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Questa Baseline and Pre-Mining Ground-Water Quality Investigation 4. Historical Surface-Water Quality for the Red River Valley, New Mexico

By Ann S. Maest, D. Kirk Nordstrom, and Sara H. LoVetere

U.S. Geological Survey, Boulder, CO

Water Resources Investigation Report 03-XXX

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Explanation of Abbreviations

AAS (atomic absorption spectrometry)
Ag (silver)
Al (aluminum)
Alk (alkalinity)
ANC (acid neutralizing capacity)
As (arsenic)
B (boron)
Ba (barium)
Be (beryllium)
Bi (bismuth)
BOD (biological oxygen demand)
°C (degrees Celsius)
Ca (calcium)
$CaCO_3$ (calcium carbonate)
Cd (cadmium)
chl-a,b,c (chlorophyll-a,b,c)
cfs (cubic feet per second)
Cl (chloride)
CLP (Contract Laboratory Procedure)
CN (cyanide)
Co (cobalt)
CO (Colorado)
CO_3 (carbonate)
COD (chemical oxygen demand)
Cr (chromium)
Cr (creek)
Cu (copper)
_d (dissolved)
DO (dissolved oxygen)
DOC (dissolved organic carbon)
DOM (dissolved organic matter)
DIM (dissolved inorganic matter)
Eh (redox potential)
EPA (Environmental Protection Agency)
F (fluoride)
Fe (iron)
Ga (gallium)
Ge (germanium)
GFAAS (graphite-furnace atomic absorption spectrometry)
Hard (hardness)
HDPE (high density polyethylene)
HF (hydrofluoric acid)
Hg (mercury)
HNO_3 (nitric acid)
hr (hour)
H_2SO_4 (sulfuric acid)
ICP-MS (inductively-coupled argon-plasma – mass spectrometry)
ICP-AES (inductively-coupled argon-plasma – atomic emission spectrometry)
JTU (Jackson turbidity units)
K (potassium)
L (liters)
La (lanthanum)
Mg (magnesium)
mg/L (milligrams per liter)
mL (milliliters)
µm (micrometer)
µg/L (micrograms per liter)
Mn (manganese)
Mo (molybdenum)
Na (sodium)
Nb (niobium)
NH_3 (ammonia)
Ni (nickel)
NM (New Mexico)
NMDGF (New Mexico Department of Game and Fish)
NMED (New Mexico Environment Department)
NO_2 (nitrite)
NO_3 (nitrate)
NTU (nephelometric turbidity units)
P (phosphorous)
Pb (lead)
PO_4 (phosphate)
POTW (publicly owned treatment

works)
q (data quality flag)
QAPP (quality assurance project plan)
QA/QC (quality assurance/quality control)
Sb (antimony)
SC (specific conductance)
Se (selenium)
Si (silica)
Sn (tin)
SO_4 (sulfate)
Sr (strontium)
T (temperature)
_t (total)
TAL (target analyte list)
TDS (total dissolved solids)
Tl (thallium)
TOC (total organic carbon)
TSS (total suspended sediment)
US EPA (United States Environmental Protection Agency)
US HEW (U.S. Department of Health, Education, and Welfare)
V (vanadium)
WWTP (waste water treatment plant)
WY (water year)
Zn (zinc)
_? (not known if total or dissolved)

Abstract

This report presents a compilation and evaluation of historical surface-water quality data for the Red River in northern New Mexico. Water-quality samples have been collected from 1965, the year open-pit mining began at the Molycorp Molybdenum Mine, to the present. The historical surface water data compilation has focused on the Questa Ranger Station, located approximately two kilometers downstream of streams that drain the mine site, because of the long-term water quality and flow record at this U.S. Geological Survey gage location. Data from locations upstream of the mine site and downstream of natural scar areas are also included. The mine area and other drainages upstream and downstream of the mine are naturally mineralized, and the U.S. Geological Survey is currently conducting a baseline and pre-mining ground-water quality investigation in the Red River valley.

One of the main purposes of compiling and evaluating the historical surface-water quality information is to gather all the data in one document and to describe its quality. Others have compiled Red River historical water quality data, but not all parameters were reported, a comprehensive evaluation of the methods used to collect and analyze the samples was not conducted, geochemical interpretations were not included, and/or the data were not evaluated with respect to water flow dynamics. Very few of the historical sampling efforts included sampling or quality assurance/quality control plans. Detection limits for metals and arsenic were elevated in a number of the studies compared to those for graphite furnace and ICP-MS and preclude comparisons to criteria for the protection of aquatic life in the Red River. However, major- and minor-element, and in some cases trace-element data are reliable and useful for evaluating chemical, temporal, and spatial trends and for establishing an historical framework for the more recent surface-water quality data collected by the USGS.

In mineralized or mined areas, it is common to see relationships between concentrations and flow or between concentrations and changes in the hydrograph record. The gathered historical data were examined in the context of hydrologic timing by discriminating

sampling events based on associated measured flows at the Questa Ranger Station. Five hydrologic timings were defined: rising limb, peak, falling limb, storm, and low flow. A trend of increasing sulfate concentrations and loads at the Questa Ranger Station over time, potentially related to mining inputs, was apparent when the dynamic events of snowmelt and summer rainstorm were eliminated and only low-flow concentrations were considered. An inverse relationship was found to exist between sulfate concentrations and discharge seasonally. Both rising limb and storm-event sulfate concentrations were lower than low-flow concentrations. However, a number of samples collected during summer thunderstorm and rising limb times had sulfate values equal to or higher than low-flow concentrations, suggesting that collecting samples as monthly composites, for example, will dampen or eliminate peaks in releases of sulfate from mineralized or mined areas in the Red River basin. These results show that the highest sulfate concentrations can be expected to occur early in snowmelt runoff and during summer storm events, as long as sampling is timed to capture releases during these events. When flows first increase in the spring, or during summer thunderstorm events, the first flush of sulfide oxidation products from scar and mine-disturbed areas reach the Red River and are not yet diluted by rising river waters.

A more limited number of samples was collected upstream of the Molycorp facilities and downstream of sulfate inputs from natural scar areas. The increase in sulfate concentrations and loads over time at the Questa Ranger Station was not seen at locations upstream of the mine and downstream of scar areas. Zinc concentrations downstream of the mine at the Questa Ranger Station were uniformly higher than those upstream of the mine and downstream of scar areas, suggesting that additional zinc sources enter the river in the vicinity of the mine.

A plot of calcium versus sulfate concentrations at the Questa Ranger Station suggests that the Red River is not well buffered and that during higher flow events, Red River water is diluted by calcium-carbonate waters, most likely from upstream of scar areas and from unmineralized Red River tributaries. The effect of pyrite oxidation on Red River water chemistry is more pronounced after 198??, most likely from mining activity. The alkalinity values in the Red River also indicate that the river is not well buffered with respect to pH, and that both mined and scar areas contribute to observed drops in alkalinity. These effects were most apparent during summer thunderstorm and rising limb times, which were associated with elevated zinc concentrations, a decrease in alkalinity, and increases in sulfate and conductivity, again demonstrating that hydrologic timing is critical to interpretation of concentration changes in this mineralized and mined drainage.

Introduction

The historical surface water quality evaluation is part of the Questa baseline and pre-mining ground-water quality investigation, hereafter the Questa pre-mining study, conducted by the U.S. Geological Survey. The baseline and pre-mining study began with a Joint Powers Agreement between the U.S. Geological Survey (USGS) and the New Mexico Environment Department (NMED) on April 30, 2001. The overall objective of the investigation is to infer the pre-mining ground-water quality at the Questa Molycorp mine site. As part of this investigation, the USGS has compiled and evaluated historical surface-water quality data for the Red River.

Physical Description of Study Area

The study area is located in Taos County in north-central New Mexico on the western slope of the Taos Range of the Sangre de Cristo Mountains within the Carson National Forest. The area can be characterized as a rugged and altered terrain with steep slopes and V-shaped valleys. The study reach is in the Red River valley between the Questa Ranger station (elevation 7,480 feet or 2.280 m) at the west end and the Town of Red River (elevation 8,680 feet or 2,646 m) at the east end (figure 1). The Molycorp, Inc. Questa Molybdenum mine, referred to as the mine site, is located on the north side of State Highway No. 38 and the Red River 13 km east of the Ranger Station. The mine site is approximately 18 km^2 and encompasses three tributary valleys to the Red River: Capulin Canyon, Goathill Gulch and Sulphur Gulch, from west to east respectively.

Mining activities produced extensive underground workings and an open-pit of approximately 7.8 km^2 near or in Sulphur Gulch. Waste-rock piles cover steep slopes on the north side of the Red River between Capulin Canyon and Spring Gulch (a tributary valley of Sulphur Gulch). Hydrothermally altered bedrock is found in Capulin, Goathill, Sulphur, Hansen, Straight, and Hottentot drainages (figure 1). Weathering of extensively altered rock has resulted in steep, highly erosive, sparsely vegetated "scars" that are clearly visible from the ground and in aerial photographs.

Climate and Vegetation

The Red River valley is located within a semi-arid desert that receives precipitation throughout the year and sustains moderate biodiversity. Between 1915 and 2002, the annual average temperature was 4°C, and the precipitation and snowfall were 52 cm and 370 cm, respectively, and the daily temperatures generally fluctuated by 40 degrees throughout the year (Western Regional Climate Center, 2003).

Climate and vegetation vary greatly within short distances because of differences in topography, weather, and sediment composition. The altitude in the study area ranges from 2,280 m at the Ranger Station to 3,277 m at the divide. Orographic effects of mountainous topography lead to precipitation on the windward slopes and localized storms within tributary valleys. Major precipitation events include summer thunderstorms and winter-spring snowstorms. Thunderstorms are responsible for mass wasting in hydrothermally altered areas, producing debris flows that potentially impact vegetation, alluvial aquifers, and the Red River. Winter snowpack contributes to ground water recharge through snowmelt infiltration and runoff.

Hillslope composition varies among hydrothermally altered sediments, waste rock overburden, and moderate soil development. Some scar areas and hill slopes with soil horizons primarily support Ponderosa pines (*Pinus ponderosa*), Limber pines (*Pinus flexius*), and Douglas-fir (*Pseudotsuga taxifolia*). Along the river bank there are also Willows (*Salix* spp.), Cottonwoods (*Populus* spp.), primary vegetation, and flowering vegetation.

Table 1. Red River monthly climate summary from January 1915 to December 2002.

	Average Max. Temperature (°C)	Average Min. Temperature (°C)	Average Total Precipitation (cm)	Average Total Snow Fall (cm)	Average Snow Depth (cm)
January	2.5	-15.4	2.7	50.8	22.9
February	4.1	-13.4	2.9	53.1	22.9
March	6.7	-9.7	4.5	73.7	17.8
April	12.0	-5.6	4.4	55.4	5.1
May	16.9	-1.8	4.5	18.8	0.0
June	22.6	1.8	3.3	0.3	0.0
July	24.4	4.9	7.4	0.0	0.0
August	23.2	4.6	8.0	0.0	0.0
September	20.4	0.9	4.2	1.3	0.0
October	14.8	-3.8	3.8	21.3	0.0
November	7.2	-10.0	3.4	47.0	5.1
December	3.1	-14.4	2.9	48.0	15.2
Annual	**13.2**	**-5.2**	**52.0**	**369.8**	**7.6**

Data source: Western Regional Climate Center, 2003.

Geology

Ground water passes though, and may geochemically interact with, the various types of earth materials discussed below. These include fractured bedrock, soil and alluvium, and waste rock. These are discussed separately because they have differing origins, geochemical and hydraulic properties, and locations in the landscape. This section summarizes the work of Schilling (1956), Rehrig (1969), Lipman (1981), and Meyer and Leonardson (1990), in addition to observations made by the USGS scientists currently working at the site.

The Taos Range of the Sangre de Cristo Mountains is composed of Precambrian metamorphic assemblages and granitic intrusives overlain by Tertiary volcanics. Late Oligocene to early Miocene granitic plutons and associated hydrothermal alteration were the source of molybdenite and other sulfide mineralization.

The Red River valley is located along the southern edge of the Questa volcanic caldera and contains complex structural features and extensive hydrothermal alteration. In the Red River valley, most of the visible rocks are Tertiary volcanics with smaller areas of Precambrian metamorphics and granitic stocks. The volcanics are primarily intermediate to felsic composition (andesites to rhyolites), and they have been intruded by quartz monzonites and granites. The hydrothermally altered tuffs often contain pyrite mineralization (generally 1-3 percent).

The primary mineralogy of most of these units has been modified by hydrothermal solutions producing a variety of secondary mineral phases. The types of minerals formed are a function of the initial mineralogy and the degree of alteration. The three principal alteration zones include highly altered quartz-sericite-pyrite (QSP), less-altered argillic (dominantly kaolinite) zones, and mildly altered propylitic zones (containing calcite mineralization). Calcite, goethite, and sericite are widely distributed in the Red River valley as revealed by the Airborne Visible/InfraRed Imaging Spectrometer (AVIRIS) study (Livo and Clark, 2002). Calcite is an important mineral in the Red River valley because its dissolution effectively neutralizes the acid inflows so that pH values in the Red River tend to be alkaline (pH 7-8). Gypsum is commonly found throughout the Red River valley as a secondary product of acid-sulfate weathering from pyrite oxidation reacting with calcite.

The major minerals in subsurface samples collected during mineral exploration and mining are biotite, calcite, chalcopyrite, fluorite, galena, molybdenite, pyrite, quartz, rhodocrosite, and sphalerite. Mining activities produced roughly 328 million tons of rock overburden in Capulin Canyon, along the north slope of the Red River, and in Goathill, Sulphur and Spring Gulches (URS, 2001). The abundant minerals in waste rock samples include chlorite, gypsum, illite, illite-smectite, jarosite, kaolinite, muscovite (Gale and Thompson, 2001).

Ground Water

Ground water is influenced by the climate, geology, and anthropogenic activities in the Red River valley. There are three major types of water-bearing units present: fractured bedrock, waste rock piles, and soil and alluvium, all of which contain variable amounts of acid and metal-generating minerals (Vincent, written communication, 2003). Bedrock constitutes the largest aquifer in the study area in terms of rock mass, but probably contains only small amounts of ground water because of low porosity and hydraulic conductivity that are controlled by fractures. Waste rock piles and scars with associated debris fans are geochemically reactive, have high porosity, and a fast rate of infiltration.

Alluvial aquifers are restricted, compared to bedrock aquifers, and have variable compositions. Stream flow and hillslope processes have been eroding the mountainous study area throughout the late Cenozoic, and deposits of unconsolidated sediments are found in only specific locations and are relatively small in volume. Rock outcrops are relatively rare, and hillslope soils are thin and composed of materials eroded from just up slope. Debris fans are located at the mouths of most tributaries, and composed of sediments shed from their tributary watersheds. Where the tributary watersheds contain "erosion scars" the debris fans are large and active, and contain both coarse and fine-grained debris-flow sediments. The chemistry of these sediments likely reflects the chemistry of their rapidly eroding and altered erosion scars. Sediments deposited by the Red River, in contrast, generally consist of well washed sandy-gravel and are composed of a mix of the lithologies found in the entire Red River Watershed. The largest debris fans caused the Red River to aggrade behind the fans during the Quaternary. Thus water flowing in the shallow alluvial aquifers likely passes alternately through Red River alluvium and debris fan alluvium. Both the Red River alluvium and debris fan alluvium are less than several hundred meters wide and less than 60 m thick (Vincent, written communication, 2003).

Alluvial ground water is a calcium-sulfate water type, while bedrock ground water is generally calcium-magnesium-sulfate water. Ground water down gradient from the waste rock dumps and scars has acidic pH values and elevated metal concentrations compared to ground water up gradient from altered areas. Most wells developed in the Red River valley were installed to monitor water quality down gradient from mining operations (waste rock dumps and tailings piles) and/or scar areas.

Surface Water

The Red River originates at Wheeler Peak at an elevation of 40,098 m, flows roughly 13 km north to the town of Red River, and continues for 34 km west to the town of Questa where it ultimately discharges to the Rio Grande River. The drainage area upstream of the Questa Ranger Station is 292.7 km^2. Peak streamflow usually occurs from late May to mid-June, with snowmelt-related flows beginning to increase in late March through mid-April. Summer thunderstorms are prevalent in July and August. The mean annual discharge of the Red River at the Questa Ranger Station has ranged from 12.8 to 103 cfs between 1930 and 2001 while the average daily discharge ranged from 2.5 to 557 cfs between 1965 and 2001 (National System for Historic Streamflow Data, 2003).

The main drainages in the vicinity of the mine site are Capulin Canyon, Goathill Gulch and Sulphur Gulch on the north side of the Red River (figure 1). Upstream of the mine site, Little Hansen, Hansen, Straight, and Hottentot Creeks drain scar areas while Mallette and Bitter Creeks drain non-scar areas on the north side of the Red River. Bear, Columbine, Pioneer, and Placer Creeks drain largely unmineralized land on the south side of the river. Downstream of the mine site the Red River joins with Cabresto Creek, entering from the north side of the Red River, before it discharges to the Rio Grande.

Springs and shallow alluvial groundwater discharge to the Red River rendering it a gaining stream over much of its length (Smolka and Tague, 1989). Roughly 20 ephemeral seeps and springs arise along the banks of the Red River between the Questa Ranger Station and the town of Red River (SPRI, 1995; SRK, 1995). The majority of the seeps and springs can run acidic (pH 2-4) with high conductance, TDS and metal concentrations. Springs downgradient of scar and mined areas on the north side of the

Red River often have a milky aluminum hydroxide precipitate that affect the color and turbidity of the Red River (Vail Engineering, Inc. 1989).

Mining History

Molycorp, Inc. operates a molybdenum mine 6.4 kilometers (km) east of the town of Questa, New Mexico on approximately 7.8 square km of land surrounded by the Carson National Forest. The Red River forms the southern boundary of the mine site and flows to the west where it joins the Rio Grande River (figure 1). State and federal authorities have raised concerns about potential injury to the Red River fishery and aquatic life since open-pit mining began in 1965. The history of the Molycorp Mine site is available from Molycorp (www.molycorp.com), NMED, and the U.S. Environmental Protection Agency (US EPA; www.epa.gov/superfurn/sites/npl/nar1599.htm). The following is a summary of that information and other data that pertain to the study of surface water in the Red River valley.

A pair of prospectors first discovered molybdenite in Sulphur Gulch in 1914. Small-scale underground mining began in 1920 and continued until an open-pit mine was developed in 1965. In 1954 there were over 56 km of mine workings. Molycorp began removing the rock overburden at Sulphur Gulch in 1964, and within a year began extracting molybdenite from the open pit. Overburden and waste rock from open-pit mining was deposited primarily in Sulphur and Goathill Gulches and between these two areas on the south-facing slopes along the north side of the Red River (URS, 2001). Tailings were transported the 14.5 km from the mine to the tailings facility located near the confluence of the Red River and the Rio Grande. Up to 80 spills from the tailings pipeline occurred between 1966 and 1976 (Slifer, 1996). Water used in the mill operation was produced from the Red River and the Red River alluvial aquifer.

Baseline surveys of Red River water quality were conducted by the U.S. Department of Health, Education and Welfare (US HEW) in 1966 (Federal Water Pollution Control Administration, 1966) and in 1971 by the US EPA. The reports concluded that the water quality was high in 1966 and that the chemical quality and biological conditions remained very good in 1971, with the exception of tailings pipeline breaks (US EPA, 1971). In the early 1970's, the New Mexico Department of Game and Fish (NMDGF), however, noticed that fish were absent in the middle reach of the Red River where there had been 572 fish per mile in 1960 (Slifer, 1996).

In 1980, the US EPA performed a preliminary assessment of the Red River-Questa site (Melancon et al., 1982). The study found biologic toxicity, high concentrations of arsenic, and concentrations of cadmium and silver that exceeded water quality standards for the protection of aquatic life. Four surveys were performed between 1984 and 1988 by different bureaus within NMED that indicated progressive degradation in the Red River (Slifer, 1996; URS, 2001). The Bureau of Land Management (BLM) studied Red River water quality between 1978 and 1986 (Garn, 1985), and documented a downstream

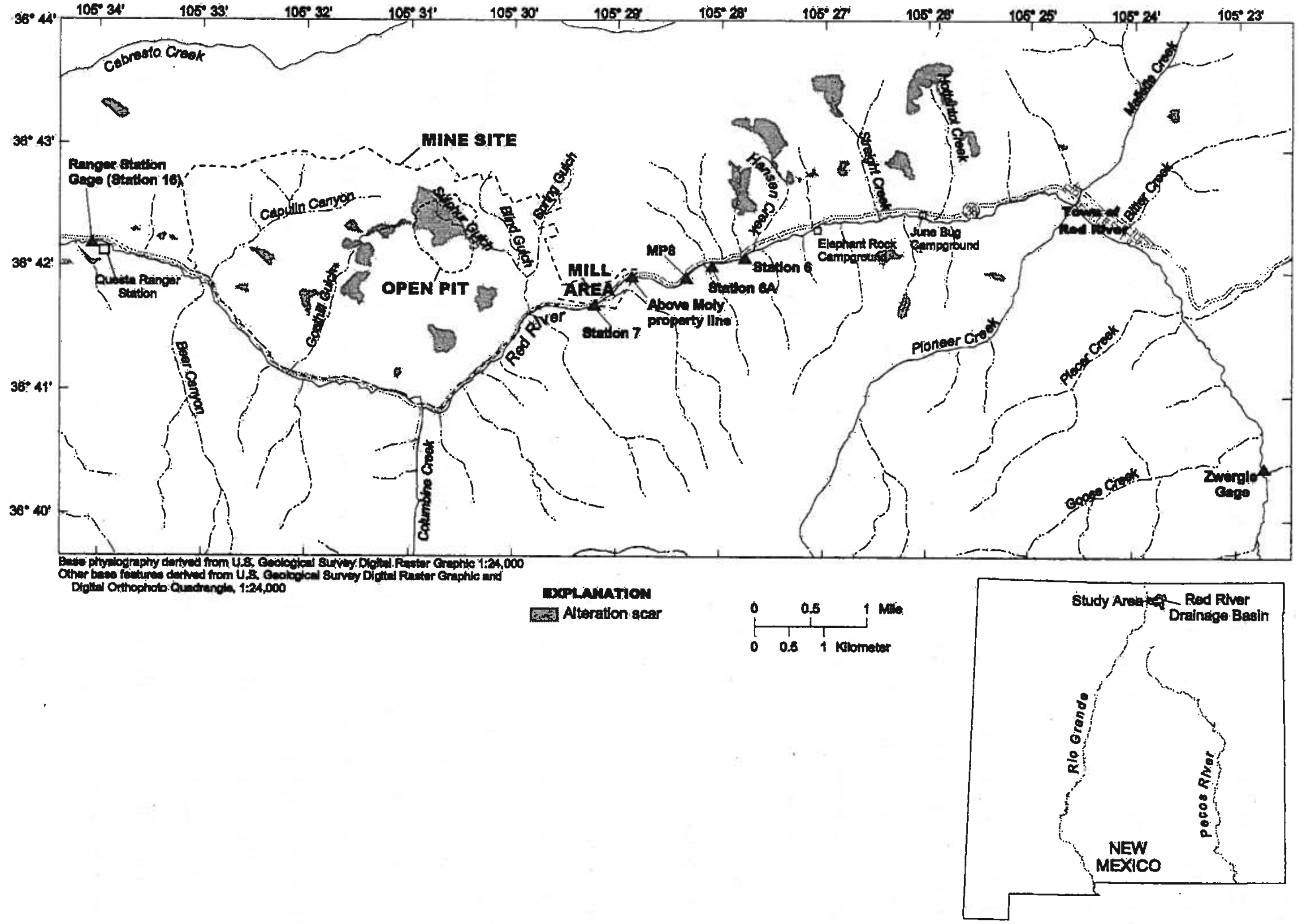

Figure 1. Map showing the Red River valley and surface water sampling locations.

increase in concentrations of metals and other constituents, at times exceeding water quality standards, and related the impacts to mining. Smolka and Tague (1987, 1989) conducted water studies that showed increased loading from storm events, but concentrations in the Red River did not exceed aquatic toxicity thresholds. However, biological indices were substantially reduced downstream of the Molycorp Mine. Summaries of these and other water-quality investigations are discussed and reviewed in the Discussion section.

In 1983, Molycorp ceased open-pit mining and initiated operations in the new phase of underground mining. The switch effectively stopped the dumping of waste rock in Capulin Canyon, along the north slope of the Red River, and in Goathill, Sulphur and Spring Gulches, and increased the volume of tailings slurry transported via pipeline to the impoundment in Questa. It is estimated that roughly 328 million tons of waste rock (295 million metric tons) were deposited near the open-pit between 1964 and 1983 (RGC, 2000; Slifer, 1996).

Low market values for molybdenum drove the mine to shut down between 1986 and 1989 and again in 1992. From 1992 to 1995, while the underground mine was shut down, pumping of the underground mine stopped, and the workings were allowed to flood. Point-source discharges from the tailings facility at Questa were monitored through a discharge permit issued by US EPA, and two discharge points for stormwater runoff from the mine site were added when the permit was renewed in 1993 (Slifer, 1996). A discharge permit for the mine site was issued in November 2000. The permit dictated quarterly sampling, which was initiated in June 2001. In 2002, Molycorp and US EPA entered into an Administrative Order on Consent (AOC) to define the nature and extent of contamination from the mine site. Currently, Molycorp is required to collect soil, rock, water, animal, and plant samples for the Remedial Investigation as defined in the AOC.

Although a considerable number of surface-water analyses in the Red River valley were collected from 1966 to the present, the data were not compiled in a single document, did not undergo data quality evaluation, and have not been utilized to interpret water-rock interactions. The purpose of this report is to compile and evaluate historical surface water quality data in the Red River valley between the Questa Ranger Station and the town of Red River. "Historical" data are defined as all data existing from the earliest available record until the current USGS study began collecting water-quality samples in 2001. It is also the purpose of this report to delineate any spatial and temporal trends in the data and to obtain some preliminary information on water-rock interactions or any other factors affecting temporal trends in Red River water quality.

Methods for Compiling and Reviewing Historical Surface-Water Quality Data

For the purposes of this report, historical water-quality data are defined as those from samples collected on or before the February 2001 sampling of Vail Engineering. USGS water analyses will be reported separately as part of the Questa pre-mining study. Water-quality samples have been collected on the Red River from 1965 to the present. The location with the longest period of record for water-quality data is the Questa Ranger Station, where there has been continuous streamflow-gaging by the USGS since October 1, 1924. The USGS streamflow-gaging station is located downstream of the Molycorp Mine in Questa, New Mexico (figure 1). Because of the long-term water quality and flow record, the historical surface water data compilation has focused on the Questa Ranger Station. In addition, data from locations upstream of the mine site and downstream of natural scar areas are also included in the compilation.

The historical surface-water quality data for the Red River are contained in Federal and State agency reports, consultant reports, and on computer files or databases that are not associated with any report. One of the main purposes of compiling and evaluating the historical surface-water quality information is to gather all the data in one document and to describe its quality. Vail Engineering, URS, and other, under contract to Molycorp, have compiled historical surface-water quality data in the past. However, not all parameters were reported, a comprehensive evaluation of the methods used to collect and analyze the samples was not conducted, geochemical interpretations were not included, and/or the data were not evaluated with respect to water flow dynamics. In addition, the review and evaluation presented herein was conducted by the USGS, who is independent of the mine. For this report, original sources were reviewed for information on collection and analysis methods, and the data were gathered from these original sources. Once compiled and evaluated for quality, the historical surface water quality data is useful for evaluating chemical, temporal, and spatial trends and for establishing an historical framework for the more recent surface-water quality data collected by the USGS.

Water-quality sampling events, locations, and parameters are presented in table 1. The US HEW and the US EPA conducted water-quality sampling on the Red River, its tributaries, and the Rio Grande in the mid-1960's to the mid-1970's. NMED and Vail Engineering, under contract to Molycorp, Inc., collected the majority of the water-quality samples on the Red River and its tributaries in the 1980's and 1990's. The source of the data, and, if available, the author of the report containing the data, are listed in table 1. Table 1 shows that when metals were determined on Red River and tributary samples, the most common analyte suite was Al, Fe, Mn, and Zn. For a number of sampling events, sulfate was the only anion determined. Flow was usually only available for samples collected at the Questa Ranger Station, although the USGS streamflow-gaging station located upstream of the town of Red River (Zwergle Gage, see figure 1), operated from May 1, 1963 to December 31, 1973. Water-quality samples were collected from the Zwergle Gage location on the Red River in 1997 and 1998 (Allen and others, 1999).

Sample collection, preservation and analysis methods, laboratories, and quality assurance/quality control (QA/QC) plans used for surface-water quality sampling are presented in table 2. When a document containing surface-water quality information was associated with the analytical data, it was reviewed for sample collection, preservation, and analysis methods and other quality control issues. The references for the documents are listed in both tables 1 and 2, and full citations can be found in the reference section at the end of this report. For several documents and sampling events, not all QA/QC information was available; for these instances, the entries are left blank in table 2.

In table 2, the collection methods column includes frequency of sampling for a given sampling event, whether samples were composited, whether replicate field samples were collected, where in the stream the samples were collected (e.g., mid-depth), whether samples were collected by pump or grab, and whether the sampling was synoptic. Most of the samples collected before the mid-1980's were unfiltered (although Faith, 1974 of the New Mexico Institute of Mining and Technology is an exception to this). If samples collected before the mid-1980's were filtered, the filtration was for suspended sediment and metals, most notably suspended aluminum and iron. When filtering was conducted, 0.45-µm filters were used; no historical water-quality samples were filtered through 0.1-µm filters. Similarly, preservation of samples was not common before the mid-1980's (again, Faith, 1974 is an exception to this). Unfortunately, Faith did not collect any samples at the Questa Ranger Station.

Table 2 also lists analytical methods used to determine metals and other parameters. Samples collected in the 1960's and early 1970's used colorimetric or flame atomic-absorption spectrometry (AAS) for determination of metals, and consequently, high detection limits were common. However, Faith, (1974) used graphite-furnace AAS for the determination of trace metals, iron and manganese. Standard Methods (APHA/AWWA, 1975) and US EPA methods (US EPA, 1979) were used by NMDGF (Jacobi, Smolka, and Tague, 1984, 1986, 1987, 1989, 1993) since the mid-1980's. Allen and others (1999) of the University of New Mexico, was the only report in which inductively-coupled argon-plasma spectrometry-mass spectrometry (ICP-MS) was used for determination of trace metals; other sampling efforts generally used inductively-coupled argon-plasma spectrometry (ICP) for determination of trace and minor metals.

Table 2. Sampling Events, Dates, and Analyses.

Table ~~1~~ 2. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
US HEW, 1966	11/3-8/1965	HEW	Alk, As, Ca, Cl, Fe, Mg, NO_3, Pb, pH, SC, SO4, TDS, TSS, Zn	Yes	Red River (5 locations)	
Molycorp, Inc., 1979	1/31/1966 - 9/1979	USGS, BLM, Molycorp, NMEID (outfalls)	Ca, Cd, Cu, F, Fe, Mg, Mo, Mn, SO_4, TDS, TSS, Zn	Red River at Fish hatchery, Red River at mouth, outfalls	Red River (7 locations); Red River at fish hatchery; outfalls 001, 002, 003; wells below tailings dam	Tested for CN in Red River
US EPA, 1971	11/2-5/1970	EPA	Alk, Al, As, Ca, Fe, Mg, NO_3, Pb, pH, SC, SO_4, TDS, TSS, Zn	Yes	Red River (5 locations)	
Thorne Ecological Institute, 1972	Surface water: June, July, August, Sept 30, Oct, Nov 1971; Jan 15, Feb 26, Mar 25, Apr 30 1972. Biology: May 17, June 23, July 28, Sept 3, October 8, Nov 14, 1971.	Thorne Ecological Institute	Ag, As, B, Ba, Be, Bi, Cd, coliform, Cr, Cu, CO_3, DO, Ga, Ge, hard, Hg, La, Mn, Mo, Nb, Ni, Pb, pH, PO_4, Se, SO_4, T, turb, TSS, Zn	Yes	Red River (6 locations, not Ranger Station), mine drainage, Sulfur Gulch, tailings pond influent/effluent, Pope Lake, north drainage, 2 wells. Biology: 4 on Red River, 1 in Pope Creek (settling pond effluent).	In some cases sampled immediately after a storm event or tailings break.
Pennak, 1972	Oct.8-9, 1971	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Pope Cr; State Fish hatchery. Pope Cr (settling pond effluent).	
Pennack, 1976	October 5-6, 1976	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery. Pope Cr (settling pond effluent).	Compared to October 8-9, 1971 sampling (in Pennack, 1972), which occurred the day after a tailings break.

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Pennack, 1977	March 12-13, 1977	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery. Pope Cr (settling pond effluent).	March 1977 sampling in response to March 8 tailings break.
Pennak, 1978a	March 29-30, 1978	Pennak	DO, DIM, DOM, "free/bound CO2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery. Pope Cr (settling pond effluent).	No chemical data -- results similar to earlier samplings. Macroinvertebrate density given.
Pennak, 1978b	March 29-30 and July 25-26, 1978	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery. Pope Cr (settling pond effluent).	26 July 1978: "extremely heavy pollution load" observed at Station 1 - no rain, assume light tan particles from streamside construction upriver.
Pennak, 1979	August 5-6 and September 9-10, 1979	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery (up/down); mouth of RR. Pope Cr (settling pond effluent).	Highest runoff in 40 years in spring/summer 1979.
Pennak, 1981	July 18-19, 1981	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery (up/down); mouth of RR. Pope Cr (settling pond effluent).	1981 runoff below normal. Tailings still embedded but better than 1979. Goat Hill and Eagle Rock locations only continuing "problems."

