Navajo Operations
Environmental Impact Statement
Water Quality Resource Report

Western Colorado Area Office
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cover photograph - Confluence of the Animas and San Juan Rivers on June 6, 2000 during high flow release from Navajo Reservoir

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Introduction

The San Juan River, which has a drainage area of approximately 24,900 square miles, flows from the western slope of the Continental Divide to Lake Powell, Utah. It flows through three states, Colorado, New Mexico, and Utah and its watershed encompasses parts of four states, the three it flows through and Arizona.

As part of the Navajo Reservoir Operations Environmental Impact Statement public meetings, water quality in the San Juan River was expressed as a concern in several of the meetings. This report reviews and summarizes water quality data collected in the San Juan Basin from Navajo Reservoir to Lake Powell as part of ongoing studies for irrigation projects, water development projects, and general surveys of eater quality impacts to endangered species.

Description of Study Area

The San Juan watershed comprises an area of approximately 24,900 square miles from the western slope of the Continental Divide in Colorado and New Mexico to Lake Powell, Utah (Figure 1). In New Mexico, it encompasses all of San Juan County, most of the northern half of McKinley and the western half of Rio Arriba counties, and a small corner of Sandoval County. In Colorado, it encompasses all of Archuletta, Montezuma, La Plata, Dolores, San Juan, and portions of Montrose, Hinsdale, and Mineral counties. In Utah, it encompasses San Juan county and in Arizona, it encompasses Navajo and Apache counties.

The San Juan River headwaters are located in southwest Colorado on the western slope of the Continental Divide in the San Juan Mountains. The river flows southwestward above Pagosa Springs, Colorado to Navajo Reservoir. Navajo Reservoir is located on the border between Colorado and New Mexico with the majority of the reservoir in the state of New Mexico. The Colorado portion of the reservoir is located within the boundaries of the Southern Ute Indian Reservation.

From Navajo Reservoir, the San Juan River flows southwest to Blanco, New Mexico and then turns westward to the Navajo Nation boundary west of Waterflow, New Mexico (Figure 2). The San Juan River continues west and northwest before entering Colorado near the "Four Corners" landmark. In Colorado, the San Juan River flows through the Ute Mountain Ute Indian Reservation before entering Utah where it flows into Lake Powell.

Major perennial tributaries include Los Pinos, Animas, La Plata, Mancos, and Navajo rivers in Colorado and New Mexico; McElmo, Montezuma, and Chinle creeks and Cottonwood Wash in Utah and Arizona. Arizona contains only the headwaters of Chinle Creek. Major ephemeral tributaries in New Mexico include La Jara Creek, Gobernador Canyon, Canyon Largo, and Chaco Wash.

The floor of the San Juan River Valley was originally populated by grasses, but these have mostly been replaced with irrigated croplands. The intermediate broad mesas are now predominately vegetated by grasses, sagebrush, pygmy pinon, and junipers. The higher elevations are populated by stands of pine, fir, and spruce.

Abell (1994) reports that San Juan River Basin land use in 1974 comprised of 25 percent federally owned, 13 percent private, and state and local governments owned and managed 3 percent. The remaining portion, nearly 60 percent comprises four Native American reservations, the Navajo, Ute Mountain Ute, Southern Ute Indian, and the Jicarilla Apache reservations.

Water Quantity

The San Juan River and its major tributaries, the Navajo, Piedra, Los Pinos, Animas, and La Plata Rivers, all have headwaters beginning in the San Juan Mountains. All have similar hydrographs showing peak flows in the spring time from snowpack melting and late summer peaks from monsoon rains. Figures 3, 4, and 5 are average daily streamflow histograms of the San Juan River at Pagosa Springs (Colorado), Farmington (New Mexico), and Bluff (Utah), respectfully. Figures 6, 7, and 8 are average annual streamflow histograms of the San Juan River at same stations. Figure 9 is a histogram comparison of the average annual streamflow at Pagosa Springs, CO, Farmington, NM, Bluff, UT, and Animas River at Farmington.

Other tributaries of the San Juan River with large drainage areas are Canyon Largo, Chaco River, Chinle Wash, Montezuma, and McElmo Creeks. These tributaries drain most of the southern part of the basin and usually flow only during the monsoon period (July through October) from storms moving through the basin and lasting for short periods.

Hydrologic modification in the upper part of the San Juan River basin can affect the quality and beneficial uses of the San Juan River. Transbasin export of water for the San Juan-Chama Project from the Navajo River reduces flow and quality of the water downstream. The Navajo River segment in Colorado has been listed on past state's 303(d) list of impaired rivers for sediment, but through watershed improvement, the segment was dropped from the draft 2000 list.

Navajo Dam and Reservoir has a major impact on sediment movement through the river system. Sediment from the upper watershed is deposited and stored in the reservoir with released water from the dam having very little sediment. Downstream of the dam, irrigation diversions can reduce flows significantly during low flow releases. Low flow releases from the dam during irrigation season can be seriously depleted from diversions (Citizen's Ditch and Hammond) between Archuleta and Blanco, New Mexico, before return flows augment the river. Tributaries in the San Juan River segment from Blanco to Farmington can contribute large amounts of sediment during late season thunderstorms. Canyon Largo had an active stream gage during the early 1980's and recorded peak flows of 4,200 to 4,800 cfs during several years for short durations.

The Bloomfield-Farmington-Kirtland-Fruitland development corridor along the San Juan River has impacted both water quantity and quality. Extensive development has occurred on the floodplain and next to the active channel. Water quality is impacted from urban runoff, septic systems, small animal farms, runoff and sediment from tributaries, and grazing all along this corridor. Return flows from irrigation projects increase flow within this reach.

Other irrigation diversions exist from Farmington to just downstream of Shiprock, New Mexico (Farmers Mutual Ditch, Jewett Valley Ditch, Fruitland, Hogback, and Cudei diversions). In addition, the two coal power plants divert a large amount (up to 80 cfs) of water for use in the power plants. Downstream of Shiprock, New Mexico, diversions are sparse and the river is mostly impacted from oil and gas development near or on the river floodplain and tributary inflows.

Water Quality

Factors Affecting Water Quality

Climate

The climate of the San Juan River basin is semiarid to arid and is characterized by small annual precipitation, large potential evaporation, and large daily and annual fluctuations in temperature. Distant high mountains shield the area from much precipitation. The higher part of the basin is in Colorado with the San Juan Mountains (10,000 - 14,000 feet elevation) and the lowest part of the basin is the confluence of the Colorado and San Juan Rivers (3,600 feet elevation).

Precipitation occurs as snow in the mountains ranging from 25 to 50 inches while the lower part of the basin ranges from 6 to 8 inches (NRCS, 1974). Most snowfall occurs from November through April. Spring runoff creates a peak runoff period which occurs from April to June depending on the location of the river or stream. Nearly half of the annual precipitation falls during July through October, usually during thunderstorms. Tributaries of the San Juan River that originate in Arizona and New Mexico produce intermittent and high sediment load streamflows during this period because of the sparse vegetation. Average precipitation in the San Juan River area ranged from 7 inches at Fruitland to 12 inches along the Colorado border (NRCS, 1980).

Average annual potential evaporation is 77 inches at Farmington and 79 inches at Navajo Dam (USGS, 1993). Average temperatures rarely reach 100 degrees Fahrenheit or higher and only a few days have temperatures of zero or less. For 1961 through 1990 average temperatures at Fruitland were 28.6 degrees Fahrenheit in January and 75 degrees Fahrenheit in July. The growing season is about 160 days.

Evaporation for the period from May through October averages 49 inches at Farmington, but can be approximately 25 percent higher on the plateau, where there is more wind (NRCS, 1980). Winds in the valley mainly blow from the east to the west, with an average spring windspeed of 10 miles per hour. Winds of 25 miles per hour or greater occur only 1 per cent of the time, but occasionally blow dust when the soil is dry (NRCS, 1980).

Geology and Soils

The San Juan River area includes the broad, terraced San Juan River valley. The San Juan River valley is characterized by unconsolidated clay, silt, sand, and gravel, and terrace gravel and cobble deposits. The clay, silt, sand, and gravel deposits probably do not exceed 100 feet in thickness and the terrace deposits generally do not exceed 30 feet in thickness (USGS, 1993). The bedrock encountered along the river includes sedimentary strata composed of interbedded sandstone, siltstone, mudstone, and shale from varying formations (Table A).

Navajo Dam and Reservoir is located within the San Juan geologic structural basin (Figure 10). This basin occupies approximately 7,700 square miles in the eastern part of the Colorado Plateau of northern New Mexico and southern Colorado. Bedrock around Navajo Reservoir consists of nearly horizontal beds of sandstone, shale, and siltstone of the San Jose Formation (formerly named the Wasatch Formation). This formation is an ancient stream/river deposit resulting from Laramide erosion and redeposition of uplifted materials from the San Juan and San Pedro Mountains to the north and east of the basin. The San Jose Formation has a maximum thickness of about 2,000 feet at the center of the San Juan Basin.

Many of the geologic formations of the San Juan Basin were deposited in marine or blackish water environments. Sulfates and sodium chloride are prevalent salts in most of these formations. Other formations were deposited in drier periods and are composed of sandstone sandwiched between these shale formations. The water in sandstone (aquifers) is often static and saline. When a flow path to the surface is established, these saline waters can enter surface waters and contribute to increased water quality problems.

Erosion affects water quality by contributing sediment and runoff to surface waters. Erosion of saline shales, dissolution of surface salts, and soils contributes to poor quality runoff water, especially during thunderstorms. Low level snowmelt on saline rocks may also contribute significantly to salinity. Studies conducted on Mancos Shale in the Upper Colorado River Basin have demonstrated a positive relationship between sediment yield and salt production (DOI, 1999). Sediment yield increases as a result of either upland erosion or streambank and gully erosion. Upland erosion is attributed to rill and inter-rill flow. Salt and sediment yields are dependent upon storm period, landform type, and soluble mineral content of the rock.

The highest salt and sediment concentrations occur in the first streamflow event following a long period of no discharge (DOI, 1999). The Geological Survey (1997) found high levels of metals in the high flow during spring runoff in the Animas River. These metals were stored in colloidal phase of the bed load during the winter months and released during high spring runoff.

Agricultural and Irrigation Projects

Agricultural activities in the basin can cause increased levels of salinity, sediments, nutrients, pesticides, and selenium and other trace elements in nearby receiving waters. Water quality studies by the USGS on irrigation projects in the San Juan River area indicate elevated levels of some trace elements in water, bottom-sediment, soil, and biota on most irrigated areas. While the levels were not sufficiently elevated to be of concern to fish, wildlife, and human health, some samples exceeded applicable standards and criteria (USGS, 1998).

Irrigated agriculture is the largest user of water in the Colorado River Basin and a major contributor to the salinity of the system. Irrigated lands contribute approximately 37 percent (3.4 million tons of salt per year) (DOI, 1999). Irrigation increases salinity by consuming water and by dissolving salts found in the underlying saline soils and geologic formations, usually marine shales.

Natural diffuse sources of salt occur gradually over long reaches of the river system. Salt pickup occurs over large surface areas from underlying soils, geologic formations, and from stream channels and banks. Salt pickup is difficult to identify, measure, or control; yet diffuse sources contribute the largest overall share of the salts in the Colorado River (DOI, 1999).

The San Juan River Unit area, a 23,000 square-mile watershed, contributes approximately 1 million tons of salt annually to the Colorado River Basin (DOI, 1999). Early reconnaissance shows significant salt loading in the river between Shiprock, New Mexico, and the Four Corners area (DOI, 1999). The Hammond Project, Navajo Indian Irrigation Project (NIIP), and the Hogback Irrigation Project are the principal irrigation sources of salt in the San Juan River Basin.

Land Use - Grazing and urban development

A Reclamation assessment of the San Juan River in 1978 gave a brief summary of the history of the San Juan River area. "Prior to 1800 there is little information concerning the San Juan Basin. The Spanish Colonial Government and later administrations showed little interest in the exploitation and development of the lands outside of the Rio Grande Valley. By the late 1820's, however, the first Anglo-Americans reached the San Juan Basin hunting for beaver and other furbearing mammals, but these efforts were terminated by 1830. In the late 1800's, irrigation projects and establishment of Farmington (1876), Bloomfield (1881), Aztec (1890), and Bluff (mid 1880's) began to utilize waters in the basin. From this time to approximately the mid 1960's agricultural and urban developments were undertaken almost entirely within the San Juan River floodplain."

Recently development of large-scale irrigation projects (Hammond, Hogback, and Navajo Indian Irrigation Project) and energy-related development (electrical generation and coal mining) have led to development outside the river floodplain (Reclamation, 1978).

Urbanization is one of the smaller land uses in the basin, but mostly occurs along the San Juan River and tributaries. Point sources from urbanization can include discharge from wastewater-treatment plants, leachate from septic systems, solid-waste disposal, leaking underground storage tanks, industrial discharges, and storm runoff. All of these sources have the potential to add nutrients, pesticides, various chemicals, hydrocarbons, trace elements, and salts to nearby waters.

Air particulate deposition

Air deposition of pollutants can affect nearby water bodies. Mineral, oil and gas, and industrial development can release pollutants into the atmosphere that can be deposited into nearby water bodies. Dust from fields or denuded areas can also transported by wind to nearby water bodies.

A review of the EPA's Toxics Release Inventory (TRI) for New Mexico indicated that San Juan County released in 1998 (1995 core chemicals in pounds) a total of 711,388 pounds of air emissions, 8,468 pounds of surface water discharges, and 6,797,689 pounds of land releases, totaling 13,064,685 pounds.

The 1998 TRI for New Mexico indicates several sources of air pollutants in San Juan County:

San Juan Generating Station, Waterflow, San Juan County - 455,521 pounds
Four Corners Stream Electric Station, Fruitland, San Juan County - 255,842 pounds
San Juan Refinery, Bloomfield, San Juan County - 167,627 pounds

A report released from the Environmental Working Group (1999) using EPA data reported the two San Juan County power plants are among the top 50 mercury polluters and together release yearly approximately 1,300 pounds of mercury.

Mineral Exploration and Development

Metal mining is an important activity that occurred in the headwaters of several tributaries (Animas, La Plata, San Juan, and Mancos rivers). Past mining activities have included the extraction of copper, gold, silver, lead, and zinc. These rivers have been affected by point-and nonpoint-source mine drainage and natural drainage of mineral areas. The upper Animas River is affected by acid mine drainage.

In 1900 the first gas and oil wells were discovered near Farmington (NRCS, 1980). The first drilling for oil in the lower San Juan River area occurred in 1907 (Reclamation, 1969). Intermittent exploration continued in both areas until major oil and gas deposits were found in the 1950's. The development of oil, gas, and coal resources lead to a sudden increase in population during the 1950's. Many drill holes and wells were drilled within the active floodplain and alluvial valley of the San Juan River. Pipelines cross the valley floor, San Juan River, and side tributaries. Activity within the valley floor increases the possibility of pollutants being released into surface waters.

During the development of the atomic bomb, exploration and development of uranium, vanadium, and radium in the San Juan Basin reached a peak in the middle to late 1950's. A uranium processing waste site is located near the San Juan River upstream of Shiprock, New Mexico and on the Animas River near Durango, Colorado.

Hydrology

The San Juan River and its major tributaries, the Navajo, Piedra, Los Pinos, Animas, and La Plata Rivers, all have headwaters in the San Juan Mountains. Other tributaries which have large drainage areas are Canyon Largo, Chaco River, Chinle Wash, Montezuma, and McElmo Creeks. Less than 20 percent of the basin area produces over 90 percent of the water supply (NRCS, 1974).

High spring runoff months of April through June produce over 56 percent of the stream discharge from the basin (NRCS, 1974). These spring runoff events area result of snowpack accumulation in the mountains from October to April.

