The data collected at the East Helena Plant from 1984 to present can be used to address the nature and extent of any hazardous waste or hazardous constituent releases, if any, at, or migrating from, the Plant. The quality of validated data is discussed in the following sections.

3.3.1 Quality of Water and Soil Data for Phase II, Comprehensive RI/FS and Post-RI/FS Biannual Sampling (1984-1997)

Phase I sample results (1984 through 1985) were visually validated, however, the quality of these data was not recorded. Therefore, this section does not further discuss Phase I data. Phase II, Comprehensive RI/FS water and soil data, and Post RI/FS biannual water monitoring data were validated according to EPA Contract Laboratory Procedures (CLP). The only exception was the validation of hydrocarbon analyses because EPA CLP procedures have not been developed for these laboratory procedures. Therefore hydrocarbon data were validated by Standard procedures only. The validation level of Post RI/FS non-biannual sampling data associated with various construction and design phases are addressed in Section 3.2.

The overall quality of the water monitoring data was deemed acceptable for purposes of the Phase II, Comprehensive RI/FS, and Post RI/FS projects. The following data quality comments are general statements that reflect the quality of the data for Phase II, Comprehensive RI/FS and Post RI/FS biannual sampling data. These comments were not designed to detail specific instances, but to be used in the review of sample data for trends and anomalies. These statements were formulated from compiling systematic occurrences and trends of the quality control results. The quality of Post RI/FS non-biannual sampling data associated with various construction and design phases are addressed in Section 3.2.

3.3.1.1 Data Quality Objectives

Data quality objectives included the overall completeness, precision and accuracy of the data.

Completeness

Completeness is defined as the percentage of samples not rejected. The completeness goal for Phase II, Comprehensive RI/FS, and Post RI/FS biannual sampling projects is 90%, which was clearly met on all sampling events.

Asarco proposes that the following data not be used in the assessment of site conditions:

- The 43 sample results, which were rejected due to quality control violations since the fall 1986 sampling event. No inorganic sample results have been rejected since the fall 1989 sampling event (refer to Table 3-3-1).
- Numerous sample results have been designated as anomalies based on field splits, field duplicates, inter-element comparisons, historical data and professional judgment (refer to Table 3-3-1).

Accuracy

Accuracy is determined by quantitatively assessing the laboratory's ability to measure a known concentration. Accuracy is evaluated by recoveries on the field standards, laboratory control standards and laboratory spikes.

- In general, the accuracy for fall 1986 to spring 1997 sampling events has been very good. Less than 10% of the data were qualified due to poor recovery rates for spikes and standards. During most sampling events, less than 5% of the data were qualified due to accuracy violations.
- Most of the accuracy violations were due to poor field standard recovery rates, otherwise no correlation or trends were found concerning accuracy.

Precision

Precision is determined by the measure of the reproducibility of the data as evaluated by the relative percent difference for both field and laboratory duplicates.

TABLE 3-3-1. SUMMARY OF REJECTED AND ANOMALOUS SAMPLE RESULTS

Site Code	Sample Date	Sample No.	Parameter	Result	Unit	Flag (*)
Plant Site Monitoring Wells						
APSD-2	11/8/1995	AHCL-9511-105	**DEPTH TO WATER LEVEL (FEET)**	11.55	feet	A
APSD-7	10/5/1994	AHCL-9410-100	**ARSENIC +3**	86	mg/L	A
APSD-10	4/25/1995	AHCL-9504-126	**TDS (MEASURED AT 180 C)**	592	mg/L	A
DH-1	4/29/1993	EHC-9305-116	**ARSENIC +5**	0.112	mg/L	A
DH-2	5/3/1988	AEH-8804-301	**ARSENIC +3**	0.56	mg/L	A
DH-5	12/19/1988	AEH-8812-125	**CHLORIDE (CL)**	69	mg/L	A
DH-5	4/18/1989	AEH-8904-204	**DEPTH TO WATER LEVEL (FEET)**	38.49	feet	A
DH-5	5/26/1994	AHCL-9405-259	**SC (MEASURED AT 25 C) (FLD)**	2010	umhos/cm	A
DH-5	4/27/1988	AEH-8804-304	**SULFATE (SO4)**	150	mg/L	A
DH-6	4/27/1992	AEH-9204-177	**CHLORIDE (CL)**	190	mg/L	A
DH-7	4/27/1988	AEH-8804-306	**ZINC (ZN) DIS**	0.115	mg/L	A
DH-8	4/28/1990	AEH-9005-407	**ARSENIC +3**	0.26	mg/L	A
DH-8	12/15/1988	AEH-8812-128	**SULFATE (SO4)**	1500	mg/L	R
DH-9	5/2/1988	AEH-8804-308	**LEAD (PB) DIS**	0.005	mg/L	R
DH-9	5/7/1997	EHC-9705-121	**SC (MEASURED AT 25 C) (FLD)**	423	umhos/cm	R
DH-12	11/17/1987	AEH-8711-227A	**ARSENIC (AS) DIS**	0.006	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**CADMIUM (CD) DIS**	0.001	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**COPPER (CU) DIS**	0.008	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**IRON (FE) DIS**	0.021	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**LEAD (PB) DIS**	0.005	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**MANGANESE (MN) DIS**	0.006	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**PH**	7.8	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**SC (MEASURED AT 25 C)**	344	umhos/cm	A
DH-12	11/17/1987	AEH-8711-227A	**SC (UMHOS/CM AT 25 C) (FLD)**	363	umhos/cm	A
DH-12	11/17/1987	AEH-8711-227A	**SULFATE (SO4)**	71	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**TDS (MEASURED AT 180 C)**	233	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**TOTAL SUSPENDED SOLIDS**	12	mg/L	A
DH-12	11/17/1987	AEH-8711-227A	**ZINC (ZN) DIS**	0.008	mg/L	A
DH-12	5/16/1995	EHC-9505-115	**2,4-DINITROPHENOL**	<0.05	mg/L	R
DH-12	5/16/1995	EHC-9505-115	**HEXACHLOROCYCLOPENTADIENE**	<0.01	mg/L	R
DH-20	12/15/1988	AEH-8812-138	**SULFATE (SO4)**	2	mg/L	R
DH-21	12/28/1988	AEH-8812-139	**PH (FLD)**	3.61	pH	A
DH-24	8/12/1987	AEH-8708-12	**DEPTH TO WATER LEVEL (FEET)**	16.33	feet	A
DH-28	12/21/1988	AEH-8812-145	**PH (FLD)**	8.24	pH	A
DH-28	5/7/1994	EHC-9405-127	**SC (MEASURED AT 25 C) (FLD)**	3980	umhos/cm	A
DH-28	11/18/1994	EHC-9411-127	**SC (MEASURED AT 25 C) (FLD)**	101300	umhos/cm	A
East Helena Groundwater Monitoring Wells						
EH-50	2/2/1987	AEH-8701-108	**CHLORIDE (CL)**	450	mg/L	A
EH-50	12/13/1988	AEH-8812-161	**SC (UMHOS/CM AT 25 C) (FLD)**	222	umhos/cm	A
EH-51	12/14/1988	AEH-8812-162	**SULFATE (SO4)**	180	mg/L	R
EH-52	4/20/1988	AEH-8804-344	**DEPTH TO WATER LEVEL (FEET)**	3.58	feet	A
EH-60	5/8/1991	AEH-9105-127	**2,4,5-TRICHLOROPHENOL**	<0.05	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2,4,6-TRICHLOROPHENOL**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2,4-DICHLOROPHENOL**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2,4-DIMETHYLPHENOL**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2,4-DINITROPHENOL**	<0.05	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2-CHLOROPHENOL**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2-METHYLPHENOL (O-CRESOL)**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**2-NITROPHENOL**	<0.01	mg/L	R

TABLE 3-3-1. SUMMARY OF REJECTED AND ANOMALOUS SAMPLE RESULTS

Site Code	Sample Date	Sample No.	Parameter	Result	Unit	Flag (*)
East Helena Groundwater Monitoring Wells (cont.)						
EH-60	5/8/1991	AEH-9105-127	**4,6-DINITRO-2-METHYLPHENOL**	<0.05	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**4-CHLORO-3-METHYLPHENOL**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**4-METHYLPHENOL (P-CRESOL)**	<0.01	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**4-NITROPHENOL**	<0.05	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**PENTACHLOROPHENOL**	<0.05	mg/L	R
EH-60	5/8/1991	AEH-9105-127	**PHENOL**	<0.01	mg/L	R
EH-60	12/14/1988	AEH-8812-169	**SULFATE (SO4)**	630	mg/L	R
EH-60	5/16/1995	EHC-9505-148	**2,4-DINITROPHENOL**	<0.05	mg/L	R
EH-60	5/16/1995	EHC-9505-148	**HEXACHLOROCYCLOPENTADIENE**	<0.01	mg/L	R
EH-60 DUP	5/16/1995	EHC-9505-178	**2,4-DINITROPHENOL**	<0.05	mg/L	R
EH-60 DUP	5/16/1995	EHC-9505-178	**HEXACHLOROCYCLOPENTADIENE**	<0.01	mg/L	R
EH-61	12/15/1988	AEH-8812-170	**SULFATE (SO4)**	470	mg/L	R
EH-62	5/9/1995	EHC-9505-150	**SC (UMHOS/CM AT 25 C) (FLD)**	347	umhos/cm	A
Private Groundwater Monitoring Wells						
AMCHEM2	12/7/1990	AEH-9011-763	**SC (MEASURED AT 25 C) (FLD)**	3512	umhos/cm	A
AMCHEM2	12/6/1988	AEH-8812-181	**SULFATE (SO4)**	28	mg/L	R
AMCHEM2	4/27/1989	AEH-8904-252	**TDS (MEASURED AT 180 C)**	431	mg/L	R
AMCHEM4	12/7/1990	AEH-9011-764	**SC (MEASURED AT 25 C) (FLD)**	2916	umhos/cm	A
AMCHEM4	12/6/1988	AEH-8812-209	**SULFATE (SO4)**	24	mg/L	R
AMCHEM4	4/27/1989	AEH-8904-286	**TDS (MEASURED AT 180 C)**	361	mg/L	R
CASEY	5/1/1989	AEH-8904-296	**ARSENIC (AS) DIS**	0.004	mg/L	R
DHULST	12/7/1990	AEH-9011-766	**SC (MEASURED AT 25 C) (FLD)**	4850	umhos/cm	A
DHULST	12/6/1988	AEH-8812-210	**SULFATE (SO4)**	74	mg/L	R
DHULST	4/27/1989	AEH-8904-287	**TDS (MEASURED AT 180 C)**	523	mg/L	R
DUEL	5/1/1989	AEH-8904-254	**ARSENIC (AS) DIS**	0.004	mg/L	R
DUEL	12/7/1990	AEH-9011-761	**SC (MEASURED AT 25 C) (FLD)**	2651	umhos/cm	A
LHULST	12/7/1990	AEH-9011-770	**SC (MEASURED AT 25 C) (FLD)**	4260	umhos/cm	A
LHULST	12/6/1988	AEH-8812-211	**SULFATE (SO4)**	58	mg/L	R
LHULST	4/27/1989	AEH-8904-289	**TDS (MEASURED AT 180 C)**	446	mg/L	R
WALTER	12/6/1988	AEH-8812-184	**SULFATE (SO4)**	48	mg/L	R
WALTER	4/27/1989	AEH-8904-255	**TDS (MEASURED AT 180 C)**	283	mg/L	R
Plant Process Fluids						
LL-1D	10/13/1994	AHCL-9410-209	**ARSENIC (AS) TOT**	14	mg/L	A
LL-1D	10/13/1994	AHCL-9410-209	**CADMIUM (CD) TOT**	4.5	mg/L	A
LL-1D	10/13/1994	AHCL-9410-209	**COPPER (CU) TOT**	3.9	mg/L	A
LL-1D	10/13/1994	AHCL-9410-209	**IRON (FE) TOT**	15	mg/L	A
LL-1D	10/13/1994	AHCL-9410-209	**LEAD (PB) TOT**	22	mg/L	A
LL-1D	10/13/1994	AHCL-9410-209	**ZINC (ZN) TOT**	8	mg/L	A
LL-1S	4/25/1995	AHCL-9504-111	**ARSENIC +3**	0.292	mg/L	A
LL-1S	5/24/1995	AHCL-9505-118	**ARSENIC +3**	0.56	mg/L	A
Surface Water						
PPC-3	4/25/1989	AEH-8904-285	**ARSENIC (AS) DIS**	0.008	mg/L	R
PPC-5	4/25/1989	AEH-8904-284	**TDS (MEASURED AT 180 C)**	186	mg/L	R
PPC-7	4/25/1989	AEH-8904-282	**TDS (MEASURED AT 180 C)**	183	mg/L	R
PPC-8	4/25/1989	AEH-8904-281	**TDS (MEASURED AT 180 C)**	185	mg/L	R
WD-2	5/11/1993	EHC-9305-176	**SC (MEASURED AT 25 C) (FLD)**	662	umhos/cm	A

* A = Anomalous Result; R = Rejected Result.

- Overall precision for the fall 1986 to spring 1997 sampling events was very good. Less than 10% of data were qualified due to precision violations. For most sampling events, less than 5% of the data were qualified.
- Precision generally improved over the sampling years.
- Most field duplicate imprecision involved dissolved arsenic, arsenic III and arsenic V, especially at low concentrations.
- Most laboratory duplicate imprecision can be attributed to arsenic V and dissolved lead at low concentrations.
- The precision for arsenic III and arsenic V field duplicates improved starting with the fall of 1994 sampling event.

3.3.1.2 Field and Laboratory Quality Control Concerns

The following are general quality control concerns that were evidenced by field and laboratory control sample results and non-compliance to CLP procedures.

Field Blanks

The detection of analytes in a field blank may be an indication of systematic contamination. Blank contamination affects the interpretation of low-level results (up to five times the blank level). These low-level results may be biased high.

- Field blank contamination occurred from the fall 1986 through the fall 1994 sampling events. Field blank contaminants include: arsenic, arsenic III, arsenic V, cadmium, calcium, chloride, copper, lead, total dissolved solids, and zinc.
- Blanks for arsenic speciation samples indicated a contamination problem beginning with the fall 1986 sampling events and extending through fall of 1994.
- Zinc was detected in field blanks during most sampling periods from spring 1990 through spring 1997 sampling events. Zinc contamination is a common sampling problem because of its many sources. In most cases, the concentrations of zinc in

the associated samples were greater than five times the blank level, so the interpretation of the sample results was not affected by the blank contamination.

Laboratory Quality Control

Laboratory quality control samples were typically within the desired control limits. However, there were some exceptions with certain methods and analytes. Following is an outline of these exceptions:

Graphite Furnace

The graphite furnace (GFAA) instrument was used for low-level lead and arsenic analyses (starting in 1993 for arsenic) until the fall 1996 sampling event, when low level analytes began to be analyzed by ICP-MS. Systematic problems associated with the graphite furnace were:

- Quality control frequency did not meet requirements.
- Analytical spike recoveries exceeded control limits.
- Many of the lead results were qualified due to graphite furnace quality control violations.

Arsenic (low level)

Arsenic is normally a very difficult element to analyze because of the inherent interference of other elements. This phenomenon was not exclusive to a particular analytical method. The precision and accuracy were particularly affected at low level concentrations.

Arsenic Speciation

Most of the arsenic III and arsenic V results for sampling periods fall 1986 through fall of 1994 were qualified due to analytical method and contamination problems. The results for these analytes started to improve for the spring 1995 sampling event due to the improvement in the speciation preparation procedures.

The possible source of contamination may have been in the Asarco Plant site laboratory, where samples were prepared until the spring of 1993. From the 1993 spring sampling event to the present, the arsenic speciation samples have been prepared at the Hydrometrics East Helena Laboratory. Contamination was still a problem in 1993 and 1994, which may have been due to the use of reagents brought over from the Asarco laboratory. Contamination problems have decreased since the 1994 fall sampling event.

Starting with the 1996 fall sampling period, low level arsenic III and V analytes were analyzed by ICP-MS, producing more consistent results. Most method and contamination problems only affected samples with very low arsenic concentrations. The significance of the problems associated with arsenic speciation is discussed further in the EPA Comment Responses in Appendix 4-1-1.

Semi-Volatile Organic Analyses

Surrogate recovery rates for the fall 1986 sampling event through the spring 1992 sampling event for semi-volatile organic analyses (SVOA) were, in many cases, less than 10% According to CLP, results less than the detection limit and associated with surrogate recovery rates of less than 10% can be rejected. This violation resulted in the rejection of all SVOA data for one sample (site EH-60, sampled 5/8/91). However, in most cases the results were not rejected. Despite problems with the surrogate recovery rates, the overall quality of these data was deemed acceptable for the purposes of the project.

4. EVALUATION OF CURRENT CONDITIONS

As described in Sections 1.0 and 3.0, data from the plant site surface soils, process fluids, surface water, slag and ore storage operable units were obtained and evaluated as part of the Process Ponds RI/FS (Hydrometrics, 1989) and the Comprehensive RI/FS (Hydrometrics, 1990a). Additional data were collected as part of post-RI monitoring efforts from 1990 through 1998, the RD/RA efforts for process ponds and other non-CERCLA activities. In this section, current soil and water quality trends are examined within the plant site and along potential migration pathways.

4.1 PLANT SITE SOILS AND ORE STORAGE AREAS

The evaluation of surface soils, subsurface soils and the ore storage areas includes discussion of on-site surface soils, stockpiles and slag. Process pond sediments are addressed separately in Section 4.2, surface water bottom sediments in Section 4.3 and subsurface sediment stratigraphy and quality in Section 4.4.

4.1.1 Surface Soils

Plant site surface soils were addressed as part of the Comprehensive RI/FS (Hydrometrics, 1990a). The plant site surface soil investigation focused primarily on ore storage areas in the plant and other unpaved areas at various locations.

Surface soil samples (0-4 inch depth) were collected during installation of monitoring wells at nine sites (see Figure 4-1-1). Surface soil samples (0-1 inch depth) were also collected at 26 other plant site locations (see Figure 4-1-1). The areas sampled for surface soils (0-1 inch depth) included the former Upper Ore Storage Area (4 samples), the Lower Ore Storage Area (5 samples), railroad tracks east and south of the Thawhouse (7 samples), the perimeter of the slag pile (4 samples), other unpaved areas within the main facility (4 samples) and unpaved areas outside of the main facility (2 samples).

LEGEND

● SC-3	SOIL BORING NUMBER
◉DH-24	MONITORING WELL NUMBER
39	SAMPLE INTERVAL 0-2 FEET
31	SAMPLE INTERVAL 2-4 FEET
21	SAMPLE INTERVAL 4-6 FEET
18	SAMPLE INTERVAL 6-8 FEET
16	SAMPLE INTERVAL 8-10 FEET
21	SAMPLE INTERVAL 10-12 FEET
NS	SAMPLE INTERVAL 14-16 FEET
19	SAMPLE INTERVAL 19-21 FEET
28	SAMPLE INTERVAL 24-26 FEET
90	SAMPLE INTERVAL 30-32 FEET
NS	NO SAMPLE
***	INTERVAL EXCEEDS BORING DEPTH
*	EP TOXICITY ANALYSIS ONLY
▨	AREA WHERE SOIL HAS BEEN EXCAVATED AS PART OF PROCESS PONDS REMEDIAL ACTION

CONCENTRATION (mg/kg) →

COLOR KEY

COLOR	CONCENTRATION
58	0-100 (mg/kg)
388	101-500 (mg/kg)
675	501-1000 (mg/kg)
2458	1001-5000 (mg/kg)
7500	>5000 (mg/kg)

NOTES:

SOIL EXCAVATION DEPTHS ARE SHOWN ON THE FOLLOWING FIGURES:
THORNOCK LAKE – FIGURE 4-1-3
SPEISS POND AND PIT – FIGURE 4-1-4
ACID PLANT WATER TREATMENT FACILITY – FIGURE 4-1-5

ASARCO INCORPORATED
CC/RA EAST HELENA FACILITY

ARSENIC CONCENTRATIONS IN
STRATIGRAPHIC SAMPLES
0-32 FEET

Hydrometrics, Inc.
Consulting Scientists, Engineers, and Contractors
Helena, Montana
2727 Airport Road (406) 443-4150

EXHIBIT
4-1-1

UPDATE TIME: 10:59AM
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The sampling methodology used at the surface soil sampling sites is described in detail in the Comprehensive RI/FS (Hydrometrics, 1990a). In general, three samples were collected around a center stake and composited into one sample at each location. The samples were analyzed for the 12 metals shown in Table 4-1-1. A statistical summary of the data is in Table 4-1-2. Arsenic, cadmium, copper, lead and zinc concentrations in surface soils are shown for both surface soil sampling sites and monitoring well locations on Figure 4-1-1.

All of the metals analyzed in plant site soils were elevated compared to background values (see Table 4-1-2). Of the metals analyzed arsenic, cadmium, copper, lead and zinc had the highest concentrations. The highest concentrations of arsenic, cadmium and lead were from samples collected in the Upper Ore Storage Area and the railroad tracks east and south of the Thawhouse. The lowest concentrations were from samples collected from the perimeter of the slag pile and unpaved areas outside of the plant site.

In the RI (Hydrometrics, 1990a), an analysis of variance (ANOV) was calculated to test differences between geometric mean concentrations of metals for different use areas on the plant site. The least significant difference (LSD) method of multiple comparisons was then used to separate the means. Table 4-1-3 shows the results of the analysis.

4.1.2 Subsurface Soils

Plant site subsurface soils were addressed as part of the Comprehensive RI/FS (Hydrometrics 1990a). During the RI, subsurface samples were collected from 50 soil boring and monitoring well locations on the site (see Exhibit 4-1-1). Since completion of the RI (1990) supplemental subsurface soil data has been obtained as part of post-RI remedial activities for the Process Ponds. The post-RI subsurface data include collection of sample cores from Lower Lake, Former Thornock Lake, the Speiss Pond and Pit areas, the former Acid Plant Water Treatment Facility settling pond, and the Acid Plant Sediment Drying Areas.

Table 4-1-1 - Surface Soil Sample Results - 1987 Phase II Investigation

	Parameter											
Station #	**Ag**	**As**	**Cd**	**Cu**	**Hg**	**Cr**	**Mn**	**Pb**	**Sb**	**Se**	**Tl**	**Zn**
SS-1	--	6075	6000	14575	240	22	1590	19350	980	423	182	23625
SS-2	209	3475	1813	3225	236	20	230	24975	107	518	118	10050
SS-3	64	1078	413	1090	--	19	400	10875	5	69	35	3075
SS-4	193	5650	14725	12175	104	23	890	23625	783	186	280	44050
SS-5	199	1495	1093	8850	2.2	27	--	21875	53	13	33	46625
SS-6	124	3300	253	4200	9.2	14	453	19400	5	13	59	3975
SS-7	157	3400	373	8500	4.5	12	195	22350	508	19	57	43725
SS-8	185	3800	1013	18600	15	30	1285	21400	189	71	29	14250
SS-10	197	3900	1613	8350	12	38	1823	23900	197	17	52	30425
SS-11	169	6525	5800	20700	17	36	2353	22100	1970	113	103	67175
SS-12	186	35500	5325	31450	--	27	2445	19975	1395	97	86	63650
SS-14	63	1098	212	1918	0.97	12	308	8900	206	21	9.9	30125
SS-15	30	385	172	9750	2	29	1858	3250	5	13	9.9	3975
SS-16	14	121	92	16375	0.75	14	338	1368	5	13	9.9	1868
SS-17	74	795	212	1813	0.87	15	220	6200	129	13	12	2235
SS-18	174	13450	23400	29200	70	86	2018	19325	2260	498	515	67175
SS-19	199	21625	2373	19850	--	46	11700	20250	1943	99	74	23300
SS-20	179	5450	1733	18625	0.6	27	1615	19225	2850	31	63	26275
SS-21	211	17075	1693	35350	--	79	950	22575	4950	221	52	14875
SS-22	201	3100	2213	11300	0.87	13	1083	21950	1770	13	76	23625
SS-23	12	121	212	320	--	26	410	11600	5	13	14	1093
SS-24	169	2115	613	4275	19	18	--	16575	5	13	33	7325
SS-28	214	8625	2525	23600	360	15	1703	1535	--	320	220	23925
SS-29	174	9525	2575	23700	90	27	2600	20300	4125	142	278	48550
SS-30	199	1633	373	5600	4	15	1510	12725	425	15	25	7925
SS-31	167	2625	813	6900	4.7	27	660	14600	81	33	27	84650

Notes: All concentrations reported in ug/g (dry wt.).
Surface soil refers to soil sampled at a depth of 0-1 inches.

Table 4-1-2 - Statistical Summary of Soil Samples - 1987 Phase II Investigation

Element	N(1)	Arithmetic Mean	Standard Deviation	Minimum Value	Maximum Value	Geometric Mean	Geo. Mean(2) Background	Enrichment Factor(3)
Ag	25	150.5	65.9	12.0	214.0	122.1	0.20	610.6
As	26	6228.5	7977.8	121.0	35500.0	2987.3	16.50	181.0
Cd	26	2985.8	5176.2	92.0	23400.0	1127.5	0.24	4697.7
Cr	26	27.6	18.3	12.0	86.0	23.8	15.30	1.6
Cu	26	13088.1	9953.9	320.0	35350.0	8488.3	16.30	520.8
Hg	21	56.8	100.0	0.6	360.0	9.9	0.08	124.2
Mn	24	1609.9	2283.8	195.0	11700.0	968.9	336.00	2.9
Pb	26	16546.3	7213.2	1368.0	24975.0	13552.4	11.60	1168.3
Sb	25	998.0	1365.5	5.0	4950.0	193.5	0.27	716.5
Se	26	115.3	155.2	13.0	518.0	49.1	0.07	701.2
Tl	26	94.3	116.0	9.9	515.0	52.9	0.09	588.2
Zn	26	27597.9	23891.5	1093.0	84650.0	16043.8	46.90	342.1

Notes: All concentrations reported in ug/g (dry wt.).
Surface soil refers to soil sampled at a depth of 0-1 inches.

Footnote: (1) Unequal sample sizes due to rejection of some data during data validation process.
(2) Source: Comprehensive RI/FS Report (Hydrometrics, 1990a)
(3) Enrichment factor = geometric mean plant soils / geometric mean background.

Table 4-1-3 - Geometric Means of Soil Samples by Area

Element[1]	Upper Ore Storage Area	Lower Ore Storage Area	R.R. Tracks East & South of Thawhouse	Perimeter of Slag Pile	Misc. Bare Areas within Main Facility	Misc. Bare Areas Outside Main Facility
Ag	137.1 B	169.8 B	162.9 B	45.8 A	196.3 B	45.1 A
As	3365 BC	3013 B	9057 C	605.3 A	4519 BC	505.8 A
Cd	2851 C	699.8 AB	2710 C	228.6 A	1521 BC	360.3 AB
Cr	20.9 A	22 AB	38.4 B	19.1 A	16.7 A	21.6 AB
Cu	5000 A	8670 BC	17219 C	6776 BC	13709 C	1169 A
Hg	180.7 B	6.96 A	4.99 A	1.62 A	18.3 A	19 AB
Mn	601.2 A	674.5 A	1726 A	598.4 A	1641 A	410.2 A
Pb	18750 BC	21727 C	17298 BC	4898 A	9661 AB	13868 BC
Sb	142.2 B	87.1 B	1556 C	25.4 AB	1459 C	5 A
Se	230.1 C	20.8 A	90.2 BC	18.5 A	54.6 AB	13 A
Tl	120.5 D	44.2 BC	75 CD	12.7 A	103.8 CD	21.5 AB
Zn	13397 A	20370 A	24831 A	11722 A	21577 A	2831 A

Notes: All concentrations reported in ug/g (dry wt.).
Surface soil refers to soil sampled at a depth of 0-1 inches.

Footnote: (1) Letters A, B, C & D represent statistical groupings. Values within same element (rows) followed by same letter not significantly different at P = 0.10.

4.1.2.1 RI/FS Subsurface Soil Data

During the RI, subsurface samples were collected from 45 soil borings at monitoring well locations during well construction. Supplemental subsurface data were also collected from test pit locations at nine of the monitoring well sites (DH-1, DH-2, DH-3, DH-6, DH-7, DH-10, DH-11, DH-13 and DH-17), and from 5 soil core locations (SC-1 through SC-5) which were not completed as monitoring wells. With the exception of the test pit locations, soil samples were collected at two foot increments to a depth of 10 feet using split-spoons, with additional sampling conducted at 5 foot intervals to the depth of completion. At test pit locations, additional increments were sampled (0-4 inches, 4-8 inches, 8-12 inches, 1-2 feet, 2-3 feet, 3-4 feet and 4-5 feet) to a depth of 5 feet. The number of samples analyzed at individual sites varies, depending on the depth of completion and sample recovery rates. Subsurface soil samples collected during the RI were analyzed for total arsenic and metals. Sampling intervals and soil analytical results are shown in the soil quality database in Appendix 3-1-3. Exhibits 4-1-1, 4-1-2 and 4-1-3 present the soil quality data for arsenic, cadmium and lead at each sampling location.