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Pennak, 1983	October 20-22, 1982	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery (up/down); mouth of RR. Pope Cr (settling pond effluent).	No macroinverts collected at Station 7 (0.4km upstream of Rio Grande) - river too deep. Pope Cr not sampled - dry. Quintiplicate macro samples taken.
Pennak, 1984	October 18-20, 1983	Pennak	DO, DIM, DOM, "free/bound CO_2", imbeddedness, pH, T, TSS, turb	No	Red River: Molycorp line; Eagle Rock CG; Goat Hill CG; Pope Cr; State Fish hatchery (up/down); mouth of RR. Pope Cr (settling pond effluent).	Sampled Big and Little Arsenic Springs (east wall Rio Grande 2-3mi upstream of Red River) - results in separate report Dec 1983.
Faith/NM BMMR, 1974	6/4-6/1974	Faith	Al, Alk, Ca, Cl, Cu, Eh, Fe, K, Mg, Mo, Mn, Na, Ni, pH, SO_4, Sn	Yes	Red River (Where???not Ranger Station), spatial and diel variability	spatial (horizontal across stream) and temporal (diel) variability examined
US EPA, 1982	9/5-14/1980	EPA	Alk, Ag, Al, As, Cd, Cr, Cu, DO, Ni, NO_3, Pb, pH, SC, TDS, TOC, TSS, turb, Se, Zn	No	Red River (8 locations, not including Ranger Station)	
Jacobi and Smolka, 1984	1/25-27/1984	NMED	Ag, Al, Alk, As, Ba, Cd, Cr, Cu, DO, Hg, K, Mg, Mo, Mn, Na, Ni, NO_3, Pb, pH, SC, Se, SO_4, T, TDS, turb, TSS, Zn	No	Red River (7 locations), Cabresto Cr, Red River POTW	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Garn, 1985; WATSTOR	10/17/78 - 12/24/86	USGS	Alk, Ca, Cd, Cl, Cu, CN, DOC, F, Fe, K, Mg, Mn, Mo, Na, nutrients, pH, SC, SO_4, TDS, TSS, Zn	Yes	Red River (7 locations), Cabresto Creek	
Smolka and Tague, 1987	2/27/86, 8/18-21/1986	NMED	Ag, Al, Alk, As, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Mo, Mn, Na, Ni, Pb, pH, SC, Se, SO_4, TDS, turb	No	Red River (4 locations), Rio Grande, Cabresto Cr	Runoff event Aug 18, 1986 in arroyo and at WWTP
Smolka and Tague, 1989	3/25/1988	Smolka and Tague	Ag, Al, As, Ba, Cd, Cr, Cu, Fe, Hg, Mo, Mn, Ni, Pb, pH, SC, Se, TDS, TSS, turb, Zn	No	Red River (8 locations), Goose Cr, Bitter Cr, Pioneer Cr, Columbine Cr	rainstorm event Bitter Cr - total and diss metals; seepage study from Zwergle Dam and Ranger Station
US EPA, 1988	~9/21/1988	EPA	Alk, Cl, hard, NH_3, pH, salinity, SC	No	Red River (5 locations, including Ranger Station), Bitter Creek	24-hr bioassays w/ adult Daphnia pulex and fathead minnow embryos (<18-hr old); chem results are from day 0 of tests
ENSR, 1988	October 10 - 12, 1988	ENSR	Al, Alk, Ba, Cd, Cl, Cu, DO, Fe, Mo, Mn, Pb, pH, SC, SO_4, T, TDS, TSS, turb, Zn	No	7 stations on Red River (Incl. Ranger Station), 1 on Pope Creek.	benthic and algal populations, density, diversity, benthic community indices
NMED, 1992	4/9/1991	NMED	Ag, Al, Alk, As, B, Ba, Be, Ca, Cd, chl-a,b,c, Cl, Co, Cr, Cu, DO, Fe, Hg, K, Mg, Mo, Mn, Na, Ni, NO3, Pb, pH, PO_4, SC, Se, Si, SO_4, Sr, T, TDS, turb, V, Zn	No	Fawn and Eagle Rock Lakes	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Smolka and Tague, 1989	9/13-26/1988, 10/25/1988	NMED	Ag, Al, Alk, As, Ba, Cd, Cr, Cu, Fe, Hg, K, Mg, Mo, Mn, Na, Ni, Pb, pH, SC, Se, SO_4, TDS, turb, TSS, Zn	No	Red River (6 locations), Columbine Cr, Rio Grande	
Vail Eng., 1989	11/4/65, 11/4/70, 8/20/81, 7/26/88, 11/29/1988 (11/29/88 also in App I Vail 1993)	Vail Engineering	Al, As, Fe, Mn, Pb, Zn (11/20/88 only); Alk, F, pH, SO_4, TDS, turb, TSS	at Ranger Station only	Red River (14 locations), Pioneer Cr, Columbine Cr, Eagle Rock Lake	7/26/88 - short thunderstorm
NMED, 1993 and Storet	2/26 - 12/16/1992	NMED	Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mo, Mn, Ni, Pb, Se, Sn, Sr, V, Zn (2/26, 3/25, 4/29 only); Alk, Ca, Cl, K, Mg, Na, NO_3, pH, SC, SO_4, TDS, turb, TSS	No	Red River (8 locations)	
Vail Eng., 1993	7/25/1992	Molycorp	Al, Ca (limited), Cd, Cu, F, Fe, Mg, Mo, Mn, Pb, pH, SO_4, TDS, TSS, Zn	Yes	Red River (17 locations), Eagle Rock Lake, Columbine Cr	Rainstorm event July 25, 1992
Vail Eng., 1993	10/22/1992	Vail Engineering	Al, Alk, F, Fe, Mn, pH, SC, SO_4, TDS, turb, TSS, Zn	Yes	Red River (17 locations), Columbine Creek	
Vail Eng., 1993	2/16/1993	Molycorp	Al, Alk, F, Fe, Mn, pH, SC, SO_4, TDS, TSS, Zn	Yes	Red River (11 locations)	
URS/EPA	4/12/1993	Vail?	Al, Alk, Cd, Cu, Fe, Mo, Pb, pH, SO_4, TDS	No	Red River	remove?
Vail File	11/10/1993	Vail Engineering	Al, Alk, F, Fe, Mn, pH, SC, SO_4, TDS, TSS, Zn	at Ranger Station only	Red River (21 locations), Columbine Creek	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
URS, 2001	Nov-93	Vail Engineering	Al, Cu, Fe, Mn, SO_4, Zn	No	Red River	
Vail File	2/11/1994	Moly	Al, Alk, F, Fe, Mn, pH, SC, SO_4, TDS, TSS, Zn	at Ranger Station only	Red River (12 locations)	
SPRI, 1995	5/15/94, 10/13/1994	Vail Engineering	Al, Alk, Ca, Cd, Cl (5/15 only), Cu, F, Fe, K, Mg, Mo, Mn, Na, Pb, pH, SC, SO_4, TDS, TSS, Zn	at Ranger Station only	Red River (22 locations), Bitter Creek, Hanson Creek, Columbine Creek, Cabin Spring	
Woodward Clyde, 1994; Kent, 1995	6/26/1994	Woodward Clyde (field params); NMED	Al, Alk, Ba, Ca, Co, Hg, Mg, Mn, NO_3, Pb, pH, SC, SO_4, TDS, TOC, TSS, Zn	No	Red River (3 locations), Capulin Canyon drainage, Hansen Cr, Goathill seep	
MC CD	6/27/1994	?	Ag, Al, Alk, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mo, Mn, Ni, NH_3, Pb, Sb, Se, Tl, V, Zn	No	Red River -- where else??	
Woodward-Clyde, 1996; Vail File; Kent, 1995	11/7-8/1994	NMED	Ag, Al, Alk, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mo, Mn, Ni, Pb, pH, Sb, SC, Se, SO_4, TDS, Tl, TSS, V, Zn	At six location on Red River	9 Red River locations (not Ranger Station), Columbine Creek	
Vail File	2/14/1995	Vail Engineering	Al, Alk, F, Fe, Mn, pH, SC, SO_4, TDS, TSS, Zn	at Ranger Station only	Red River (22 locations), Columbine Creek, Cabin Spring	
Woodward-Clyde, 1996	11/9/1995	Vail Engineering, WC	Ag, Al, Alk, As, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, NO_3, Pb, pH, Sb, SC, Se, SO_4, TDS, Tl, TSS, turb, V, Zn	at Ranger Station only	Red River (20 locations), Bitter Creek, Hanson Creek, HautNTaut, Columbine Creek, mine water, 4 springs	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Vail File	2/26/1996	Vail Engineering	Al, F, Mg, Mn, pH, SC, SO_4, Zn	at Ranger Station only	Red River (21 locations), Portal Spring, Columbine Creek, Cabin Spring, Cabresto Creek	
Vail File	11/5/1996	Vail Engineering	Al, Mg, Mn, pH, SC, SO_4, Zn	No	Red River (20 locations), Hanson Creek, Columbine Creek, 5 springs	
Vail File	3/13/1997	Vail Engineering	Al, Mg, Mn, pH, SC, SO_4, turb, Zn	at Ranger Station, Hanson, springs only	Red River (24 locations), Hanson Creek, Columbine Creek, 6 springs, Cabresto Creek, Sawmill Creek, 4 wells	
Allen et al., 1999	13/5 dates for 3/2 locations between 6/10/97 and 7/16/98	NMBMMR, UNM	Al, Alk, Ca, Cd, Cl, Co, Cu, DO, Eh, F, Fe, K, Mg, Mn, Na, Ni, NO_3, pH, SC, SO_4, T, Zn	Yes	Red River (5 locations -- not Ranger Station), Columbine Creek	
Allen et al., 1999	2/21/98, 7/16/98, 10/22/1998	NMBMMR, UNM	Al, Co, Cu, Fe, Mn, Mo, Ni, Zn	No	6 Red River locations - sediment grab samples	
Allen et al., 1999	7 dates between 8/14/97 and 4/29/98, 9/19/97, 6/4/98	NMBMMR, UNM	Al, Co, Cu, Fe, Mn, Mo, Ni, Zn	No	5 Red River locations, Eagle Rock, Fawn Lakes - sediment trap samples	
Allen et al., 1999	9/19/97, 7/16/98, 10/22-23/98	NMBMMR, UNM	Al, Co, Cu, Fe, Mn, Mo, Ni, Zn	No	4 Red River locations - terrace sediment samples	
Allen et al., 1999	Jan-98	NMBMMR, UNM	Al, Co, Cu, Fe, Mn, Mo, Ni, Zn	No	Eagle Rock, Fawn Lakes - sediment core samples	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Allen et al., 1999	8/15/97 - 10/23/98	NMBMMR, UNM	Al, Co, Cu, Fe, Mn, Mo, Ni, Zn	No	Capulin Canyon, Hansen Creek, Columbine Creek, Goathill Gulch, 2 Red River locations - crust, cement, sediments assoc w/ scar areas	
Allen et al., 1999	1997/1998	NMBMMR, UNM	Mn,Cu,Zn	No	5 Red River locations - tree ring samples	
Vail File	6/10/97 - 7/16/98	Vail Engineering	Al,Fe,Mn,Zn	at Ranger Station only	Red River (6 locations; Ranger Station has flow but no chemistry), Columbine Cr	
Vail File	7/21/1997	Vail Engineering	Al, Alk, Mg, Mn, pH, SC, SO_4, turb, Zn	No	Red River (24 locations), Hanson Creek, Columbine Creek, Bear Creek, 6 springs, 3 wells	
Vail File; URS, 2001	9/9/1997	Vail Engineering, URS (flow only)	Alk, F, Fe, Mg, Mn, pH, SC, SO_4, TDS, TSS, turb, Zn	Ranger Station (URS), Hanson Cr (est)	Red River (25 locations), Hanson Creek, Columbine Creek, Bear Creek, Mallette Creek, 4 springs, 4 wells	
Vail File; URS, 2001	11/3/1997	Vail Engineering, URS (flow only)	Al, F, Mg, Mn, pH, SC, SO_4, Zn	Ranger Station (URS)	Red River (19 locations, 15 field params only), Hanson Creek, Cabin Springs, mine water, 3 wells	
Vail File; URS, 2001	3/9/1998	Vail Engineering, URS (flow only)	Al, F, Mg, Mn, pH, SC, SO_4, Zn	Ranger Station (URS)	Red River (22 locations, only 6 w/ metals, Columbine Creek, 5 springs, mine water, 5 wells	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Vail File	4/30/1998	Vail Engineering	Cu, F, hard, Mn, pH, SC, SO_4, TSS, Zn	No	Red River (21 locations, 5 field params only), Bitter Creek, Columbine, Mallette Creek, 4 springs, mine water, 3 wells	
Vail File	8/27/1998	Vail Engineering	pH, SC	borehole only	Hanson Creek, Hanson trib, borehole only	
Vail File	10/20/1998	Vail Engineering	Al, Zn, Mo, Cu (Red River and wells only); F, pH, SC, SO_4	10 Red River stations, Columbine, Bear Creek	Red River (24 locations, only 3 w/ metals), Columbine Creek, 2 wells, Bear Creek	
Vail File	2/25/1999	Vail Engineering	pH, SC, SO_4, turb	No	Red River (23 locations); 2 springs, Columbine Cr, mine water (pH, SC only)	
Vail File	9/27/1999	Vail Engineering	SC	No	Red River (17 locations), Columbine Creek, 6 wells	
Vail File; Vail Eng., 2000; URS, 2001	10/13/1999	Vail Engineering, URS (flow only)	Mn, Al, Zn (6 Red River, 3 springs, 4 wells); F, Mg, pH, SC, SO_4	8 Red River stations, Columbine Cr, South Ditch	Red River (23 locations), Columbine Cr, Mallette Cr, Pioneer Cr, 3 springs, 6 wells	
Vail File; URS, 2001	3/15/2000	Vail Engineering, URS (flow only)	Al, F, Mg, Mn, pH, SC, SO_4, turb, Zn	13 Red River stations, Columbine Cr	Red River (22 locations), Columbine Cr, Bear Cr, 5 springs, 4 wells, mine water	
Kent/NMED, 1995	6/26-27/94, 11/7-8/1994	NMED	Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Co, Cu, Fe, Hg, K, Mg, Mn, Ni, Pb, pH, SC, Sb, Se, T, Tl, V, Zn	No	Red River (7 locations - not Ranger Station), Columbine Creek, 5 seeps	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
Robertson Geoconsultants, 2000b	3/24/00 - 11/06/00	RCG?	Ag, Al, Alk, As, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, K, Mg, Mn, Mo, Na, Ni, NO_3, Pb, pH, Sb, SC, Se, SO_4, T, Tl, TDS, TSS, V, Zn	Yes	Red River (15 locations); Bitter, Columbine, Hottentot, Straight, Little Hansen, Pioneer, Capulin creeks; springs; wells; mine water	Diurnal variability Straight, Hansen Cr. (Apr 16, 2000). Season trends , thunderstorm events (7/18/00 and 8/6/00)
Medine, 2000; MC CD	5/1-12/2000	HydroQual? RGC????	Al, Alk, Ca, Cd, Cl, Co, Cu, F, Fe, K, Mg, Mn, Mo, Na, Ni, NO_3, Pb, pH, SC, SO_4, TDS, TSS, Zn	9 Red River locations, Bitter Cr, Columbine Cr	Red River (10 locations), Bitter Cr, Columbine Cr, 1 seep	
Vail File	9/6/2000	Vail Engineering	Al, Mn, Zn (6 Red River, 1 springs, 3 wells); F, pH, SC, SO_4	16 Red River, Columbine Cr, Pioneer Cr	Red River (23 locations), 1 spring, Columbine Creek, Pioneer Cr, 3 wells	
Vail File	11/3/2000	Vail Engineering	Al, Zn (6 Red River, 4 wells); Alk, F, pH, SC, SO_4	13 Red River stations, Columbine Cr	Red River (23 locations), Columbine, 4 wells	
Vail File	2/20/2001	Vail Engineering	Al, Cu, Mn, Mo, Zn (9 Red River, 2 springs); F, Mg, pH, SC, SO_4, TDS	13 Red River stations, Columbine Cr, Mallette Cr	Red River (17 locations), Columbine Cr, Mallette Cr, 3 springs, 3 wells	
MC CD	5/22/2001, 8/21/2001, 11/12/2001	?	Ag, Al, Alk, As, Ba, Be, BOD, Ca, Cd, Cl, COD, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, NO_3, Pb, pH, SC, Se, SO_4, T, TDS, V, Zn	Ranger Station - others?	Ranger Station - others?	

Table 1. Sampling Events, Dates, and Analyses.

Reference	Sample Event Dates	Collected by	Water Quality Parameters	Flow with Sampling	Locations	Special sampling events
URS, 2001	1994-99	Molycorp, NMED/WCC, SRK, RGC	Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, V, Zn (just had Yes for conventional/field parameters -- check on this)	No	Red River, ABA, shake flask, paste pH, mine rock TAL, TCLP, rinse pH/cond	
Woodward Clyde, 1994	6/26-28/1994	NMED	Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Co, Cu, Fe, Hg, K, Mg, Mn, Ni, Pb, pH, Sb, SC, Sb, Se, T, Tl, V, Zn	No	Red River (7 locations - not Ranger Station), Columbine Creek, 5 seeps	
Woodward Clyde, 1996	4/18-27/1994, 6/26-28/94, 11/7-8/1994, 5/9/1995	NMED	Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Ni, Pb, pH, Sb, SC, Se, T, Tl, V, Zn	No	Red River (7 locations - not Ranger Station), Columbine Creek, 5 seeps	

Table 3. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Table ~~2~~ 3. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
US HEW, 1966	Grabs every 9 hrs, composited at 2-hr intervals, composited 3 8-hr interval samples	No		APHA/AWWA, 1965. SO_4: turbidimetric; hard: EDTA titration; Fe, Zn,As,Pb: colorimetric	New Mexico State Public Health Lab, Albuquerque, NM	No	High detection limits for Pb, Zn
US EPA, 1971	Composite samples: every 2 hrs for 8 hrs; 1 24-hr sampling in 3 8-hr segments. Bacteriological: collected in sterile, glass bottles. Surber sampler, sieving for macroinvertebrates.	TDS only	Bacteria: ice; macroinvertebrates: 5% formalin.	APHA/AWWA, 1971. Fe, Pb:colorimetric, Zn:AAS, Total, fecal coliform, fecal streptococci. Benthics hand-picked and sugar flotation technique, keyed, classed as clean water, faculatative, or tolerant.	New Mexico State Health Department Laboartory, Albuquerque, NM	No	
Thorne Ecological Institute, 1972	No information on water methods; macroinvertebrates: Surber sampler; periphyton scraped from rock w/ sharp scalpel for 5-10 minutes from 3-8 rocks/location.	Assume unfiltered	Periphyton: formalin.	As,B,Mo,Se,CN,NO_3,PO_4-colorimetric; Hg-cold vapor; Ba,Cl-titration; Cd,Pb- APDC extraction/flame AAS; Cr,Cu,Fe,Mn,Zn - flame AAS; sulfate, TSS - gravimetric. US EPA 1979a; APHA/AWWA, 1971; USGS, 1970	Geolabs, a division of Natural Resources Laboratory, Inc., Lakewood CO	No	High detection limits for colorimetric methods. Data available only for Sept 1971 and all dates in 1972.
Faith, 1974		0.45 µm	HNO_3	SO_4: gravimetric; Cl: $HgNO_3$ titration; Na,K,Mg: AAS; Ca: EDTA titration; Fe,Mn,Al,Cu,Ni,Sn: GFAAS; Mo,SiO_2: colorimetric; filter residue digested.	Assume NM Institute of Mining and Technology	No	

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Pennak, 1976		Suspended samples only				No	More focus on benthics than water quality. No metals determined. Also sampled on 17 May 1971.
Pennak, 1977		Suspended samples only				No	
Pennak, May 1978		Suspended samples only				No	Assumes "thin yellowish-tan chemical deposit" above the Eagle Rock from Molycorp operations (pg. 1). Noted reduction in macroinverts at Eagle Rock, some coated with precipitate (pg. 2).
Pennak, Oct 1978		Suspended samples only				No	Now state yellowish-tan chemical deposit is naturally-occurring. Note improvement in 1978 conditions.

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Molycorp, Inc, 1979		Some dissolved measure-ments			Outfall samples by State Scientific Laboratory and University of Colorado's Molybdenum Project in Boulder, CO.	No	Monthly record of flow, Cu, Zn at fish hatchery from 1/31/66 - 4/27/99 and Red River mouth from 1/4/66 - 5/14/69. In outfall 001, 002, 003 flow, CN. Outfall 001 (decant water tailings) permit violations for CN, F, Fe, foam; 002 for Mn. High Mo concs in outfalls 001, 002 (1430-3200 µg/l) in 1975. High Mo concs up/downstream hatchery in late '70s (BLM data).
Pennak, 1979		Suspended samples only				No	Productivity in 1979 very low compared to other years. Natural stream "catastrophe" of much greater magnitude than man-made events(pg. 11).

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Pennak, 1981		Suspended samples only				No	More species found at most locations. The stream is now in "better biological shape" than at any previous time sampled.
USEPA; Melancon et al., 1982	Triplicate grabs at mid depth; ISCO: 24-hr composites at 1-hr intervals for metals (8 3-hr composities)	0.45-µm	ICP metals: Ultrex HNO_3; see Table 4 for volumes, preservation; Table 3 for specs; Table 5 for methods, precision/accuracy	ICP-AES	UCLA - metals Biomedical and Environmental Science Lab.; EMSL-LV for field params	No	Arsenic method unreliable; high Cd and Ag detection limits.
Pennak, 1983		Suspended samples only				No	1982 summer frequent/heavy rains - flows in Oct ~2x "normal," similar to 1979 summer; lowest variability in pH (7.5-7.7) at all stations; macroinvertebrate species slowly increasing.

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Pennak, 1984		Suspended samples only				No	Highest, longest spring runoff sampled; Red River warmer than usual; substrate had higher % rubble, small rubble (1-4in) reduced; formed sand and gravel bars.
Jacobi and Smolka, 1984	1-L polyethylene cubitainers cleaned in 10% v/v HCl, pre-rinsed with sample water. Surface water collected 6x during a 45-hr period beginning on Jan 25, 1984; chain-of-custody used.	No	H_2SO_4 for nitrate/phos; TSS,TDS refrig; Mg,Na,K,Cl,SO_4,HCO_3,alk refrig (no acid); As,Ba,Cd,Pb, Hg,Mo,Se,Zn HNO_3+ice	APHA/AWWA, 1975; USEPA, 1979a	Scientific Laboratory Division, Albuquerque	NMEID, 1982	
Smolka and Tague, 1987	Turb: 250-mL clean polypropylene bottles; 1-L polyethylene cubitainers for nutrients, TSS, TDS, major cations/anions, trace metals; pre-rinsed with sample water; chain-of-custody forms used.	Mg, Ca,K,Na dissolved; 2/27/86 sample total and dissolved metals	Nutrients: H_2SO_4, 4°C; anions: 4°C; turbidity: 4°C; metals: HNO_3; CN: pH 12, NaOH	US EPA, 1979a; FR, 1979; US EPA, 1982	Scientific Laboratory Division, Albuquerque	NMEID, 1986	

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
U.S. EPA, 1988		No	On ice at 4°C	No information given; bioassays: EPA, EPA/600/4-85/013, 1985.	Inorganic Laboratory, US EPA, Houston, Region VI	No	Results from day 0 of bioassay tests
ENSR, 1988	Surface water: 1-L containers, mid-depth in thalweg; Macroinvertebrates: Surber sampler or net; rocks scraped with pocket knife.	Suspended and dissolved.	On ice, acidified to pH 2 w/ HNO_3 at lab; periphyton preserved w/ 5% formalin	Detection limits (µg/l) = Cd 5; Pb 50; Mo 20; Cu 10; Al 500, Ba 500. No information on methods.	Molycorp's on site analytical laboratory for surface water	No	High detection limit for Pb
Smolka and Tague, 1989	Turb: 250-mL clean polypropylene bottles; TSS, TDS, major cations/anions, trace metals: 1-L polyethylene cubitainers.	0.45-µm Millipore	Nutrients: H_2SO_4, 4°C; anions: 4°C; turbidity: 4°C; metals: HNO_3; CN: pH 12, NaOH	Turb: Hach 2100A Turbidimeter; seds screened through 2-mm screen: EP Toxicity test; others same as Smolka and Tague, 1987; APHA/AWWA, 1975; US EPA, 1979a	Scientific Laboratory Division, Albuquerque	NMEID 1986	
Vail Engineering, 1989	17 samples over a 12-mi segment of river - synoptic over 4 hrs.	Yes	NA	NA	Assay Laboratory at Questa Mine	No	
NMED, 1992	Turb: 250-mL clean polypropylene bottles; Nutrients, TSS, TDS, major cations/anions, trace metals: 1-L polyethylene cubitainers; fish, macroinvertebrates, diatoms sampled.	filtered and unfiltered samples	Nutrients: H_2SO_4, 4°C; anions: 4°C; turbidity: 4°C; metals: HNO_3	US EPA, 1979a; FR, 1979; US EPA, 1982	Scientific Laboratory Division, Albuquerque	NMED, 1991	only in Fawn Lake and Eagle Rock Lake - fed by water from Red River

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
NMED; L.R. Smolka for Red River portion, 1993	Turb: 250-mL clean polypropylene bottles; nutrients, TSS, TDS, major cations/anions, trace metals: 1-L polyethylene cubitainers.	Yes	Nutrients: H_2SO_4, 4°C; anions: 4°C; turbidity: 4°C; metals: HNO_3	US EPA, 1979a; FR, 1979; US EPA, 1982	Scientific Laboratory Division, Albuquerque	NMED, 1991	
Vail Engineering, 1993		Al only			Assay Laboratory at Questa Mine	No	
Woodward-Clyde, 1994	Collected splits from NMED (June 1994) - pre-preserved sample bottles	Same as Kent, 1995	Same as Kent, 1995	Same as Kent, 1995	ETC Northwest, Redmond, WA	CLP methods, TAL list	Field observations of NMED June 1994 sampling event, review of Kent, 1995
Kent, 1995	1-L HDPE bottles, 250-mL beaker, plastic scoop, or tygon tubing for collecting seep water; split w/ Woodward-Clyde. Decontaminated beakers with Alconox between samples; used chain of custody; measured pH w/ litmus paper; duplicate/blank samples.	Yes; did not decontaminate w/ HNO3 between samples	HNO_3 to pH 2 for TAL list, H_2SO_4 for general chem, on ice	CLP for TAL list; Alk: SM2320B; NH_3: EPA 350.2; Cl: EPA 325.3; COD: EPA 410.4; NO_3/NO_2: EPA 353.2; PO_4/P: EPA 365.3; SO_4: EPA 375.4; TDS/TSS: EPA160.1/160.2; DOC: EPA 9060	Silver Valley Labs, Kellogg, ID	CLP methods, TAL list. Work plan: NMED 1994.	Blew into 4-L cubitainers before filling; did not decontaminate filtration device between samples
SPRI, 1995		Al only			Molycorp's on site analytical laboratory for surface water	No	

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Woodward-Clyde, 1996	Collected splits from NMED (June 1994) - pre-preserved sample bottles	Same as Kent, 1995	Same as Kent, 1995	Same as Kent, 1995	ETC Northwest, Redmond, WA	CLP methods, TAL list	
Allen et al., 1999	Stream samples: peristaltic pump; equipment blanks, field replicates, chain-of-custody. Used sediment traps. Alluvium: natural scar areas. Fe coatings: low -pH seeps; cemented fluvial sand/gravel: <100 mesh. Al crusts: removed w/ polypropylene spatula and using peristaltic pump over floc.	0.45-µm in-line Gelman	HNO_3 for metals, on ice for anions	Major cations: flame AAS; anions: Dionex-500X; trace metals: ICP-MS. Sed samples dried, 100-mesh sieve, Digestion using 1:1:1.5 mix of HNO_3, $HCLO_4$, HF. Standard calibration curves basalt working standard UNM B1. Spiked samples.	University of New Mexico	No	
Vail Engineering, 2000	Synoptic sampling, samples collected mid-stream, in upstream direction; botles filled with mouth pointing upstream; chain of custody used.	Filtered at the lab within 20 hrs of collection	Iced after collection;preservation at laboratory within 20 hrs of collection		CDS Labs, Durango, CO (now Acculabs, Inc.)	No	

Table 2. Sample Collection, Preservation, and Analysis Methods, Laboratory, and Quality Control Plans.

Reference	Collection Methods	Filtered?	Preservation	Laboratory Methods	Laboratory	QAPP?	Comments
Robertson Geoconsultants Inc., 2000b	Dupes, equip blanks, chain-of-custody, field blanks; See work plan RGC report 052008/1 for details.	0.45-µm, disposable syringe and in-line filters	Metals: HNO_3; anions: on ice. See RGC report 052008/1	See appendix B RCG report 052008/6	ACZ, Steamboat Springs (Mar-Jun 2000); after ~mid-June 2000 Paragon Analytics Inc. Some splits to ACZ and Molycorp Lab for AZ/AC for F.	Final QA/QC analysis will be completed at end of 2000 field season. See RGC report 052008/1.	Found thunderstorm generated more contaminant loading than snowmelt event
Garn, 1985	Sampled ~10x/yr ~ monthly; winter bimonthly; spring runoff - near peak flow and rising and falling stages; event samples.	Yes	Yes	Skougstad, M.W. et al., 1979.	USGS laboratory in Denver, CO	No	data in WATSTOR
Medine, 2000				ICP		No	Don't have text for this doc - only tables and figures

Chemical analyses of surface-water samples were conducted at commercial, government, and university laboratories. Very few of the sampling efforts included sampling plans or QA/QC plans, such as quality assurance project plans (QAPPs). However, sampling performed by New Mexico State agencies usually did include a sampling or QA/QC plan.

Results

Table 3 contains the water-quality data for the Red River at the Questa Ranger Station from 1965 to 2001. A more limited set of water-quality data from stations upstream of the Questa Ranger Station but downstream of hydrothermal scar areas is also included in table 4. The source of the water-quality data is indicated in tables 3 and 4 and corresponds to the Reference columns in tables 1 and 2.

Criteria used to discriminate sampling events based on seasonal and storm event flows are defined in table 5 and used in tables 3 and 4. Rules were established to discriminate sampling events based on seasonal flows, as shown in the Definition column in table 5. Five hydrologic timings were defined: rising limb, peak, falling limb, storm, and low flow. Rising limb was defined as starting when flows first increased as a result of snowmelt (usually in April) and ending when flows reached 50 percent of the peak flow for that water year (WY). Peak flow was defined as starting and ending at 50 percent of peak flow on either side of the peak (usually late April/early May). Falling limb started after the peak when flows fell to 5 percent of peak values and ended when flows fell to 25 percent of peak values. Low flows started at 25 percent of peak flow after the peak and continued to the start of the rising limb the following year. Storm events are defined as increases in flow superimposed on the low flow portions of the hydrograph (summer thunderstorms). To determine percent of peak flow, average daily flows were compared to maximum daily discharge (peak flow). The relevant peak flow was defined as the previous peak. For example, if the sampling date was between October 1, 1999, and the start of the rising limb in 2000, the relevant peak flow for these dates would be the peak flow for 1999, not 2000. Relationships between the hydrologic timing (for example, low flow) and concentrations are discussed in the following section.

Table 4. Water-Quality Data at the Questa Ranger Station on the Red River from 1065 to 2001.

