payoff for salinity control is that decreased sediment yields and moderated flood flow energies should combine to transport less salt from the uplands, as well as from gullies and established channels.

Vegetation management, either indirectly through the design and implementation of livestock grazing plans or directly through vegetation manipulation, is an important erosion and salinity control technique. Reduced runoff and erosion combine to achieve reductions in the amount of salt that moves off site.

Proper land use, including the objectives of grazing systems that incorporate increased cover, appropriate seasons of use, and riparian protection, is a preferred salinity control technique, as is minimizing activities that disturb the surface. However, on the most highly saline sites, maximum potential plant cover is usually inadequate to provide leverage for significant control of surface runoff, erosion, and associated salt mobilization. In those cases where watershed condition is so severely degraded that recovery will be ineffective under normal land management practices, mechanical land treatments and structural alternatives may be the only effective salinity control options. Land treatments involve soil tillage techniques such as contour furrowing, ripping, and rangeland pitting. Structural features include rangeland dikes, retention and gully plugs, and retention and detention reservoirs.

BLM manages riparian-wetland and aquatic zones to achieve healthy and productive conditions for long-term benefits and values and, in Utah and Colorado, salt controls have been created by establishing riparian pasture and off-channel livestock watering practices. Cottonwood and willow tree poles have been planted on several ephemeral drainages. The planting areas are protected until the poles are well established. Soil-vegetation ecological site surveys continue to be an important baseline information source to understand from where, and by what processes, salts are transported to surface or groundwater.

Point Source Control

Many point sources of saline water exist on the public lands as either wells or springs. Close cooperation with the State is required for plugging of orphaned wells, and good field-level coordination with the private entities operating in oil and gas fields has led to additional point source control accomplishments. BLM has developed a water source inventory to identify and characterize water uses and respective sources on the public lands. Saline springs are identified through the program. Control of saline springs is analyzed through BLM's land-use planning process with major sources being brought to Reclamation's attention.

Estimating Salinity Control

It is difficult to estimate the actual reduction in the salinity of the Colorado River that may be attributed to BLM management activities. There are many physical, chemical, and biological processes that affect the movement of salt from an upland project area to the Colorado River or a perennial tributary to the Colorado. As the distance between a project and the nearest perennial flow increases, it quickly becomes impossible to quantify the amount of salt that would reach the perennial flow and the amount of time required for the salt to arrive at the perennial flow. For these reasons, BLM prefers to estimate the amount of salt that is retained on the project site by management actions. It is assumed that the salt retained would have been moved off site by surface runoff if the project had not been implemented. Table 11 shows the estimated salt retained by BLM management in the Basin through 2004. Utah's estimate substantially increased due to the plugging of 2 saline-flowing wells.

Table 11 – Estimated Salt Retained on BLM Lands (tons per year)

State	Thru 1996	1997	1998	1999	2000	2001	2002	2003	2004
Arizona	na	40	50	50	70	1,360	1,400	1,400	1,400
Colorado	na	670	810	840	1,350	4,140	4,140	4,140	4,140
Nevada	na	10	30	60	70	70	70	70	*
New Mexico	na	380	420	900	920	960	980	950	1,000
Utah	na	1,370	1,650	1,830	1,910	2,090	2,140	2,140	6,060
Wyoming	na	380	410	1,220	1,300	1,360	1,400	1,590	1,750
Totals	na	2,850	3,370	4,900	5,620	9,980	10,130	10,290	14,350
Cumulative Total	36,170	39,020	42,390	47,290	52,910	62,890	73,020	83,310	97,660

Note: Rounded to the nearest 10 tons.

* Nevada no longer receives salinity control funding and is not tracked

RECLAMATION

Background

The Bureau of Reclamation involvement in the Colorado River Basin Salinity Control Program dates back to the early 1960's. In 1968, Reclamation initiated a cooperative reconnaissance study in the Upper Colorado Basin with objectives to identify feasible control measures and estimate their costs. This investigation evolved into a number of several salinity control units. In 1974, Public Law 93-320 authorized the construction of the

Grand Valley, Paradox, Crystal Geyser, Las Vegas Wash Units. In 1984, Public Law 98-569 authorized the construction of the Lower Gunnison and McElmo Creek Units.

By 1993, Reclamation had gained 20 years of experience with the program and identified new and innovative opportunities to control salinity, including cooperative efforts with USDA, BLM, and private interests, which would be very cost effective. However, these opportunities could not be implemented because the Congress did not specifically authorize them. The DOI Inspector General's audit report (1993) noted the Salinity Control Act directed that "the Secretary shall give preference to implementing practices which reduce salinity at the least cost per unit of salinity reduction." The Inspector General concluded that the congressional authorization process for Reclamation projects impedes the implementation of cost-effective measures by restricting the program to specific, authorized units (specific areas).

The Inspector General recommended that Reclamation seek changes in the Salinity Control Act to simplify the process for obtaining congressional approval of new, cost-effective salinity control projects. Specifically, the Inspector General recommended Reclamation seek authorities similar to those provided to USDA in the 1984 amendments to the act, wherein USDA was empowered with programmatic planning and construction authority. At the time, USDA had only to submit a report to the Congress and wait 60 days before it could proceed if the Congress did not object. In contrast, Reclamation was required to seek approval of its projects through legislation. This had proved to be a cumbersome way to manage the program. With broader authorities, Reclamation would be able to take advantage of opportunities as they presented themselves, thus reducing costs.

Reclamation agreed with the Inspector General and wanted to explore any other innovative ideas, which would help improve the effectiveness of its program and take advantage of opportunities that were not envisioned 20 years ago. With most of the cost-effective portions of the authorized program nearing completion, this was a pivotal moment for the program. It would either be reauthorized or end in 1998 due to appropriation ceiling limits. From Reclamation's point of view, it seemed a very appropriate time to reassess the direction of the program.