As shown in Exhibit 4-1-1, arsenic concentrations in subsurface soil vary from less than 100 mg/kg to greater than 10,000 mg/kg within the plant site area. The highest concentrations of arsenic (above 5000 mg/kg) were in the southern half for the site in the former acid plant sediment drying areas, at DH-19, ASPD-13 and ASPD-14 near the former Acid Plant Water Treatment Facility. Elevated concentration of arsenic (above 1000 mg/kg) also was observed in fill material in the area between Upper Lake and Lower Lake. Arsenic concentrations in excess of 1000 mg/kg were also detected in shallow soils from the southern end of the lower ore storage yard (SC-4), and in soils at DH-21, DH-9 and DH-23. Arsenic concentrations are generally less than 500 mg/kg in the subsurface soils on the northern half of the plant site and in the East Helena area.

Many of the sampling locations in the plant site area show a progressive decrease in arsenic concentration with depth and then an increase again at the water table (Figure 4-1-2). The concentration increase within the saturated zone is an indication of lateral transport and attenuation processes within the aquifer. As shown in Figure 4-1-2, these increased concentrations generally extend only 10 to 15 feet beneath the water table.

Cadmium concentrations in subsurface soil range from less than 1 mg/kg to greater than 1000 mg/kg (Exhibit 4-1-2). Similar to the pattern observed for arsenic, the highest cadmium concentrations (greater than 500 mg/kg) were found in the Acid Plant Water Treatment Facility at wells DH-19 and ASPD-14. Cadmium values above 100 mg/kg were found at various locations on the plant site including the area between Upper Lake and Lower Lake, the ore storage yard (SC-4 and SC-3), the Speiss Pit area (DH-28) and in one sample from DH-10 on the northern edge of the slag pile.

Lead concentrations in subsurface soils range from less than 10 mg/kg to 197,000 mg/kg (Exhibit 4-1-3). The areas of high concentration are generally similar to arsenic and cadmium. Lead is also high at locations where slag is present. Lead concentrations in excess of 10,000 mg/kg were detected at various locations on the southern half of the plant site including:

- The former acid plant sediment drying areas (ASPD-14 and DH-29),
- In DH-19 near the former acid plant water treatment facility,
- In fill material in the former upper ore storage area between Upper and Lower Lake,
- At sites where slag is present (DH-4, DH-5 and DH-23), and
- In shallow fill material at DH-27.

The highest arsenic and metal concentrations are associated with previously identified source areas on the southern half of the plant site.

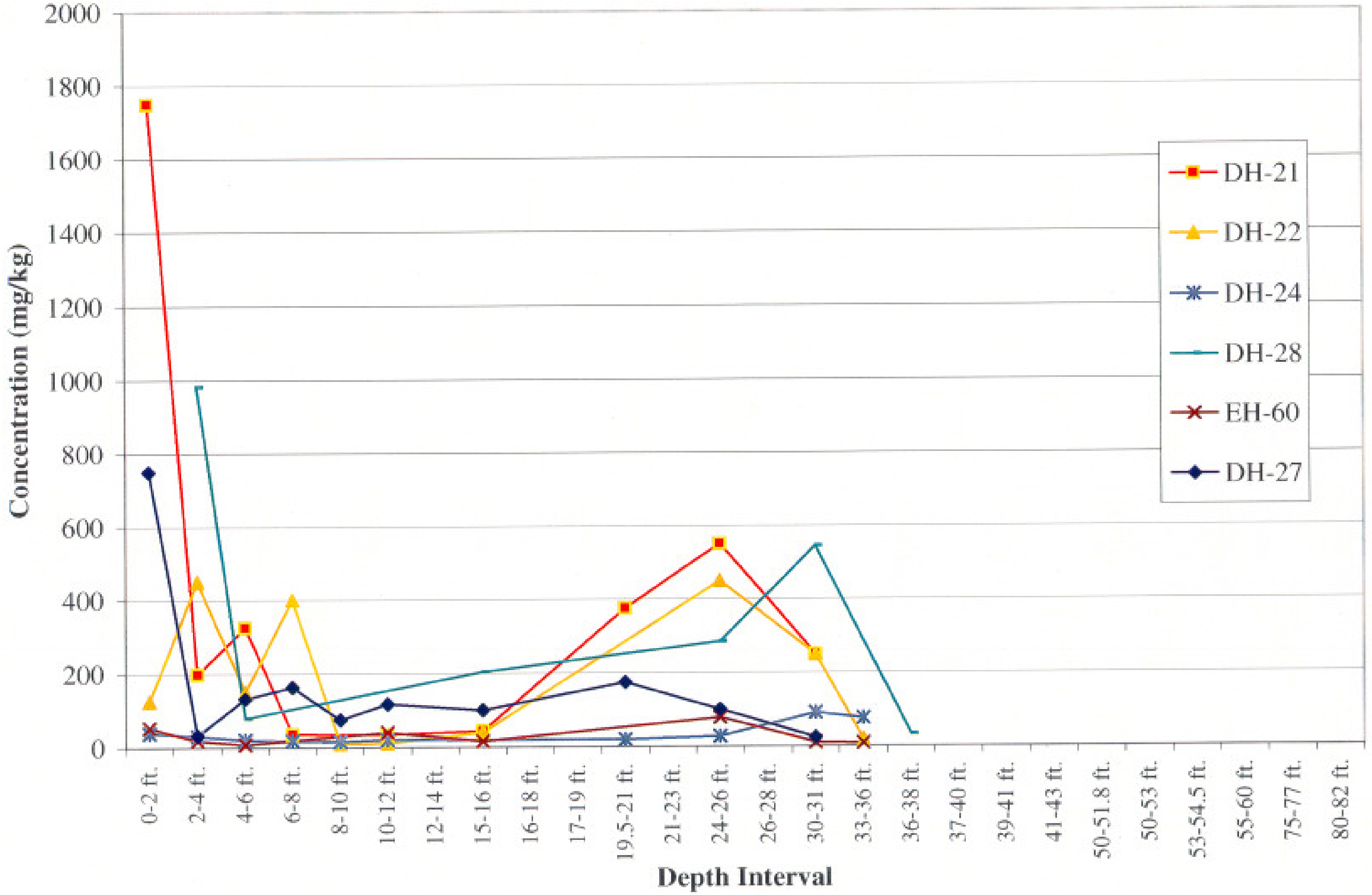


FIGURE 4-1-2. SOIL ARSENIC CONCENTRATIONS VERSUS DEPTH AT SELECTED PLANT SITE MONITORING WELL LOCATIONS

4.1.2.2 Post-RI Subsurface Sample Data

Since the RI, additional subsurface soil characterization was conducted as part of implementation of remedial measures in accordance with the Process Ponds ROD. The results of these additional investigations are described below:

Lower Lake

The Record of Decision (ROD), issued by the Environmental Protection Agency (EPA) in November 1989, required the removal of all process sludge plus 24 inches of underlying marsh deposits from Lower Lake. The Explanation of Significant Differences (ESD), issued by the EPA on June 17, 1993, modified the ROD removal requirements by reducing the removal depth of underlying marsh deposits from 24 inches to six inches. The ESD was based on an examination of the decrease of arsenic and metals in the marsh deposits with increasing depth (Hydrometrics, 1993). The ESD explained:

> ". . . core samples were taken and leachability tests were conducted for each layer, as well as for the two layers together. The additional tests demonstrated that the sludge layer, despite being delisted, exhibits characteristics of a hazardous waste. The results also indicated that the underlying marsh sediments were not the source of contamination that they were originally thought to be; in fact, the tests concluded that by excavating only six inches of marsh sediments instead of two feet of marsh sediments, the remedy would be protective of human health and the environment."

Beginning in 1994 and concluding in 1996, process sludge and the top 6-inches of the marsh deposits (collectively referred to as Lower Lake sediments) were dredged from the lake. The dredged sediments were mechanically dewatered and the filter cake from the dewatering operation was transported to an interim covered stockpile in the Lower Ore Storage Area. Approximately 31,000 cubic yards of dewatered Lower Lake sediments were transported to the Lower Ore Storage Area. Four thousand cubic yards of these sediments were smelted prior to the remainder of stockpile being covered with a geomembrane liner in October 1997. The sediments were covered in accordance with the plan for a Short Term Storage Facility for Lower Lake Process Sludge and Marsh Deposits (Hydrometrics, 1997d). The sediments will remain in this interim storage facility while EPA considers Asarco's request to modify the sediment smelting requirement of the ROD, and instead dispose of these materials in a proposed on-site CAMU.

As part of Lower Lake remedial design and remediation activities, an extensive core sampling and subsequent analysis program was conducted in April and June, 1995 (Hydrometrics, 1995). Results of this program provide a comprehensive assessment of the sediments dredged from Lower Lake as well as characterize the marsh deposits remaining in the lake.

- In April and June of 1995, sediment core samples were collected at 42 sites in Lower Lake for laboratory analysis of arsenic, copper, cadmium, lead and zinc. Soil samples were composited in 6 inch intervals and submitted for XRF analysis. The soil core lithology was logged in the field as process sludge, top of the marsh deposits and marsh deposits. These distinctions were used for the summary statistics presented in Table 4-1-4. The purpose of the sampling program was to determine as accurately as possible, the elevation of the interface between the process sludge and the underlying marsh deposits, since the interface was the "benchmark" from which the required dredging was determined. Since the "benchmark" for setting the Lower Lake sediments removal target was the top of the marsh deposits, lithological descriptions alone should have provided sufficient data to determine this interface. However, XRF analyses were also conducted to provide additional assurance that the process sludge/marsh deposits interface was accurately located, especially in areas where there were no distinct sand layers to uniquely characterized the marsh deposits. In this regard, lithological descriptions and XRF analysis (total arsenic and metals) were compared for each of the analyzed cores to verify the correlation between lithologic descriptions and

TABLE 4-1-4: STATISTICAL SUMMARY OF LOWER LAKE SOIL CORE DATA

Interval 1 (Process Sludge)	**Total Arsenic (mg/Kg)**	**Total Cadmium (mg/Kg)**	**Total Copper (mg/Kg)**	**Total Lead (mg/Kg)**	**Total Zinc (mg/Kg)**
Geometric Mean	13249	2258	6352	30620	19585
Average	16582	2994	7421	34128	21478
Median	13694	2522	6594	32800	18790
Minimum	2532	452	2131	11891	6877
Maximum	40860	15524	16144	70170	42592
Standard Deviation	10178	3049	4123	15855	9372
Count	21	21	21	21	21
Interval 2 (Top of Marsh to 6 inches)					
Geometric Mean	1879	263	1143	6018	5840
Average	2130	306	1378	7193	6399
Median	1865	254	1091	6146	5759
Minimum	665	54	240	1457	1769
Maximum	6924	758	3753	18017	11248
Standard Deviation	1285	174	870	4240	2665
Count	21	21	21	21	21
Interval 3 (6 to 12 inches)					
Geometric Mean	1040	52	675	2923	3443
Average	1513	215	945	5006	4189
Median	930	109	568	2191	2796
Minimum	188	3	93	541	721
Maximum	10668	2077	4728	37422	11661
Standard Deviation	1812	388	961	6896	2876
Count	41	41	41	41	41
Interval 4 (12 to 18 inches)					
Geometric Mean	784	128	595	2416	3085
Average	1882	624	1146	6485	4228
Median	707	103	495	1852	2906
Minimum	126	15	75	407	590
Maximum	11540	8269	5671	37380	16750
Standard Deviation	3071	1827	1625	11189	3946
Count	20	20	20	20	20
Interval 5 (18 to 36 inches)					
Geometric Mean	260	31	409	1071	2052
Average	1171	106	973	4714	2969
Median	113	13	240	666	1674
Minimum	77	8	91	292	972
Maximum	6917	480	4644	28069	10793
Standard Deviation	2544	177	1641	10323	3507
Count	7	7	7	7	7

arsenic and metals concentrations in the process sludge and marsh deposits. In addition, ten split samples were analyzed at Asarco's TSC-SLC laboratories for the same parameters. An excellent correlation between XRF and wet chemistry methods were obtained.

XRF analysis of the cores found that total arsenic and metals values dropped off immediately and significantly as materials containing sand and/or mica, which uniquely characterized the presence of marsh deposits, were encountered. In addition, areas which had been dredged in 1994 and did not contain any of the material determined to be process sludge, showed relatively low total metals levels. These areas, which contained no process sludge and had relatively low metal values (i.e., metal values comparable to those found more than six inches below the interface in areas not dredged), were determined to have met the project removal targets. In some areas, it was difficult to determine the top of the marsh deposits because the cores consisted mostly of clay and little or no sand or mica. In these areas, XRF data were compared to XRF data for other areas of the lake where the top of the marsh deposits was clearly evident from the lithological logs to determine removal requirements.

Other Lower Lake sediment core samples were also collected at various times as part of the Lower Lake remediation. The extent of each of these sample collections was more limited than the 1995 effort and, typically, the samples were subjected to various leaching methods instead of total constituents by XRF. Results of these other analyses were, however, consistent with analytical results for the 1995 samples, in that, all results show substantial arsenic and metals were present in the process sludge, but decline rapidly once in the marsh deposits were encountered. Since a detailed discussion of the results of these other sampling efforts would not substantively contribute to a better understanding of the marsh deposits still in Lower Lake, that discussion is not included in this document. However, for purposes of including all the available information on Lower Lake sediment, all of the data are included in Appendix and the supplemental sampling events are outlined below.

- In October 1991, core samples were collected at eight sites. TCLP tests were conducted on these core samples.
- Additional core samples were gathered in April and May 1992 from nine sites. EPTOX and TCLP tests were conducted on these core samples and the leachate was analyzed for total arsenic and metals. During the April and May 1992 sampling period, three additional core samples of Lower Lake bottom sediments were collected; one from a previously unsampled site and two from sites originally sampled in October, 1991. These three samples were also analyzed for total arsenic and metals.
- In August of 1992, seven sites from the April and May 1992 sampling event were re-sampled and the leachate from EPA Method 1312 and EPTOX were analyzed for total arsenic and metals.
- In June 1992, one treatment sludge sample was collected from the in-situ pilot scale treatment area. This sample was analyzed for total arsenic and metals.
- In October 1992, five core samples were taken at six inch intervals (from 8.5 ft. to 11.0 ft. below the water surface) from site LH-34 which had been previously sampled in August 1992. These samples were analyzed for total arsenic and metals.

Former Thornock Lake

Former Thornock Lake was an unlined process pond used to contain plant water and storm water runoff prior to 1987. Thornock Lake was replaced with a steel tank within a concrete vault during 1986 and 1987. Prior to placement of the tank, a portion of the sediments in the former pond area were removed to a depth of five feet. At this depth, test results from the underlying coarse sediments showed that arsenic and metal concentrations were near background level (refer to Table 4-1-5, sites TH-1 and TH-2). The excavated area was

TABLE 4-1-5: FORMER THORNOCK LAKE SOIL SAMPLING RESULTS FOR ARSENIC, CADMIUM AND LEAD

Sample Site	Sample Date	Sample Depth[1]	Material	Total Metals (mg/Kg)			EP Tox (mg/L)[2]			SPLP (mg/L)[2][4]		
				As	Cd	Pb	As	Cd	Pb	As	Cd	Pb
TH-1	12/18/87	1-2 ft.	----	34950	16525	17325	----	----	----	----	----	----
	12/18/87	2-3 ft.	----	43900	35000	21075	----	----	----	----	----	----
	12/18/87	3-4 ft.	----	120375	106950	21875	----	----	----	----	----	----
	12/18/87	4-5 ft.	----	52	0.75	6.8	----	----	----	----	----	----
TH-2	12/18/87	0.5-2 ft.	----	691	242	8935	----	----	----	----	----	----
	12/18/87	2-4 ft.	----	44	3.8	221	----	----	----	----	----	----
	12/18/87	6-8 ft.	----	22	3.4	170	----	----	----	----	----	----
	12/18/87	8-10 ft.	----	53	1.9	14	----	----	----	----	----	----
	12/18/87	10-12 ft.	----	191	5.5	64	----	----	----	----	----	----
	12/18/87	15-17 ft.	----	164	3	28	----	----	----	----	----	----
	12/18/87	20-21 ft.	----	52	1.5	24	----	----	----	----	----	----
	12/18/87	25-27 ft.	----	21	1.5	41	----	----	----	----	----	----
TL-3	6/24/91	0-4 inches	Fine-grained sediments	45000	33175	158500	193	133	0.6	----	----	----
	6/24/91	4-12 inches	Fine-grained sediments	43900	23225	95000	58.5	31.3	0.3	----	----	----
	6/24/91	1-2 ft.	Fine-grained sediments	36254	15725	64000	118	58.2	1.6	----	----	----
	6/24/91	2-3 ft.	Fine-grained sediments	455	22	2183	0.2	<0.1	0.3	----	----	----
	6/24/91	3-4 ft.	Alluvium	1458	11	230	9.5	<0.1	<0.1	----	----	----
	6/24/91	4-5 ft.	Alluvium	580	14	353	6	0.1	<0.1	----	----	----
TL-4	6/24/91	0-4 inches	Fine-grained sediments	4375	2378	8875	13	16	0.5	----	----	----
	6/24/91	4-12 inches	Fine-grained sediments	550	270	990	3.2	0.6	<0.1	----	----	----
	6/24/91	1-2 ft.	Fine-grained sediments	940	458	990	1.9	0.2	<0.1	----	----	----
	6/24/91	2-3 ft.	Fine-grained sediments	375	127	61	4.8	0.3	<0.1	----	----	----
	6/24/91	3-4 ft.	Fine-grained sediments	310	105	64	4.7	0.2	<0.1	----	----	----
	6/24/91	4'-4.5'	Alluvium	535	154	66	3.6	0.1	<0.1	----	----	----
TL-001	12/10/91	3-4 ft.	GW - Sands, gravels and cobbles (to 12" dia)	1163	135	328	2.8	0.15	<0.1	1.4	0.01	<.1
TL-002	12/10/91	3-4 ft.	GW - Sands, gravels and cobbles (to 12" dia)	1788	493	5250	2.0	1.9	<0.1	0.63	0.31	<.1
TL-003	12/10/91	3-4 ft.	GW - Sands, gravels and cobbles (to 12" dia)	1053	235	1225	2.0	0.78	<0.1	1.6	0.05	<.1
TL-004	12/10/91	3-4 ft.	GW - Sands, gravels and cobbles (to 12" dia)	853	23	453	2.2	0.02	<0.1	2.0	<.01	<.1
TL-005	12/10/91	+ 1 ft.	Slag/Sludge sample (above grade)	3055	510	14,500	0.93	1.3	0.8	1.2	<.01	<.1
TL-006	12/10/91	0	F. gr. sludge intermixed with slag pieces (to 6" dia.)	750	2.2	98	0.23	<.01	<0.1	0.22	<.01	<.1
TL-007	12/10/91	1-2 ft.	F. gr. sludge intermixed with slag pieces (to 6" dia.)	513	0.91	33	<.1	<.01	<0.1	0.32	<.01	<.1
TL-008	12/10/91	2-3 ft.	Sandy, clayey, silt vermucuilte, pyrite present	1400	27	55	2.6	<.01	<0.1	3.8	<.01	<.1
TL-009	12/10/91	3-4 ft.	GW - Sands, gravels and cobbles (to 12" dia)	678	28	130	1.8	<.01	<0.1	2.2	<.01	<.1

Notes: (1) Measured from top of natural sediment - i.e., initial pond bottom elevation.

(2) EPToxicity Limits: As=5 mg/L, Cd = 0.5 mg/L, Pb = 5 mg/L

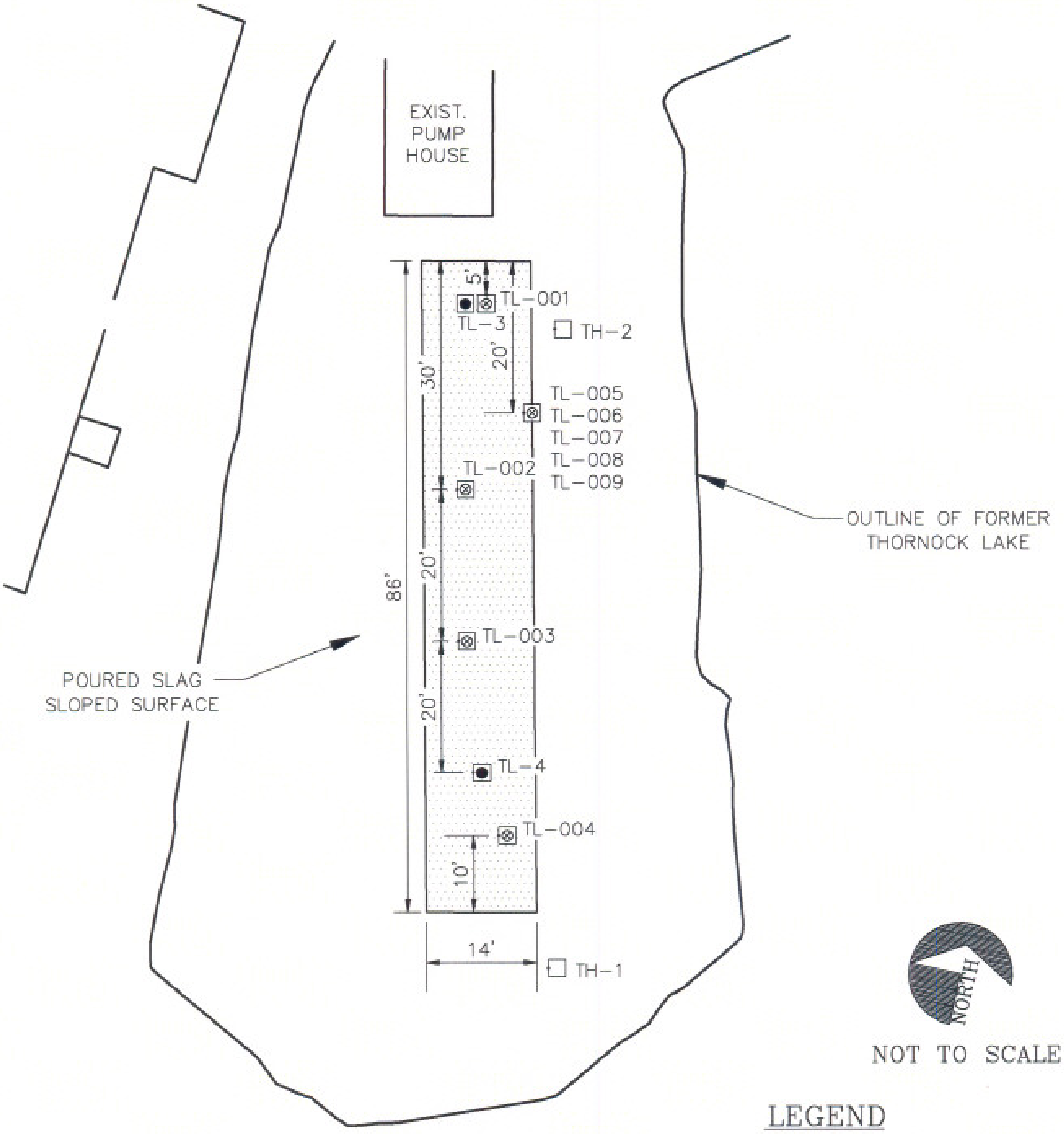
(3) SPLP - Synthetic Precipitation Leach Procedure

backfilled with clean fill to facilitate placement of the new tank and vault. Sediments excavated from Former Thornock Lake were smelted.

The 1989 Process Ponds ROD required that the remaining sediments be removed from former Thornock Lake. The depth of excavation was determined by EP toxicity testing of the sediments. In June 1991 twelve pre-excavation soil samples from Former Thornock Lake were collected from two test pits (TL-3 and TL-4), at each end of the former pond area (see Figure 4-1-3). Soil samples were collected at approximately one-foot intervals to a total depth of 4.5 feet at TL-3 and to 5 feet at TL-4. Laboratory analyses of these samples showed that the majority of the metals and arsenic were contained in fine-grained sediments that had accumulated within the former process pond (Table 4-1-5).

The Thornock Lake bottom sediments generally consisted of fine-grained, plastic, organic clay with elevated concentrations of arsenic and metals. Beneath these fine-grained sediments were coarser-grained sand, gravel and cobbles. Based on the analytical results, it was determined that slag, remaining fine-grained sediment, and 3.5 to 4 feet of the underlying coarse-grained sediment would be removed from the former pond area. Excavation was conducted in accordance with the work plan submitted to EPA on October 22, 1991 (see Remedial Action Report, Hydrometrics 1992) and under oversight provided by EPA. Approximately 185 cubic yards of slag were excavated and placed on the smelter slag pile. An additional 407 cubic yards of fine-grained sediment and alluvium were excavated and stockpiled in the Lower Ore Storage Area and subsequently smelted. The excavation area is shown on Figure 4-1-3 and Exhibit 4-1-1.

In December 1991, four soil samples (TL-001 through TL-004) were collected from the bottom of the completed excavation. Five additional samples were collected in one-foot intervals vertically at a single location along the north wall of the excavation (TL-005 through TL-009). These soil samples were submitted for analysis of total arsenic and selected metals, EP Toxicity testing, and synthetic precipitation leaching procedure testing (SPLP). Laboratory results (see Table 4-1-5) indicate arsenic and lead concentrations for all



LEGEND

□	TH-1	PRE-EXCAVATION SOIL SAMPLE LOCATION. (DECEMBER 1987)
●	TL-4	PRE-EXCAVATION SOIL SAMPLE LOCATION. (JUNE 1991)
⊠	TL-004	POST-EXCAVATION SOIL SAMPLE LOCATION. (DECEMBER 1991)

NOTE:
TH-1 & TH-2 LOCATION IS APPROXIMATE.

ASARCO INCORPORATED
CC/RA EAST HELENA FACILITY

THORNOCK LAKE SOIL EXCAVATION AND SAMPLING LOCATIONS

FIGURE
4-1-3

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Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors post-excavation samples were below EP Toxicity limits with the exception of one sample (TL-002) which exceeded EP toxicity limits for cadmium. Remedial activities for Thornock Lake are described in additional detail in Hydrometrics May 1992 report, titled “Excavation of Bottom Sediments from Former Thornock Lake.”

Speiss Pond and Speiss Pit Area

The speiss settling pond (the “Speiss Pond”) and speiss granulating pit (the “Speiss Pit”) were formerly located immediately to the north of the dross plant. Until 1991, the Speiss Pond and Speiss Pit were used to store water for use in the speiss granulation process. Speiss, a molten copper bearing material, was granulated by spraying it with water in the Speiss Pit. The water then drained to the Speiss Pond to be recirculated during the next granulating cycle. In 1991, Asarco switched to an air granulation process, which used only a light water mist, thus eliminating the need for a speiss process water circuit.

The Speiss Pond and Speiss Pit were identified early in the RI/FS process as potential sources of process water seepage to groundwater. Remediation of the Speiss Pond and Speiss Pit area was initiated in 1988 with the HDPE lining of the Speiss Pond. Later in 1988, a portion of the original Speiss Pond was removed and replaced with a tank (the “Speiss Tank”) with leak detection and secondary containment. Soils were also excavated in the surrounding area as part of grading and storm water improvements. A total of 2500 cubic yards of soil were excavated during this phase of remediation. During these initial speiss pond excavation activities, oversite was provided by EPA. The remaining portion of the Speiss Pond was removed in 1992 in accordance with the Process Pond ROD, and the Final Design Report for Sediment and Soil Excavation and Smelting (Hydrometrics 1991b). During excavation in 1992, an additional 235 cubic yards of soil were removed as EPA provided oversight (Hydrometrics 1992b). Soil was excavated to a depth of approximately 20 feet beneath the original Speiss Pond structure. Excavated Soils were subsequently stored in the Lower Ore Storage area (see Section 4.1.3 below).

The Speiss Pit was removed and replaced with a new pit in 1995 during construction of the new dross-reverberatory building. In accordance with the Process Pond ROD, and the Final Design Report for Sediment and Soil Excavation and Smelting (Hydrometrics 1991b), a total of 250 cubic yards of soil were removed to a depth of 17 feet beneath the original Speiss Pit. During excavation of the speiss pit in 1995, oversight was provided by EPA. Subsequent to excavation, the soils were stored in the Lower Ore Storage Area (see Section 4.1.3 below). The depth and lateral extent of soil excavation in the Speiss Pond and Speiss Pit area are shown in Figure 4-1-4 and Exhibit 4-1-1.

No soil sample results were recorded for the Speiss Pond demolition phase since remediation objectives were depth-based, but pre-excavation soil samples were collected at soil borings and monitoring wells and show the general distribution of metals in subsurface soils. Soils data are available from two monitoring wells (DH-21 and DH-28) and nine soil borings (SS-1 through SS-9). Two post excavation samples (SPIT-01 and SPIT-02) were also collected at the former Speiss Pit. Soil sample locations in the Speiss Pond and Speiss Pit area are shown in Figure 4-1-4. Soils from the monitoring well DH-21 and from the Speiss Pit excavation were analyzed for total arsenic and EP Toxicity testing was also conducted on soils from DH-21 and from the nine borings in the Speiss Pond area. Pre and post-excavation soils data are summarized in Table 4-1-6. Sequential extraction analyses were also run on soils from monitoring well DH-21, adjacent to the Speiss Pond excavation. The data are included in Appendix 3-1-3.