Table 8. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION	4	HEW	HEW,1966				11/03/65	Low Flow	26
RANGER STATION	4	HEW	HEW,1966				11/04/65	Low Flow	26
RANGER STATION	4	HEW	HEW,1966				11/04/65	Low Flow	26
RANGER STATION	4	HEW	HEW,1966	26.3			11/04/65	Low Flow	26
RANGER STATION		Vail	Vail, June 89	26.3			11/04/65	Low Flow	26
RANGER STATION	4	HEW	HEW,1966				11/07/65	Low Flow	25
RANGER STATION	4	HEW	HEW,1966				11/08/65	Low Flow	25
RANGER STATION	4	EPA	EPA, 1971				11/02/70	Low Flow	13
RANGER STATION	4	EPA	EPA, 1971				11/03/70	Low Flow	12
RANGER STATION	4	EPA	EPA, 1971	11.19			11/04/70	Low Flow	11
RANGER STATION		Vail	Vail, June 89	11.9			11/04/70	Low Flow	11
RANGER STATION	4	EPA	EPA, 1971				11/05/70	Low Flow	12
RANGER STATION	4	EPA	EPA, 1971				11/05/70	Low Flow	12
RANGER STATION	4	EPA	EPA, 1971				11/05/70	Low Flow	12
RANGER STATION		Vail Engineering	Molycorp 10-10-79				01/15/77	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				02/15/77	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				03/08/77	Low Flow	5.5
RANGER STATION		Vail Engineering	Molycorp 10-10-79				03/15/77	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				04/15/77	Rising Limb	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				05/15/77	Peak	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				06/15/77	Peak	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				07/15/77	Falling Limb	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				08/15/77	storm	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				09/15/77	storm	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION		Vail Engineering	Molycorp 10-10-79				10/15/77	storm	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				11/15/77	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				12/15/77	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				01/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				02/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				03/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				04/15/78	Rising Limb	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				05/15/78	Peak	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				06/15/78	Peak	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				07/15/78	Falling Limb	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				08/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				09/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				10/15/78	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	7.7		10:00	10/17/78	Low Flow	8.1
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	7.6		10:20	10/17/78	Low Flow	8.1
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	9.6		13:35	11/14/78	Low Flow	11
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	9.6		13:55	11/14/78	Low Flow	11
RANGER STATION		Vail Engineering	Molycorp 10-10-79				11/15/78	Low Flow	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION		Vail Engineering	Molycorp 10-10-79				12/15/78	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				01/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	6.8		10:00	01/16/79	Low Flow	6.8
RANGER STATION		Vail Engineering	Molycorp 10-10-79				02/15/79	Low Flow	
RANGER STATION		Vail Engineering	Molycorp 10-10-79				03/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	12		11:15	03/20/79	Low Flow	11
RANGER STATION		Vail Engineering	Molycorp 10-10-79				04/15/79	Rising Limb	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	131		8:35	04/26/79	Rising Limb	131
RANGER STATION		Vail Engineering	Molycorp 10-10-79				05/15/79	Rising Limb	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	359		12:50	05/23/79	Peak	378
Ranger Station			Molycorp 10-10-79				06/10/79	Peak	510.00
RANGER STATION		Obby Davidson	Molycorp 10-10-79				06/14/79	Peak	484
RANGER STATION		Vail Engineering	Molycorp 10-10-79				06/15/79	Peak	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	354		14:15	06/18/79	Peak	372
Ranger Station		Pamela	Molycorp 10-10-79				07/05/79	Falling Limb	249
Ranger Station		Obby Davidson	Molycorp 10-10-79				07/14/79	Falling Limb	162
RANGER STATION		Vail Engineering	Molycorp 10-10-79				07/15/79	Falling Limb	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	117		9:40	07/24/79	Low Flow	114

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
Ranger Station		Obby Davidson	Molycorp 10-10-79				07/27/79	Low Flow	103
Ranger Station		Obby Davidson	Molycorp 10-10-79				08/04/79	Low Flow	76
Ranger Station		Obby Davidson	Molycorp 10-10-79				08/10/79	Low Flow	78
RANGER STATION		Vail Engineering	Molycorp 10-10-79				08/15/79	Falling Limb	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	45		14:30	08/29/79	Low Flow	46
RANGER STATION		Vail Engineering	Molycorp 10-10-79				09/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	24		16:00	09/25/79	Low Flow	26
RANGER STATION		Vail Engineering	Molycorp 10-10-79				10/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	24		14:50	10/24/79	Low Flow	23
RANGER STATION		Vail Engineering	Molycorp 10-10-79				11/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	12		11:40	12/04/79	Low Flow	13
RANGER STATION		Vail Engineering	Molycorp 10-10-79				12/15/79	Low Flow	
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	14		13:30	12/17/79	Low Flow	14
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	13		14:30	12/17/79	Low Flow	14
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	13		11:55	02/07/80	Low Flow	13
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	17		15:30	04/02/80	Low Flow	15
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	38		18:30	04/28/80	Rising Limb	38
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	176		15:40	06/03/80	Falling Limb	176

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	82		16:00	07/09/80	Falling Limb	85
QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	32		16:45	08/14/80	Low Flow	31
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	46		9:00	09/10/80	storm	44
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	12		14:45	10/14/80	Low Flow	13
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	5		14:20	11/19/80	Low Flow	4.9
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	9.5		16:15	01/08/81	Low Flow	7.5
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	5.9		12:45	03/10/81	Low Flow	5.9
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	5		12:30	03/11/81	Low Flow	5.3
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	12		16:00	04/13/81	Rising Limb	12
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	19		16:30	05/14/81	Rising Limb	19
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	51		14:15	06/10/81	Peak	47
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	20		15:30	07/14/81	Low Flow	18
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	18		22:00	07/17/81	Low Flow	15
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	29			08/12/81	storm	28
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	19		16:00	08/13/81	storm	21
RANGER STATION		Vail	Vail, June 89	40			08/20/81	Low Flow	19
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	15		14:00	10/09/81	Low Flow	14
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	13		11:00	11/05/81	Low Flow	13

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	13		11:50	02/17/82	Low Flow	13
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	15		14:15	03/24/82	Low Flow	15
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	30		13:30	04/29/82	Rising Limb	29
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	131		15:00	06/02/82	Peak	137
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	76		15:00	07/06/82	Falling Limb	77
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	43		17:00	08/20/82	Low Flow	45
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	51		14:35	09/16/82	storm	52
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	32		16:00	10/19/82	Low Flow	35
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	21		16:45	12/07/82	Low Flow	19
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	22		16:30	02/08/83	Low Flow	17
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	81		15:00	04/26/83	Rising Limb	83
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	247		15:15	06/07/83	Peak	265
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	123		13:40	07/21/83	Falling Limb	116
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	47		13:00	08/31/83	Low Flow	46
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	14		11:15	11/04/83	Low Flow	17
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	9.1		14:30	01/10/84	Low Flow	7
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			1700	01/25/84	Low Flow	11
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			915	01/26/84	Low Flow	11

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			1240	01/26/84	Low Flow	11
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			1630	01/26/84	Low Flow	11
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			2145	01/26/84	Low Flow	11
RANGER STATION	HRG 24	Jacobi & Smolka	Jacobi and Smolka, 1984			1100	01/27/84	Low Flow	10
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	13		10:00	04/05/84	Low Flow	14
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	351		14:45	05/25/84	Peak	377
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	95		15:00	06/28/84	Falling Limb	92
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	18		13:30	09/27/84	Low Flow	22
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	8.8		10:00	01/16/85	Low Flow	13
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	332		10:00	06/12/85	Peak	320
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	93		14:00	07/12/85	Falling Limb	104
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	108		19:05	07/20/85	Falling Limb	102
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	33		14:00	10/29/85	Low Flow	32
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	12		16:00	12/20/85	Low Flow	10
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87			1415	02/27/86	Low Flow	17
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	114		14:30	05/22/86	Rising Limb	135
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	240		16:30	06/12/86	Peak	252
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87		storm	1630	08/18/86	Low Flow	42

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87			1055	08/19/86	Low Flow	40
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87			1545	08/19/86	Low Flow	40
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87			1120	08/20/86	Low Flow	38
RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, Oct 87			1535	08/20/86	Low Flow	38
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	44		15:30	08/26/86	storm	48
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	1100		22:00	09/07/86	Low Flow	39
RED RIVER NEAR QUESTA, NM	8265000	BLM	Garn, 1985; WATSTOR	25		13:00	12/24/86	Low Flow	27
16 RANGER STATION	HRG 24	Smolka & Tague	Smolka and Tague, May 89			1500	03/25/88	Low Flow	21
Ranger Station Gage		Molycorp	Vail, July 1989				07/26/88	Storm	37
16 RANGER STATION	3500	Smolka & Tague	Smolka and Tague, May 89		storm	1115	09/13/88	Storm	138
16 RANGER STATION	3500	Smolka & Tague	Smolka and Tague, May 89			1100	09/20/88	storm	57
Ranger Station	7	EPA	US EPA, 1988				09/21/88	storm	58
16 RANGER STATION	3500	Smolka & Tague	Smolka and Tague, May 89			940	09/26/88	Storm	47
		ENSR	ENSR, 1988			900	10/12/88	Low Flow	41
16 RANGER STATION	3500	Smolka & Tague	Smolka and Tague, May 89			1615	10/25/88	Low Flow	31
16 RANGER STATION	3500	Vail	Vail, June 89	17			11/29/88	Low Flow	13
17 RANGER STATION	16, 3300	Vail	Vail, July 1993	17			11/29/88	Low Flow	13
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1300	02/26/92	Low Flow	23
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1220	03/25/92	Rising Limb	27
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1200	04/29/92	Rising Limb	135
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1235	05/27/92	Peak	160

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1225	06/30/92	Falling Limb	103
RANGER STATION		Molycorp	Vail, July 1993				07/25/92	Falling Limb	61
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1230	07/29/92	Falling Limb	56
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1205	08/26/92	storm	53
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1040	09/30/92	Low Flow	30
17 RANGER STATION	16, 3300	Vail	Vail, July 1993	25.0			10/22/92	Low Flow	25
RANGER STATION	HRG 24	Smolka	NMED, June 1993			920	10/28/92	Low Flow	25
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1215	11/24/92	Low Flow	16
RANGER STATION	HRG 24	Smolka	NMED, June 1993			1155	12/16/92	Low Flow	12
16 RANGER STATION	16, 3300	Molycorp	Vail, July 1993	22.0			02/16/93	Low Flow	21
16 RANGER STATION	3500	Vail	Vail File	25.0			11/10/93	Low Flow	26
16 RANGER STATION	3500	Molycorp	Vail File	16.8			02/11/94	Low Flow	23
16 RANGER STATION	RR-16	SPRI	SPRI, April 1995				05/15/94	Peak	
RANGER STATION		Woodward Clyde	Woodward Clyde, Sept 1994				06/26/94	Falling Limb	155
RANGER STATION		NMED	Kent, Oct 1995				06/26/94	Falling Limb	155
RANGER STATION	16		MC CD				06/27/94	Falling Limb	144
RANGER STATION	16	SPRI	SPRI, April 1995			am	10/13/94	Low Flow	27
RANGER STATION	16	SPRI	SPRI, April 1995			pm	10/13/94	Low Flow	27
16 RANGER STATION	3500	Vail	Vail File	21.5			02/14/95	Low Flow	21
16 RANGER STATION	3500	Vail	Vail File	27.0			11/09/95	Low Flow	28
RANGER STATION	16		MC CD				11/09/95	Low Flow	28
RANGER STATION	RR-16		Woodward Clyde, June 1996				11/09/95	Low Flow	28
RANGER STATION	RR-16	Vail	Vail File	22.5			02/26/96	Low Flow	22
16 RANGER STATION	3500	Vail	Vail File	16.2			11/05/96	Low Flow	17

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
16 RANGER STATION	3500	Vail	Vail File	16.9			03/13/97	Rising Limb	14
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	283			06/10/97	Falling Limb	283
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	53			07/17/97	Low Flow	53
RANGER STATION GAGE	3500	Vail	Vail File		No mill well or river diversions		07/21/97	Storm	59
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	43			08/14/97	Low Flow	43
RANGER STATION GAGE	3500	Vail	Vail File		River diversion was on		09/09/97	Low Flow	28
RANGER STATION GAGE		Vail	URS, 2001	27.93			09/09/97	Low Flow	28
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	22			09/18/97	Low Flow	22
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	19			10/23/97	Low Flow	19
RANGER STATION GAGE	3500	Vail	Vail File				11/03/97	Low Flow	21
RANGER STATION GAGE		Vail	URS, 2001	23.64			11/03/97	Low Flow	21
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	9			11/20/97	Low Flow	9
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	9			12/19/97	Low Flow	8.9
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	17			01/14/98	Low Flow	17
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	12			02/20/98	Low Flow	12
RANGER STATION GAGE	3500	Vail	Vail File				03/09/98	Low Flow	15
RANGER STATION GAGE		Vail	URS, 2001	18.13			03/09/98	Low Flow	15

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	16			03/19/98	Rising Limb	16
RANGER STATION GAGE	3500	Vail	Vail File				04/30/98	Rising Limb	54
RANGER STATION GAGE	3500	NM ONRT	Allen, 1999	54			04/30/98	Rising Limb	54
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	137			06/04/98	Peak	137
RANGER STATION GAGE	3501	NM ONRT	Allen, 1999	57			07/16/98	Falling Limb	57
RANGER STATION GAGE		Vail	Vail File	21.1	(Note: ERRATIC Mill River Diversions)		10/20/98	Low Flow	21
RANGER STATION GAGE	3500	Vail	Vail File				02/25/99	Low Flow	14
RANGER STATION GAGE	3500	Vail	Vail File				09/27/99	Low Flow	25
RANGER STATION GAGE	3500	Vail	Vail File	25.37	(includes South Ditch)		10/13/99	Low Flow	23
RANGER STATION GAGE		Vail	URS, 2001	24.93			10/13/99	Low Flow	23
RANGER STATION GAGE	3500	Vail	Vail File	18.00			03/15/00	Low Flow	16
RANGER STATION GAGE		Vail	URS, 2001	14.68			03/15/00	Low Flow	16
RANGER STATION	16		MC CD				05/01/00	Peak	46
RANGER STATION	16		Medine, 2000	41			05/01/00	Peak	46
			RGC, 2000b				07/18/00	Storm	25
			RGC, 2000b		duplicate		07/18/00	Storm	25
			RGC, 2000b				08/06/00	Storm	12
RANGER STATION GAGE	3500	Vail	Vail File	10.73			09/06/00	Low Flow	12

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Station Name	ID	Collected by	Source	Meas Flow (cfs)	Comment	Time (24-hr)	Date (dd-mm-yy)	Hydrologic Timing	Avg Daily Flow (cfs)
RANGER STATION GAGE	3500	Vail	Vail File	15.00	+/-		11/03/00	Low Flow	13
RANGER STATION GAGE		Vail/Martinez	Vail File	6.37			02/20/01	Low Flow	10
RANGER STATION	16		MC CD	145.5			05/22/01	Peak	187
RANGER STATION	16		MC CD				05/22/01	Peak	187
RANGER STATION	16		MC CD	21.15			08/21/01	Low Flow	37
RANGER STATION	16		MC CD	13.8			11/12/01	Low Flow	no data
RANGER STATION	16		MC CD				11/12/01	Low Flow	no data
RANGER STATION	16		MC CD				11/12/01	Low Flow	no data
RANGER STATION	16		MC CD				11/12/01	Low Flow	no data
RANGER STATION	16		MC CD				11/12/01	Low Flow	no data

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
11/03/65		119	21.85		7.9	7.6	255	242		5.0	180
11/04/65		119	21.85		8.0	7.5	260	253		4.0	195
11/04/65		119	21.85		8.5	7.5	260	262		4.5	200
11/04/65		119	21.85		8.4	7.5	255	253		2.3	170
11/04/65		119	21.85		8.1						186
11/07/65		119	21.01		7.8	7.6	250	266		3.8	
11/08/65		119	21.01		7.8		250			3.0	
11/02/70		189	6.88		6.5	7.0	260	250		3.9	173
11/03/70		189	6.35		6.6	7.0	260	260		2.8	185
11/04/70		189	5.82		7.0	7.7	250	255		2.2	90
11/04/70		189	5.82		6.8						160
11/05/70		189	6.35		6.9	7.3	245	255		1.0	183
11/05/70		189	6.35		6.8	7.4	255	250		2.8	170
11/05/70		189	6.35		6.8	7.1	260	245		2.8	158
01/15/77	4.41	157		2.81							211 A
02/15/77	4.81	157		3.06							192 A
03/08/77		29	18.97								
03/15/77	5.11	157		3.25							201 A
04/15/77	10.00	29		34.48							184 A
05/15/77	21.90	29		75.52							157 A
06/15/77	22.70	29		78.28							217 A
07/15/77	26.80	29		92.41							152 A
08/15/77	21.40	29		73.79							162 A
09/15/77	17.80	29		61.38							155 A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
10/15/77	13.80	29		47.59							170 A
11/15/77	10.90	29		37.59							221 A
12/15/77	8.71	29		30.03							157 A
01/15/78	9.04	29		31.17							201 A
02/15/78	9.49	29		32.72							185 A
03/15/78	9.63	29		33.21							189 A
04/15/78	27.80	107		25.98							148 A
05/15/78	71.60	107		66.92							123 A
06/15/78	88.60	107		82.80							115 A
07/15/78	33.10	107		30.93							128 A
08/15/78	16.70	107		15.61							181 A
09/15/78	8.81	107		8.23							191 A
10/15/78	9.04	107		8.45							199 A
10/17/78		107	7.57		7.7			278			
10/17/78		107	7.57								
11/14/78		107	10.28								
11/14/78		107	10.28		7.8			257			
11/15/78	10.50	107		9.81							178 A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
12/15/78	4.53	107		4.23							250 A
01/15/79	5.95	107		5.56							210 A
01/16/79		107	6.36		7.8			250			187
02/15/79	6.65	107		6.21							202 A
03/15/79	10.20	107		9.53							199 A
03/20/79		107			8.2			270			
04/15/79	62.90	557		11.29							185 A
04/26/79		557	23.52		7.6			150			122
05/15/79	267.00	557		47.94							127 A
05/23/79		557	67.86		7.7			150			92
06/10/79		557	91.56	0.00							
06/14/79		557	86.89		7.6						99
06/15/79	405.00	557		72.71							110 A
06/18/79		557	66.79		7.9			147			
07/05/79		557	44.70		7.6						99
07/14/79		557	29.08								
07/15/79	172.00	557		30.88							139 A
07/24/79		557	20.47		8			190			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
07/27/79		557	18.49								
08/04/79		557	13.64								
08/10/79		557	14.00								
08/15/79	65.50	557		11.76							162 A
08/29/79		557	8.26		7.8			250			158
09/15/79	30.50	557		5.48							
09/25/79		557	4.67		7.7			240			
10/15/79	23.10	557		4.15							
10/24/79		557	4.13		7.7			281			186
11/15/79	15.60	557		2.80							
12/04/79		557	2.33		7.1			340			198
12/15/79	13.50	557		2.42							
12/17/79		557	2.51		7.8			350			201
12/17/79		557	2.51		7.5			340			
02/07/80		557	2.33		7.5			290			132
04/02/80		557	2.69		7.6			294			132
04/28/80		278	13.67		7.7			278			164
06/03/80		278	63.31		8			157			93

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
07/09/80		278	30.58		7.8			190			118
08/14/80		278	11.15		8			238			157
09/10/80		278	15.83		8			220			142
10/14/80		278	4.68		7.7	7.7	270	302			200
11/19/80		278	1.76		7	7.6		320	354		209
01/08/81		278	2.70		7.3	7.4		290	320		210
03/10/81		278	2.12		7.1	7.5		340	362		232
03/11/81		278	1.91		7.2	7.6		330	350		242
04/13/81		47	25.53		7.6	7.5		278	290		174
05/14/81		47	40.43		7.7	7.7		271	271		170
06/10/81		47	100.00		7.5	7.7		185	200		118
07/14/81		47	38.30		7.8	7.6		270	280		173
07/17/81		47	31.91		7.5	7.5		270	310		
08/12/81		47	59.57			4.1			508		
08/13/81		47	44.68		7.5	7.2		258	283		169
08/20/81		47	40.43		7.2						
10/09/81		47	29.79		7.5	7.7		280	278		185
11/05/81		47	27.66		7.6	7.8		290	309		190

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
02/17/82		47	27.66		7.3			325			
03/24/82		47	31.91		7.2			320			
04/29/82		142	20.42		7.4			250			
06/02/82		142	96.48		6.8			160			
07/06/82		142	54.23		7.6			200			
08/20/82		142	31.69		7.7			285			
09/16/82		142	36.62		7.3			235			
10/19/82		142	24.65		7.4			265			
12/07/82		142	13.38		7.1			295			
02/08/83		142	11.97		7.3			310			
04/26/83		332	25.00		6.8			240			
06/07/83		332	79.82		7.2			145			
07/21/83		332	34.94		7.3			200			
08/31/83		332	13.86		7.2			290			
11/04/83		332	5.12		7.2			290			
01/10/84		332	2.11		7.3			345			
01/25/84		332	3.31		6.8		266			0.2	
01/26/84		332	3.31		6.9		188			0.2	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
01/26/84		332	3.31		6.9		173			0.0	
01/26/84		332	3.31		6.9		203			0.8	
01/26/84		332	3.31		6.9		187			0.2	
01/27/84		332	3.01		6.9		186			0.5	
04/05/84		332	4.22		7			320			
05/25/84		377	100.00		7			132			
06/28/84		377	24.40		7.1			180			
09/27/84		377	5.84		7			310			
01/16/85		377	3.45		6.9			350			
06/12/85		322	99.38		7.4			155			
07/12/85		322	32.30		8.2			225			
07/20/85		322	31.68		4.7	4.6		420	355		
10/29/85		322	9.94								
12/20/85		322	3.11					345			
02/27/86		332	5.12		7.2		308			8.0	210
05/22/86		325	41.54			8		170	189		
06/12/86		325	77.54		7.8	8.1		160	170		
08/18/86		325	12.92		7.3		306			16.2	240

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
08/19/86		325	12.31		7.3		298			13.0	234
08/19/86		325	12.31		7.3		305			15.9	294
08/20/86		325	11.69		7.2		298			13.5	300
08/20/86		325	11.69		7.3		302			15.0	236
08/26/86		325	14.77		7.4			280			
09/07/86		325	12.00		3.8	3.9		1100	1160		
12/24/86		325	8.31		7.3	6.8		345	390		
03/25/88		277	7.58		6.8		381			9.0	290
07/26/88		101	36.63								1,112
09/13/88		101	136.63		6.8		230			9.2	927
09/20/88		101	56.44		7.6		210			8.2	184
09/21/88		101	57.43	0.00	7.9						
09/26/88		101	46.53		7.2		271			6.5	200
10/12/88		152	26.97			7.5					256
10/25/88		152	20.39		7.3		311			8.3	230
11/29/88		101	12.87		7.1						263
11/29/88		101	12.87		7.1						263
02/26/92		469	4.90		7.4		272			3.1	283
03/25/92		184	14.67		6.5		322			7.6	322
04/29/92		184	73.37		7.1		176			9.0	142
05/27/92		184	86.96		7.4		186			8.5	148

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
06/30/92		184	55.98		6.6		218			11.9	160
07/25/92		184	33.15		7.5						236
07/29/92		184	30.43		7.7		298			12.5	196
08/26/92		184	28.80		7.8		268			13.5	186
09/30/92		184	16.30		7.1		371			7.2	256
10/22/92		184	13.59		7.39		427				331
10/28/92		184	13.59		7.1		355			5.3	280
11/24/92		184	8.70		6.8		348			0.5	333
12/16/92		184	6.52		7.0		358			0.3	340
02/16/93		184	11.41		7.2		458				338
11/10/93		184	14.13		7.27		425				262
02/11/94		184	12.50		6.9		450				352
05/15/94	244	399		61.15			171			54.0°F	150
06/26/94		399	38.85		7.2		228			13.7	
06/26/94		399	38.85								156
06/27/94		399	36.09	0.00							
10/13/94		359	7.52								278
10/13/94		359	7.52		7.8		400				268
02/14/95		399	5.26		7.6		438				286
11/09/95		359	7.80		7.7	7.6	388	367			310
11/09/95		359	7.80	0.00		7.6		367			263
11/09/95		359	7.80		7.7	7.6	389	367		5.7	263
02/26/96		359	6.13		7.4		448				
11/05/96		55	30.91		6.9	7.39	478	454			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
03/13/97		347	4.03		6.8	7.47	420	415			
06/10/97		347	81.56								
07/17/97		347	15.27								
07/21/97		347	17.00		7.9	7.5	272	268			
08/14/97		347	12.39								
09/09/97		347	8.07		7.8	7.5	333	331			235
09/09/97		347	8.07								
09/18/97		347	6.34								
10/23/97		347	5.48								
11/03/97		347	6.05	0.00	7.5	7.3	346	332			
11/03/97		347	6.05								
11/20/97		347	2.59								
12/19/97		347	2.56								
01/14/98		347	4.90								
02/20/98		347	3.46								
03/09/98		347	4.32	0.00	6.9	7.4	410	396			
03/09/98		347	4.32								

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
03/19/98		139	11.51								
04/30/98		139	38.85	0.00	7.0	7.8	246	240			
04/30/98		139	38.85								
06/04/98		139	98.56								
07/16/98		139	41.01								
10/20/98		139	15.11	0.00	7.9		334				
02/25/99		139	10.07	0.00	7.8		384				
09/27/99		288	8.68	0.00			296				
10/13/99		288	7.99	0.00		7.8	312				
10/13/99		288	7.99								
03/15/00		288	5.56	0.00	7.7		386				
03/15/00		288	5.56								
05/01/00		48	95.83	0.00		6.9					180
05/01/00		48	95.83		7.8		277				180
07/18/00		48	52.08			4.8		550			
07/18/00		48	52.08								
08/06/00		48	25.00			6.2		380			300
09/06/00		48	25.00	0.00	7.9		384				

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Avg Monthly Flow (cfs)	Max Avg Daily flow - runoff (cfs)	Percent of Max Flow - Daily	Percent of Max Flow - Monthly	pH-field (SU)	pH-lab (SU)	SC-field (mS/cm)	SC-lab (mS/cm)	SC, 25°C (mS/cm)	Temp (field) (°C)	TDS, meas (mg/L) q
11/03/00		48	27.08	0.00	7.8		382				
02/20/01		48	20.83	0.00	7.7						340
05/22/01		218	85.78	0.00	7.41		174			5.7	110
05/22/01		218	85.78	0.00	7.41		174			5.7	110
08/21/01		218	16.97	0.00	7.88		288			14.5	220
11/12/01		no data			7.74		386			5.3	260
11/12/01		no data			7.74		386			5.3	260
11/12/01		no data			7.74					5.3	260
11/12/01		no data			7.74					5.3	260
11/12/01		no data			7.74					5.3	260

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
11/03/65		8.0			1.5	15.8	120		120.7	
11/04/65		8.0			1.9	3.9	120		120.1	
11/04/65		78.0			1.7	3.9	125		125.0	
11/04/65		8.0			1.7	3.9				
11/04/65		25								
11/07/65					1.5					
11/08/65					1.7					
11/02/70		4.0				5	105		105.1	
11/03/70		1.0				4	130		130.2	
11/04/70		1.0				11	120		120.0	
11/04/70		2.7								
11/05/70		1.0				5	110		110.1	
11/05/70		2.0				10	105		105.1	
11/05/70		7.0				20	135		135.1	
01/15/77		18.0 A								
02/15/77		18.0 A								
03/08/77										
03/15/77		221.0 A				3				
04/15/77		14.0 A								
05/15/77		13.0 A								
06/15/77		201.0 A								
07/15/77		112.0 A								
08/15/77		335.0 A								
09/15/77		332.0 A								

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
10/15/77		28.0 A								
11/15/77		25.0 A								
12/15/77		17.0 A								
01/15/78		14 A								
02/15/78		18 A								
03/15/78		11 A								
04/15/78		38 A								
05/15/78		161 A								
06/15/78		30 A								
07/15/78		69 A								
08/15/78		28 A								
09/15/78		18 A								
10/15/78		5 A								
10/17/78			1.4							3.4
10/17/78		13								
11/14/78										
11/14/78		20	0.9						110.4	6
11/15/78		11 A								

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
12/15/78		11 A								
01/15/79		36 A								
01/16/79		20	0.8						133.7	8.2
02/15/79		16 A								
03/15/79		11 A								
03/20/79		27	1.5						125.8	13
04/15/79		205 A								
04/26/79		554	6.8						81.4	99
05/15/79		367 A								
05/23/79		1370							63.9	150
06/10/79		980								
06/14/79		458							57.3	
06/15/79		296 A								
06/18/79		1160	10						60.2	140
07/05/79		458							57.3	
07/14/79										
07/15/79		18 A								
07/24/79		12	2.8						86.8	2.5

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
07/27/79										
08/04/79										
08/10/79										
08/15/79		39 A								
08/29/79		66	0.9						109.6	9.2
09/15/79										
09/25/79		16	3.7						114.2	5.7
10/15/79										
10/24/79			2.6						120.0	4.7
11/15/79									0.0	
12/04/79		41	2.9						143.6	12
12/15/79										
12/17/79		212							144.1	130
12/17/79		462							172.3	
02/07/80									140.3	1
04/02/80		30	2.2						126.6	8.8
04/28/80		478	2						115.8	17
06/03/80			4.6						66.9	7.2

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
07/09/80			1.3						88.9	2.1
08/14/80		2	4						110.8	66
09/10/80		144	5.2						106.7	40
10/14/80			4.1						136.1	0.4
11/19/80			1						141.6	18
01/08/81			14						142.0	13
03/10/81		150	1.6						159.0	56
03/11/81		27	2.2						156.9	31
04/13/81		54	4.2						125.4	33
05/14/81			3						122.0	4.6
06/10/81		63	4.3						89.7	5.2
07/14/81		35	2.1						128.3	18
07/17/81		3970							131.2	
08/12/81		6550							225.1	
08/13/81		41	2						122.0	9.1
08/20/81										
10/09/81		30	1.7						130.7	8.8
11/05/81		11	1.3						136.6	0.5

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
02/17/82		39	0.9							
03/24/82		32	1.3							
04/29/82										
06/02/82		99								
07/06/82		22	1.5							
08/20/82		397	8.3							
09/16/82		63	1.5							
10/19/82		3								
12/07/82		26	1.2							
02/08/83		47	1.7							
04/26/83		300	8.3							
06/07/83		351	4.5							
07/21/83		63	2.4							
08/31/83		31	1							
11/04/83			1							
01/10/84		44	0.7							
01/25/84										
01/26/84										

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
01/26/84										
01/26/84										
01/26/84										
01/27/84										
04/05/84		67	0.8							
05/25/84		1210								
06/28/84		19	1							
09/27/84		28	0.7							
01/16/85			1							
06/12/85		215	4.3							
07/12/85		19	1.3							
07/20/85										130
10/29/85		3								
12/20/85										
02/27/86									212.2	
05/22/86			3.1							
06/12/86			4.5							24
08/18/86									190.4	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
08/19/86									167.4	
08/19/86										
08/20/86									168.0	
08/20/86										
08/26/86			2.4							
09/07/86										
12/24/86			1.8							10
03/25/88		21.0		1						
07/26/88		47,844								
09/13/88		210.0		11			183			
09/20/88		17.0		2			198			
09/21/88										
09/26/88		15.0		1			185			
10/12/88		17.0								
10/25/88		17.0					154			
11/29/88		50								
11/29/88		49.6								
02/26/92		25					295		171.8	11.5
03/25/92		49		5 K			208		208.2	22.0
04/29/92		158		4			110		109.6	78.0
05/27/92		20		5 K			113		113.0	19.0

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
06/30/92		12		1			111		111.2	6.0
07/25/92		450								
07/29/92		4		2			159		159.4	5.0
08/26/92		3 K		2			152		151.9	11.6
09/30/92		13		2 K			168		167.7	6.8
10/22/92		32								
10/28/92		18		1			193		193.4	7.6
11/24/92		33		1 K			214		214.1	13.2
12/16/92		24		1			210		210.0	11.2
02/16/93		21.0								
11/10/93		16.0								
02/11/94		13.0								
05/15/94		106.0							73.7	
06/26/94										
06/26/94		14.0		2.7					96.7	
06/27/94									96.5	
10/13/94		8.0								
10/13/94		9.3								
02/14/95		22								
11/09/95		10.0								
11/09/95		9.2		1 U				167	166.9	
11/09/95		9.2							166.9	
02/26/96										
11/05/96										

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
03/13/97										
06/10/97										
07/17/97										
07/21/97										
08/14/97										
09/09/97		11.2								
09/09/97										
09/18/97										
10/23/97										
11/03/97										
11/03/97										
11/20/97										
12/19/97										
01/14/98										
02/20/98										
03/09/98										12.0
03/09/98										

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
03/19/98										
04/30/98		16.5					109			
04/30/98										
06/04/98										
07/16/98										
10/20/98										
02/25/99										8.7
09/27/99										
10/13/99										
10/13/99										
03/15/00										
03/15/00										
05/01/00	168	6	2					129	129.0	
05/01/00	168	6	2						129.0	
07/18/00		720							260.0	
07/18/00										
08/06/00		870							191.7	
09/06/00										

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	TDS, calc (mg/L)	TSS (mg/L) q	DOC (mg/L)	TOC (mg/L) q	BOD (mg/L) q	COD (mg/L) q	Hard_t (mg/L $CaCO_3$)	Hard_d (mg/L $CaCO_3$)	Hard_calc (mg/L $CaCO_3$)	NTU - field
11/03/00										
02/20/01										
05/22/01					3 U	23			72.2	
05/22/01					3 U	12			73.1	
08/21/01					5 U	15 U			167.7	
11/12/01					4 U	10 U			167.7	
11/12/01					4 U	10 U			167.7	
11/12/01										
11/12/01					4 U	10 U			167.7	
11/12/01					4 U	10 U			167.7	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
11/03/65		5	33			33	9.3			9.3			
11/04/65		4.3	34.4			34.4	8.3			8.3			
11/04/65		5.9	34.4			34.4	9.5			9.5			
11/04/65		8.7	34			34							
11/04/65		5.6											
11/07/65		4	36			36							
11/08/65		6.3											
11/02/70		6.1			34	34			4.9	4.9			
11/03/70		6.5			36	36			9.8	9.8			
11/04/70		60			38	38			6.1	6.1			
11/04/70		26.9											
11/05/70		9			36	36			4.9	4.9			
11/05/70		8.5			36	36			3.7	3.7			
11/05/70		10			34	34			12.2	12.2			
01/15/77		10 A											
02/15/77		10 A											
03/08/77		18,000 (max for 1/77-6/79)											
03/15/77		623 A											
04/15/77		11 A											
05/15/77		7 A											
06/15/77		17 A											
07/15/77		77 A											
08/15/77		61 A											
09/15/77		170 A											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
10/15/77		15 A											
11/15/77		20 A											
12/15/77		11 A											
01/15/78		U,A											
02/15/78		U,A											
03/15/78		12 A											
04/15/78		25 A											
05/15/78		49 A											
06/15/78		12 A											
07/15/78		18 A											
08/15/78		12 A											
09/15/78		9 A											
10/15/78		8 A											
10/17/78		A											
10/17/78		A											
11/14/78		A											
11/14/78		A	34			34	6.2			6.2			
11/15/78		11 A											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
12/15/78		12 A											
01/15/79		13 A											
01/16/79			42			42	7			7	4.3		0.9
02/15/79		12 A											
03/15/79		14 A											
03/20/79		A	38			38	7.5			7.5			
04/15/79		77 A											
04/26/79		A	25			25	4.6			4.6	3.4		1.1
05/15/79		147 A											
05/23/79		A	20			20	3.4			3.4	2.9		1.2
06/10/79													
06/14/79					18	18			3	3			
06/15/79		175 A											
06/18/79		A	19			19	3.1			3.1			
07/05/79		A			18	18			3	3			
07/14/79													
07/15/79		7 A											
07/24/79			27			27	4.7			4.7			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
07/27/79													
08/04/79													
08/10/79													
08/15/79		24 A											
08/29/79			34			34	6			6	3.7		1
09/15/79													
09/25/79			35			35	6.5			6.5			
10/15/79													
10/24/79			36			36	7.3			7.3	4.6		1.2
11/15/79													
12/04/79			44			44	8.2			8.2	5		1.2
12/15/79													
12/17/79			45			45	7.7			7.7	5.1		1.7
12/17/79			55			55	8.5			8.5	5.3		2.1
02/07/80			42			42	8.6			8.6	5.8		1.1
04/02/80			38			38	7.7			7.7	4.5		1
04/28/80			35			35	6.9			6.9	4.6		1
06/03/80			21			21	3.5			3.5	3.1		0.7

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
07/09/80			28			28	4.6			4.6	3.4		0.9
08/14/80			34			34	6.3			6.3	4.5		1.1
09/10/80			33			33	5.9			5.9	3.8		1.4
10/14/80			41			41	8.2			8.2	5		1.1
11/19/80			43			43	8.3			8.3	4.8		1.2
01/08/81			43			43	8.4			8.4	5.2		1.1
03/10/81			48			48	9.5			9.5	5.1		1.2
03/11/81			47			47	9.6			9.6	5.4		1.2
04/13/81			38			38	7.4			7.4	5.2		1.3
05/14/81			37			37	7.2			7.2	4.4		1.1
06/10/81			28			28	4.8			4.8	3.4		1
07/14/81			39			39	7.5			7.5	5		1.3
07/17/81			41			41	7			7	4.7		
08/12/81			72			72	11			11	6		
08/13/81			37			37	7.2			7.2	5.6		1.2
08/20/81		7.5											
10/09/81			39			39	8.1			8.1	4.6		1.3
11/05/81			41			41	8.3			8.3	4.6		1.3

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
02/17/82													
03/24/82													
04/29/82													
06/02/82													
07/06/82													
08/20/82													
09/16/82													
10/19/82													
12/07/82													
02/08/83													
04/26/83													
06/07/83													
07/21/83													
08/31/83													
11/04/83													
01/10/84													
01/25/84		8											
01/26/84		7											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
01/26/84		7											
01/26/84		7.2											
01/26/84		7											
01/27/84		6.5											
04/05/84													
05/25/84													
06/28/84													
09/27/84													
01/16/85													
06/12/85													
07/12/85													
07/20/85													
10/29/85													
12/20/85													
02/27/86			40.8			40.8	26.8			26.8	4.6		0.8
05/22/86													
06/12/86													
08/18/86		9.3	46.4			46.4	18.1			18.1	10.0		5.0