Public Review

In 1994, Reclamation initiated a public review of the Salinity Control Program. The goal of the public review was to completely reexamine the program and its authorities, to gather a broad range of new ideas, to review the lessons of past experiences, to formulate new guidelines and methodologies, and to draft new salinity control legislation to bring this program into the next century.

The public review began on March 24, 1994, with a news release and individual notices mailed to more than 400 entities including congressional representatives; members of the Forum; local, State, and Federal agencies; environmental organizations; and other interested parties. The notices stated Reclamation's purpose in conducting the review, provided background on the salinity problem in the Colorado River Basin, and the current program for addressing those problems. The notices then suggested several options regarding the Salinity Control Program.

Reclamation received responses from private individuals and local, State, and Federal agencies. The majority of the comments were from local and State agencies expressing support for Reclamation's leadership role in the program, having found that the old program could be improved in several ways.

The public review of the program found that in the future, the program should:

- Consider alternatives to Government planned projects
- Allow non-Federal construction
- Consider proposals to control salinity anywhere in the Colorado River Basin
- Consider non-traditional methods
- Be competitive (consider cost and performance risk in its ranking criteria)
- Continue to be voluntary (rather than regulatory)

The comments supported implementing the Inspector General's recommendation (to seek broader authorities for Reclamation). In 1994, Reclamation and the Basin States developed legislation to broaden Reclamation's authorities so that it could manage the implementation of the program without further congressional approval. This legislation was introduced in the Congress late in 1994 and was approved and signed into law (Public Law 104-20) in 1995. The 1995 amendments to the Salinity Control Act authorized Reclamation to pursue salinity control throughout the Colorado River Basin and required Reclamation to develop guidelines on how it would implement this new, basinwide approach to the Program.

Guidelines

Reclamation has prepared guidelines for its new Basinwide Salinity Control Program, which implements the recommendations made in the review of the program. As an alternative to adopting new, specific regulations, Reclamation administers the program through existing procurement techniques and established Federal regulations. Since February 1996, the program has been made available to the general public through this annual competitive process.

In 1984, Public Law 98-569 directed the Secretary to give preference to those projects which reduce salinity at the least cost per ton of salinity control. Since that time, cost effectiveness (cost per ton of salt removed) has been used to prioritize the implementation of salinity controls. However, cost effectiveness is only an estimate (prediction) of the project's cost and effectiveness at controlling salinity. Depending upon the project, there can be a degree of uncertainty in either of these values. Given the diversity of proposals that Reclamation may receive, an evaluation of the proposal's risks has been included in the current selection process.

Ultimately, there is a tradeoff between risk and cost. In the end, eliminating risk may cost more than accepting some risk. A ranking committee is assembled to evaluate the tradeoffs between cost effectiveness and performance risks. The ranking committee is made up of representatives from the two cost-sharing partners, the Basin States and Reclamation. After the committee ranks the proposals, Reclamation attempts to negotiate the final terms of an agreement with the most highly ranked proponents. The first awards under this new process began in FY97.

Performance Review

One of the greatest advantages of the new program comes from the integration of Reclamation's program with USDA's program. Water conservation within irrigation projects on saline soils is the single most effective salinity control measure found in the past 30 years of investigations. By integrating USDA's on-farm irrigation improvements with Reclamation's off-farm improvements, extremely high efficiencies can be obtained. If the landscape permits, pressure from piped delivery systems (laterals) may be used to drive sprinkler irrigation systems at efficiency rates far better than those normally obtained by flood systems. The new authorities allow Reclamation much greater flexibility (in both timing and funding) to work with USDA to develop these types of projects.

The new authorities also allow Reclamation to respond to opportunities that are time-sensitive. Cost-sharing partners (State and Federal agencies) often have funds available at very specific times. Under its old methods of planning, authorization, funding, and construction, it would often take significant time periods - even decades - for Reclamation to be ready to proceed with a project. None of Reclamation's past projects were able to attract cost sharing because of this. For example, the Ashley Project (a joint effort by Utah, Reclamation, and the Environmental Protection Agency [EPA]) will eliminate 9,000 tons of salt per year. Reclamation's Basinwide Salinity Control Program is a relatively minor, but important part of the project ($3 million in a $18 million project). Once Reclamation had committed to fund its part of the project, funds were included in EPA's budget by the Congress to complete the partnership.

Another significant advantage of the program is that projects are "owned" by the proponent, not Reclamation. The proponent is responsible to perform on its proposal. Costs paid by Reclamation are controlled and limited by an agreement. Yet, unforeseen cost overruns can occur. The proponent has several options: the project may be terminated or the proponent may choose to cover the overruns with their own funds or borrow funds from State programs. The proponent may also choose to reformulate the project costs and recompete the project through the entire award process. For example, pipeline bedding and materials costs for the Ferron Project were underestimated in the proposal and subsequent construction cooperative agreement. The proponent was denied permission to award materials contracts for the pipeline, since the costs were beyond those contained in the agreement. After months of negotiations and analysis, the proponents elected to terminate the project, reformulate it, and recompete against other proposals the following year. Their project was found to be competitive at the reformulated cost and was allowed to proceed. Since this project ran into difficulties, none of the other projects have shown any problems.

In 1998, Reclamation received a record number of proposals. Many were well within the competitive range awarded in 1997. Proposals included a proposal to improve the efficiency of Reclamation's deep well injection project (Paradox Valley Unit), an extension of a project awarded in 1997, one reformulated project awarded in 1997, an industrial use proposal, a cost-shared selenium control demonstration project, and several irrigation improvement projects. No new projects were awarded in 1999/2000 due to appropriation ceiling limits in P.L. 104-20. With the additional $100 million provided by P.L. 106-459, Reclamation reopened its request for proposal process in 2001. Projects have been completed and in 2004 a new request for proposals was issued for new projects. Table 12, below, shows the Reclamation projects and the salinity controlled since 1998.