Acid Plant Water Treatment Facility

Prior to 1992, suspended sediments from the acid scrubbing process were settled in a concrete lined settling pond and in-line settling tubs (dumpsters), and neutralized by lime application at the former acid reclaim facility. This system was identified in the RI as a source of process water seepage to groundwater. A new Acid Plant Water Reclaim Facility was completed in November 1992 and the original settling pond was subsequently demolished beginning in February 1993.

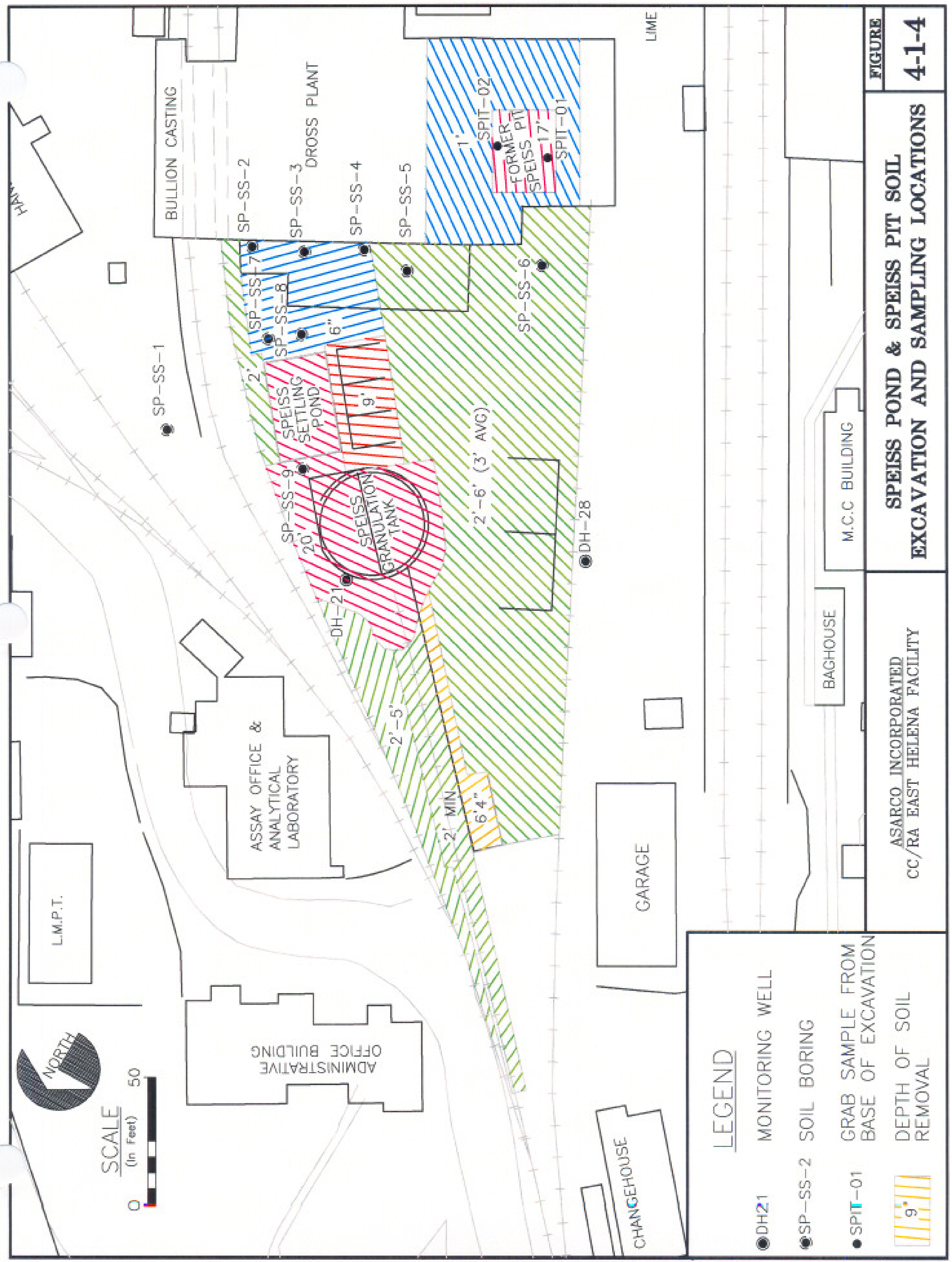

FIGURE 4-1-4

SPEISS POND & SPEISS PIT SOIL EXCAVATION AND SAMPLING LOCATIONS

ASARCO INCORPORATED
CC/RA EAST HELENA FACILITY

UPDATE TIME: 10:50AM
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Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

TABLE 4-1-6: SPEISS POND AND SPEISS PIT SOIL SAMPLING RESULTS FOR ARSENIC, CADMIUM & LEAD

Arsenic	EP Toxicity As (mg/L)										Total As (mg/Kg)			
DATE	7/25/89	7/25/89	7/25/89	7/26/89	7/26/89	7/28/89	7/28/89	7/28/89	7/28/89	4/23/87	4/23/87	12/11/87	7/24/95	7/24/95
DEPTH \ *SITE*	*SP-SS-1*	*SP-SS-2*	*SP-SS-3*	*SP-SS-4*	*SP-SS-5*	*SP-SS-6*	*SP-SS-7*	*SP-SS-8*	*SP-SS-9*	*DH-21*	*DH-21*	*DH-28*	*SPIT-01*	*SPIT-02*
surface	----	----	----	----	----	----	----	----	----	----	----	----	----	----
0-2 ft.	1.5	0.55	7.5	4.6	1	0.97	<0.2	0.49	0.82	1.5	1750	----	----	----
1-3 ft.	----	----	----	----	----	----	----	----	----		----	749	----	----
2-4 ft.	0.21	0.71	6.4	2.4	<0.2	0.23	0.27	0.2	1	0.91	198	983	----	----
4-6 ft.	<0.2	2.7	4.9	4.2	<0.2	<0.2	<0.2	0.2	<0.2	----	325	79	----	----
6-8 ft.	0.24	0.56	0.39	4.5	<0.2	<0.2	<0.2	0.2	3.4	0.025	36	----	----	----
8-10 ft.	2.3	<0.2	0.93	<0.2	0.69	<0.2	0.23	<0.2	2.9	----	----	----	----	----
10-12 ft.	0.67	0.26	0.28	1.6	0.38	<0.2	<0.2	<0.2	0.45	0.011	34	----	----	----
12-14 ft.	2.3	1.1	0.51	0.57	0.29	<0.2	0.91	<0.2	0.23	----	----	----	----	----
14-16 ft.	3.6	0.31	0.23	1.3	0.26	<0.2	<0.2	<0.2	4.9	----	43	204	----	----
16-18 ft.	<0.2	0.27	<0.2	0.64	0.25	<0.2	<0.2	<0.2	5.8	----	----	----	----	----
18-20 ft.	----	0.96	<0.2	1.7	----	<0.2	0.63	----	2.4	----	----	----	----	----
20-21 ft.	----	----	----	----	----	----	----	----	----	----	375	----	723	1425
24-26 ft.	----	----	----	----	----	----	----	----	----	----	550	285	----	----
30-31 ft.	----	----	----	----	----	----	----	----	----	----	250	545	----	----
36-38 ft.	----	----	----	----	----	----	----	----	----	----	----	32	----	----

Cadmium	EP Toxicity Cd (mg/L)										Total Cd (mg/Kg)			
DEPTH \ *SITE*	*SP-SS-1*	*SP-SS-2*	*SP-SS-3*	*SP-SS-4*	*SP-SS-5*	*SP-SS-6*	*SP-SS-7*	*SP-SS-8*	*SP-SS-9*	*DH-21*	*DH-21*	*DH-28*	*SPIT-01*	*SPIT-02*
surface	----	----	----	----	----	----	----	----	----	----	----	----	----	----
0-2 ft.	0.21	0.1	1.1	0.09	1.6	0.07	1.5	2.5	1.3	0.88	90	----	----	----
1-3 ft.	----	----	----	----	----	----	----	----	----	----	----	306	----	----
2-4 ft.	<0.05	<0.05	0.55	0.35	2.2	0.06	1.9	2	0.22	0.16	5.5	200	----	----
4-6 ft.	<0.05	0.22	0.41	<0.05	0.1	<0.05	<0.05	0.38	<0.05	----	4.5	1.1	----	----
6-8 ft.	<0.05	0.07	<0.05	0.06	0.08	<0.05	<0.05	0.1	<0.05	0.003	6	----	----	----
8-10 ft.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	----	----	----	----	----
10-12 ft.	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05	<0.05	0.001	<0.5	----	----	----
12-14 ft.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	----	----	----	----	----
14-16 ft.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	----	<0.5	1.2	----	----
16-18 ft.	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	----	----	----	----	----
18-20 ft.	----	<0.05	<0.05	<0.05	----	<0.05	<0.05	----	<0.05	----	----	----	----	----
20-21 ft.	----	----	----	----	----	----	----	----	----	----	1.5	----	<10	<10
24-26 ft.	----	----	----	----	----	----	----	----	----	----	1	27	----	----
30-31 ft.	----	----	----	----	----	----	----	----	----	----	4.5	352	----	----
36-38 ft.	----	----	----	----	----	----	----	----	----	----	----	9.8	----	----

Lead	EP Toxicity Pb (mg/L)										Total Pb (mg/Kg)			
DEPTH \ *SITE*	*SP-SS-1*	*SP-SS-2*	*SP-SS-3*	*SP-SS-4*	*SP-SS-5*	*SP-SS-6*	*SP-SS-7*	*SP-SS-8*	*SP-SS-9*	*DH-21*	*DH-21*	*DH-28*	*SPIT-01*	*SPIT-02*
surface	----	----	----	----	----	----	----	----	----	----	----	----	----	----
0-2 ft.	0.15	0.74	5.4	0.3	25	0.3	18	58	7.1	29	5500	----	----	----
1-3 ft.	----	----	----	----	----	----	----	----	----	----	----	2600	----	----
2-4 ft.	<0.1	0.19	3.1	0.79	16	0.84	17	33	2.1	1.4	170	8535	----	----
4-6 ft.	<0.1	2.1	2.9	<0.1	0.18	<0.1	0.23	3.1	<0.1	----	185	22	----	----
6-8 ft.	<0.1	0.28	0.54	<0.1	0.34	<0.1	<0.1	0.41	<0.1	<0.013	21	----	----	----
8-10 ft.	<0.1	0.12	1.8	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	----	----	----	----	----
10-12 ft.	<0.1	<0.1	0.56	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.013	11	----	----	----
12-14 ft.	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	----	----	----	----	----
14-16 ft.	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	----	12	20	----	----
16-18 ft.	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	----	----	----	----	----
18-20 ft.	----	<0.1	<0.1	<0.1	----	<0.1	<0.1	----	<0.1	----	----	----	----	----
20-21 ft.	----	----	----	----	----	----	----	----	----	----	38	----	919	4520
24-26 ft.	----	----	----	----	----	----	----	----	----	----	14	24	----	----
30-31 ft.	----	----	----	----	----	----	----	----	----	----	94	18	----	----
36-38 ft.	----	----	----	----	----	----	----	----	----	----	----	28	----	----

Notes: EPToxicity Limits: As=5 mg/L, Cd = 0.5 mg/L, Pb = 5 mg/L

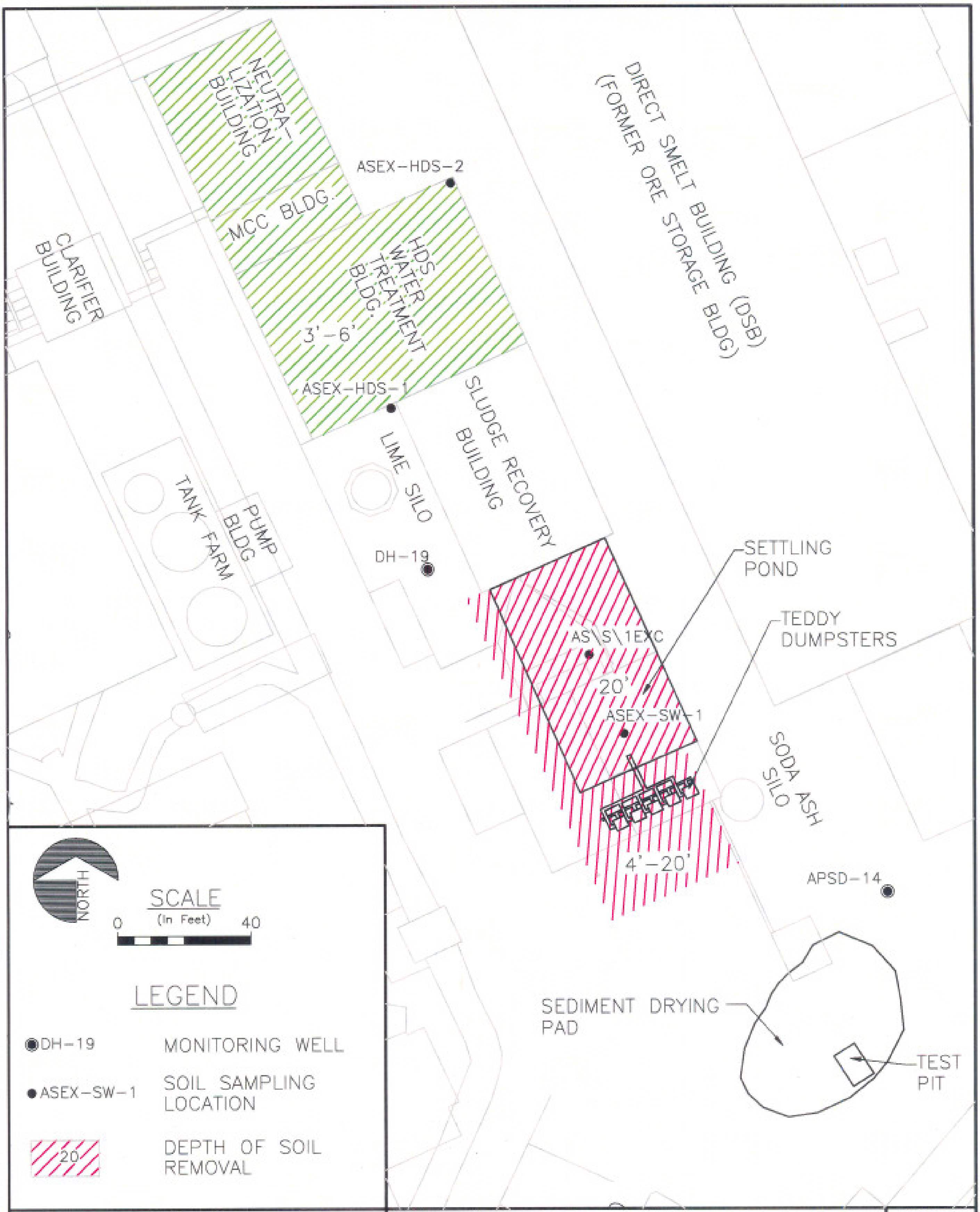
In accordance with the Process Pond ROD and the Final Design Report for Sediment and Soil Excavation and Smelting (Hydrometrics 1991b), soil was excavated to a maximum depth of approximately 20 feet at the settling pond (Hydrometrics 1992b). Because the soils were partially cemented or indurated beneath the settling pond, the excavation could be advanced 8 to 11 feet below the water table. A total of 2200 cubic yards of soil was excavated from beneath the settling pond. Soils were also excavated and sampled in the area north of the settling pond during construction of the HDS Water Treatment Facility. Figure 4-1-5 shows the limits and depth of excavations in the vicinity of the acid plant treatment facility. Excavated soils were subsequently stored in the Lower Ore Storage Area (see Section 4.1.3, below).

One pre-excavation soil sample was taken on April 1, 1993 following removal of the settling pond's concrete walls and floor (ASEX-SW-1). Excavation of soils underlying the former pond was completed on April 28, 1993. One post-excavation soil sample was taken from the settling pond excavated soil pile (AS\S\1EXC) and two samples were collected from the base of the excavation at the HDS building site (ASEX-HDS-1 and HDS-2). Soil sample locations are shown in Figure 4-1-5. These soils were analyzed for total arsenic and selected metals, and EP Toxicity.

Pre- and post-excavation sample results are summarized in Table 4-1-7. Soils data were also collected at monitoring well DH-19 immediately downgradient of the settling pond. The soil samples from DH-19 were analyzed for total arsenic and metals. Sequential extraction analyses were also run on selected samples. These data are included in the soil quality data base in Appendix 3-1-3.

Acid Plant Sediment Drying Areas

From 1977 through 1991, sludge from the Acid Plant Water Treatment Facility was stored on the Acid Plant Sediment Drying (APSD) Pad between Upper Lake and Lower Lake. In July



ASARCO INCORPORATED
CC/RA EAST HELENA FACILITY

SOIL EXCAVATION DEPTHS AT ACID PLANT WATER TREATMENT FACILITY

FIGURE
4-1-5

UPDATE TIME: 1:04PM
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Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

TABLE 4-1-7: ACID PLANT WATER TREATMENT FACILITY SOIL SAMPLING RESULTS FOR ARSENIC, CADMIUM & LEAD

Arsenic	**TCLP As (mg/L)**	**EP TOX As (mg/L)**	**Total As (mg/Kg)**				
DATE	5/17/93	4/22/87	4/22/87	4/8/93	4/8/93	4/1/93	5/17/93
DEPTH \ *SITE*	*AS\S\1EXC*	*DH-19*	*DH-19*	*ASEX-HDS-1*	*ASEX-HDS-2*	*ASEX-SW-1*	*AS\S\1EXC*
surface	----	----	----	----	----	----	----
0-2 ft.	----	0.22	2400	----	----	----	----
2-4 ft.	----	0.68	950	----	----	----	----
4-6 ft.	----	0.29	650	9591	53	----	----
6-8 ft.	----	3.5	11100	----	----	2346	----
8-10 ft.	----	12000	12000	----	----	----	----
10-12 ft.	----	10	2750	----	----	----	----
14-16 ft.	----	5.1	850	----	----	----	----
20-22 ft.	0.33	----	225	----	----	----	8548
24-26 ft.	----	0.06	175	----	----	----	----

Cadmium	**TCLP Cd (mg/L)**	**EP TOX Cd (mg/L)**	**Total Cd (mg/Kg)**				
DEPTH \ *SITE*	*AS\S\1EXC*	*DH-19*	*DH-19*	*ASEX-HDS-1*	*ASEX-HDS-2*	*ASEX-SW-1*	*AS\S\1EXC*
surface	----	----	----	----	----	----	----
0-2 ft.	----	10	480	----	----	----	----
2-4 ft.	----	6	285	----	----	----	----
4-6 ft.	----	2.7	50	305	7	----	----
6-8 ft.	----	2	690	----	----	138	----
8-10 ft.	----	425	425	----	----	----	----
10-12 ft.	----	1.2	180	----	----	----	----
14-16 ft.	----	0.37	140	----	----	----	----
20-22 ft.	6.3	230	230	----	----	----	884
24-26 ft.	----	1	120	----	----	----	----

Lead	**TCLP Pb (mg/L)**	**EP TOX Pb (mg/L)**	**Total Pb (mg/Kg)**				
DEPTH \ *SITE*	*AS\S\1EXC*	*DH-19*	*DH-19*	*ASEX-HDS-1*	*ASEX-HDS-2*	*ASEX-SW-1*	*AS\S\1EXC*
surface	----	----	----			----	----
0-2 ft.	----	49	14250	----	----	----	----
2-4 ft.	----	39	12000	----	----	----	----
4-6 ft.	----	0.22	600	13347	455	----	----
6-8 ft.	----	0.088	2600	----	----	3741	----
8-10 ft.	----	800	800	----	----	----	----
10-12 ft.	----	0.013	135	----	----	----	----
14-16 ft.	----	0.013	155	----	----	----	----
20-22 ft.	8.4	115	115	----	----	----	44325
24-26 ft.	----	0.0065	34	----	----	----	----

Notes: EP Toxicity Characteristic Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L
Toxicity Characteristic Leaching Procedure (TCLP) Regulatory Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L

of 1991, the use of Acid Plant sludge was permanently discontinued. The dried Acid Plant sludge was subsequently smelted.

Subsurface soils data have been collected from the following sites in the Acid Plant Sediment Drying area adjacent to Lower Lake:

- Monitoring well (DH-29) was drilled on the northwest side of the pad during RI activities. Soil samples were collected to a depth of 19 feet and analyzed for total arsenic and metals.
- In August of 1991, four post-RI monitoring wells (ASPD-1 through ASPD-4) were installed at sites in and adjacent to the former sediment drying area (see Exhibit 4-1-1). Drill hole soil samples were taken at two-foot intervals and analyzed for arsenic and metals using the EP Toxicity test procedure.
- In response to an EPA informational request (See Appendix 3-1-1), additional borehole samples (1-7 ft. composites) were taken at nine (9) sites in the sediment drying pad area (APSD-P1 through P4, P6, P8 and P9) in August and September of 1996. These samples were analyzed for total arsenic and metals, TCLP and synthetic precipitation leaching procedure tests (SPLP).

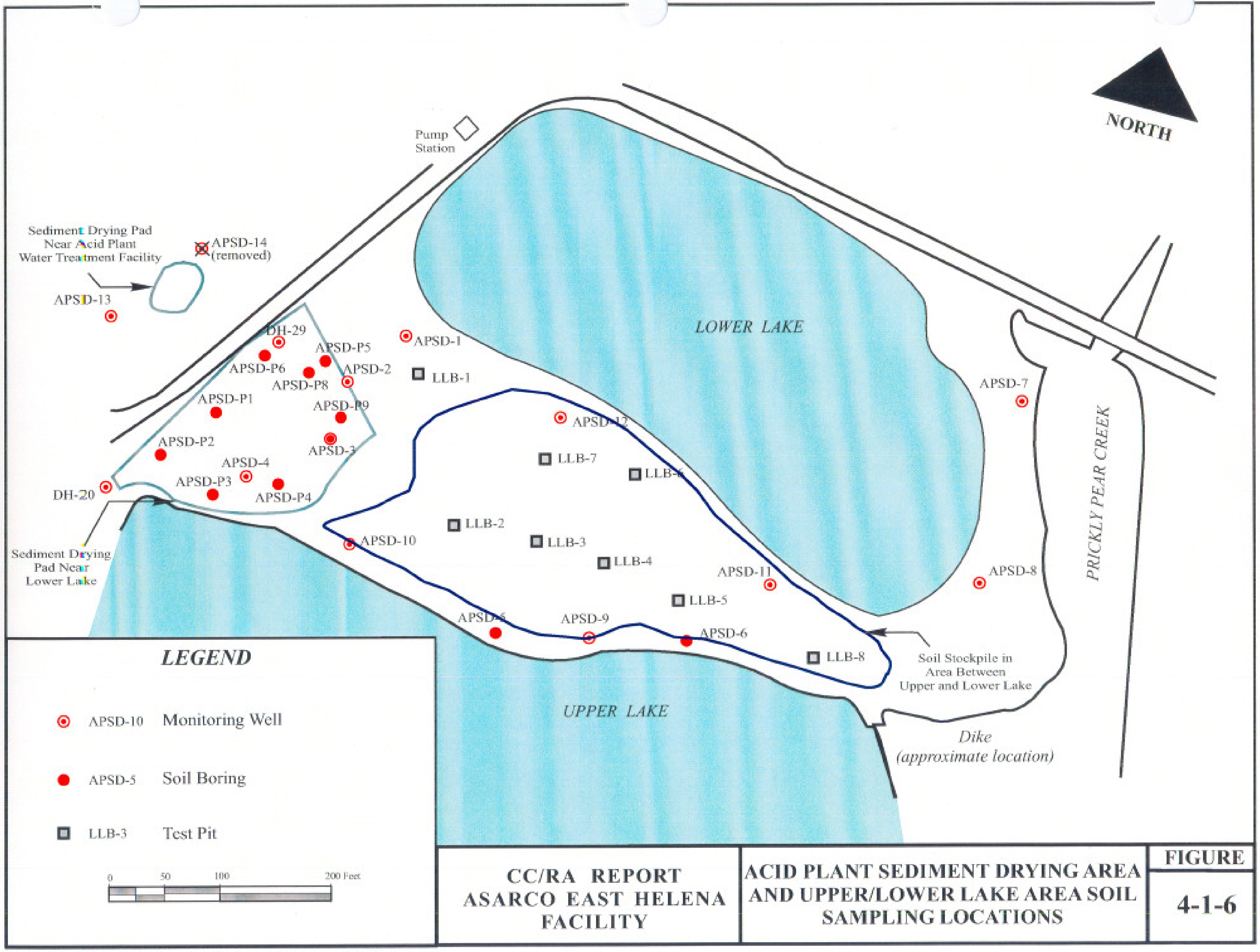
Table 4-1-8 summarizes subsurface soil data for the APSD Pad.

A second smaller sediment drying pad (0.04 acres) was located nearer to the former acid plant water treatment facility (Figure 4-1-6). APSD-13 and APSD-14 were installed nearby to evaluate soil quality. Soil samples were collected at 2 ft intervals to depths of 23 feet at APSD-13 and 16 feet at APSD-14. Soils were analyzed for total and TCLP arsenic and metals. Analytical results are summarized in Table 4-1-8. In accordance with the Process Pond ROD and the Final Design Report for Sediment and Soil Excavation and Smelting (Hydrometrics 1991 b) sediments from the small sediment drying area adjacent to the former acid plant water treatment facility (see Figure 4-1-6) were excavated. The sediments were subsequently transported to the Lower Ore Storage area for storage (see Figure 4-1-7).

TABLE 4-1-8: ACID PLANT SEDIMENT DRYING AREA SOIL SAMPLING RESULTS FOR ARSENIC, CADMIUM & LEAD

Arsenic	EP TOX As (mg/L)				TCLP As (mg/L)							Total As (mg/Kg)							
DATE	8/20/91	8/20/91	8/21/91	8/21/91	8/16/96	8/16/96	8/16/96	8/16/96	8/16/96	9/20/96	9/20/96	12/11/87	8/16/96	8/16/96	8/16/96	8/16/96	8/16/96	9/20/96	9/20/96
DEPTH \ *SITE*	*APSD-1*	*APSD-2*	*APSD-3*	*APSD-4*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*	*DH-29*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*
0-2 ft.	0.02	2.5	2.8	0.11	<0.1	3.5	1.0	0.27	22.0	5.2	17.0	1,335	310	1600	360	3100	2980	2874	5813
1-2 ft.	0.14	----	----	----								----							
2-3 ft.	----	----	----	----								----							
2-4 ft.	0.18	0.13	5.5	7.3								620							
3-5 ft.	----	----	----	----								----							
4-6 ft.	0.03	0.04	5.6	4.6								2,225							
6-8 ft.	0.04	0.02	----	2.6			Composite Samples from 0 to 7 feet					305			Composite Samples from 0 to 7 feet				
8-10 ft.	0.33	<0.02	0.52	1.8	----	----	----	----	----	----	----	335	----	----	----	----	----	----	----
9-10 ft.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
10-11 ft.	0.1	<0.02	0.45	0.08	----	----	----	----	----	----	----	342	----	----	----	----	----	----	----
11-12 ft.	----	<0.02	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
12-14 ft.	<0.02	0.09	----	0.07	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
14-16 ft.	----	0.41	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
16-18 ft.	----	0.05	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
17-19 ft.	----	----	----	----	----	----	----	----	----	----	----	82	----	----	----	----	----	----	----
Cadmium	EP TOX Cd (mg/L)																		
DEPTH \ *SITE*	*APSD-1*	*APSD-2*	*APSD-3*	*APSD-4*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*	*DH-29*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*
0-2 ft.	2	4.8	3.7	2.6	----	----	----	----	----	15.0	8.2	146	<100	420	<100	380	480	844	602
1-2 ft.	0.25	----	----	----	----	----	----	----	----			----							
2-3 ft.	----	----	----	----	----	----	----	----	----			----							
2-4 ft.	0.15	0.11	4	1.5	----	----	----	----	----			119							
3-5 ft.	----	----	----	----	----	----	----	----	----			----							
4-6 ft.	0.03	0.07	8.6	0.1	----	----	----	----	----			120							
6-8 ft.	<0.01	0.07	----	<0.01	----	----	----	----	----			58			Composite Samples from 0 to 7 feet				
8-10 ft.	<0.01	0.04	0.8	0.01	----	----	----	----	----	----	----	40	----	----	----	----	----	----	----
9-10 ft.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
10-11 ft.	<0.01	0.05	0.28	<0.01	----	----	----	----	----	----	----	27	----	----	----	----	----	----	----
11-12 ft.	----	0.05	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
12-14 ft.	<0.01	0.12	----	<0.01	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
14-16 ft.	----	0.06	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
16-18 ft.	----	0.1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
17-19 ft.	----	----	----	----	----	----	----	----	----	----	----	27	----	----	----	----	----	----	----
Lead	EP TOX Pb (mg/L)																		
DEPTH \ *SITE*	*APSD-1*	*APSD-2*	*APSD-3*	*APSD-4*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*	*DH-29*	*APSD-P1*	*APSD-P2*	*APSD-P3*	*APSD-P4*	*APSD-P6*	*APSD-P8*	*APSD-P9*
0-2 ft.	50	3	0.02	2.5	----	----	----	----	----	5.2	0.6	26800	4900	4800	3100	610	11100	7589	1869
1-2 ft.	0.9	----	----	----	----	----	----	----	----			----							
2-3 ft.	----	----	----	----	----	----	----	----	----			----							
2-4 ft.	0.66	0.1	<0.02	0.04	----	----	----	----	----			2265							
3-5 ft.	----	----	----		----	----	----	----	----			----							
4-6 ft.	0.1	0.03	<0.02	<0.02	----	----	----	----	----			1038							
6-8 ft.	0.05	0.07	----	<0.02	----	----	----	----	----			6720			Composite Samples from 0 to 7 feet				
8-10 ft.	0.08	0.04	0.03	<0.02	----	----	----	----	----	----	----	5070	----	----	----	----	----	----	----
9-10 ft.	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
10-11 ft.	0.03	0.03	0.02	<0.02	----	----	----	----	----	----	----	9523	----	----	----	----	----	----	----
11-12 ft.	----	0.06	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
12-14 ft.	0.02	0.14	----	<0.02	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
14-16 ft.	----	0.33	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
16-18 ft.	----	0.07	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
17-19 ft.	----	----	----	----	----	----	----	----	----	----	----	483	----	----	----	----	----	----	----

Notes: EP Toxicity Characteristic Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L.
Toxicity Characteristic Leaching Procedure (TCLP) Regulatory Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L.



