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A RECONNAISSANCE STUDY OF MERCURY AND BASE METAL CONCENTRATIONS IN WATER, AND STREAM- AND LAKE-SEDIMENT SAMPLES ALONG THE PECOS RIVER, EASTERN NEW MEXICO

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Abstract— Water quality of the Pecos River has become a major concern as population in eastern New Mexico increases together with a corresponding increase in multiple uses for agriculture, municipal, domestic and recreational purposes. Samples of fish, waterfowl and small mammals have been found to contain elevated levels of certain metals and other pollutants. In this study, water and stream- and lake-sediments were collected along the Pecos River during a five-day period in September 1992 and were analyzed for mercury, lead, copper and zinc. Sediments were also analyzed for chromium. Mercury, lead, copper and zinc concentrations in sediments are elevated above and immediately below the Pecos mine waste dumps, suggesting that the waste dumps, outcropping zones of mineralization and the outcropping rocks may be potential sources. However, elsewhere in the Pecos drainage basin other sources for these metals should be considered as well.

INTRODUCTION

Water quality of the Pecos River has regional and international concerns as population in eastern New Mexico increases together with a corresponding increase in uses for agriculture, municipal, domestic, industrial and recreational purposes. It has been reported that fish, waterfowl and small mammals from along the Pecos River contain elevated levels of selenium, mercury, lead, cadmium, chromium and other pollutants (U.S. Bureau of Reclamation, written comm. 1992; S. J. Haness, U.S. Department of Health and Human Services, written comm. 1991). Mercury levels in fish fillets obtained in 1991 from Sumner Lake ranged from 0.5 to 17.1 ppm (dry weight; L. A. Brandvold, unpublished data, 1991). The federal standards are 1 ppm Hg in fish intended for consumption. The Lisboa Springs Fish Hatchery (New Mexico Game and Fish Department, NMGFD), north of the village of Pecos, has experienced several fish kills, which may in part be attributed to contaminated water. The fish kills and hatchery management are presently being studied by the U.S. Fish and Wildlife Service and NMGFD. The Pecos mining district is an old (1880s to 1944) mining district near the boundary of the Pecos Wilderness Area, 19 km upstream from the fish hatchery and has been cited as a possible source of contaminants by government agencies. Other mining districts throughout eastern New Mexico have drainages that enter the Pecos River below the village of Pecos, but have not been examined to determine if they too are possible sources of contamination. Other sources of possible contamination certainly include cities and towns, agricultural activities, private ponds draining into the river, automobile exhaust and input from atmospheric pollution.

There has been and continues to be numerous significant scientific studies in the Pecos River drainage basin. In the 1970s, the U.S. Department of Energy examined the chemistry of both water and stream sediments in the Pecos River drainage basin as part of the National Uranium Resource Evaluation Program (Bolivar et al., 1980; Union Carbide Corp., 1981a, b, c; Erdman et al., 1992). Brandvold (1978) analyzed mercury concentrations in water samples from along the Pecos River and found all but one sample to be below 2 ppb Hg. Sample #43, from near Artesia, contained 7.4 ppb Hg. Currently the New Mexico Environment Department (NMED), NMGFD and the New Mexico Parks and Recreation Department are monitoring mercury concentrations in fish from the Pecos River and the reservoirs along the river. Local agencies and municipalities monitor water quality in their areas of administration. However, the most politically sensitive investigations are in the Pecos mine area. AMAX, NMGFD, the New Mexico State Highway and Transportation Department and the State of New Mexico are conducting ongoing remedial investigations and feasibility studies of the Pecos mine area, adjacent campgrounds and recreational areas, NM Highway 63 and the Lisboa Springs Fish Hatchery. Because of potential, but unknown, contamination to the lakes downstream from the Pecos mine, the U.S. Bureau of Reclamation in cooperation with the New Mexico Institute of Mining and Technology and the New Mexico Bureau of Mines and Mineral Resources are conducting investigations of water and snow quality and characterizing the chemistry of stream and lake sediments from the headwaters of the Pecos River to Sumner Lake. This report, an expansion of the U.S. Bureau of Reclamation study, is one of the first comprehensive studies to examine water quality and chemistry of stream and lake sediments from near the headwaters of the Pecos River to south of Brantley Lake, north of Carlsbad.

The purposes of this study were to (1) determine the concentration and distribution of mercury and base metals in sediments and water along the Pecos River, (2) locate areas of high concentrations of these metals, (3) locate possible sources for any areas of high concentrations, and (4) recommend further research. This was a reconnaissance study only; additional more detailed studies are under way. Water and stream- and lake-sediment samples were collected to determine how much effect sediment composition has on Pecos River basin water quality. Samples were collected from near the headwaters of the Pecos southward to below Brantley Lake, during a five-day span in September 1992 to provide a regional outlook within a specific time interval.

AREA OF STUDY

The Pecos River is a significant source of surface and subsurface water supplies for eastern New Mexico, west Texas and Coahuila, Mexico (Fig. 1). The headwaters are in the Pecos Wilderness in the Sangre de Cristo Mountains, with additional drainages from the Pedernal uplift, Capitan Mountains, Sierra Blanca and Guadalupe Mountains (Fig. 1). Elevations range from 1000 to over 3600 m. The river flows southward through the towns and cities of Pecos, Santa Rosa, Fort Sumner, Roswell, Artesia and Carlsbad into west Texas and finally enters the Rio Grande at the international border with Coahuila (Fig. 1).

Eastern New Mexico is predominantly a rural agricultural area, but the larger cities have some light industry. Petroleum and potash production are important in southeastern New Mexico. There is currently no metal mining within the Pecos drainage basin.

GEOLOGY

The geology of the Pecos drainage basin is diverse and rocks range in age from Proterozoic through recent. Lithologies are likewise diverse, ranging from metamorphic volcanics to granites to syenites to shales, limestones and sandstones (New Mexico Geological Society, 1982).

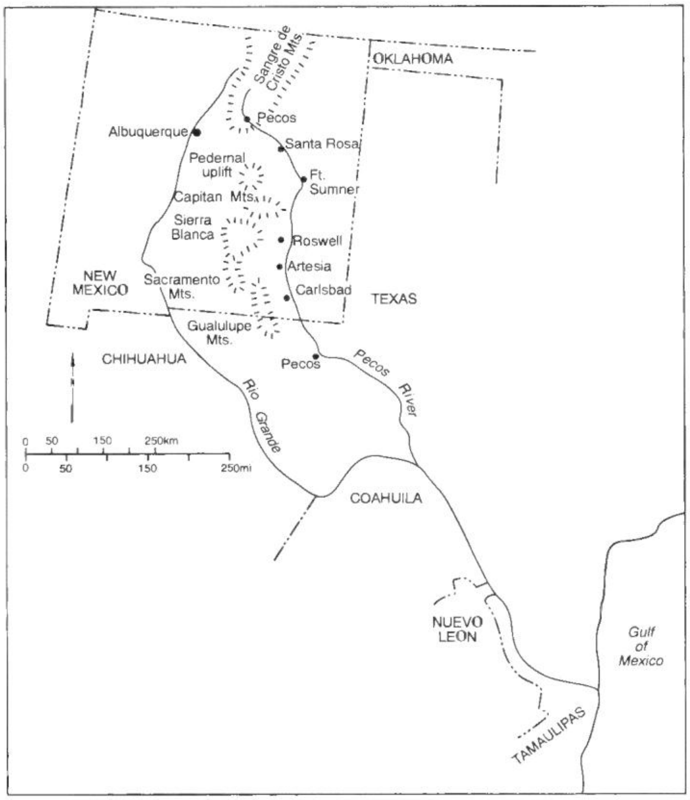

FIGURE 1. Pecos River drainage basin.

Mining has occurred throughout the Pecos drainage area (Table I; Fig. 2), but total production has not been as significant as elsewhere in New Mexico. The largest mining district in the Pecos drainage basin is the Pecos mining district (Table 1). The majority of the deposits are precious- and base-metal vein deposits and sedimentary-copper deposits. There are no known mercury deposits in the state of New Mexico and mercury is typically low in similar mineralized districts elsewhere in the state (Table 2).

PECOS MINE

The Pecos mine (also known as Tererro, Cowles, Hamilton and Willow Creek) is located near the confluence of Willow Creek and the Pecos River and has been cited as a source of contamination to the Pecos River drainage basin by NMED. In 1881, a highly mineralized outcrop was discovered along the southern slope of Willow Creek Canyon near the river junction. Subsequently claims were filed and development begun. A shaft was sunk to 121.9 m and initial ore mined averaged 17% Zn, 4% Pb, 1% Cu, 3 oz/ton (103 ppm) Ag and 0.12 oz/ton (4 ppm) Au. The mine was eventually developed to 518 m. Several additional shafts and adits access the main workings, which extend lengthwise along the ore bodies for 609.6 m. In 1930, 1200 gallons/min (4542 L/min) of water was pumped from the mine; none of the water was acidic (Matson and Hoag, 1930). No mill tailings are at the site because the ore was transported to Alamitos Arroyo for processing. Total production from the Pecos mine from 1927 to 1944 amounts to 2,301,428 tons of ore containing 18,490,400 lbs Cu, 178,813 oz Au, 5,476,511 oz Ag, 133,942,500 lbs Pb and 421,543,000 lbs Zn (0.4% Cu, 2.9% Pb, 9.1% Zn) and was worth over $40 million (from compilation of Harley, 1940, and unpublished reports by V. T. McLemore). This figure includes production from the shaft (1927 to 1939) and some additional production from the dumps during the 1940s.