Table 12 – Reclamation Basinwide Salinity Control Program Salt Controlled, tons/year

	GRAND VALLEY STAGE 1	GRAND VALLEY STAGE 2	Meeker	Las Vegas	BOR Uinta	BOR LG	BOR McElmo	BOR Hammond	Paradox	BOR PSR	Total BOR
1998	21,900	109,400	48,000	3,800		41,380	23,000	16,043	128,000	21,580	413,104
1999	21,900	109,400	48,000	3,800		41,380	23,000	24,065	128,000	21,580	421,125
2000	21,900	109,400	48,000	3,800	18,685	43,675	23,000	32,087	76,000	21,580	398,127
2001	21,900	109,400	48,000	3,800	18,685	43,675	23,000	40,108	109,000	21,580	439,149
2002	21,900	109,400	48,000	3,800	18,685	43,675	23,000	48,130	109,000	21,580	447,170
2003	21,900	109,400	48,000	3,800	18,685	43,675	23,000	48,130	112,000	21,580	450,170
2004	21,900	105,600	48,000	3,800	138,374	43,675	23,000	48,130	112,000	24,629	569,108

Lower Gunnison (LG)

Price San Rafael (PSR)

CHAPTER 6 - OTHER WATER QUALITY ISSUES

Salinity is not the only water quality concern in the Colorado River Basin. Other issues include selenium and trace element toxicity to aquatic life, boron's toxic effects to plants and crop growth, ammonium perchlorate contamination in both domestic water and crop irrigation as well as Uranium mine tailings.

PERCHLORATE

Ammonium perchlorate is a salt which is used as an oxidizer for solid propellants, explosives, fireworks and some munitions. The perchlorate ion is water soluble and environmentally stable. It has been found in surface and groundwater in the Colorado River basin, as well as some lettuce and milk samples collected in the lower basin. Health wise, perchlorate can disrupt normal thyroid functioning (National Academy of Science, 2005).

THM

Bromide and algae combine to produce taste, odor, and potentially toxic trihalomethanes (THM) with oxidation by either chlorination or ozonation during potable water treatment. Specific entities involved with water treatment in California, Nevada, and Arizona have requested that Reclamation and USGS look at existing data and consider adding bromide analysis to water sampling in the basin to quantify the sources of bromide. The formation of brominated disinfection by-products during drinking water disinfection is possible if the raw water contains bromide. Chloroform is normally the predominant THM species; however, in the water containing bromide, brominated trihalomethanes, bromodichloromethane, chlorodibromomethane, bromoform, and bromate as well as chloroacetic acids and bromoacetic acids and dichloroacetonitrile can be formed (Bull and Kopfler, 1991). Two trihalomethanes, chloroform and bromodichloromethane, are suspected carcinogens for humans. These THM products formed during water treatment have human health concerns, and are not easily treated. High organic matter in water due to algal blooms also influences the THM process.

ALGAE

Algal blooms also play an important role in water treatment issues, and noxious and potentially toxic blue-green algae blooms are a particular concern. Dillion Reservoir in the Colorado River headwaters, Scofield Reservoir on the Price River in Utah, and Las Vegas Bay in Lake Mead, Nevada have or need specific nutrient control programs to reduce algal problems. Specific blue-green algae species and associated organic chemical by-products have now been identified and added to EPA's list for study as potential future maximum contaminant level (MCL) compounds for drinking water standards. Knowledge of health issues and drinking water treatment problems due to potential toxic chemical by-products from blue-green algae break down has greatly increased over the past decade. Concerns over the toxic chemicals associated with these blooms continue to grow. Algae blooms are also a concern to aesthetics, fish, and wildlife uses of water at other locations in the Colorado River Basin.

TMDL's

Nutrient Total Maximum Daily Loading (TMDL's) program are being developed in several watersheds. A Selenium TMDL Project is ongoing on the Gunnison River in Colorado. The Salton Sea is the major surface water sink for a significant portion of the Colorado River's salt and trace elements. Salinity, algae, anoxia and hydrogen sulfide generation are significant water quality problems at Salton Sea. The Salton Sea has become a major winter waterfowl area for both Pacific Flyways in North and South America. Fish and waterfowl kills at Salton Sea are increasingly becoming a concern with several endangered species at risk (Barnum, 2005). Recent studies have shown that generation of hydrogen sulfide and degassing within Salton Sea is an important process causing fish kills. The precipitation of calcite, gypsum, and other minerals in Salton Sea are also important to understanding the salt budgets and cycles at Salton Sea (Holdren and Montano, 2002). Recent studies also indicate that hydrogen sulfide generation and degassing is also a major component of salt loss in the Salton Sea (Amrhein, 2005).

The Colorado River Basin Salinity Forum established a selenium sub-committee in 2004. A basinwide selenium budget was presented in Progress Report 21. The Department of the Interior's National Irrigation Water Quality Program jointly conducted a salinity/selenium reduction off-farm conveyance pilot project in the Gunnison River Basin (Butler, 2001). Reclamation, USGS, Colorado Gunnison River Selenium (TMDL) Committee, and U.S. Fish and Wildlife Service (FWS) participated in this project. It was determined that approximately 0.1 pounds of selenium were reduced per ton of salt reduction. Additional joint selenium studies by Reclamation and the USGS (Stephens et al., 1992) found that selenium could be reduced and precipitate or simply pass through on-farm areas near Jensen, Utah. The Colorado pilot project site was chosen because it had a high potential for reduction of selenium. Therefore, the 0.1 pound reduction of selenium per ton of salt is probably the high end of selenium reduction from irrigation efficiency improvement salinity control. However, if an additional 400,000 tons of future salt reduction from irrigation efficiency improvements are built in the future with a selenium reduction of only 0.05 pound/ton of salt; the selenium reduction may not be insignificant. If selenium can be reduced from a long term average below Glen Canyon Dam from 2.4 μg/L to about 1.8 μg/L this would meet the lower basin states selenium standards of 2.0 μg/L. Furthermore, it could produce about a 25% reduction of selenium in agricultural drains and shallow wetlands around Salton Sea, a reduction of 12 to 9 μg/L.