The Colorado Water Conservation Board (CWCB, 2000) fact sheet for the Dolores and San Juan Basins lists no major imports into the San Juan Basin, but major exports include the San Juan-Chama Project (86,331 acre-feet) and several smaller diversions in the northeast San Juan Mountains (2,264 acre-feet).

Data Sources and Compilation

Data is summarized from many reports done by federal agencies (Bureau of Indian Affairs (BIA), United States Geological Survey (USGS), and Reclamation) within the last ten years. The USGS has conducted studies under the Department of the Interior's National Irrigation Water Quality Project (USGS, 1993 and 1998). The San Juan River Recovery Implementation Program (SJRIP) was initiated in October 1991 and began collecting data on water quality on the San Juan River. In addition, water quality data was collected and analyzed as part of the Navajo Indian Irrigation Project (NIIP) environmental studies on the San Juan River mainstem as well as tributaries, seeps, springs, ponds, and wells on the NIIP project lands.

Data was also retrieved from the EPA Storage and Retrieval System (STORET) database. This data was complied for the Final Supplemental Environmental Impact Statement (FSEIS) for the Animas-La Plata Project (ALP) and used in the water quality analysis. As reported "The complied database contained approximately 275,000 observations collected mainly from 1950-1998. A subset, approximately 74,000 measurements of the parameters regulated by the states, was selected and formed the database for the water quality analysis." The completed water quality analysis can be found in the FSEIS Technical Appendices, Appendix 3.

Water quality data have been historically collected along the San Juan River at numerous stations, mostly near USGS gaging stations. Figure 11, Water Quality Sample Sites, shows the location of many of the water quality sample sites used in past studies. The USGS gaging stations now in operation are documented in Table B.

Water Quality Investigations

Historical Water Quality Data

Water quality data available for the sample sites primarily includes field measurements (pH, water temperature, specific conductance, and flow measurements or estimates), major cations and anions, and trace elements (dissolved and total metals and nonmetals). Limited fecal coliform data is available from a low flow test period in 1996 and 2001 between Archuleta and Shiprock, New Mexico. Table C shows the historical water quality values in the San Juan River from Farmington to Bluff gaging stations (see Figure 11 for locations).

The following paragraphs are brief summaries of the detailed results produced by these documents. The summaries are general in nature and the reports should be read for detailed analysis of the findings.

Historical USGS Investigations

The early USGS investigation (USGS, 1993) was a reconnaissance level study to identify whether irrigation drainage: 1) has caused or had the potential to cause significant harmful effects to human health, fish, and wildlife; or 2) may adversely affect the suitability of water for other beneficial uses. conditions in the San Juan Basin. This study sampled the San Juan River, diversions, wetlands, ponds, and streams within the areas of discharge of the irrigation (Hammond, NIIP, and Hogback) projects. Several trace elements were found to be elevated above background. The lists includes barium, cadmium, chromium, aluminum, lead, molybdenum, strontium, zinc, vanadium, iron, and mercury. Of these constituents, only aluminum, cadmium, chromium, lead, iron, mercury, and zinc are regulated by the States and Tribes. It concluded that selenium was the major trace element of concern in all sampled media (water, bottom sediments, and biota). Four classes of pesticides were found to have higher than detection limit levels in water samples taken from NIIP. Elevated levels of organochlorine compounds were also found in some samples of bottom sediments and biota. Later studies (for NIIP and SJRIP) found aluminum, arsenic, copper, selenium, and zinc to be of concern, mostly for affects on the endangered fish, not regulatory standards in the surface waters. The ALP study appears to be the first to look at regulatory standards and calculate projected concentrations based on Project flows, and then compare to the number of exceedences in the state regulatory standards.

The USGS investigation by Thomas et al., 1998, was a detailed study of selenium and selected constituents in water, bottom sediments, soil, and biota associated with irrigation drainage in the San Juan River area. Selenium was much less concentrated in water samples than in bottom-sediment, soil, or biota samples. Mean selenium concentrations in water samples were greatest from seeps and tributaries draining irrigated lands; less concentrated at irrigation-drainage sites and ponds on irrigated land; and least concentrated at irrigation-supply sites, backwater, and San Juan River sites. Water samples, bottom sediments, and soils from sites within Cretaceous rocks had significantly greater selenium concentrations than water samples from sites with non-Cretaceous rocks. Of the irrigation projects evaluated in the San Juan River area, selenium levels were generally greatest from the Hogback Project and NIIP. Other elevated trace elements in water, bottom sediments, soils, or biota included lead, molybdenum, strontium, zinc, vanadium, barium, cadmium, chromium, iron, mercury, and aluminum.

NIIP Investigations

The NIIP Biological Assessment (BIA,1999) by Keller-Bliesner Engineering assessed the impacts from full development of NIIP. The primary purpose of this assessment was to evaluate the effect of full development of NIIP on the environment, especially the two endangered fish species found in the San Juan River. The Water Quality Analysis section concluded that the project will increase arsenic, copper, selenium, and zinc levels in the San Juan River. It was concluded that levels of arsenic and zinc levels would be below levels of concern for the two endangered fish species. Conclusions on copper were less certain, but are not expected to impact the two endangered fish species. Selenium received a low hazard potential, but uncertainty about actual levels in biota downstream from the project and chronic toxicity to razorback sucker leaves the possibility of some impact to the recovery of the species. Since the Navajo Nation water quality regulations were finalized in 1999, there does not appear to be any comparison of water quality to Navajo Nation standards in this assessment.

San Juan River Recovery Implementation Program Investigations

The San Juan River Recovery Implementation Program study on environmental contaminants in aquatic plants, invertebrates, and fishes of the San Juan River mainstem was completed in 1999. This study gathered and evaluated contaminant data collected from 1990 to 1996. The trace elements evaluated included aluminum, arsenic, copper, selenium, and zinc. Aluminum appeared to be related to sediment geochemistry and most animals associated with sediment had elevated levels. Arsenic levels showed no consistent pattern for any river reach or site. Elevated arsenic levels were found in most plants and some invertebrates and fish. Elevated copper levels were found in the trout from upstream coldwater river reaches. Generally copper concentrations in plants, invertebrates, and fish increased downstream from the coldwater areas. Selenium concentrations were clearly elevated in all biota above ambient background concentrations. Zinc concentrations in plants, invertebrates, and fish from Farmington to the "Mixer area" (RM 135) were generally higher than the rest of the river and it appears the source may be the Animas River. The study found no consistent correlation between contaminant concentrations and instream flow discharges.

Samples from the study area contained low concentrations of organochlorine pesticides and polychlorinated biphenyls(PCB's). Polycyclic aromatic hydrocarbons (PAH's) were sampled at several locations in the study area and not detected in whole-water samples collected by conventional water sampling-techniques and detected in only one bottom-sediment sample. In samples involving a semipermeable-membrane-device (SPMD'S) low concentrations of PAH's were found around the refinery near Bloomfield and in the Hammond Project canal nearby. But PAH's in the Hammond Canal do not appear to reach the San Juan River by this route.

Animas-La Plata Project Investigations

In the water quality section for the Final Supplemental Environmental Impact Statement of the Animas - La Plata Project, the database used showed a number of parameters in New Mexico and Utah that periodically exceed the standards. Above Farmington, New Mexico, there are a few historic exceedences in the San Juan River for aluminum, mercury, selenium, cadmium, and lead. The number of exceedences increases between Farmington and Shiprock, New Mexico including several for copper and zinc. At Four Corners, New Mexico, the number of exceedences decreases and then increases again at Mexican Hat, Utah. According to Utah regulations, there are exceedences in nutrients and total suspended solids. The database used consisted of EPA Storage and Retrieval System (STORET)-Reclamation-BIA water quality results.

The supplement also reports: "These historic values could be slightly affected by the operation of Navajo Dam for endangered fish." The increase in spring runoff flows will result in improvement of water quality during the runoff period, but the lower flows during the rest of the year will have a greater return flow percentage and may impact the water quality of the San Juan River. Monitoring over the last seven years of modified flows have not detected a measurable change in water quality.

Some Parameters of Concern in the San Juan River

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs are multiple aromatic carbon rings (two or more) that share at least two carbon atoms per ring. They exist in the environment as both natural and man-made products. Whenever hydrocarbons are discharged into the streams or arroyos, PAHs are probably present. The most common method of producing PAHs is through the combustion of hydrocarbons in internal combustion engines, coal fired generation plants, and forest and agricultural fires.

Out of the hundreds of different PAHs, only a few are toxic, carcinogenic, and relatively common. Most PAHs have a very low solubility in water and are relatively heavy molecules which get trapped easily in bottom sediments. They also have a strong attraction to organic material.

In 1993, the Fish and Wildlife Service and Bureau of Land Management developed a study plan to identify and investigate possible sources of PAHs due to the federal oil and gas leasing program (BLM, 2000). The study is divided into three phases and establishes a baseline data set, identification and remediation of sources of PAHs, and long term monitoring in the basin.

The summary of the BLM study (BLM 2000) indicated:

a) Ephemeral streams sampled during storm water runoff events (22 samples in 10 drainages) indicated no detectable PAH levels;

b) Well pit remediation program was designed to clean up potential groundwater contamination and the majority of the pits sampled in Phase 1 sampling have been remediated;

c) Airborne contamination indicated Naphthalene was found in quantifiable levels at all locations, but were at concentrations quite low and potential biological effects in the aquatic ecosystem of the San Juan River system appear to be minimal.

The BLM is continuing to sample storm water events around the basin for PAHs and publishes results regularly.

Selenium

Most of the following information can be found in the Draft Guidelines for Interpretation of the Biological Effects of Selected Constituents in Irrigation Water (DOI 1998).

Selenium is a semi-metallic trace element which is widely distributed in natural ecosystems. In the Western United States it is found in Cretaceous age marine sedimentary rocks (shales and siltstones). It can also be found in abundance in some volcanic derived rocks. Selenium is highly mobile in environments found in the alkaline soils and marine rocks of the West.

The most common form found in natural waters are selenious acid (H^2SeO^3) and selenic acid (H^2SeO^4), which correspond to the salts selenite (Se^{+4}) and selenate (Se^{+6}), respectively.

In addition to finding selenium in Cretaceous sedimentary rocks, it can be found in disposal of coal fly ash; irrigation return flows; mining of sulfide ores, uranium, bentonite, and coal; or oil refinery wastewater.

The Four Corners area has two coal burning plants supplied by coal mining around the area.

Uranium mining has occurred in the Four Corners area, also. The other sources of selenium come from irrigated farm lands, oil refineries, alkaline soils, and outcrops of selenium bearing rocks of Cretaceous marine origin. Based on these conditions, you would expect selenium to be naturally present in the environment around the Four Corners area (Figure 12)[1]. In fact, according to the USGS reports (1993 and 1998) on the San Juan River Basin, selenium occurs within the soils, bottom sediments, water, and biological samples. It is clear from sampling results in these reports that selenium is bioaccumulating in the biota; and with the many sources of selenium, will continue to occur. The reports show areas where non-Cretaceous rocks occur had lower selenium concentrations compared to areas with Cretaceous age rocks (Mancos Shale being one of the major rock formation contributors).

The selenium concentrations measured in the mainstem of the San Juan River have a mean value below the aquatic life chronic criteria of 2 μg/L. The historical values (0.6 to 1.3 μg/L) from Table C indicate selenium increases downstream to the Four Corners USGS gage and decreases at the Bluff USGS gage. All the means are below the aquatic life chronic criteria and this is expected to be the case under full develop of the NIIP and ALP projects. However, the surrounding tributary inflows, backwaters within the valley, irrigation return flows, surface runoff, and storm water discharges (from industrial and municipals sources) in the San Juan River valley usually have higher selenium concentrations than the mainstem San Juan River. The 1998 USGS report indicated "selenium was much less concentrated in water samples than in bottom-sediment, soil, or biota samples collected in the San Juan River study area." As the amount of water in the mainstem of the San Juan River decreases under development, its ability to dilute the inflow concentrations decreases and San Juan River concentrations can be expected to rise.

Other constituents

Studies (USGS, SJRIP, NIIP) on the San Juan River indicate most constituents are not reaching levels of concern in the mainstem of the San Juan River. Organochlorine pesticides can be found in low concentrations sometimes, but the amount of agriculture occurring along the river and the amount of pesticides used is low (USGS 1998).

The SJRIP (1999) identified contaminants of concern to be arsenic, copper, selenium, zinc, and PAHs. Selenium and PAHs have already been discussed. Arsenic was found to be elevated in plants and fish but no consistent pattern of accumulation or sources were identified (Figure 13). Copper was found elevated in trout in the cold water portions of the upper river reaches (below Navajo dam) and increased concentrations were found in plants, invertebrates, and fish as sampling moved downstream. No source for copper was identified (Figure 14). Zinc concentrations were found to increase downstream of the Animas River confluence in biota and the source is probably mine tailings in the Upper Animas River watershed (Figure 15). Mine tailing remediation is occurring and zinc concentrations have noticeably decreased in the Animas River from Silverton to just upstream of Durango, Colorado.

In late 2000, the New Mexico Environment Department and New Mexico Department of Health conducted an initial survey of the San Juan River for drug residues. The discovery in Europe of pharmaceutical residues in waters, originating from treated sewage effluent, has given rise to increased surveillance in the United States. On the San Juan River, the State tested the

[1] Figure 12 and the following Figures 13, 14, and 15 are derived from means or averages taken from data in the previous discussions. These means were spatially oriented to produce these general maps which show where the consitutients change within the San Juan River watershed.

Farmington effluent outfall and the San Juan River at Bloomfield, Hogback, and Shiprock. The State found detectable levels of ethynyl estradiol (a synthetic estrogen hormone used in birth control pills) at Bloomfield and no detectable drug residues at Hogback or Shiprock. Caffeine and propoxyphene (Darvon) were present in the Farmington effluent, but not downstream at Hogback or Shiprock. This initial survey indicates drug residues can be present in ambient waters, but at very low levels.

The lower flows from Navajo Dam to Farmington caused the Total Dissolved Solids (TDS) to increase in this section during past low flow tests. The salinity control in the Colorado River Basin is overseen by the Colorado River Salinity Control Forum and is monitored by the Interstate Stream Commission in the Office of the State Engineer (New Mexico). The Standards for salinity in the Colorado River Basin are 723 mg/L below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L at Imperial Dam. The overall volume of water leaving New Mexico will be approximately the same after reoperation, hence flow weighted average salinity values should be near the present values. Reclamation continues to look for ways to reduce overall salinity in the San Juan River basin. Reclamation recently completed funding the lining of canals for the Hammond Water Conservancy District.

Water Quality Regulations applicable to the San Juan River

Water quality regulations have been developed and applied to the San Juan River (downstream of Navajo Dam) from the three states (Colorado, New Mexico, and Utah) and three Indian reservations (Southern Ute Indian, Ute Mountain Ute, and the Navajo Nation) through which it flows. The Ute Mountain Ute Tribe has developed draft water quality regulations and these will be available for public comment in Summer 2002. The Southern Ute Indian reservation has sections of non-Indian land throughout and the tribal water quality regulations presently apply only to reservation land owned by the tribe within the reservation boundary. The State of Colorado has water quality jurisdiction on non-Indian land, but the EPA and Tribe do not agree with this arrangement. A recent agreement between the State of Colorado and Tribe forms an Environment Commission which may resolve environmental conflicts between the State and Tribe.

In developing water quality regulations, the waterbodies are classified depending on their beneficial uses. Table D lists the beneficial uses for the Navajo Reservoir and the San Juan River for the three states and reservations.

The states are required under the Clean Water Act (CWA) to report to the Environmental Protection Agency (EPA) on the condition of the streams, rivers, and lakes within their boundaries. One of these reports is a list of impaired (does not meet its intended use) stream or river segments, frequently referred to as a 303(d) list. This list generally indicates the waterbody segment, a probable source of pollutant, uses not supported, and specific pollutant. The agency must develop a plan to improve the condition of the waterbody and meet its intended use. The State of Colorado 303(d) list does not have any San Juan River segments listed. The tribes are presently exempt from having to report impaired waterbodies to the EPA.

