AN EVALUATION OF MERCURY CONTAMINATION AT THE WICHITA MOUNTAINS WILDLIFE REFUGE, OKLAHOMA

COMPLETION REPORT

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INTRODUCTION

A period of intensive gold prospecting occurred in the Wichita Mountains of Oklahoma during the late 1800's with about 3000 miners eventually working the area hoping to find their fortunes (Wilson 1983). The granite rock was dug by hand and then crushed in hand made mule- or horse-powered grinders constructed in the ground from local rocks. In these primitive grinders, called arrastras, the crushed rock was mixed into a slurry with water and then mercury was added to the slurry. Gold and silver, if present, formed an amalgam with the mercury which was collected from the bottom of the arrastra and then heated to drive off the mercury. This enriched ore concentrate would later be refined into a pure product. In a different concentrating method, the ground ore slurry was poured over mercury coated copper plates and the precious metals adhered to the plates. The two known arrastras on the Wichita Mountains Wildlife Refuge (Fig. 1), at Cedar Creek and Panther Creek, have been restored and the Cedar Creek arrastra is a registered National Historical Site. As gold fever spread throughout the mountains, larger facilities were built for working the ore. There are remains of two smelters on the refuge, at Fawn Creek and Blue Beaver Creek, and two more on adjacent lands.

The Oklahoma Water Resources Board (OWRB) sampled soil from three arrastras, two on the refuge and one just north of the refuge boundary, in 1984. Results of the analysis showed extremely high mercury levels in soil from the Cedar Creek site. Values for total mercury in the six samples from Cedar Creek ranged from 92 to 9,548 micrograms/gram (ppm) with a mean of 2,052 ppm. The analytical method used by the OWRB measured the total amount of all chemical forms of mercury in the samples. All forms of mercury are not equally available to organisms so further testing was required to assess the biological hazards of large mercury residues.

Mercury is known to have many undesirable effects on fish and wildlife species. It binds with and affects the configuration of nucleic acids and inhibits a large number of enzymes. Organic mercury compounds are very lipid soluble, which may explain their biological effects. Armstrong (1979) reviewed the effects of mercury on fish and reported that acutely toxic doses could be as low as 0.01 mg/L (ppm). Chronic exposure led to emaciated fish with brain lesions and cataracts. Behavioral changes also were noted. Black ducks fed a diet containing 3 ppm mercury for 28 weeks showed a decrease in clutch size, decreased production, and a decrease in the number of eggs incubated (Finley and Stendell1978). These authors reported thatsurvivalalso was lower in the mercury-fed birds. A study from Canada showed similar adverse effects on reproduction when ring-necked pheasants were fed mercury (Finreite 1971).

Since Department of the Interior lands are involved, and mercury contamination may represent a hazard to trusteeship species, an investigative study was designed. The objective of this study was to determine the extent of metal contamination in soils associated with old mine works on the Wichita Mountains Wildlife Refuge and to assess the biological hazard that these levels of metals may represent to fish and wildlife resources.

METHODS AND PROCEDURES

Interviews were conducted with long-time refuge employees and with others who have an interest in, and are knowledgeable about, gold mining in the Wichita Mountains. The sites where mining occurred were marked on a map (Fig. 1) and visited to determine if any evidence of ore processing still exists. Soil samples were taken at those sites where smelters or arrastras were identified. Samples were taken with a stainless steel scoop, placed in sterile plastic bags and kept cool until sent to an analytical laboratory. Twelve samples collected in March 1985 were analyzed for 22 elements by an inductively coupled plasma emission spectrophotometer at the Environmental Trace Substances Laboratory at the University of Missouri. The concentration of total mercury in eight samples taken from in and around the arrastras was determined using the cold vapor technique.

The initial results showed elevated concentrations of some metals, including mercury (Table 1). However, not all of the total amount of metals in a sample are biologically available. The criteria given in 40 CFR 261.24 specify an Extraction Procedure (EP) toxicity value that determines if a solid waste is hazardous. Following review of these initial results, additional samples were taken at each of the sites. At the arrastras a grid system was established and additional samples taken at the points indicated on Figures 2 and 3. At the Panther Creek arrastra 15 samples were taken, some at the surface and some at a depth of six inches. Seventeen samples were collected at the Cedar Creek arrastra in the same manner. One sample at each arrastra was duplicated as a blind quality control sample. At the Fawn Creek smelter, one sample was taken and three were taken at the Blue Beaver smelter.