In the hotter climates around the Salton Sea selenium does not appear to be accumulating and recycling in the food chain at the water sediment interface in shallow wetlands. In the cooler climates in the upper basin and with higher selenium inflow concentrations the accumulation of high sediment selenium concentrations appears to be an important factor in reaching a selenium hazard. If a hotter climate and higher permeable soils beneath a shallow wetland have less a tendency to accumulate selenium to toxic levels for waterfowl and aquatic life, then this selenium reduction may not be insignificant (Miller, 2005). Selenium concentrations in fish are generally high throughout the Colorado River Basin. However, proving selenium hazards, particularly in the lower basin, has been difficult.

URANIUM MINE TAILINGS

A large pile of Uranium mine tailings are found upstream from Lake Powell at Moab, Utah. The Department of Energy (DOE) Web page for the Moab Atlas Uranium Tailings Clean up is http://gj.em.doe.gov/moab/moabnews.htm. The Final Environmental Statement can be found at http://gj.em.doe.gov/moab/eis/feis.htm. The Record of decision was issued in September 2005. The FES calls for ground water remediation taking decades and costing around one million/year. DOE has announced that the preferred alternative is the off-site disposal near Cresent Jct, Utah using predominantly rail transportation to haul the material (http://gj.em.doe.gov/moab/release04_06_2005.pdf). Total costs could approach 400 million dollars. Ground water remediation will remove water quality impacts to fish in the river primarily from ammonia. The risk of a major flood washing away significant parts of the tailings was a consideration in picking an alternative. All downstream States and water users have preferred an off-site remediation alternative which removes the tailings from the river bank.

A small Uranium mill site at White Canyon, Utah was run from 1949 to 1953 which generated about 23,000 tons of tailings. The mill was removed before Lake Powell inundated the site in 1964, but the tailings were left. The site is in the inflow zone of Lake Powell and has been, and continues to be covered with sediment. Reclamation scientists have examined the area and found that there is over 30' of sediment covering the mill site containing the tailings and the "gross alpha" levels (radioactivity measurement) in the water downstream from the tailing site are no different than those of the inflow water above the mill site.

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APPENDIX A – SALINITY DATA

The historical flow and quality of water data have been calculated using the U.S. Geological Survey (USGS) database and computer techniques developed jointly by the Bureau of Reclamation (Reclamation) and USGS. The purpose of the analysis was to develop a consistent, documented methodology for the calculation of monthly salt loads in the Colorado River Basin.

The salinity computation method was originally developed for the trend studies conducted by Reclamation and USGS (Liebermann, et al., 1986). Several procedures were evaluated. A 3-year moving regression was determined to be the best overall method in terms of providing the most complete record, preserving short-term fluctuations, and being insensitive to minor errors in the data. Using this method, daily salt load (L) was computed from discharge (Q) and when available, conductivity (S): $L = aQ^bS^c$. For days without specific conductivity data, a slight variation of the equation for load as a function of discharge was used: $L = a'Q^{b'}$.

The coefficients a, b, and c for each year of record were typically estimated by regression analysis using data from a 3-year period surrounding the year of interest. For example, coefficients for 1990 were derived with data from l989 through 1991. The last year of salinity data computed for this report uses 2 years of data for obvious reasons. It is subject to change and will be updated in the next report as data become available to complete the analysis for that year.

Daily loads were added to yield the monthly values given. Monthly values were then added to yield annual values. All values shown are rounded but were computed using un-rounded values.

For this analysis, salt-load data were based on total dissolved solids (TDS) as the sum of constituents, whenever possible. Sum of constituents was defined to include calcium, magnesium, sodium, chloride, sulfate, a measure of the carbonate equivalent of alkalinity and, if measured, silica and potassium. If a sum-of-constituents value could not be computed, TDS as residue on evaporation (at 180 degrees Celsius) was substituted.

Extensive error analyses were performed on the data. Suspect values were corrected according to published records or deleted. The resultant data set is considered by Reclamation and USGS to be the best available for stations in the Colorado River Basin. Annual values based on the new method were compared to values in previous Quality of Water Colorado River Basin Progress Reports for selected stations. The observed differences were between plus or minus 5 percent, with mean differences approximately zero. Changes in the progress report database can, therefore, be considered generally insignificant and unbiased.