State of New Mexico draft 2000-2002 section 303(d) listing of impaired stream and river segments lists segments that fail to meet support uses. The San Juan River is not supported on the following sections: (1) San Juan River from Cañon Largo to Navajo Dam (turbidity and stream bottom deposits), (2) from Animas River confluence to Cañon Largo (stream bottom segments and fecal coliform), and (3) from Chaco River confluence to Animas River confluence (stream bottom deposits).

State of Utah draft 2002 section 303(d) listing of impaired stream and river segments lists segments that fail to meet support uses. The mainstem San Juan River had no segments listed in the year 2000 303(d) list. Segment and TMDL segments on tributaries of the San Juan River include Cottonwood Wash, Indian Creek, North Creek, Mill Creek, Castle Creek, Onion Creek, and Johnson Creek. Most of these segments are far away from the San Juan River or drain into the Colorado River and have no to very little effect on the mainstem San Juan River.

Two tables where created to show how some water quality regulations change along the San Juan River (Table E) and in Navajo Reservoir (Table F). They show the chronic aquatic life standards for each agency as well as a few other parameters which have no aquatic life standards, but are included for general information.

Comparison of Water Quality Standards

The low releases after the spring runoff would probably cause concentration increases and possible exceedences of standards. If the exceedences occurred more than once in three years, a violation of the state or Native American water quality standards would occur. Although past sampling during short duration (four month) low flows indicated no violations, long-term low flows may cause violations of the water quality standards or an increase in bioaccumulation of some trace elements.

The State of New Mexico has proposed revisions to the New Mexico Standards (December 2001) which change the way exceedences are determined. The proposed regulations state: "Compliance with chronic water quality standards shall be determined from the arithmetic mean of the analytical results of samples collected using applicable protocols. Chronic standards shall not be exceeded more than once every three years." The old standard used a mean of four consecutive day samples which was rarely done. Since the analysis used in the this report and ALP EIS uses a one time grab sample as a means to determine exceedences, it is a very conservative approach to looking at standards.

The proposed revisions also include Human Health standards for a number of pollutants. Since these proposed standards are not final law, no attempt was made in this report to address the new regulations.

In the 2000 ALP Final Supplement EIS a water quality evaluation was done with full development of NIIP and ALP. Because of the way ALP is now configured (with a wide range of possible developments), it was difficult to predict what would happen to water quality in the streams and rivers affected by ALP. With the changes in the Riverware model and reoperation of Navajo the evaluation is an approximation of what changes could occur. Population increases and uncontrolled development in the floodplain could have an additional impact on water quality. There is no way to accurately predict these impacts, but through a well defined monitoring program, impacts can be identified and mitigated for.

The Navajo Nation and Ute Mountain Ute Tribe had not developed any water quality standards at the time of the ALP analysis, so only the State standards for New Mexico, Colorado, and Utah were used in the analysis. The ALP analysis looked at the historical data and computed the number exceedences (single grab samples compared to chronic and acute standard) that occurred. Then with return flows from ALP development added in, the calculation was done again to see if any change in the number of exceedences occurred. The following tables are taken from the ALP FSEIS Technical Appendix 3 Water Quality Analysis.

For the San Juan River from Farmington to Shiprock, the number of exceedences did not change

(Table G) and the calculated measurable increases were only for dissolved cadmium and chromium (Table H). For the San Juan River from Shiprock to the Four Corners USGS gage, the calculations show cadmium exceedences will increase by one with full development (Table I). The Shiprock data collected at the USGS gage station indicates that dissolved cadmium was measured at 3 μg/L several times. The standard depends on the hardness which should be sampled and determined at the time of sampling. This does not always occur, sometimes samples are collected only for certain parameters, therefore hardness dependent standards can not always be determined. The mean and average hardness at the Shiprock USGS gage was 220 and 245 mg/L, respectively. For 3 μg/L of dissolved cadmium to exceed the standard, hardness must be 150 mg/L. This is an example of how difficult it can be to predict changes in water quality parameters. Table J indicates the calculated increases for the San Juan River from Shiprock to Four Corners. There are increases in some constituents (10-25%), mostly during low flow periods of the year.

In Table K, from Four Corners, NM to Mexican Hat, UT, the number of exceedences increase by one (out of 56 observations) for cadmium and three for Total Suspended Solids (out of 283 observations). In Table L the measurable increases show increases (10-25%) for selected constituents during the low flow periods of the year, similar to the segment from Shiprock to Four Corners.

The addition of Navajo Nation and Ute Mountain Ute water quality standards should not greatly change the number of exceedences. The standards developed by the States and Tribes are mostly derived from the same guidelines from the EPA. However, Tribes designated uses of the river segment can be different which would change the comparison of standards used.

Future Activity

The impacts projected from this action depend on projects (NIIP and ALP) that are not planned to be fully completed for another 30-50 years or may never be completed. The impacts projected from these projects may or may not occur. If the operation of Navajo Reservoir occurs within the next several years, flows will be lowered at least during the winter months and may extend into the fall or summer. These lower flows in effect cause higher concentrations, leading to possible exceedences of the water quality standards. Insignificant increases in the exceedences are expected within the short term (10 years?), because NIIP and ALP will not be fully developed.

The major "water quality stresses" being applied to the San Juan River mainstem occur from: 1) growth along the river valley, 2) tributary degradation, and 3) land use changes along the river. Along with the change in the flow regime from reoperation, the San Juan River is approaching the limit of its ability to maintain its water quality. Affects on biota from bioaccumulation have been documented in USGS (1993 and 1998) reports and will continue to occur regardless of Navajo reoperation. The problems occurring along the San Juan River cannot be identified as to a single cause, but are an accumulation of a number of slowly occurring, long term problems.

The Federal and State legislation identified to control this degradation is based on developed chronic water quality criteria and the continuing monitoring of pollutants. When a pollutant is identified as a problem the State (and sometimes the EPA) will establish Total Maximum Daily Loads (TMDLs) for that pollutant within the stream segment identified.

To aid the State and Tribal agencies in the monitoring of the San Juan River it is suggested that a coordinated effort be applied to sample and monitor the San Juan River. The San Juan River Recovery Implementation Program has established a long term water quality sampling program upon which the State and Tribal agencies could use as a base and expand upon. The State's of New Mexico, Colorado, and Utah along with the Reclamation, BLM, BIA, Navajo Nation and Ute Mountain Ute Tribe should develop a sampling plan to monitor pollutants in the basin. A centralized water quality database would also benefit the regulatory agencies and others looking at the water quality within the basin.

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TABLES

Table A
Geologic Formations in the San Juan River Basin

System	Series	Formation	Features
Tertiary	Eocene	San Jose Formation	Navajo Reservoir, San Juan River
	Paleocene	Nacimiento Formation	San Juan River, Bloomfield
Cretaceous	Upper Cretaceous	Ojo Alamo Sandstone	San Juan River
		Kirtland Formation	San Juan River, Farmington
		Lewis Shale	San Juan River
		Cliff House Sandstone	San Juan River
		Menefee Formation	San Juan River
		Picture Cliffs Sandstone	San Juan River
		Mancos Shale	San Juan River, Shiprock
Jurassic		Many different formations	San Juan River
Triassic			
Permian			
Pennsylvanian			San Juan River Lake Powell

Note: shaded formations indicate shale or fine-grained rocks that may be sources for elevated selenium levels in soil and water.

Table B
Active USGS gaging stations on the mainstem of the San Juan River between Navajo Reservoir and Lake Powell

Station Number	Station Location	Latitude	Longitude	Period of Record	Drainage Area
09355500	San Juan River near Archuleta, NM	36:48:05	107:41:51	1954-present	approximately 3,260 sq. mi.
09365000	San Juan River at Farmington, NM	36:43:22	108:13:30	1912-present	approximately 7,240 sq. mi.
09368000	San Juan River at Shiprock, NM	36:46:52	108:41:23	1927-present	approximately 12,900 sq. mi.
09371010	San Juan River at Four Corners, CO	37:00:20	109:02:00	1977-present	approximately 14,600 sq. mi.
09379500	San Juan River near Bluff, UT	37:08:49	109:51:51	1914-present	approximately 23,000 sq. mi.

Table C Historic Water Quality Measurements on the San Juan River								
	Farmington		*Shiprock*		*Four Corners*		*Bluff*	
Parameter	n	mean	n	mean	n	mean	n	mean
Alkalinity Total (mg/l as CaCO3)	607	114	646	119	59	121	2333	147
Aluminum Dissolved (μg/l as Al)	34	34.4	138	58.5	40	63.9	174	64.1
Aluminum Total (μg/l as Al)	30	5283	83	15636	30	11373	134	20500
Arsenic Dissolved (μg/l as As)	76	1.9	267	2.3	78	1.8	345	1.9
Arsenic Total (μg/l as As)	78	2.8	224	4.4	72	3.8	309	4.3
Boron Dissolved (μg/l as B)	315	49.5	678	103.9	45	126.0	1720	68.7
Cadmium Dissolved (μg/l as Cd)	11	0.8	71	0.9	15	1.2	56	1.0
Cadmium Total (μg/l as Cd)	12	5.7	29	3.6	7	3.7	15	3.7
Calcium Dissolved (mg/l as Ca)	859	61.6	1178	72.4	135	65.6	2627	93.8
Calcium Total (mg/l as Ca)	5	71.5	12	70.8	6	78.8	23	88.8
Chloride Total in Water (mg/l)	830	9.8	1084	16.9	104	13.5	2568	20.6
Chromium Dissolved (μg/l as Cr)	4	11.3	53	3.2	4	2.9	48	2.5
Chromium Total (μg/l as Cr)	9	51.8	25	22.5	5	17.0	17	52.1
Cobalt Dissolved (μg/l as Co)	9	1.5	67	1.4	10	1.6	53	1.5
Cobalt Total (μg/l as Co)	13	44.4	29	22.9	7	10.6	21	41.7
Copper Dissolved (μg/l as Cu)	45	3.8	165	4.2	48	5.0	203	4.9
Copper Total (μg/l as Cu)	45	29.5	121	35.5	42	20.8	163	35.8
Hardness Calc. (mg/l as CaCO3)	859	189	1154	237	123	222	2589	326
Hardness Total (mg/l as CaCO3)	824	189	969	245	45	224	2423	336
Iron Dissolved (μg/l as Fe)	164	47.2	251	31.2	42	22.0	69	30.5
Iron Total (μg/l as Fe)	15	25691	39	30449	13	13405	201	4809
Lead Dissolved (μg/l as Pb)	67	0.7	256	1.5	70	0.8	343	1.0
Lead Total (μg/l as Pb)	79	30.3	222	27.6	71	23.6	305	26.1
Magnesium Dissolved (mg/l as Mg)	859	8.4	1176	13.4	135	14.4	2628	25.0
Magnesium Total (mg/l as Mg)	5	11.9	12	14.0	6	17.4	23	27.1
Manganese Dissolved (μg/l as Mn)	26	22.3	110	45.0	30	6.3	86	6.1
Manganese Total (μg/l as Mn)	20	852	56	978	27	449	39	1109
Mercury Dissolved (μg/l as Hg)	70	0.12	254	0.13	75	0.10	338	0.11

Table C Historic Water Quality Measurements on the San Juan River								
	Farmington		*Shiprock*		*Four Corners*		*Bluff*	
Parameter	n	mean	n	mean	n	mean	n	mean
Mercury Total (µg/l as Hg)	78	0.14	225	0.15	71	0.13	309	0.14
Nickel Dissolved (µg/l as Ni)	28	6.1	146	4.6	36	5.2	184	4.6
Nickel Total (µg/l as Ni)	28	6.8	105	12.1	39	9.7	144	15.5
Nitrite + Nitrate Total (mg/l as N)	47	0.27	98	0.39	27	0.74	55	0.78
Oxygen Dissolved (mg/l)	251	9.5	455	9.8	159	9.5	478	9.2
pH Lab (Standard Units)	879	7.81	1097	7.89	107	8.25	1357	7.78
pH Field (Standard Units)	60	8.13	190	8.26	60	8.25	285	8.20
Phosphorus Total (mg/l as P)	59	0.27	164	0.32	31	0.37	95	0.58
Residue Total Filtrable (Dried at 180° C) (mg/l)	374	382	667	498	102	422	1313	656
Selenium Dissolved (µg/l as Se)	81	0.6	277	1.0	78	1.3	349	1.1
Selenium Total (µg/l as Se)	76	0.7	227	0.9	71	1.6	309	1.4
Selenium Total Recoverable (µg/l as Se)	10	0.5	29	1.0	10	0.9	47	0.8
Silver Dissolved (µg/l as Ag)	2	0.75	51	0.56	n/a	n/a	45	0.56
Silver Total (µg/l as Ag)	2	0.75	10	1.10	n/a	n/a	9	2.06
Sodium Dissolved (mg/l as Na)	836	44.7	951	64.6	112	49.3	2047	79.2
Sodium Total (mg/l as Na)	5	37.7	12	38.5	6	43.8	23	58.2
Solids Susp.-residue on Evap. At 180° C (mg/l)	59	242	191	956	60	663	283	934
Specific Conductance (µmhos/cm @ 25° C)	905	550	1136	716	112	644	2020	931
Sulfate Total (mg/l as SO4)	827	154	1083	225	104	193	2568	329
Temperature Water (°C)	60	10.6	227	12.2	79	12.4	343	12.6
Zinc Dissolved (µg/l as Zn)	80	9.2	268	9.2	77	7.8	346	15.7
Zinc Total (µg/l as Zn)	75	92.9	224	114.1	71	204.0	306	109.6

Table C Source: Final Supplemental Environmental Impact Statement, Animas-La Plata Project, Technical Appendices, Water Quality Analysis, July 2000

Table D Beneficial Use Designations		
Navajo Reservoir	Southern Ute Indian Tribe and State of Colorado	Aquatic Life Warm 1, Recreation 1, Water Supply, Agriculture
	State of New Mexico	Coldwater fishery, warmwater fishery, irrigation storage, livestock watering, wildlife habitat, M&I water storage, primary contact
San Juan River (from Navajo Dam to Lake Powell)	State of New Mexico Segment 20.6.4.401 - main stem from border upstream to Hwy 64 at Blanco Segment 20.6.4.405 - main stem from Hwy 64 at Blanco upstream to Navajo Dam	Segment 20.6.4.401 - M&I water supply, irrigation, livestock watering, wildlife habitat, secondary contact, marginal coldwater fishery and warmwater fishery Segment 20.6.4.405 - High quality coldwater fishery, irrigation, livestock watering, wildlife habitat, M&I water supply, and secondary contact
	Navajo Nation	domestic water supply, primary human contact, secondary human contact, agricultural water supply, cold water habitat, livestock and wildlife watering
	Ute Mountain Ute Tribe	draft regulations under development - warm water aquatic life, wildlife ecology, recreation 2
	State of Colorado	Montezuma County segment - aquatic life warm 1, recreation 1, agriculture
	State of Utah	1C domestic use, 2B secondary contact, 3B warm water fishery, 4 agricultural