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
08/19/86		12	40			40	16.4			16.4	10		5
08/19/86		8											
08/20/86		9.4	48			48	11.7			11.7	10		5
08/20/86		7.5											
08/26/86													
09/07/86													
12/24/86													
03/25/88	10												
07/26/88													
09/13/88	410						20.1			20.1	4		2
09/20/88	8						18.9			18.9	4		1
09/21/88													
09/26/88	9						15.9			15.9	2		1
10/12/88													
10/25/88	1						4.6			4.6	5		1
11/29/88		22											
11/29/88		22											
02/26/92			49.0			49.0	12.0			12.0	6.0		2.0
03/25/92			57.0			57.0	16.0			16.0	6.0		1.0
04/29/92			34.0			34.0	6.0			6.0	3.0		1.0
05/27/92			37.0			37.0	5.0			5.0	5.0		1.0

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
06/30/92			33.0			33.0	7.0			7.0	4.0		1.0
07/25/92													
07/29/92			49.0			49.0	9.0			9.0	5.0		1.0
08/26/92			46.0			46.0	9.0			9.0	4.0		1.0
09/30/92			49.0			49.0	11.0			11.0	6.0		2.0
10/22/92		9											
10/28/92			56.0			56.0	13.0			13.0	6.0		2.0
11/24/92			61.0			61.0	15.0			15.0	7.0		2.0
12/16/92			61.0			61.0	14.0			14.0	7.0		2.0
02/16/93													
11/10/93													
02/11/94													
05/15/94				22.1		22.1		4.5		4.5		2.7	
06/26/94													
06/26/94			29 J	29.8 J		29	5.89	6.21		5.89			
06/27/94			29	29.2		29	5.84	5.85		5.84	3.24	3.22	0.719
10/13/94								0.946		0.946			
10/13/94								0.92		0.92			
02/14/95													
11/09/95								19.2		19.2			
11/09/95			47.7	43.7		47.7	11.6	10.6		11.6	5.59	4.45	1.24
11/09/95	5.24		47.7	43.7		47.7	11.6	10.6		11.6	5.59	4.45 J	1.24
02/26/96								12.7		12.7			
11/05/96								15.2		15.2			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
03/13/97		9						12.1		12.1			
06/10/97													
07/17/97													
07/21/97		2.4						7.8		7.8			
08/14/97													
09/09/97		8.0						9.5		9.5			
09/09/97													
09/18/97													
10/23/97													
11/03/97								10.1		10.1			
11/03/97													
11/20/97													
12/19/97													
01/14/98													
02/20/98													
03/09/98	11.9							11.8		11.8			
03/09/98													

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
03/19/98													
04/30/98													
04/30/98													
06/04/98													
07/16/98													
10/20/98													
02/25/99													
09/27/99													
10/13/99								9.2		9.2			
10/13/99													
03/15/00	7.2							12.0		12.0			
03/15/00													
05/01/00			38.3	37.8		38.3	8.1	8.1		8.1	4.4	4	1
05/01/00			38.3	37.8		38.3	8.1	8.1		8.1	4.4	4	1
07/18/00			86	87		86	11	14		11	6.6	6.9	2.1
07/18/00								14.1					
08/06/00			57	62		57	12	15		12	6.1	7.1	1.7
09/06/00													

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	NTU - lab	JTU q	Ca_d (mg/L) q	Ca_t (mg/L) q	Ca_? (mg/L)	Ca d,t,? (mg/L)	Mg_d (mg/L)	Mg_t (mg/L)	Mg_? (mg/L)	Mg d,t,? (mg/L)	Na_d (mg/L) q	Na_t (mg/L) q	K_d (mg/L)
11/03/00													
02/20/01								14.0		14.0			
05/22/01			22	22		22	4.2	4.5		4.2	10 U	10 U	0.76
05/22/01			22	23		22	4.4	4.5		4.4	10 U	10 U	0.81
08/21/01			49	48		49	11	11		11	10 U	10 U	1.3
11/12/01			49	49		49	11	11		11	5.2	5.1	1.4
11/12/01			49	49		49	11	11		11	5.1	5.2	1.4
11/12/01													
11/12/01			49	49		49	11	11		11	5.1	5.2	1.4
11/12/01			49	49		49	11	11		11	5.2	5.1	1.4

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
11/03/65		62		62			57.9	57.9			
11/04/65		63		63			55	55			
11/04/65		67		67			58.9	58.9			
11/04/65		62		62			54.5	54.5			
11/04/65		64		64			56	56			
11/07/65							55	55			
11/08/65											
11/02/70		50		50			54	54			
11/03/70		80		80			52	52			
11/04/70		69.2		69.2			55	55			
11/04/70		66		66			54	54			
11/05/70		56		56			56	56			
11/05/70		64		64			50	50			
11/05/70		80		80			55	55			
01/15/77		103 A		103 A							
02/15/77		107 A		107 A							
03/08/77											
03/15/77		109 A		109 A							
04/15/77		60 A		60 A							
05/15/77		40 A		40 A							
06/15/77		57 A		57 A							
07/15/77		58 A		58 A							
08/15/77		55 A		55 A							
09/15/77		55 A		55 A							

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
10/15/77		53 A		53 A							
11/15/77		101 A		101 A							
12/15/77		82 A		82 A							
01/15/78		102 A		102 A							
02/15/78		100 A		100 A							
03/15/78		81 A		81 A							
04/15/78		40 A		40 A							
05/15/78		27 A		27 A							
06/15/78		18 A		18 A							
07/15/78		45 A		45 A							
08/15/78		53 A		53 A							
09/15/78		59 A		59 A							
10/15/78		95 A		95 A							
10/17/78											
10/17/78											
11/14/78											
11/14/78					108			108		130	
11/15/78		73 A		73 A							

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
12/15/78		144 A		144 A							
01/15/79		112 A		112 A							
01/16/79		95		95	38			38		46	
02/15/79		104 A		104 A							
03/15/79		86 A		86 A							
03/20/79					49			49		60	
04/15/79		56 A		56 A							
04/26/79		46		46	41			41		50	
05/15/79		33 A		33 A							
05/23/79		29		29	38			38		46	
06/10/79											
06/14/79		14		14							
06/15/79		16 A		16 A							
06/18/79					48			48		58	
07/05/79											
07/14/79											
07/15/79		28 A		28 A							
07/24/79					56			56		68	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
07/27/79											
08/04/79											
08/10/79											
08/15/79		32 A		32 A							
08/29/79		64		64	61			61		74	
09/15/79											
09/25/79					51			51		62	
10/15/79											
10/24/79		83		83	52			52		64	
11/15/79											
12/04/79		100		100	38			38		46	
12/15/79											
12/17/79		100		100	45			45			
12/17/79											
02/07/80		36		36	38			38			
04/02/80		100		100	44			44		54	
04/28/80		74		74	48			48		58	
06/03/80		28		28	42			42			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
07/09/80		40		40	51			51		62	
08/14/80		66		66	49			49		66	
09/10/80		55		55	50			50		70	
10/14/80		100		100	48			48		54	
11/19/80		120		120	33			33		40	
01/08/81		110		110	43			43		52	
03/10/81		140		140	28			28		34	
03/11/81		150		150	34			34		42	
04/13/81		87		87	43			43		52	
05/14/81		77		77	41			41		50	
06/10/81		47		47							
07/14/81		83		83	48			48		58	
07/17/81											
08/12/81											
08/13/81		74		74	49			49		60	
08/20/81		118		118			40	40			
10/09/81		92		92	48			48			
11/05/81		97		97	43			43			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
02/17/82					36			36			
03/24/82					39			39			
04/29/82											
06/02/82											
07/06/82					51			51		62	
08/20/82					51			51			
09/16/82					62			62			
10/19/82					49			49			
12/07/82					41			41			
02/08/83					44			44			
04/26/83					28			28			
06/07/83					39			39			
07/21/83					48			48			
08/31/83					61			61			
11/04/83					48			48			
01/10/84					28			28			
01/25/84											
01/26/84											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
01/26/84											
01/26/84											
01/26/84											
01/27/84		130.8		130.8							
04/05/84					28			28			
05/25/84					33			33			
06/28/84					48			48			
09/27/84					39			39			
01/16/85											
06/12/85											
07/12/85					30			30			
07/20/85					0			0			
10/29/85											
12/20/85											
02/27/86		123		123	50			50			
05/22/86											
06/12/86											
08/18/86		105		105	40			40			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
08/19/86		115		115	40			40			
08/19/86		160		160							
08/20/86		118		118	40			40			
08/20/86											
08/26/86											
09/07/86											
12/24/86											
03/25/88											
07/26/88			278	278							
09/13/88		120		120				8	10		
09/20/88		85		85				45	54		
09/21/88							48	48			
09/26/88		96		96				44	53		
10/12/88					58			58			
10/25/88		118		118				41	51		
11/29/88		137		137			26	26			
11/29/88		137		137			26	26			
02/26/92		166		166	30.6			30.6			
03/25/92		175		175	18.4			18.4	22.4		
04/29/92		58.2		58.2	29.6			29.6	36.1		
05/27/92		49.2		49.2	43.4			43.4	52.9		

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
06/30/92		67.7		67.7	45.4			45.4	55.4		
07/25/92			59	59							
07/29/92		98.8		98.8	48.6			48.6	59.3		
08/26/92		94.5		94.5	49.8			49.8	60.7		
09/30/92		142		142	42.5			42.5	51.3		
10/22/92		152		152			44	44			
10/28/92		162		162	34.9			34.9	43		
11/24/92		205		205	21.5			21.5	26.6		
12/16/92		206		206	24			24	29.6		
02/16/93		202		202			29	29			
11/10/93		129		129			43	43			
02/11/94		171		171			25	25			
05/15/94	1 U	28.9		28.9	41			41			
06/26/94											
06/26/94		53.7		53.7		45.4		45.4			
06/27/94	0.851				54			54			
10/13/94		196		196	49			49			
10/13/94		197		197	44			44			
02/14/95		144		144			39	39			
11/09/95		136		136			47	47			
11/09/95 U	1.06 U	133		133	47.8			47.8	47.8		5 U
11/09/95 U	1.06 U		133	133	47.8			47.8	47.8		
02/26/96		163		163							
11/05/96		185		185							

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
03/13/97		148		148							
06/10/97											
07/17/97											
07/21/97		70		70	55			55			
08/14/97											
09/09/97		114		114	45			45			
09/09/97											
09/18/97											
10/23/97											
11/03/97		128		128							
11/03/97											
11/20/97											
12/19/97											
01/14/98											
02/20/98											
03/09/98		150		150							
03/09/98											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy) q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
03/19/98											
04/30/98		70		70							
04/30/98											
06/04/98											
07/16/98											
10/20/98		110		110							
02/25/99		128		128							
09/27/99											
10/13/99		102		102							
10/13/99											
03/15/00		136		136							
03/15/00											
05/01/00	1.1	80		80	51			51	51		
05/01/00	1.1	80		80	51				51		
07/18/00	6.3	360		360	10 U			10 U			
07/18/00											
08/06/00	5.3	160		160	19			19			
09/06/00		170		170							

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	q	K_t (mg/L) q	SO_4_d (mg/L) q	SO_4_t (mg/L)	SO_4_d,_t (mg/L) q	Alk_t (mg/L $CaCO_3$) q	Alk_d (mg/L $CaCO_3$)	Alk_? (mg/L $CaCO_3$) q	Alk_t or ? (mg/L $CaCO_3$) q	Bicarbonate (mg/L $CaCO_3$)	ANC_t (mg/L HCO_3)	Carbonate (mg/L $CaCO_3$) q
11/03/00			150		150			48	48			
02/20/01			190		190							
05/22/01		1	36		36	49			49	49		20 U
05/22/01		1	36		36	48			48	48		20 U
08/21/01	U	1.2 U	110	110	110	51			51	51		10 U
11/12/01		1.5	130		130	45			45	45		10 U
11/12/01		1.5	130	130	130	45			45	45		10 U
11/12/01				130	130	45			45	45		
11/12/01		1.5		130	130	45			45	45		10 U
11/12/01		1.5		130	130	45			45	45		10 U

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	$F\_d,\_t$ (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
11/03/65				1		1 U						
11/04/65				1.5		1 U						
11/04/65				0.5		1 U						
11/04/65				1.5		1 U						
11/04/65												
11/07/65				2		1 U						
11/08/65												
11/02/70				2		0.01						
11/03/70				0		0.01						
11/04/70				0		0.02						
11/04/70												
11/05/70				2		0.01						
11/05/70				0		0.01						
11/05/70				0		0.02						
01/15/77	0.8	A	0.8 A									
02/15/77	0.7	A	0.7 A									
03/08/77												
03/15/77	0.9	A	0.9 A									
04/15/77	1.1		1.1 A									
05/15/77	0.5		0.5 A									
06/15/77	0.7		0.7 A									
07/15/77	0.6		0.6									
08/15/77	0.5	A	0.5 A									
09/15/77	0.5	A	0.5 A									

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
10/15/77	0.5	A	0.5 A									
11/15/77	0.7	A	0.7 A									
12/15/77	0.8	A	0.8 A									
01/15/78	0.8	A	0.8 A									
02/15/78	0.7	A	0.7 A									
03/15/78	0.7	A	0.7 A									
04/15/78	0.6	A	0.6 A									
05/15/78	0.6	A	0.6 A									
06/15/78	0.4	A	0.4 A									
07/15/78	0.5		0.5									
08/15/78	0.7	A	0.7 A									
09/15/78	0.8	A	0.8 A									
10/15/78	1	A	1 A									
10/17/78								0.03				
10/17/78												
11/14/78												
11/14/78												
11/15/78	0.8	A	0.8 A									

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
12/15/78	0.9	A	0.9 A									
01/15/79	0.9	A	0.9 A									
01/16/79	0.7		0.7	1.8				0.2				
02/15/79	0.8	A	0.8 A									
03/15/79	0.7	A	0.7 A									
03/20/79								0.2				
04/15/79	0.9	A	0.9 A									
04/26/79	0.4		0.4	2				0.5				
05/15/79	0.4	A	0.4 A									
05/23/79	0.4		0.4	1.4				0.15				
06/10/79												
06/14/79	0.3		0.3									
06/15/79	0.3	A	0.3 A									
06/18/79								0.11				
07/05/79												
07/14/79												
07/15/79	0.5	A	0.5 A									
07/24/79								0.19				

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
07/27/79												
08/04/79												
08/10/79												
08/15/79	0.6	A	0.6 A									
08/29/79	0.5		0.5	1.7				0.12				
09/15/79												
09/25/79								0.15				
10/15/79												
10/24/79	0.6		0.6	2				0.15				
11/15/79												
12/04/79	1.1		1.1	2.7				0.25				
12/15/79												
12/17/79	0.5		0.5	2.5				0.28				
12/17/79												
02/07/80	0.4		0.4	0.6				0.3				
04/02/80	0.7		0.7	2.5				0.18				
04/28/80	0.5		0.5	2.1				0.9				
06/03/80	0.1		0.1	0.8				0.08				

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
07/09/80	0.5		0.5	1				0.07				
08/14/80	0.6		0.6	2.5				0.17				
09/10/80	0.4		0.4	2				0.14				
10/14/80	1.8		1.8	2.2				0.04				
11/19/80	0.9		0.9	2.2				0.17				
01/08/81	0.9		0.9	1.9				0.35				
03/10/81	1.1		1.1	2.2				0.02				
03/11/81	1		1	2.2				0.01				
04/13/81	0.8		0.8	2.8				0.14				
05/14/81	0.6		0.6	1.5				0.08				
06/10/81	0.4		0.4	1				0.11				
07/14/81	0.7		0.7	1.9				0.25				
07/17/81												
08/12/81												
08/13/81	0.5		0.5	1.6				0.3				
08/20/81												
10/09/81	0.8		0.8	2.7				0.24				
11/05/81	0.8		0.8	2.5				0.32				

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
02/17/82												
03/24/82												
04/29/82												
06/02/82												
07/06/82												
08/20/82												
09/16/82												
10/19/82												
12/07/82												
02/08/83												
04/26/83												
06/07/83												
07/21/83												
08/31/83												
11/04/83												
01/10/84												
01/25/84												
01/26/84												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
01/26/84												
01/26/84												
01/26/84												
01/27/84												
04/05/84												
05/25/84												
06/28/84												
09/27/84												
01/16/85												
06/12/85												
07/12/85												
07/20/85												
10/29/85												
12/20/85												
02/27/86											0.001	
05/22/86												
06/12/86												
08/18/86											0.001	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
08/19/86											0.001	
08/19/86												
08/20/86											0.001	
08/20/86												
08/26/86												
09/07/86												23
12/24/86												
03/25/88											0.001	
07/26/88												3
09/13/88										0.001	0.002	0.07
09/20/88										0.001	0.001	0.05
09/21/88	0.7		0.7									
09/26/88										0.001	0.001	0.10
10/12/88					20							0.50 U
10/25/88											0.001	
11/29/88	1.2		1.2									
11/29/88	1.2		1.2									4.4
02/26/92								0.41		0.1 K		0.10 K
03/25/92								0.42		0.1 K		0.10 K
04/29/92					5 K			0.14		0.1 K		0.10 K
05/27/92					5 K			0.17				

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
06/30/92					5 K			0.3				
07/25/92		0.8	0.8									
07/29/92					5 K			0.35				
08/26/92					5			0.25				
09/30/92					5 K			0.48				
10/22/92	0.948		0.948									0.79
10/28/92					5.5			0.4				
11/24/92					6.5			0.55				
12/16/92					5.4			0.66				
02/16/93	1.1		1.1									0.50
11/10/93	1.18		1.18									2.80
02/11/94	1.6		1.6									0.50
05/15/94	0.35		0.35	6.5								0.50 U
06/26/94												
06/26/94								160				
06/27/94									0.05 U	0.0024 U	0.0024 U	0.284
10/13/94	1.2		1.2									0.5 U
10/13/94	1.1		1.1									0.5 U
02/14/95	1.000		1.000									0.05
11/09/95	1.2		1.2									0.11
11/09/95	1.1		1.1	3	U		0.32			0.0055 U	0.0055 U	0.113
11/09/95		1.1	1.1		3.0 U		0.32			0.005 U	0.005 U	0.113 J
02/26/96		1.42	1.42									
11/05/96												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
03/13/97												
06/10/97												
07/17/97												
07/21/97												
08/14/97												
09/09/97	0.98		0.98									0.50 U
09/09/97												
09/18/97												
10/23/97												
11/03/97	0.90		0.90									
11/03/97												
11/20/97												
12/19/97												
01/14/98												
02/20/98												
03/09/98	1.00		1.00									
03/09/98												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
03/19/98												
04/30/98	0.51		0.51									
04/30/98												
06/04/98												
07/16/98												
10/20/98	0.72		0.72									
02/25/99												
09/27/99												
10/13/99	0.70		0.70									0.11
10/13/99												
03/15/00	0.8		0.8									0.10
03/15/00												
05/01/00	0.5		0.5	2			0.5	0.5				0.21
05/01/00	0.5		0.5	2			0.5	0.5				0.21
07/18/00	0.53		0.53	4.9						0.01 U	0.01 U	0.23
07/18/00											0.01 U	
08/06/00	0.92		0.92	4.4						0.01 U	0.01 U	0.2 U
09/06/00	0.7		0.7									

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	F_d (mg/L)	F_t (mg/L) q	F_d,_t (mg/L) q	Cl_d (mg/L)	Cl_t (mg/L) q	NO_3 (mg/L) q	NO_3 (mg/L N) q	Nitrate + Nitrate (mg/L N)	NH_3 (mg/L) q	Ag_d (mg/L) q	Ag_t (mg/L) q	Al_d (mg/L) q
11/03/00	0.8		0.8									
02/20/01	0.94		0.94									0.05 U
05/22/01	0.5	U	0.5 U	1.5			0.2 U			0.002 U	0.002 U	0.23
05/22/01	0.5	U	0.5 U	1.5	1.5		0.2 U			0.002 U	0.002 U	0.26
08/21/01	1		1	3.7			0.31			0.002 U	0.002 U	0.29
11/12/01	0.81		0.81	3.5			0.26			0.002 U	0.002 U	0.13
11/12/01	0.81		0.81	3.4			0.28			0.002 U	0.002 U	0.12
11/12/01							0.28					
11/12/01		0.81	0.81		3.5		0.26				0.002	0.12
11/12/01		0.81	0.81		3.4		0.28				0.002 U	0.13

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
11/03/65				0.010 U							
11/04/65				0.010 U							
11/04/65				0.010 U							
11/04/65				0.010 U							
11/04/65											
11/07/65				0.010 U							
11/08/65				0.010 U							
11/02/70				0.010 U							
11/03/70				0.010 U							
11/04/70				0.010 U							
11/04/70				0.010 U							
11/05/70				0.010 U							
11/05/70				0.010 U							
11/05/70				0.010 U							
01/15/77											0.01 U,A
02/15/77											0.01 U,A
03/08/77											
03/15/77											0.01 U,A
04/15/77											0.01 U,A
05/15/77											0.01 U,A
06/15/77											0.01 U,A
07/15/77											0.01 U,A
08/15/77											0.01 U,A
09/15/77											0.01 U,A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
10/15/77											0.01 U,A
11/15/77											0.01 U,A
12/15/77											0.01 U,A
01/15/78											0.01 U,A
02/15/78											0.01 U,A
03/15/78											0.01 U,A
04/15/78											0.01 U,A
05/15/78											0.01 U,A
06/15/78											0.01 U,A
07/15/78											0.01 U,A
08/15/78											0.01 U,A
09/15/78											0.01 U,A
10/15/78											0.01 U,A
10/17/78											
10/17/78											
11/14/78											
11/14/78											
11/15/78											0.01 U,A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
12/15/78											0.01 U,A
01/15/79											0.01 U,A
01/16/79											
02/15/79											0.01 U,A
03/15/79											0.01 U,A
03/20/79											
04/15/79											0.01 U,A
04/26/79											
05/15/79											0.01 U,A
05/23/79											
06/10/79											
06/14/79											ND
06/15/79											0.01 U,A
06/18/79									0.002 U		
07/05/79											U
07/14/79											
07/15/79											0.01 U,A
07/24/79									0.002 U		

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
07/27/79											
08/04/79											
08/10/79											
08/15/79											0.01 U,A
08/29/79									0.002 U		
09/15/79											0.01 U,A
09/25/79									0.002 U		
10/15/79											0.01 U,A
10/24/79										0	
11/15/79											0.01 U,A
12/04/79										0.001	
12/15/79											0.01 U,A
12/17/79										0.001	
12/17/79											
02/07/80										0.001	
04/02/80											
04/28/80										0.001	
06/03/80											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
07/09/80										0.001	
08/14/80											
09/10/80										0.001	
10/14/80										0.001	
11/19/80										0.009	
01/08/81										0.001	
03/10/81										0.001	
03/11/81										0.001	
04/13/81											
05/14/81										0.001	
06/10/81											
07/14/81										0.001	
07/17/81					0.03		0.001		0.001 U		
08/12/81				0.022	0.026		0.002		0.002	0.001	
08/13/81										0.001	
08/20/81											
10/09/81											
11/05/81										0.001 U	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
02/17/82										0.001 U	
03/24/82										0.68	
04/29/82										0.41	
06/02/82										0.19	
07/06/82										0.23	
08/20/82										0.42	
09/16/82										0.32	
10/19/82										0.48	
12/07/82										0.75	
02/08/83										0.8	
04/26/83										1.4	
06/07/83										0.35	
07/21/83										0.49	
08/31/83										0.48	
11/04/83										0.64	
01/10/84										1.4	
01/25/84											
01/26/84											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
01/26/84											
01/26/84											
01/26/84											
01/27/84				0.005		0.1				0.001	
04/05/84										2.2	
05/25/84										0.62	
06/28/84										0.37	
09/27/84										0.92	
01/16/85										1.8	
06/12/85										0.49	
07/12/85										0.67	
07/20/85											
10/29/85											
12/20/85											
02/27/86		3.4		0.005		0.04				0.001	
05/22/86										0.27	
06/12/86										0.29	
08/18/86		3.34		0.005		0.1				0.001	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
08/19/86		3.26		0.005		0.1				0.001	
08/19/86											
08/20/86		3.41		0.005		0.1				0.001	
08/20/86											
08/26/86										1.4	
09/07/86		220	0.001 U		0.024	0.7			0.006	1 U	
12/24/86										1.1	
03/25/88		4.60	0.005	0.005		0.1				0.001	
07/26/88	1,453	1,456									
09/13/88	16.93	17.00	0.005	0.012	0.1	0.5			0.001	0.002	
09/20/88	1.95	2.00	0.005	0.005	0.1	0.1			0.001	0.001	
09/21/88											
09/26/88	2.00	2.10	0.005	0.005	0.1	0.1			0.001	0.001	
10/12/88	1.80				0.5 U				0.005		
10/25/88		1.31	0.005	0.005		0.05				0.001	
11/29/88											
11/29/88	7.1	11.50									
02/26/92		5.20	0.005 K		0.1 K		0.1 K		0.001 K		
03/25/92		9.00	0.005 K		0.1 K		0.1 K		0.003		
04/29/92			0.005 K		0.1 K		0.1 K		0.001 K		
05/27/92											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
06/30/92											
07/25/92		12.8								0.01 U	
07/29/92											
08/26/92											
09/30/92											
10/22/92	3.36	4.15									
10/28/92											
11/24/92											
12/16/92											
02/16/93	5.10	5.60									
11/10/93	3.30	6.10									
02/11/94	7.60	8.10									
05/15/94	0.83									0.005 U	
06/26/94											
06/26/94		1.36			0.027 J	0.04 J					
06/27/94		1.05	0.0033 U	0.0033 U	0.029	0.0313	0.0003 U	0.00049	0.0017 U	0.0017 U	
10/13/94	2.9	3.4								0.01 U	
10/13/94	2.9	3.4								0.01 U	
02/14/95	2.70	2.75									
11/09/95	3.80	3.91									
11/09/95		2.23	0.001 U	0.001 U	0.0332	0.0331	0.0005 U	0.0005 U	0.0011	0.0031 U	
11/09/95		2.23	0.001 U	0.001 U	0.033 J	0.033 J	0.0005 U	0.0005 JU	0.001	0.003 U	
02/26/96		3.4									
11/05/96		3.40									

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
03/13/97		3.00									
06/10/97											
07/17/97											
07/21/97		1.35									
08/14/97											
09/09/97											
09/09/97											
09/18/97											
10/23/97											
11/03/97		2.20									
11/03/97											
11/20/97											
12/19/97											
01/14/98											
02/20/98											
03/09/98		3.30									
03/09/98											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
03/19/98											
04/30/98											
04/30/98											
06/04/98											
07/16/98											
10/20/98		1.40									
02/25/99											
09/27/99											
10/13/99		1.50									
10/13/99											
03/15/00		2.50									
03/15/00											
05/01/00		1.21							0.0005		
05/01/00		1.21							0.0005		
07/18/00		10	0.01 U	0.01 U	0.01 U	0.34	0.005 U	0.005 U	0.005 U	0.005 U	
07/18/00		9.57		0.01 U		0.439		0.005 U	0.005 U	0.005 U	
08/06/00		18	0.01 U	0.01 U	0.01 U	0.62	0.005 U	0.005 U	0.005 U	0.005 U	
09/06/00		1.70									

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Al_s (mg/L) q	Al_t (mg/L) q	As_d (mg/L) q	As_t (mg/L) q	Ba_d (mg/L) q	Ba_t (mg/L) q	Be_d (mg/L) q	Be_t (mg/L) q	Cd_d (mg/L) q	Cd_t (mg/L) q	Cd_? (mg/L) q
11/03/00		1.70									
02/20/01		3.30									
05/22/01		1.2	0.005 U	0.005 U	0.025	0.043	0.004 U	0.004 U	0.001 U	0.001 U	
05/22/01		1.2	0.005 U	0.005 U	0.026	0.044	0.004 U	0.004 U	0.001 U	0.001 U	
08/21/01		1.6	0.005 U	0.005 U	0.032	0.035	0.004 U	0.004 U	0.001 U	0.001	
11/12/01		1.9	0.005 U	0.005 U	0.031	0.032	0.004 U	0.004 U	0.001 U	0.001 U	
11/12/01		1.9	0.005 U	0.005 U	0.03	0.032	0.004 U	0.004 U	0.001 U	0.001 U	
11/12/01											
11/12/01		1.9		0.005	0.03	0.03		0.004		0.001	
11/12/01		1.9		0.005 U	0.03	0.03		0.004 U		0.001 U	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
11/03/65									0.02 U		0.02 U
11/04/65									0.02 U		0.02 U
11/04/65									0.02 U		0.02 U
11/04/65									0.02 U		0.02 U
11/04/65											
11/07/65									0.02 U		0.02 U
11/08/65											
11/02/70									0.08		
11/03/70									0.0		
11/04/70									0.08		
11/04/70									0.2		
11/05/70									0.20		
11/05/70									0.12		
11/05/70									0.08		
01/15/77											0.73 A
02/15/77											0.5 A
03/08/77											
03/15/77											5.02 A
04/15/77											0.68 A
05/15/77											0.74 A
06/15/77											4.45 A
07/15/77											13.38 A
08/15/77											4.52 A
09/15/77											18.35 A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
10/15/77											1.8 A
11/15/77											1.62 A
12/15/77											1.13 A
01/15/78											1.31 A
02/15/78											0.73 A
03/15/78											0.88 A
04/15/78											2 A
05/15/78											7.01 A
06/15/78											1.26 A
07/15/78											2.43 A
08/15/78											0.58 A
09/15/78											0.59 A
10/15/78											0.45 A
10/17/78						0.02 U					
10/17/78											
11/14/78											
11/14/78											
11/15/78											0.97 A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
12/15/78											0.45 A
01/15/79								U,A			0.7 A
01/16/79						0.02 U			0.12		
02/15/79								U,A			2.46 A
03/15/79								U,A			1.1 A
03/20/79											
04/15/79								U,A			25.25 A
04/26/79						0.02 U			0.01 U		
05/15/79								0.13 A			18.05 A
05/23/79								A	0.03		
06/10/79											
06/14/79					0.047			0.01 U			14.08
06/15/79								0.03 A			14.07 A
06/18/79											
07/05/79					0.047			0.01 U			14.08
07/14/79											
07/15/79								0.01 U,A			1.44 A
07/24/79											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
07/27/79											
08/04/79											
08/10/79											
08/15/79								0.01 U,A			2.49 A
08/29/79						0.02 U			0.01 U		
09/15/79											
09/25/79											
10/15/79											
10/24/79									0.01		
11/15/79											
12/04/79									0.02		
12/15/79											
12/17/79									0.01		
12/17/79									0.01		
02/07/80									0.02		
04/02/80									0.01 U		
04/28/80									0.01 U		
06/03/80									0.14		

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
07/09/80									0.01		
08/14/80									0.02		
09/10/80									0.02		
10/14/80									0.01		
11/19/80									0.14		
01/08/81									0.08		
03/10/81									0.07		
03/11/81									0.11		
04/13/81						0.005			0.02		
05/14/81									0.02		
06/10/81									0.03		
07/14/81									0.01		
07/17/81	0.003 U			0.02		0.01 U	0.11		0.02	38	
08/12/81	0.023			0.06		0.04	0.48		0.01 U	180	
08/13/81									0.01 U		
08/20/81											
10/09/81									0.01 U		
11/05/81									0.02		

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
02/17/82							0.036		0.03		
03/24/82							0.023		0.01		
04/29/82							0.017		0.07		
06/02/82							0.017		0.04		
07/06/82							0.008		0.02		
08/20/82							0.026		0.003 U		
09/16/82							0.023		0.02		
10/19/82							0.017		0.03		
12/07/82							0.025		0.04		
02/08/83							0.035		0.03		
04/26/83							0.085				
06/07/83							0.019		0.05		
07/21/83							0.023				
08/31/83							0.022				
11/04/83							0.027		0.01		
01/10/84							0.048		0.01		
01/25/84											
01/26/84											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
01/26/84											
01/26/84											
01/26/84											
01/27/84											
04/05/84							0.049		0.06		
05/25/84							0.08		0.04		
06/28/84							0.016		0.01		
09/27/84							0.031		0.02		
01/16/85							0.044		0.2		
06/12/85							0.027		0.04		
07/12/85							0.016		0.01		
07/20/85							0.32		0.03		
10/29/85											
12/20/85							0.052		0.12		
02/27/86				0.005			0.05			0.44	
05/22/86							0.006		0.02		
06/12/86							0.021		0.29		
08/18/86				0.005			0.05			1.1	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
08/19/86				0.005			0.05			4.03	
08/19/86											
08/20/86				0.005			0.05			0.85	
08/20/86											
08/26/86							0.056		0.02		
09/07/86			0.01 U	0.45		0.51	2.1		0.13	940	
12/24/86							0.031		0.08		
03/25/88				0.005			0.06			0.34	
07/26/88											
09/13/88			0.005	0.032		0.05	0.13		0.05	45	
09/20/88			0.013	0.005		0.05	0.05		0.05	0.59	
09/21/88											
09/26/88			0.005	0.005		0.05	0.05		0.05	0.44	
10/12/88						0.02			0.04		
10/25/88				0.005			0.05			0.44	
11/29/88											
11/29/88											2.17
02/26/92	0.05 K		0.005 K			0.1 K			0.100 K		
03/25/92	0.05 K		0.005 K			0.1 K			0.200		
04/29/92	0.05 K		0.005 K			0.01 K			0.100 K		
05/27/92											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
06/30/92											
07/25/92							0.114			27.9	
07/29/92											
08/26/92											
09/30/92											
10/22/92											0.2
10/28/92											
11/24/92											
12/16/92											
02/16/93											0.524
11/10/93											0.301
02/11/94											0.36
05/15/94							0.024			2.72	
06/26/94											
06/26/94	0.005 J	0.006 J									
06/27/94	0.0035 U	0.0044	0.0023 U	0.0028		0.0021 U	0.0108		0.045 U	0.233	
10/13/94							0.03			0.342	
10/13/94							0.03			0.432	
02/14/95											0.408
11/09/95											0.339
11/09/95	0.0059	0.0055	0.0046 U	0.0046 U		0.0042 U	0.0247		0.0181 U	0.184	
11/09/95	0.0059 J	0.005	0.0046 U	0.0046 U		0.0042 U	0.0247 J		0.0181 U	0.184	
02/26/96											
11/05/96											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
03/13/97											
06/10/97											
07/17/97											
07/21/97											
08/14/97											
09/09/97									0.2 U		
09/09/97											
09/18/97											
10/23/97											
11/03/97											
11/03/97											
11/20/97											
12/19/97											
01/14/98											
02/20/98											
03/09/98											
03/09/98											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
03/19/98											
04/30/98						0.02 U					
04/30/98											
06/04/98											
07/16/98											
10/20/98						0.25 U					
02/25/99											
09/27/99											
10/13/99											
10/13/99											
03/15/00											
03/15/00											
05/01/00	0.0022	0.0026				0.005	0.005			0.33	
05/01/00	0.0022	0.0026				0.005	0.005			0.33	
07/18/00	0.01 U	0.012	0.01 U	0.011		0.01 U	0.075		0.01 U	32	
07/18/00		0.0126		0.0119			0.0848			39.3	
08/06/00	0.01 U	0.02	0.01 U	0.013		0.01 U	0.18		0.1	36	
09/06/00											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Co_d (mg/L) q	Co_t (mg/L) q	Cr_d (mg/L) q	Cr_t (mg/L) q	Cr_? (mg/L)	Cu_d (mg/L) q	Cu_t (mg/L) q	Cu_? (mg/L) q	Fe_d (mg/L) q	Fe_t (mg/L) q	Fe_? (mg/L) q
11/03/00											
02/20/01							0.033				
05/22/01			0.01 U	0.01 U		0.01 U	0.01		0.22	1.1	
05/22/01			0.01 U	0.01 U		0.01 U	0.013		0.1 U	1.2	
08/21/01			0.01 U	0.01 U		0.01 U	0.017		0.1 U	0.32	
11/12/01			0.01 U	0.01 U		0.0016	0.019		0.1 U	0.27	
11/12/01			0.01 U	0.01 U		0.002	0.019		0.1 U	0.26	
11/12/01											
11/12/01				0.01		0.002	0.01			0.26	
11/12/01				0.01 U		0.0016	0.01			0.27	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
11/03/65	0.02 U										
11/04/65	0.02 U										
11/04/65	0.02 U										
11/04/65	0.02 U										
11/04/65											
11/07/65	0.02 U										
11/08/65											
11/02/70											
11/03/70											
11/04/70											
11/04/70											
11/05/70											
11/05/70											
11/05/70											
01/15/77	0.73 A						0.75 A	0.75 A			U,A
02/15/77	0.5 A						0.6 A	0.6 A			U,A
03/08/77											
03/15/77	5.02 A						1.1 A	1.1 A			0.02 A
04/15/77	0.68 A						0.48 A	0.48 A			U,A
05/15/77	0.74 A						0.28 A	0.28 A			U,A
06/15/77	4.45 A						0.83 A	0.83 A			0.27 A
07/15/77	13.38 A						0.45 A	0.45 A			0.01 A
08/15/77	4.52 A						0.42 A	0.42 A			U,A
09/15/77	18.25 A						0.58 A	0.58 A			0.04 A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
10/15/77	1.8						0.33 A	0.33 A			U,A
11/15/77	1.62 A						0.45 A	0.45 A			U,A
12/15/77	1.13 A						0.62 A	0.62 A			U,A
01/15/78	1.31 A						0.51 A	0.51 A			U,A
02/15/78	0.73 A						0.63 A	0.63 A			U,A
03/15/78	0.88 A						0.49 A	0.49 A			U,A
04/15/78	2						0.17 A	0.17 A			U,A
05/15/78	7.01 A						0.23 A	0.23 A			0.06 A
06/15/78	1.26 A						0.12 A	0.12 A			U,A
07/15/78	2.43 A						0.26 A	0.26 A			U,A
08/15/78	0.58 A						0.17 A	0.17 A			U,A
09/15/78	0.59 A						0.33 A	0.33 A			U,A
10/15/78	0.45						0.44 A	0.44 A			0.01 A
10/17/78									0.014	0.012	
10/17/78											
11/14/78											
11/14/78										0.017	
11/15/78	0.97 A						0.39 A	0.39 A			U,A