Southwell Laboratory, Inc., Oklahoma City, performed the EP toxicity analytical work. Each sample was analyzed for cadmium, chromium, lead, and mercury following EPA Method 1310, Extraction Procedure Toxicity. The detection limits for these metals at this laboratory are cadmium 0.0001 mg/L, chromium 0.0002 mg/L, lead 0.0007 mg/L, and mercury 0.0003 mg/L. Briefly, the EP toxicity test is conducted by placing a certain known amount of material in a beaker, adding a certain amount of distilled water, shaking or stirring the mixture for 24 hours, passing the water through a filter and then analyzing the filtrate for the metals.

RESULTS AND DISCUSSION

Table 1 compares the total metal residues of nine metals in soils and smelter slag and Table 2 gives the results of the EP toxicity analyses.

According to EPA regulations (40 CFR 261.24) a solid waste exhibits the characteristic of EP toxicity if the analyses show that the concentration exceeds 1.0 mg/L cadmium, 5.0 mg/L chromium, 5.0 mg/L lead, and 0.2 mg/L of mercury.

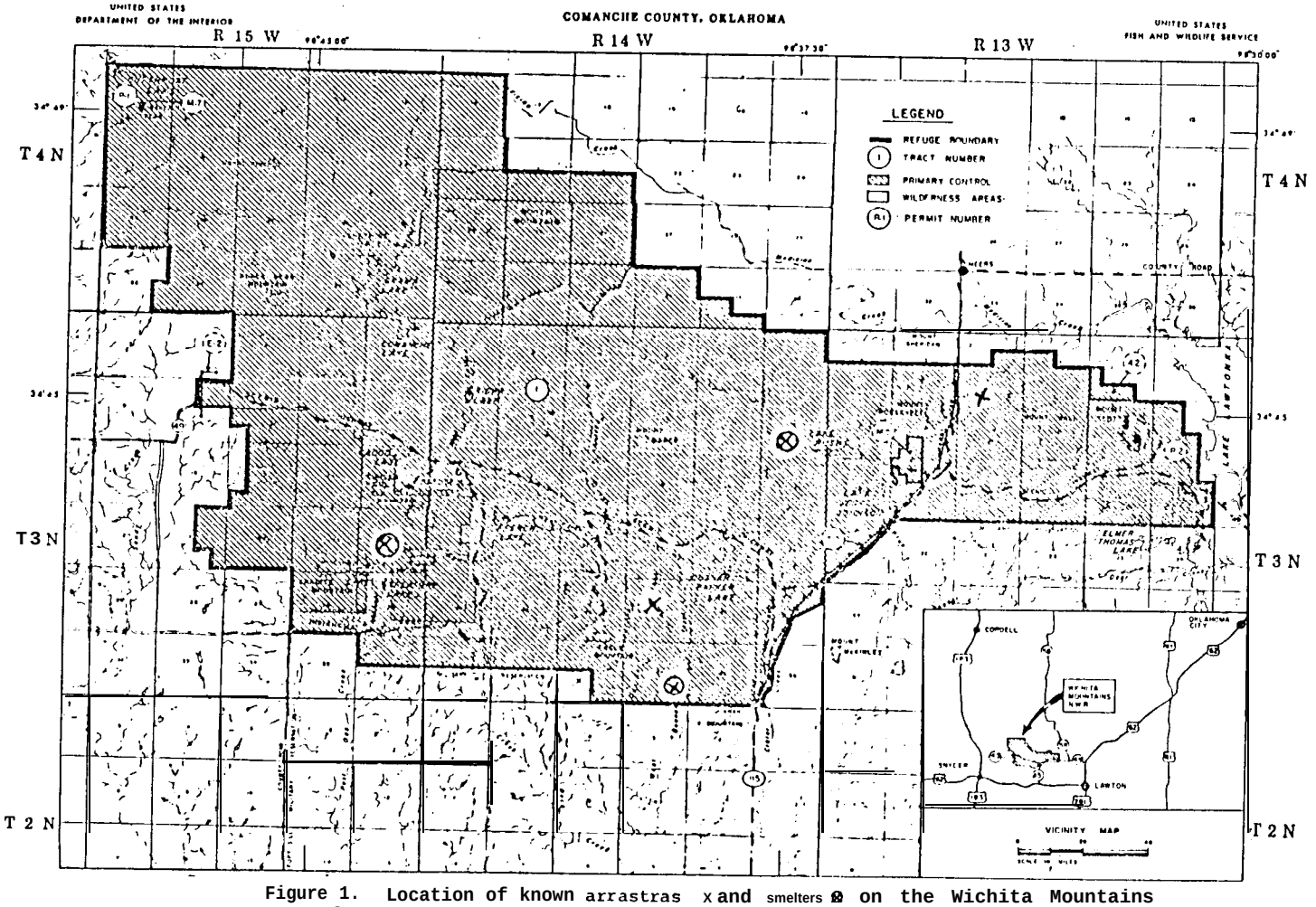

Figure 1. Location of known arrastras x and smelters ⊗ on the Wichita Mountains refuge.

Table 1. Metal residue values in soil samples taken from the Wichita Mountain Wildlife Refuge, Oklahoma, March 1985.