Mineralization at the Pecos mine occurs in Proterozoic igneous and metamorphic rocks (Riesmeyer and Robertson, 1979; Robertson et al., 1986). Overlying the Proterozoic rocks are Paleozoic sedimentary rocks. Two stratabound, lens-shaped ore bodies were mined. Ore consisted of sphalerite, galena and chalcopyrite in a gangue of quartz, chlorite, pyrite and sericite. Silver and gold are present together with minor occurrences of pyrrhotite, bornite, magnetite, hematite and tourmaline. Examination of panned concentrates from Willow Creek by the mine waste dumps revealed the presence of chalcopyrite, pyrite, galena, sphalerite, garnet, olivine, quartz and feldspar (V. T. McLemore, 9/14/92). Outcrop samples north of the Pecos mine contained 0.33-0.53% Cu and 1.6-2.6% Zn (U.S. Geological Survey et al., 1980).

In 1950, NMGFD purchased approximately 2000 acres in the Pecos mine area, which includes the mine site, mine waste dumps and adjacent valley areas. The mineral rights were transferred to a trust and leased to various companies from 1950 to 1988 (S. M. Stoller Corp., written comm., March 18, 1993). NMGFD and other government agencies utilized the mine waste dumps for road fill and base material in the campgrounds along the Pecos River from the 1930s through the late 1970s. Subsequently these areas have been remediated to prevent heavy metal exposure (mainly lead) to the general public. Additional remedial studies are under way.

Recent work by AMAX Resource Conservation Co. indicates that the mine waste dump varies in thickness from 6 to 13 m. The composition and texture of the dump are heterogeneous and difficult to characterize accurately. The dump is underlain by either clay material or limestone bedrock (S. M. Stoller Corp., written comm., March 18, 1993). Thirteen monitoring wells have been drilled in or near the dump to monitor ground water flow (M. J. Logsdon, written comm., June 25, 1992).

Acid water, caused by oxidation of pyrite, periodically seeps from the waste dumps located east of the Pecos River just below the confluence with Willow Creek. White and brown precipitates or froth are present along the course of the seep. Sample 4 was collected along this seep. The seep enters a wetlands (approximately 5 acres) and very little, if any precipitate would be expected to reach the river except perhaps during periods of heavy runoff from major rain storms.

METHODS OF STUDY

Sampling methods

Sample sites along the Pecos River from the Pecos Wilderness boundary southward to north of Carlsbad were determined prior to collection. Field conditions are summarized in Table 3. Sample sites were determined on the basis of well-maintained and easy access by vehicle or by motor boat and proximity to known mines and towns (Fig. 2; Table 3).

Water samples were collected in plastic bottles and acidified to prevent precipitation of dissolved metals. Field measurements on unacidified water samples included pH, temperature, conductivity and alkalinity (Fig. 3). One water sample was collected from each lake. Stream-sediment samples were collected at each site. The river was typically shallow, enabling the sample collector to wade into the river and obtain a sediment sample near the center of the river bed. Samples were stored in plastic bags and sieved at the laboratory.

Bottom lake-sediment samples were collected from Santa Rosa, Sumner and Brantley Lakes using a motor boat or work barge and a bottom-grab sampler (Fig. 4). Only the top layer of lake sediment could be collected using this device. These three lakes were chosen because of different ages of lake impoundment (Table 3), the large amount of sediment buildup that contributes to bioaccumulation of metals, particularly mercury, up the food chain to fish, and good accessibility. In addition, Perch Lake (16), a natural freshwater lake near Santa Rosa. was also sampled.

Laboratory methods

A portion of each sediment sample was removed and frozen for later study. Approximately 3 g of wet sample were used for a mercury determination by cold vapor atomic absorption following digestion with reverse *aqua regia.* Percent moisture was also determined in the wet sample to allow calculation of dry weight mercury. The detection limit varied between 5-10 ppb, depending on sample dry weight and amount of mercury in the blank. Samples were air-dried and the >2 mm size fraction (10 mesh) was removed by screening. This fraction was not

TABLE 1. Mining districts that have drainages into the Pecos River (modified from North and McLemore, 1986; McLemore and Chenoweth, 1989). Production statistics from published references, U.S. Bureau of Mines Mineral Yearbooks, and unpublished reports (compiled by V. T. McLemore).

District	Period of Production	Production Au (oz)	Ag (oz)	Cu (lbs)	Pb (lbs)	Zn (lbs)	U_3O_8 (lbs)	Other commodities (no production)	Type of Deposit	Description	References
Pecos (Willow Creek)	1927-1944	178,813	6,200,000	18,490,400	133,942,500	421,543,000	--	--	Volcanogenic, massive sulfide, placer gold	Massive sulfide deposits in Precambrian rocks	Riesmeyer and Robertson (1978), Harley (1940); Johnson (1972)
El Porvenir	1955-1956	--	--	--	--	--	32	Th,REE	Volcanogenic, massive sulfide, pegmatite	Massive sulfide deposits in Precambrian rocks, pegmatite	Harley (1940), McLemore et al. (1988a,b)
Elk Mountain Spring Mountain	None	--	--	--	--	--	--	U,Th,REE,Pb	Pegmatite, possible sulfides in veins	Quartz veins in metamorphic rocks containing pyrite and galena. Pegmatites	Klich (1983)
Santa Fe	1956-1957	--	96	11,400	--	--	--	Cu,Pb,Zn, Ag,Au	Volcanogenic, massive sulfide	Massive sulfide deposits in Precambrian schist and phylite	Elston (1967), Fulp (1982), Robertson et al. (1986)
Glorieta	prior to 1905	--	--	50,000	--	--	--	Cu,Ag,U	Sedimentary copper	Stratabound, sedimentary copper deposits in Permian sandstones	Elston (1967), Soulé (1956)
Tecolote	1900-1954	19	128	19,112	2,816	--	--	Zn,U,Th, REE,Be	Sedimentary copper	Stratabound, sedimentary copper deposits in Permian sandstones	McLemore and North (1985), Soulé (1956)
Pastura (Guadalupe)	1916-1969	2	42,494	13,578,214	58,723	--	--	U	Sedimentary copper	Stratabound, sedimentary copper deposits in Triassic Permian sandstones	McLemore and North (1985), Soulé (1956), Sandusky and Kaufman and (1972)
Gallinas	1900-1955	7	23,723	385,418	1,726,738	17,344	--	REE,Th,U, Zn,Fe,fluorite	Great Plains Margin, sedimentary copper	veins filling fractures and breccia zones in Yeso Fm (Permian) and Tertiary intrusive	McLemore (1991), Perhac (1970), Griswold (1959)
Nogal	1865-1942	15,000	20,000	unknown	unknown	unknown	--	Cu,Pb,Zn,Mo,	Great Plains Margin, placer	Veins in Tertiary volcanics and intrusives	McLemore (1991), Thompson, (1973) Griswold (1959)
Capitan Mtns.	1954	--	--	--	--			Th,REE,Fe	Great Plains Margin	Veins in Tertiary granite	McLemore and Phillips (1991)
Lone Eagle	1905-1956	--	21	35,236	--	--	--	U,Th	Sedimentary copper, Uranium in limestone	Stratabound, sedimentary copper deposits in Permian sandstones;Uranium limestone	Soulé (1956), Molts (1962) Finch (1972)
Red Lake	1950's?		--	--	unknown	--	--	Cu,Ag,Pb,Zn	Mississippi Valley type	Veins in collapse breccia in Permian Rustler Fm	North and McLemore (1986)
Two Ladies Prospects	1950's?	--	--	--	unknown	--	--	Pb,Zn,Ag	Mississippi Valley Type	Replacement and veins in breccia in Permian dolomite	

TABLE 2. Mercury concentrations in selected mining districts and other areas throughout New Mexico (samples collected by V. T. McLemore and analyzed by L. A. Brandvold). See North and McLemore (1986) for locations and description of these districts. *Districts or areas within the Pecos drainage basin.