Table E

Physical, Biological, and Inorganic Numeric (chronic) Standards

San Juan River

Parameter	New Mexico Segment 2405	New Mexico Segment 2401	Navajo Nation	Ute Mountain Ute Tribe State of Colorado	Utah
Use	high quality coldwater fishery	marginal coldwater fishery	coldwater habitat	Aquatic life warm 1	warm water fishery
dissolved oxygen (mg/l)	6	6	6	5	3.0-5.0 (1 day average)
pH	6.6-8.8	6.6-9.0	6.6-8.8	6.5-9.0	6.5-9.0
fecal coliform (#/100 ml)	200	400	200	200	200
conductivity (μmhos/cm)	400	NCNS	NCNS	NCNS	NCNS
turbidity (NTU)	10	NCNS	10	NCNS	10 (increase)
un-ionized ammonia as nitrogen (mg/l)	see regulations	see regulations	see regulations	0.06	see regulations
total residual chlorine (μg/l)	11	11	5	11	NCNS
free cyanide (μg/l)	5.2	5.2	5.2 (total)	5.2	5.2
sulfide (mg/l)	NCNS	NCNS	NCNS	0.002	NCNS
nitrate (mg/l)	NCNS	NCNS	NCNS	10	4
chloride (mg/l)	NCNS	NCNS	NCNS	0.011	0.011
phosphorus (mg/l)	0.1	NCNS	NCNS	NCNS	0.05
total chlordane (μg/l)	0.0043	0.0043	0.004	NCNS	0.0043
temperature (degrees C)	20	32.2	20	30	27
Total Organic Carbon (mg/l)	7	NCNS	NCNS	NCNS	NCNS

Metal Numeric (chronic) Standards

Parameter	New Mexico Segment 2405	New Mexico Segment 2401	Navajo Nation	Ute Mountain Ute Tribe State of Colorado	Utah
aluminum (μg/l)	87	87	87	87	87
antimony (μg/l)	NCNS	NCNS	30	NCNS	NCNS
arsenic (μg/l)	150	150	NCNS	100(Trec)	NCNS
trivalent arsenic (μg/l)	NCNS	NCNS	190	NCNS	190
beryllium (μg/l)	5.3	5.3	5.3	NCNS	NCNS
cadmium (μg/l)	HD	HD	HD	HD	1.1
trivalent chromium (μg/l)	HD	HD	HD	100(Trec)	210
hexavalent chromium (μg/l)	HD	HD	11	11	11
copper (μg/l)	HD	HD	HD	HD	12
iron (total) (μg/l)	NCNS	NCNS	NCNS	2200(Trec)	1000
iron (dissolved) (μg/l)	NCNS	NCNS	NCNS	300	NCNS
lead (μg/l)	HD	HD	HD	HD	3.2
manganese (total) (μg/l)	NCNS	NCNS	NCNS	1000 (Trec)	NCNS
manganese (dissolved) (μg/l)	NCNS	NCNS	NCNS	HD	NCNS
mercury (μg/l)	0.012 (total)	0.012 (total)	0.012 (total)	0.01(total)	0.012
nickel (μg/l)	HD	HD	HD	HD	160
selenium (μg/l)	5 (Trec)	5 (Trec)	2 (total)	17	5 (dissolved)
silver (μg/l)	HD	HD	NCNS	HD	4.1
thallium (μg/l)	NCNS	NCNS	150	15	NCNS
uranium (μg/l)	NCNS	NCNS	NCNS	HD	NCNS
zinc (μg/l)	HD	HD	HD	HD	110

NCNS - No Calculated Numeric Standard
HD - hardness dependant - see applicable regulations for formula
Trec - Total Recoverable
Fecal Coliform standards apply to domestic water supply or primary human contact uses and are shown here because New Mexico segment 2401 is impaired for this parameter.

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General note - regulations have been developed for all uses - usually aquatic life regulations are most conservative and are given here as a comparison between agencies.
See each agencies regulations for detailed descriptions of standards for different uses.

New Mexico, Utah, and Navajo Nation metal numeric standards are for dissolved samples unless otherwise noted.
Utah used a hardness of 100mg/l to generate hardness dependant metal parameters

Standards taken from latest water quality standards - New Mexico 2000, Navajo Nation 1999, Ute Mountain Ute Tribe (draft 2000), Colorado 1999, Utah 2000
State of Colorado water quality regulations apply to the San Juan River segment in Colorado.

Table F

Physical, Biological, and Inorganic Numeric (chronic) Standards

Parameter		*Navajo Reservoir*	
Use	**Colorado** fishery - warm 1	**Southern Ute Indian Tribe** fishery - warm 1	**State of New Mexico** fishery - coldwater
dissolved oxygen (mg/l)	5	5	6
pH	6.5-9.0	6.5-9.0	6.6-8.8
fecal coliform (#/100 ml)	200	200	200
turbidity (NTU)	NCNS	NCNS	25
un-ionized ammonia as nitrogen (mg/l)	0.02	see regulations	see regulations
total residual chlorine (mg/l)	0.011	0.011	0.011
free cyanide (mg/l)	0.005	0.005	0.0052
sulfide (mg/l)	0.002	0.002	NCNS
boron (mg/l)	0.75	NCNS	NCNS
nitrite (mg/l)	0.5	case by case	NCNS
nitrate (mg/l)	10	NCNS	NCNS
chloride (mg/l)	250	230	NCNS
sulfate (mg/l)	250	NCNS	NCNS
phosphorus (mg/l)	NCNS	NCNS	0.1
temperature (degrees C)	30	30	20

Metal Numeric (chronic) Standards

aluminum (µg/l)	87	87	87
arsenic (µg/l)	50	150	150
beryllium (µg/l)	NCNS	NCNS	5.3
cadmium (µg/l)	0.4	HD	HD
trivalent chromium (µg/l)	50	HD	HD
hexavalent chromium (µg/l)	25	11	NCNS
copper (µg/l)	5	HD	HD
iron (total) (µg/l)	1000	NCNS	NCNS
iron (dissolved) (µg/l)	*300*	*1000*	*NCNS*
lead (µg/l)	4	HD	HD
manganese (total) (µg/l)	1000	NCNS	NCNS
manganese (dissolved) (µg/l)	50	1000	NCNS
mercury (µg/l)	0.05	0.012 (a)	0.012 (total)
nickel (µg/l)	50	HD	HD
selenium (µg/l)	10	5	5 (Trec)
silver (µg/l)	0.1	HD	NCNS
thallium (µg/l)	15	15	NCNS
zinc (µg/l)	50	HD	HD
uranium (µg/l)	HD	HD	NCNS

Notes

NCNS - No Calculated Numeric Standard
HD - hardness dependant - see applicable regulations for formula
Trec - Total Recoverable
Fecal Coliform standards apply to domestic water supply or primary human contact uses.
Note (a) - special conditions exist see water quality regulations for detailed description

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General note - regulations have been developed for all uses - aquatic life regulations are given here as a comparison between agencies.
See each agencies regulations for detailed descriptions of standards for different uses.

Colorado metal numeric standards are for Total Recoverable samples unless otherwise noted.
Southern Ute Indian Tribe metal numeric standards for aquatic life are for dissolved samples unless otherwise noted.
New Mexico metal numeric standards are for dissolved samples unless otherwise noted.

Standards taken from latest water quality standards - Colorado 1999, Southern Ute Indian Tribe 1997, New Mexico State 2000

Table G

Exceedence Values for the San Juan River between Farmington and Shiprock, NM			
		Exceedences	
Parameter	Number of Observations	Observed	Calculated w/ALP
pH	1287	33	33
Temperature	227	0	0
Fecal Coliforms	173	73	73
Al(acute)	138	2	2
Al(chronic)	138	15	15
Be(acute)	46	0	0
Be(chronic)	46	0	0
Hg(acute)	225(193)	0	0
Hg(chronic)	225(193)	32	32
Se(acute)	83	0	0
Se(chronic)	83	28	28
Ag(acute)	51(51)	0	0
Cyanide(acute)	1	0	0
Cyanide(chronic)	1	0	0
Chlordane(acute)	13	0	0
Chlordane(chronic)	13	13	13
Cd (acute)	68(71)	0	0
Cd (chronic)	68(71)	11	11
Cr(acute)	52(53)	0	0
Cr(chronic)	52(53)	0	0
Cu(acute)	162(165)	0	0
Cu(chronic)	162(165)	1	1
Pb(acute)	150(256)	0	0
Pb(chronic)	162(165)	13	13

Ni(acute)	143(146)	0	0
Ni(chronic)	143(146)	0	0
Zn(acute)	163(268)	0	0
Zn(chronic)	163(268)	1	1

For mercury, the first value shows total number of measurements and the second value shows the number of measurements below the detection limit.
For other metals, the first of the double numbers indicates the number of observations with hardness measurements used in the exceedence calculation.

Table H

Calculated Measurable increases for the San Juan River between Farmington and Shiprock, NM					
Parameter	**Means**		**Measurable Increase**		
	Observed	**Calculated w/ALP**	**means**	**By Month**	**By Flow Intervals**
pH Lab & Field standard units					
Temperature Water (°C)	12.7	12.7	no		
Fecal Coliforms Membr Filter M-FC broth 44.5° C	1884	1884	no		
Fecal Coliforms Membr Filter M-FC 0.7 µM	920	920	no		
Aluminum Dissolved (µg/L as Al)	51.6	51.6	no		
Beryllium Dissolved (µg/L as Be)	0.8	0.8	no		
Mercury Dissolved (µg/L as Hg)	0.19	0.20	no		
Mercury Total (µg/L as Hg)	0.21	0.22	no		
Selenium Dissolved (µg/L as Se)	1.1	1.1	no		
Selenium Total (µg/L as Se)	1.3	1.3	no		
Calc Selenium Total Recoverable in water as Se µg/L	1.1	1.2	no		
Silver Dissolved (µg/L as Ag)	0.98	1.02	no		
Cyanide Total (mg/L as CN)	0.03	0.03	no		
Chlordane (tech mix & metabs) whole water µg/L	0.10	0.10	no		
Cadmium Dissolved (µg/L as Cd)	1.2	1.3	yes		
Chromium Dissolved (µg/L as Cr)	4.0	4.2	yes		
Copper Dissolved (µg/L as Cu)	4.4	4.5	no		
Lead Dissolved (µg/L as Pb)	1.8	1.9	no		
Nickel Dissolved (µg/L as Ni)	6.4	6.7	no		

Zinc Dissolved (µg/L as Zn)	11.6	12.0	no	

Table I

Exceedence values for the San Juan River between Shiprock, NM and Four Corners, CO			
		Exceedences	
Parameter	**Number of Observations**	**Observed**	**Calculated w/ALP**
pH	167	1	1
Temperature	79	0	0
Fecal Coliforms	23	4	4
Al(acute)	40	1	1
Al(chronic)	40	1	1
Be(acute)	14	0	0
Be(chronic)	14	0	0
Hg(acute)	71(64)	0	0
Hg(chronic)	71(64)	7	7
Se(acute)	71	0	0
Se(chronic)	71	10	10
Ag(acute)	0	0	0
Cyanide(acute)	0	0	0
Cyanide(chronic)	0	0	0
Chlordane(acute)	0	0	0
Chlordane(chronic)	0	0	0
Cd (acute)	15(15)	0	0
Cd (chronic)	15(15)	2	3
Cr(acute)	4(4)	0	0
Cr(chronic)	4(4)	0	0
Cu(acute)	48(48)	0	0
Cu(chronic)	48(48)	0	0
Pb(acute)	41(70)	0	0
Pb(chronic)	41(70)	0	0

Ni(acute)	36(36)	0	0
Ni(chronic)	36(36)	0	0
Zn(acute)	48(77)	0	0
Zn(chronic)	48(77)	0	0
Chlorine(acute)	0	0	0
Chlorine(chronic)	0	0	0
Additional Parameters in Colorado Portion of River at Four Corners			
Ammonia(acute)	26	0	0
Ammonia(chronic)	26	0	0
Fecal Coliforms	23	13	13
Sulfide	0	0	0
B	45	0	0
Nitrite	7	0	0
As(chronic)	72	0	0
Cd (acute)	15	1	2
Fe(chronic)	13	7	7
Mn(chronic)	27[27]	0	0
Ag(acute)	0	0	0
Ag (chronic)	0	0	0

For manganese and mercury, the first value shows total number of measurements and the second value shows the number of measurements below the detection limit.
For other metals, the first of the double numbers indicates the number of observations with hardness measurements used in the exceedence calculation.

Table J

Calculated Measurable Increases for the San Juan River between Shiprock, NM and Four Corners, NM					
Parameter	Means		Measurable Increase		
	Observed	Calculated w/ALP	Means	By Month	By Flow Intervals
pH lab and Field standard units	8.15	8.15	no		
Temperature water (°C)	13.8	13.8	no		
Fecal Coliforms Membr filter M-FC 0.7 μM	193	193	no		
Aluminum Dissolved (μg/L as Al)	40.8	40.8	no		
Beryllium Dissolved (μg/L as Be)	1.6	1.6	no		
Mercury Dissolved (μg/L as Hg)	0.10	0.10	no	Jul-Oct	<10%
Mercury Total (μg/L as Hg)	0.14	0.15	no	Jul-Nov	<10%
Selenium Dissolved (μg/L as Se)	1.1	1.2	no	May Jul-Sep	<25%
Selenium Total (μg/L as Se)	1.4	1.4	no	Aug Sep	<25%
Calc Selenium Total Recoverable in water as Se μg/L	1.1	1.2	no	May Jul-Sep	<25%
Cadmium Dissolved (μg/L as Cd)	1.2	1.3	yes		<10% <25%
Chromium Dissolved (μg/L as Cr)	4.6	5.0	no		
Copper Dissolved (μg/L as Cu)	4.4	4.6	no	Jul	
Lead Dissolved (μg/L as Pb)	1.0	1.0	no	Feb Apr Jul Sep Oct	<10%
Nickel Dissolved (μg/L as Ni)	5.5	5.7	no	Aug-Nov	<10%
Zinc Dissolved (μg/L as Zn)	8.1	8.2	no	Feb, Aug-Nov	<10%
Additional parameters in Colorado portion of the river at Four Corners					

Oxygen Dissolved mg/L	9.12	9.12	no		
Ammonia unionized (mg/L as N)	0.003	0.003	no		
Boron Dissolved (µg/L as B)	100.1	103.8	no		
Nitrate Nitrogen Dissolved (mg/L as N)	0.006	0.006	no		
Arsenic Total (µg/L as As)	3.9	4.0	no		
Iron Total (µg/L as Fe)	13400	14340	yes		
Manganese Dissolved (µg/L as Mn)	6.6	6.0	yes		
Manganese Total (µg/L as Mn)	620	647	no		

Table K

Exceedence values for the San Juan River between Four Corners, CO and Mexican Hat, UT			
		Exceedences	
Parameter	**Number of Observations**	**Observed**	**Calculated w/ALP**
Oxygen (dissolved)	478	9	9
Temperature	309	0	0
pH	1607	3	3
Al (acute)	174	3	3
Al (chronic)	174	22	22
As (acute)	345	0	0
As (chronic)	345	0	0
Cd (acute)	53(56)	1	1
Cd (chronic)	53(56)	5	6
CrVI (acute)	0	0	0
CrVI (chronic)	0	0	0
Cr (acute)	45(48)	0	0
Cr (chronic)	45(48)	0	0
Cu (acute)	201(203)	0	0
Cu (chronic)	201(203)	0	0
Cyanide (acute)	0	0	0
Cyanide (chronic)	0	0	0
Fe	201	18	18
Pb (acute)	198(343)	0	0
Pb (chronic)	198(343)	4	4
Hg (acute)	338(305)	1	1
Hg (chronic)	338(305)	33	33
Ni (acute)	183(184)	0	0

Ni (chronic)	198(343)	0	0
Se (acute)	349	0	0
Se (chronic)	349	6	6
Ag (acute)	44(45)	0	0
Zn (acute)	93(95)	0	0
Zn (chronic)	93(95)	0	0
Ammonia (acute)	612	0	0
Ammonia (chronic)	612	0	0
Chlorine (acute)	0	0	0
Chlorine (chronic)	0	0	0
Sulfide	0	0	0
Gross Beta	0	0	0
BOD_5	0	0	0
Nitrate	1891	15	15
Phosphorus	95	80	80
Total Suspended Solids	283	194	197

For mercury, the first value shows total number of measurements and the second value shows the number of measurements below the detection limit.
For other metals, the first of the double numbers indicates the number of observations with hardness measurements used in the exceedence calculation.