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ACID PLANT SEDIMENT DRYING AREA AND UPPER/LOWER LAKE AREA SOIL SAMPLING LOCATIONS

FIGURE
4-1-6

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PLANT AREA
SOIL STOCKPILES

FIGURE
4-1-7

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Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

Former Upper Ore Storage Area between Upper Lake and Lower Lake

The area between Upper and Lower Lake formerly contained stockpiles of ore and fluxes, as well as soil piles and construction debris from historical plant site activities. Storage of ore in this area was discontinued in 1989 and remaining ore materials were removed (see Figure 4-1-7).

Soil quality data were collected between Upper and Lower Lake as part of several investigations.

- Eight exploratory test pits (LLB-1 through LLB-8) were excavated and sampled in 1990. Soil samples were collected from the test pits at depths of 1 to 2 feet, 2 to 3 feet, 3 to 5 feet and 9 to 10 feet. These samples were analyzed for total and TCLP metals. The test pits were exploratory in nature and were not conducted as part of the RD/RA program.
- Soil samples were also collected between Upper and Lower Lake in October 1993 during installation of monitoring wells APSD-9 through APSD-12. Soil samples were collected at two-foot intervals to depths of 14 to 16 feet and analyzed for total arsenic and metals.

Sample locations are shown in Figure 4-1-6. The test pit and APSD drilling and analytical results were presented and discussed in the March 1994 Pre-Final (90%) Design Report for Lower Lake and are summarized in Table 4-1-8.

The soils data from APSD 9 through 12 show soil arsenic concentrations ranging from 58 mg/kg to 2,525 mg/kg in the soil pile areas between Upper and Lower Lakes with the highest concentrations present at DH-9 and DH-10 at depths of 8 to 10 feet. Similar or higher concentration ranges were reported at shallow depths in test pits LLB-1 through LLB-8. Cadmium concentrations ranged from 1 to 396 mg/kg in the APDS wells and lead ranges from 366 to 28,651 mg/kg. All eight of the LLB test pit locations had samples failing TCLP for 1 or more parameters (see results in Table 4-1-9).

TABLE 4-1-9: UPPER AND LOWER LAKE AREA SOIL SAMPLING RESULTS FOR ARSENIC, CADMIUM & LEAD

APSD SITES										
Arsenic	EP Tox As (mg/L)		Total As (mg/Kg)							
DATE	8/21/91	8/21/91	10/20/93	10/20/93	10/20/93	10/20/93	10/20/93	10/20/93	10/25/93	10/20/93
DEPTH \ *SITE*	*APSD-5*	*APSD-6*	*APSD-7*	*APSD-8*	*APSD-9*	*APSD-10*	*APSD-11*	*APSD-12*	*APSD-13*	*APSD-14*
0-2 ft.	0.15	0.34	1256	509	543	1299	850	881	7433	----
2-4 ft.	0.18	0.07	293	----	851	895	1266	738	7443	3379
4-6 ft.	0.21	0.03	202	352	1631	891	81	191	7551	15778
6-8 ft.	0.08	0.14	378	----	1754	1954	217	68	5952	9319
8-10 ft.	0.12	0.11	----	320	2391	2525	130	----	5167	10686
10-12 ft.	0.02	0.02	----	326	1461	1242	112	94	5757	----
10-16 ft.	----	----	443	----	----	----	----	----	----	----
12-14 ft.	0.03	0.07	----	93	840	1184	59	80	7194	13842
14-16 ft.	0.03	----	----	68	471	462	----	----	2724	1232
16-18 ft.	----	----	----	----	----	----	----	----	2324	----
18-20 ft.	----	----	----	----	----	----	----	----	1233	----
19-21 ft.	----	----	----	----	----	----	----	----	1760	----
21-23 ft.	----	----	----	----	----	----	----	----	945	----
Cadmium	EP Tox Cd (mg/L)		Total Cd (mg/Kg)							
DEPTH \ *SITE*	*APSD-5*	*APSD-6*	*APSD-7*	*APSD-8*	*APSD-9*	*APSD-10*	*APSD-11*	*APSD-12*	*APSD-13*	*APSD-14*
0-2 ft.	0.36	5.2	336	116	113	125	244	158	111	----
2-4 ft.	0.12	0.22	152	----	80	230	329	396	107	99
4-6 ft.	0.37	0.95	50	19	43	187	9	49	130	349
6-8 ft.	0.13	2.6	46	----	37	288	37	24	127	485
8-10 ft.	0.22	1.9	----	32	42	220	24	----	102	489
10-12 ft.	0.17	0.97	----	16	34	110	11	24	81	----
10-16 ft.	----	----	47	----	----	----	----	----	----	----
12-14 ft.	0.2	0.13	----	1	23	69	6	7	113	509
14-16 ft.	0.28	----	----	2	21	33	----	----	101	965
16-18 ft.	----	----	----	----	----	----	----	----	172	----
18-20 ft.	----	----	----	----	----	----	----	----	165	----
19-21 ft.	----	----	----	----	----	----	----	----	176	----
21-23 ft.	----	----	----	----	----	----	----	----	263	----
Lead	EP Tox Pb (mg/L)		Total Pb (mg/Kg)							
DEPTH \ *SITE*	*APSD-5*	*APSD-6*	*APSD-7*	*APSD-8*	*APSD-9*	*APSD-10*	*APSD-11*	*APSD-12*	*APSD-13*	*APSD-14*
0-2 ft.	1.8	45	34521	10071	6875	20507	11895	11315	256	----
2-4 ft.	0.85	4.9	4433	----	6436	29431	17064	9060	149	197730
4-6 ft.	1.9	10.6	2921	748	8878	21943	439	1213	197	16794
6-8 ft.	0.12	26	2150	----	6862	28651	1736	406	90	7103
8-10 ft.	2.5	13.3	----	1405	7907	24971	961	----	81	12959
10-12 ft.	0.26	5.1	----	615	7005	7107	430	542	77	----
10-16 ft.	----	----	1714	----	----	----	----	----	----	----
12-14 ft.	0.59	0.59	----	223	3613	4097	258	366	197	16430
14-16 ft.	1	----	----	187	2526	1996	----	----	295	538
16-18 ft.	----	----	----	----	----	----	----	----	298	----
18-20 ft.	----	----	----	----	----	----	----	----	8053	----
19-21 ft.	----	----	----	----	----	----	----	----	47	----
21-23 ft.	----	----	----	----	----	----	----	----	51	----

LLB SITES																
Arsenic	TCLP As (mg/L)								Total As (mg/Kg)							
DATE	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90	11/7/90
DEPTH \ *SITE*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*
0-2 ft.	28	3.5	513	0.97	8.5	1.5	1.2	19	2100	780	27000	2800	<30	1800	1800	13000
2-3 ft.	0.66	0.85	1.2	0.62	0.57	0.48	16	1.2	70	1200	1900	610	2400	8000	3500	2700
3-5 ft.	0.21	0.54	0.27	0.41	----	0.19	----	----	50	440	900	7700	----	3300	----	----
9-10 ft.	2.2	0.37	----	<0.1	----	----	----	----	50	<30	----	1000	----	----	----	----
Cadmium	TCLP Cd (mg/L)								Total Cd (mg/L)							
DEPTH \ *SITE*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*
0-2 ft.	13	0.9	126	35	0.33	6.6	12	43	480	90	5900	950	<10	290	380	3000
2-3 ft.	0.3	3.3	7.7	2	12	8.8	14	14	20	210	380	250	500	830	650	780
3-5 ft.	0.32	3	3.7	12	----	4.7	----	----	10	110	130	4100	----	700	----	----
9-10 ft.	0.35	0.15	----	2	----	----	----	----	20	<10	----	80	----	----	----	----
Lead	TCLP Pb (mg/L)								Total Pb (mg/L)							
DEPTH \ *SITE*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*	*LLB-1*	*LLB-2*	*LLB-3*	*LLB-4*	*LLB-5*	*LLB-6*	*LLB-7*	*LLB-8*
0-2 ft.	3.3	0.68	1.2	184	2.2	51	176	51	2400	4600	7700	11000	460	15000	18000	11000
2-3 ft.	2	36	100	161	240	88	11	179	590	6300	16000	12000	37000	45000	6200	24000
3-5 ft.	2.1	12	153	53	----	130	----	----	570	3500	9600	41000	----	15000	----	----
9-10 ft.	4.8	0.62	----	45	----	----	----	----	620	580	----	7900	----	----	----	----

Notes: EP Toxicity Characteristic Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L
Toxicity Characteristic Leaching Procedure (TCLP) Regulatory Limits: As 5 mg/L, Cd = 1 mg/L, Pb = 5 mg/L

~~1.1.3~~4.1.3 Stockpiles

There are four stockpiles areas on the plant site (Figure 4-1-7) consisting of the following:

1. Soil stockpiles between Upper Lake and Lower Lake (estimated 17,000 cubic yards);
2. The Shew Ridge soil stockpile along the western boundary of the lower ore storage yard (volume unknown);
3. The Lower Lake sediment stockpile in the lower ore storage area (27,000 cubic yards); and
4. The lower ore storage area stockpiles (24,000 cubic yards).

Asarco has proposed constructing an on-site containment facility, which would serve as a remedial action measure for a large portion of these soils. A Corrective Action Management Unit (CAMU) Draft Design Report (Hydrometrics, 1997b) describing this proposal has been submitted to EPA for review and comment.

Stockpiles between Upper and Lower Lake

The area between Upper and Lower Lake formerly served as the Upper Ore Storage Area and contained stockpiles of ore and fluxes, as well as soil piles and construction debris from historical plant site activities. Storage of ore in this area was discontinued in 1989 and remaining ore materials were removed. However, piles of soil and construction debris remain.

Soil samples were collected from existing stockpiles in 1994 as part of the preliminary design analysis for the CAMU and analyzed for total arsenic and lead. The sample results are shown on Exhibit 4-1-4. Thirty eight separate samples were collected from soil stockpiles in area between Upper Lake and Lower Lake (see sample results on Exhibit 4-1-4 for Pile#101 through Pile#115). The sampling results indicate arsenic is present in soil stockpiles at concentrations ranging from 228 to 14,290 mg/kg and lead at concentrations ranging from 3,004 to 46,341 mg/kg. Asarco has included removal of all of the soil stockpiles from this area as part of a CAMU proposal (see Section 5).

<THE FOLLOWING DISCUSSION OF SUBSURFACE SOIL QUALITY DATA HAS BEEN MOVED TO SECTION 4-1-4>

~~Soil quality data were collected between Upper and Lower Lake as part of several investigations.~~

- ~~Eight exploratory test pits were excavated and sampled in 1990. Soil samples were collected from the test pits at depths of 1 to 2 feet, 2 to 3 feet and 3 to 5 feet and analyzed for total and TCLP metals. The test pits were exploratory in nature and were not conducted as part of the RD/RA program.~~
- ~~Four boreholes (APSD 1 through 4) were completed in the former acid plant sediment drying area adjacent to Lower Lake and two boreholes (APSD-5 and APSD-6) were drilled in the area between Upper and Lower Lakes in 1991. Soil samples were collected at 2 foot intervals to depths of 14 to 17 feet. The samples were analyzed for EP Toxicity.~~
- ~~Soil samples were also collected between Upper and Lower Lake in October 1993 during installation of monitoring wells APSD-9 through APSD-12. Soil samples~~
- ~~were collected at two-foot intervals to depths of 14 to 16 feet and analyzed for arsenic and metals by XRF.~~

~~Sample locations are shown in Figure 4-1-3. The test pit and APSD drilling and analytical results were presented and discussed in the Pre-Final (90%) Lower Lake Remediation Project~~

~~FIGURE 4-1-3. SOIL BORING, MONITORING WELL BORING AND TEST PIT LOCATIONS IN THE UPPER.LOWER LAKE AREA~~
~~(K:\DATA\PROJECT\0867\ULLOCAT.CDR)~~

~~Report in March 1994 (Hydrometrics, 1994b). The analytical results are in the CC/RA soil data base in Appendix 3-1-2, and soil boring and monitoring well logs are in Appendix 4-4-1.~~

~~The soils data from APSD 9 through 12 show soil arsenic concentrations ranging from 58 mg/kg to 2,525 mg/kg in the soil pile areas between Upper and Lower Lakes with the highest concentrations present at DH-9 and DH-10 at depths of 8 to 10 feet. Similar or higher concentration ranges were reported at shallow depths in test pits LLB-1 through LLB-8. Cadmium concentrations ranged from 1 to 396 mg/kg in the APDS wells and lead ranges from 366 to 28,651 mg/kg. All eight of the LLB test pit locations had samples failing TCLP for 1 or more parameters (see results in Appendix 3-1-2).~~

~~A Supplemental Environmental Investigation (SEP) for the area between Upper and Lower Lakes is in progress and specifies removal of contaminated stockpile soils from this area. A remedial action plan addressing soil removal in this area has not been completed. However, Asarco has included removal of soil stockpiles from this area in the CAMU proposal (see Section 5).~~

Shew Ridge, Lower Lake Sediment and Lower Ore Storage Stockpiles

In 1989, a new concentrate storage and handling building (CSHB) was constructed ~~as part of the ROD requirements~~ to contain ore stockpiles stored outdoors in the ore storage yard. During construction, soils from the building excavation were visually segregated and then later tested by EPTOX. Soils passing EPTOX were placed in the Shew Ridge soil stockpile along the western perimeter of the lower ore storage yard. The remaining soils were placed in a second stockpile in the lower ore storage yard (Figure 4-1-7). The original EPTOX analyses were not located during the file review for this project. Additional sampling is, therefore, included as an identified data need for establishing the final disposition of soils in the Shew Ridge soil stockpile (see Section 5).

In addition to soils excavated during construction of the CSHB, the lower ore storage area also contains soils excavated as a result of lead SIP and CERCLA remedial activities on site. In 1994, there was a total of about 50 separate piles in the lower ore storage area consisting of a variety of materials including excavated soils, concrete rubble, wood, fines, asphalt~~,~~ and slag ~~and organic matter~~. Material from those stockpiles was sampled and analyzed by XRF for lead and arsenic. Analytical results are in Appendix 3-1-3 ("pile" series samples) and are summarized on Exhibit 4-1-4. Average concentrations of lead and arsenic were 20,900 ppm and 3250 ppm, respectively. Those materials have since been consolidated into one area of the lower ore storage yard next to the Lower Lake sediments (Figure 4-1-7). Asarco has recommended the 24,000 cubic yards of material in stockpiles in this area be placed in the proposed CAMU.

A Lower Lake sediment stockpile is also in the Lower Ore Storage Area. Sampling and dredging of bottom sediments from Lower Lake was one of the remedial actions specified in EPA's 1989 ROD. The dredged sediments were mechanically dewatered and the filter cake from the dewatering operation was transported to an interim covered stockpile in the Lower Ore Storage Area.

Prior analyses of soil cores from Lower Lake indicate that these sediments would likely fail TCLP (see Appendix 3-1-1, "LLB series data"). Accordingly, the ROD required that the dewatered sediments by stored in the concentrate storage and handling building (CSHB) until they could be smelted. During remedial design, it was discovered that the volume of dried sediments would be too great to store in the CSHB. A Short-Term Storage Plan (Hydrometrics 1997d) was prepared and submitted to EPA. Following EPA review of the Short-Term Storage Plan, a temporary cover for the dewatered sediments was implemented. As a result, the sediments currently reside in a short-term storage facility located in the ore storage area. The sediments are being stored in a protected environment to prevent contamination of the adjacent area from dispersion of the sediments by wind and water. The sediments are located on a concrete pad to prevent contact with adjacent soils. A containment berm around the perimeter of the sediment pile diverts run-on. A geomembrane cover over the sediments prevents wind and water dispersion and eliminates subsequent generation of leachate.

Approximately 31,000 cubic yards of dewatered sediments were transported to the Lower Ore Storage Area. Four thousand cubic yards of these sediments were smelted prior to the stockpile being covered with a geomembrane liner in October 1997. The sediments will remain in this interim storage facility while EPA considers Asarco's request to modify the sediment smelting requirement of the ROD, and instead dispose of these materials in the on-site CAMU.

4.1.4 Slag

The effect of the slag pile on groundwater and surface water was evaluated as part of the 1990 Comprehensive RI/FS. The evaluation was conducted in accordance with procedures presented in the Comprehensive RI/FS Work Plan (Hydrometrics 1987). Based on the results of the evaluation, the RI/FS concluded that the potential for impacts to groundwater and surface water from slag is low and the subsequent ROD did not specify any remedial action for the Slag Pile Operable Unit. Post-RI/FS monitoring at adjacent surface water and groundwater monitoring sites is on-going. A summary of the slag investigation and the findings of the RI relative to slag are presented below.

4.1.4.1 Investigation of Potential Groundwater Impacts

Slag Infiltration Test Basin Construction, Water Level Measurement, Water Quality Sampling and Analysis

Infiltration and percolation of precipitation into the slag pile were directly measured in slag test basins constructed in fumed and unfumed slag. Fumed slag is a by-product of the zinc recovery process, which consisted of air injection into molten slag to recover zinc oxide. Unfumed slag is a by-product of the blast furnace which has not been further processed through the zinc recovery process. The zinc recovery process was suspended in 1982 and zinc is no longer recovered from the slag. Since 1982, unfumed slag has been placed in an area segregated from fumed slag.

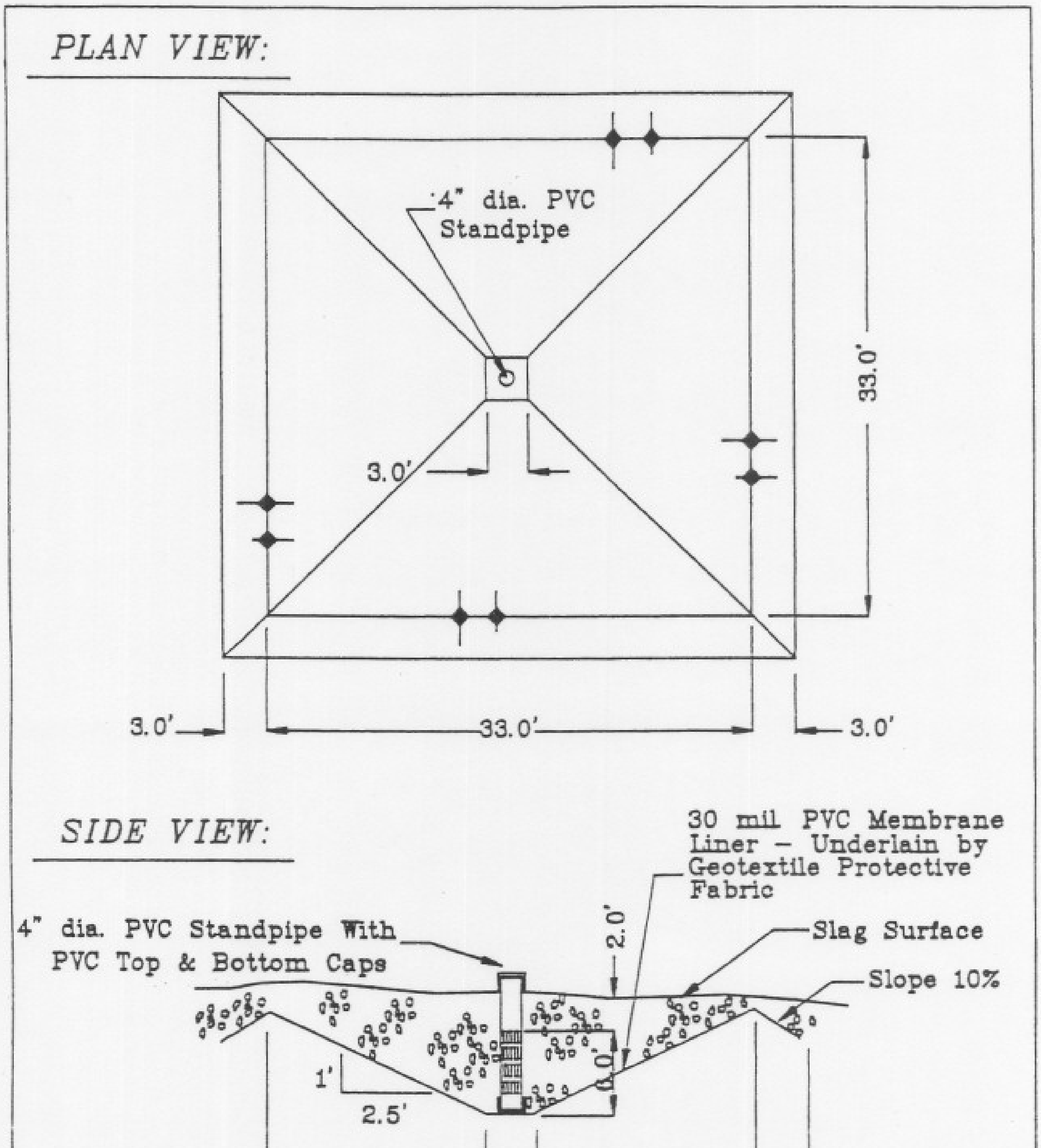
Two slag infiltration catchment basins were constructed; one in a typical location in the fumed slag, and one in a typical location in unfumed slag. Construction of the test basins included removal of a 2 to 3 meter layer of slag, placement of an impervious 36-mil reinforced Hypalon liner in the excavation, installation of a collection sump, and replacement of the slag. Figure 4-1-8 shows the slag test basin design.

Water elevations in the collection sumps were measured periodically, and after rainfall or snowmelt events to determine the actual accumulation of water in the slag basins. Collected water was pumped from the sump, sent to the TSC laboratory, and tested for the parameters listed in Table 3-2-2. Analytical results of water collected in the test basins are summarized in Appendix 4-1-2.

Slag Material Sampling and Analysis

To supplement slag information collected from the test basins, samples of slag were collected from the test basin sites and sent to the TSC lab for "bottle roll" tests. Estimates of slag leachability were obtained by conducting "bottle roll" test on slag samples. Bottle roll tests involved placing samples of slag in bottles in the laboratory, adding deionized water, agitating the bottles for approximately 24 hours, then analyzing the water for concentrations of arsenic and metals. Details of the bottle roll extraction tests are in the Quality Assurance Project Plan (QAPP) Addendum to the Phase II Water Resources Investigation Work Plan (Hydrometrics, 1986). Bottle roll test results are in Appendix 4-1-2.

FIGURE 4-1-8 SLAG TEST BASIN DESIGN



NOTE: PVC Standpipe is schedule 40, capped on both ends and perforated with saw-cut slots from 2.0' to 8.0' beneath the slag surface.

In addition to the slag sampling and bottle roll test performed as part of the East Helena RI activities, additional slag samples were collected and analyzed using the EP toxicity procedure. Results of these analyses are also in Appendix 4-1-2.

Assessment of Groundwater Impacts

In an effort to estimate infiltration rates, the volume of water retained in the slag test basins was calculated for 13 time intervals, beginning December 23, 1986 and ending February 10, 1988. These volumes were compared to the volumes of precipitation during the same periods and converted to percentages, as summarized in Table 4-1-10. The percentage of precipitation retained in the basins varied from -6.7% to 61.9% in the fumed slag, and -45% to 61.8% in the unfumed slag (negative percentages indicate evaporation rates exceed precipitation collected in the test basins). Although there is a relationship of test basin water level fluctuations to precipitation (see Figures 4-1-9 and 4-1-10), the relationship may be complicated by variable evaporation, hence, infiltration rates are variable.

Concentrations of arsenic and metals from test basin water samples **(**see Appendix 4-1-2**)** were low compared to plant area groundwater. Dissolved arsenic varied from 0.0198 mg/l to 0.075 mg/l in the fumed slag, and 0.353 to 0.590 mg/l in the unfumed slag during the study period. Dissolved cadmium varied from 0.003 to 0.075 mg/l in the fumed slag, and 0.003 to 0.0063 mg/l in the unfumed slag. Dissolved lead varied from 0.016 to 0.045 mg/l in the fumed slag, and 0.021 to 0.098 mg/l in the unfumed slag.

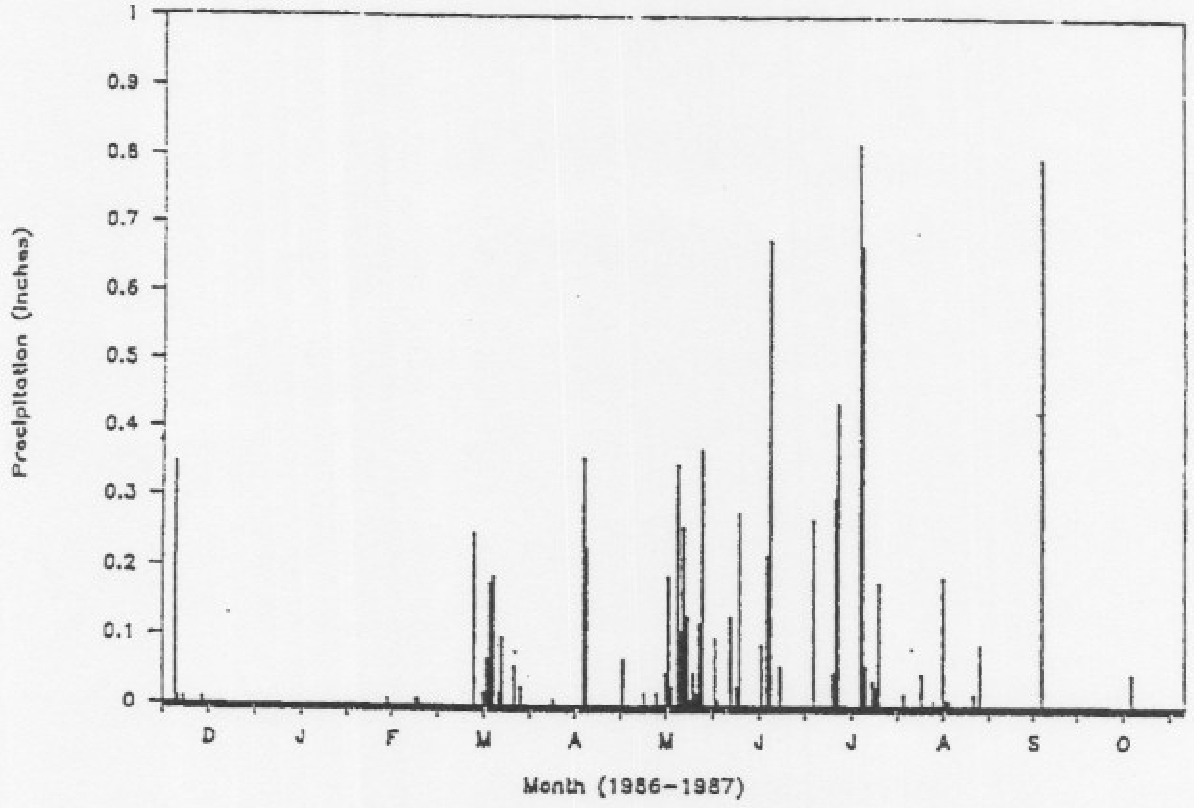
The concentrations of arsenic and metals from bottle roll testing (See Appendix 4-1-2**)** were similar to the slag test basin water quality. For the fumed slag, dissolved arsenic was 0.19 mg/l, cadmium was 0.003 mg/l, and lead was less than 0.017 mg/l. For the unfumed slag, dissolved arsenic was 0.31 mg/l, cadmium was 0.003 mg/l and lead was 0.083 mg/l.