Mining	Type of Deposit	Location	Rock Type	Hg ppb
El Cuervo	Sedimentary Hydrothermal Ba-F-Pb	Southwest-Central Santa Fe County	Sandstone	<200-700
Sabinoso	Sedimentary Copper	San Miguel County	Sandstone, shale	<300-1,300
Steeple Rock	Epithermal vein	Western Grant County	volcanics	<200-3,500
Gallinas*	Great Plains Margin	Lincoln County	volcanics, limestone	17-1,190
Santa Rosa Tar Sand* (not a mining district)	None	Guadalupe County (Santa Rosa Lake)	Sandstone	10
Rocky Arroyo Uranium* Prospect (Carlsbad Area)	Uranium in Limestone	Eddy County	limestone	60
Cornudas Mountains	Great Plains Margin	Southeastern Otero County	igneous dikes, clay gouge	20-170

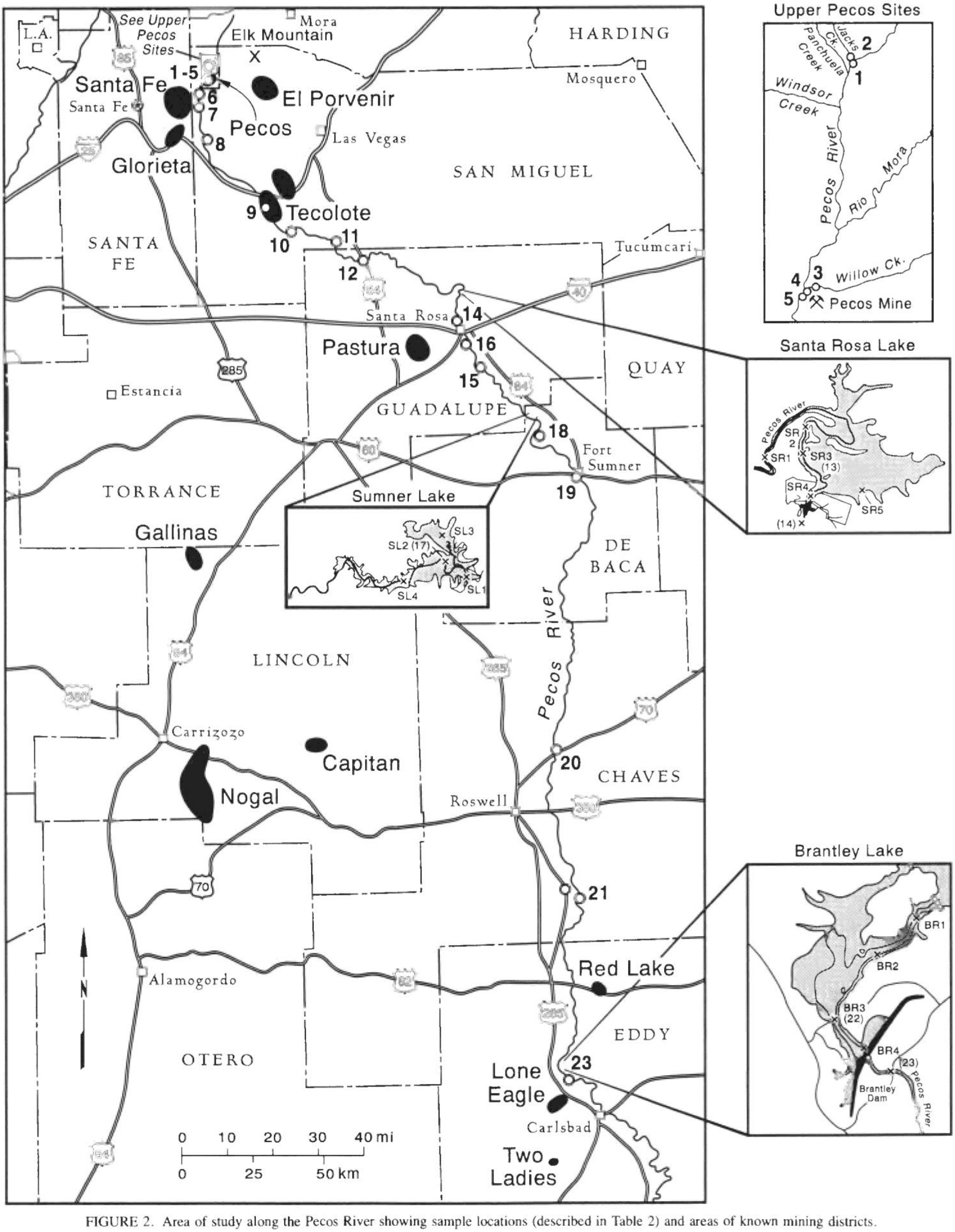

FIGURE 2. Area of study along the Pecos River showing sample locations (described in Table 2) and areas of known mining districts.

TABLE 3. Description of sample sites along the Pecos River. Sumner Lake was impounded in August 1937, Santa Rosa in 1980 and Brantley Lake in 1989.

Sample No.	Name	Date Collected	Latitude	Longitude	Water Depth (ft)	Water Flow	Comments
1	Upper Pecos	9/24/92	35.49.30	105.39.05	0.5	slow	probably bank material
2	Jack's Creek		35.49.30	105.39.07	2.0	fast	mostly boulders
3	Willow Creek		35.45.35	105.40.05	0.5	moderate	above mine waste, E. of road
4	Below Seep #1		35.45.30	105.40.15	0.4	very slow	ED Seep #1, wt. and brn preciptate
5	Pecos, below Willow Creek		35.45.27	105.40.10	1.0	fast	mostly boulders
6	Above hatchery		35.37.00	105.41.00	3.0	fast	Above diversion dam-(1) near bank (2) midstream
7	Below hatchery		35.36.30	105.41.0	2.5	fast	below hatchery outlet
8	Pecos at 233		35.34.32	105.40.10	2.0	moderate	patches of sand, mostly boulders
9	Dam at San Miguel	9/23/92	35.22.00	105.26.45	3.0	moderate	sandstone outcrop forms one side
10	Villanueva		35.15.30	105.20.15	2.5	moderate	gravel
11	Tecolotito		35.20.20	105.14.20	1.5	fast	boulders
12	Dilia		35.26.15	105.11.25	2.0	moderate	sandstone outcrop forms one side
SR1	Pecos at Santa Rosa	9/25/92	35.03.25	104.42.02	4.0	moderate	gravel
SR2	Santa Rosa Lake		35.03.40	104.41.30	38.0	fast	brown with black mud
SR3-13	Catfish Falls		35.03.25	104.41.30	57.0	moderate	sandstone outcrop forms one side
SR4	Santa Rosa dam		35.02.00	104.41.00	87.0	moderate	rocky bottom
SR5	Asphalt pits		35.02.00	104.40.00	3.5		off beach near asphalt pits
14	Below dam		35.01.35	104.40.00	0.2		below ponded area below dam
15	Puerto del Luna		34.54.00	104.37.30	2.0	moderate	no outcrop, sand and mud
16	Perch Lake		34.49.45	104.39.45	10.0		green plants on top of sediment
SL1	Inlet	9/26/92	34.39.15	104.26.30	3.0		inlet
SL2-17	Sumner Lake		34.37.45	104.23.45	8.0	moderate	no outcrop, sand and mud
SL3	Alamogordo arm		34.38.30	104.22.25	5.0		Alamogordo arm, intersection of two creeks
SL4	Dam		34.36.45	104.23.00	36.0		inlet
18	Below Sumner dam		34.35.30	104.23.00	0.0	very fast	bank sample - too deep
19	Ft. Sumner bridge		34.29.00	104.15.03	0.0	fast	bank sample - thin layer of sediment on bank
20	US 70		33.38.45	104.22.30	2.5	moderate	
21	Hagerman		33.07.2	104.16.45	4.0	fast	near bank
BR1	Brantley Lake inlet	9/27/92	32.35.15	104.21.00	5.0	fast	inlet brown sediment
BR2	Brantley Lake		32.34.45	104.22.35	15.0	moderate	black, smelly mud
BR3-22	Ramp		32.33.05	104.22.30	30.0	fast	black, smelly mud
BR4	Dam		32.32.45	104.22.25	33.0		black, smelly mud
23	Below Brantley Dam		32.32.25	104.21.00	3.0	moderate	gravel-black, smelly mud

FIGURE 3. Taking field measurements.

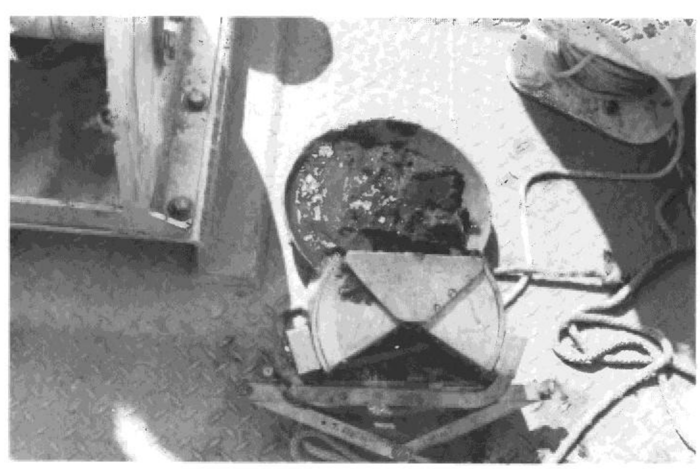

FIGURE 4. Bottom-grab sampler used to collect lake sediments for this study.

further analyzed. Mercury was also determined in an air-dried sample by rapidly heating the sample, trapping the released mercury on silver wool and heating the silver wool to drive off the mercury, which was detected by atomic absorption. A detection limit of 1 ppb was obtained with this method. The air-dried stream-sediment samples were further fractionated by screening with a 200 mesh (75 µm) stainless steel screen. For discussion purposes the <75 µm fraction is considered to be suspended or suspendable sediment, and the >75 µm to 2 mm fraction is considered as bottom sediment. The lake-sediment samples appeared to be mostly less than 200 mesh but proved to be too difficult and time consuming to screen. Samples were digested with *aqua regia* and copper (detection limit 5 to 15 ppm), lead (detection limit 15 ppm), zinc (detection limit 5 ppm) and chromium (detection limit 10 ppm) were determined by flame atomic absorption.

Mercury was determined in the water samples by the standard permanganate digestion followed by cold vapor atomic absorption (detection limit 0.2 ppb). Zinc was determined by flame atomic absorption (detection limit 5 ppb). Copper and lead were determined by graphite furnace atomic absorption (detection limits 1 ppb).