LOCATION	ELEMENT (PPM)								
	Cd	Cr	cu	Ni	Pb	Sr	V	Zn	Hg
Cedar Creek above	0.63	20	8.8	7.0	26	82.9	39.	64.6	1.9
Cedar Creek in arrastra	0.3	14	14	9.6	50	131	58.2	244	160
Cedar Creek below	0.4	13	8.4	7.1	39	111	53.0	168	13.8
Cedar Creek downhill	0.4	14	6	5.5	31	83.8	61.5	66.8	1.4
Panther Creek above	0.6	46	7	9.9	52	65.2	94.1	77.4	2.2
Panther Creek in arrastra	3.3	26	12	11.0	66	147	42.	1560	0.1
Panther Creek below	0.3	7.9	15	11.0	30	358	89.1	74.9	0.21
Panther Creek downhill	0.4	7.8	1	3.0	37	47.1	25	56.3	0.31
Fawn Creek smelter	0.4	8.7	5.5	4.0	260	33.7	28	115	ND *
Fawn Creek mine	0.6	6.0	4.7	3.0	56	38.5	8.5	107	ND
Blue Beaver smelter below slag	0.2	56.0	28	44.0	290	93.0	138	150	ND
Blue Beaver bare spot	0.2	26.0	8.6	14.0	42	44.3	58.6	102	ND
Blue Beaver bottom of smelter	0.2	8.1	6.3	6.3	150	98.8	28	94	ND
"Background soil concentration" 1/	3.0-4.0	40-137	23-1200	14-31	23-640	25-165	46-107	46-490	0.07
"Phytotoxically excessive concentration in soil" 2/	3-8	75-100	60-100	100	100	--	60	300	0.3-5
EP toxicity (ppm) 3/	1.0	5.0			5.0	--	--	--	0.2

1/ Values from Bowen, 1979.
2/ Values from Kabata-Pendias and Pendias. 1984.
3/ 40 CFR 261.24 (July 1, 1985, page 365).
* ND = Not Determined.