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
12/15/78	0.45 A						0.45 A	0.45 A			U,A
01/15/79	0.7 A						0.4 A	0.4 A			U,A
01/16/79					0.48				0.009	0.01	
02/15/79	2.46 A						0.34 A	0.34 A			U,A
03/15/79	1.1 A						0.38 A	0.38 A			U,A
03/20/79										0.008	
04/15/79	25.25						0.77 A	0.77 A			U,A
04/26/79					0.25				0.01 U	0.01	
05/15/79	18.05 A						0.87 A	0.87 A			0.03 A
05/23/79					0.08				0.006	0.017	
06/10/79											
06/14/79	14.08			0.000063			0.89	0.89			U
06/15/79	14.07 A						0.88 A	0.88 A			0.05 A
06/18/79										0.009	
07/05/79	14.08			0.000063			0.89	0.89			U
07/14/79											
07/15/79	1.44 A						0.33 A	0.33 A			U,A
07/24/79										0.004	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
07/27/79											
08/04/79											
08/10/79											
08/15/79	2.49 A						0.26 A	0.26 A			U,A
08/29/79					0.18				0.012	0.008	
09/15/79											
09/25/79										0.006	
10/15/79											
10/24/79					0.31				0.001	0.007	
11/15/79											
12/04/79					0.6				0.01 U	0.003	
12/15/79											
12/17/79					0.49				0.053	0.052	
12/17/79					0.58					0.13	
02/07/80					0.49				0.01 U	0.007	
04/02/80					0.45				0.01 U	0.01	
04/28/80					0.39				0.01 U	0.006	
06/03/80					0.11				0.002	0	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
07/09/80					0.16				0.01 U	0.006	
08/14/80					0.3				0.006	0.007	
09/10/80					0.19				0.01 U	0.009	
10/14/80					0.49				0.006	0.008	
11/19/80					0.94				0.01 U	0.012	
01/08/81					0.6				0.01	0.009	
03/10/81					0.95				0.01 U	0.027	
03/11/81					0.99				0.014	0.011	
04/13/81					0.47				0.01 U	0.1	
05/14/81					0.35				0.01 U	0.001	
06/10/81					0.16				0.01 U	0.006	
07/14/81					0.35				0.011	0.019	
07/17/81	38				0.061	0.7		0.7	0.019	0.03	
08/12/81	180				1.5	2.6		2.6	0.01 U	0.14	
08/13/81					0.34				0.01	0.008	
08/20/81											
10/09/81					0.39				0.01	0.007	
11/05/81					0.46				0.01 U	0.008	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
02/17/82					0.59				0.01	0.01	
03/24/82					0.51				0.007	0.008	
04/29/82					0.27				0.004	0.004	
06/02/82					0.086				0.002	0.003	
07/06/82					0.005				0.002	0.004	
08/20/82					0.27				0.045	0.017	
09/16/82					0.26				0.003	0.004	
10/19/82					0.39				0.005	0.005	
12/07/82					0.53				0.004	0.002	
02/08/83					0.52				0.004	0.005	
04/26/83					1.2				0.002	0.005	
06/07/83					0.13				0.001 U	0.006	
07/21/83					0.25				0.001 U	0.005	
08/31/83					0.43				0.004	0.004	
11/04/83					0.62				0.006	0.012	
01/10/84									0.009	0.008	
01/25/84											
01/26/84											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
01/26/84											
01/26/84											
01/26/84											
01/27/84			0.0050				1.25	1.25		0.010	
04/05/84					1.4				0.006	0.006	
05/25/84					0.15				0.002	0.013	
06/28/84					0.27				0.004	0.005	
09/27/84					0.84				0.004	0.005	
01/16/85					1.7				0.004	0.004	
06/12/85					0.28				0.002	0.001	
07/12/85					0.001				0.002	0.002	
07/20/85					0.86				0.001 U	0.1	
10/29/85											
12/20/85					1.6				0.004	0.004	
02/27/86	0.44		0.0005			1		1		0.010	
05/22/86					0.25				0.002	0.001	
06/12/86					0.24				0.006	0.003	
08/18/86	1.1		0.0005			0.89		0.89		0.010	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
08/19/86	4.03		0.0005			0.95		0.95		0.010	
08/19/86											
08/20/86	0.85		0.0005			1.04		1.04		0.010	
08/20/86											
08/26/86					1.4				0.005	0.004	
09/07/86	940				12	18		18	0.001	0.036	
12/24/86					0.99				0.008	0.008	
03/25/88	0.34		0.0005			1.2		1.2		0.010	
07/26/88											
09/13/88	45	0.0005	0.0005		0.8	1.3		1.3	0.01	0.033	
09/20/88	0.59	0.0005	0.0005		0.61	0.6		0.6	0.01	0.010	
09/21/88											
09/26/88	0.44	0.0005	0.0005		0.66	0.64		0.64	0.01	0.010	
10/12/88					0.72				0.72		
10/25/88	0.44		0.0005			0.78		0.78		0.010	
11/29/88											
11/29/88	2.17						1.39	1.39			
02/26/92			0.0005 K		1.600				0.1 K		
03/25/92			0.0005 K		3.000				0.1 K		
04/29/92			0.0005 K		0.760				0.01 K		
05/27/92											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
06/30/92											
07/25/92	27.9					1.2		1.2		0.5	
07/29/92											
08/26/92											
09/30/92											
10/22/92	0.2						1.13	1.13			
10/28/92											
11/24/92											
12/16/92											
02/16/93	0.524					1.5		1.5			
11/10/93	0.301						0.932	0.932			
02/11/94	0.36						1.68	1.68			
05/15/94	2.72					0.29		0.29		0.020 U	
06/26/94											
06/26/94			0.00022		0.369	0.407		0.407			
06/27/94	0.233	0.0001 U	0.0001 U		0.378	0.408		0.408	0.02 U	0.02 U	
10/13/94	0.342					0.946		0.946		0.1 U	
10/13/94	0.432					0.902		0.902		0.1 U	
02/14/95	0.408					0.828		0.828			
11/09/95	0.339					0.87		0.87			
11/09/95	0.184		0.0002 U	0.0002 U	0.815	0.759		0.759	0.0078 U	0.0078 U	
11/09/95	0.184	0.0002 U	0.0002 U		0.815	0.759		0.759	0.0078 U	0.0078 U	
02/26/96						0.546		0.546			
11/05/96						1.1		1.1			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
03/13/97						0.66		0.66			
06/10/97											
07/17/97											
07/21/97						0.41		0.41			
08/14/97											
09/09/97											
09/09/97											
09/18/97											
10/23/97											
11/03/97						0.6		0.6			
11/03/97											
11/20/97											
12/19/97											
01/14/98											
02/20/98											
03/09/98						0.50		0.50			
03/09/98											

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
03/19/98											
04/30/98						0.20		0.20			
04/30/98											
06/04/98											
07/16/98											
10/20/98											0.1 U
02/25/99											
09/27/99											
10/13/99						0.27		0.27			
10/13/99											
03/15/00						0.41		0.41			
03/15/00											
05/01/00	0.33				0.182	0.2		0.2	0.0022	0.0022	
05/01/00	0.33				0.182	0.2		0.2	0.0022	0.0022	
07/18/00	32				0.74	0.92		0.92	0.01 U	0.014	
07/18/00	39.3					0.952		0.952		0.0179	
08/06/00	36				0.098	1.1		1.1	0.01 U	0.019	
09/06/00						0.34		0.34			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Fe_t, _? (mg/L) q	Hg_d (mg/L) q	Hg_t (mg/L) q	Hg_? (mg/L) q	Mn_d (mg/L)	Mn_t (mg/L)	Mn_? (mg/L) q	Mn_t, ? (mg/L) q	Mo_d (mg/L) q	Mo_t (mg/L) q	Mo_? (mg/L) q
11/03/00											
02/20/01						0.62		0.62		0.010 U	
05/22/01	1.1		0.0002 U		0.12	0.17		0.17	0.1 U	0.1 U	
05/22/01	1.2		0.0002 U		0.12	0.18		0.18	0.1 U	0.1 U	
08/21/01	0.32		0.0002 U		0.45	0.46		0.46	0.1 U	0.1 U	
11/12/01	0.27		0.0002 U		0.38	0.39		0.39		0.1 U	
11/12/01	0.26		0.0002 U		0.38	0.39		0.39		0.1 U	
11/12/01											
11/12/01	0.26		0.0002 U			0.39		0.39	0.1 U	0.1	
11/12/01	0.27		0.0002 U			0.39		0.39	0.1 U	0.1 U	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
11/03/65						0.020 U						
11/04/65						0.020 U						
11/04/65						0.020 U						
11/04/65						0.020 U						
11/04/65												
11/07/65						0.020 U						
11/08/65						0.020 U						
11/02/70						0.02 U						
11/03/70						0.02 U						
11/04/70						0.02 U						
11/04/70						0.02 U						
11/05/70						0.02 U						
11/05/70						0.02 U						
11/05/70						0.02 U						
01/15/77												
02/15/77												
03/08/77												
03/15/77												
04/15/77												
05/15/77												
06/15/77												
07/15/77												
08/15/77												
09/15/77												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
10/15/77												
11/15/77												
12/15/77												
01/15/78												
02/15/78												
03/15/78												
04/15/78												
05/15/78												
06/15/78												
07/15/78												
08/15/78												
09/15/78												
10/15/78												
10/17/78				0.04								
10/17/78												
11/14/78												
11/14/78				0.01								
11/15/78												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
12/15/78												
01/15/79												
01/16/79				0.03								11
02/15/79												
03/15/79												
03/20/79				0.02								
04/15/79												
04/26/79				0.2								12
05/15/79												
05/23/79				0.36								9.8
06/10/79												
06/14/79			0.043			ND						
06/15/79												
06/18/79				0.3								
07/05/79			0.043									
07/14/79												
07/15/79												
07/24/79				0.01								

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
07/27/79												
08/04/79												
08/10/79												
08/15/79												
08/29/79				0.11								10
09/15/79												
09/25/79				0.02								
10/15/79												
10/24/79				0.02								19
11/15/79												
12/04/79				0.03								11
12/15/79												
12/17/79				0.23								10
12/17/79												
02/07/80				0.04								13
04/02/80				0.06								10
04/28/80				0.07								11
06/03/80				0.04								10

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
07/09/80				0.03								9
08/14/80				0.13								11
09/10/80				0.2								9.9
10/14/80				0.05								11
11/19/80				0.01								10
01/08/81				0.08								11
03/10/81				0.03								10
03/11/81												10
04/13/81				0.12								9.4
05/14/81				0.02								10
06/10/81				0.02								8.2
07/14/81				0.08								11
07/17/81					0.01 U	0.16						10
08/12/81					0.01 U	0.84				0.005		14
08/13/81				0.14								11
08/20/81												
10/09/81				0.08								12
11/05/81				0.04								11

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
02/17/82					0.001 U							
03/24/82												
04/29/82												
06/02/82												
07/06/82												
08/20/82												
09/16/82												
10/19/82												
12/07/82												
02/08/83												
04/26/83												
06/07/83												
07/21/83												
08/31/83												
11/04/83												
01/10/84												
01/25/84												
01/26/84												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
01/26/84												
01/26/84												
01/26/84												
01/27/84						0.005				0.005		
04/05/84												
05/25/84												
06/28/84												
09/27/84												
01/16/85												
06/12/85												
07/12/85												
07/20/85												
10/29/85												
12/20/85												
02/27/86		0.05				0.010				0.005		
05/22/86												
06/12/86												
08/18/86		0.05				0.010				0.005		

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
08/19/86		0.05				0.010				0.005		
08/19/86												
08/20/86		0.05				0.010				0.005		
08/20/86												
08/26/86												
09/07/86	0.2	0.034			0.01 U	3.3						
12/24/86												
03/25/88						0.010				0.005		
07/26/88												
09/13/88	0.05	0.05			0.01	0.120			0.005	0.005		
09/20/88	0.05	0.05			0.01	0.005			0.005	0.005		
09/21/88												
09/26/88	0.05	0.05			0.01	0.010			0.005	0.005		
10/12/88					0.05 U							
10/25/88						0.005				0.005		
11/29/88												
11/29/88												
02/26/92	0.1 K				0.005 K				0.005 K			
03/25/92	0.1 K				0.005 K				0.005 K			
04/29/92	0.1 K				0.005 K				0.005 K			
05/27/92												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
06/30/92												
07/25/92						0.12						
07/29/92												
08/26/92												
09/30/92												
10/22/92												
10/28/92												
11/24/92												
12/16/92												
02/16/93												
11/10/93												
02/11/94												
05/15/94						0.014						
06/26/94												
06/26/94						0.002 J						
06/27/94	0.0076	0.0165		0.05 U	0.0019 U	0.0019 U	0.03 U	0.03 U	0.01 U	0.0022 U		
10/13/94						0.1 U						
10/13/94						0.1 U						
02/14/95												
11/09/95												
11/09/95	0.0299	0.0236				0.001 U	0.0005 U	0.00029	0.002 U	0.002 U		
11/09/95	0.0299 J	0.0236 J			0.001 UJ	0.001 UJ	0.0005 U	0.0029	0.002 UJ	0.002 UJ		
02/26/96												
11/05/96												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
03/13/97												
06/10/97												
07/17/97												
07/21/97												
08/14/97												
09/09/97												
09/09/97												
09/18/97												
10/23/97												
11/03/97												
11/03/97												
11/20/97												
12/19/97												
01/14/98												
02/20/98												
03/09/98												
03/09/98												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
03/19/98												
04/30/98												
04/30/98												
06/04/98												
07/16/98												
10/20/98												
02/25/99												
09/27/99												
10/13/99												
10/13/99												
03/15/00												
03/15/00												
05/01/00	0.011	0.014										
05/01/00	0.011	0.014										
07/18/00	0.037	0.048			0.003 U	0.13	0.02 U	0.02 U	0.005 U	0.005 U		
07/18/00		0.0491				0.167		0.02 U		0.005 U		
08/06/00	0.02 U	0.077			0.003 U	0.12	0.02 U	0.02 U	0.005 U	0.005 U		
09/06/00												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	Ni_d (mg/L) q	Ni_t (mg/L) q	Ni_? (mg/L)	P_t (mg/L) q	Pb_d (mg/L) q	Pb_t (mg/L) q	Sb_d (mg/L) q	Sb_t (mg/L) q	Se_d (mg/L) q	Se_t (mg/L) q	Si_d (mg/L)	SiO_2_d (mg/L)
11/03/00												
02/20/01												
05/22/01	0.02 U	0.02 U			0.003 U	0.0034			0.005 U	0.005 U		
05/22/01	0.02 U	0.02 U			0.003 U	0.003 U			0.005 U	0.005 U		
08/21/01	0.021	0.022			0.003 U	0.003 U			0.005 U	0.005 U	5.2	
11/12/01	0.018	0.019			0.003 U	0.003 U			0.005 U	0.005 U		
11/12/01	0.018	0.019			0.003 U	0.003 U			0.005 U	0.005 U		
11/12/01												
11/12/01	0.01	0.01				0.003				0.005	4.9	
11/12/01	0.01	0.01				0.003 U				0.005 U	5	

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
11/03/65							1.00 U		1.00 U			
11/04/65							1.00 U		1.00 U			
11/04/65							1.00 U		1.00 U			
11/04/65							1.00 U		1.00 U	1.6	1.2	25.8
11/04/65												
11/07/65							1.00 U		1.00 U			
11/08/65							1.00 U		1.00 U			
11/02/70							0.02		0.02			
11/03/70							0.01		0.01			
11/04/70							0.01 U		0.01 U			
11/04/70							0.01 U		0.01 U			
11/05/70							0.01 U		0.01 U			
11/05/70							0.02		0.02			
11/05/70							0.02		0.02			
01/15/77								0.18 A	0.18 A			
02/15/77								0.16 A	0.16 A			
03/08/77												
03/15/77								0.36 A	0.36 A			
04/15/77								0.19 A	0.19 A			
05/15/77								0.11 A	0.11 A			
06/15/77								0.24 A	0.24 A			
07/15/77								0.27 A	0.27 A			
08/15/77								0.17 A	0.17 A			
09/15/77								0.21 A	0.21 A			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge imbalance (%)
10/15/77								0.22 A	0.22 A			
11/15/77								0.11 A	0.11 A			
12/15/77								0.10 A	0.10 A			
01/15/78								0.06 A	0.06 A			
02/15/78								0.12 A	0.12 A			
03/15/78								0.11 A	0.11 A			
04/15/78								0.11 A	0.11 A			
05/15/78								0.11 A	0.11 A			
06/15/78								0.07 A	0.07 A			
07/15/78								0.07 A	0.07 A			
08/15/78								0.08 A	0.08 A			
09/15/78								0.08 A	0.08 A			
10/15/78								0.11 A	0.11 A			
10/17/78						0.05	0.09		0.09			
10/17/78												
11/14/78												
11/14/78							0.07		0.07			
11/15/78								0.23 A	0.23 A			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge imbalance (%)
12/15/78								0.07 A	0.07 A			
01/15/79								0.06 A	0.06 A			
01/16/79						0.1	0.13		0.13			
02/15/79								0.05 A	0.05 A			
03/15/79								0.11 A	0.11 A			
03/20/79							0.12		0.12			
04/15/79								0.09 A	0.09 A			
04/26/79						0.2	0.2		0.2			
05/15/79								0.30 A	0.30 A			
05/23/79						0.2 U	0.11		0.11			
06/10/79												
06/14/79								0.40	0.40			
06/15/79								0.22 A	0.22 A			
06/18/79							0.18		0.18			
07/05/79								0.40	0.40			
07/14/79												
07/15/79								0.08 A	0.08 A			
07/24/79							0.09		0.09			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
07/27/79												
08/04/79												
08/10/79												
08/15/79								0.12 A	0.12 A			
08/29/79						0.003 U	0.09		0.09			
09/15/79												
09/25/79							0.06		0.06			
10/15/79												
10/24/79						0.05	0.06		0.06			
11/15/79												
12/04/79						0.13	0.14		0.14			
12/15/79												
12/17/79						0.08	0.17		0.17			
12/17/79						0.06	0.27		0.27			
02/07/80						0.09	0.16		0.16			
04/02/80						0.07	0.12		0.12			
04/28/80						0.05	0.11		0.11			
06/03/80						0.02	0.05		0.05			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
07/09/80						0.02	0.05		0.05			
08/14/80						0.03	0.11		0.11			
09/10/80						0.03	0.14		0.14			
10/14/80						0.07	0.33		0.33			
11/19/80						0.19						
01/08/81						0.11	0.14		0.14			
03/10/81						0.16	0.26		0.26			
03/11/81						0.21	0.22		0.22			
04/13/81						0.05	0.13		0.13			
05/14/81						0.04	0.16		0.16			
06/10/81						0.06	0.06		0.06			
07/14/81						0.03	0.09		0.09			
07/17/81				0.006 U		0.014	0.23		0.23			
08/12/81				0.006 U		0.36	0.75		0.75			
08/13/81						0.038	0.1		0.1			
08/20/81												
10/09/81						0.043	0.11		0.11			
11/05/81						0.078	0.12		0.12			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
02/17/82						0.11	0.16		0.16			
03/24/82						0.072	0.12		0.12			
04/29/82						0.046	0.09		0.09			
06/02/82						0.03	0.05		0.05			
07/06/82						0.036	0.06		0.06			
08/20/82						0.005	0.07		0.07			
09/16/82						0.059	0.07		0.07			
10/19/82						0.063	0.11		0.11			
12/07/82						0.11	0.16		0.16			
02/08/83						0.091	0.17		0.17			
04/26/83						0.19	0.42		0.42			
06/07/83						0.028	0.07		0.07			
07/21/83						0.04	0.12		0.12			
08/31/83						0.053	0.16		0.16			
11/04/83						0.09	0.2		0.2			
01/10/84						0.23	0.31		0.31			
01/25/84												
01/26/84												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
01/26/84												
01/26/84												
01/26/84												
01/27/84							0.280		0.280			
04/05/84						0.25	0.33		0.33			
05/25/84						0.041	0.17		0.17			
06/28/84						0.047	0.09		0.09			
09/27/84						0.1	0.2		0.2			
01/16/85						0.34	0.37		0.37			
06/12/85						0.046	0.19		0.19			
07/12/85						0.011	0.12		0.12			
07/20/85						0.26	0.67		0.67			
10/29/85												
12/20/85						0.29	0.34		0.34			
02/27/86							0.22		0.22			
05/22/86						0.037	0.06		0.06			
06/12/86						0.07	0.08		0.08			
08/18/86							0.19		0.19			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
08/19/86							0.02		0.02	3	2.8	10.2
08/19/86												
08/20/86							0.22		0.22	3.1	2.8	8.4
08/20/86							0.21		0.21			
08/26/86						0.18	0.29		0.29			
09/07/86						2.6	4.4		4.4			
12/24/86						0.19	0.21		0.21			
03/25/88							0.26		0.26			
07/26/88												
09/13/88						0.07	0.30		0.30	1.8	2.3	-28.6
09/20/88						0.12	0.10		0.10	1.7	1.7	0.7
09/21/88												
09/26/88						0.10	0.12		0.12			
10/12/88						0.12			0.12			
10/25/88							0.13		0.13			
11/29/88												
11/29/88								0.37	0.37			
02/26/92				0.100 K		0.30						
03/25/92				0.100 K		0.60						
04/29/92				0.100 K		0.10 K						
05/27/92												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
06/30/92												
07/25/92							0.281		0.281			
07/29/92												
08/26/92												
09/30/92												
10/22/92									0.273			
10/28/92												
11/24/92												
12/16/92												
02/16/93								0.348	0.348			
11/10/93								0.225	0.225			
02/11/94								0.355	0.355			
05/15/94	14						0.073		0.073			
06/26/94												
06/26/94						0.06	0.095		0.095			
06/27/94		0.0019 U	0.0019 U	0.0023 U	0.0023 U	0.0583	0.104		0.104			
10/13/94							0.23		0.23			
10/13/94							0.228		0.228			
02/14/95								0.265	0.265			
11/09/95							0.280		0.280			
11/09/95		0.001 U	0.0012 U	0.0039 U	0.0039 U	0.126	0.191		0.191	3.6	3.8	-1.85
11/09/95		0.001 U	0.0012 U	0.0039 U	0.0039 U	0.126	0.191		0.191			
02/26/96							0.232		0.232			
11/05/96							0.3		0.3			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
03/13/97							0.19		0.19			
06/10/97												
07/17/97												
07/21/97							0.12		0.12			
08/14/97												
09/09/97							0.25 U		0.25 U			
09/09/97												
09/18/97												
10/23/97												
11/03/97							0.25 U		0.25 U			
11/03/97												
11/20/97												
12/19/97												
01/14/98												
02/20/98												
03/09/98							0.25 U		0.25 U			
03/09/98												

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
03/19/98												
04/30/98							0.06		0.06			
04/30/98												
06/04/98												
07/16/98												
10/20/98							0.25 U		0.25 U			
02/25/99												
09/27/99												
10/13/99												
10/13/99												
03/15/00						0.055			0.055			
03/15/00												
05/01/00						0.06	0.09		0.09	2.8	2.8	0
05/01/00						0.06	0.09		0.09	2.8	2.8	0
07/18/00		0.01 U	0.01 U	0.01 U	0.014	0.12	0.32		0.32			
07/18/00			0.01 U		0.0149		0.345		0.345			
08/06/00		0.01 U	0.01 U	0.01 U	0.017	0.02 U	0.77		0.77			
09/06/00							0.110		0.110			

Table 3. Historical Water Quality Data for the Red River at the Ranger Station.

Date (dd-mm-yy)	SiO_2_t (mg/L)	Tl_d (mg/L) q	Tl_t (mg/L) q	V_d (mg/L) q	V_t (mg/L) q	Zn_d (mg/L) q	Zn_t (mg/L) q	Zn_? (mg/L) q	Zn_t,d,? (mg/L) q	Total cations (meq/L)	Total anions (meq/L)	Charge Imbalance (%)
11/03/00							0.14		0.14			
02/20/01							0.22		0.22			
05/22/01						0.028	0.052		0.052			
05/22/01						0.031	0.06		0.06			
08/21/01	5.6			0.01 U	0.01 U	0.075	0.15		0.15			
11/12/01	5.6			0.01 U	0.01 U	0.089	0.13		0.13			
11/12/01	5.5			0.01 U	0.01 U	0.088	0.13		0.13			
11/12/01												
11/12/01	5.5				0.01	0.08	0.13		0.13			
11/12/01	5.6				0.01 U	0.08	0.13		0.13			

Table 5. Water-Quality Data upstream of the Molycorp Molybdenum Mine.

Table ~~4~~ 5. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L) q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l) q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
7 ABOVE MILL	11/29/1988	33200		65					0.23	4.10	0.08	2.30	1.80	7.7
7 ABOVE MILL	10/22/1992	33200		85		317			0.21	1.60	0.071	0.90	0.70	8.19
7 ABOVE MILL	2/16/1993	33200		113		336			0.274	2.50	0.083	2.00	0.50	7.7
7 ABOVE MILL	11/10/1993	33200		80		327			0.237	2.30	0.1	1.10	1.20	7.5
7 ABOVE MILL	2/11/1994	33200		103		341			0.36	2.50	0.107	2.00	0.50	7.46
7 ABOVE MILL	10/13/1994	33200		93		296			0.143	1.25	0.051	0.75	0.50	7.6
ABOVE MILL	11/7/1994		18.0	74	3,259	178		8.22	0.208	1.070	0.069		0.12	6
7 ABOVE MILL	2/14/1995	33200		103		341			0.175	1.18	0.088	1.10	0.08	8.1
7 ABOVE MILL	11/9/1995	33200		83		294	289	6.0	0.160	2.13	0.090	2.00	0.13	8.1
7 ABOVE MILL	2/26/1996	33200		102		335		10.9	0.155	1.70	0.056			7.8
7 ABOVE MILL	11/5/1996	33200		96		331	316	9.9	0.200	1.10	0.090 U			7.4
7 ABOVE MILL	3/13/1997	33200		102		346	346	9.4	0.26	1.30	0.09 U			7.4
7 ABOVE MILL	7/21/1997	33200		40		224	219	6.1	0.079	0.46	0.040			8.7
7 ABOVE MILL	9/9/1997	33200		74		262	259	7.2	<0.2		0.25 U		<0.5	8.1
7 ABOVE MILL	11/3/1997	33200		94		306	291	9.1	<0.2	0.50	0.25 U			7.4
7 ABOVE MILL	3/9/1998	33200		112		353	333	10.3	0.30	2.00	0.25 U			7.8
7 ABOVE MILL	4/30/1998	33200		49		223	218		<0.2		0.05 U			7.5
7 ABOVE MILL	10/20/1998	33200	14.88	70	2,548	279				0.60	0.25 U			8.1

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L)	q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l)	q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
7 ABOVE MILL	2/25/1999	33200		92			322									8.2
7 ABOVE MILL	9/27/1999	33200					264									
7 ABOVE MILL	10/13/1999	33200	15.37	78		2,933	273		7.7	0.120					0.24	
7 ABOVE MILL	3/15/2000	33200	9.31	100		2,278	328		10.0	0.19	1.00	0.014			0.10	8.3
7 ABOVE MILL	9/6/2000	33200	9.56	106		2,479	311			0.17	0.75	0.05	U			8.3
7 ABOVE MILL	11/3/2000	33200	8.99	87		1,913	308				0.81	0.045				8.0
7 ABOVE MILL	2/20/2001	33200	5.05	120		1,483	358		12.0	0.33	2.00	0.110			0.064	7.9
ABOVE MOLY PROP LINE	9/13/1988	34300		103			213			0.62	8.90	0.15		8.85	0.05	7.2
ABOVE MOLY PROP LINE	9/20/1988	34300		46			166			0.1	0.60	0.05		0.46	0.14	7.9
ABOVE MOLY PROP LINE	9/26/1988	34300		51			199			0.1	0.70	0.05		0.60	0.10	7.5
ABOVE MOLY PROP LINE	10/25/1988	34300	20	67		3,278	237			0.15	1.08	0.05				7.8
6A DNSTR. OF HANSON	11/29/1988	39800														
6A DNSTR. HANSON CR.	10/22/1992	39800														
6A DNSTR. HANSON CR.	2/16/1993	39800														
6A DNSTR. HANSON CR.	11/10/1993	39800		83			330			0.254	2.70	0.084		1.3	1.4	7.63
6A DNSTR. HANSON CR.	2/11/1994	39800														
6A DNSTR. HANSON CR.	10/13/1994	39800		97			291			0.121	1.25	0.044		0.75	0.5	7.2
6A DNSTR. HANSON CR.	2/14/1995	39800		96			340			0.168	1.16	0.066		1.10	0.06	7.7

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L) q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l) q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
6A DNSTR. HANSON CR.	11/9/1995	39800		77		286	281	5.2	0.170	1.88	0.090	1.80	0.08	7.7
6A DNSTR. HANSON CR.	2/26/1996	39800		96		330		11.4	0.149	0.80	0.060			7.4
6A DNSTR. HANSON CR.	11/5/1996	39800		98		334	321	10.1	0.300	1.50	0.090 U			6.7
6A DNSTR. HANSON CR.	3/13/1997	39800		104		350	348	9.9	0.30	2.30	0.09 U			7.0
6A DNSTR. HANSON CR.	7/21/1997	39800				223								8.1
6A DNSTR. HANSON CR.	9/9/1997	39800		65		259	257	7.1	<0.2		0.25 U		<0.5	7.9
6A DNSTR. HANSON CR.	11/3/1997	39800				307								6.9
6A DNSTR. HANSON CR.	3/9/1998	39800		106		355	334							7.6
6A DNSTR. HANSON CR.	4/30/1998	39800												
6A DNSTR. HANSON CR.	10/20/1998	39800	15.37	70	2,632	279								7.8
6A DNSTR. HANSON CR.	2/25/1999	39800		100		327								7.6
6A DNSTR. HANSON CR.	9/27/1999	39800				259								
6A DNSTR. HANSON CR.	10/13/1999	39800		74		271								
6A DNSTR. HANSON CR.	3/15/2000	39800	11.39	98	2,731	330		10.0	0.20	0.96	0.039		<0.10	7.4
6A DNSTR. HANSON CR.	9/6/2000	39800	* 9.27	104		310								7.7
6A DNSTR. HANSON CR.	11/3/2000	39800	10.11	89	2,201	305								7.7
6A DNSTR. HANSON CR.	2/20/2001	39800	6.13			354								7.9
6 BELOW HANSON CR.	11/4/1965	42200	17.0	47	1,955	237					1 U			7.4

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L) q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l) q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
6 BELOW HANSON CR.	11/4/1970	42200	12.7	60	1,863	255					0.01 U			7.2
6 BELOW HANSON CR.	11/29/1988	42200		46					0.18	3.00	0.04	1.20	1.80	7.7
6 BELOW HANSON CR.	11/10/1993	42200		71		304			0.164	1.15	0.052	0.65	0.50	7.46
6 BELOW HANSON CR.	2/11/1994	42200		74		279			0.29	5.50	0.046	5.00	0.50	7.62
6 BELOW HANSON CR.	10/13/1994	42200		68		271			0.055	1.00	0.035	0.50	0.50	7.4
6 BELOW HANSON CR.	2/14/1995	42200		80		306			0.091	0.39	0.074	0.32	0.07	8.1
6 BELOW HANSON CR.	11/9/1995	42200		63		261	260	5.0	0.100	0.65	0.070	0.60	0.05	8.1
6 BELOW HANSON CR.	2/26/1996	42200		75		297		9.7	0.083	0.70	0.029			7.9
6 BELOW HANSON CR.	11/5/1996	42200		76		298	291	8.5	0.100	0.70	0.090 U			6.4
6 BELOW HANSON CR.	3/13/1997	42200		88		318	319	8.8	0.20	1.90	0.09 U			7.2
6 BELOW HANSON CR.	7/21/1997	42200				211								8.2
6 BELOW HANSON CR.	9/9/1997	42200				241								8.2
6 BELOW HANSON CR.	11/3/1997	42200												
6 BELOW HANSON CR.	3/9/1998	42200		90		332	313							7.8
6 BELOW HANSON CR.	4/30/1998	42200		44		209	205							7.4
6 BELOW HANSON CR.	10/20/1998	42200		54		256								8.2
6 BELOW HANSON CR.	2/25/1999	42200		70		294								8.3
6 BELOW HANSON CR.	9/27/1999	42200												