RESULTS

We emphasize that it is difficult to take representative samples from some river systems. Water flow rates, location of samples within the stream bed and time of collection may affect the results. Numerous studies are required to obtain representative results. Because of time constraints, water samples were not filtered before being acidified. Filtering would have removed any precipitates that may have had metals associated with them. Thus the reported values are not true "dissolved" values and may be higher than actual dissolved values. However, with the exception of mercury, which is a total value, they are not total values either, because the samples were not acid digested prior to analysis as the Environmental Protection Agency (EPA) requires on values reported as total. For the purposes of comparison in this preliminary study, recognizing that the values may be erroneously high, the values are considered to be dissolved. Distances between some sample sites are large and in general represent a low-density sampling. Many sample sites are near bridges and contamination from the bridge itself or from automobile exhaust is a possibility. Water flow rates were not measured. Future studies should address some of these aspects.

pH values of water samples (Table 4) ranged between 7.6 and 8.6, typical for New Mexico surface waters, except for site 4 (at the seep below the waste dumps) where the pH was 6.2 and site 5 (at the river below the seep and wetlands) where the pH was 9.1.

For reference purposes, average dissolved lead, copper and zinc values and total mercury values in stream water and Rio Grande water are shown in Table 4. As a result of federal legislation, the Pecos River has been classified as a fishery by the New Mexico Water Quality Control Commission (NMWQCC). Inherent in this classification are stream standard limits for dissolved lead, copper and zinc and total mercury as well as many others. These standards, with the exception of mercury, are based on the hardness of the water and thus vary for each site. Again for reference purposes, these standards are listed in

TABLE 4. Chemical analyses of water samples along the Pecos River from 9/23/92 to 9/27/92.

Sample	pH	Temp. C.	Conductivity µ mhos/cm	Alkalinity ppm HCO	Total Hg ppb	Pb ppb	Cu ppb	Zn ppb
1	7.60	15.0	200	170	<.2	<1	3	<5
2	8.20	12.0	170	140	<.2	2	2	<5
3	8.40	14.0	233	200	<.2	3	4	40
4	6.20	22.0	900	190	<.2	50	1080	115,000
5	9.10	21.5	160	120	<.2	6	3	410
6	8.30	18.0	180	140	<.2	2	3	60
7	8.05	16.5	180	140	<.2	2	1	60
8	8.35	18.0	195	140	<.2	<1	<1	30
9	7.95	21.5	225	140	<.2	9	4	60
10	8.20	23.0	262	170	<.2	<1	2	<5
11	8.10	20.5	250	170	<.2	1	2	<5
12	8.60	26.0	315	221	<.2	3	3	<5
SR3-13	8.40	26.0	380	150	<.2	2	4	5
14	8.05	24.5	585	170				
15	8.00	24.0	2480	190	<.2	<1	1	14
16	7.90	21.5	2650	185				
SL2-17	8.40	20.0	1300	140	1.0	<1	1	10
18	8.40	21.0	1250	140				
19	8.10	20.0	1250	150				
20	8.00	29.0	2000	120	<.2	3	4	10
21	8.00	27.0	3490	150	<.2	2	<1	8
BR3-22	8.30	24.0	3550	150	<.2	7	6	20
23	8.30	22.0	3250	120				
Stream water (Drever, 1988)					0.07	1.00	7.0	30.0
Rio Grande water (Brandvold and Brandvold, 1990)					0.6	6.4	13	36
NMWQCC[1] Stream Standards (chronic) for fisheries[2]								
Pecos at Terrero (100 ppm $CaCo_3$)					.012	3.2	12	106
Pecos above Santa Rosa Lake (350 ppm $CaCo_3$)					.012	16	34	306
Pecos at Hagerman (1000 ppm $CaCo_3$)					.012	60	85	746

[1]New Mexico Water Quality Control Commission.
[2]Except for mercury, standards are calculated based on hardness values (in parenthesis) obtained from U.S.G.S. data on STORET.

Table 4 for several sites based on hardness data obtained from U.S. Geological Survey (USGS) data on STORET. These stream standards are also compared graphically to values from this report in Fig 5.

X-ray diffraction analysis of the brown and the white precipitates from site 4 indicates that the precipitate is a mixture of iron, copper, zinc, sulfates and aluminum hydroxides. Goslarite ($ZnSO_4.H_20$) is reported by AMAX (J. W. Todd, written comm., March 12, 1993; S. M. Stoller Corp., written comm., March 18, 1993). Chemical analyses of the precipitates range from 0.10 to 0.47% Cu, 1.20 to 1.27% Zn, 4.09 to 4.90% Fe and 0.06 to 0.15% Pb. The low pH water in the seep contained high levels of copper and zinc and elevated lead, which is not surprising (Table 4). As the pH rises, lead and copper levels drop quickly to background. Zinc, which is more soluble, remains elevated for a longer distance downstream and may be absorbed on iron-manganese oxides or by organic material in the sediment.

Chemical analyses data on the stream and lake sediments (Table 5) show values for both mercury determinations, but these were averaged for graphical and statistical purposes. Mercury, lead, copper and chromium are elevated in sediment samples from Willow Creek (site 3). The mercury concentration at site 3 is above crustal abundance but is less than mercury concentrations from some other mining districts in New Mexico (Table 2). These elements, with the exception of chromium, are also elevated in the sediments at site 4, but this is at the seep, which is east of the Pecos River. This was not unexpected (see discussion of precipitates above). At site 5 mercury, lead, copper and zinc are also elevated but are significantly lower than at site 3 (Willow Creek). Mercury concentrations at sites 3 and 5 are near the reported mercury concentration in average shale (Table 5; Krauskopf, 1979). By site 6 (above the hatchery), mercury, lead and copper are essentially at or below crustal levels. Zinc remains elevated. Lead, copper and zinc are elevated in sediments at site 8 (just below the village of Pecos and Alamitos Arroyo).

STATISTICAL ANALYSES

Correlation coefficients and factor analysis of the water and stream-sediment metal concentrations (Tables 5-7) were performed using MSTAT (SRIE Pty. Ltd., 1992). Correlation coefficients are measures of the linearity or correlation between two variables. Pearson correlation coefficients greater than 0.35 ($n = 35$) are significant and correlation coefficients greater than 0.8 exhibit strong correlation between the two variables. Factor analysis reduces a set of numerous variables to a lesser number of mutually uncorrelated factors that may be related to similar origins or sources. For the purposes of statistical analyses, any concentrations below the detection limit were assigned one-half the value of the detection limit because the computer programs will not function using values of zero.

PRELIMINARY CONCLUSIONS

A few preliminary conclusions can be drawn from this reconnaissance study. However, these conclusions are subject to revision as more data are collected.

Lead and zinc concentrations in Pecos River water samples were above average dissolved concentrations found in streamwaters (Table 4), whereas copper was lower. When the Pecos concentrations are compared with those found in another river in New Mexico, the Rio Grande (Table 4), copper and mercury concentrations are lower and lead concentration is about the same. Zinc concentrations appeared slightly elevated in the upper Pecos. Comparing the Pecos concentra-