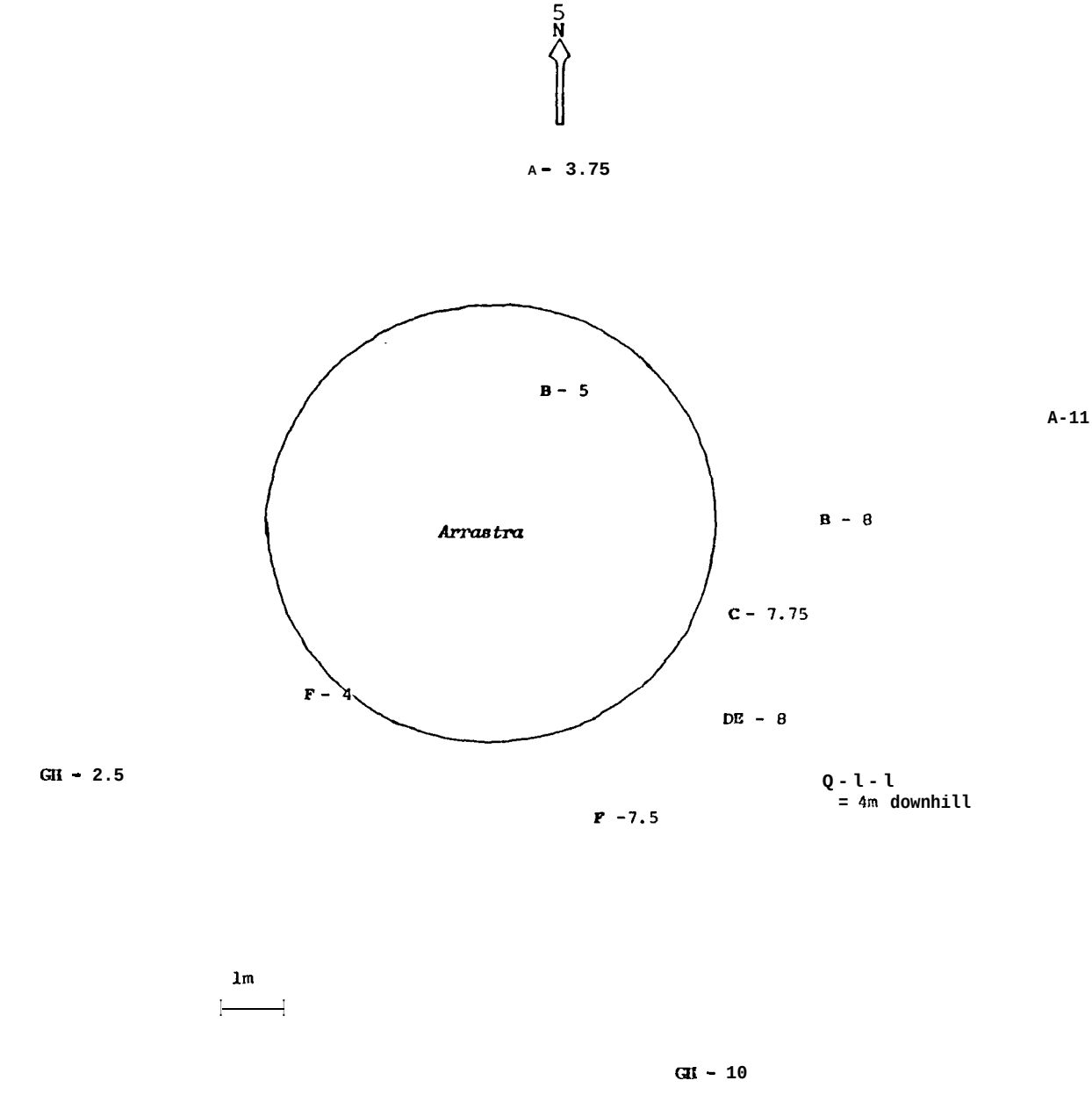

Figure 2. Each reference point indicates where one or more soil samples were taken in and around the Panther Creek arrastra for EP toxicity analysis. See Table 2 for analytical results.