Table L

Calculated Measurable Increases for the San Juan River between Four Corners, NM and Mexican Hat, UT					
	Means		Measurable Increase		
Parameter	**Observed**	**Calculated w/ALP**	**Mean**	**By Month**	**Parameter**
Oxygen Dissolved mg/L	8.74	8.74	no		
Temperature water (°C)	13.9	13.9	no		
pH lab & field standard units	7.82	7.82	no		
Aluminum Dissolved (µg/L as Al)	54.9	54.9	no		
Arsenic Dissolved (µg/L as As)	3.1	3.2	no	Jul-Nov	<10%
Cadmium Dissolved (µg/L as Cd)	1.6	1.7	no		<25%
Chromium Dissolved (µg/L as Cr)	3.2	3.3	no		<25%
Copper Dissolved (µg/L as Cu)	5.2	5.4	no	Jul-Nov	<10% <25%
Iron Total (µg/L as Fe)	4218	4466	yes	Jul-Sep	
Lead Dissolved (µg/L as Pb)	1.6	1.6	no	Aug-Sep	<10% <25%
Mercury Dissolved (µg/L as Hg)	0.21	0.22	no	Jul-Oct	<10% <25%
Nickel Dissolved (µg/L as Ni)	8.1	8.4	no	Jul-Oct	<10%
Selenium Dissolved (µg/L as Se)	1.2	1.2	no	Jul-Sep	
Silver Dissolved (µg/L as Ag)	1.00	1.04	no		<25%
Zinc Dissolved (µg/L as Zn)	19.3	20.0	no	Jul-Sep	<10%
Ammonia Unionized (mg/L as N)	0.002	0.002	no		
Nitrate Nitrogen Dissolved (mg/L as N)	0.49	0.51	no		
Phosphorus Total (mg/L as P)	0.51	0.51	no		
Solids Susp-Residue on evap at 180° C (mg/L)	745	771	no	Jul-Oct	<10%

Figures

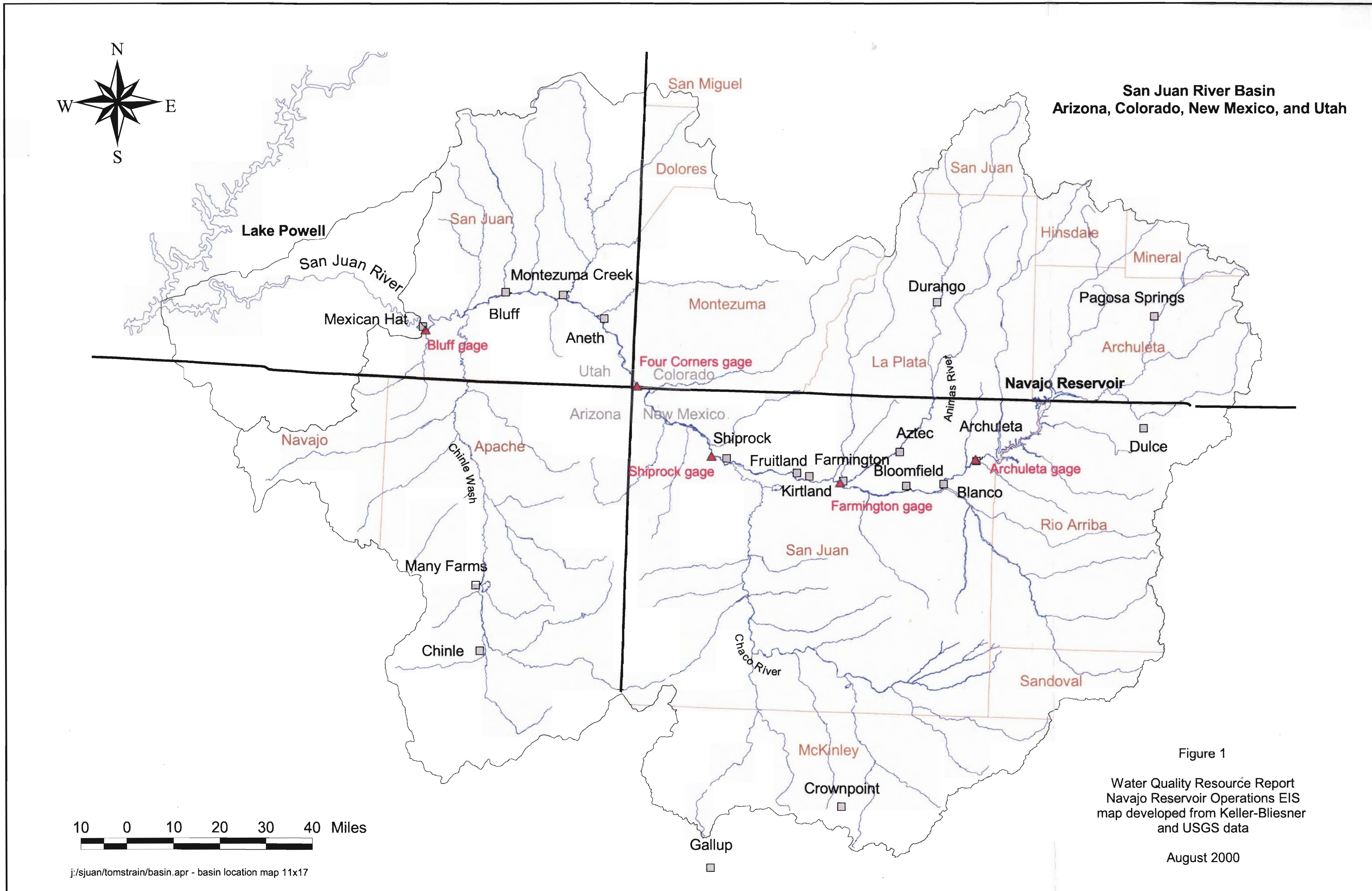


Figure 1

Water Quality Resource Report
Navajo Reservoir Operations EIS
map developed from Keller-Bliesner
and USGS data

August 2000

9-6-2000

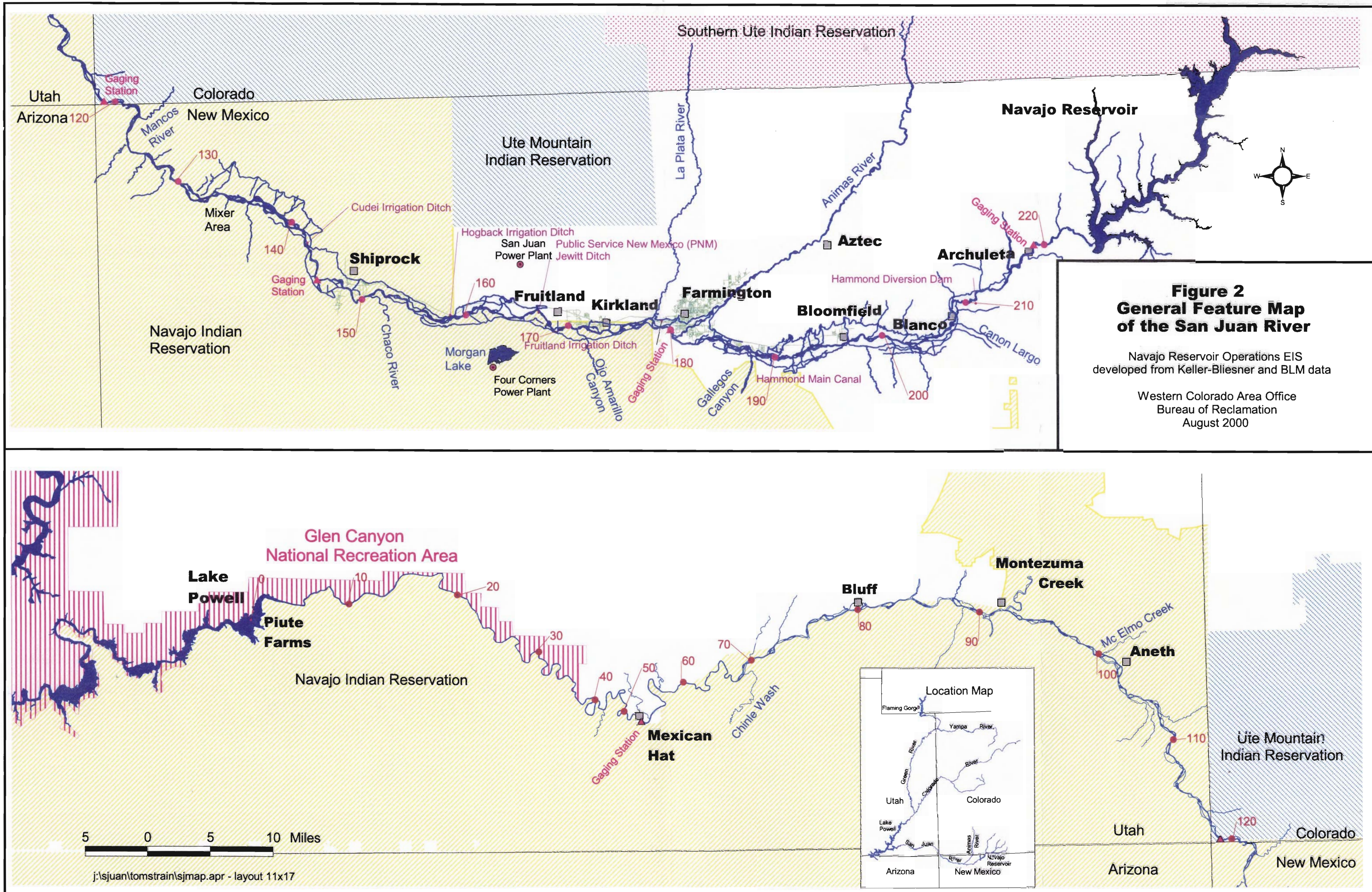
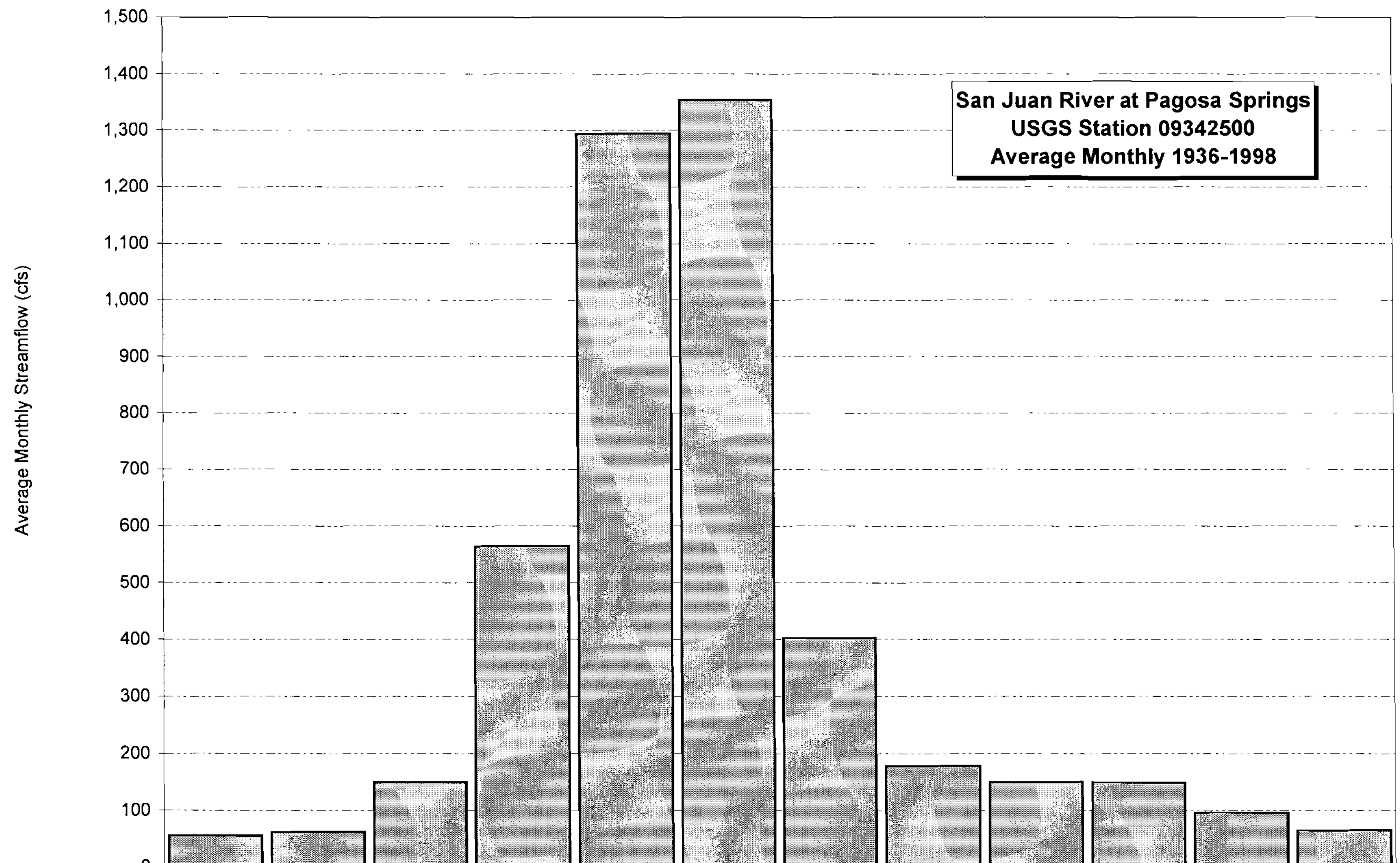


Figure 2
General Feature Map of the San Juan River

Navajo Reservoir Operations EIS
developed from Keller-Bliesner and BLM data

Western Colorado Area Office
Bureau of Reclamation
August 2000

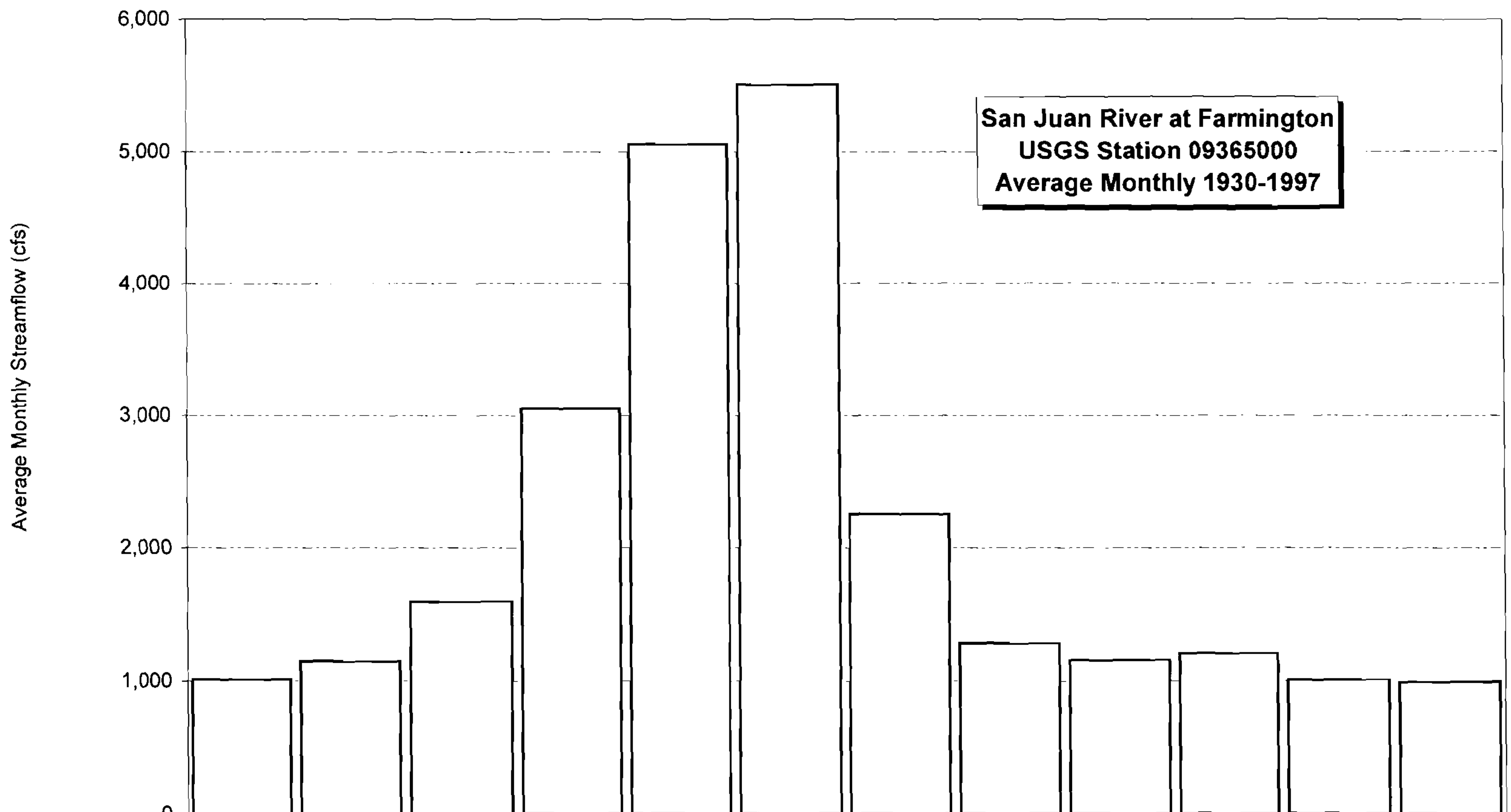
9-6-2000



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly 1936-1998	55.7	62.7	149.9	564.3	1,294.1	1,353.7	402.8	178.1	150.2	149.2	96.2	65.4