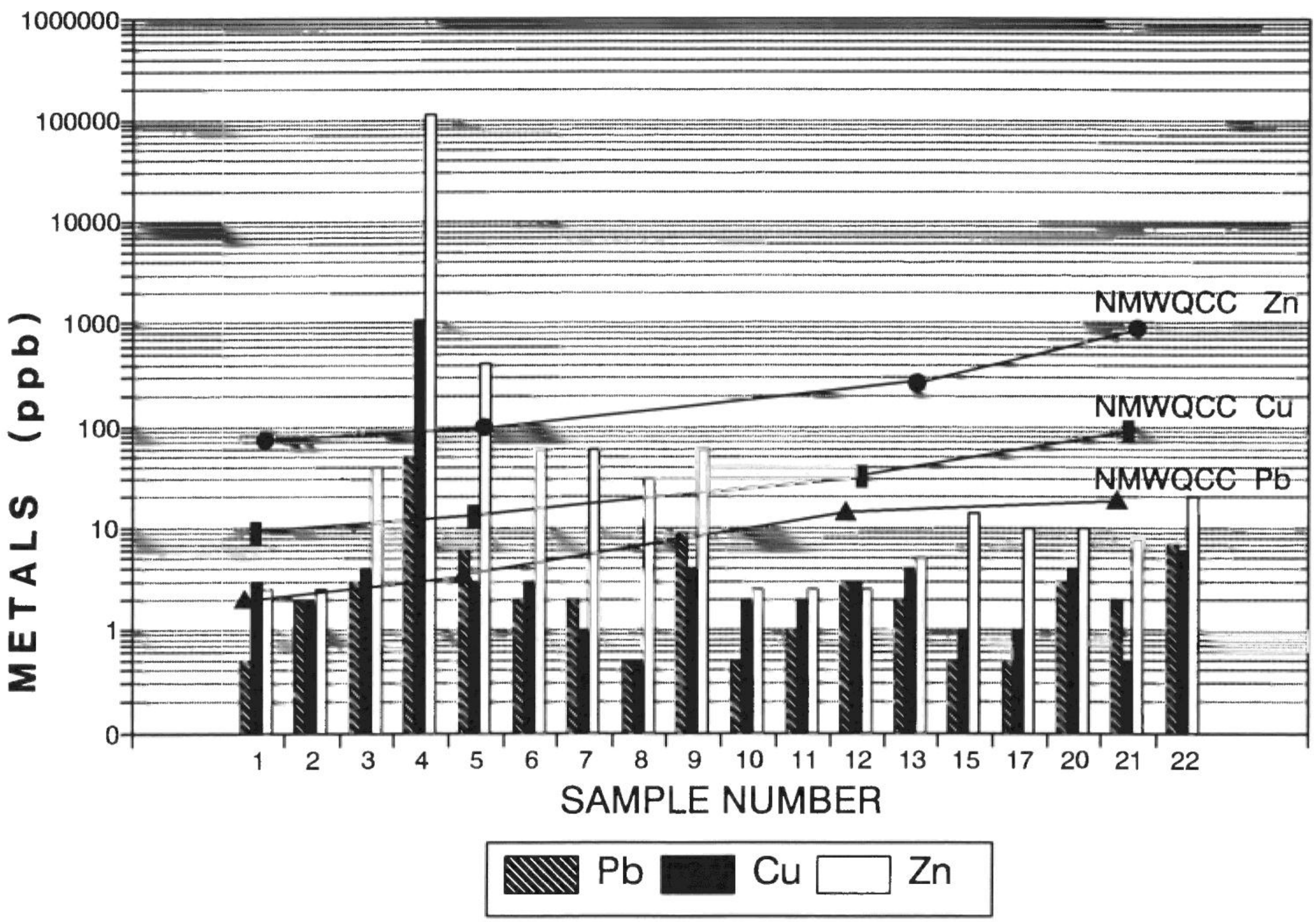

FIGURE 5. Copper, lead and zinc analyses of water samples along the Pecos River. Sample locations shown on Fig. 2.

TABLE 5. Chemical analyses of stream and lake sediments along the Pecos River. Two size fractions were obtained on stream sediment and lake sediment samples; <75 μm (suspendable sediment) and >75 μm–2 mm (bottom sediment). *Analyses by silver wool method; **analyses by cold vapor method. NS = No sample; these samples were not fractionated beyond removing >2 mm size. Average values from Krauskopf (1979).

Sample No.	Total Hg* ppb	Total Hg ** ppb	Pb ppm <75 μm	Pb ppm >75 μm-2mm	Cu ppm <75 μm	Cu ppm >75 μm-2mm	Zn ppm <75μm	Zn ppm >75 μm-2mm	Cr ppm <75 μm	Cr ppm >75 μm-2mm
1	16	23	30	25	17	15	110	90	28	43
2	24	25	110	65	40	23	330	210	35	30
3	400	390	3600	3400	1100	1900	7200	14400	220	219
4	150	245	860	610	2100	1400	20000	9800	88	145
5	90	110	300	255	310	280	3100	2900	62	130
6	NS	12	94	60	55	32	1300	860	22	22
7	8	<10	67	35	35	15	830	500	19	20
8	14	14	590	340	270	330	990	900	22	43
9	27	6	27	65	<15	35	51	115	24	73
10	2	<10	44	30	<15	<15	75	40	28	114
11	<1	6	46	18	<15	<15	45	20	95	95
12	2	<5	23	21	15	<15	32	25	18	163
SR1	27	16	NS	40	NS	17	NS	85	NS	28
SR2	38	14	NS	35	NS	<15	NS	50	NS	31
SR3-13	28	40	NS	80	NS	22	NS	95	NS	36
SR4	30	39	NS	70	NS	36	NS	110	NS	35
SR5	11	<5	19	12	<15	<15	21	10	12	37
14	8	7	NS	35	NS	<15	NS	50	NS	NS
15	3	<10	21	17	<15	<15	37	16	16	59
16	<1	<6	35	35	10	7.3	16	20	10	15
SL1	15	32	NS	30	NS	<15	NS	41	NS	31
SL2-17	9	10	NS	20	NS	<15	NS	27	NS	19
SL3	10	<10	NS	30	NS	<15	NS	50	NS	26
SL4	18	10	NS	35	NS	18	NS	50	NS	32
18	12	<6	NS	20	NS	<15	NS	20	NS	40
19	11	15	21	15	<15	<15	27	15	13	56
20	1	6	114	15	<15	<15	66	10	80	60
21	2	<6	19	15	<15	<15	18	12	14	40
BR1	16	<6	NS	36	NS	15	NS	50	NS	31
BR2	17	31	50	35	20	18	55	55	29	38
BR3-22	24	30	NS	55	NS	20	NS	63	NS	33
BR4	43	30	NS	70	NS	16	NS	67	NS	30
23	2	<6	30	20	<15	8.6	24	17	16	125
Average crust		20		12.5		50		70		100
Average granite		30		20		12		50		20
Average basalt		10		3.5		100		100		200
Average shale		300		20		50		90		100

TABLE 6. Correlation coefficients of chemical analyses of stream and lake sediments from along the Pecos River.

	Hg	Pb <75 μm	Pb >75 μm-2 mm	Cu <75 μm	Cu >75 μm-2mm	Zn <75 μm	Zn >75 μm-2mm	Cr >75 μm-2mm
Hg	1.0							
Pb<75 μm	0.95	1.00						
Pb Bottom	0.97	0.99	1.00					
Cu <75 μm	0.77	0.76	0.72	1.00				
Cu >75 μm-2mm	0.96	0.97	0.96	0.88	1.00			
Zn <75 μm	0.69	0.64	0.60	0.98	0.80	1.00		
Zn >75 μm-2mm	0.98	0.96	0.96	0.86	0.99	0.79	1.00	
Cr <75 μm	0.45	0.77	0.81	0.34	0.68	0.22	0.70	
Cr >75 μm-2mm	0.46	0.52	0.53	0.19	0.46	0.09	0.48	1.0

TABLE 7. Factor matrix of chemical analyses of stream and lake sediments from along the Pecos River.

FACTORS	1	2	3	4
Hg	0.96	0.23	-0.02	-0.16
Pb >75 μm-2mm	0.93	0.31	-0.20	-0.02
Cu >75 μm-2mm	0.96	0.23	0.03	0.12
Zn >75 μm-2mm	0.96	0.25	0.07	0.03
Cr >75 μm-2mm	0.25	0.97	-0.01	0.00

tions with New Mexico Water Quality Control Commission Fishery Stream Standards, site 5 (just below the confluence with Willow Creek) was the only site (excluding site 4) with concentrations above the standards for lead and zinc only.

Conductivity increased downstream in the Pecos River (Table 4), possibly a natural result from Permian evaporites and limestones and/or contamination from agricultural areas as well as evaporation.

Mercury and zinc concentrations in sediments were typically below crustal abundances or below averages for common lithologies found in the Pecos drainage basin (Krauskopf, 1979), with the exception of site 3 (Jacks Creek) through site 8 (below the Village of Pecos) (Figs. 6, 7; Table 5). Copper and chromium concentrations in sediments were below crustal abundances, except for samples near the Pecos mine waste

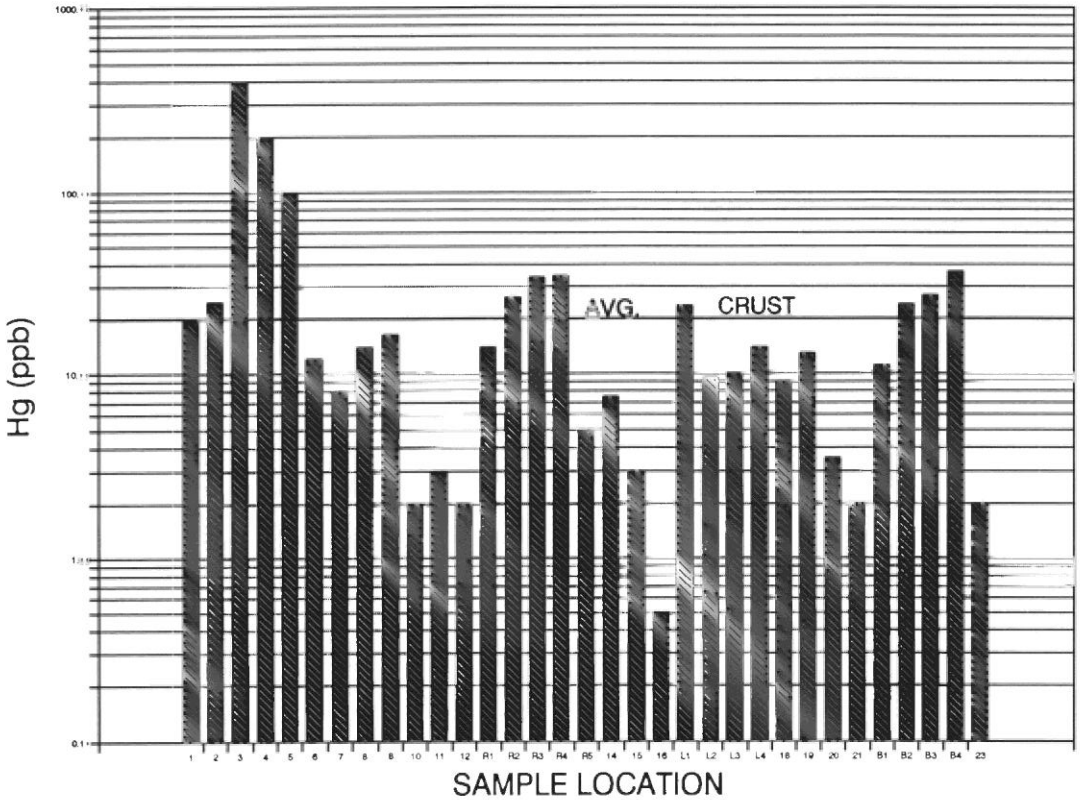

FIGURE 6. Total mercury analyses in sediments along the Pecos River. Sample locations shown on Fig. 2.