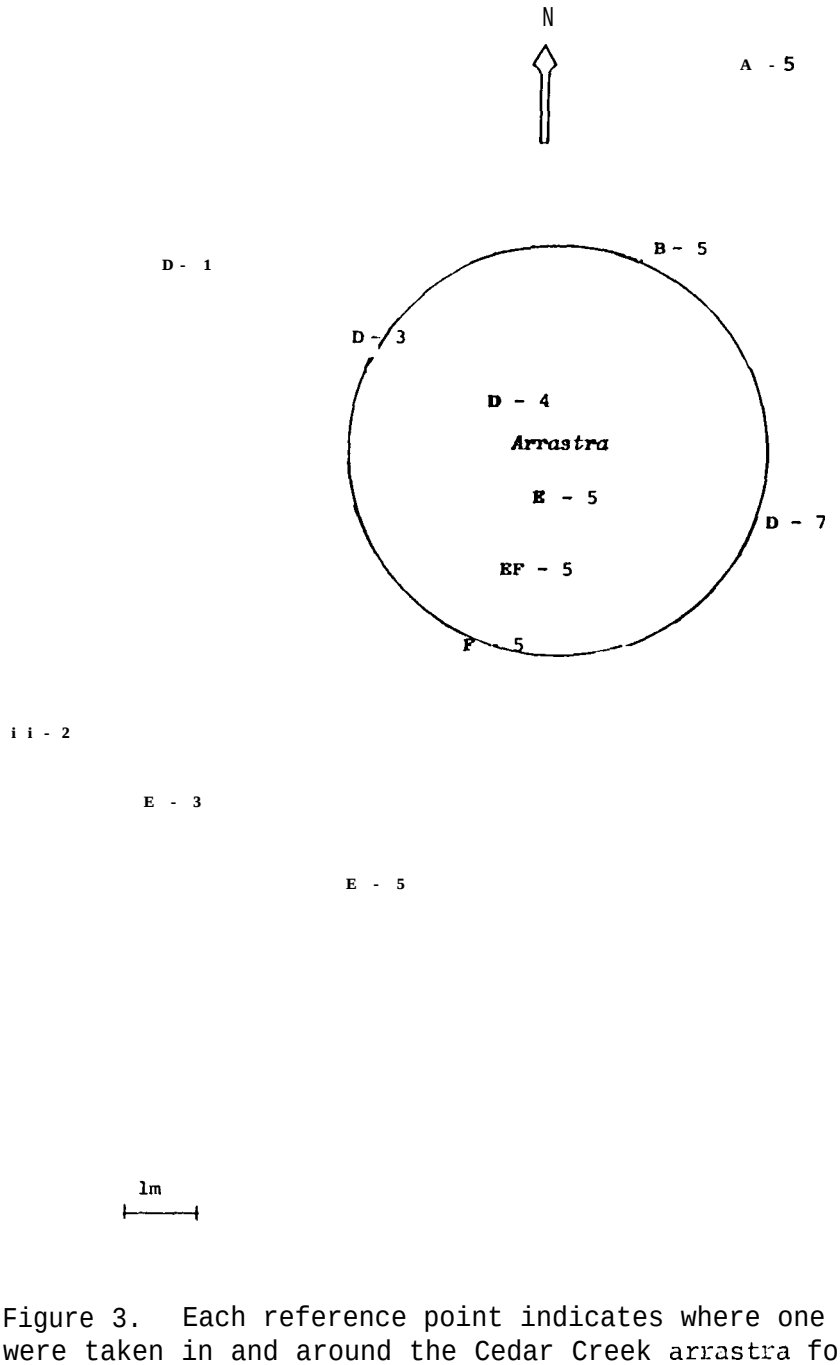

Figure 3. Each reference point indicates where one or more soil samples were taken in and around the Cedar Creek arrastra for EP toxicity analysis. See Table 2 for analytical results.

Table 2. EP toxicity values for samples taken 22-23 April 1986 at old mining associated sites on the Wichita Mountains Wildlife Refuge. All values are in mg/L. The letter and first number refer to the point on a grid over the arrastra at which that sample was taken. The last digit of a site number indicates the depth at which the sample was taken, 1 = surface to 3 inches, 2 = 3 to 6 inches.