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L) q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l) q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
6 BELOW HANSON CR.	10/13/1999	42200		58		248								
6 BELOW HANSON CR.	3/15/2000	42200						-	-	-		-	-	-
6 BELOW HANSON CR.	9/6/2000	42200		80		282								8.3
6 BELOW HANSON CR.	11/3/2000	42200		70		280								8.2
6 BELOW HANSON CR.	2/20/2001	42200												
6 BELOW HANSON CR.	10/22/1992	42400		66		286			0.126	0.89	0.053	0.39	0.50	8.23
6 BELOW HANSON CR.	2/16/1993	42400		86		305			0.179	1.33	0.041	0.83	0.50	7.6
BELOW HANSON CR.	11/7/1994			59		160		7.24	0.138	0.612	0.049		0.05	6
MP 8 (1 MILE ABOVE MILL)	6/10/1997			22.6		33		3.3					<.15	7.96
MP 8 (1 MILE ABOVE MILL)	7/17/1997			53.3				5.7	<0.10	0.30	0.013		0.19	8.37
MP 8 (1 MILE ABOVE MILL)	8/14/1997			51.7		50		5.9					0.23	8.20
MP 8 (1 MILE ABOVE MILL)	9/18/1997			75.6		251		7.7					0.15	7.93
MP 8 (1 MILE ABOVE MILL)	10/23/1997			76.8		32		10.8	0.13	0.78	0.031		0.17	7.79
MP 8 (1 MILE ABOVE MILL)	11/20/1997			76.6		286		8.2					<0.15	7.99
MP 8 (1 MILE ABOVE MILL)	12/19/1997			84		78		10.1					<0.15	7.85
MP 8 (1 MILE ABOVE MILL)	1/14/1998			96.9		321		9.4	0.25	1.60	0.069		0.17	7.95
MP 8 (1 MILE ABOVE MILL)	2/20/1998			103.1		60		12.2					<0.15	8.03
MP 8 (1 MILE ABOVE MILL)	3/19/1998			92.8		52		10.6					<0.15	7.70

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	Station #	Avg Daily Flow (cfs)	SO_4 (mg/L) q	SO_4 Load (kg/d)	SC (field) µS/cm	SC (lab) µS/cm	Mg_t (mg/L)	Mn_t (mg/L)	Al_t (mg/l)	Zn t, ? (mg/l) q	Al_s (mg/l)	Al_d (mg/l)	pH (SU) field
MP 8 (1 MILE ABOVE MILL)	4/30/1998			53.1		54		5.9	<0.10	1.50	0.043		<0.15	7.94
MP 8 (1 MILE ABOVE MILL)	6/4/1998			26.1		45		4.0					<0.15	7.69
MP 8 (1 MILE ABOVE MILL)	7/16/1998			43.1		- -		5.3	<0.10	0.63	0.025		<0.15	7.88

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
7 ABOVE MILL	11/29/1988		55	163	33.7	10		0.5	1.48		
7 ABOVE MILL	10/22/1992		62	184	6.0	4		0.358	0.31		
7 ABOVE MILL	2/16/1993		49	230	8.0			0.37	0.442		
7 ABOVE MILL	11/10/1993		66	198	2.0			0.368	0.78		
7 ABOVE MILL	2/11/1994		54	250	6.0			0.43	0.48		
7 ABOVE MILL	10/13/1994		70	228	8.7			0.6	0.342		
ABOVE MILL	11/7/1994		58	220	9				0.394		
7 ABOVE MILL	2/14/1995		58	262	8.0			0.480	0.306		
7 ABOVE MILL	11/9/1995	7.9	66	208	2.8	2.46		0.30	0.281		
7 ABOVE MILL	2/26/1996							0.407			
7 ABOVE MILL	11/5/1996	7.94									
7 ABOVE MILL	3/13/1997	7.83				7.6					
7 ABOVE MILL	7/21/1997	8.0	65			1.2					
7 ABOVE MILL	9/9/1997	7.8	57	185	9.4	6.9		0.28	<0.2		
7 ABOVE MILL	11/3/1997	7.8						0.40			
7 ABOVE MILL	3/9/1998	7.5			13.8	16		0.46			
7 ABOVE MILL	4/30/1998	7.7	99		14.6			0.28			
7 ABOVE MILL	10/20/1998							0.31		0.100 U	0.250 U

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
7 ABOVE MILL	2/25/1999						7.0				
7 ABOVE MILL	9/27/1999										
7 ABOVE MILL	10/13/1999	7.86						0.3			
7 ABOVE MILL	3/15/2000							0.4			
7 ABOVE MILL	9/6/2000							0.4			
7 ABOVE MILL	11/3/2000		58					0.4			
7 ABOVE MILL	2/20/2001			230				0.70	0.041	0.100 U	
ABOVE MOLY PROP LINE	9/13/1988		18	198	198.0	320			33		
ABOVE MOLY PROP LINE	9/20/1988		55	144	10.0	5			0.54		
ABOVE MOLY PROP LINE	9/26/1988		56	150	6.0	5			0.35		
ABOVE MOLY PROP LINE	10/25/1988		58	174	3.0				0.23		
6A DNSTR. OF HANSON	11/29/1988										
6A DNSTR. HANSON CR.	10/22/1992										
6A DNSTR. HANSON CR.	2/16/1993										
6A DNSTR. HANSON CR.	11/10/1993		56	184	8			0.378	0.604		
6A DNSTR. HANSON CR.	2/11/1994										
6A DNSTR. HANSON CR.	10/13/1994		76	224	7.3			0.5	0.27		
6A DNSTR. HANSON CR.	2/14/1995		50	260	9.5			0.472	0.323		

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
6A DNSTR. HANSON CR.	11/9/1995	7.6	62	206	4.0	2.82		0.30	0.329		
6A DNSTR. HANSON CR.	2/26/1996							0.386			
6A DNSTR. HANSON CR.	11/5/1996	7.32									
6A DNSTR. HANSON CR.	3/13/1997	7.30				47					
6A DNSTR. HANSON CR.	7/21/1997										
6A DNSTR. HANSON CR.	9/9/1997	7.6	63	180	5.8	6.2		0.27	<0.2		
6A DNSTR. HANSON CR.	11/3/1997										
6A DNSTR. HANSON CR.	3/9/1998				10.7	15					
6A DNSTR. HANSON CR.	4/30/1998										
6A DNSTR. HANSON CR.	10/20/1998							0.29			
6A DNSTR. HANSON CR.	2/25/1999						5.5				
6A DNSTR. HANSON CR.	9/27/1999										
6A DNSTR. HANSON CR.	10/13/1999	7.64									
6A DNSTR. HANSON CR.	3/15/2000							0.4			
6A DNSTR. HANSON CR.	9/6/2000										
6A DNSTR. HANSON CR.	11/3/2000		64								
6A DNSTR. HANSON CR.	2/20/2001										
6 BELOW HANSON CR.	11/4/1965		62	165	8.0	2.3			<0.02		

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
6 BELOW HANSON CR.	11/4/1970		60	193	0.0	4.5			0.12		
6 BELOW HANSON CR.	11/29/1988		62	149	17.8	8		0.5	0.64		
6 BELOW HANSON CR.	11/10/1993		63	164	7.0			0.3	1.02		
6 BELOW HANSON CR.	2/11/1994		61	204	5.0			0.33	0.63		
6 BELOW HANSON CR.	10/13/1994		68	212	5.3			0.5	0.234		
6 BELOW HANSON CR.	2/14/1995		68	224	6.5			0.374	0.323		
6 BELOW HANSON CR.	11/9/1995	7.9	73	180		1.71		0.30	0.406		
6 BELOW HANSON CR.	2/26/1996							0.322			
6 BELOW HANSON CR.	11/5/1996	7.70									
6 BELOW HANSON CR.	3/13/1997	7.72				72					
6 BELOW HANSON CR.	7/21/1997										
6 BELOW HANSON CR.	9/9/1997										
6 BELOW HANSON CR.	11/3/1997										
6 BELOW HANSON CR.	3/9/1998				2.6	14					
6 BELOW HANSON CR.	4/30/1998	7.5									
6 BELOW HANSON CR.	10/20/1998							0.25			
6 BELOW HANSON CR.	2/25/1999						4.7				
6 BELOW HANSON CR.	9/27/1999										

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
6 BELOW HANSON CR.	10/13/1999	8.12									
6 BELOW HANSON CR.	3/15/2000	-		-	-	-		-	-		
6 BELOW HANSON CR.	9/6/2000										
6 BELOW HANSON CR.	11/3/2000		66								
6 BELOW HANSON CR.	2/20/2001										
6 BELOW HANSON CR.	10/22/1992		72	176	4.7	4		0.268	0.359		
6 BELOW HANSON CR.	2/16/1993		46	200	6.0			0.32	0.467		
BELOW HANSON CR.	11/7/1994		62	206	6				0.376		
MP 8 (1 MILE ABOVE MILL)	6/10/1997		60.5					0.1			
MP 8 (1 MILE ABOVE MILL)	7/17/1997		55.5						0.20		
MP 8 (1 MILE ABOVE MILL)	8/14/1997		60.0					0.2			
MP 8 (1 MILE ABOVE MILL)	9/18/1997		58.5								
MP 8 (1 MILE ABOVE MILL)	10/23/1997		54.7					0.5	<.20		
MP 8 (1 MILE ABOVE MILL)	11/20/1997		62.5					0.3			
MP 8 (1 MILE ABOVE MILL)	12/19/1997		45.0								
MP 8 (1 MILE ABOVE MILL)	1/14/1998		55.8					1.3	2.36		
MP 8 (1 MILE ABOVE MILL)	2/20/1998		42.0					0.7			
MP 8 (1 MILE ABOVE MILL)	3/19/1998		57.0					0.5			

Table 4. Water-Quality Data Upstream of the Molycorp Molybdenum Mine.

Station Name	Date	pH (SU) lab	Alk_t (mg/l $CaCO_3$) q	TDS (mg/l)	TSS (mg/l)	JTU	NTU	F (mg/l)	Fe_t,_? (mg/l)	Mo (mg/l) q	Cu (mg/l) q
MP 8 (1 MILE ABOVE MILL)	4/30/1998		50.0					1.1	1.05		
MP 8 (1 MILE ABOVE MILL)	6/4/1998		58.5					0.1			
MP 8 (1 MILE ABOVE MILL)	7/16/1998		54.3					0.5	0.80		

Discussion

Review of Selected Water-Quality Reports

The sample collection, preservation, and analysis methods are presented in table 2. Analytical issues that may limit the usefulness of previous Red River water-quality studies are discussed in this section. In addition, the results of a limited number of studies are discussed to provide a context for the presentation of water-quality data in this section.

Arsenic, iron, lead, and zinc were determined using colorimetric methods in US HEW (1966). The detection limits for lead (20 µg/L) and zinc (1000 µg/L) in the US HEW study are elevated compared to those for graphite furnace, ICP-MS, or even flame AAS and may preclude comparisons to criteria for the protection of aquatic life in the Red River. Similarly, detection limits for many of the elements determined using spectrographic methods in the Thorne Ecological Institute (1972) report prohibit comparisons to water-quality standards or criteria. For example, spectrographic detection limits were 100 mg/L for iron, 1 mg/L for silver, 500 mg/L for arsenic, 2 mg/L for beryllium, 50 mg/L for cadmium, 2 mg/L for molybdenum, and 10 mg/L for lead. However, for analytes determined by flame AAS, detection limits are in the parts per billion range (e.g., 20 µg/L for copper and 40 µg/L for iron).

Although the Pennak (1976 to 1984) reports discuss water quality, no metals were determined, and the focus was predominantly on benthic aquatic life. The cause of the "yellowish-tan" precipitate was attributed to Molycorp operations in May 1978 and to naturally-occurring streamside deposits upstream of the Eagle Rock campground in October 1978.

Table 6. Criteria Used to Define Hydrologic Timing of Sampling Events.

Hydrologic Timing	Definition	Approximate Dates	Number of Sampling Events	Years Sampled
Rising Limb	Starts when flows begin to increase in the spring; stops at 50 percent of peak flow[1]	April 1 - May 15	17	1977-83, 1986, 1992, 1997, 1998
Peak	Rising or falling limb and 50 percent or more of peak flow	May, June	22	1977-79, 1981-86, 1992, 1994, 1998, 2000, 2001
Falling Limb	Starts after peak flow when flows decrease to 50 percent of peak flow; stops when flows fall to 25 percent of peak flow	June 1 – August 15	20	1978-80, 1982-85, 1992, 1994, 1997, 1998
Storm	Summer thunderstorm event; generally requires a noticeable peak in flow relative to flows before and after storm.	Summer	18	1977, 1980-82, 1986, 1988, 1997, 2000
Low Flow	Starts at 25 percent of peak flow and ends when flows start to increase in spring	August 15 – April 1	140	1965, 1970, 1977-86, 1988, 1992-2001
None	No flow data available	NA	5	Water year 2001

1 If date falls between October 1 and start of rising limb, peak flow used is for previous year
NA not applicable

The US EPA report by Melancon and others (1982) concluded that concentrations of total arsenic, cadmium, and silver exceeded acute aquatic life criteria in the Red River. However, cadmium and silver detection limits were 7.5 and 12.0 µg/L, respectively, and the arsenic detection limit was 110 µg/L. Arsenic concentrations are higher than those reported in any other water-quality study of the Red River. For example, the highest arsenic concentration reported at the Questa Ranger Station (table 3) from 1966 to 2001 was 22 µg/L; arsenic concentrations reported by Melancon and others (1982) ranged from 633 µg/L upstream of the town of Red River to 1,400 µg/L approximately 200m upstream of the State fish hatchery, which is downstream of the Questa Ranger Station. Arsenic was determined by ICP-AES, which is one of the least sensitive methods available for arsenic. The arsenic values reported in Melancon and others. (1982) were not considered reliable because all other arsenic values measured in the Red River were lower. Furthermore, arsenic mineralization is rare in the Red River valley (Schilling, 1956).

Only three of eight locations sampled by Melancon and others (1982) had detectable cadmium concentrations, and these ranged from 7.8 µg/L at one of the upstream control locations to 11.5 µg/L at the other upstream control location. These values are less than twice the detection limit of 7.5 µg/L and cannot be considered reliable. Similarly, silver was detected at only two of eight locations; the values were 16.0 and 19.2 µg/L, which are only slightly higher than the detection limit of 12.0 µg/L. Silver is also highly insoluble (<1 µg/L) in most freshwaters. Consequently, conclusions about exceedences of arsenic, cadmium, and silver aquatic criterion values are not reliable.

The detection limits for lead (50 µg/L), copper (10 µg/L), and cadmium (5 µg/L) in ENSR (1988) were higher than many detected values in other studies (especially for dissolved metal concentrations). Detection limits for zinc (10 µg/L) in the ENSR (1988) study were acceptable, because measured zinc concentrations in the Red River at the Questa Ranger Station and other locations were usually substantially higher than 10 µg/L.

The Allen and others (1999) report prepared for the New Mexico Office of the Natural Resources Trustee concluded that water quality and aquatic life impacts in the Red River are related to mining at the Molycorp Mine. Allen and others (1999) compared metal concentrations in pond sediments in scar areas upstream from the mine and in a pond downstream of the mine. Concentrations in the pond affected by scar weathering but not influenced by the mine remained constant over time, while concentrations in the pond downstream of the mine increase after the 1980's by a substantial amount (including up to five times higher concentrations for zinc). White, gelatinous layers high in aluminum were also observed in pond sediments downstream of the mine.

URS (2001) states that concentration changes over time are only related to changes in precipitation and the amount of pumping by Molycorp. They ascribe the better water quality from 1965 to the early 1970s to lower precipitation from the early 1950's to the middle 1960's and consequent lower loadings to the Red River. However, decreases in precipitation often lead to increased solute concentrations and detrimental water quality, even if loadings decrease. Because there is no water quality data prior to 1965, these comments are purely conjectural. Additionally, average mean annual streamflow at the Questa Ranger Station from 1955 to 1965 was 41.7 cubic feet per second (cfs), which is close to the average mean annual streamflow from 1930 to 2000. The ensuing ten-year period (1965 to 1975) did have a lower average mean annual streamflow (33.7 cfs), but it was during this period that water quality began to diminish in the Red River.

URS (2001) attributed improvements in the water quality of the Red River to increased pumping of the mill water supply wells, which decreased the amount of high-solute groundwater discharging to the Red River. The worsening of Red River water quality in the 1980's and 1990's was attributed to the cessation of pumping, which caused Cabin Springs and Portal Springs to resume discharge to the Red River. Certainly the pumping of water with higher solute concentrations would improve Red River water quality, but the source of that water is not identified. URS (2001) additionally attributed the worsening water quality during this time period to increased precipitation from 1978 to 1993 and the resulting increase in loadings from hydrothermal scar areas upstream of the mine site. Average mean annual streamflow was somewhat higher during this period (51.3 cfs), but again, increases in loadings do not equate to increases in concentrations and water quality effects. URS (2001) attributed the recent improvement in Red River water quality to Molycorp's elimination of flow from upper Capulin Canyon, Sulphur Gulch, and Goathill Gulch, along with pumping of the mill water supply wells. Although such improvements in mine site water management must result in improvements in Red River water quality, it is difficult to assign specific improvements from specific source controls.

Historical Water-Quality Trends

Water-quality data and flow for the Red River have been plotted as a function of time (date of sample collection) and as parameter plots to evaluate trends in concentrations over time and relationships between water-quality parameters.

In mineralized or mined areas, it is common to see relationships between concentrations and flow or between concentrations and changes in the hydrograph record. For example, concentrations of metals in streams draining mined areas can increase during the rising limb of the hydrograph before dilution occurs (Jambor and others, 2000). Stored acid and metals from the oxidation of pyrite and other sulfides (unsaturated zone waters and efflorescent salts) are flushed from soils, mine wastes, and unmined but mineralized areas by melting snow or rain and washed into receiving streams. To determine if similar mechanisms were operating in the study area, hydrographs for all years containing sampling events were examined to find the hydrologic conditions during sampling. Average daily discharge values were taken from the U.S. Geological Survey web site (http://waterdata.usgs.gov/nm/nwis/discharge) for the Questa Ranger Station on the Red River, site # 08265000.

Sampling dates from water years 1966 to 1982 and 1983 to 2001 are shown on hydrographs in figures 2 and 3, respectively. In total, there were 190 separate sampling dates when water quality samples were collected on the Red River at the Questa Ranger Station. On a limited number of additional dates only flow was measured, but those events are not included in figures 2 and 3 or in table 3. Figure 2 shows the wide variability in peak discharge values, ranging from a low of 29 cfs in 1977 and a high of 557 cfs in 1979. The earliest sampling events were in November 1965 and November 1971, both during times of low flow. A number of samples collected from 1977 through 1979 were average monthly composites (Molycorp, 1979), and some of the most consistent sampling coverage for different flow conditions was during this time. Most samples from water years 1983 to 2001 (figure 3) were collected during low flow conditions, although there were five summer thunderstorm samples collected in 1988 and a number of non-low-flow samples collected in 1992, 1994, 1997, and 1998. Table 5 shows the years in which samples from different hydrologic timing conditions were collected.

Using the time period with the best continuous temporal coverage (1977 to 1979), a clear relationship between flow and sulfate concentrations is apparent in figure 4. An inverse relationship exists between sulfate concentrations and discharge seasonally. Under low flow conditions, sulfate concentrations are generally higher (60 – 140 mg/L), but considerable dilution takes place during snowmelt and storm events, bringing the sulfate concentrations to well below 60 mg/L. The lowest sulfate concentrations correspond to peak flows when stream water is most diluted with low-sulfate waters. High sulfate concentrations were similar during low-flow times in different water years, while the lowest annual sulfate concentrations varied depending on the magnitude of peak flow for that year. As shown in figure 4, sulfate concentrations measured during peak snowmelt were highest in 1977, which had the lowest peak discharge on record, and lowest in 1979,

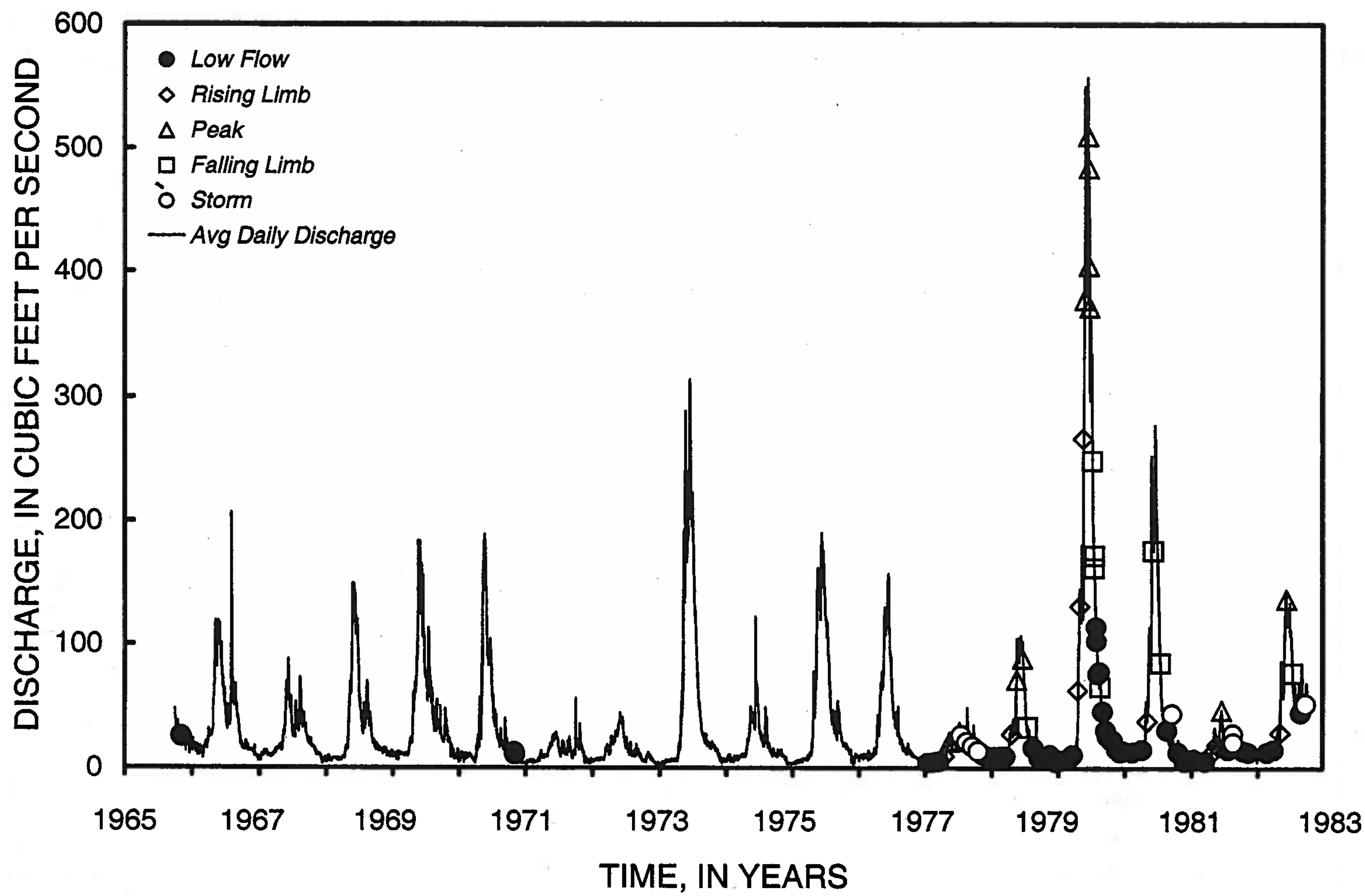

Figure 2. Graph showing average daily discharge and timing of surface water samples collected in the Red River at the Ranger Station in water years 1966 to 1982.

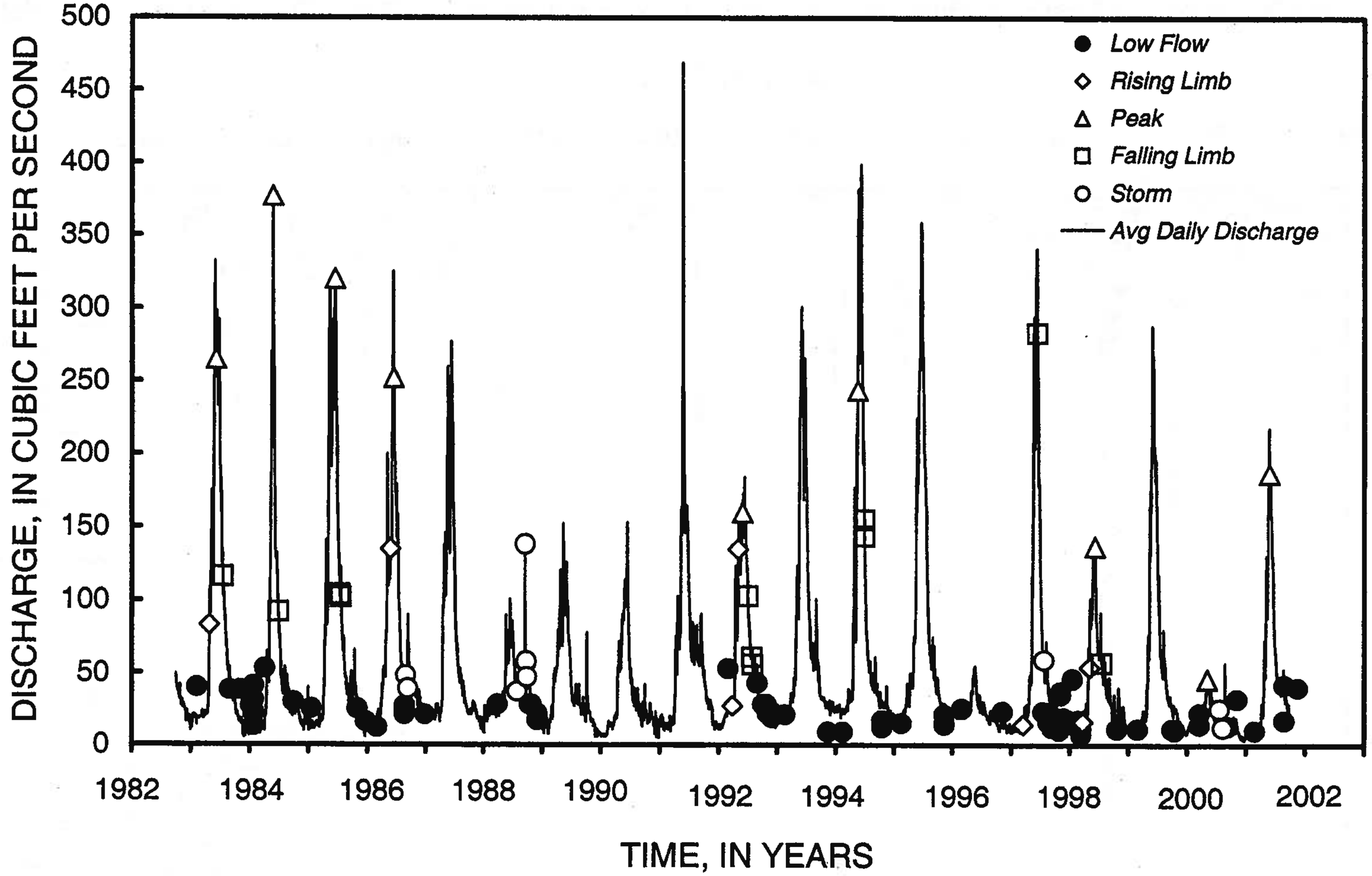

Figure 3. Graph showing average daily discharge and timing of surface water samples collected in the Red River at the Ranger Station in water years 1983 to 2001.

which had the highest snowmelt-related discharge on record at the Questa Ranger Station for this time period. Both rising limb and storm-event sulfate concentrations were lower than low-flow concentrations, suggesting that collecting samples as composites over a month dampen or eliminate peaks in releases of sulfate from mineralized or mined areas in the basin.

Using the hydrologic discrimination described above (see table 5), historic sulfate concentrations from 1965 to 2001 were plotted against time in figure 5. A time line of relevant mining activities at the Molycorp Mine is also included in figure 5. A trend of increasing sulfate concentrations over time, potentially related to mining inputs, is apparent when the dynamic events of snowmelt and summer rainstorm are eliminated and only low-flow concentrations are considered. Without using hydrologic discrimination, the trend is obscured by dilution during non-low-flow times. Sulfate concentrations increased from sometime after 1971 to approximately 1992, more than doubling from approximately 60 mg/L in 1965 and 1971 to almost 200 mg/L in 1992 and 1993. After this time, a possible trend of decreasing sulfate concentrations is evident in figure 5. The decrease in sulfate concentration may be related to restarting the mine and the pumping of alluvial groundwater, as shown on the time line in figure 5. Alluvial wells from the Red River in the vicinity of the mine were pumped starting in the early 1990's for make-up water for the mill. Alluvial groundwater along the Red River generally has higher sulfate concentrations than does surface water (LoVetere and others, unpublished data, 2003). By decreasing the amount of alluvial groundwater entering the Red River at the mine site, concentrations of sulfate and other constituents downstream in the Red River should decrease. In addition, flow of Capulin Gulch water to the Red River was captured beginning in 1985. Removal of this high-sulfate water input (the sulfate concentration in Capulin Canyon on November 9, 1995 was 1,270 mg/l; Vail File and Woodward Clyde, June 1996) to the Red River would also decrease sulfate concentrations at the Questa Ranger Station.

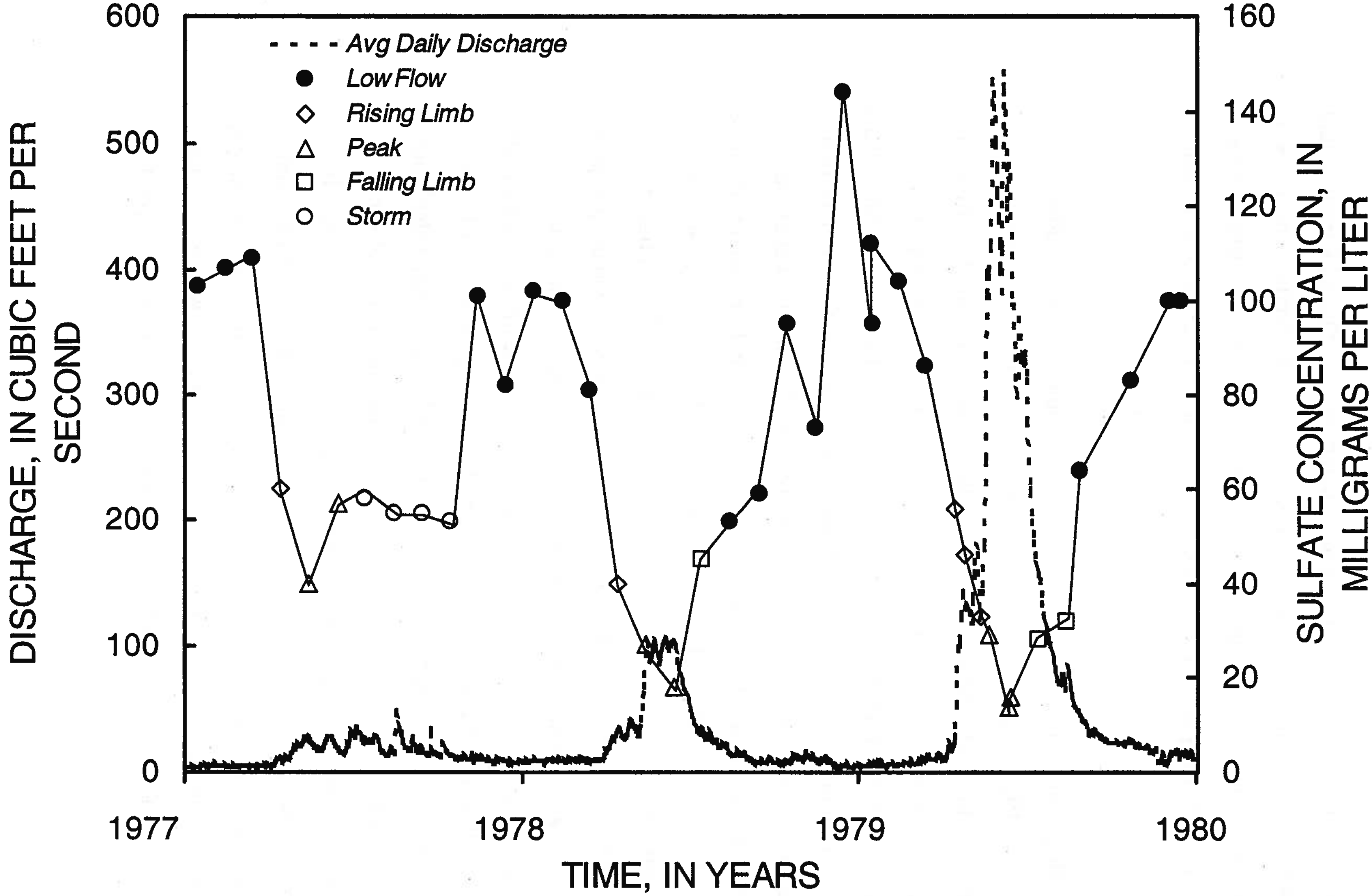

Figure 4. Graph showing sulfate concentrations and average daily discharge in the Red River at the Questa Ranger Station, from January 1977 to December 1979.