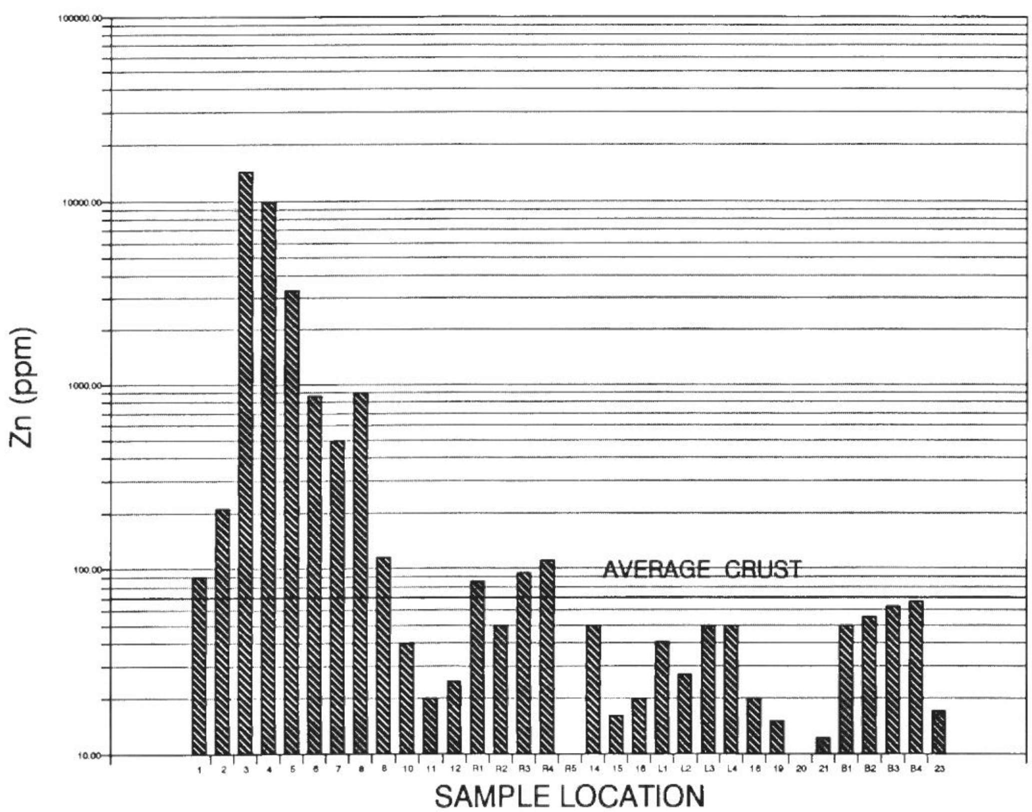

FIGURE 7. Zinc in sediments along the Pecos River.

dumps (Figs. 8, 9; Table 5). Mercury, lead, copper and zinc concentrations in sediments are elevated in samples from above the Pecos mine waste dumps (Figs. 6, 7, 8, 10; Table 5), suggesting that outcropping zones of mineralization and maybe the outcropping rocks are sources of contamination as well as the waste dumps themselves. This area is being examined in greater detail.

Lead concentrations in Pecos River sediments were above crustal abundances (Fig. 10). Lead concentrations in river sediments elsewhere in New Mexico are also typically above crustal abundances (Brandvold and Brandvold, 1990; U.S. Geological Survey et al., 1980; examination of NUKE and USGS stream sediment data from throughout New Mexico). Some studies indicate that lead and mercury concentrations in the atmosphere are increasing with time as a result of human-induced pollution (Eddington and Robbins, 1976; Cranstom and Buckley, 1972; Nater and Grigal, 1992; Swain et al., 1992). A major source of lead into the atmosphere has been automobile exhaust from leaded gasoline. Precipitation washes some of these pollutants from the atmosphere into water supplies and soils. It is also possible that rocks and sediments throughout New Mexico may be enriched in lead relative to crustal abundances.

Concentrations of metals in Pecos River sediments were typically higher in lake sediments than in stream sediments, with the above-mentioned exceptions. The concentrations of metals in the bottom sediment fraction (75 vm-2 mm) are typically lower than in the <75 fraction. Clay-size fractions tend to contain higher concentrations of metals than sand- and silt-size fractions. Mineralogical studies of the sediments are under way.

Apparently even though mercury, lead, copper and zinc concentrations were elevated in some sediments, the concentrations in the sediments have little effect, if any, on metal concentrations in the water. However, these metals in sediments may still enter the food chain and eventually concentrate in fish. Bioaccumulation of metals is a very complex issue and is not the focus of this report.

The white and brown precipitates or froth from the seep below the waste dumps (4) were high in zinc and other metals. During high runoff events, it is possible that the precipitate enters the Pecos River and subsequently may enter the fish hatchery at Lisboa Springs. Reported fish kills could be in part, a result of contamination by this precipitate during high runoff events. However, a U.S. Fish and Wildlife Service report suggests that the fish kills at Lisboa Springs State Fish Hatchery are due to a combination of water quality factors including temperature, periodic presence of toxic concentrations of metals and the possible introduction of diseases (Albuquerque Journal, Feb. 16, 1993). Furthermore, fish along the Pecos River between the mine waste dumps and the hatchery (a distance of 19 km) appear healthy and show no effects from potential contamination. Sampling of fish from the Pecos River shows no detectable mercury concentrations (J. W. Todd, written comm., March 12, 1993). Metal concentrations increased in sediments

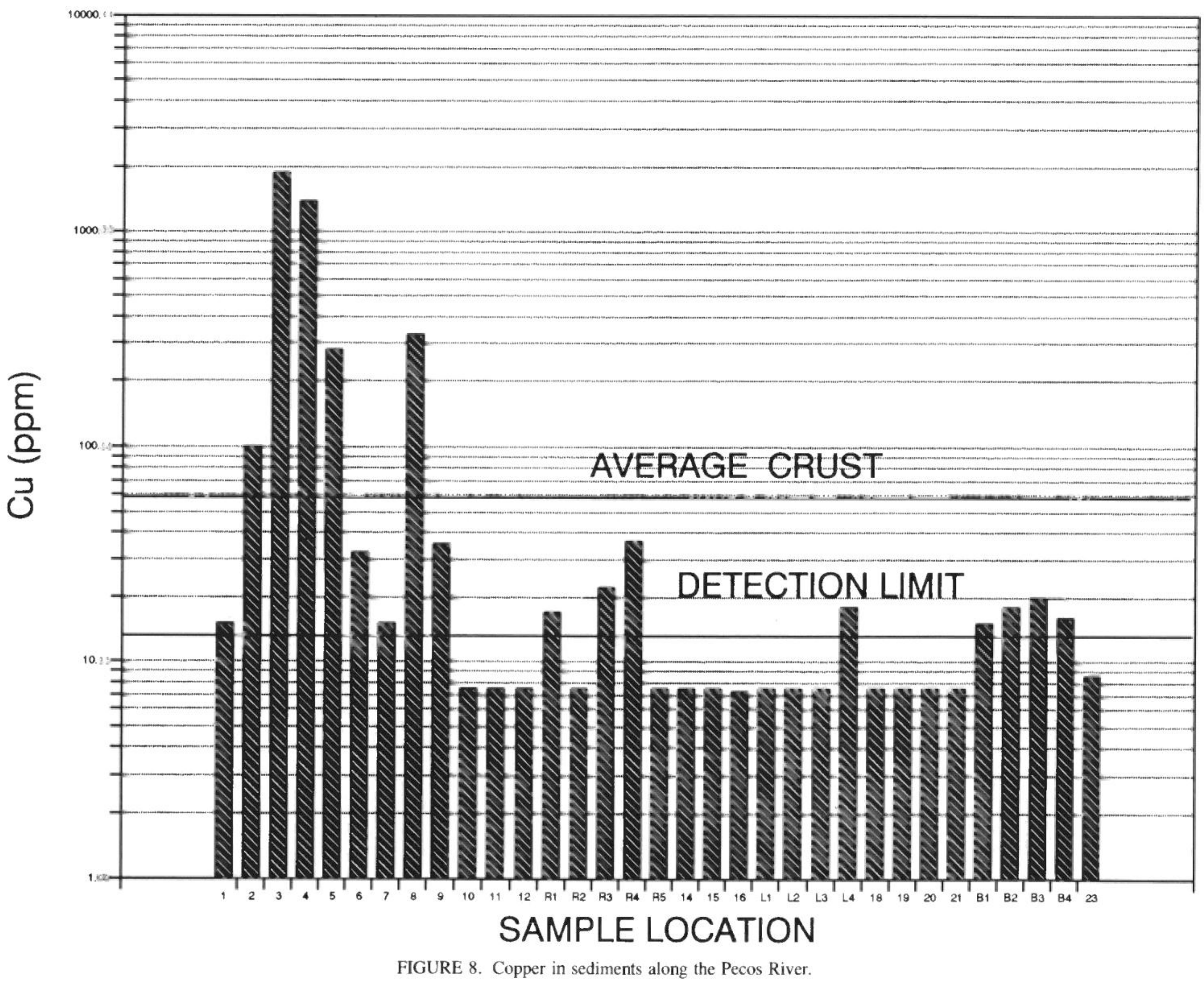

FIGURE 8. Copper in sediments along the Pecos River.