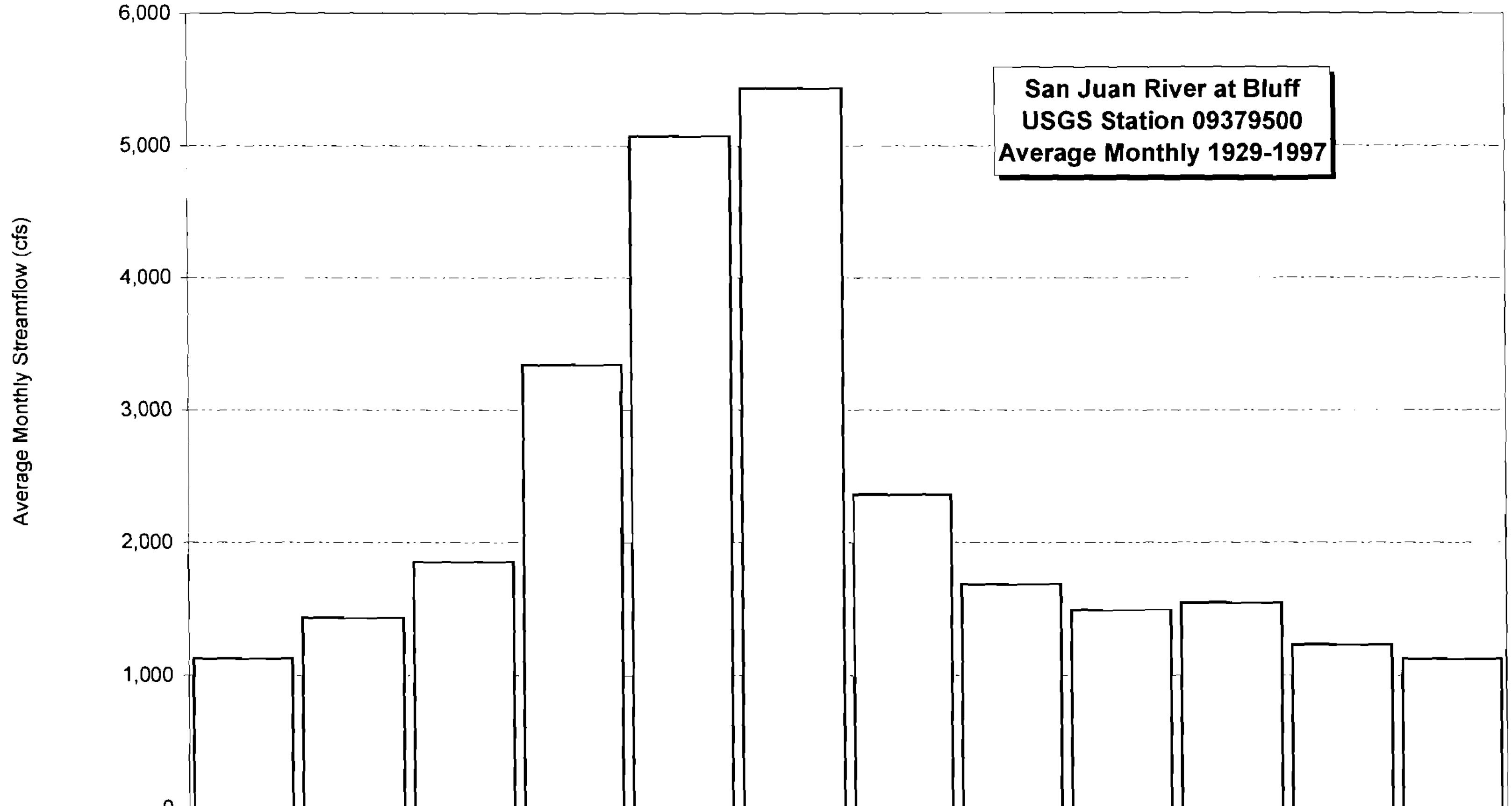
1936-1998

Figure 3



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly 1930-1997	1,010.6	1,144.2	1,592.4	3,051.7	5,055.6	5,505.5	2,251.9	1,277.9	1,151.9	1,205.6	1,008.4	987.7

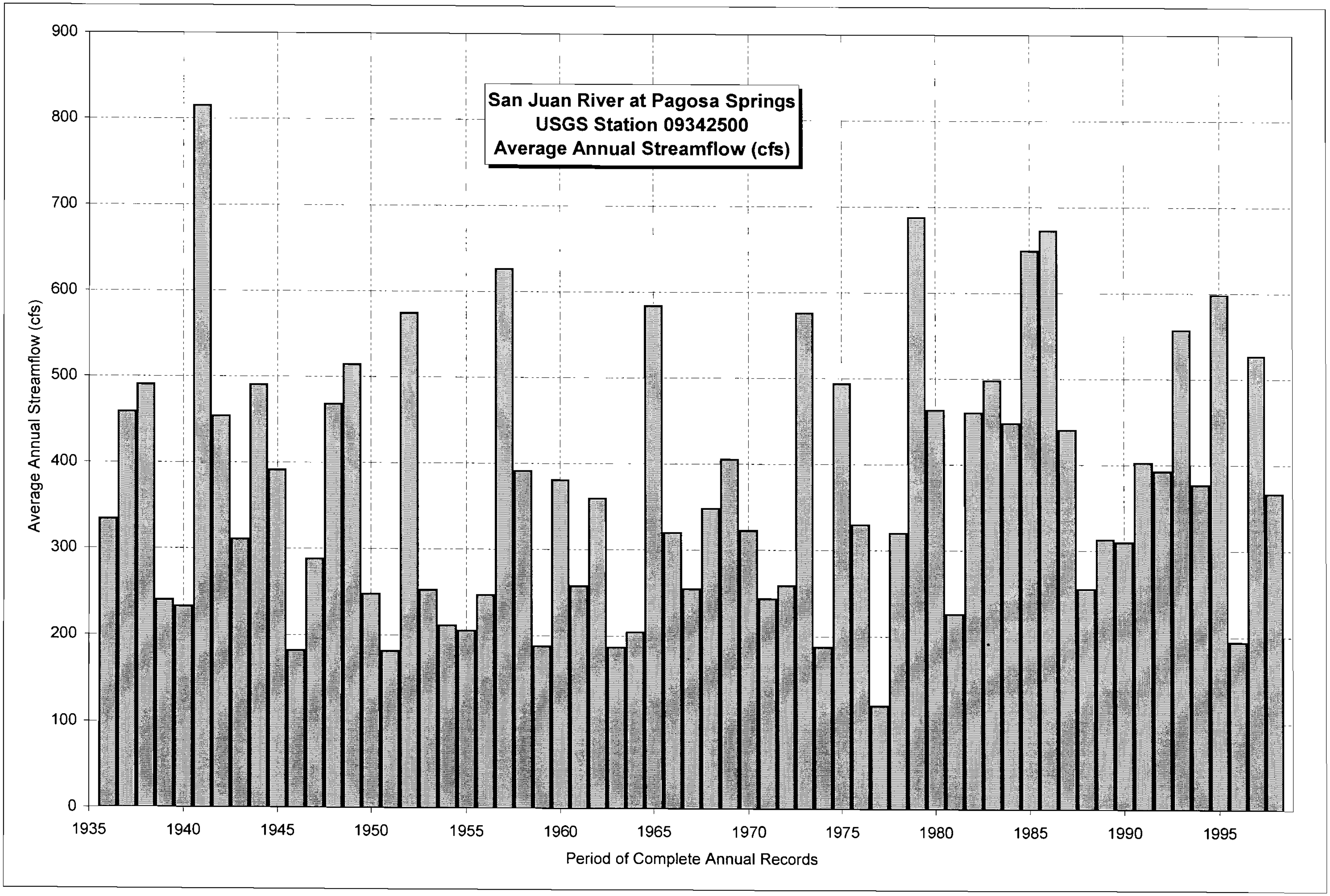
Figure 4



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly 1929-1997	1,125.1	1,430.7	1,850.8	3,339.6	5,070.6	5,432.2	2,359.1	1,682.9	1,488.8	1,540.4	1,225.0	1,122.0

1929-1997

Figure 5



HistoricStreamflowStats Chart2

9/11/00

Figure 6

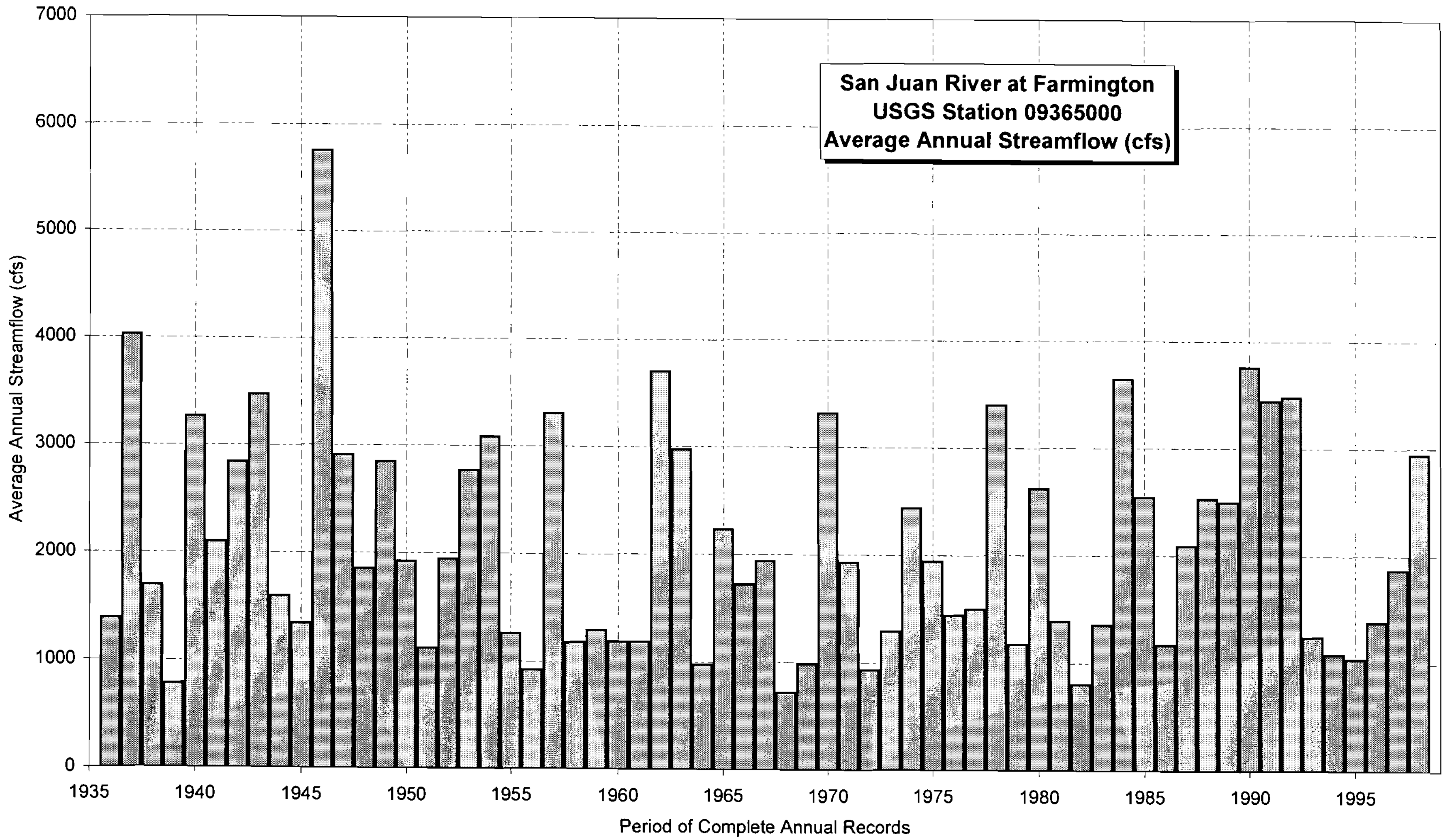

San Juan River at Farmington
USGS Station 09365000
Average Annual Streamflow (cfs)
Average Annual Streamflow (cfs)
Period of Complete Annual Records
7000
6000
5000
4000
3000
2000
1000
0
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995