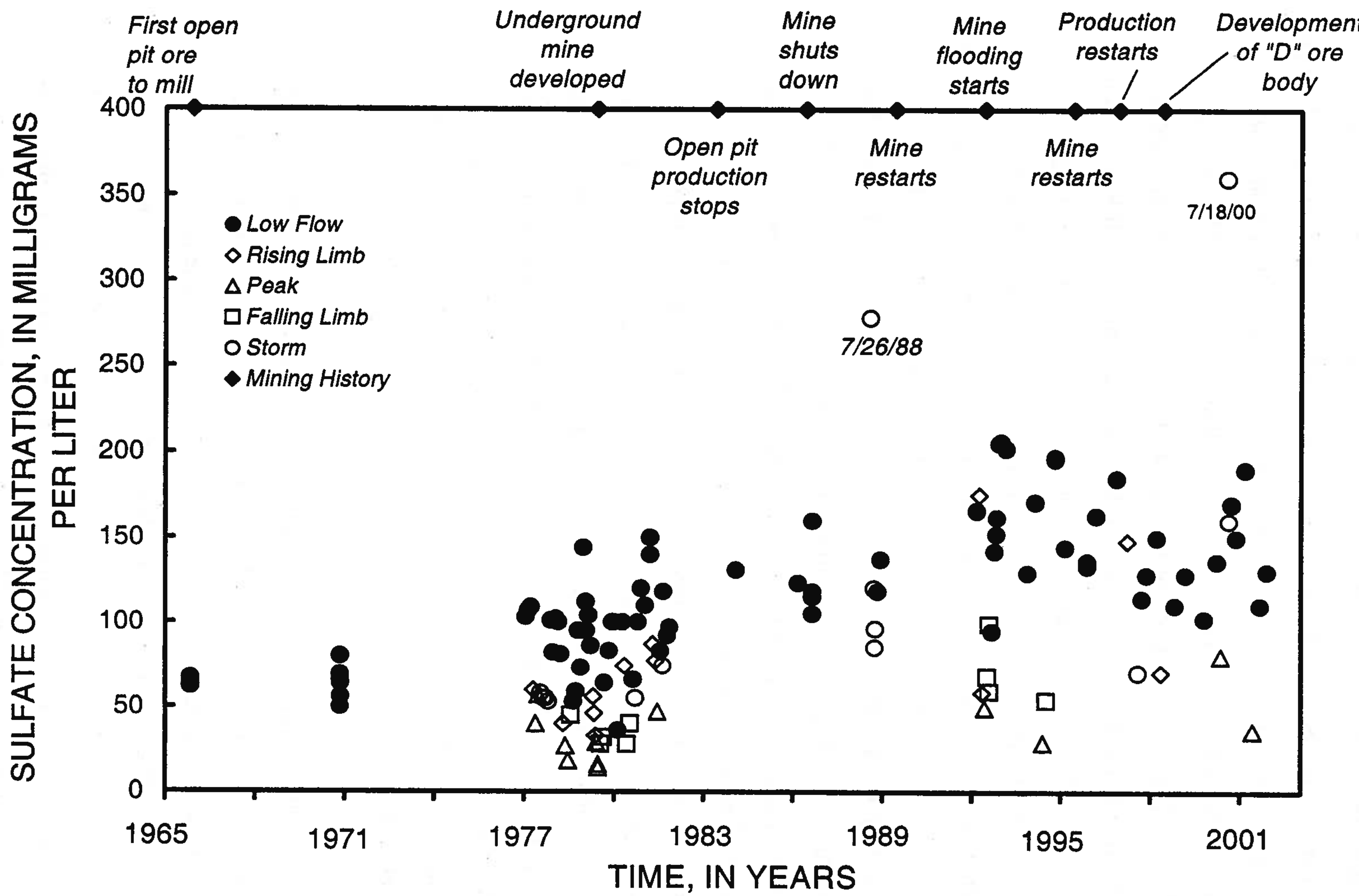

Figure 5. Graph showing sulfate concentrations in the Red River at the Questa Ranger Station from 1966 to 2001, and timing of mining history.

Although most of the transient-flow sulfate concentrations were lower than low-flow values, a number of samples collected during summer thunderstorm and rising limb times had sulfate values equal to or higher than low-flow concentrations. Two rising limb samples with elevated sulfate concentrations were collected on March 25, 1992 and March 13, 1997; sulfate concentrations were 175 and 148 mg/L, respectively (see figure 5). When flows first begin to increase in the spring, the first flush of sulfide oxidation products from scar and mine-disturbed areas reach the Red River and are not yet diluted by waters of lower total dissolved solids (TDS) concentrations that are present as snowmelt increases. One of the summer thunderstorm samples collected on July 18, 2000 had the highest historical sulfate concentration, 350 mg/L (RGC, 2000). Another storm sample collected by Molycorp on July 26, 1988 had a sulfate value of 278 mg/L (Vail, 1989) (see figure 5). The high-concentration storm-event samples may reflect flushing of pyrite oxidation products such as gypsum or evaporated unsaturated zone waters from scars and mined areas during summer thunderstorm events. The higher sulfate concentrations for these four samples and the distribution of temporal sulfate concentrations shown in figure 5 indicate that the highest sulfate concentrations can be expected to occur early in snowmelt runoff and during summer storm events, as long as sampling is timed to capture releases during these events. Recent data from a summer thunderstorm event on the Red River corroborates this theory (Philip Verplanck, unpublished data, 2002). The source of the elevated sulfate could be mine materials or mineralized catchments with hydrothermal scars.

A more limited number of samples was collected upstream of the Molycorp facilities and downstream of sulfate inputs from natural scar areas (see table 4). Sulfate concentrations from five locations downstream of Hansen Creek and upstream of the mill (see figure 1) are shown in figure 6. Figure 6 shows data only for times when sulfate concentrations were measured on the same date both upstream of the mine and at the Questa Ranger Station. Results from only two sample dates were available from this area before 1971, and no samples were collected between November 1970 and September 1988. As shown in figure 6, concentrations at the Questa Ranger Station from 1988 to 2001 were consistently higher than those from the upstream locations, usually by a factor of two. Although there is a marked paucity of data before 1988, no trend of increasing concentrations over the 35-year time period is apparent in the upstream samples. Indeed, sulfate concentrations upstream of the mine site during the 1990's (approximately 25 to 110 mg/L) are in the same range as concentrations at the Questa Ranger Station from 1965 to 1975. The most likely cause of these trends would be mining activities, but the chemical changes are small relative to the scatter in the data.

Sulfate loads in the Red River upstream and downstream of the mine are shown in figure 7a and b. Figure 7a shows sulfate load data for all dates at the Questa Ranger Station with flow discrimination, and figure 7b shows sulfate loads both upstream of the mine and at the Questa Ranger Station, only for those times when flow and sulfate were measured at both locations (with the exception of one date upstream of the mine, November 7, 1994, used to show trends in sulfate load over time upstream of the mine). Few flows were measured when upstream samples were collected because a gage is not located in this reach between Hansen Creek and the mill. Sulfate loads at the Questa Ranger Station were highest during times of high flow (rising limb, peak, and falling limb times) and during summer thunderstorms, with the highest sulfate load measured during a storm event on September 13, 1999 (figure 7a). Although there were only two sample dates when both sulfate concentration and flow was measured before 1971, sulfate loads upstream of the mine at these times were similar to those measured from the late 1980's to 2001 (figure 7b). In contrast, sulfate loads at the Questa Ranger Station during low flow followed trends seen in sulfate concentration (see figure 5), with increasing sulfate loads between 1980 and 1993, then decreasing sulfate loads between 1993 and 2001

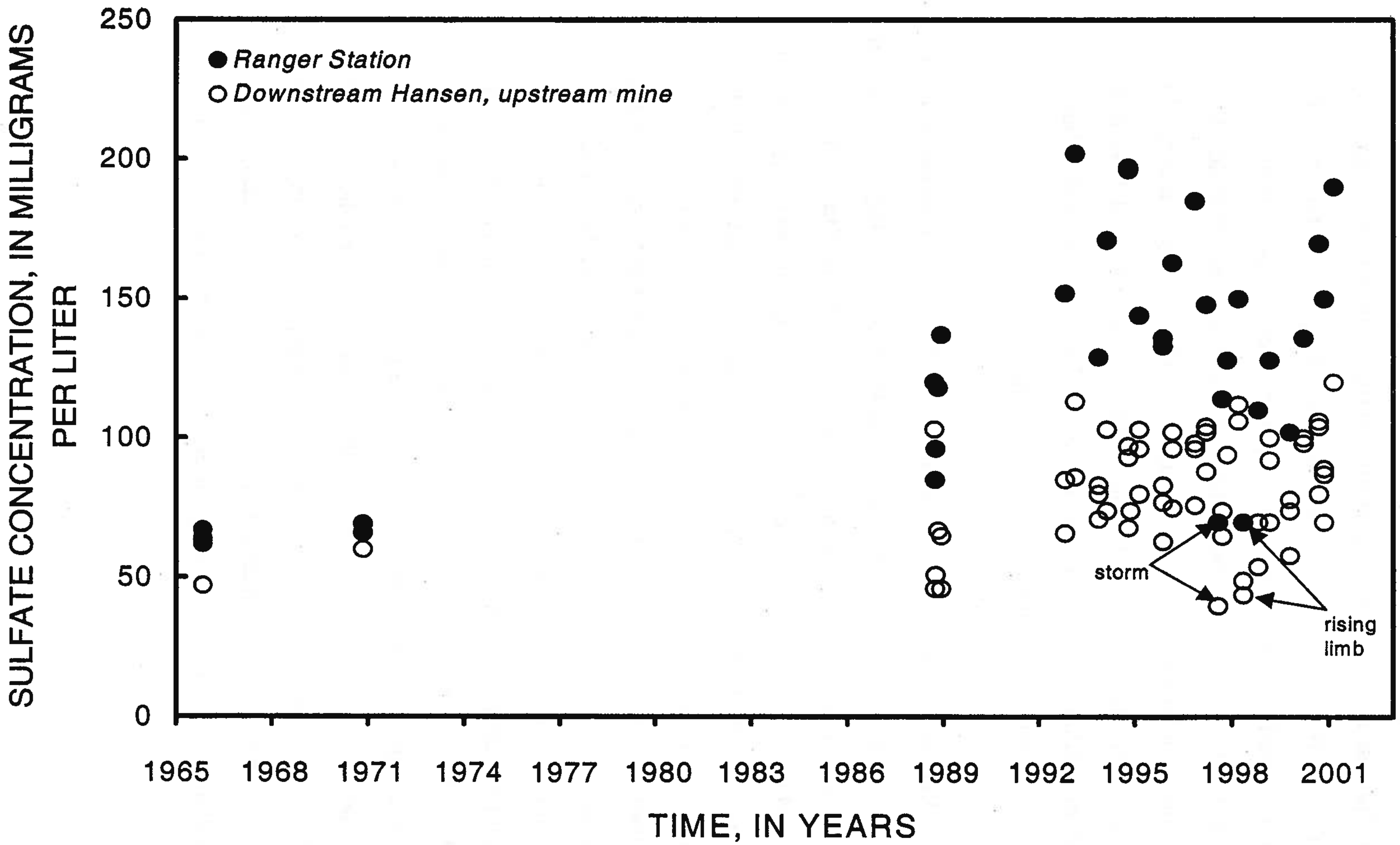

Figure 6. Graph showing sulfate concentrations in the Red River upstream and downstream of Molycorp molybdenum mine.

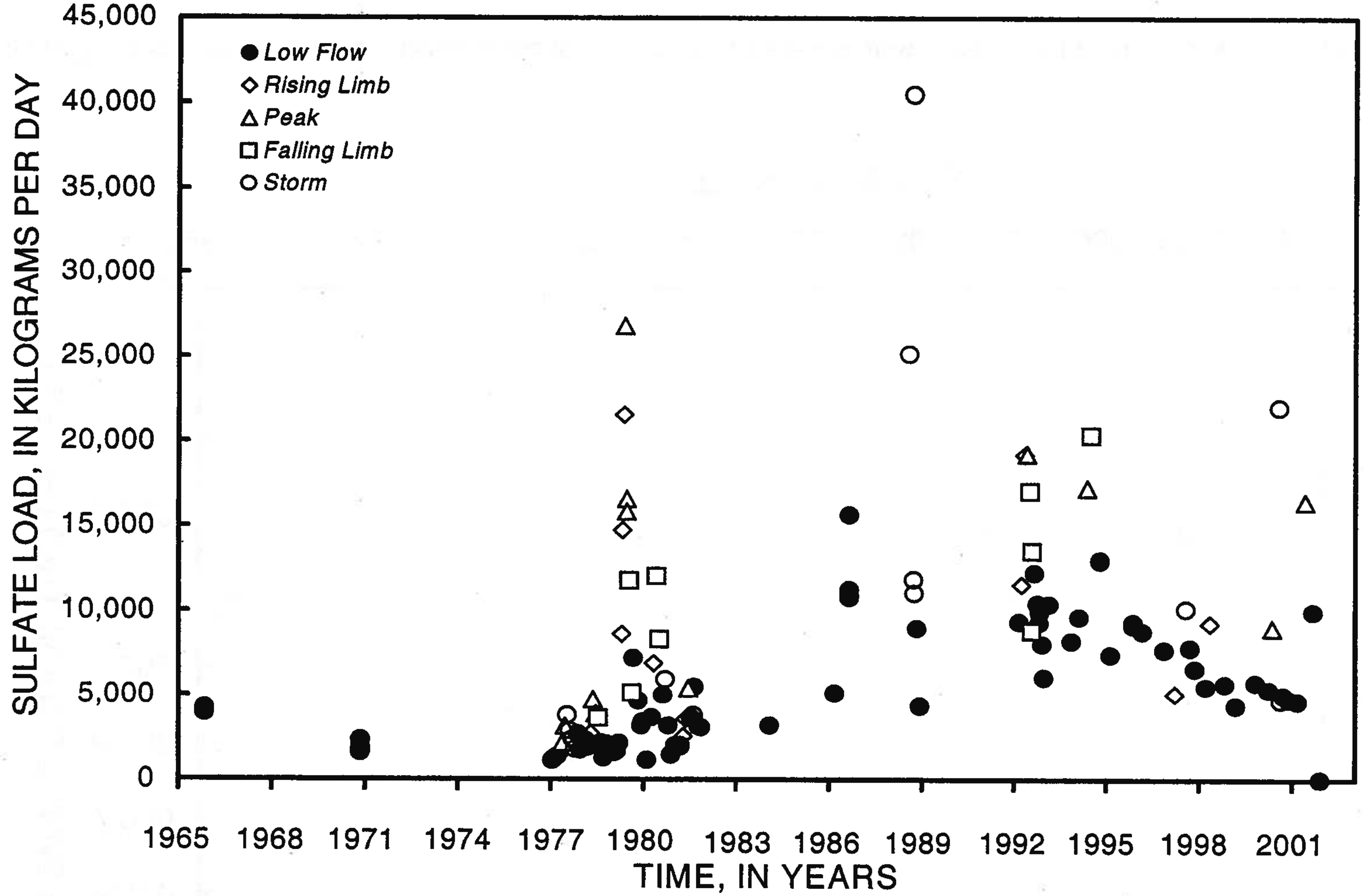

Figure 7. Graph showing sulfate loads in the Red River at the Ranger Station, with hydrologic discrimination.

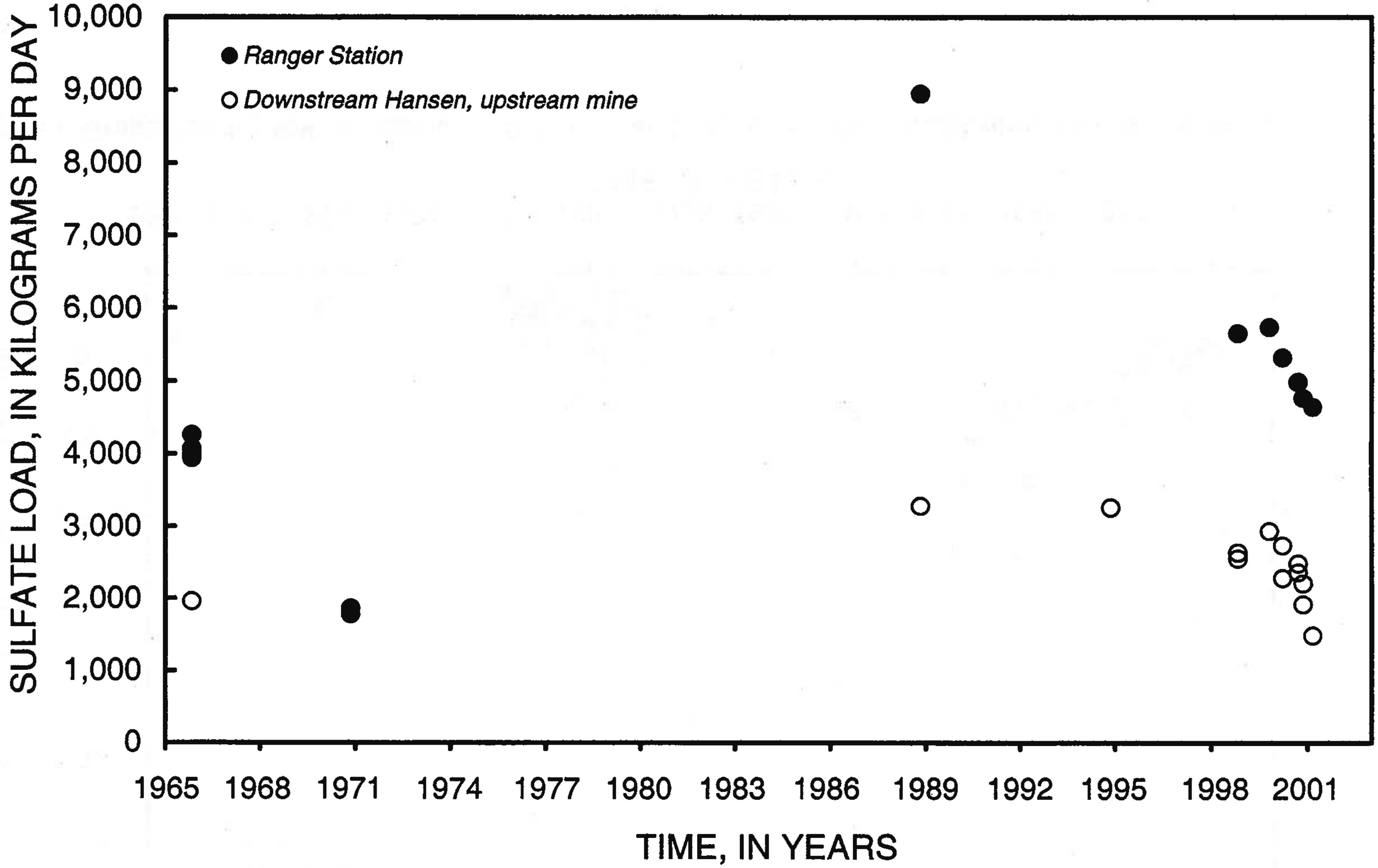

Figure 8. Graph showing sulfate loads in the Red River upstream and downstream of the Molycorp molybdenum mine.

(figure 7a). With the exception of November 4, 1970, when loads upstream of the mine and at the Questa Ranger Station were similar, sulfate loads at the Questa Ranger Station were consistently higher than loads upstream of the mine (figure 7b). Differences between sulfate loads upstream and downstream of the mine were highest in the late 1980's (on October 25, 1988 – a low-flow sampling event). Sulfate loads both upstream and downstream of the mine appeared to decrease from the mid-1990s to 2001 (figure 7b Inputs of sulfate between the mill and the Questa Ranger Station are largely limited to the mine area and would include both natural (scar-related) and mining sources. However, differences in trends between the Questa Ranger Station and upstream of the mine do suggest that differences in sulfate loads and concentrations between the two locations are related to mining inputs.

One check on the validity of the sulfate data is the correlation between sulfate and other parameters controlled by sulfate concentrations in areas with pyrite and gypsum, for example, specific conductance and total dissolved solids. In addition, for some sampling dates specific conductance values are available when sulfate was not determined, and conductance is an easier measurement than sulfate because no wet chemistry preparation is necessary. No specific conductance values were available from November 1970 to January 1988. In streams draining pyrite and/or gypsum-containing areas, sulfate and specific conductance and total dissolved solids should be highly correlated. The mine and the scar areas do contain abundant gypsum from alternation of pyrite as well as primary pyrite and anhydrite (Robertson GeoConsultants, Inc. 2000c). Figure 8 shows the relationship between sulfate concentrations and field specific conductance at the Questa Ranger Station for all sample dates. The correlation between sulfate and specific conductance is reasonably good ($R^2 = 0.64$), indicating that the sulfate values are also reasonable.

There is more continuous coverage of total dissolved solids (TDS) data than specific conductance data, and TDS provides another check on changing solute trends at the

Questa Ranger Station and the validity of the sulfate data. Because sulfate is almost always the major anion in the Red River and is commonly present in concentrations substantially higher than any other anion, it should approximate up to half of the milliequivalents in the charge balance and should also approximate up to half of the TDS. Figure 9a shows that the sulfate concentrations are between 25 to 50 percent of the TDS values. Two outliers are immediately apparent in the plot of sulfate and total dissolved solids, and both are summer thunderstorm events from 1988, as shown in figure 9a. The storm event on 9/13/88 had a sulfate concentration that is well within the range of other values. For this sample, it is likely that the TDS measurement is in error. The other sample, collected on 7/26/88, has the highest measured sulfate concentration in the historical data set. For this sample, sulfate and/or TDS may be in error. A recent sample collected on the Red River at the Questa Ranger Station during a summer thunderstorm event had a sulfate concentration of 315 mg/L (McCleskey and Verplanck, unpublished data, 2003), suggesting that the sulfate for the 7/26/88 sample is correct and the TDS value is in error. When these two outliers are removed, the correlation between TDS and sulfate is better than that between specific conductance and sulfate. Figure 9b shows the trend between TDS and sulfate for all sample dates, except 7/26/88 and 9/13/88. The R^2 value for the linear correlation is 0.83, indicating that TDS and sulfate and highly correlated and that the sulfate values are acceptable.

Another analyte that should correlate with sulfate in the Red River Valley is calcium. Most groundwaters in the alluvial aquifer along the Red River are calcium-sulfate type waters (LoVetere and others, unpublished data, 2003), and gypsum dissolution exerts a strong control on both calcium and sulfate concentrations in surface water and groundwater in the area. Samples with both calcium and sulfate measurements were limited; however, a trend between calcium and sulfate is apparent in figure 10. The data points follow the gypsum congruent dissolution line, paralleling the line at low concentration but not at high concentration. If the only source of dissolved calcium and

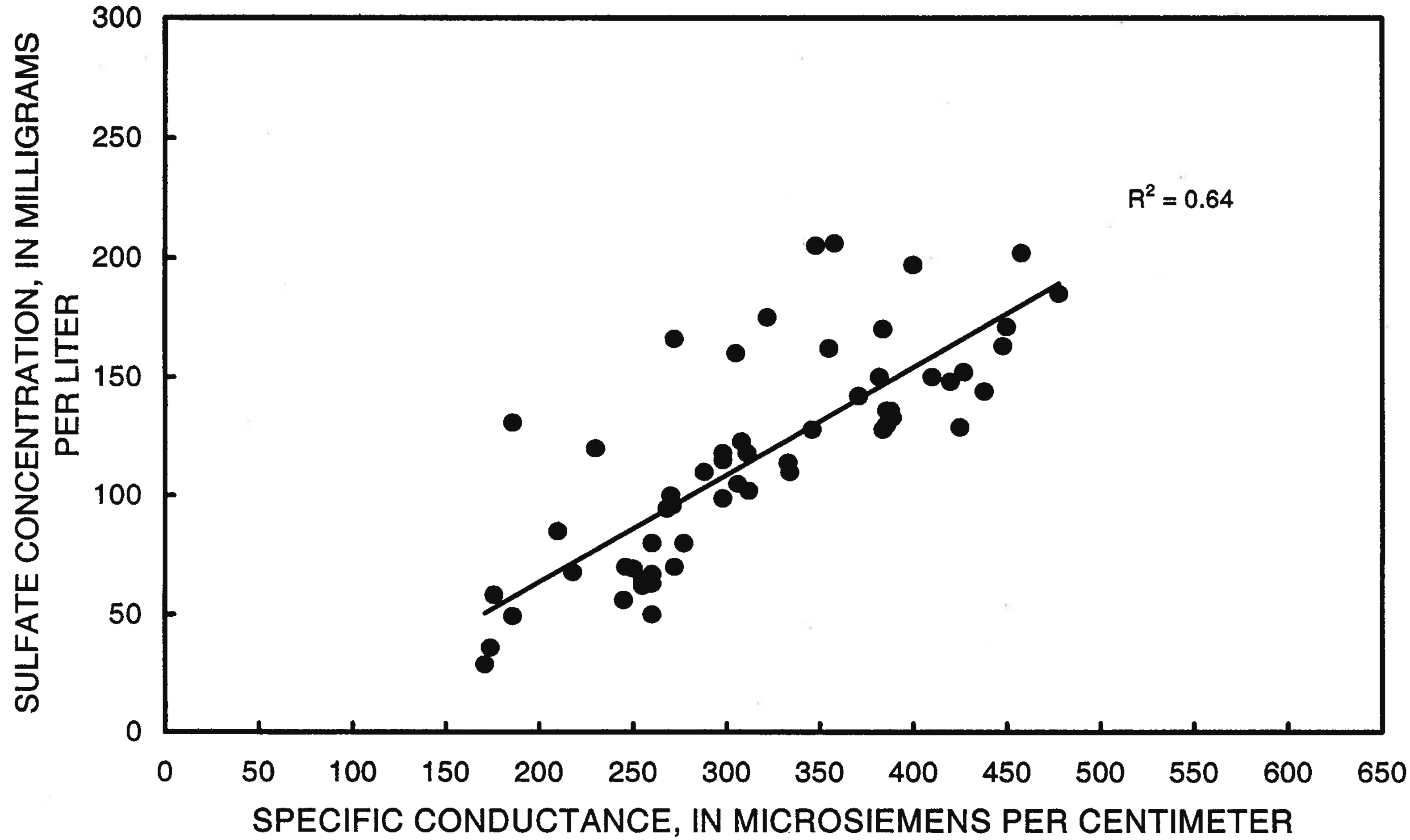

Figure 9. Graph showing specific conductance in relation to sulfate concentration in the Red River at the Questa Ranger Station.

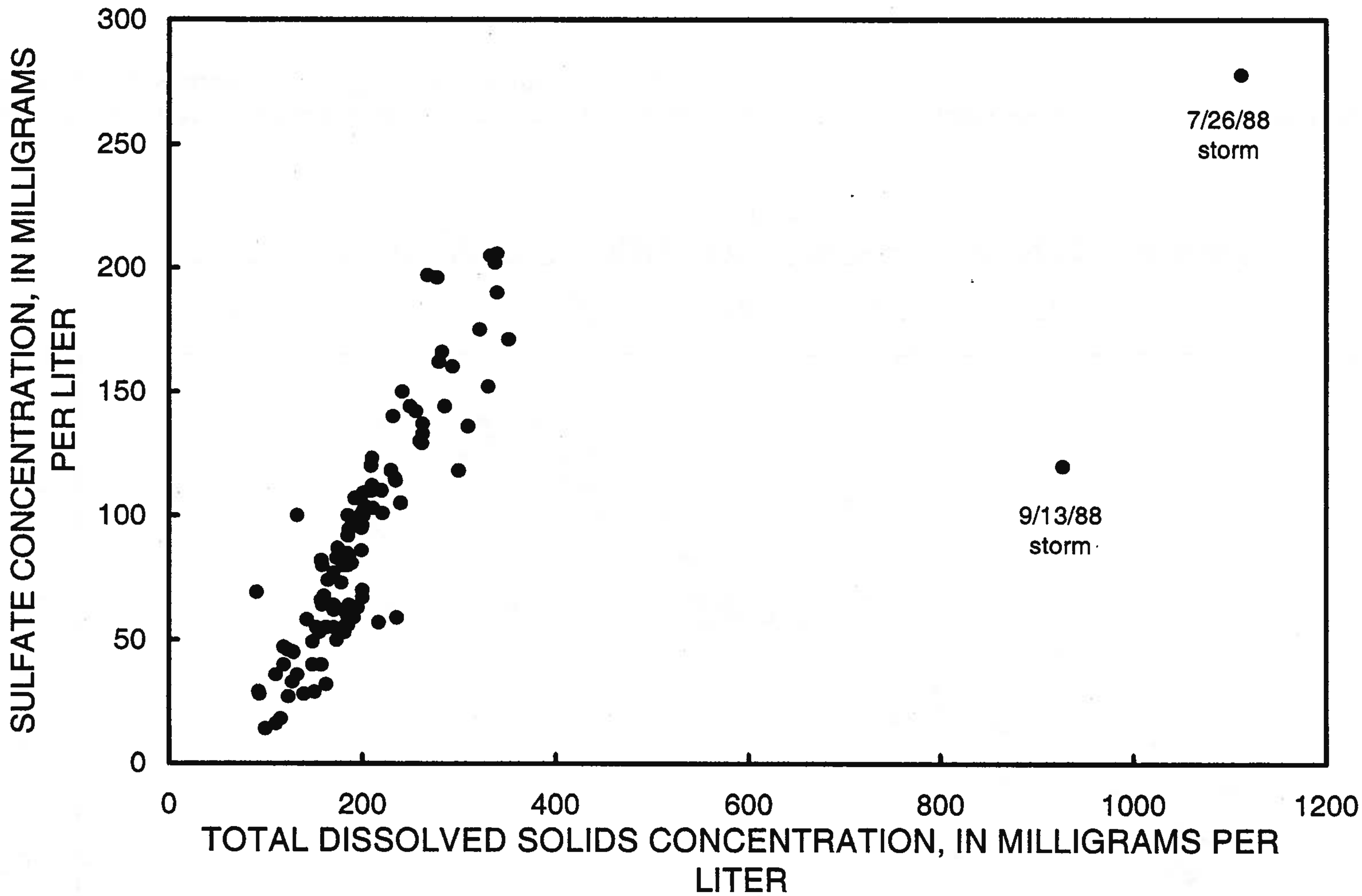

Figure 10. Graph showing sulfate concentrations in relation to total dissolved solids concentrations in the Red River at the Questa Ranger Station from 1965 to 2001, with outliers.

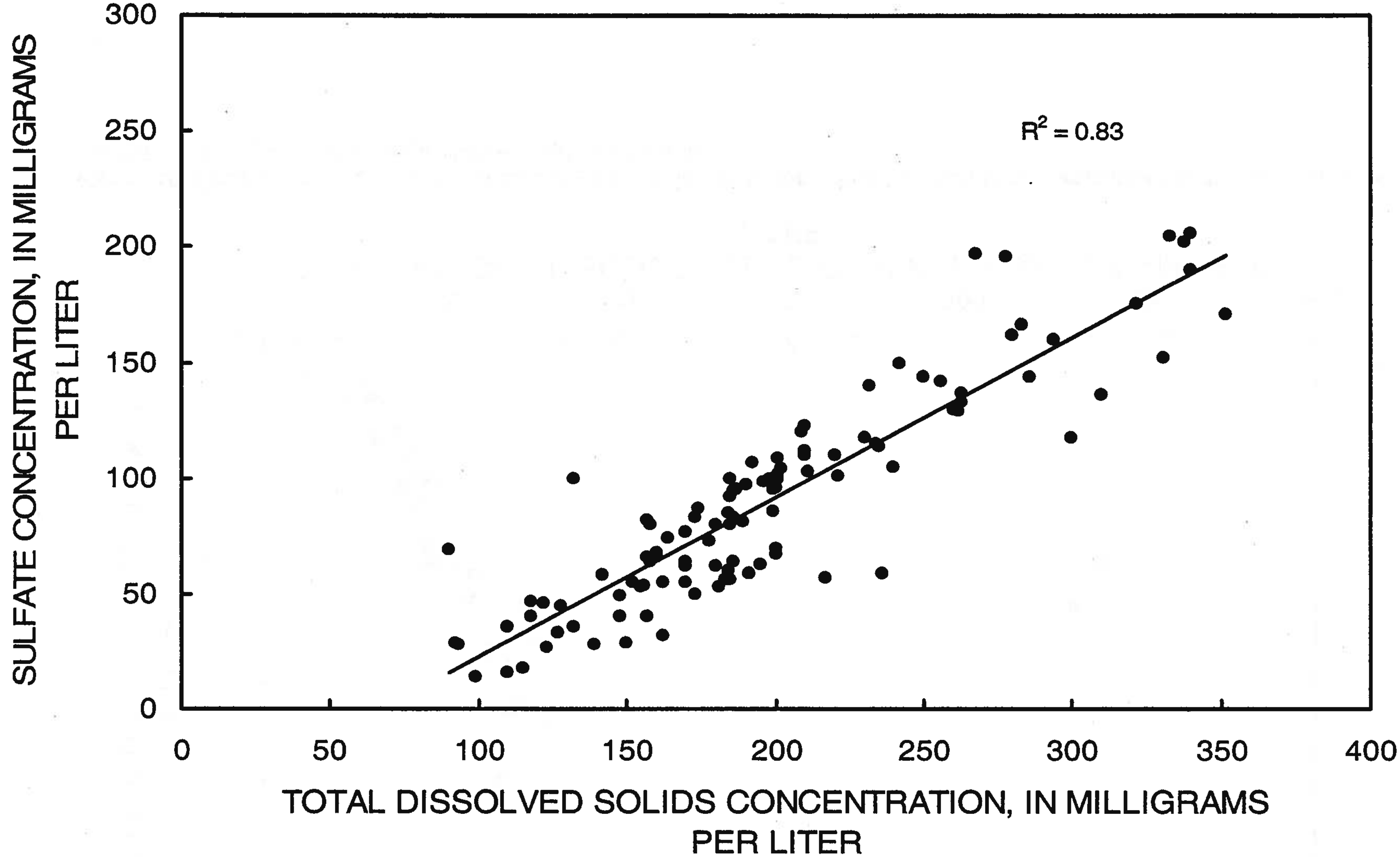

Figure 11. Graph showing sulfate concentrations in relation to total dissolved solids concentrations in the Red River at Questa Ranger Station from 1965 to 2001, without outliers.

sulfate was the dissolution of gypsum, the values should plot on the gypsum dissolution line. If calcite dissolution (or plagioclase weathering) contributes to the water chemistry, the values should plot above the line, as several of the points do at lower concentrations. Alternatively, if pyrite oxidation contributes additional sulfate, the values would plot below the line, as shown for a number of the points at higher concentrations. The points that plot above the gypsum dissolution line are generally those from higher flow events (falling limb, peak, and rising limb) and older sampling dates, as would be expected for lower concentrations. No point plotted below the gypsum dissolution line before 1980, while the majority of the low-flow sampling points plotted below the line after 1980. This trend indicates that the source of increasing sulfate concentrations over time is areas draining material that is higher in pyrite content. No conclusion can be drawn from these data regarding the location of this source.