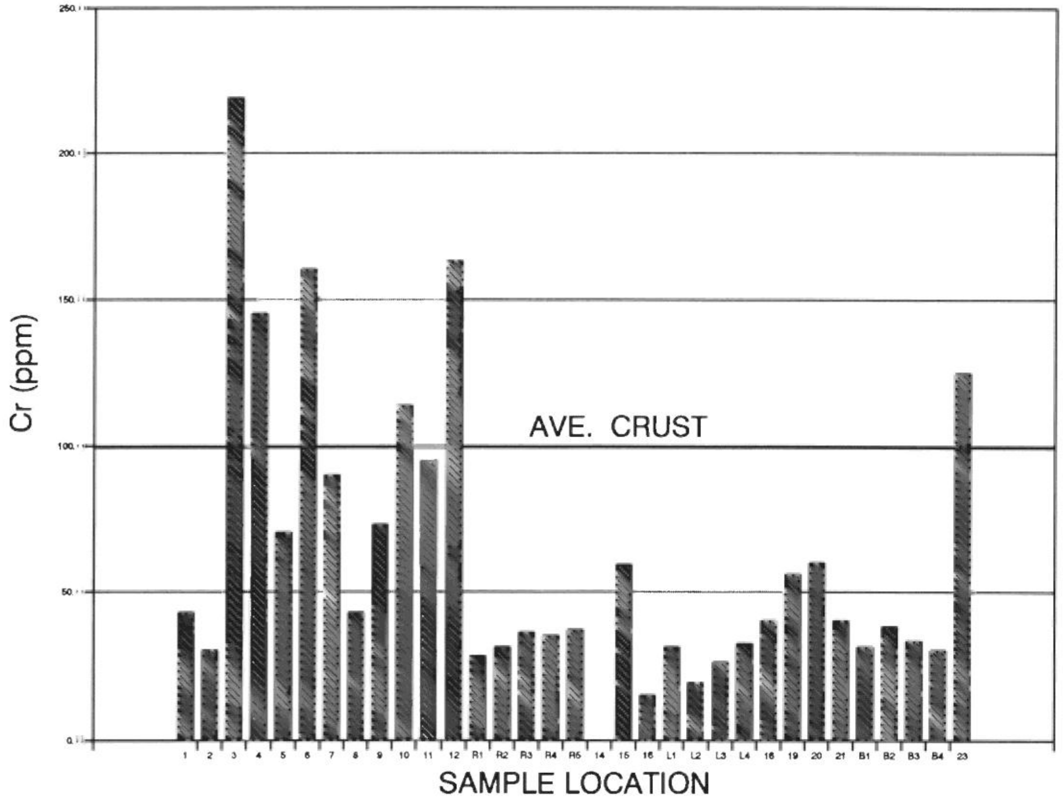

FIGURE 9. Chromium in sediments along the Pecos River.

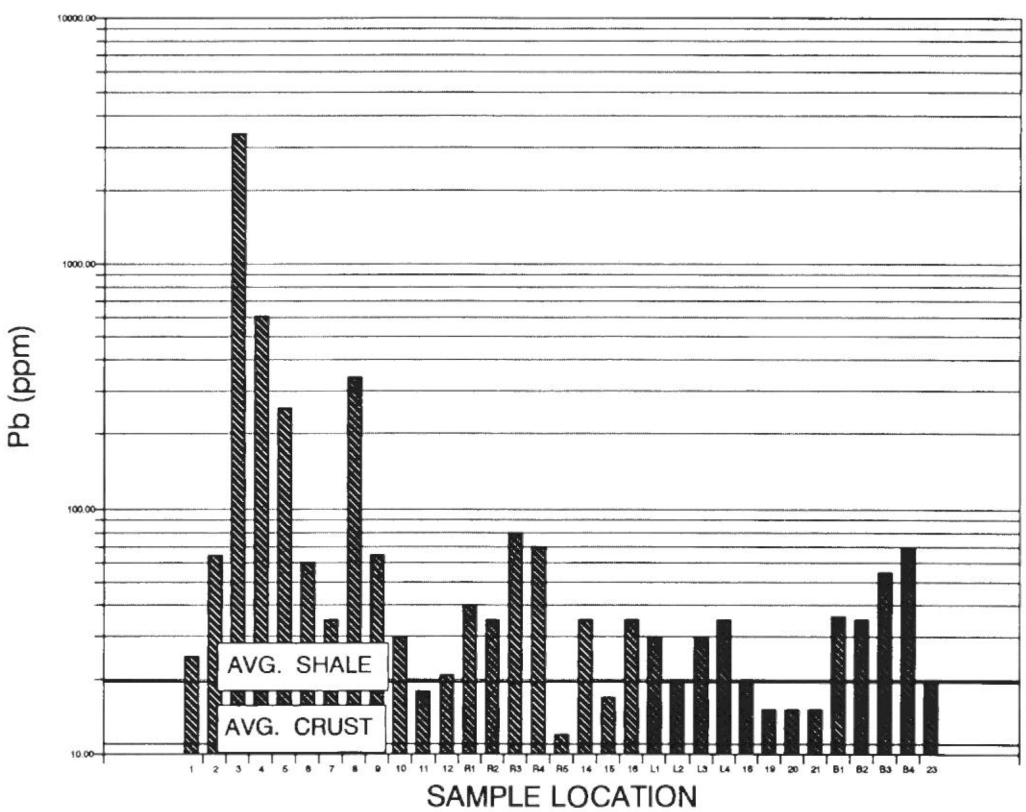

FIGURE 10. Lead in sediments along the Pecos River.

between sample sites 7 (below hatchery) and 8 (below Pecos village). This could be a result of contamination from Alamitos Arroyo, where the mill tailings are located. But there are no reported fish kills in the Pecos River in this area. This evidence suggests that the hatchery fish kills are likely due to a combination of factors and not necessarily due to contamination from the Pecos mine waste dumps.

Mercury, lead, copper and zinc concentrations in sediments are strongly correlated with each other (Tables 5-7). Chromium is slightly correlated with mercury, lead, copper and zinc. These correlations are also evident in the factor matrix where mercury, lead, copper and zinc comprise most of factor I and chromium comprises factor 2 (Table 7). This suggests at least two hypotheses. It is possible that a similar source for mercury, lead, copper and zinc exists; but a separate source for chromium. An alternative hypothesis is that mercury, lead, copper and zinc are concentrated in similar minerals in the sediments, whereas chromium is concentrated in different minerals.

The Pecos mine waste dumps, mineralized outcrops and outcropping rocks are potential sources of elevated levels of mercury, lead, copper and zinc in sediments near the mine site. However, elsewhere in the Pecos drainage basin other sources for these metals should be considered as well, especially atmospheric deposition (Swain et al., 1992) and possibly municipal, industrial and agricultural activities.

RECOMMENDATIONS

1. Analyze samples collected for this study for additional elements to better characterize the chemistry of the sediments.
2. Mineralogical and/or chemical studies are needed to determine how the metals are carried in the sediments.
3. Surveys are needed to identify and locate sources of chromium, especially near site 23.
4. Detailed geochemical surveys of sediments are needed along drainages from other mining districts and areas of mineralization within the Pecos drainage basin. Some of these areas require geological mapping and chemical analyses of the mineralized zones.
5. Measure water flow rates at time of sampling.
6. Lithogeochemical sampling around the Pecos mine is needed to characterize the chemistry of the outcropping rocks.
7. Additional sampling along the entire Pecos River is needed over an extended period of time, especially during low and high runoff events.
8. Chemical analyses of suspended sediment are needed as well as amounts of total suspended sediment during different runoff events.
9. Additional sampling away from bridges and towns is needed in order to determine the effects from the cultural features.

Most of these studies are currently in progress.

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REFERENCES

Bolivar, S. L., Sandoval, W. F., Gallimore, D. L., Martell, C. J., Hensley, W. K., Thomas, G. J. and Minor, M. M., 1980, Uranium hydrogeochemical and stream sediment reconnaissance data release for the Santa Fe NTMS quadrangle, New Mexico, including concentrations of forty-two additional elements: U.S. Department of Energy, Open-file Report GJBX-I97(80), 135 p.

Brandvold, L. A., 1978, Mercury in New Mexico surface waters: New Mexico Bureau of Mines and Mineral Resources, Circular 162, 16 p.

Brandvold, L. A. and Brandvold, D. K., 1990, A compilation of trace-metal values in water and sediments collected along the Rio Grande and its tributaries in New Mexico, data from selected published and unpublished sources: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 359, 103 p.

Cranstom, R. E. and Buckley, D. E., 1972, Mercury pathways in a river and estuary: Environmental Science and Technology, v. 6, p. 274-278.

Dreyer, J. I., 1988, The geochemistry of natural waters: Prentice Hill, Englewood Cliffs, New Jersey, 437 p.

Edgington, D. N. and Robbins, J. A., 1976, Records of lead deposition in Lake Michigan sediments since 1800: Environmental Science and Technology, v. 10, p. 266-274.

Elston, W. E., 1967, Summary of the mineral resources of Bernalillo, Sandoval, and Santa Fe Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 81, 81 p.