EP toxicity tests (see Appendix 4-1-2**)** indicate that leachable trace element concentrations from the slag are variable. From 18 tests, the results for arsenic varied from below detection level to 1.2 ppm with an average of 0.16 ppm; cadmium varied from below detection level to

TABLE 4-1-10. PRECIPITATION COLLECTED IN SLAG TEST BASINS

FUMED SLAG			
Date	**Precipitation (inches)**	**Precipitation Retained * (Inches)**	**Percent of Precipitation Retained**
12/23/86			
1/22/86	0		
2/23/87	0		
3/26/87	0.75	0.01	1.4
4/21/87	0.23	-0.01	-5.8
5/18/87	0.51	0.32	61.9
6/18/87	2.46	0.49	19.8
7/14/87	0.88	0.25	28.7
8/11/87	1.70	0.36	21.2
9/11/87	0.37	not calculated	
10/14/87	0.65	0.25	38.4
12/7/87	0.45	-0.02	-3.9
1/20/88	0.34	-0.02	-6.7
2/10/88	0.49	-0.01	-1.1
UNFUMED SLAG			
12/23/86			
1/22/87	0		
2/23/87	0		
3/26/87	0.75	0	
4/21/87	0.23	0.12	52.7
5/18/87	0.51	0.27	53.6
6/18/87	2.46	0.73	29.8
7/14/87	0.88	0.28	31.7
8/11/87	1.70	0.12	7.2
9/11/87	0.37	not calculated	
10/14/87	0.65	0.40	61.8
12/7/87	0.45	-0.05	-12.1
1/20/88	0.34	-0.15	-45.0
2/10/88	0.49	0.14	27.6

* Value is calculated based on measured water level changes and test basin geometry (Frustum of a general pyramid). Negative values indicate evaporation exceeds infiltration.



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DAILY PRECIPITATION
AT HELENA AIRPORT

FIGURE

4-1-9

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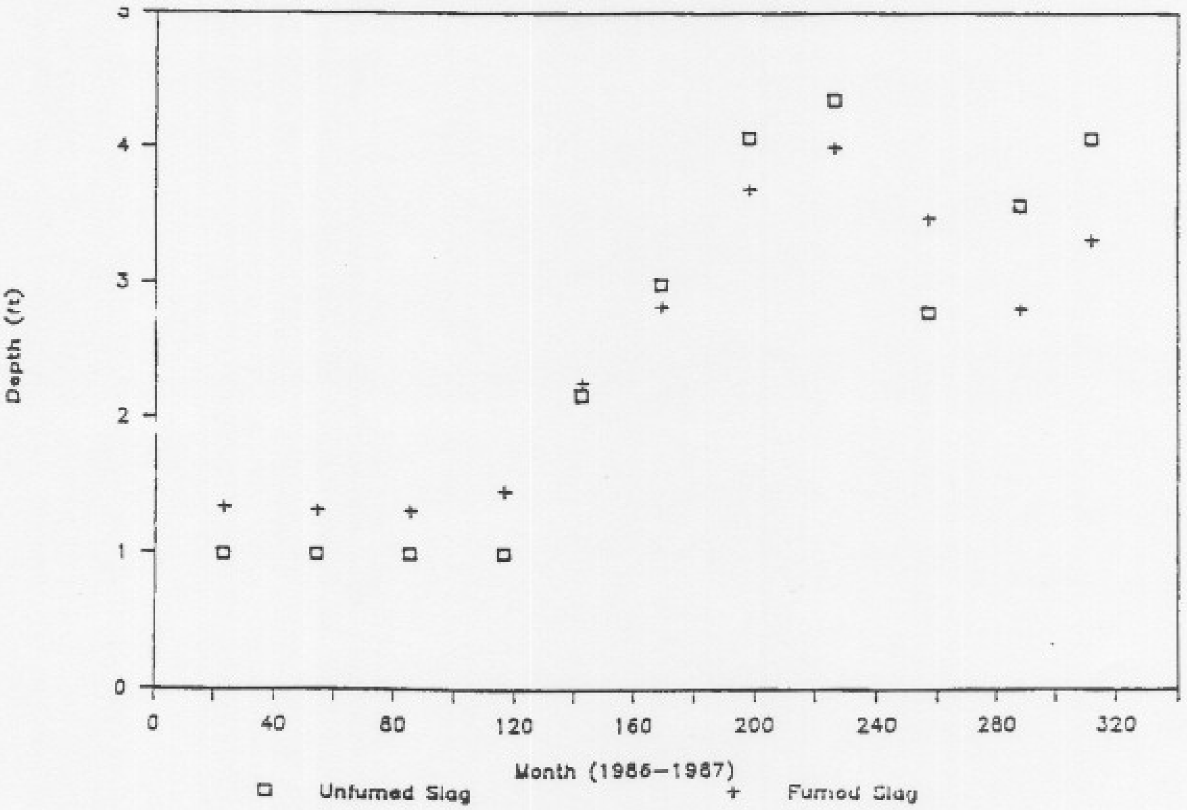
FIGURE SOURCE: COMPREHENSIVE RI/FS (ASARCO, 1990)



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FACILITY

DEPTH OF WATER IN
SLAG TEST BASIN

FIGURE
4-1-10

FIGURE SOURCE: COMPREHENSIVE RI/FS (ASARCO, 1990)

3.9 ppm, with an average of 0.26 ppm (only one cadmium value was greater than 0.25 ppm; if the 3.9 ppm value is dropped, the cadmium average concentration is 0.04 ppm); lead values varied from below detection level to 30 ppm, with an average of 5.2 ppm.

The EP Toxicity tests were not conducted as part of the Comprehensive RI/FS activities, but have been included as supplementary data. The EP Toxicity results tend to overpredict the mobility of metals compared to the other test results and observed site conditions due to the low pH of the extractant. In particular, the values for lead appear to be much higher with TCLP than with natural conditions.

Concentrations of arsenic and other metals in the groundwater system are discussed in detail in Section 4.4. In general, results of water quality from the slag basins and bottle roll analyses of slag indicate arsenic concentrations are significantly lower than concentrations observed in monitoring wells both upgradient and downgradient of the slag pile. Figures 4-1-11, 4-1-12, 4-1-13 and 4-1-14 show a comparison to slag test basin water quality, bottle roll test water quality, EP Tox test results, and groundwater quality upgradient and down gradient of the slag pile.

Based on observed recharge rates in the slag test basins and associated water quality data, the slag pile would account for only 1 to 3 percent of the observed arsenic at downgradient monitoring well DH-10 (see Figure 4-1-15). Concentrations of arsenic in these wells are similar to arsenic concentrations in DH-4 near Lower Lake, the apparent source of elevated arsenic in these wells. Based on the results of test basin water quality analyses and bottle roll tests, it is unlikely that slag significantly effects observed arsenic concentration trends on the site.

While EP-Toxicity results indicate that there is some potential for mobility of cadmium, lead and zinc from slag, the results of the test basins and bottle roll tests indicate metals concentrations released from slag is low. In addition, concentrations of cadmium, lead and

FIGURE 4-1-11. ARSENIC CONCENTRATION DATA FROM GROUNDWATER MONITORING WELLS IN THE SLAG PILE AREA, AND FROM SLAG TEST BASIN AND SLAG LEACHABILITY TESTING RESULTS

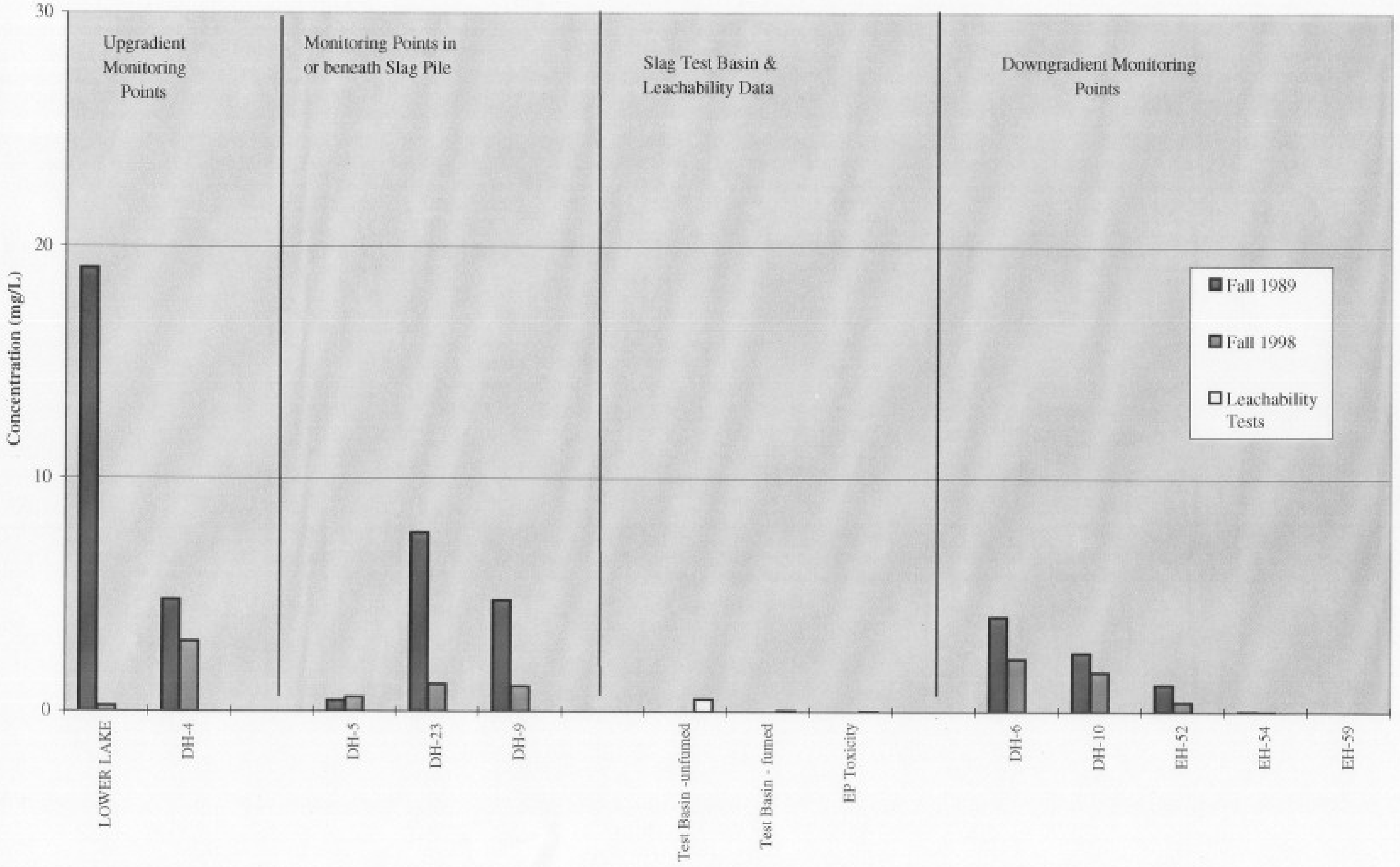

FIGURE 4-1-12. CADMIUM CONCENTRATION DATA FROM GROUNDWATER MONITORING WELLS IN THE SLAG PILE AREA, AND FROM SLAG TEST BASIN AND SLAG LEACHABILITY TESTING RESULTS

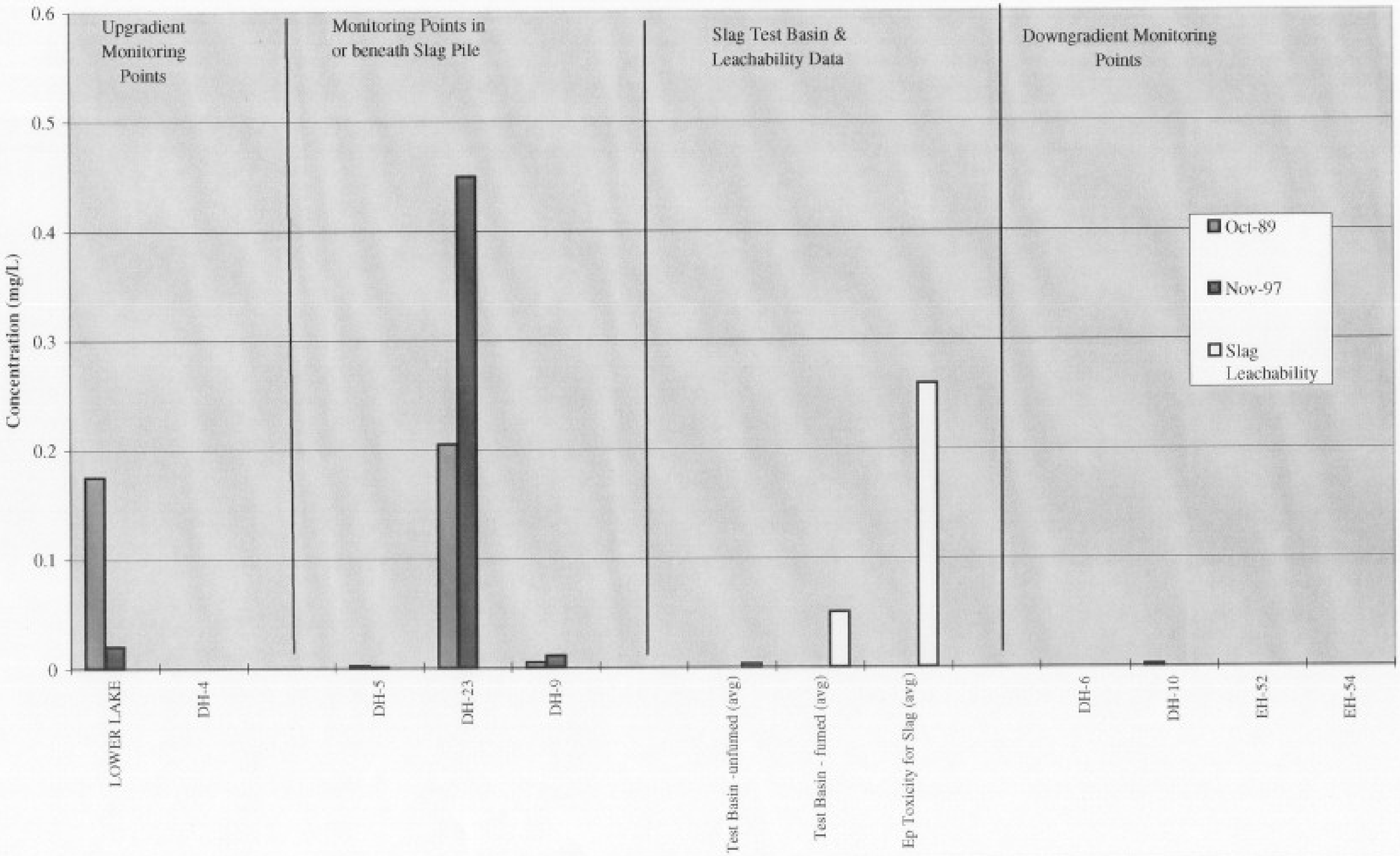

FIGURE 4-1-13. LEAD CONCENTRATION DATA FROM GROUNDWATER MONITORING WELLS IN THE SLAG PILE AREA, AND FROM SLAG TEST BASIN AND SLAG LEACHABILITY TESTING RESULTS

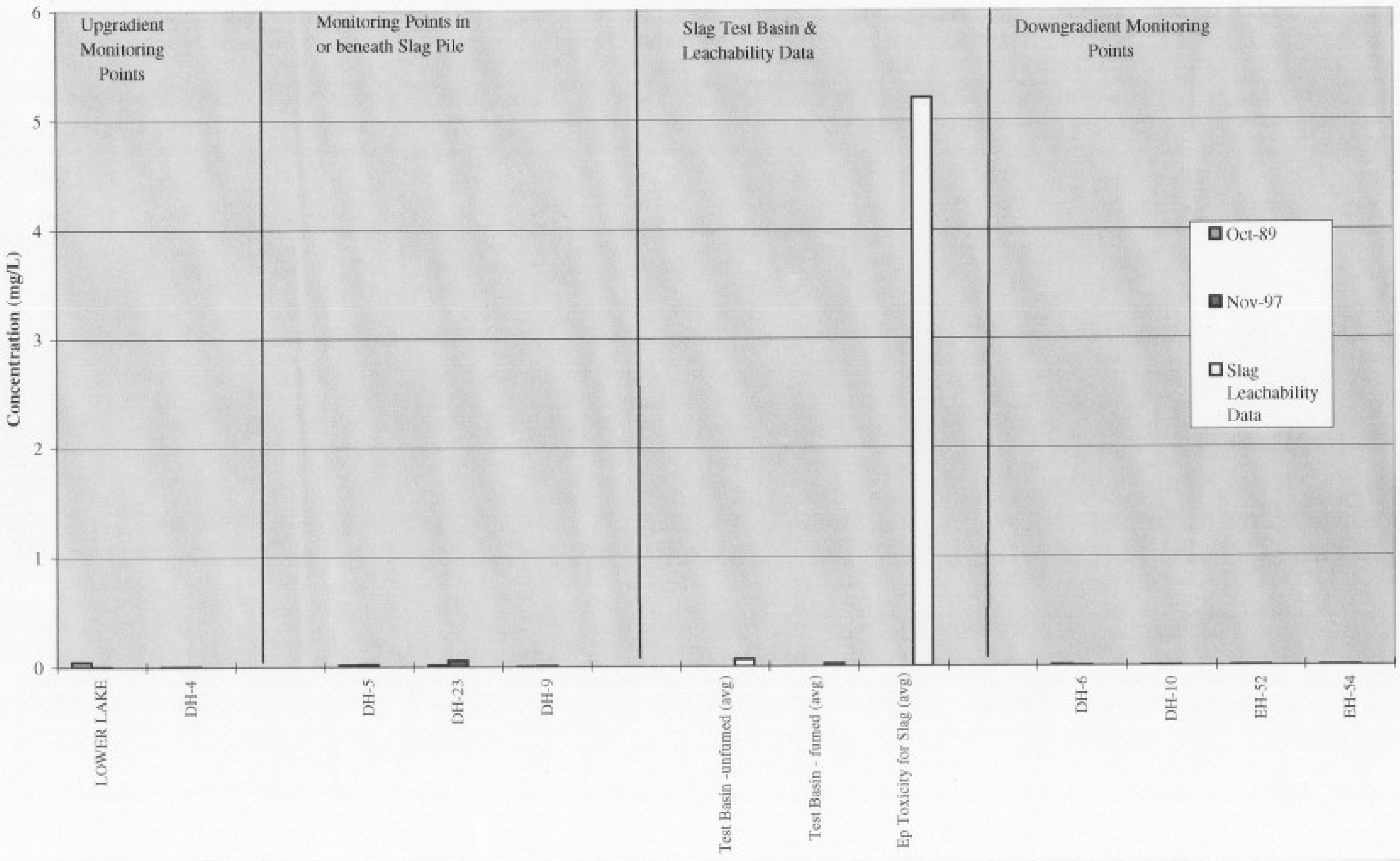

FIGURE 4-1-14. ZINC CONCENTRATION DATA FROM GROUNDWATER MONITORING WELLS IN THE SLAG PILE AREA, AND FROM SLAG TEST BASIN AND SLAG LEACHABILITY TESTING RESULTS

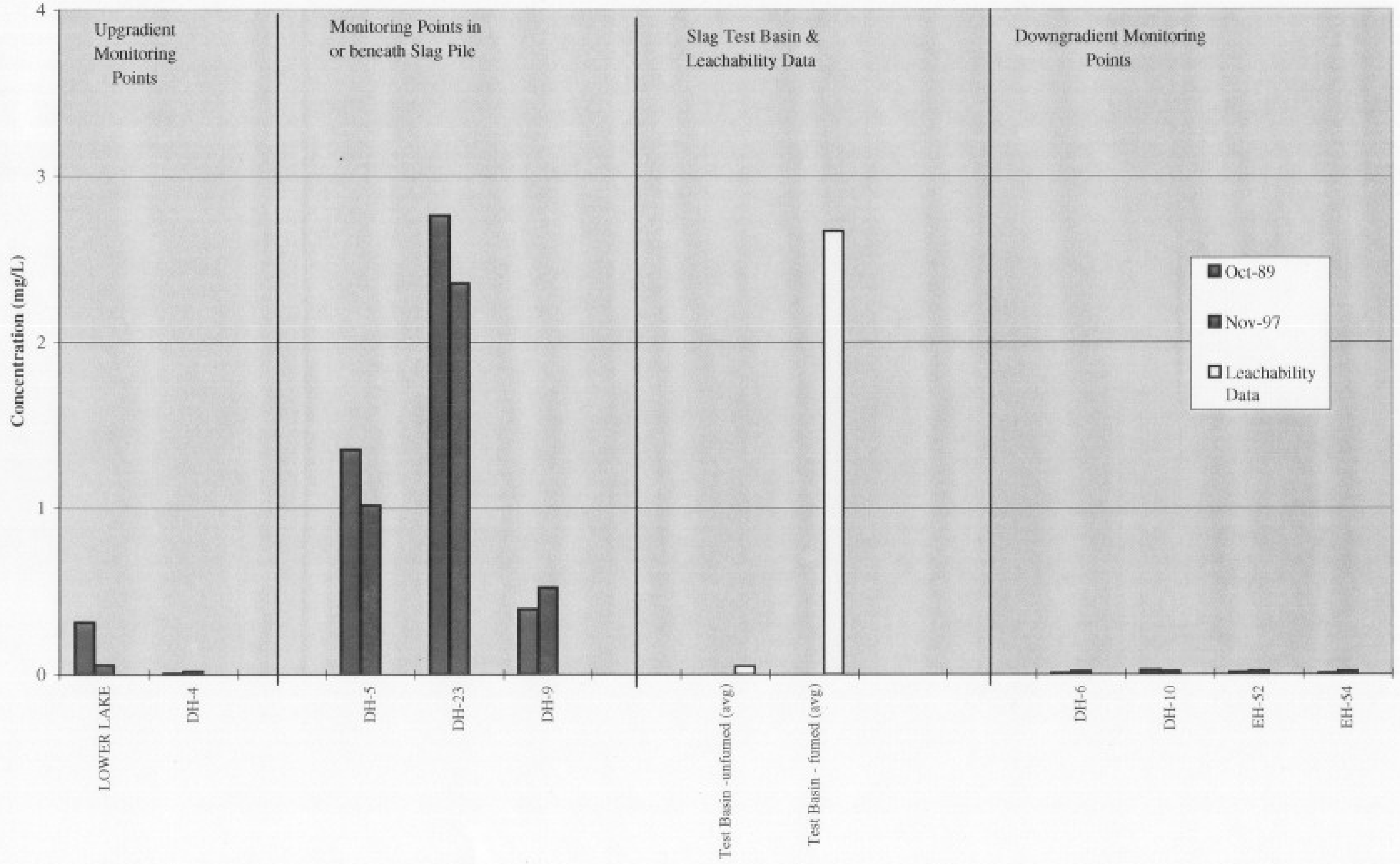

FIGURE 4-1-15. CALCULATED ARSENIC LOADING FROM SLAG VS ARSENIC LOAD IN DOWN-GRADIENT GROUNDWATER

Data Source	Arsenic Conc.(1)	Arsenic Load (2)	% of GW Load (3)
Test Basin Data			
Fumed Slag	0.036 mg/L	0.003 lb/day	0.20%
Unfumed Slag	0.53 mg/L	0.044 lb/day	2.40%
Average	0.28 mg/L	0.022 lb/day	1.30%
Max	0.59 mg/L	0.047 lb/day	2.60%
EP toxicity (avg. of 18 tests)	0.16 mg/L	0.013 lb/day	0.70%
Groundwater Load	2.13 mg/L (4)	1.8 lb/day (4)	

Notes

(1) Source RI/FS Appendix 6-1

(2) Slag load calculations assume:
20% infiltration (slag test basin average)
11.3 in/yr ppt
57 acre slag pile area

(3) Calculations based on 1.8 lb/day GW arsenic load assuming.
east side groundwater flux of 70 gpm
east side groundwater arsenic concentration of 2.13 mg/L

(4) Groundwater Load assumptions
Groundwater As Concetration 2.13 mg/L (avg from DH-10)
Groundwater flux = 70 gpm

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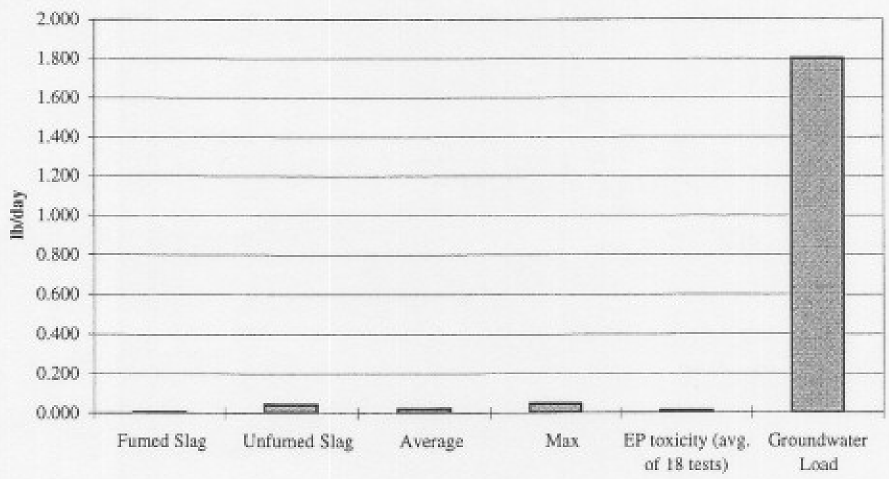
Arsenic Load



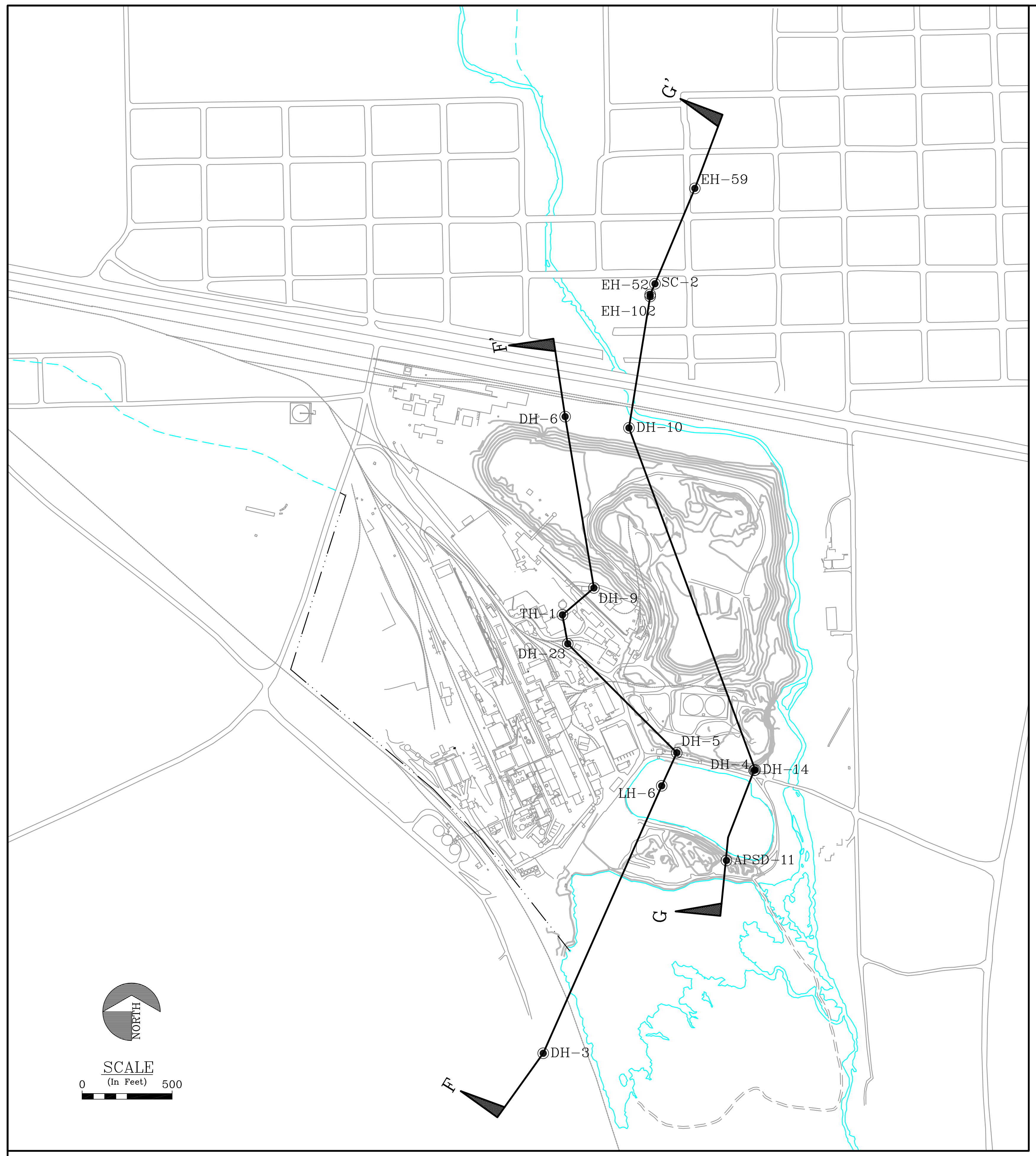
zinc is also very low. Based on the results of test basin water quality analyses, bottle roll tests, and down gradient groundwater quality, it is unlikely that slag effects observed groundwater quality trends on the site.