Figure 7

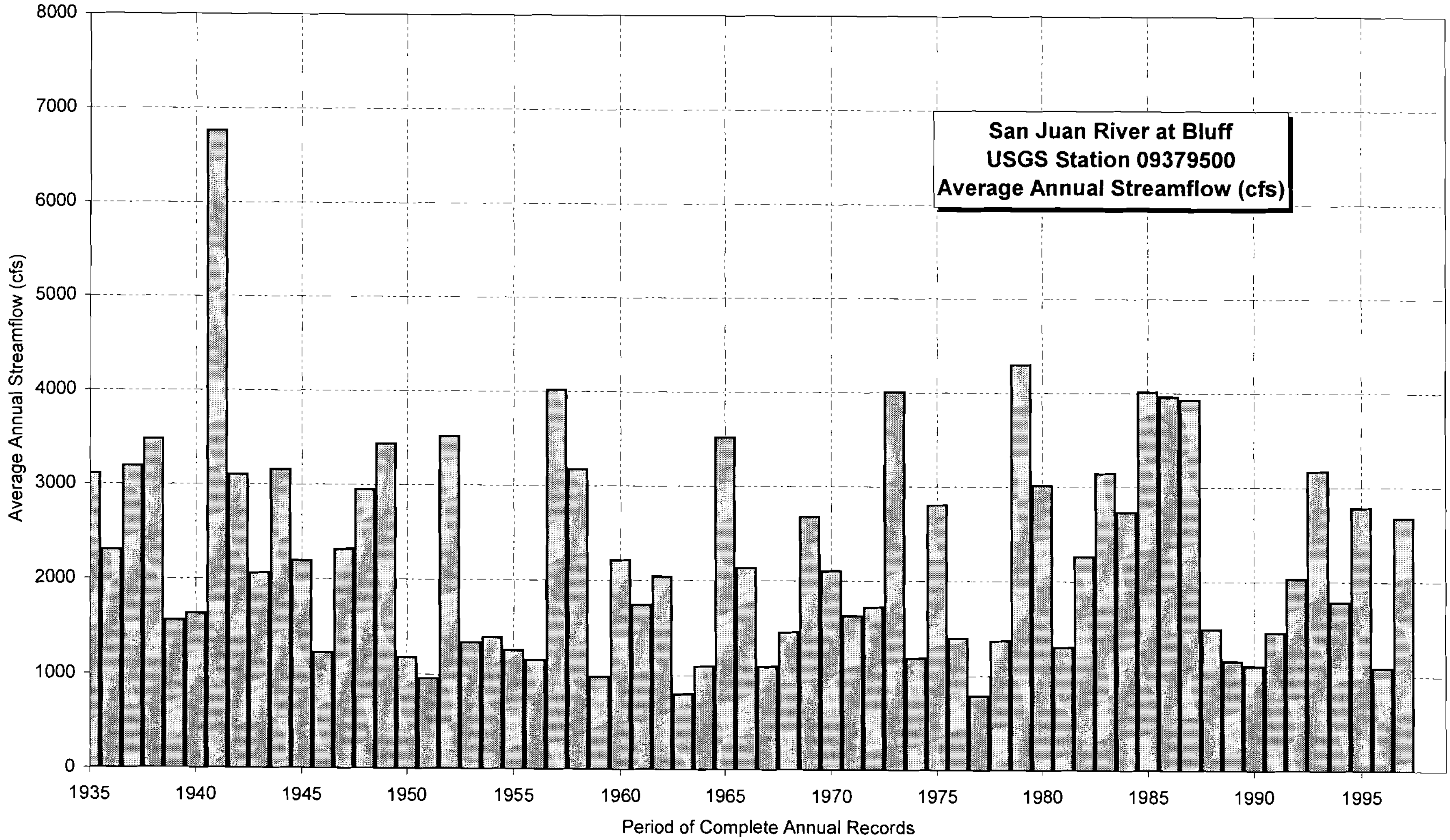

San Juan River at Bluff
USGS Station 09379500
Average Annual Streamflow (cfs)
Average Annual Streamflow (cfs)
8000
7000
6000
5000
4000
3000
2000
1000
0
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Period of Complete Annual Records

Figure 8

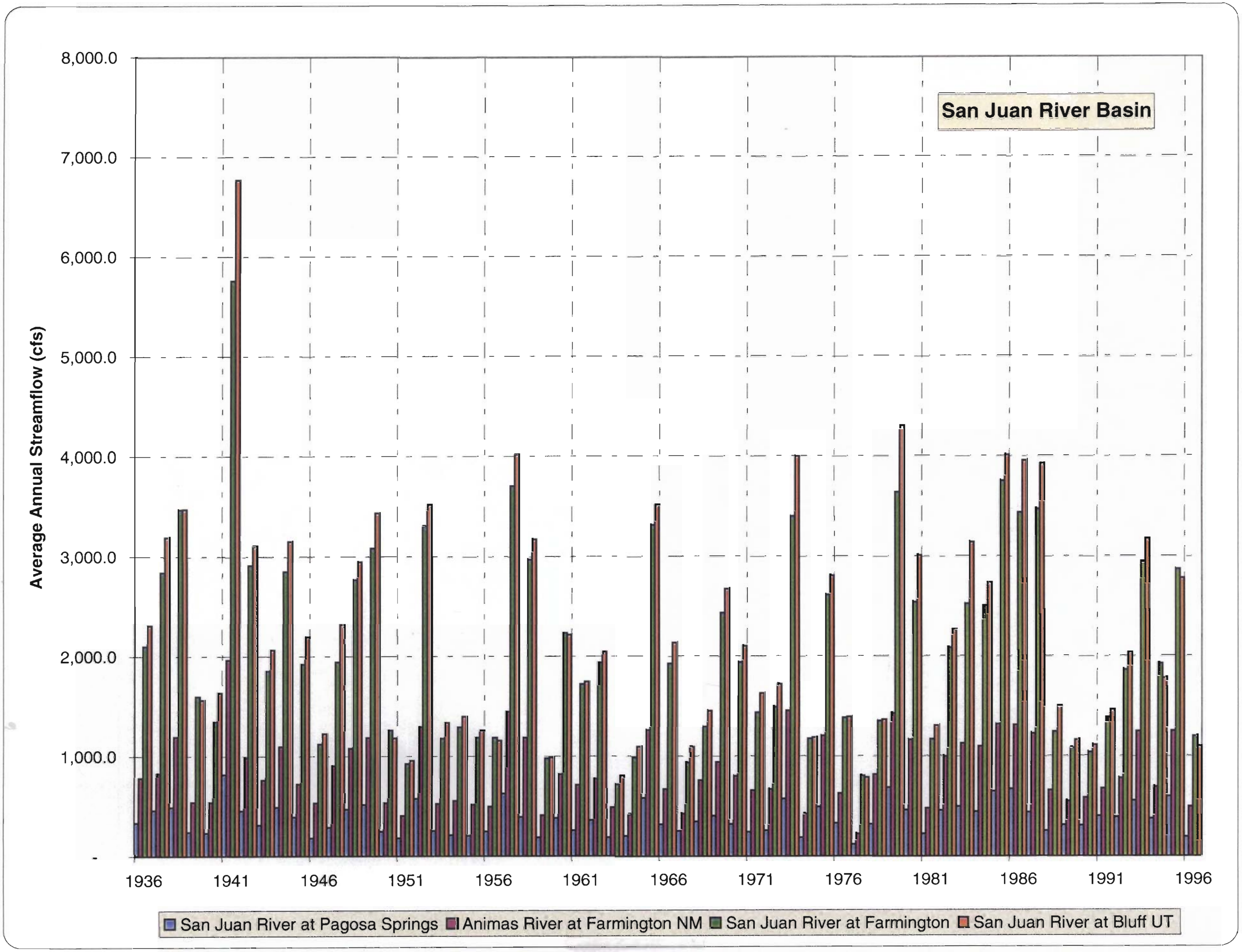

San Juan River Basin
Average Annual Streamflow (cfs)
8,000.0
7,000.0
6,000.0
5,000.0
4,000.0
3,000.0
2,000.0
1,000.0
-
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
San Juan River at Pagosa Springs
Animas River at Farmington NM
San Juan River at Farmington
San Juan River at Bluff UT

Figure 9

Generalized Geology Map of the San Juan River Basin

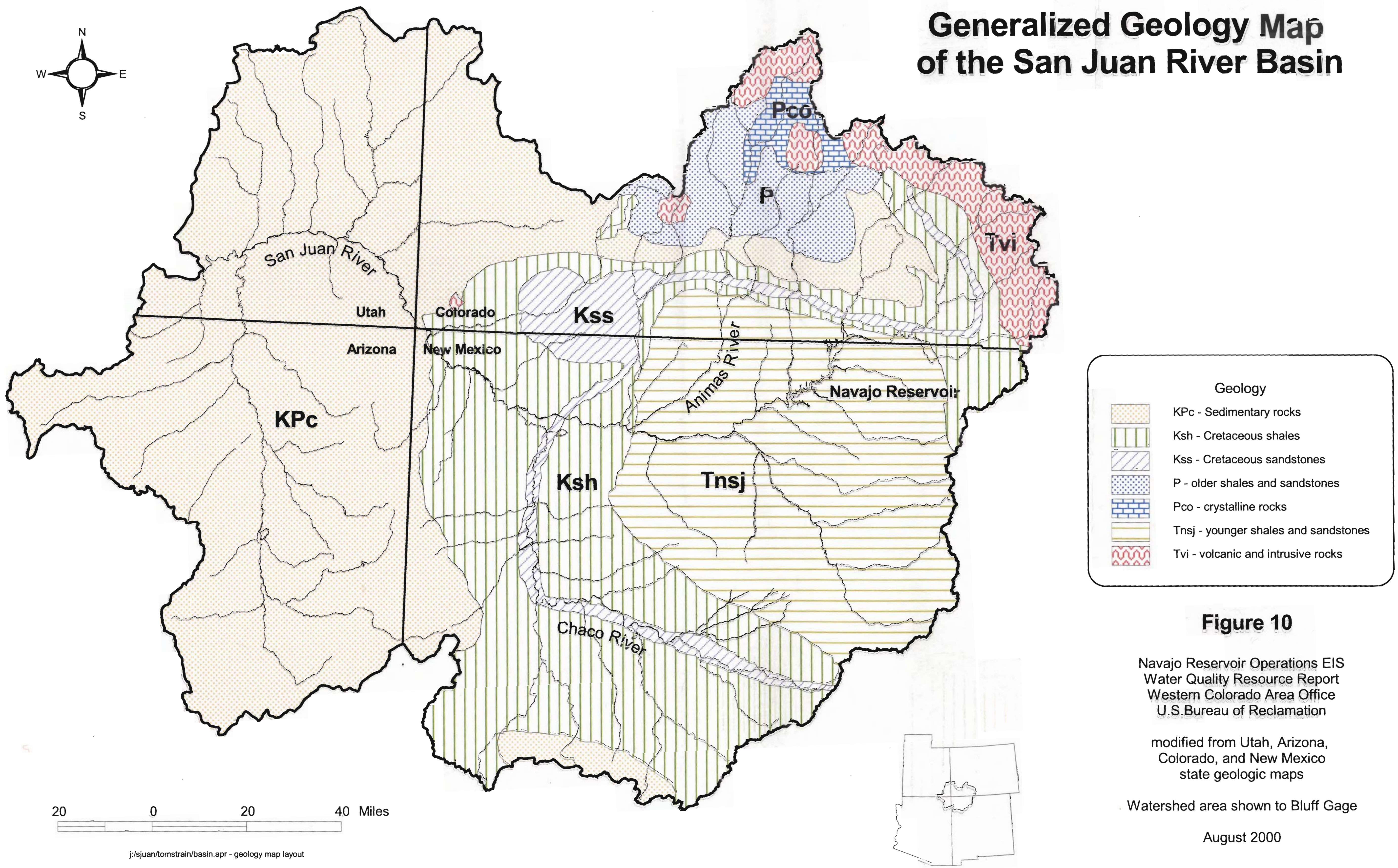


Figure 10

Navajo Reservoir Operations EIS
Water Quality Resource Report
Western Colorado Area Office
U.S.Bureau of Reclamation

modified from Utah, Arizona, Colorado, and New Mexico state geologic maps

Watershed area shown to Bluff Gage

August 2000

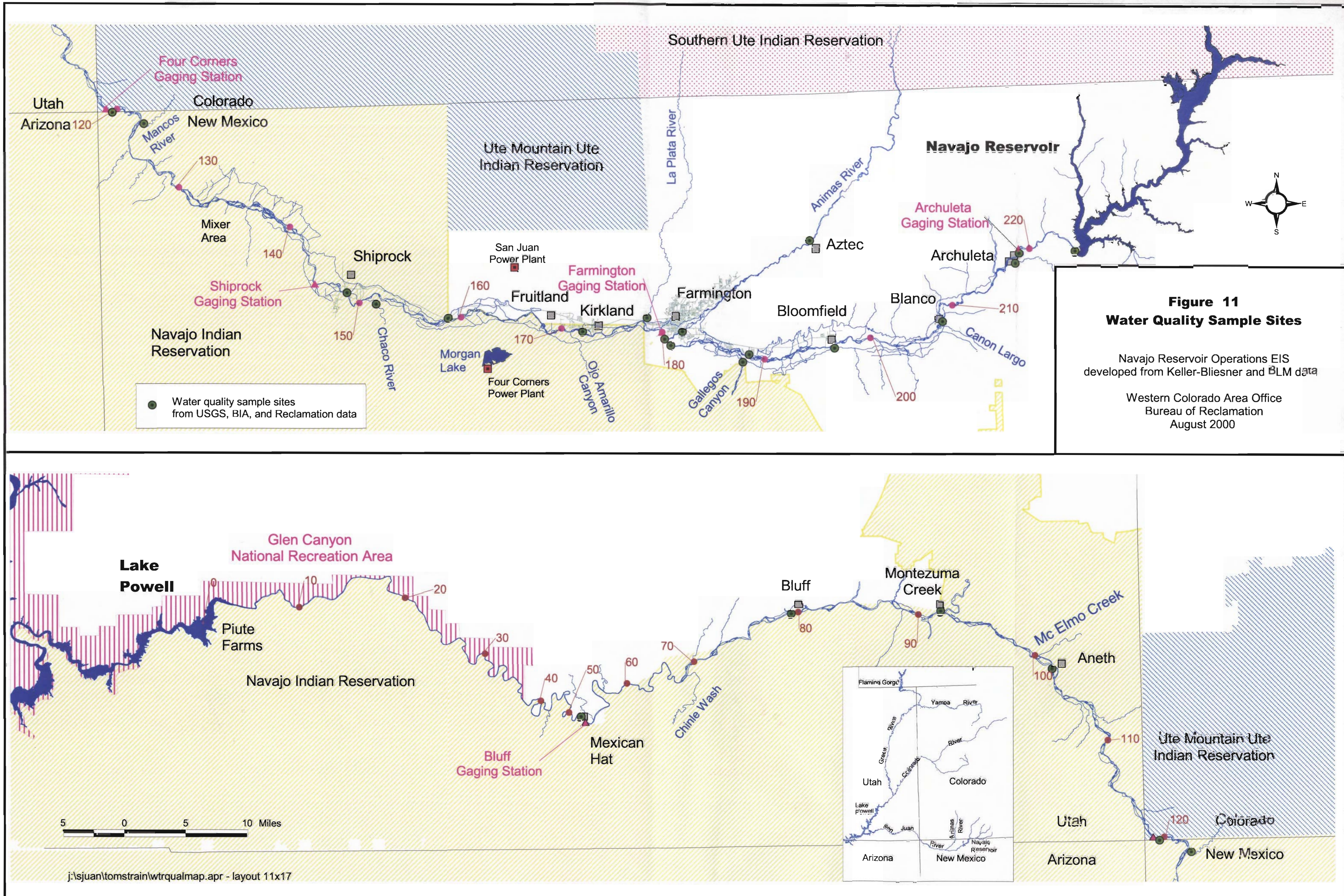
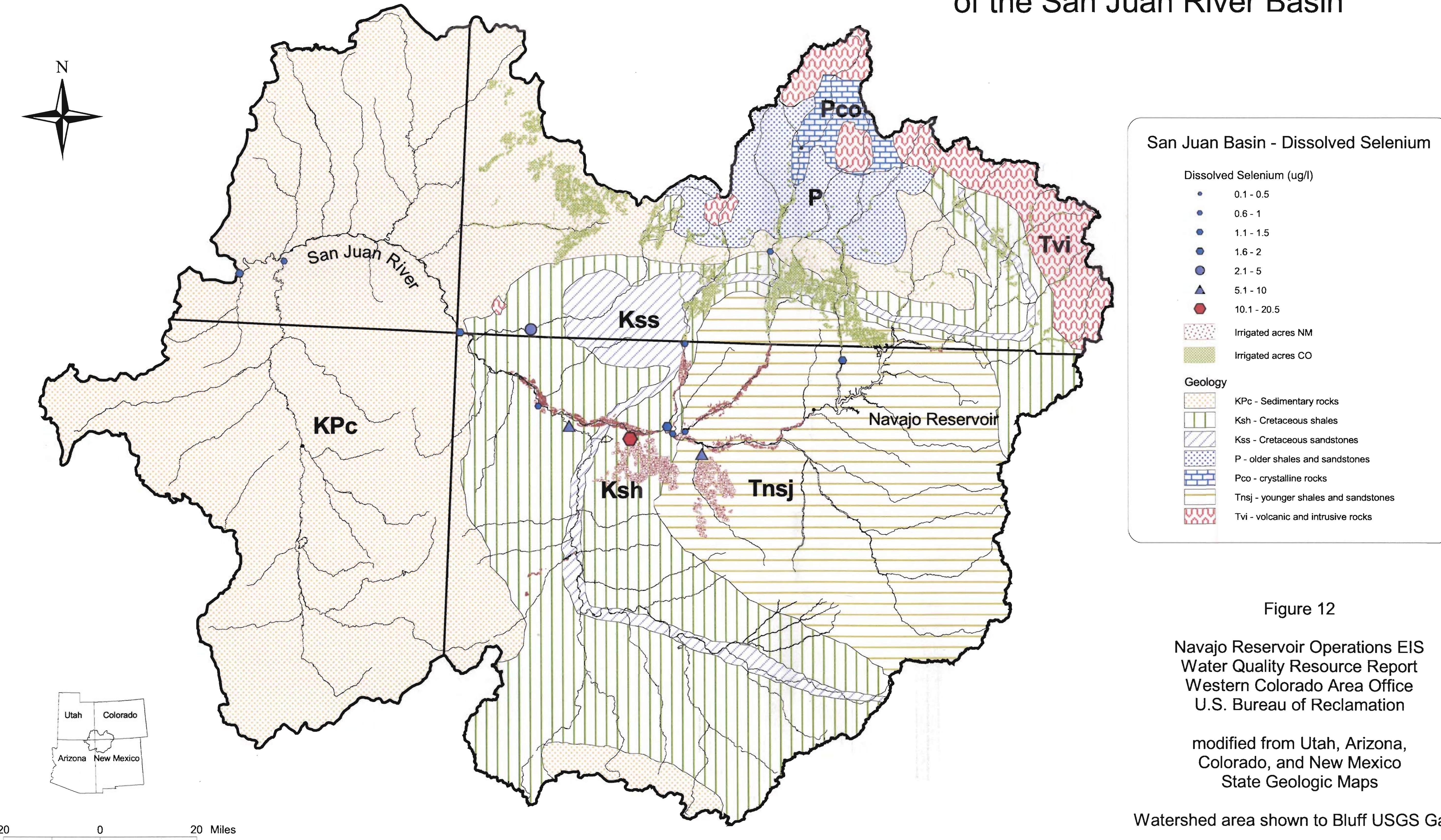