Site	Cadmium	Chromium	Lead	Mercury
Fawn Creek	< 0.005	< 0.005	< 0.05	0.003
Blue Beaver				
smelter center	< 0.005	< 0.005	< 0.05	0.004
25 meter uphill	< 0.005	< 0.005	< 0.05	0.004
6 meter downhill	< 0.005	0.012	< 0.05	0.004
Cedar Creek				
D - 7 - l	< 0.005	< 0.005	< 0.05	0.004
F - 5 - l	< 0.005	< 0.005	< 0.05	0.005
F - 5 - 2	< 0.005	0.006	< 0.05	0.004
D - 3 - l	< 0.005	< 0.005	< 0.05	0.004
D - 3 - 2	< 0.005	< 0.005	< 0.05	0.005
H - 3 - l	< 0.005	< 0.005	< 0.05	< 0.001
H - 3 - 2	< 0.005	< 0.005	< 0.05	0.004
H - 5 - l	< 0.005	< 0.005	< 0.05	0.005
H - 2 - 2	< 0.005	0.006	< 0.05	0.004
E F - 5 - 2	< 0.005	< 0.005	< 0.05	0.005
E - 5 - l	< 0.005	< 0.005	< 0.05	0.003
E F - 6 - 1	< 0.005	< 0.005	< 0.05	0.006
B - 5 - l	< 0.005	< 0.005	< 0.05	0.001
A - 5 - l	< 0.005	< 0.005	< 0.05	< 0.001
D - l - l	< 0.005	< 0.005	< 0.05	< 0.001
D - 4 - l	< 0.005	0.005	< 0.05	0.002
Panther Creek				
D E - 8 - l	< 0.005	< 0.005	< 0.05	< 0.001
D E - 8 - 2	< 0.005	0.006	< 0.05	< 0.001
B - 8 - l	< 0.005	< 0.005	< 0.05	< 0.001
A - 1 1 - 1	< 0.005	< 0.005	< 0.05	< 0.001
GH - 10 - 1	< 0.005	0.006	< 0.05	< 0.001
F - 7.5 - 1	< 0.005	0.005	< 0.05	< 0.001
GH - 2.5 - 1	< 0.005	0.005	< 0.05	< 0.001
Q - 1 - 1	< 0.005	< 0.005	< 0.05	< 0.001
R - l - l	< 0.005	< 0.005	< 0.05	< 0.001
R - l - 2	< 0.005	< 0.005	< 0.05	< 0.001
B - 5 - l	< 0.005	< 0.005	< 0.05	< 0.001
F - 4 - l	< 0.005	< 0.005	< 0.05	< 0.001
A - 3.75 - 1	< 0.005	< 0.005	< 0.05	< 0.001
C - 7.75 - 1	< 0.005	< 0.005	< 0.05	< 0.001

Cadmium, chromium, and lead values from the smelter sites were all below detection limits except for chromium in the sample taken about6 meters downhill from the Blue Beaver smelter. This value, 0.012 mg/L, is only slightly above the detection limit. Mercury values at the smelters were also slightly above the detection limit but were still well below the EPA critical EP toxicity value.

At the Cedar Creek arrastra none of the cadmium or lead values were above the detection limit. Three of the chromium values are above the detection limit, but these values are three orders of magnitude below EPA critical value. Mercury values ranged from 0.001 to 0.006 mg/L, or about 2 orders of magnitude below the EPA critical value. Cadmium and lead values at the Panther Creek arrastra are all below the detection limit. Four values for chromium are just above the detection limit but are still three orders of magnitude below the EPA critical value. All of the mercury values at Panther Creek are below the detection limit.

SUMMARY

These data indicate that mercury and other metal residues, at either the Cedar or Panther Creek arrastras or at the Blue Beaver or Fawn Creek smelters do not constitute an environmental hazard to fish or wildlife resources. The analyses for total metals in the smelter slag and soils from the arrastras show that some metals are present at elevated concentrations. However, the EP toxicity procedure, as specified by EPA, shows no hazard associated with these concentrations. The mercury that was left behind by the old mining practices is very tightly bound to the soil particles. Even if erosion washes some of these soils into a water body the mercury will not be released at normal pH levels.

RECOMMENDATIONS

It would be possible to remove the soil from the arrastras, but this would destroy their value as historical sites. No additional mercury will be placed at these sites, therefore levels will continue to decline. Further study is not called for at this time. Should environmental conditions change, for example if acidic precipitation increases, then further field monitoring may be required. These locations do not appear to warrant being placed on the Super Fund list or other lists of hazardous waste sites.

From the data presented above, the relatively small area of land involved and the remote location of the sites, the smelters or arrastras do not constitute hazards to fish and wildlife resources, the environment, or to people visiting or working on the Refuge.

LITERATURE CITED

Armstrong, F. A. J. 1979. Effects of mercury compounds on fish. In J.O. Nriagu (Ed.) The biogeochemistry of mercury in the environment. Elsevier/ North Holland Biomedical Press.

Bowen, H. J. M. 1979. Environmental Chemistry of the Elements. Academic Press. New York.

Finley, M. T. and R. C. Stendell. 1978. Survival and reproductive success of black ducks fed methyl mercury. Environ. Pollut. 16:51-64.

Finreite, N. 1971. Effects of dietary methyl mercury on ring-neck pheasants. Occ. Pap. No. 9, Canadian Wildl. Ser.

Kabata-Pendias, A. and H. Pendias. 1984. Trace elements in soils and plants. CRC Press, Inc. Boca Raton, Florida.

Wilson, S. 1983. Dauntless gold seekers of the Wichitas. Great Plains J. 22:42-78.