Stratigraphic cross-sections showing the slag pile and underlying stratigraphy **(**Figure 4-1-16**)** shows the relationship of the slag pile and underlying strata, including the perched alluvial horizon and the underlying coarser grained alluvial aquifer. Based on monitoring well stratigraphy, it is likely the perched horizon at least partially underlies the slag pile. However, there is no evidence of the perched horizon in downgradient wells (see DH-6 and DH-10). As a result, direct impacts from the slag pile at these wells is unlikely since the perched horizon is absent, and the wells are completed in the coarse grained alluvium. However, as noted above, test basin and laboratory test results indicate potential water quality impacts from the slag are low and are not responsible for the water quality concentration observed in downgradient wells.

4.1.4.2 Potential Surface Water Impacts

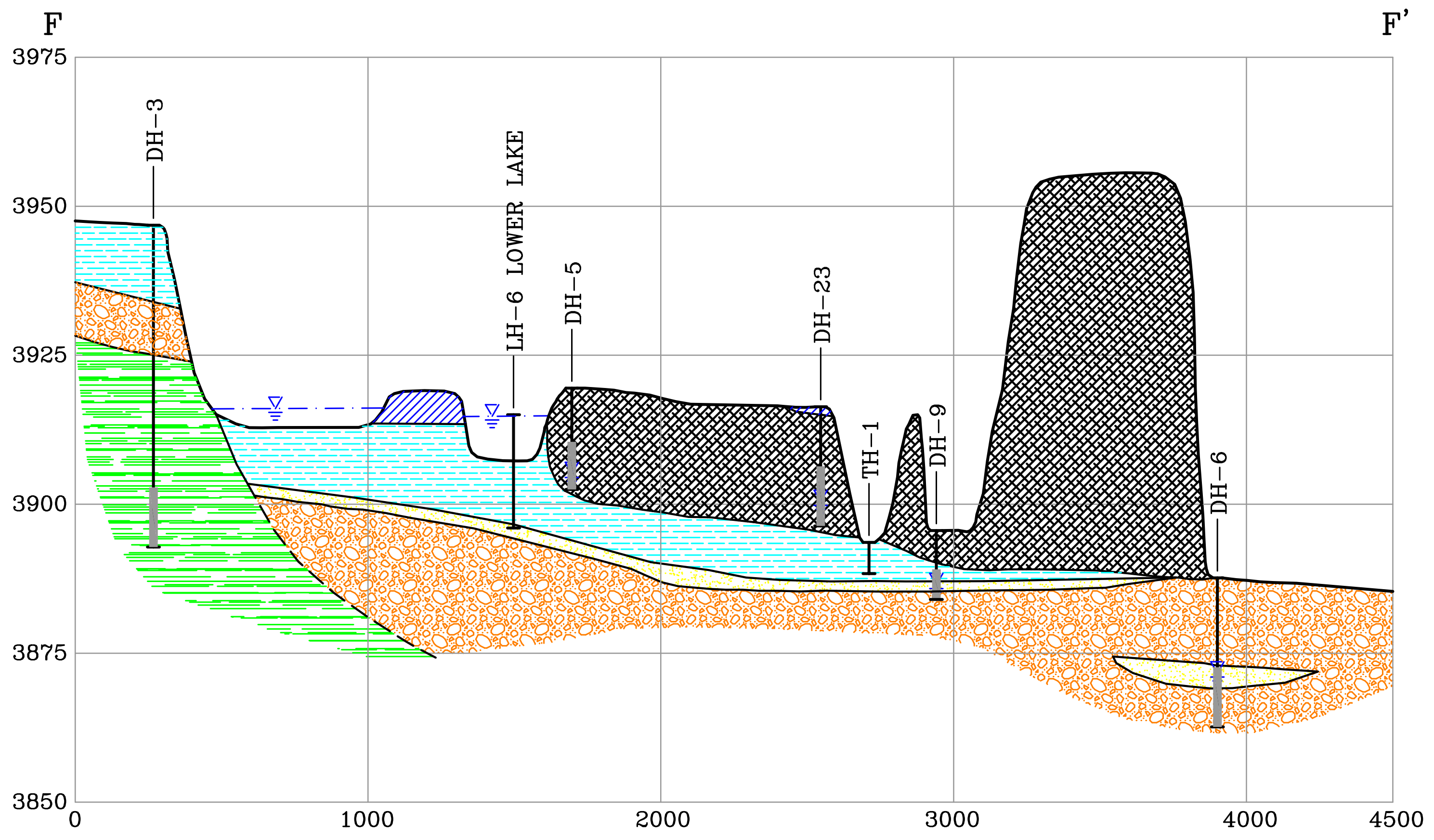
The potential for runoff transport in the slag pile area is very low due to the coarse, granular nature of the slag pile, which allows extremely rapid infiltration. Even during high precipitation events no runoff has been observed from the slag pile. Similarly seeps from the face of the slag pile have not been observed. The potential for impacts to surface water are, therefore, limited to direct contact and erosion of the slag pile where it forms steep sided banks adjacent to Prickly Pear Creek. Prickly Pear Creek is in immediate contact with the slag pile between PPC-5 and PPC-6, and adjacent to the slag pile from PPC-6 to PPC-7 (see Exhibit 3-2-1).

The 1990 Comprehensive RI/FS (Hydrometrics, 1990a) examined water quality data from Prickly Pear Creek to assess the potential impact of the slag pile on the creek. No consistent concentration or load increases were apparent in Prickly Pear Creek adjacent to the slag pile (between PPC-5 and PPC-7). The RI/FS therefore concluded that the contribution of arsenic and metals to surface water from slag is very minor. RI/FS and Post RI/FS water quality data



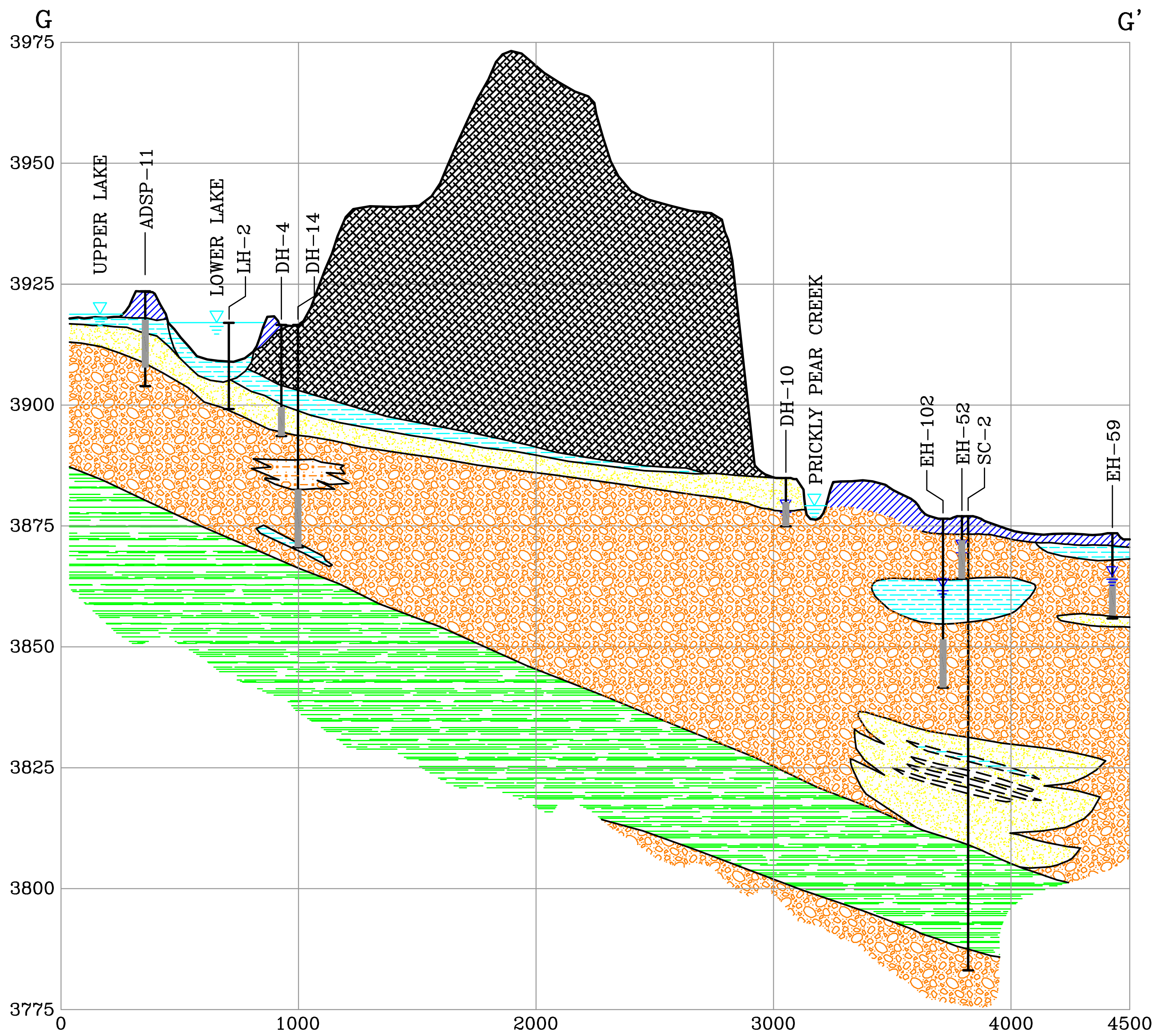
PLAN VIEW

SCALE: 1"=500'



SECTION F – F

SCALE: (H)1"=500' (V)1"=25'



SECTION G – G'

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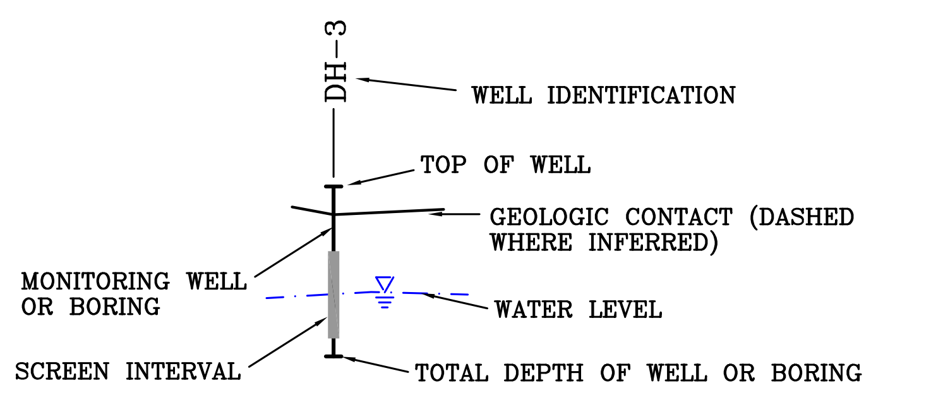
LEGEND



- ▩ SLAG, AN IRON-ZINC RICH SILICA SMELTING BY-PRODUCT PLACED WHILE IN MOLTEN STATE.
- ▨ FILL COMMONLY CONSISTS OF INTERMIXED SAND, SILT, CLAY AND GRAVEL. OFTEN INCLUDES WASTE CONSTITUENTS INCLUDING BRICKS, WOOD, COBBLES AND OTHER DEBRIS.
- ▤ SHALLOW, FINE-GRAINED DEPOSITS CONSISTING OF INORGANIC SILTS AND CLAYS. THIS UNIT ALSO CONSISTS OF ORGANIC, BLACK, SOFT, LOW-DENSITY CLAYS, SILTS AND PEAT BENEATH UPPER LAKE, AND LOWER LAKE; AND NEAR WELLS DH-4, DH-5, DH-9 AND DH-29.
- ▒ SAND, WELL-SORTED TO SILTY, UNCONSOLIDATED ALLUVIUM; GENERALLY LENTICULAR AND HETEROGENEOUS.
- ▒ ALLUVIAL GRAVEL AND COBBLES; HETEROGENEOUS, SAND, SILT OR CLAY MATRIX, VARIABLE WITH DEPTH AND LOCATION.
- ▒ GRAVEL AND COBBLES IN SILTY CLAY MATRIX.
- ▤ FINE GRAINED SEDIMENTS CONSISTING OF VOLCANIC ASH-TUFF AS WELL AS CLAYS DERIVED FROM THESE VOLCANIC DEPOSITS. UNALTERED VOLCANIC ASH-TUFF DEPOSITS ARE GENERALLY GREENISH-YELLOW-WHITE IN COLOR. ASH DEPOSITS ARE GENERALLY AT LEAST PARTIALLY DECOMPOSED TO SMECTITE OR BENTONITE CLAY 2 – 5 FEET FROM TOP BECOMING LESS CLAYEY AND MORE INDURATED WITH DEPTH.

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CURRENT CONDITIONS/ RELEASE ASSESSMENT

GEOLOGIC CROSS SECTIONS OF SLAG PILE
AND UNDERLYING STRATIGRAPHY

Hydrometrics, Inc.
Consulting Scientists, Engineers, and Contractors
Helena, Montana
2727 Airport Road (406) 443-4150

FIGURE
4-1-16

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for Prickly Pear Creek are presented and discussed in Section 4.3 of this report and post-RI/FS water quality data are generally consistent with the RI/FS findings. Average metal concentrations show only small differences between stations PPC 5, PPC 7 and PPC 8 (see Figure 4-1-17). Only one high flow stream event (May 1994) shows a pronounced increase in total arsenic load between PPC-5 and PPC-7 (see Figure 4-3-9 in Section 4.3); however, arsenic concentrations decreased from PPC-5 to PPC-7 in the May 1994 event. The calculated load increase is therefore entirely a function of the flow measurement. Since the accuracy of the flow measurements is poor during higher flow events due to increased velocities and turbulence (particularly at PPC-5 below the dam) the apparent load increase during May 1994 is probably the result of flow measurement error. The conclusion of the surface water analysis is that there is little evidence for transport of arsenic and metals from the slag pile with the possible exception being direct erosion of the slag during infrequent high stream flow events.

~~1.2~~4.2 PROCESS FLUIDS

As part of the Comprehensive RI/FS (Hydrometrics 1990a), the Process Fluids Operable Unit was divided into two sub-units: Process Ponds and Process Fluid Transport Circuits.

~~1.1.1~~4.2.1 Process Ponds

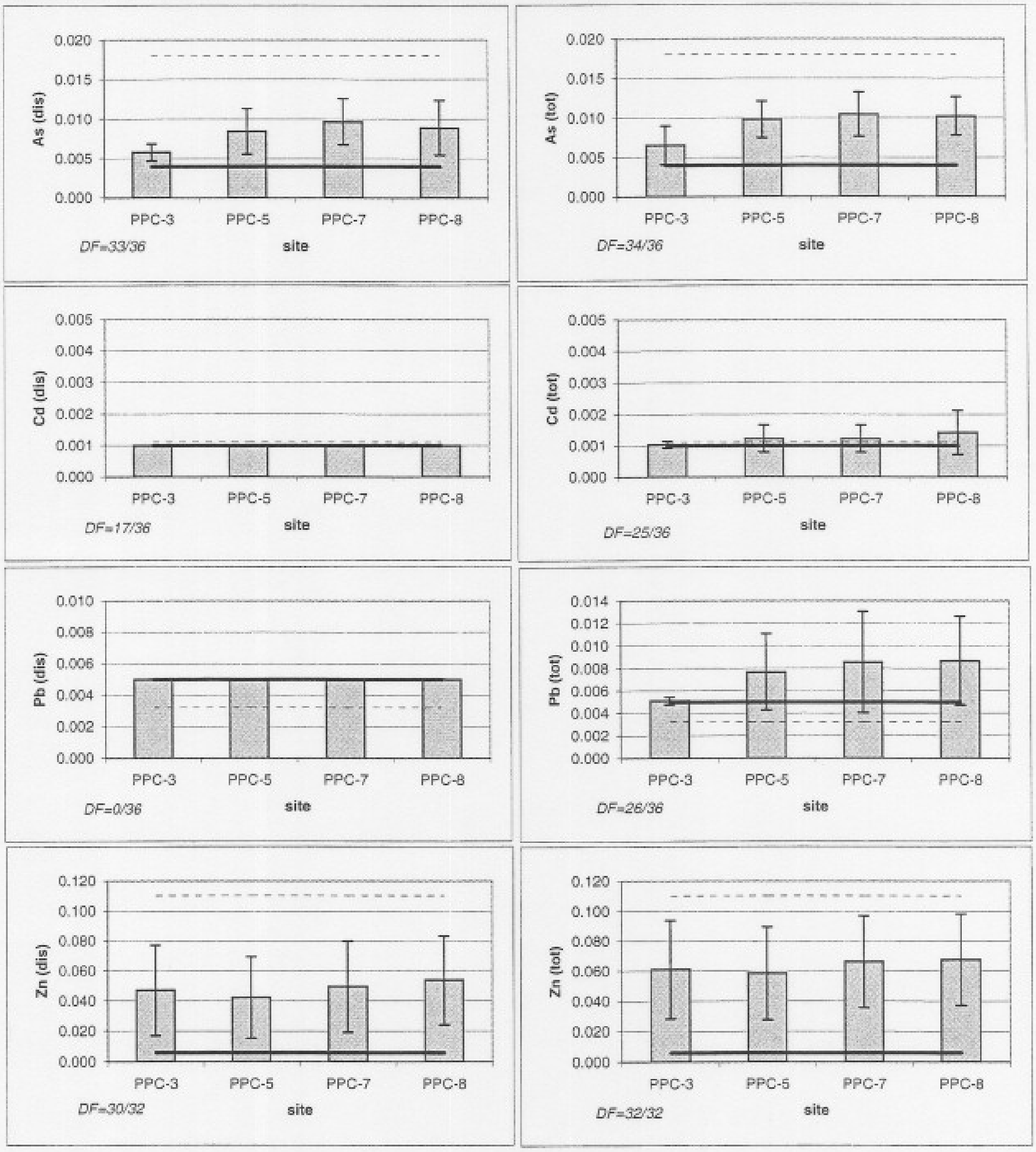
The Process Ponds include:

- Lower Lake,
- Former Thornock Lake, and
- The acid plant water treatment facility.

As described in Sections 1 and 3, the Process Ponds were addressed by the Process Ponds RI/FS (Hydrometrics, 1989), a subsequent Process Ponds ROD (US EPA, 1989), and several RD/RA documents, and remedial actions that consisted primarily of sediment excavation. The 1989 Process Pond RI consisted of:

Parameter	Average PPC-3	PPC-5	PPC-7	PPC-8
AsDis	0.006	0.008	0.010	0.009
AsTot	0.007	0.010	0.010	0.010
CdDis	0.001	0.001	0.001	0.001
CdTot	0.001	0.001	0.001	0.001
PbDis	0.005	0.005	0.005	0.005
PbTot	0.005	0.008	0.009	0.009
ZnDis	0.047	0.042	0.050	0.054
ZnTot	0.061	0.059	0.066	0.068

Parameter	Standard Deviation PPC-3	PPC-5	PPC-7	PPC-8
AsDis	0.0011	0.0029	0.0029	0.0034
AsTot	0.0025	0.0023	0.0028	0.0024
CdDis	0.0000	0.0000	0.0000	0.0000
CdTot	0.0001	0.0004	0.0004	0.0007
PbDis	0.0000	0.0000	0.0000	0.0000
PbTot	0.0003	0.0034	0.0045	0.0039
ZnDis	0.0299	0.0270	0.0304	0.0295
ZnTot	0.0328	0.0311	0.0305	0.0303



All Concentrations in mg/L.

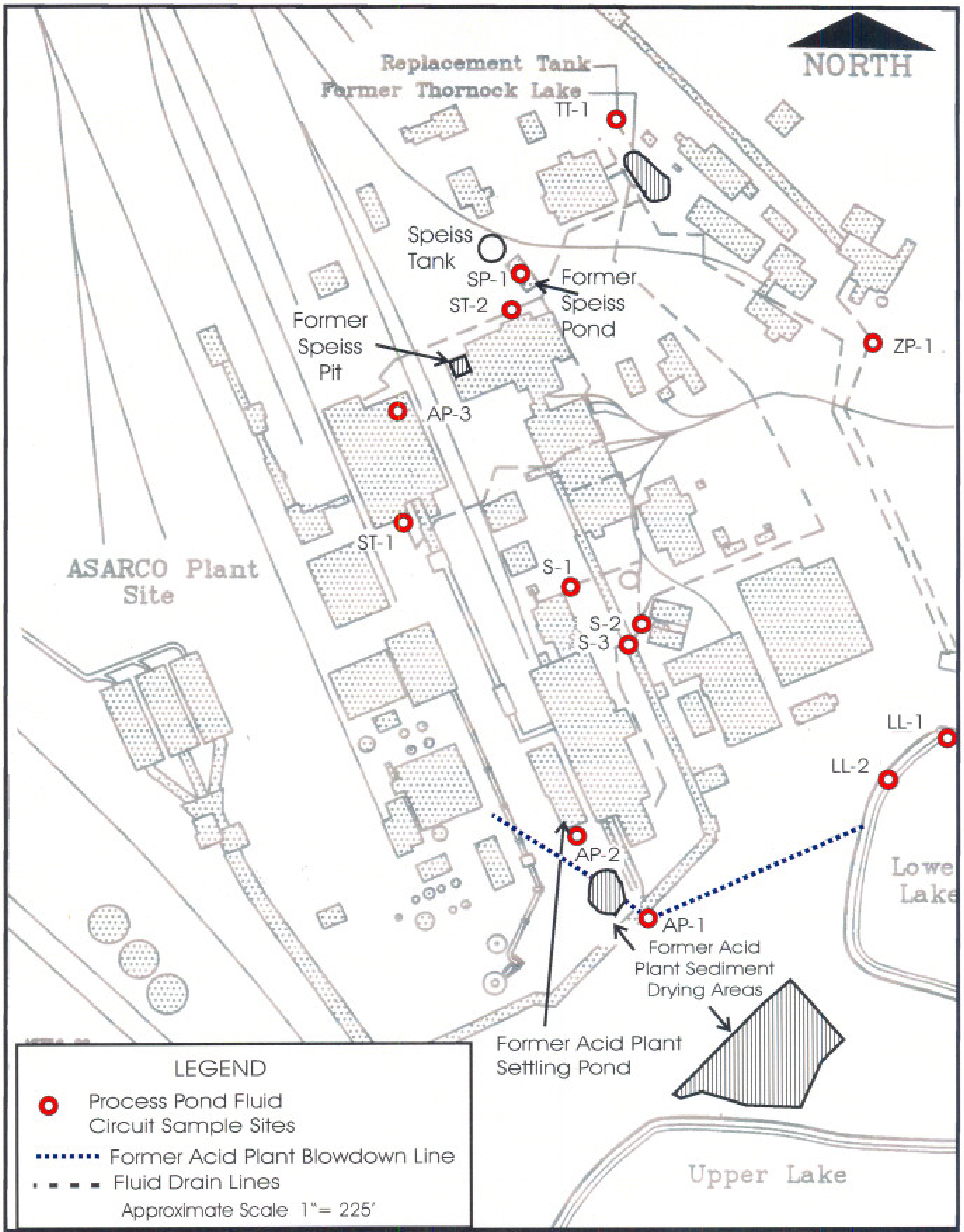
┈┈┈┈	water quality criteria (MT Human Health Standard for arsenic, Freshwater Chronic Criteria for other parameters at 100 mg/L hardness as $CaCO_3$)
━━━━	approximate detection limit (lowest detection limit if multiple limits have been used)
DF	detection frequency (i.e. number of results above detection limits/total number of analyses)

FIGURE 4-1-17. FALL (LOW FLOW) SEMIANNUAL MONITORING DATA FOR PRICKLY PEAR CREEK UPSTREAM AND DOWNSTREAM OF THE SLAG PILE

1. Collection and analysis of water samples from four process fluid ponds: Lower Lake, former Thornock Lake, the former speiss settling pond and granulating pit, and the acid plant water treatment facility. Fluid samples were collected from sites on Lower Lake (random sites and LL-1 and LL-2), the former speiss granulating pond (SP-1), three sample sites associated with the acid plant water treatment facility (AP-1, AP-2, AP-3); and random points in Thornock Lake prior to its replacement by a steel recirculation holding tank in fall 1986. The process pond sample site locations are shown in Figure 4-2-1 and analytical results are included in Appendix 3-1-1.
2. Collection and analyses of bottom sediment samples and stratigraphic samples. Bottom samples were collected from Lower Lake, former Thornock Lake, and the former speiss granulating pond. Stratigraphic samples were collected from 14 drill holes in and adjacent to the four process ponds. Lower Lake drill hole locations are shown on Exhibit 3-2-1. Drill holes and monitoring wells associated with the process ponds are discussed in detail in Section 4.4 (Groundwater).
3. A plant water balance investigation to determine the gains or losses of the main plant process water circuit into and out of Lower Lake, and to determine the storage capacity for storm runoff containment.

The general conclusions of the 1989 Process Ponds RI/FS and ROD were:

1. The four process ponds (Lower Lake, the former speiss granulating pond and pit, the acid plant water treatment facility, and former Thornock Lake) were apparent sources of metals to the hydrologic (surface water and groundwater) system.
2. Water quality sampling results showed that Lower Lake was a sodium sulfate type water, with moderately high concentrations of TDS, metals, arsenic and slightly alkaline pH. Plant water from Thornock Tank was very similar in quality to Lower Lake. Former speiss granulation process fluids were very alkaline (pH 10 or higher) with high concentrations of TDS, carbonate and arsenic. The acid plant water



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COMPREHENSIVE RI/FS
PROCESS FLUID CIRCUIT
SAMPLE SITES

FIGURE
4-2-1

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3. The RI water balance for the main plant water circuit showed a net discharge to Lower Lake of 50 to 70 gallons per minute (gpm) primarily during winter months when evaporation is at a minimum. The gains in the main plant water circuit were attributed to:
    - Plant process water from Thornock Tank,
    - Precipitation, including plant runoff water,
    - Acid plant blowdown water (average about 9 gpm), and
    - Gains in the main process water circuit from groundwater inflows collected at sumps on the plant site (about 30 to 40 gpm),
    - Waste water from the change house was discharged to plant water circuit instead of to the East Helena sanitary sewer system (10 to 20 gpm).
    - Water from drinking fountains throughout the plant discharged to the plant water circuit. Fountains were allowed to flow continuously to avoid freezing (10 gpm).

In the summer months, evaporation and dust suppression removed about 40 to 60 gpm from Lower Lake. This, however, was balanced by input from Upper Lake that was used as a source for cooling water, a portion of which discharged back to Lower Lake.

In addition to gains from the main plant fluids circuit, Lower Lake also receives recharge from Upper Lake as groundwater flows through the berm that separates Upper Lake and Lower Lake. The process fluids in the former speiss granulation circuit and the acid plant water treatment circuit were closed loops.

Two 1-million gallon tanks were installed in 1989 to remove Lower Lake as the settling/storage pond for the main process water circuit. Extensive measures were also implemented to eliminate the plant water gains and thereby eliminate the need for periodic discharges to Lower Lake. Despite these measures, Asarco was not completely successfully in eliminating all gains and as a consequence occasional discharge of plant water to Lower Lake continued until 1993 when the HDS (High Density Sludge) water treatment facility was built to treat excess main plant water circuit gains. Since January 1994, water circuit gains have been treated at the HDS plant to remove arsenic and metals prior to discharge to Lower Lake.

4. The physical and chemical characteristics of pond bottom sediments and underlying or adjacent strata are variable depending on the pond location.

- Lower Lake stratigraphy consists of one to three feet of soft silt and clay, underlain by 13 to 15 feet of fine grained marsh deposits. Concentrations of arsenic and metals in Lower Lake sediments were highest in the upper one to three feet of the loose silt and clay and decreased with depth. Soil quality data for Lower Lake sediments is in Appendix 3-1-2 (LH-series samples). In 1994 through 1996 the shallow fine-grained sediments plus 6-inches of the underlying naturally-deposited marsh deposits were dredged from the bottom of the pond as part of Lower Lake remediation.
- Former Thornock Lake bottom sediments generally consist of fine-grained, plastic, organic clay with elevated concentrations of arsenic and metals. These sediments were underlain by coarse-grained sand, gravel and cobbles. Similar to Lower Lake, the fine grained sediments had elevated concentrations of arsenic and metals. As described in Section 5, the pond was replaced with a RCRA compliant tank in 1987. The fine~~d~~-grained sediments were ~~subsequently~~ excavated in 1991 and subsequently smelted~~ in 1989~~.
- Strata near the former speiss granulating pond and pit consist predominately of gravels and cobbles in a sandy-silt matrix. Arsenic and metal concentrations were higher near the surface and generally decrease with depth, with some increase in the saturation zone. As described in Sections 4.1.2 and Section 5.0, the speiss pond was removed and replaced with a RCRA-type Tank in 1990. Sediments

underlying the pond and the pit were excavated in accordance with the Process Ponds ROD. The replacement tank is no longer used in the speiss granulation process, but is used to collect runoff from the speiss storage area adjacent to the dross facility (see Figure 4-2-1).