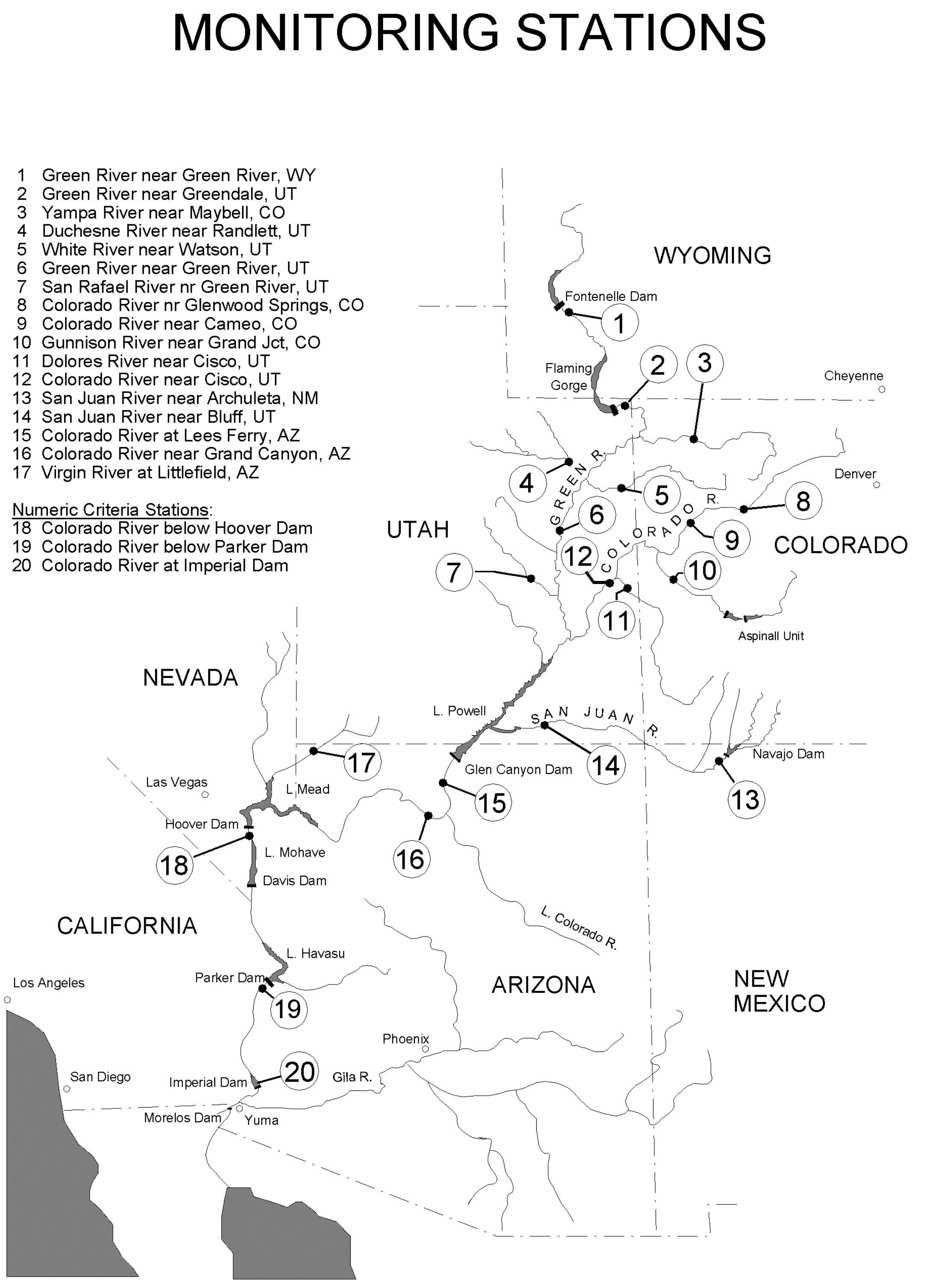

Figure A1 - Colorado River Water Quality Monitoring Stations.