The results shown in figure 10 indicate that it takes only a small amount of calcite or pyrite dissolution to change the calcium-to-sulfate ratios in the Red River at the Questa Ranger Station. The separation of sampling points according to hydrologic timing suggests that during higher flow events, Red River water is diluted by calcium-carbonate waters, most likely from upstream of the scar areas and unmineralized Red River tributaries. More recent samples show increased sulfate concentrations at the Questa Ranger Station, most likely from mining activity (see figure 5), and these waters were dominated by increasing pyrite oxidation. Samples collected by the U.S. Geological Survey in 2001 and 2002 plot even farther to the right on figure 10 (McCleskey and others, 2003 suggesting that Red River water may be more affected by pyrite oxidation over time.

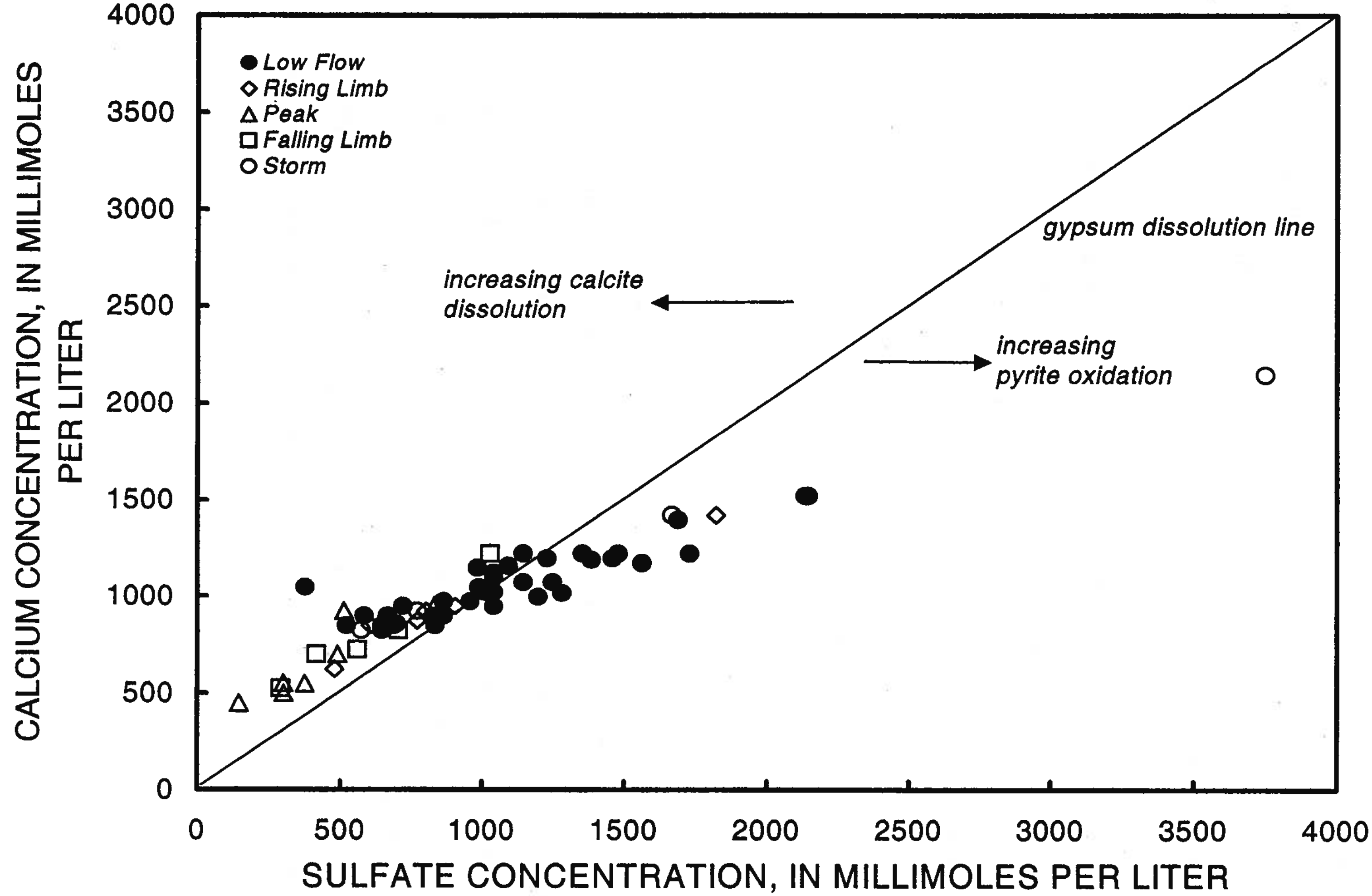

Figure 12. Graph showing calcium concentrations in relation to sulfate concentrations in the Red River at Questa Ranger Station and the gypsum congruent dissolution line.

The alkalinity values in the Red River also indicate that the river is not well buffered with respect to pH. Although there is a limited data set for alkalinity both upstream of the mine and at the Questa Ranger Station (no upstream samples were collected between November 1970 and September 1988), figure 11 shows that alkalinity values are consistently lower at the Questa Ranger Station than they are upstream of the mine (all alkalinity data at the Questa Ranger Station varied from 0 to 62, with one outlier at 108 mg/L as calcium carbonate). Low-flow alkalinity values at the Questa Ranger Station have decreased over time, with values close to 60 mg/L as $CaCO_3$ in 1965 and values between 20 and 50 by 1993. These low alkalinity values offer only limited buffering capacity, especially downstream of the mine. During a storm event in August 1988, alkalinity values dropped substantially both upstream and downstream of the mine (figure 11). The drop in alkalinity at both locations indicates that natural sources, most likely scar areas, are largely responsible for short-term changes in the buffering capacity of the Red River during storm events.

Figure 12 shows zinc concentrations upstream of the mine and at the Questa Ranger Station over time (only dates when zinc concentrations were measured at both locations are shown). The concentrations shown are a combination of total and dissolved zinc values, and in some cases, no indication was given about sample filtration. No obvious trend in concentrations over time at the Questa Ranger Station is apparent, possibly due in part to the inability to separate dissolved and unfiltered concentrations. However, zinc concentrations downstream of the mine at the Questa Ranger Station are uniformly higher than those upstream of the mine and downstream of scar areas, suggesting that additional zinc sources enter the river in the vicinity of the mine.

Dissolved and total zinc concentrations were measured by Garn (1985) between October 1978 and December 1986. Discharge (at the time of sampling, in addition to average

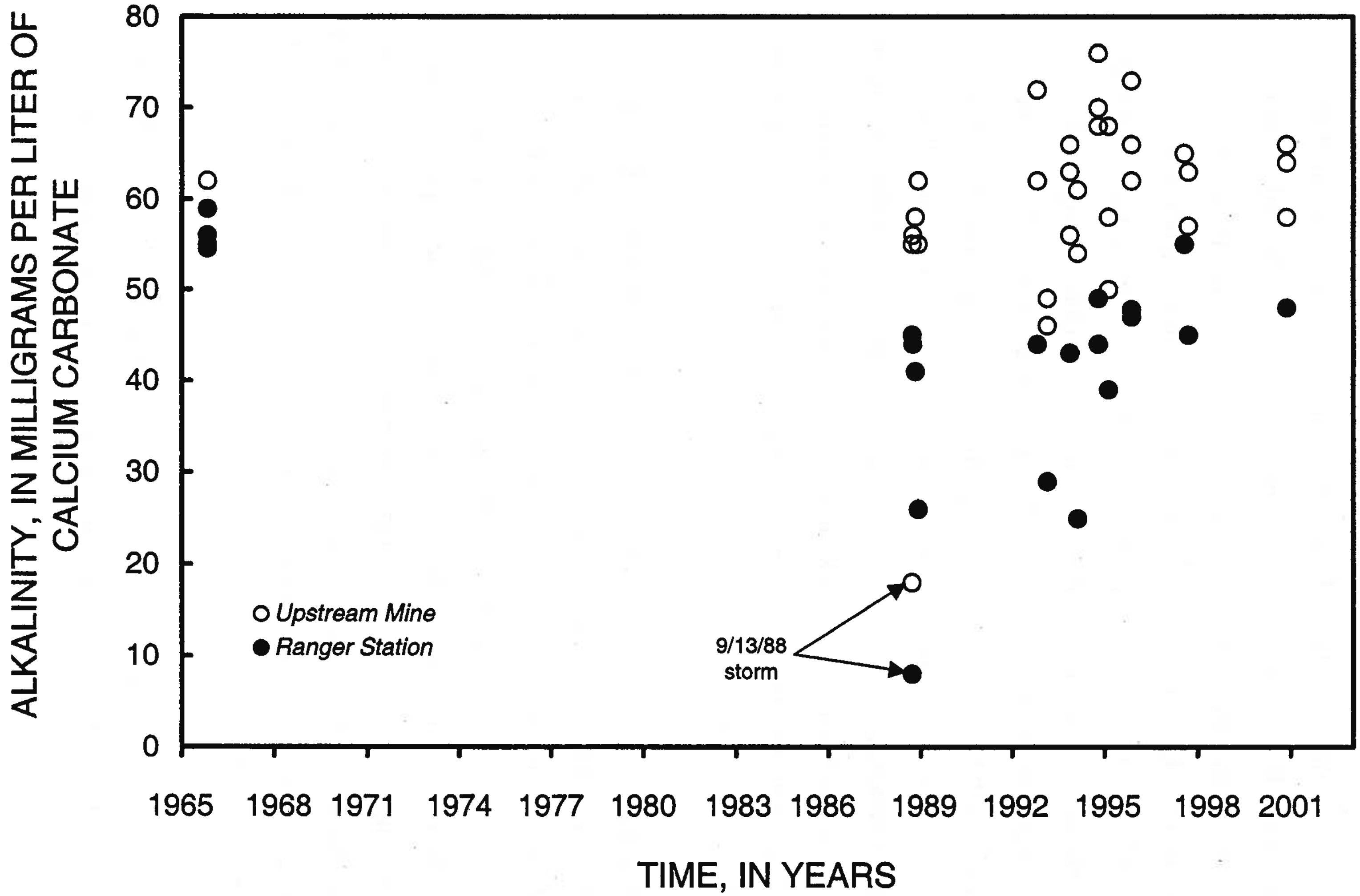

Figure 13. Graph showing alkalinity values upstream and downstream of the Molycorp molybdenum mine in the Red River.

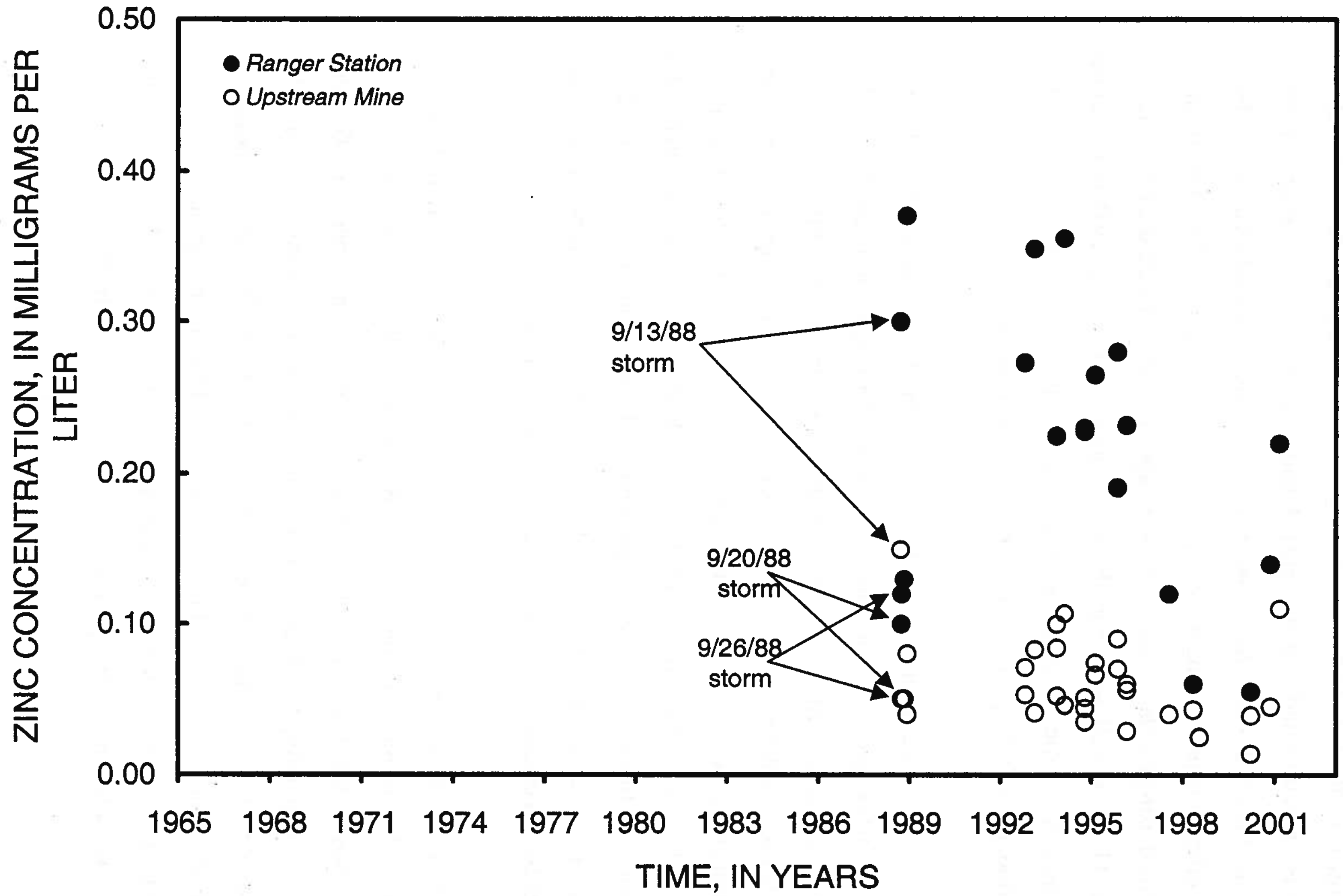

Figure 14. Graph showing zinc concentrations over time upstream and downstream of the Molycorp molybdenum mine.

daily discharge from the U.S. Geological Survey streamflow-gaging station at the Questa Ranger Station), specific conductance, field pH, and other parameters were also measured by Garn during this timeframe. The frequency of zinc measurements by Garn is higher than for any other time period, and trends in zinc concentrations related to flow events can be discerned using his data. Figure 13 shows specific conductance and pH values (measured by Garn), as well as average daily discharge, from October 1978 to December 1986. Decreases in specific conductance are associated with increases in discharge. Over this time period, pH values appeared to be decreasing somewhat.

Two time periods from the Garn (1985) data are shown in more detail in figures 14 and 15. Figure 14a shows specific conductance and average daily discharge, and figure 14b shows and total and dissolved zinc and average daily discharge from February 1982 through September 1984. Specific conductance values decreased during peak flows and increased throughout the low flow period (figure 14a). Zinc concentrations also increased throughout the low flow period and generally peaked during rising limb times. Particulate zinc is present at all times, but the highest percentage of particulate zinc is associated with the peak in zinc concentrations during the rising limb in 1983. This zinc peak is also accompanied by a decrease in alkalinity (to 28 mg/L as $CaCO_3$).

Figure 15a shows dissolved and total zinc concentrations measured by Garn in 1986. His highest measured zinc concentration (4.4 and 2.6 mg/L for total and dissolved, respectively) was measured during a summer thunderstorm on September 7, 1986. Much of the zinc measured during this thunderstorm event was present as particulate zinc. This date correlates with the rising limb of the storm, and specific conductance also peaked during the event (figure 15b). The data in figures 14 and 15 demonstrate that thunderstorm events and the rising limb of the hydrograph are associated not only with sulfate and conductivity peaks, but also with peaks in zinc concentrations.

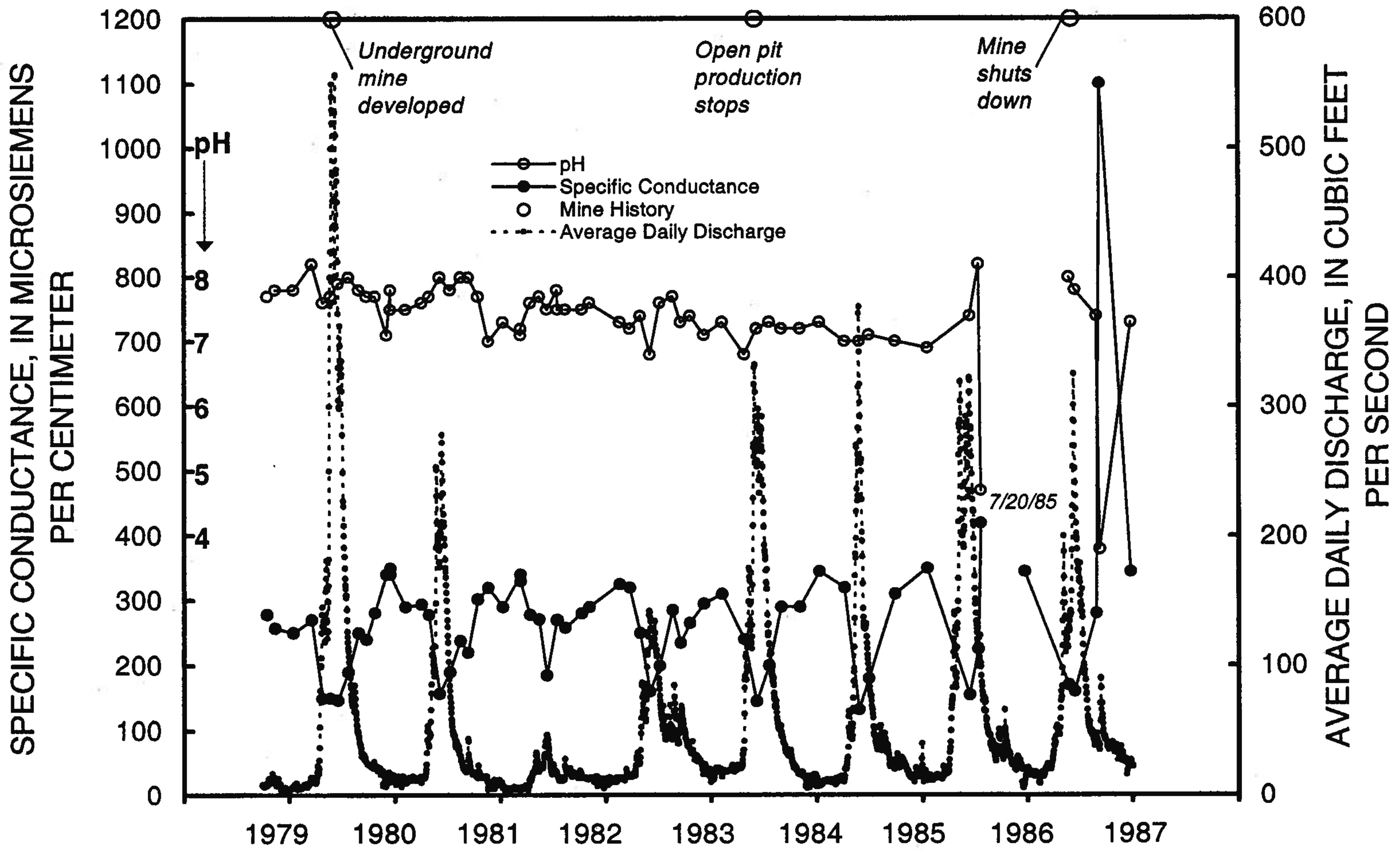

Figure 15. Graph showing specific conductance, pH, and average daily discharge in the Red River at Questa Ranger Station, from October 1978 to December 1986.

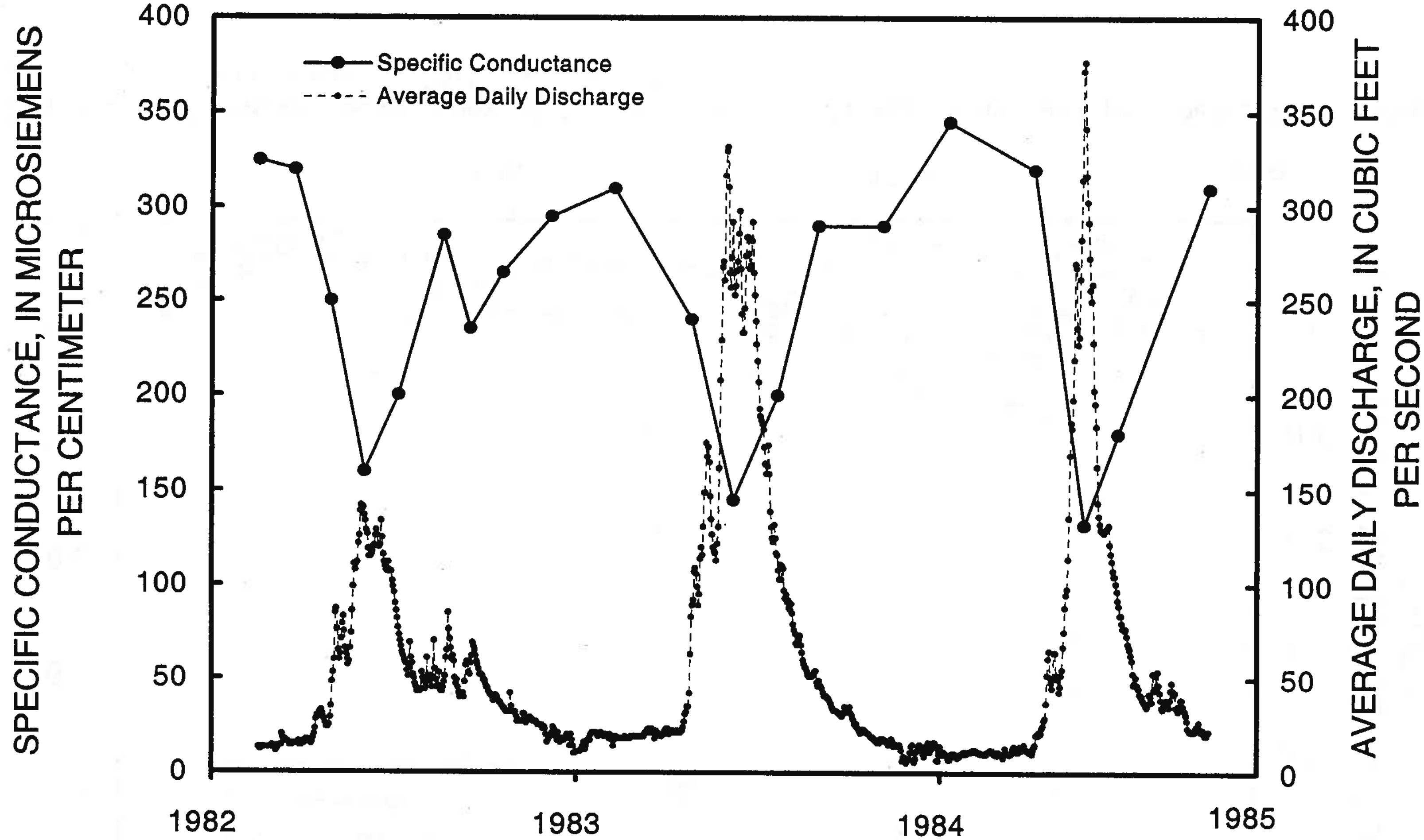

Figure 16. Graph showing specific conductance and average daily discharge in the Red River at Questa Ranger Station from February 1982 to September 1984.

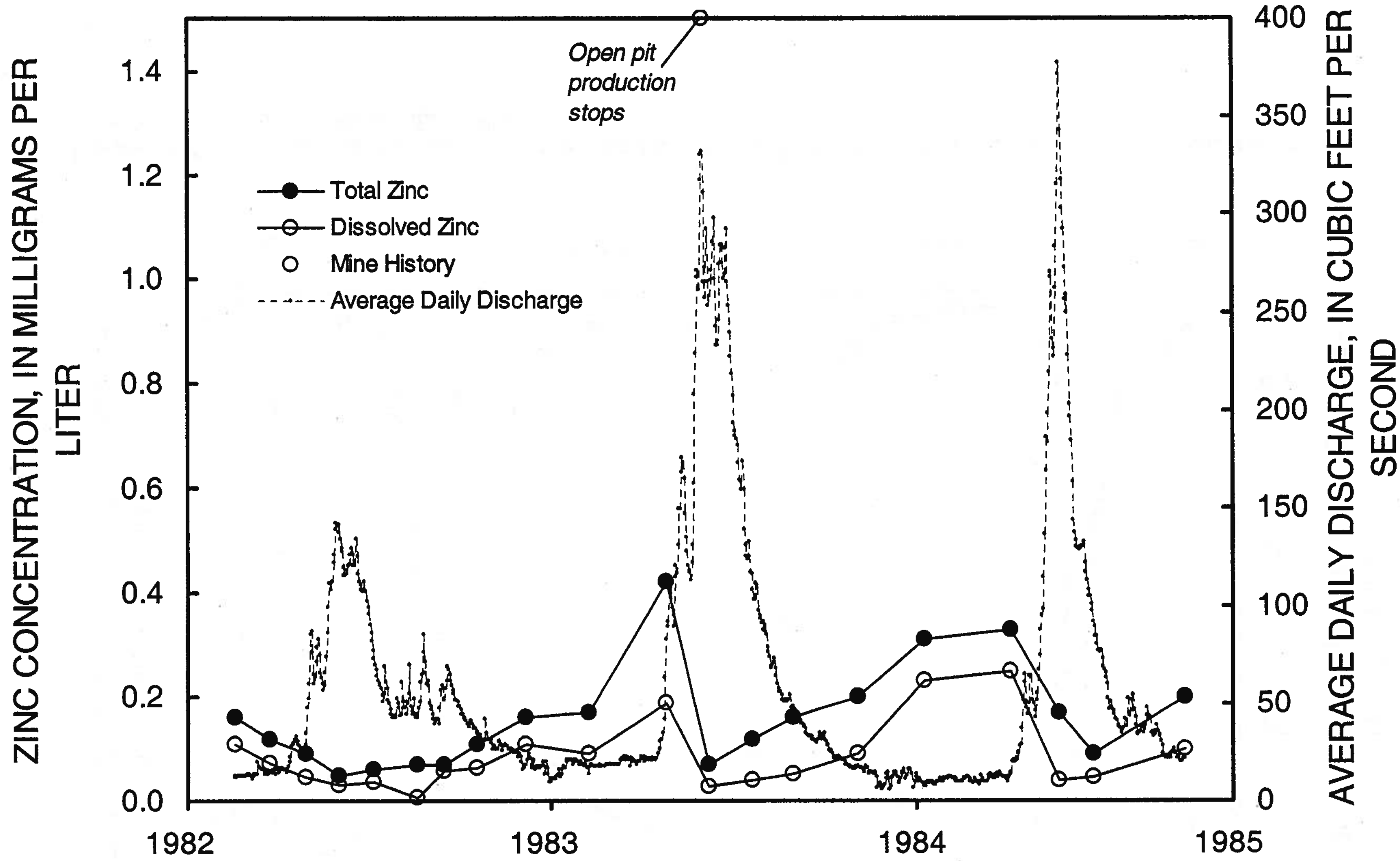

Figure 17. Graph showing total and dissolved zinc concentrations and average daily discharge in the Red River at Questa Ranger Station from February 1982 to September 1984.

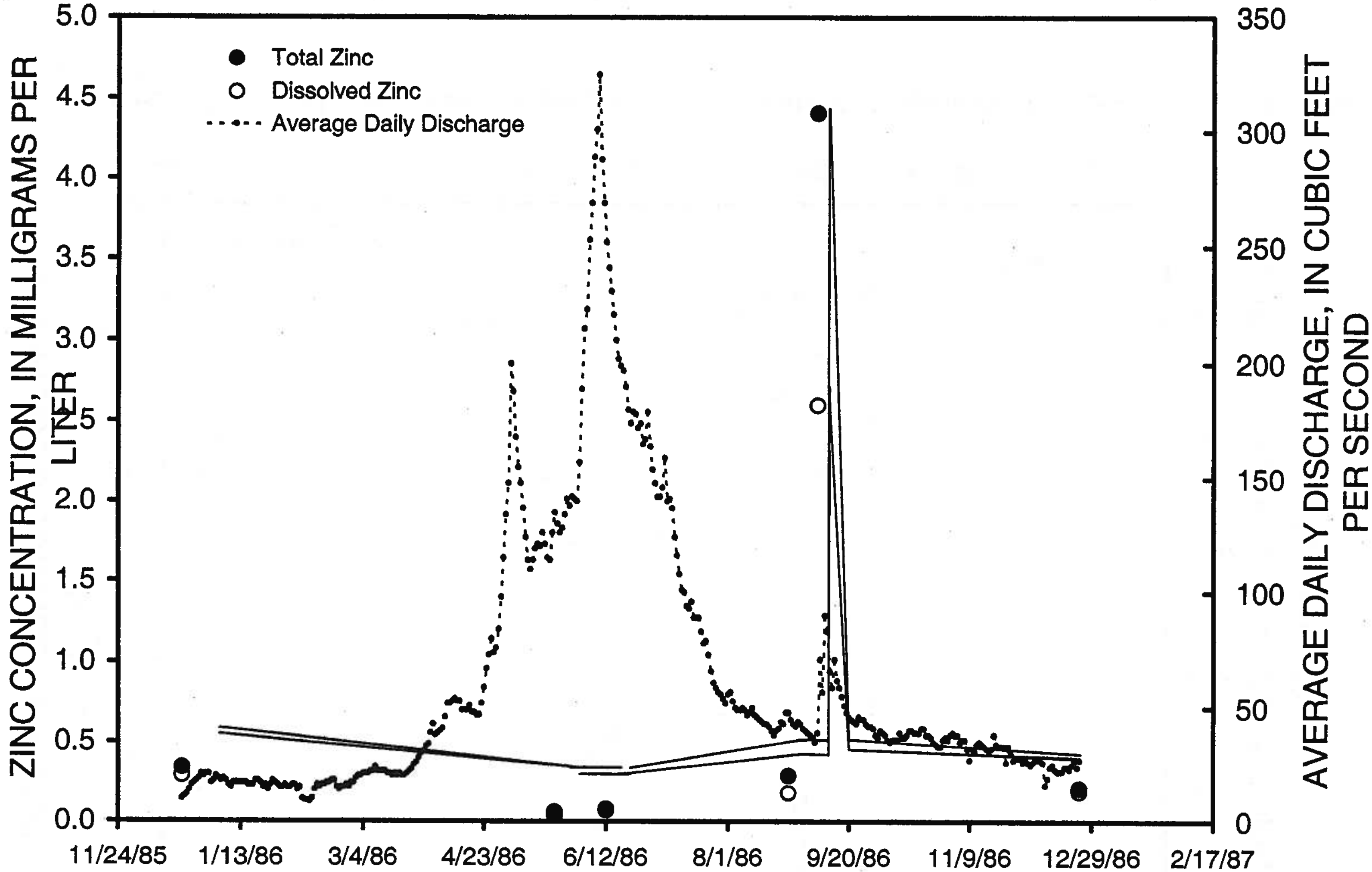

Figure 18. Graph showing dissolved and total zinc concentrations in the Red River at Questa Ranger Station in 1986.

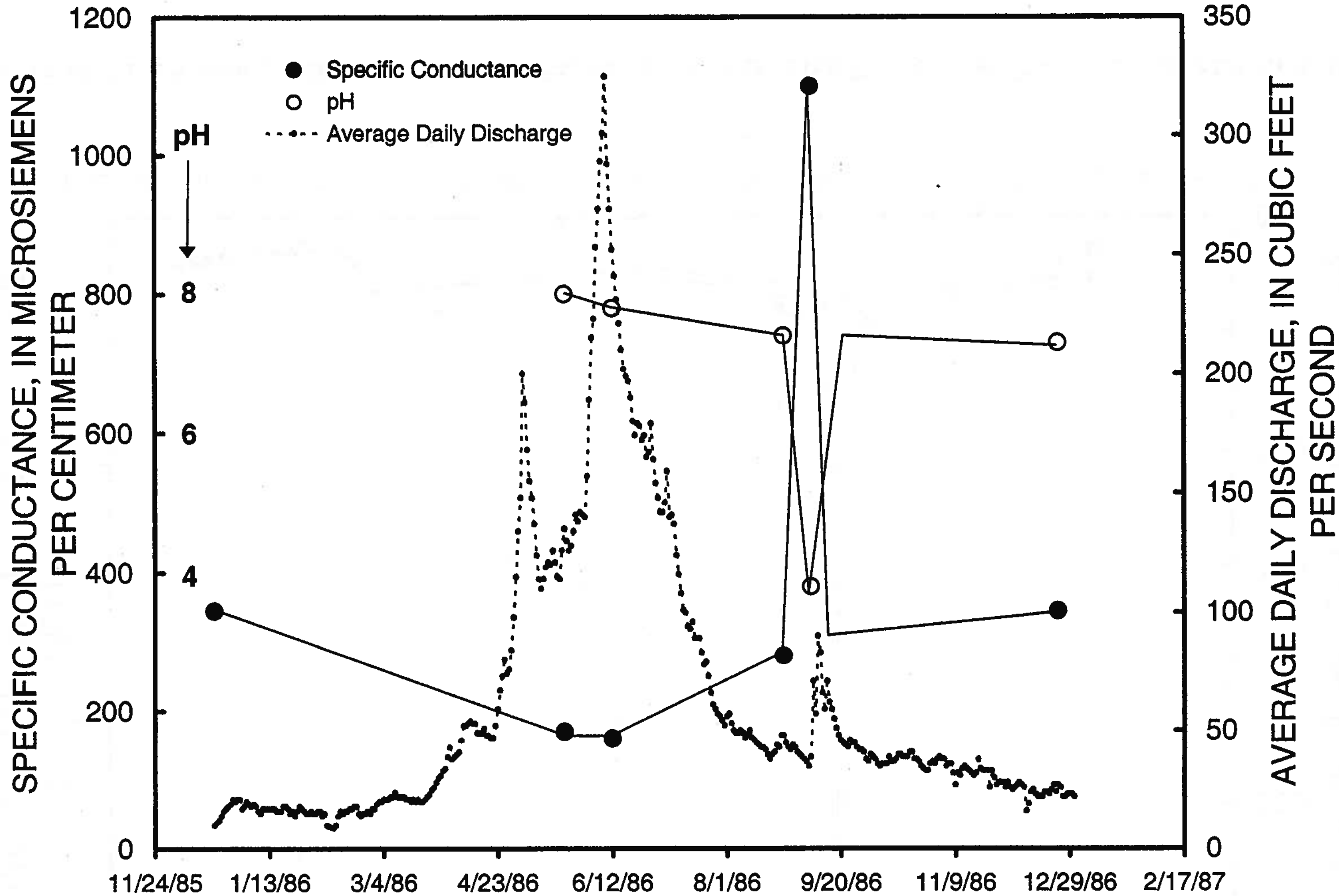

Figure 19. Graph showing pH, specific conductance, and average daily discharge in the Red River at Questa Ranger Station in 1986.

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