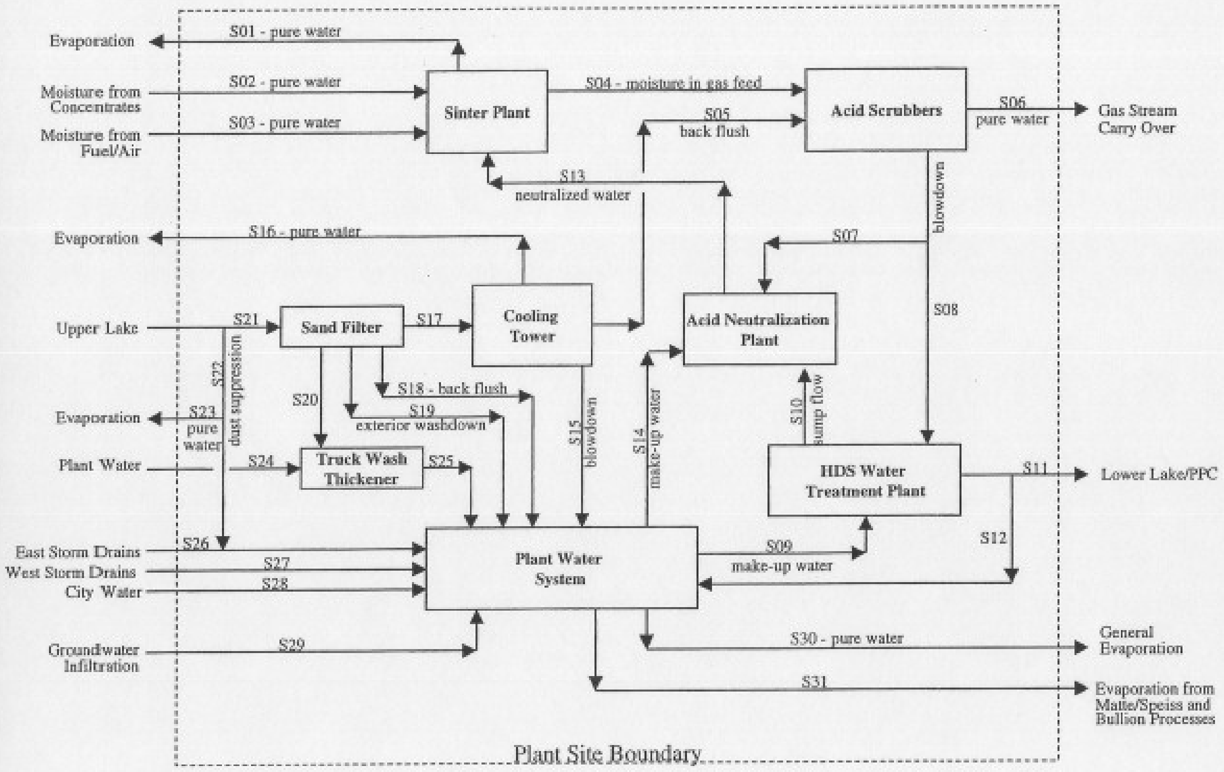
- Strata near the acid plant water treatment facility and the nearby sediment drying area (Figure 4-2-1) are similar to sediments and strata near the former speiss granulating pond. The acid plant sediment drying area near Lower Lake, is similar to Lower Lake stratigraphy. In accordance with the Process Pond ROD, the sediments underlying the acid plant water treatment concrete lined pond, and the adjacent acid plant sediment drying areas were excavated (see Figure 4-1-6). Soils underlying the former drying area adjacent to Lower Lake have not been addressed.

4.2.2 Process Fluids Circuits

Figure 4-2-2 shows the general schematic layout, flow rates and water chemistry of the present process fluid circuit network. Detailed plans of the process fluid circuits are shown in Exhibits 4-2-1, 4-2-2 & 4-2-3. The 1990 Comprehensive RI/FS identified four major process water circuits:

1. The main plant water circuit (which formerly included Lower Lake and Thornock Lake);
2. The former speiss granulating circuit (part of the blast furnace and dross plant circuit);
3. The City of East Helena municipal water supply; and
4. The acid plant and sinter plant circuit.

In addition, to those described in the RI, there also is a non-contact cooling water circuit in the acid plant. Upper Lake water is used as non-contact cooling water in this circuit. The cooling water is circulated through cooling lines in the acid plant and then to a cooling tower



Average Flow, pH, and Total Dissolved Solids (TDS)(1)

Stream No.	Flow (gpm)	pH (s.u.)	TDS (mg/L)
S01	6.0*	7.0^+	0^+
S02	9.0	7.0^+	0^+
S03	2.0	7.0^+	0^+
S04	21.1*	NM	13,299*
S05	2.0	7.3	1,186
S06	1.0	7.0^+	0^+
S07	12.4	1.6	12,736*
S08	9.7	1.6	12,736*
S09	63.2	7.0	2,013
S10	2.4*	9.7	4,762*
S11	60.2*	8.3	4,217
S12	10.9	8.3	4,217
S13	16.0	7.0	10,152
S14	1.0	7.0	2,013
S15	15.1*	7.3	1,186
S16	62.2*	7.0^+	0^+
S17	79.3	8.1	190
S18	5.0	NM	184*
S19	26.5*	8.1	190
S20	0.9	8.1	190
S21	111.6	8.1	190
S22	45.2	8.1	190
S23	33.9*	7.0^+	0^+
S24	2.5	7.0	2,013
S25	3.4*	6.1	4,372
S26	6.5*	7.6	566
S27	1.9*	7.6	566
S28	9.7	6.4	129
S29	10.0	6.2	2,859
S30	0.43*	7.0^+	0^+
S31	2.0	7.0^+	2,013

NOTES:

(1) Data collected from June through September 1998 for Plant Site Water Balance Study.

* Calculated estimate based on mass balance; other values based on direct measurements or field observations.

\+ TDS of 0 mg/L and pH of 7.0 assumed for evaporated water.

NM = not measured.

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Figure 4-2-2. General Schematic for Process Water Circuits

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where a portion of it is lost to evaporation. Blowdown from the acid plant cooling circuit is discharged to the plant water circuit.

Prior to 1990, the plant water system consisted of the primary plant water circuit (plant water) with minor circuits (former speiss granulation, acid plant water treatment) supplied from the main circuit. Ponds for holding water were part of each circuit with Lower Lake as the main holding pond, Thornock Lake as the holding pond for the main circuit, the speiss granulating pond for the speiss granulation circuit, and the acid plant settling pond for the acid plant water treatment facility. The main plant water circuit was used for fire suppression, sinter plant washdown, and cooling, and makeup water for the other plant processes.

4.2.2.1 Main Plant Water Circuit and Lower Lake

Historically, the main plant water circuit consisted of Lower Lake as the main holding facility (pond) with pipes transporting water from Lower Lake to the main plant pumphouse. The principal flows to and from Lower Lake were the inflows and outflows related to the plant process circuit. From the pumphouse, pressurized water was transported in underground pipes to the sinter plant where it was used for washdown, moisturization and cooling. This water then flowed through gravity drains to Thornock Tank where it was pumped back to Lower Lake. Pressurized lines also supplied water from the pumphouse to the fire hydrant system and to other buildings as makeup water for various processes and washdown water for dust suppression inside buildings.

Changes to the main plant water circuit began in 1990 with the construction of two, 1-million gallon storage tanks designed to replace Lower Lake. Regular discharge of plant water to Lower Lake was discontinued at that time. Lower Lake sediments were removed in 1994, 1995 and 1996 and the pond is no longer part of the main plant process fluid circuit although the pond still provides makeup water for the plant water system and accepts effluent from the HDS plant.

The HDS Plant was completed in January of 1994. The HDS plant accepts plant water to be treated prior to discharge to Lower Lake. Optimization improvements were designed and implemented to the system in 1996.

Thornock Lake was removed from the main process fluid circuit and replaced with a 93,000 gallon tank in 1986. Soils were excavated from the pond bottom in 1986, 1987 and 1991.

In 1996, Lower Lake was discontinued as the source for water used for dust suppression. Upper Lake water is now used for this purpose.

In February 1998, a water line failure was detected in the underground piping system used for fire suppression and sinter plant processes, as well as other miscellaneous uses. Water to the underground line was shut off and water to the sinter plant was supplied through a newly installed above ground piping system. The plant water circuit is shown in Exhibit 4-2-3.

4.2.2.2 Former Speiss Granulating Circuit

The former speiss granulating pond and pit were about 150 feet south and 250 feet southeast of the administration building on the north edge of the dross plant. Both the pond and pit were used to store water for use during the speiss granulation process. During speiss granulation, molten copper bearing material was allowed to flow to the pit where it was sprayed with water pumped from the speiss granulating pond. The water then drained through a twelve to fourteen inch mild steel pipe back to the speiss granulating pond to be recirculated during the next granulating cycle. Flows in the speiss granulating pond/pit circuit averaged about 150 gpm during granulation (approximately 45 minutes). Plant process water was occasionally added to the pond as makeup water. Sediment from the granulation process accumulated in the process pond and was removed periodically and reprocessed in the plant.

Air water mist granulation replaced water granulation in 1991. The speiss granulating pond was removed in 1989 and replaced with a steel tank with secondary containment. The speiss pit was removed in 1995.

Remediation of the speiss pond and pit area was initiated in 1988 with the HDPE lining of the Speiss Pond. In 1988, a portion of the original speiss pond was removed and replaced with a tank (the "Speiss Tank") with leak detection and secondary containment. As described in Section 4.1.2, soil was excavated in 1988 to 20 feet depth beneath a portion of the former pond. In 1992, the remainder of the original Speiss Pond was removed and additional soil was also excavated. In 1995, the original Speiss Pit was removed and replaced with a new pit during construction of the new dross-reverberatory building. Soil was removed to a depth of 17 feet beneath the old pit (see Section 4.1.2).

4.2.2.3 Former Acid Plant Water Circuit

The former acid plant water treatment facility consisted of a wooden trough fluid transport system, five particulate settling dumpsters, a 68 feet by 35 feet by 9 feet deep epoxy lined settling pond and two above ground mixing tanks used for lime neutralization. This system was replaced with the present acid plant water reclamation facility in 1992. Prior to 1992, suspended sediments from the acid scrubbing process were simply settled in a settling pond and in-line settling tubs (dumpsters), and neutralized by lime application at the former acid reclaim facility. The neutralized water was then sent to the sinter plant where it was used for moistening of sinter and then reintroduced to the main process fluid circuit, or it was recirculated back to the acid plant scrubber system for reuse. Sediment from the neutralization and settling process was periodically removed from the settling pond and dumpsters and subsequently placed in the sediment drying pad areas to await processing for metals recovery in the smelting process.

4.2.2.4 Additional Water Use

As described further in Section 4.3, storm water runoff is routed directly through gravity drains to Thornock Tank or to the storm water tank near the East Helena Rodeo grounds which is periodically pumped back to Thornock Tank.

City water from East Helena is used to for makeup water to the blast furnace and reverberatory furnace closed cooling system loops. City water is also used at sinks, showers, sanitary and laundry facilities throughout the plant site. After use, all city water reports directly to Thornock Tank with the exception of water used for sanitary facilities which reports first to the on-site sewer treatment plant (See Exhibit 4-2-1) prior to being discharged to Thornock Tank.

Upper Lake water is applied by water truck for dust control throughout the plant. Excess runoff from dust control application reports to Thornock Tank through gravity drains. Upper Lake water is also routed through a sand filter and used for non-contact cooling water in the acid plant (see Exhibit 4-2-2). Most of this water is evaporated through cooling towers adjacent to the acid plant.

4.2.3 Process Fluid Chemistry

4.2.3.1 Lower Lake and the Main Plant Water Circuit

Lower Lake sample data are available from 1981 through 1998 (see Appendix 3-1-1). In addition several samples from the main plant water circuit (S-1, S-2, S-3, ST-1, ST-2, TT-1, and ZP-1) were sampled and analyzed during the RI. Sample point locations are shown on Figure 4-2-1 and are described on Table 4-2-1. Historically, the main process water circuit samples results were similar to Lower Lake water chemistry, which was part of the main water circuit. Generally, the water from the main process circuit, including Lower Lake, was a sodium-sulfate type, with moderately high concentrations of TDS, metals and arsenic.

As Figures 4-2-3 and 4-2-4 show, arsenic concentrations have been variable over time and changes in water quality are related to changes in plant operating practices, modifications to

TABLE 4-2-1. RI PROCESS FLUID SAMPLING SITE DESCRIPTION

SAMPLING SITE	DESCRIPTION	LOCATION
AP-1	Acid plant drain	South of blast furnace
S-1	Ore mixing area drain sump	Near northeast corner of breaking floor building
S-2	South plant collection sump	West of main plant pumphouse
S-3	Ore mixing area drain sump	West of S-2 under blast furnace flue
ST-1	Sinter plant drain sump	South of sinter plant
ST-2	Sinter plant drain sump	North of drossing plant building
TT-1	Thornock Tank	Northeast of Changehouse
ZP-1	Zinc plant drain	South of zinc plant furnace building

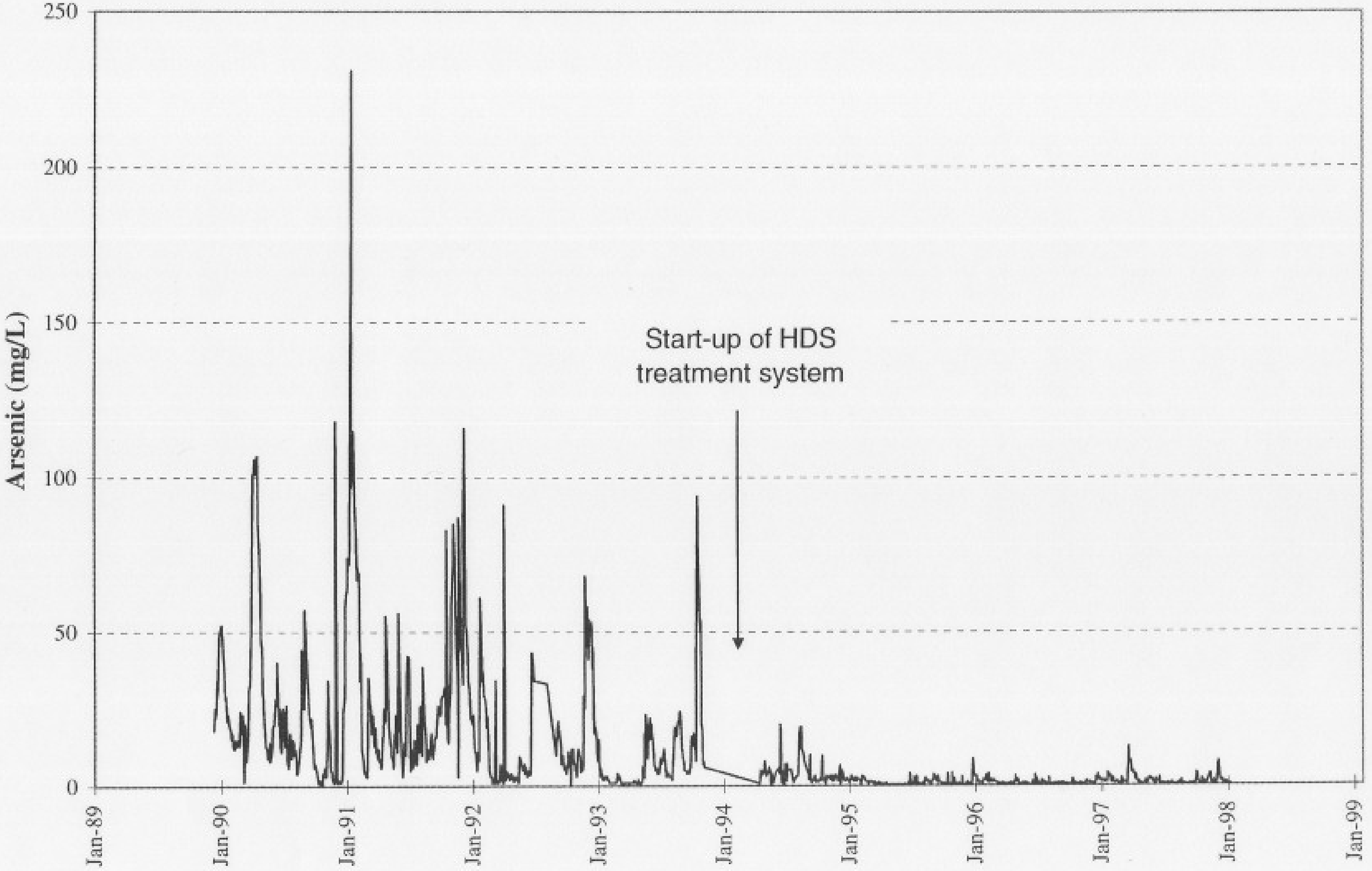

FIGURE 4-2-3. PLANT WATER (MAIN PROCESS WATER CIRCUIT) ARSENIC CONCENTRATION (1989-1997)

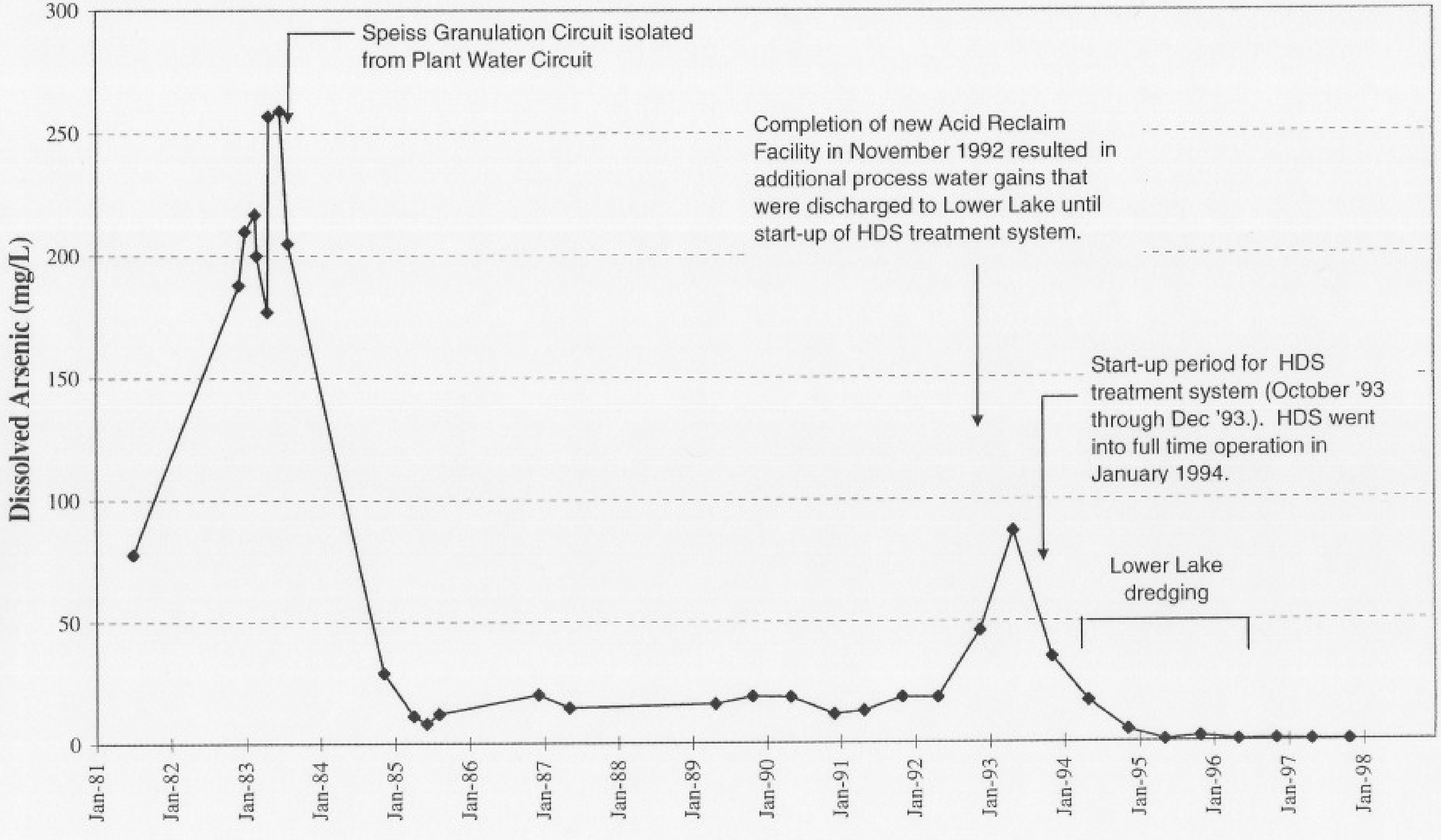

FIGURE 4-2-4. LOWER LAKE ARSENIC CONCENTRATION TREND
(1981-1997)

the water handling systems, and remedial actions for the Process Ponds (see Section 5.0, Release Assessment). Historical water quality data obtained from Lower Lake and the main process water circuit by Asarco in 1982 through 1983, show dissolved arsenic concentrations were much higher, with an average concentration of about 200 mg/l in Lower Lake, and about 50 to 100 mg/l in the main plant process water circuit. Changes in plant fluid management practices, specifically recycling of the acid plant and speiss granulating pond fluid circuits independent of the main plant water circuit, resulted in the significant decline in arsenic concentrations observed in Lower Lake in 1984.

Recent water quality for Lower Lake and the main process water circuit (plant water) are shown on Table 4-2-2. Since the implementation of the HDS water treatment system, arsenic and metal concentrations in Lower Lake have declined significantly (to less than 0.05 mg/l arsenic), while concentrations of total dissolved solids (TDS) have increased from a typical range of 1500 to 1700 mg/l to a post-treatment concentration of about 2200 mg/l. Based on sample results collected in 1998, arsenic concentrations in the main process fluid circuit have also declined and are typically 1 to 2 mg/l. Of the metals analyzed in 1998, cadmium and zinc were among the highest with concentrations of 11 mg/l and 9 mg/l, respectively.

Former Speiss Granulating Pond And Pit

Speiss process waters (see Figure 4-2-1) were sampled on six occasions from December, 1986 through December 1, 1987. These data are in Appendix 3-1-2. Speiss process fluids were very alkaline with a pH in excess of 12, and very high concentrations of total dissolved solids, carbonate and arsenic. Concentrations of total and dissolved arsenic ranged from a high of 3735 mg/l and 3733 mg/l, respectively, to a low of 55 mg/l for both total and dissolved arsenic. Concentrations of total cadmium, copper, iron, lead, manganese and zinc were also variable with the highest concentrations associated with high concentrations of total suspended solids. High pH and carbonate concentrations reflect the liberal use of lime (calcium oxide) in the drossing process.

TABLE 4-2-2 1998 PROCESS WATER QUALITY

	Plant Water Circuit		Acid Plant Circuit(3)		Speiss Area(2)			
Parameter	**Plant Water(1)**	**Dross Plant Collection Sump(2)**	**Scrubber Blowdown Water**	**Neutralized Scrubber Blowdown**	**Speiss Tank**	**Speiss Tank Secondary Containment**	**Lower Lake(4)**	**HDS Plant Effluent(5)**
pH	7.1	7.3	1.9	6.7	11.7	10.1	7.6	7.8(3)
Total Dissolved Solids	3073	2415	7248	9875	40531	19282	2270	
Calcium	382	--	329	173	--	--	347	
Chloride	514	198	1192	1790	778	263	250	
Fluoride	4.8	--	148	42	--	--	--	
Ammonia as N	23	--	230	235	--	--	--	
Nitrate + Nitrite as N	2.0	--	<0.50	<0.50	--	--	--	
Phosphate	0.13	--	0.10	0.13	--	--	--	
Total Phosphorus	0.44	--	49	32	--	--	--	
Potassium	233	--	90	91	--	--	60	
Silica	28	--	131	123	--	--	--	
Sodium	436	--	301	2542	--	--	279	
Sulfate	1454	1163	5501	3779	6765	3956	1140	2693(3)
Total Sulfur	485	--	2257	1756	--	--	--	
Acidity (ppm as $CaCO_3$)	20	--	6100	920	--	--	--	
Total Alkalinity	53	--	<1.0	974	--	--	66	
Carbonate Alkalinity	<1	--	<1.0	<1.0	--	--	--	
Bicarbonate Alkalinity	53	--	<1.0	974	--	--	81	
Aluminum	0.16	--	2.9	0.33	--	--	--	
Arsenic	1.4	0.29	1867	1716	3871	1464	0.049	0.285
Antimony	2.1	--	149	41	--	--	--	6.3
Barium	0.063	0.073	<0.050	<0.050	<0.02	0.022	--	
Beryllium	<0.010	--	<0.010	<0.010	--	--	--	
Cadmium	11	4.8	230	180	<0.1	<0.1	0.013	0.0025
Chromium	<0.050	<0.01	0.46	<0.050	<0.01	<0.01	--	
Copper	0.085	0.16	0.068	<0.050	0.65	7.5	0.016	0.009
Iron	<0.10	--	36	12	--	--	0.106	
Lead	0.20	0.44	14	0.075	2.2	6.3	0.007	<0.003
Mercury	1.2	--	2060	810	--	--	--	<0.006
Magnesium	30	--	9.9	11	--	--	8	
Manganese	5.0	--	1.3	1.4	--	--	1.1	
Nickel	0.089	--	0.31	0.23	--	--	--	
Selenium	0.47	0.35	5.9	5.3	43	39	--	0.3825
Silver	<0.050	<0.003	<0.050	<0.050	0.038	0.11	--	
Thallium	2.4	--	37	31.0	--	--	--	
Zinc	9.1	6.2	140	120	0.15	0.16	0.066	

Notes: All concentrations are in ppm except for mercury which is in ppb.
All metals results represent dissolved fraction.
(1) Plant water sample collected in May 1998 in conjunction with February 1998 Plant Water Investigation.
(2) Speiss area samples and Dross Plant Sump collected in May 1998 as grab samples for internal review.
(3) Acid Plant Circuit samples collected in March 1998 as grab samples for internal review.
(4) Lower Lake sample collected during May 1998 Post-RI/FS Monitoring.
(5) HDS effleunt data from March 1998 MPDES sampling.

Water granulation has been replaced by air water mist granulation, which uses water mist in the granulation process. While the granulation water circuit has been removed, the speiss tank is still used to collect surface water runoff from the speiss storage area north of the dross facility. As described above, this containment consists of a primary steel tank with secondary (concrete) containment. In 1998, it was observed that both the tank, as well as a sump in the secondary containment contained water, presumably precipitation and runoff from dust control spraying runoff which is also routed to the tank. Samples collected from the Tank and the Sump in May 1998, had water quality characteristics (see Table 4-2-2) similar to past granulation circuit water quality. The water from both the tank and sump is very alkaline (pH of 11.7 and 10.1, respectively), and has high concentrations of TDS and arsenic (3871 mg/L and 1464 mg/L, respectively).

Acid Plant Water Treatment Facility

Acid plant scrubber blowdown samples were collected at the acid plant water treatment facility during the RI and these data are in Appendix 3-1-2. Sample locations are shown on Figure 4-2-1 and described in Table 4-2-1. The RI data show that prior to neutralization at the acid plant reclaim facility site, these blowdown samples were characterized by low pH, (from 1.3 to 1.9), high concentrations of total dissolved solids and sulfate, and very high concentrations of arsenic. Total and dissolved arsenic concentrations ranged from a high of 3,000 mg/1 and 2867 mg/l, respectively, to a low of 1625 mg/l for both total and dissolved arsenic (see Appendix 3-2-1). Process fluid samples from site AP-3 showed significantly higher pH, and lower concentrations of TDS, TSS, sulfate and arsenic as a result of settlement and neutralization at the treatment facility.

As described in Section 4.2.1 the HDS Treatment Facility was installed to treat process water circuit gains including the main plant water circuit and the acid plant circuit. Treatment by the HDS facility results in significant improvement of acid plant water quality (see Table 4-2-2). Water quality prior to treatment is similar to past acid plant circuit water with elevated concentrations of TDS, TSS sulfate and arsenic. However, post-treatment water quality analyses (HDS Plant Effluent on Table 4-2-2) show low concentrations of arsenic and metals.

4.3 SURFACE WATER

Surface water monitoring within and adjacent to the Asarco East Helena Plant site has been conducted at the following locations:

- Prickly Pear Creek (upstream, adjacent to, and downstream of the plant site);
- Upper Lake (formed by a diversion from Prickly Pear Creek);
- Wilson Ditch (agricultural use water routed from Upper Lake); and
- Storm water runoff monitoring sites, including monitoring performed in accordance with an MPDES permit.

Surface water flow, water quality, and bottom sediment quality measurements have been collected in support of numerous investigations, including:

- Phase I Water Resources Investigation (conducted in 1984-1985) and incorporated into the Comprehensive RI/FS;
- Phase II Water Resources Monitoring (conducted in 1986-1988);
- Post-RI/FS Biannual Monitoring (conducted from 1989 through 1997);
- Lower Lake Remediation Project Monitoring (initiated in 1994); and
- EPA Administrative Orders/Requests for Information (RFIs) under Sections 308 and 309(a) of the Clean Water Act.