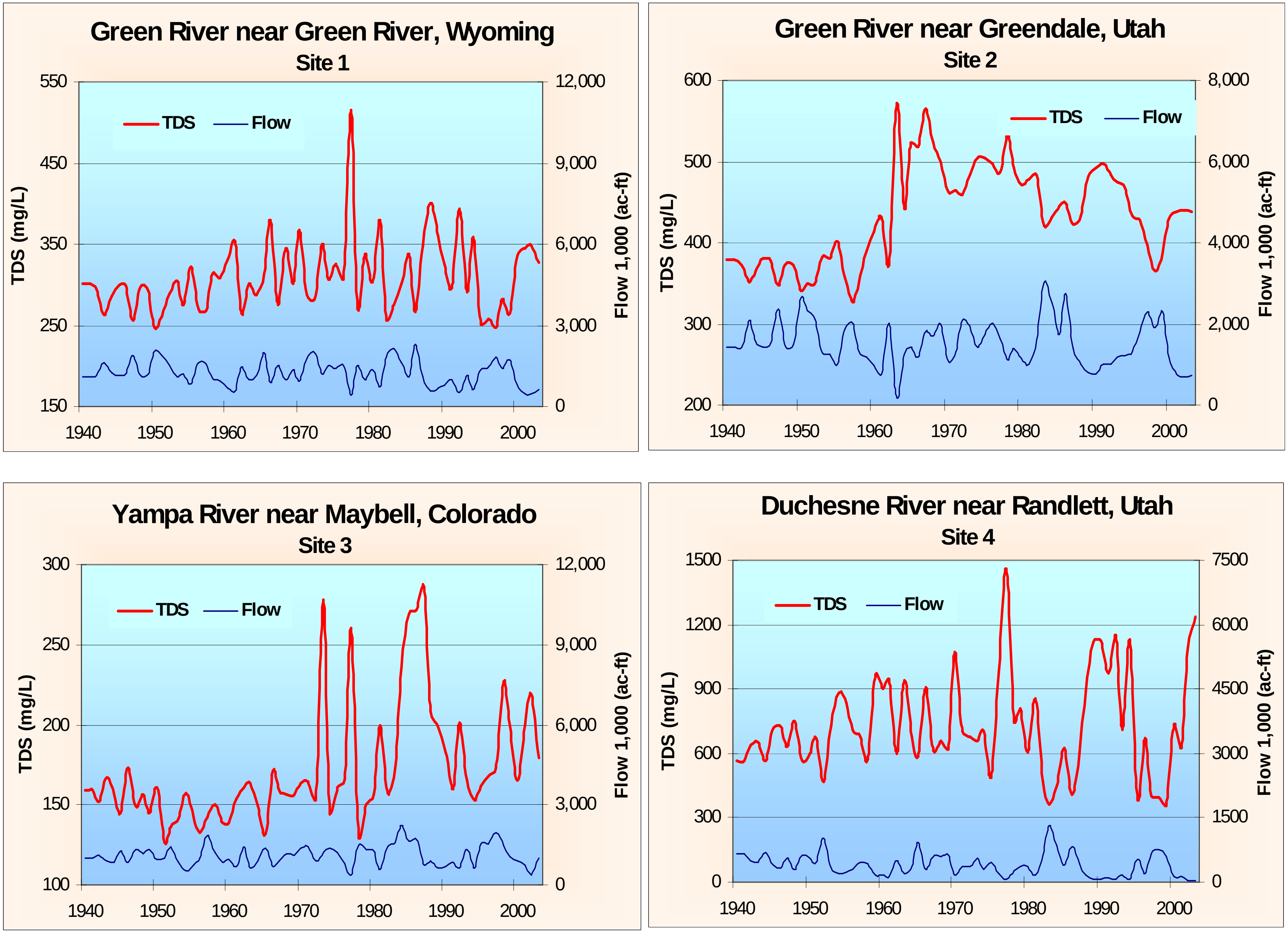

Figure A-2. Flow and TDS over time for sites 1-4. Site locations shown in Figure A-1.

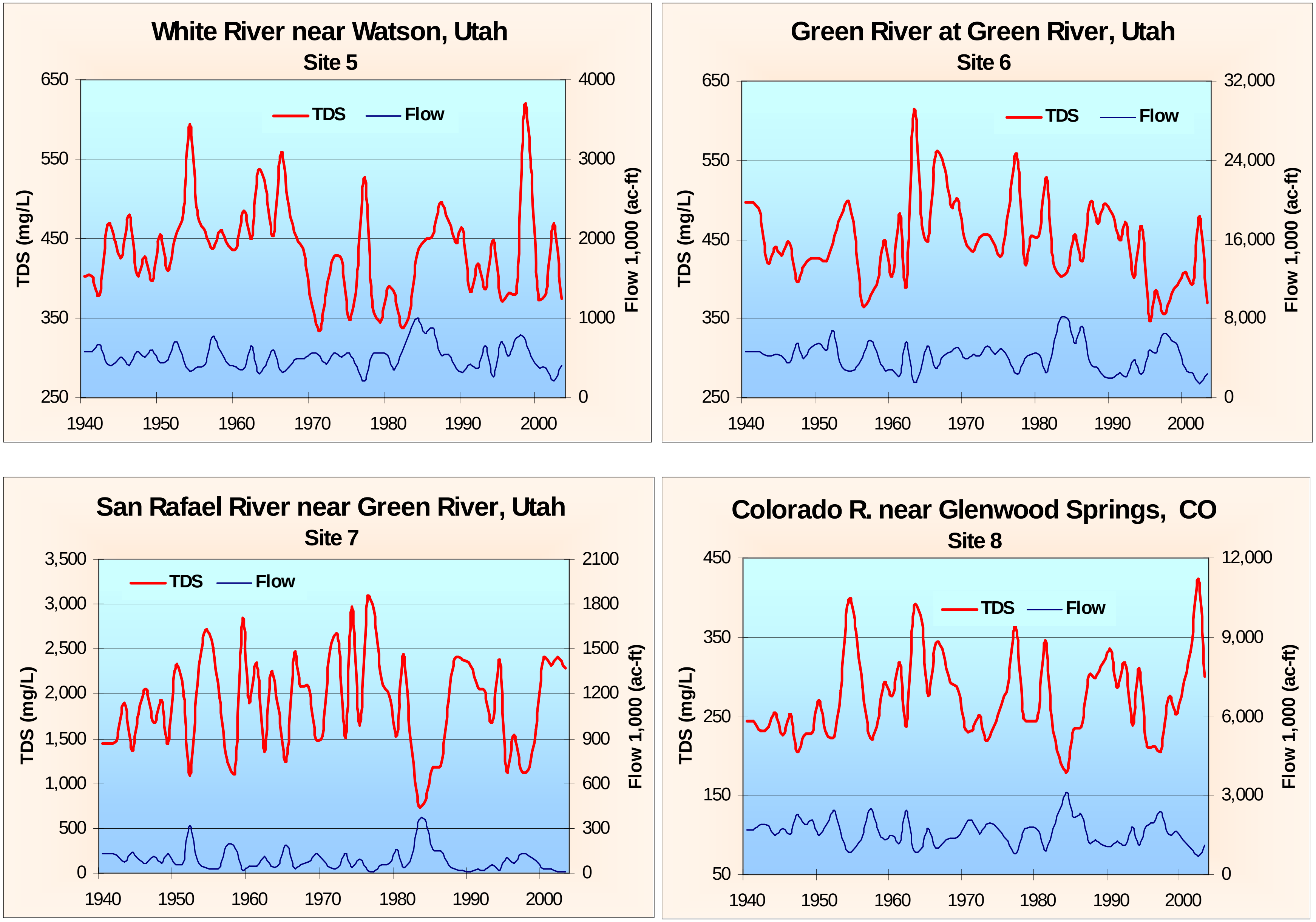

Figure A-3. Flow and TDS over time for sites 5-8. Site locations shown in figure A-1.