Figure 11
Water Quality Sample Sites
Navajo Reservoir Operations EIS
developed from Keller-Bliesner and BLM data
Western Colorado Area Office
Bureau of Reclamation
August 2000
Water quality sample sites
from USGS, BIA, and Reclamation data
Southern Ute Indian Reservation
Ute Mountain Ute Indian Reservation
Navajo Indian Reservation
Navajo Reservoir
Four Corners Gaging Station
Shiprock Gaging Station
Farmington Gaging Station
Archuleta Gaging Station
Bluff Gaging Station
Glen Canyon National Recreation Area
Lake Powell
Piute Farms
Mexican Hat
Bluff
Montezuma Creek
Aneth
Mc Elmo Creek
Chinle Wash
Utah
Arizona
Colorado
New Mexico
Mancos River
Mixer Area
Shiprock
Chaco River
San Juan Power Plant
Fruitland
Kirkland
Morgan Lake
Four Corners Power Plant
Ojo Amarillo Canyon
La Plata River
Farmington
Gallegos Canyon
Bloomfield
Animas River
Aztec
Blanco
Archuleta
Canon Largo
5 0 5 10 Miles
j:\sjuan\tomstrain\wtrqualmap.apr - layout 11x17

Generalized Geology Map of the San Juan River Basin



j:sjuan/tomstrain/basin.apr - geology,Irrigated lands, Selenium Conc.

Figure 12

Navajo Reservoir Operations EIS
Water Quality Resource Report
Western Colorado Area Office
U.S. Bureau of Reclamation

modified from Utah, Arizona, Colorado, and New Mexico State Geologic Maps

Watershed area shown to Bluff USGS Gage

January 2001

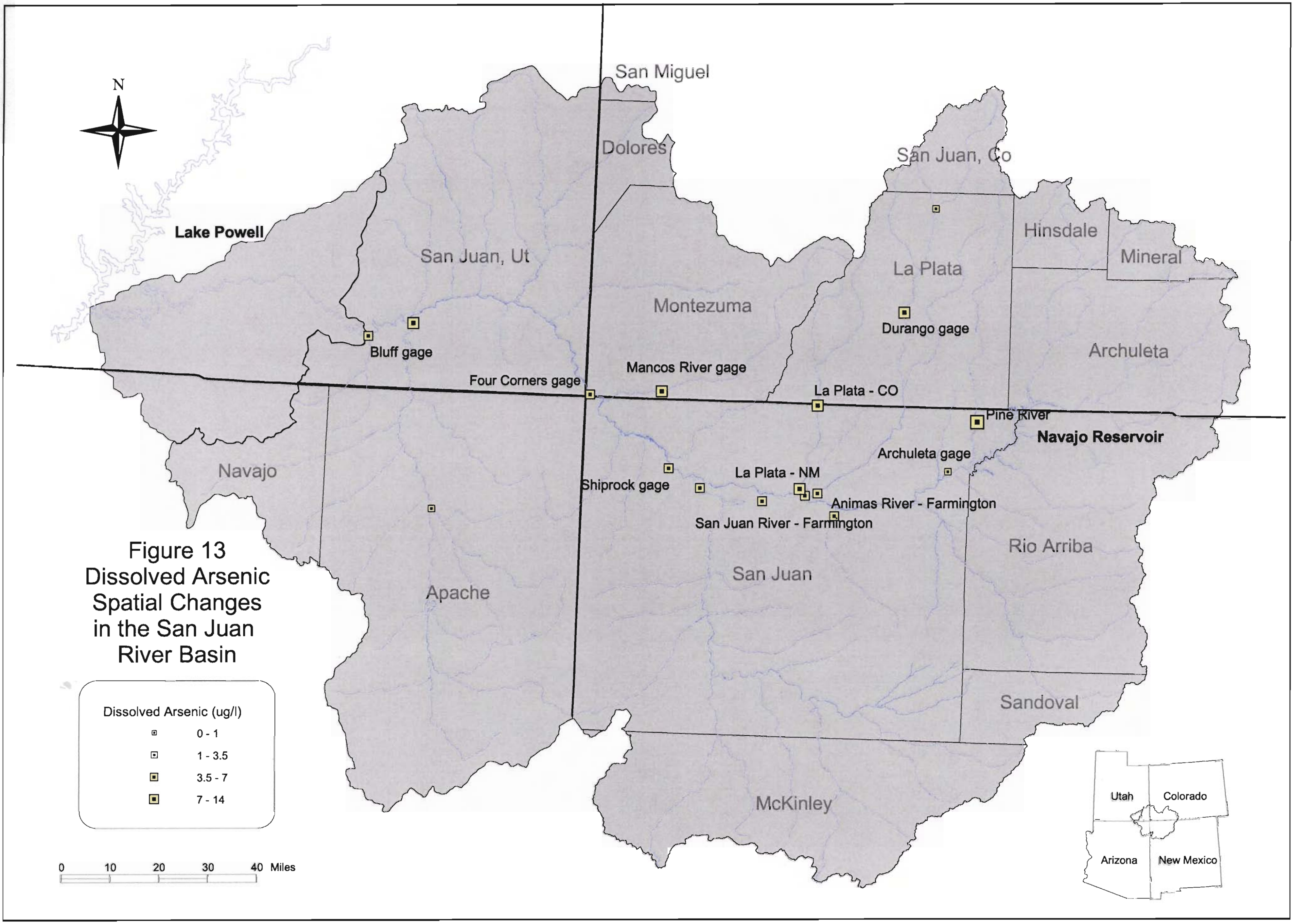


Figure 13
Dissolved Arsenic Spatial Changes in the San Juan River Basin

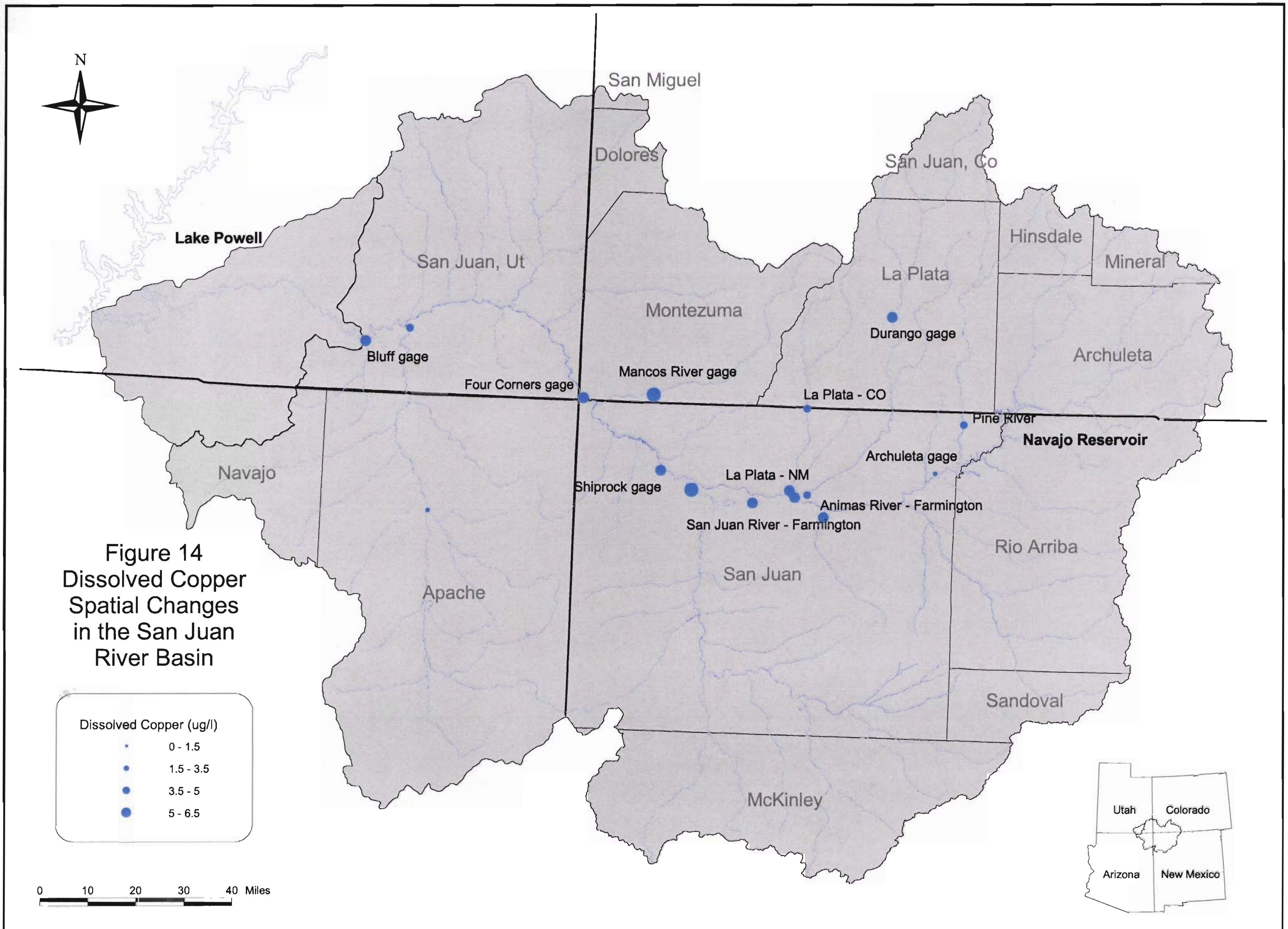


Figure 14
Dissolved Copper
Spatial Changes
in the San Juan
River Basin

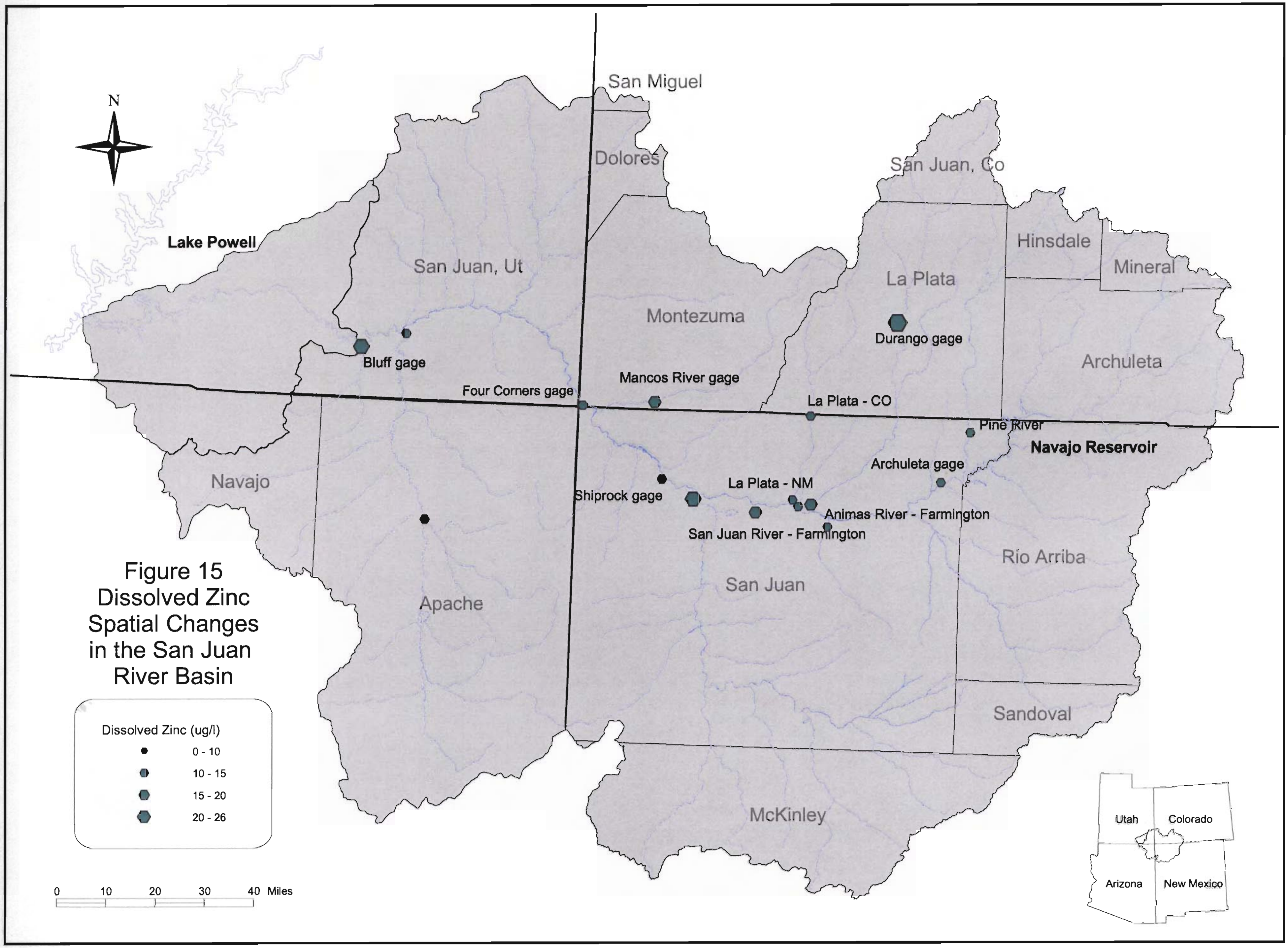


Figure 15
Dissolved Zinc
Spatial Changes
in the San Juan
River Basin