Erdman, J. A., Tidbal, R. R. and Tripp, R. B., 1992, Uranium in groundwater and geochemistry of sediments; in Mineral and energy resources of the BLM Roswell Resource area, east-central New Mexico: U.S. Geological Survey, Open-file Report 92-261, p. 43-58.

Fulp, M. S., 1982, Precambrian geology and mineralization of the Dalton Canyon volcanic center, Santa Fe County, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 199 p.

Finch, W. I., 1972, Uranium in eastern New Mexico: New Mexico Geological Society, Guidebook 23, p. 171-175.

Griswold, G. B., 1959, Mineral deposits of Lincoln County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 67, 117 p.

Harley, G. T., 1940, The geology and ore deposits of northeastern New Mexico (exclusive of Colfax County): New Mexico Bureau of Mines and Mineral Resources, Bulletin 15, 104 p.

Johnson, M. G., 1972, Placer gold deposits of New Mexico: U.S. Geological Survey, Bulletin 1348, 46 p.

Klich, I., 1933, Precambrian geology of the Elk Mountain-Spring Mountain area, San Miguel County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 180, 170 p.

Krauskopf, F. K. B., 1979, Introduction to geochemistry: McGraw-Hill Book Co., New York, New York, 617 p.

Matson, J. T. and Hoag, C., 1930, Mining practice at the Pecos mine of the American Metal Co. of New Mexico: U.S. Bureau of Mines, Information Circular 6368, 22 p.

McLemore, V. T., 1991, Base- and precious-metal deposits in Lincoln and Otero Counties, New Mexico: New Mexico Geological Society, Guidebook 42, p. 305-309.

McLemore, V. T. and Chenoweth, W. L., 1989, Uranium resources in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resources Map 18, 36 p.

McLemore, V. T. and North, R. M., 1985, Copper and uranium mineralization in east-central New Mexico: New Mexico Geological Society, Guidebook 36, p. 289-299.

McLemore, V. T., North, R. M. and Leppert, S., 1988a, Rare-earth elements (REE), niobium, and thorium occurrences in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 324, 27 p.

McLemore, V. T., North, R. M. and Leppert, S., I 988b, Rare-earth elements (REE) in New Mexico: New Mexico Geology, v. 10, p. 33-38.

McLemore, V. T. and Phillips, R. S., 1991, Geology of mineralization and associated alteration in the Capitan Mountains, Lincoln County, New Mexico: New Mexico Geological Society, Guidebook 42, p. 291-298.

Nater, E. A. and Grigal, D. F., 1992, Regional trends in mercury distribution across the Great Lakes States, North Central USA: Nature, v. 358, p. 139-141.

New Mexico Geological Society, 1982, New Mexico Highway Geologic Map: New Mexico Geological Society, scale 1:1,000,000.

North, R. M. and McLemore, V. T., 1986, Silver and gold occurrences in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Resources Map 15, 32 p.

Perhac, R. M., 1970, Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico: New Mexico Bureau of Mines and Mineal Resources, Bulletin 95, 51 p.

Reismeyer, W. D. and Robertson, J. M., 1979, Precambrian geology and ore deposits of the Pecos mine, San Miguel County, New Mexico: New Mexico Geological Society, Guidebook 30, p. 175-179.

Robertson, J. M., Fulp, M. S. and Daggett, M. D. III, 1986, Metallogenic map of volcanogenic massive sulfide occurrences in New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1853A, scale 1:1,000,000.

Sandusky, C. L. and Kaufman, W. H., 1972, Geology of the Pintada mine: New Mexico Geological Society, Guidebook 33, p. 176-177.

Soule, J. H., 1956, Reconnaissance of the "red bed" copper deposits in southeastern Colorado and New Mexico: U.S. Bureau of Mines, Information Circular 7740, 74 p.

SRIE Pty. Ltd., 1992, MSTAT: Rockware, Inc., Denver, Colo., 77 p.

Swain, E. B., Engsbram, D. R., Brigham, M. E., Henning, T. A. and Brezonik, P. L., 1992, Increasing rates of atmospheric mercury deposition in mid-continental North America: Science, v. 257, p. 784-787.

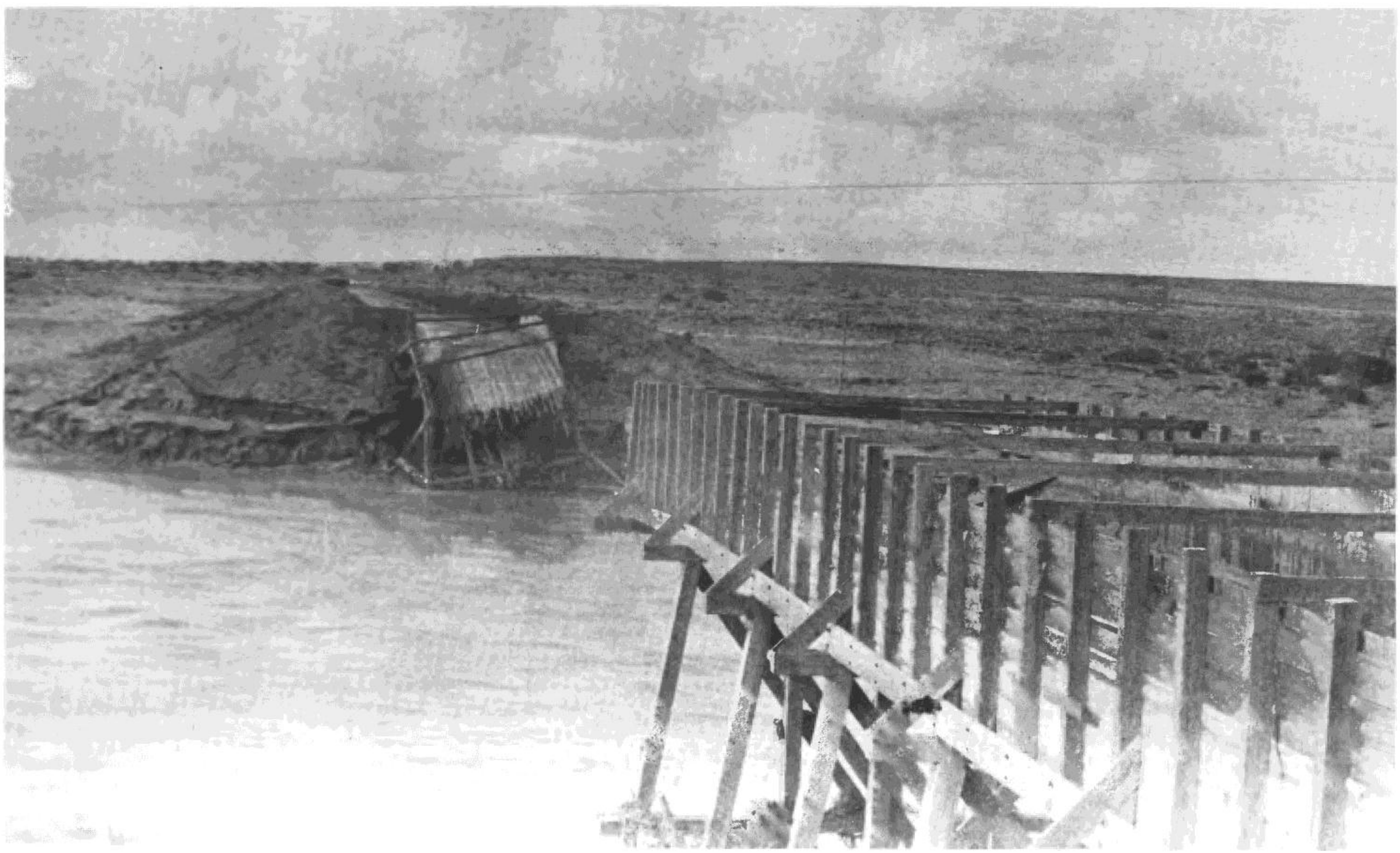
Thompson, T. B., 1973, Mineral deposits of Nogal and Bonito mining districts, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 123, 29 p.

U.S. Geological Survey, U.S. Bureau of Mines and New Mexico Bureau of Mines and Mineral Resources, 1980, Mineral resources of the Pecos Wilderness and adjacent areas, Santa Fe, San Miguel, Mora, Rio Arriba, and Taos counties, New Mexico: U.S. Geological Survey, Open-file Report 80382, 103 p.

Union Carbide Corp., 1981a, Hydrogeochemical and stream sediment reconnaisance basic data for Carlsbad quadrangle, New Mexico: U.S. Department of Energy, Open-file Report GJBX-415(81), 189 p.

Union Carbide Corp., 198 1 b, Hydrogeochemical and stream sediment reconnaissance basic data for Fort Sumner quadrangle, New Mexico: U.S. Department of Energy, Open-file Report GJBX-395(81), 161 p.

Union Carbide Corp., 1981c, Hydrogeochemical and stream sediment reconnaissance basic data for Roswell quadrangle, New Mexico: U.S. Department of Energy, Open-file Report GJBX-397(81), 187 p.



The flood of August 1893 took out the main canal's wooden flume just north of Eddy. Present concrete flume built at the same site near Carlsbad Springs in 1903 (Day 3, Stop 6). Photograph by Stringfellow. Courtesy of Southeastern New Mexico Historical Society of Carlsbad.

Dust storm of March 9, 1941, photographed 25 miles east of Carlsbad by Robert Nymeyer. Courtesy of Southeastern New Mexico Historical Society of Carlsbad.