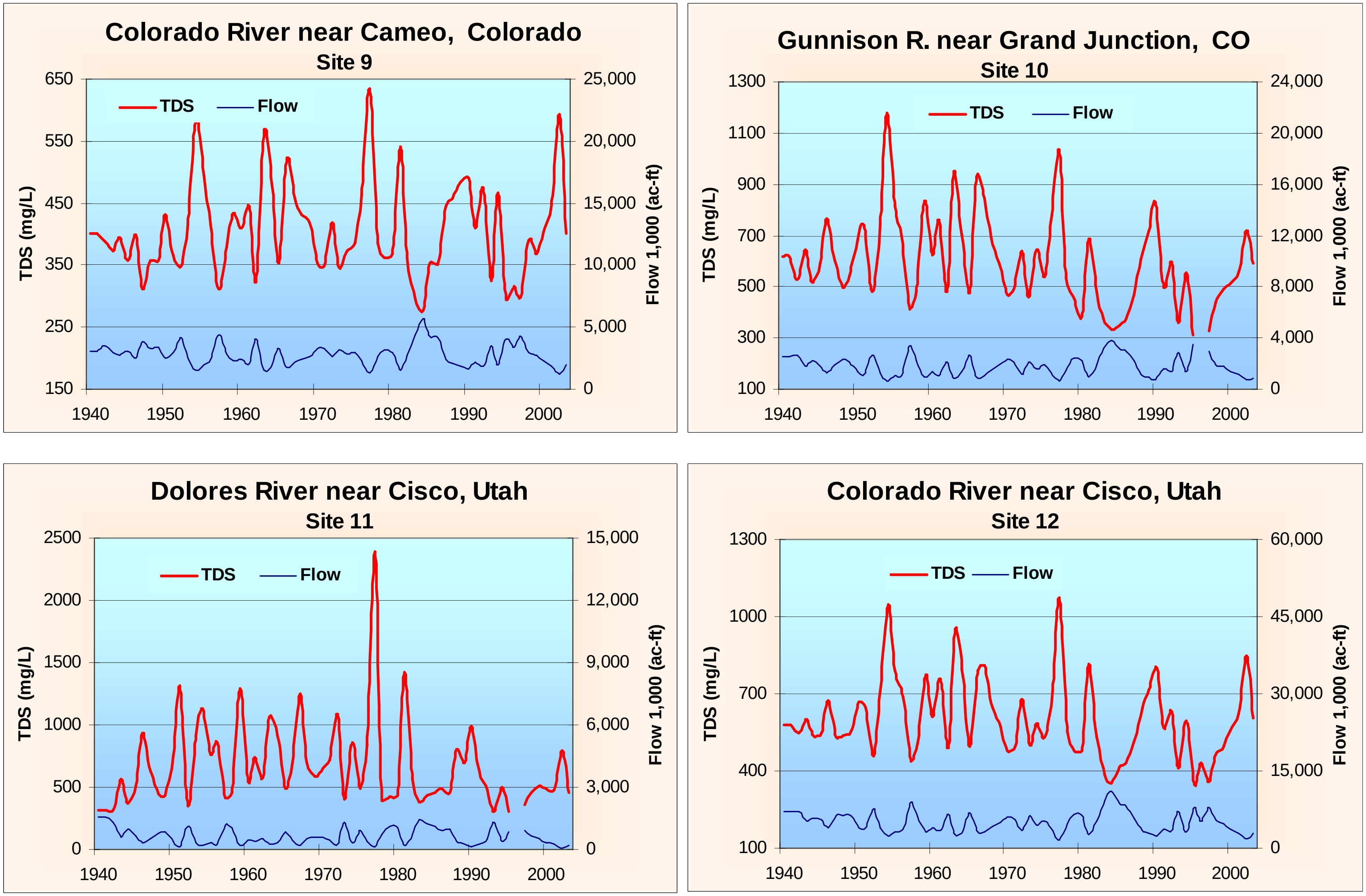

Figure A-4. Flow and TDS over time for sites 9-12. Site locations shown in Figure A-1

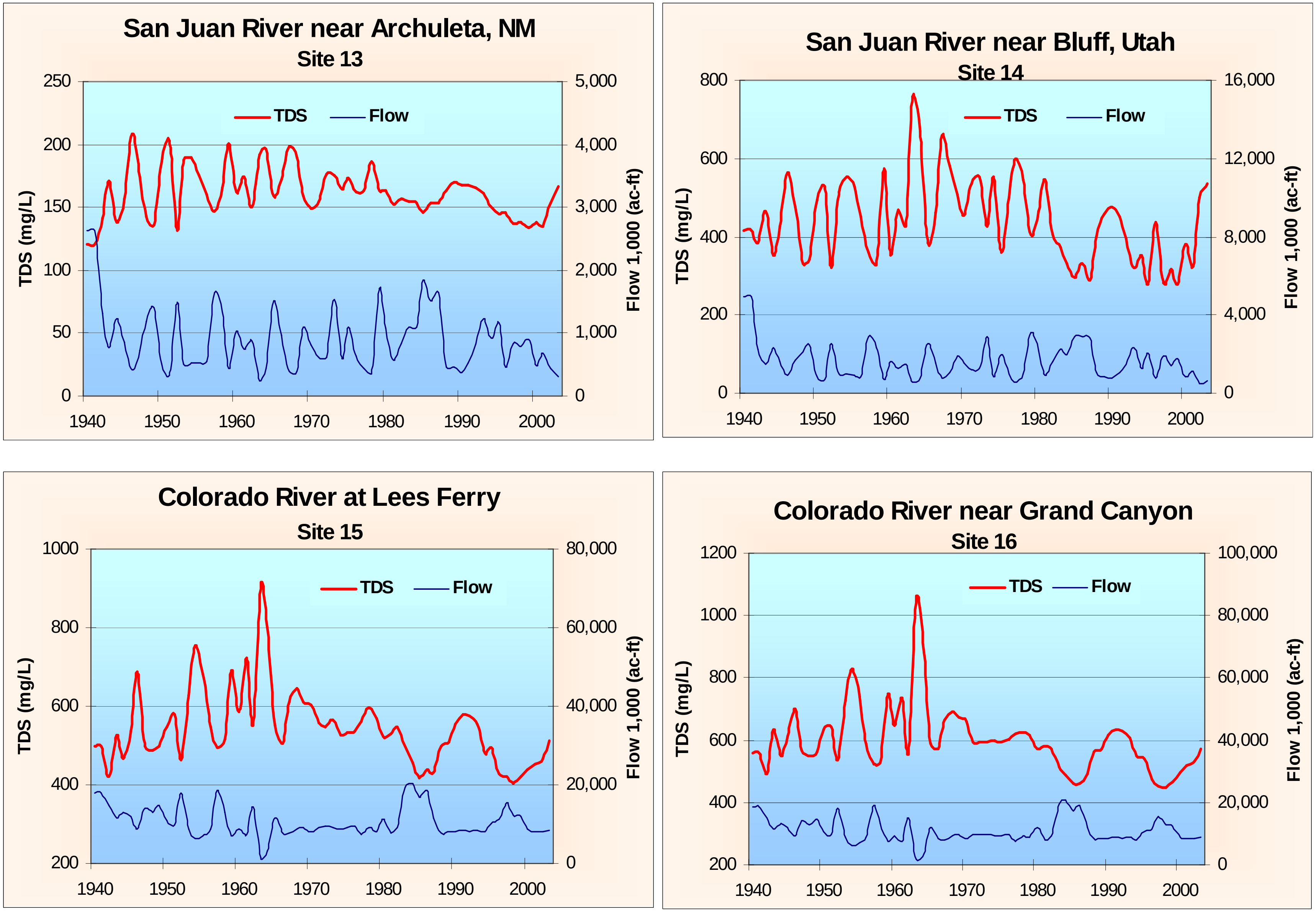

Figure A-5. Flow and TDS over time for sites 13-16. Site locations shown in Figure A-1.

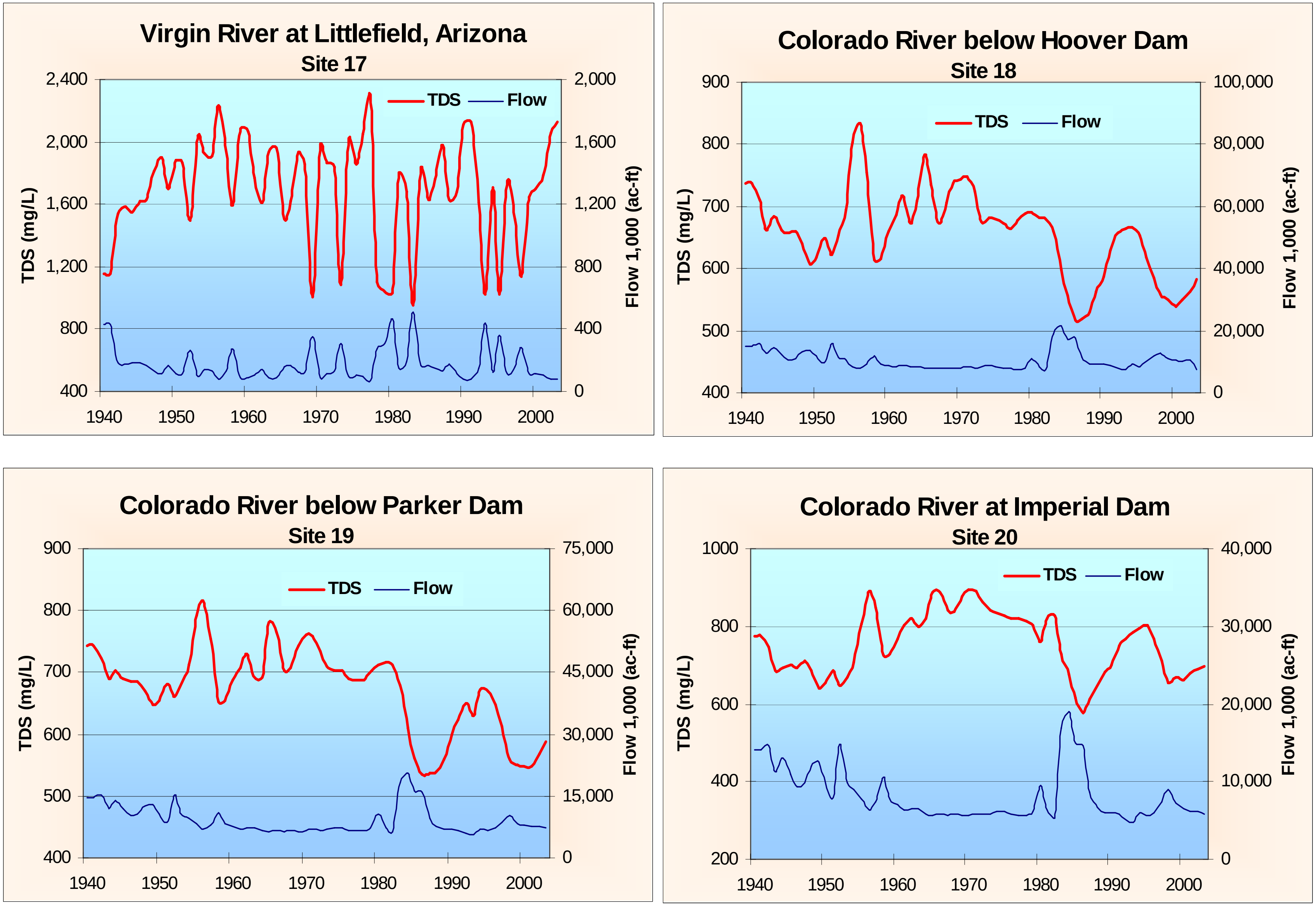

Figure A-6. Flow and TDS over time for sites 17-20. Site locations shown in Figure A-1.