A tabular summary of surface water monitoring locations showing sampling dates and measured parameters is in Table 3-2-1 and Table 3-2-2. Monitoring locations are shown on Exhibit 3-2-1 and Figure 4-3-1. Flow measurements, water quality sampling results, and sediment quality sampling results are discussed below for Prickly Pear Creek, Upper Lake, Wilson Ditch, and storm water runoff monitoring sites. Some discussion of Lower Lake water quality in terms of its potential effect on Prickly Pear Creek also is provided.

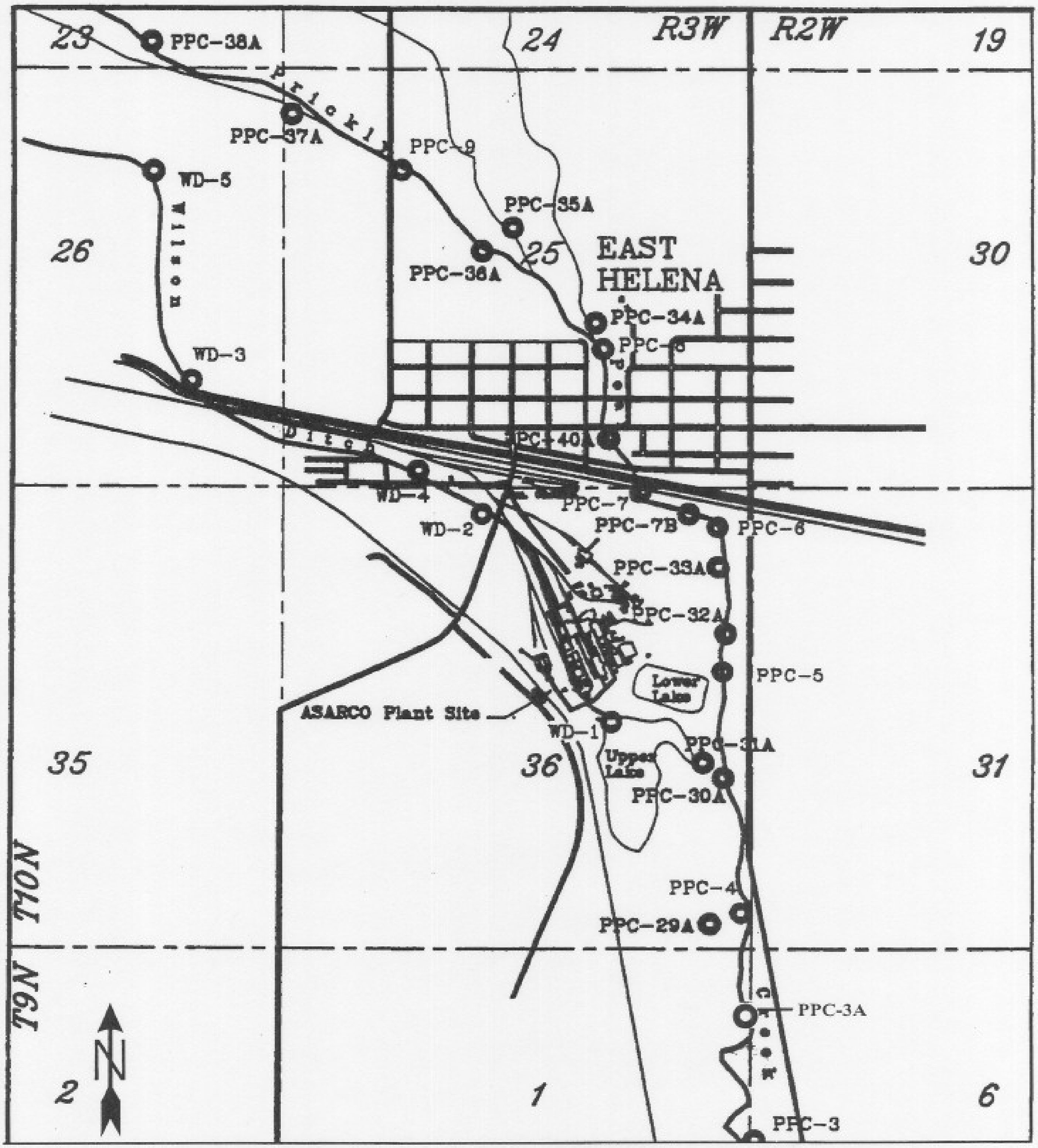

figure
not to scale

CC/RA REPORT ASARCO EAST HELENA FACILITY	SURFACE WATER FLOW AND WATER QUALITY MONITORING SITES	FIGURE 4-3-1

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FIGURE SOURCE: COMPREHENSIVE RI/FS (ASARCO, 1990)

4.3.1 Prickly Pear Creek and Upper Lake

Prickly Pear Creek, which runs along the eastern and northeastern boundaries of the plant site (Exhibit 3-2-1), is the primary surface water resource in the vicinity of the Asarco East Helena Plant. The creek has been a source of water for agriculture, mining, and industrial use for more than a century, and has been impacted by numerous activities including highway and railroad construction, subdivision developments, agricultural dewatering, acid-mine drainage from inactive mines in headwaters areas, and municipal and industrial discharges.

Maximum streamflow in Prickly Pear Creek usually occurs in response to spring snowmelt and rainfall events, and intense early summer rainstorms. Minimum streamflow occurs in midwinter, except in Lower Prickly Pear Creek (downstream of the City of East Helena), where severe summer stream dewatering occurs due to irrigation withdrawals. During the peak water demand period of July through September, the creek often is dry or nearly dry downstream of East Helena.

Upper Lake is formed by surface water diversion from Prickly Pear Creek just upstream of sampling location PPC-4 (Figure 4-3-1). Data from the 1990 RI showed that water quality in Upper Lake is essentially the same as Prickly Pear Creek upstream of the plant site (sites PPC-3 and PPC-4). Since the RI showed water quality at these two creek sampling points are the same as Upper Lake water quality, Upper Lake is not discussed separately in this evaluation. A portion of the water diverted from Prickly Pear Creek to Upper Lake is used by the Asarco plant, and the remainder is either routed through Wilson Ditch and used for agricultural purposes (stock watering and irrigation) in the area to the northwest of the plant site or returned to Prickly Pear Creek through an overflow structure.

4.3.1.1 Flow

Streamflow measurements in Prickly Pear Creek near the Asarco plant site have been collected on a seasonal basis, and occasionally more frequently, since the Phase I Water Resources Investigation was initiated in 1984. Subsequent measurements were collected during Phase II Monitoring (1986-1988) and Post-RI monitoring (1989-present), including intensive monitoring at selected sites under the Lower Lake Remediation Sampling and Analysis Plan (Hydrometrics, 1994a). All flow measurements collected through 1997 are included in the complete sample database (Appendix 3-1-1).

Figure 4-3-2 shows stream discharge measurements for sites PPC-3 (upstream of the plant site), PPC-5 (adjacent to the plant site) and PPC-7 (immediately downstream of the plant site) for the period 1984 through 1997. Figure 4-3-3 shows the stream hydrograph for Prickly Pear Creek at the USGS gaging station near Clancy, Montana (about five miles upstream of the plant site) for the same time period. It should be noted that site PPC-3 was replaced by site PPC-3A (located about 1500 feet downstream) in 1996. For the purposes of flow comparison, data from both stations have been combined.

Figures 4-3-2 and 4-3-3 indicate that base flow in Prickly Pear Creek has remained fairly stable throughout the thirteen-year monitoring period, typically near 25 to 30 cfs. Measured peak flows near the East Helena plant (Figure 4-3-2) during spring and early summer runoff have ranged from near 50 cfs to greater than 300 cfs. The complete hydrograph for the upstream gaging station (Figure 4-3-3) shows peak flows ranging from about 80 cfs to over 400 cfs, with most peak values near 150 to 200 cfs. Comparison of Figures 4-3-2 and 4-3-3 show that collection of flow (and associated water quality) data near the plant site during high flow conditions only occasionally coincides with yearly peak flows as defined by the stream hydrograph.

Increased sampling and flow measurement frequency in 1994 allowed a detailed runoff hydrograph to be developed for Prickly Pear Creek near the Asarco plant site (Figure 4-3-2). Flow data for this period show that over a two month period from early April through early June, flow in the creek increased from about 80 cfs to 310 cfs, then decreased again to about 100 cfs. Data for the upstream USGS monitoring station (Figure 4-3-2) suggest that this

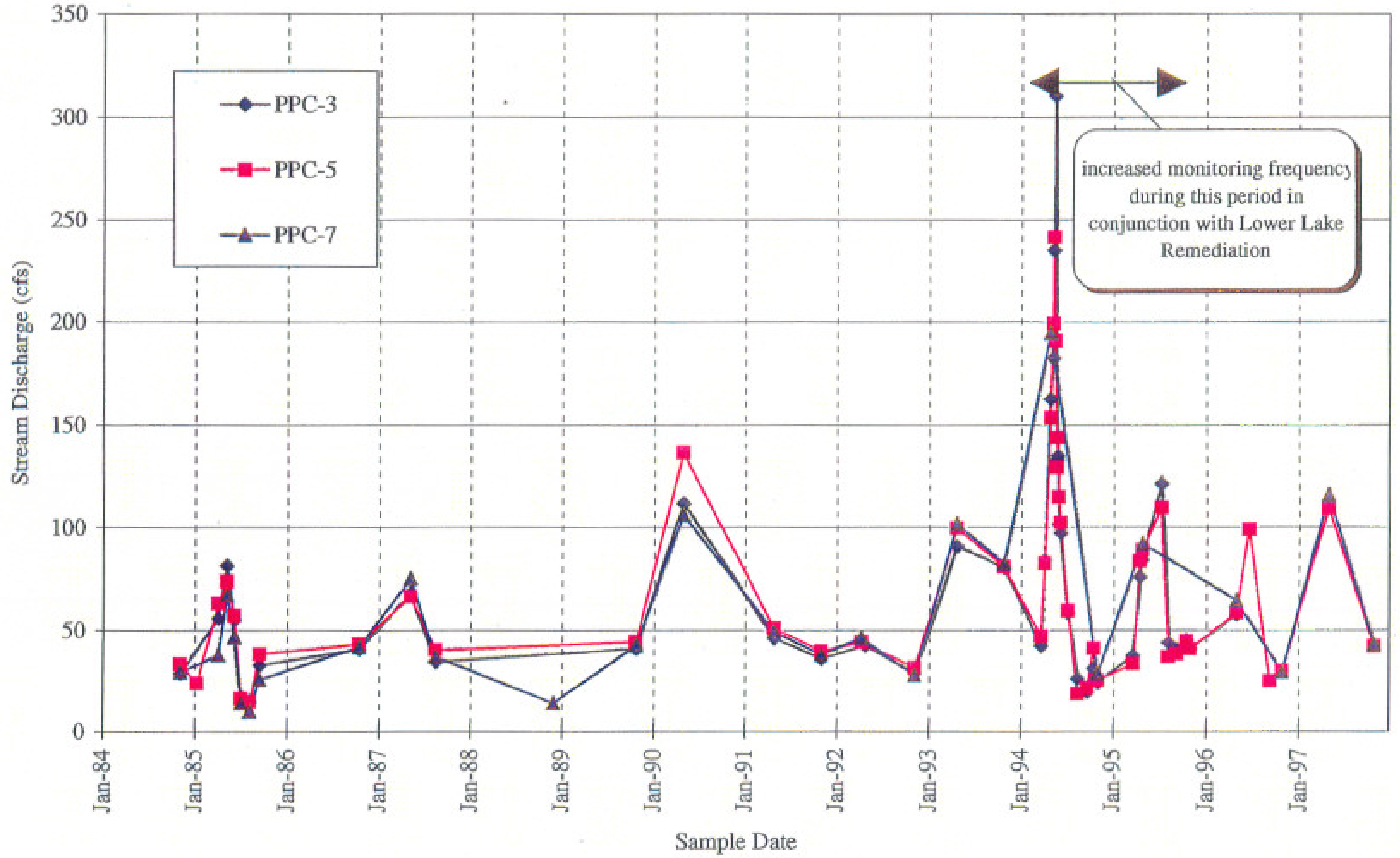


Figure 4-3-2. Prickly Pear Creek Discharge Measurements Near the Asarco East Helena Plant (1984-1997)

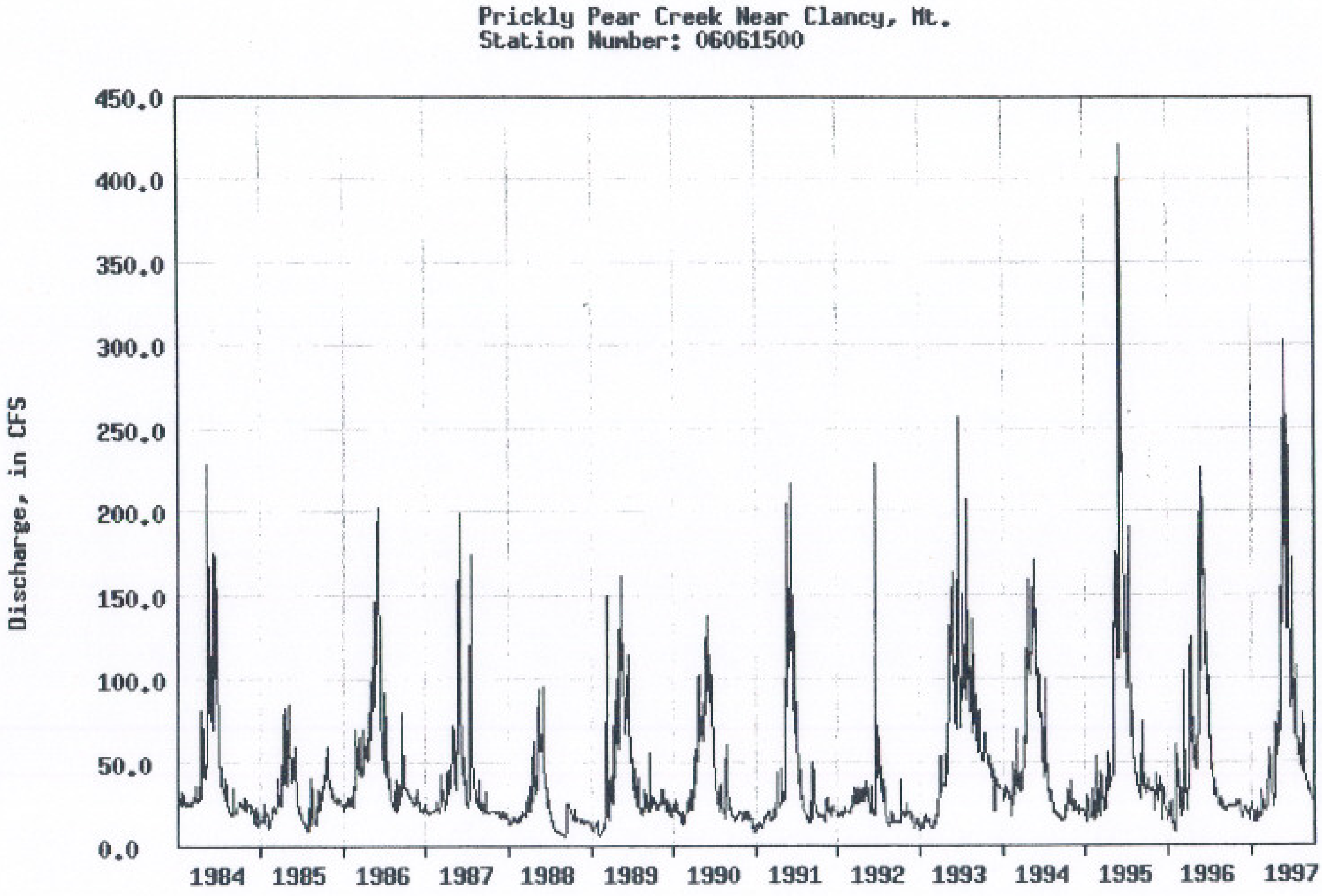


Figure 4-3-3. Prickly Pear Creek Historic Flow Hydrograph

pattern is typical in normal years, and that in dry years peak flow in the creek may be as low as 80 cfs.

The Comprehensive RI/FS for the East Helena plant site (Hydrometrics, 1990a) derived the following conclusions based on surface water flow data collected from 1984 through 1988:

1) Average streamflow upstream of the plant at site PPC-3 was between 41 and 50 cfs; average flow at the most downstream site (PPC-9) was between 18 and 25 cfs. The majority of flow lost was attributable to diversions (i.e., the Upper Lake diversion and a number of agricultural diversions);
2) Streamflow lost as a result of the Upper Lake diversion (between PPC-3 and PPC-4) was regained within 1/2 mile downstream at PPC-5, presumably as return flow from Upper Lake via underground seepage and overflow through several culverts;
3) In general, Prickly Pear Creek gains or losses in the vicinity of the plant site are of small enough magnitude to be within the estimated error of flow measurements; therefore, accurate quantification of gaining and losing reaches through synoptic streamflow measurements is not possible.

Figure 4-3-4 shows flow trends at Prickly Pear Creek monitoring stations near the Asarco plant site for several spring (high flow) and fall (low flow) monitoring events, from the site upstream of the plant (PPC-3) to the most downstream site (PPC-9). The May and August 1987 data clearly show diversions reducing flow between PPC-3 and PPC-4, and again between PPC-8 and PPC-9. With the exception of these diversions, however, no significant changes in streamflow across a particular stream reach are apparent from flow measurements for either high or low flow events. Streamflow at stations PPC-3 (upstream of the Upper Lake diversion), PPC-102, and PPC-5 (downstream of the diversion) are similar for the three years of high and low flow data shown on Figure 4-3-4. Variations in flow measured at adjacent stations for individual sampling events are generally less than 10%, within the probable error margin for streamflow measurements under the conditions present in the

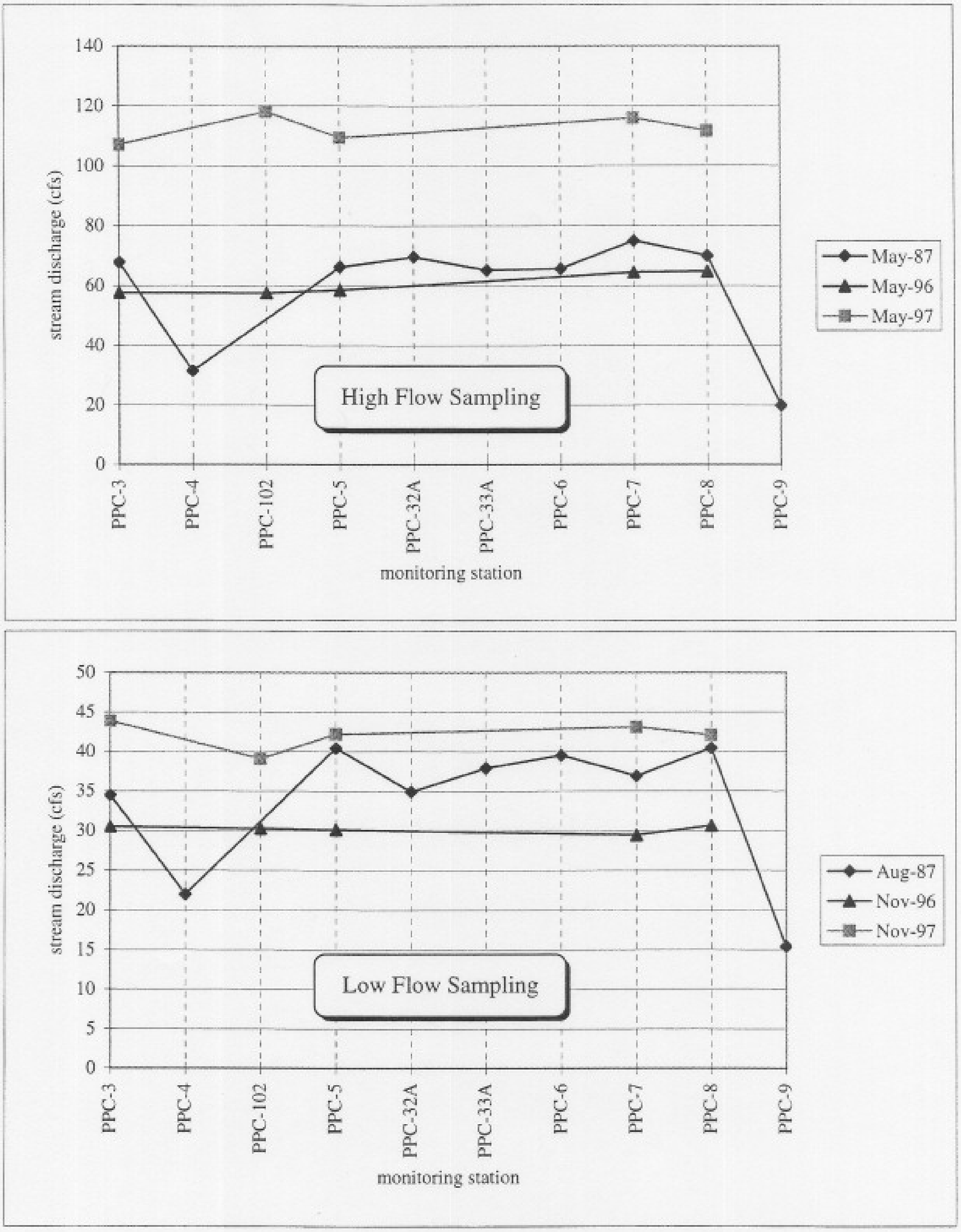


Figure 4-3-4. Prickly Pear Creek High and Low Flow Trends

creek. The primary conclusions of the 1990 RI/FS (listed above) regarding surface water flow in the vicinity of the East Helena plant site remain relevant: Flow lost from Prickly Pear Creek at the Upper Lake diversion is quickly regained a short distance downstream, and stream gains or losses through subsurface flow are too small to be accurately quantifiable through streamflow measurements.

~~1.1.1.2~~4.3.1.2 Water Quality

Water quality measurements in Prickly Pear Creek near the Asarco East Helena Plant site have been collected at approximately the same frequency as streamflow measurements. Table 3-2-1 (Section 3) lists surface water sites and frequency of monitoring for the period 1984 through 1997. Analytical water quality parameters for the various surface water sampling events are shown in Table 3-2-2. Complete water quality results for Prickly Pear Creek monitoring stations through 1997 are in Appendix 3-1-1. Typically, the parameter list for Prickly Pear Creek samples has included field-measured parameters (pH, specific conductance, dissolved oxygen, and water temperature), general physical parameters (total dissolved and suspended solids), major anions (sulfate, chloride), and a selected suite of trace constituents (arsenic and metals, including cadmium, copper, manganese, and zinc).

In general, Prickly Pear Creek is characterized as a calcium-bicarbonate type water with alkaline pH values (average pH values for individual water quality monitoring stations range from 7.1 to 8.5), moderately low concentrations of dissolved solids (average TDS ranges from 158 to 192 mg/L), and low concentrations of arsenic and metals.

Table 4-3-1 shows summary statistics for ~~compares the average concentrations of~~ dissolved and total arsenic and metals for the period of record at monitoring locations upstream, adjacent to, and downstream of the Asarco plant site. Average arsenic concentrations in the creek upgradient of the site (PPC-3 & 3A) are low (0.006 mg/L dissolved arsenic and 0.007 mg/L total arsenic at PPC-3) and increase by only about twofold in the stream reach from PPC-3 to PPC-7, where the plant site borders the creek. On average, the majority of the

TABLE 4-3-1. SUMMARY STATISTICS FOR ARSENIC AND METALS PRICKLY PEAR CREEK SITES PPC-3, PPC-3A, PPC-5, AND PPC-7 (1984-1997)

	Parameter (mg/L)											
	As		**Cd**		**Cu**		**Mn**		**Pb**		**Zn**	
Site	D	T	D	T	D	T	D	T	D	T	D	T
PPC-3 (n)	49	75	50	76	43	67	4	30	50	76	49	75
Avg	0.006	0.007	0.001	0.001	0.006	0.009	0.035	0.091	0.005	0.010	0.044	0.078
Min	<0.004	0.004	<0.001	0.001	<0.004	<0.004	0.028	0.033	<0.005	<0.005	<0.006	0.016
Max	0.016	0.027	0.003	0.004	0.019	0.020	0.041	0.240	<0.02	0.040	0.137	0.217
SD	0.002	0.003	0.0004	0.0005	0.003	0.004	0.006	0.060	0.002	0.008	0.024	0.039
PPC-3A (n)	5	5	5	5	5	5	0	0	5	5	5	5
Avg	0.005	0.007	0.001	ND	ND	0.008	NM	NM	ND	0.010	0.091	0.141
Min	<0.005	<0.005	<0.001	<0.001	<0.004	<0.004	--	--	<0.005	<0.005	0.076	0.099
Max	0.006	0.008	0.003	<0.001	<0.008	0.015	--	--	<0.005	0.020	0.112	0.212
SD	0.0005	0.001	0.0009	--	--	0.005	--	--	--	0.007	0.016	0.046
PPC-5 (n)	67	68	67	68	60	61	5	17	67	68	66	67
Avg	0.011	0.013	0.001	0.001	0.006	0.009	0.116	0.155	0.005	0.017	0.049	0.080
Min	<0.004	0.005	<0.001	<0.001	<0.004	<0.004	0.073	0.075	<0.005	<0.005	<0.006	0.015
Max	0.078	0.079	0.002	0.004	0.016	0.023	0.279	0.303	<0.02	0.075	0.150	0.241
SD	0.010	0.010	0.0003	0.0007	0.002	0.005	0.091	0.073	0.002	0.013	0.030	0.045
PPC-7 (n)	29	55	29	55	19	43	1	27	29	55	28	54
Avg	0.012	0.014	0.001	0.001	0.005	0.010	0.068	0.101	0.007	0.016	0.047	0.083
Min	<0.004	0.005	<0.001	<0.001	<0.004	<0.004	0.068	0.051	<0.005	0.005	0.008	0.028
Max	0.047	0.083	<0.005	<0.005	<0.008	0.024	0.068	0.240	0.023	0.050	0.130	0.347
SD	0.009	0.013	0.0008	0.0009	0.002	0.004	--	0.048	0.005	0.011	0.028	0.053

NOTES:
(n) = number of analyses for the given site and parameter.
Avg = average of data set; Max = maximum value; Min = minimum value; SD = standard deviation of data set.
Quality control samples (e.g. duplicates, splits) not included in statistics.
Below detect values were replaced with the detection limit for calculations (e.g. <0.001 replaced with 0.001).
Sites PPC-3 and PPC-3A are upstream and site PPC-7 is downstream of the Asarco plant; site PPC-5 is adjacent to the plant near Lower Lake.
D = dissolved analysis; T = total or total recoverable analysis (values were combined for calculations)
ND = parameter not detected; NM = parameter not measured.
A small number of water samples from PPC-3 and PPC-5 collected in 1995 and analyzed for total arsenic, lead, and zinc by XRF at elevated detection limits (5.0 mg/L) were excluded from statistics, due to the potential skewing of summary statistics by <5.0 mg/L results. These results are included in the sample database in Appendix 3-1-1.

increase occurs between PPC-3 and PPC-5, with only a slight additional increase from PPC-5 to PPC-7. Other parameters showing an appreciable increase in average concentration over this reach are total lead (from 0.010 mg/L to 0.016 mg/L), and dissolved manganese (from 0.035 mg/L to 0.068 mg/L). Both dissolved and total manganese concentrations in Prickly Pear Creek appear to increase from PPC-3 to PPC-5, and then decrease from PPC-5 to PPC-7.

Table 4-3-1 also shows that total metals and arsenic concentrations in the creek are generally slightly higher than dissolved concentrations. The particulate phase is especially important for lead and zinc (average total concentrations are approximately two times average dissolved concentrations). For arsenic, average total concentrations are about 50% greater than average dissolved concentrations.

The 1990 Comprehensive RI/FS reviewed arsenic surface water concentration and loading trends to evaluate the relationship between the Asarco plant and Prickly Pear Creek. Conclusions reported in the Comprehensive RI/FS included the following:

1) Arsenic loads increased by 0.3 to 2.3 times, and concentrations increased by about 0.7 to 3.7 times, over the stream reach from PPC-3 to PPC-7;
2) The most significant load and concentration increase in arsenic occurred near station PPC-5; no appreciable increases were apparent from PPC-5 to PPC-7, suggesting that the slag pile bordering the creek in this reach is not a significant contributor of arsenic to Prickly Pear Creek;
3) Arsenic concentration increases between PPC-3 and PPC-7 (i.e., from upstream of the plant site to downstream of the plant site) were at a maximum during periods of low flow, increasing an average of 0.014 mg/L for 1984-1986 data, and 0.008 mg/L for 1986-1988 data. The RI suggested that the observed concentration increases might be unusually high due to the exceptionally low amounts of precipitation and streamflow. High concentrations of arsenic were also present in Lower Lake at that time;

4) The increase in arsenic load and concentration between PPC-3 and PPC-7 is probably attributable to a small amount of seepage flow (estimated at approximately 13 gpm) through the earth berm that separates Lower Lake from Prickly Pear Creek.

The calculated average arsenic concentration increase of about 2 times shown in Table 4-3-1 above agrees well with the Comprehensive RI/FS data (observed concentration increases of 0.7 to 5 times). Post-RI water chemistry trends in Prickly Pear Creek, with emphasis on arsenic concentration and loading trends, are discussed further below.

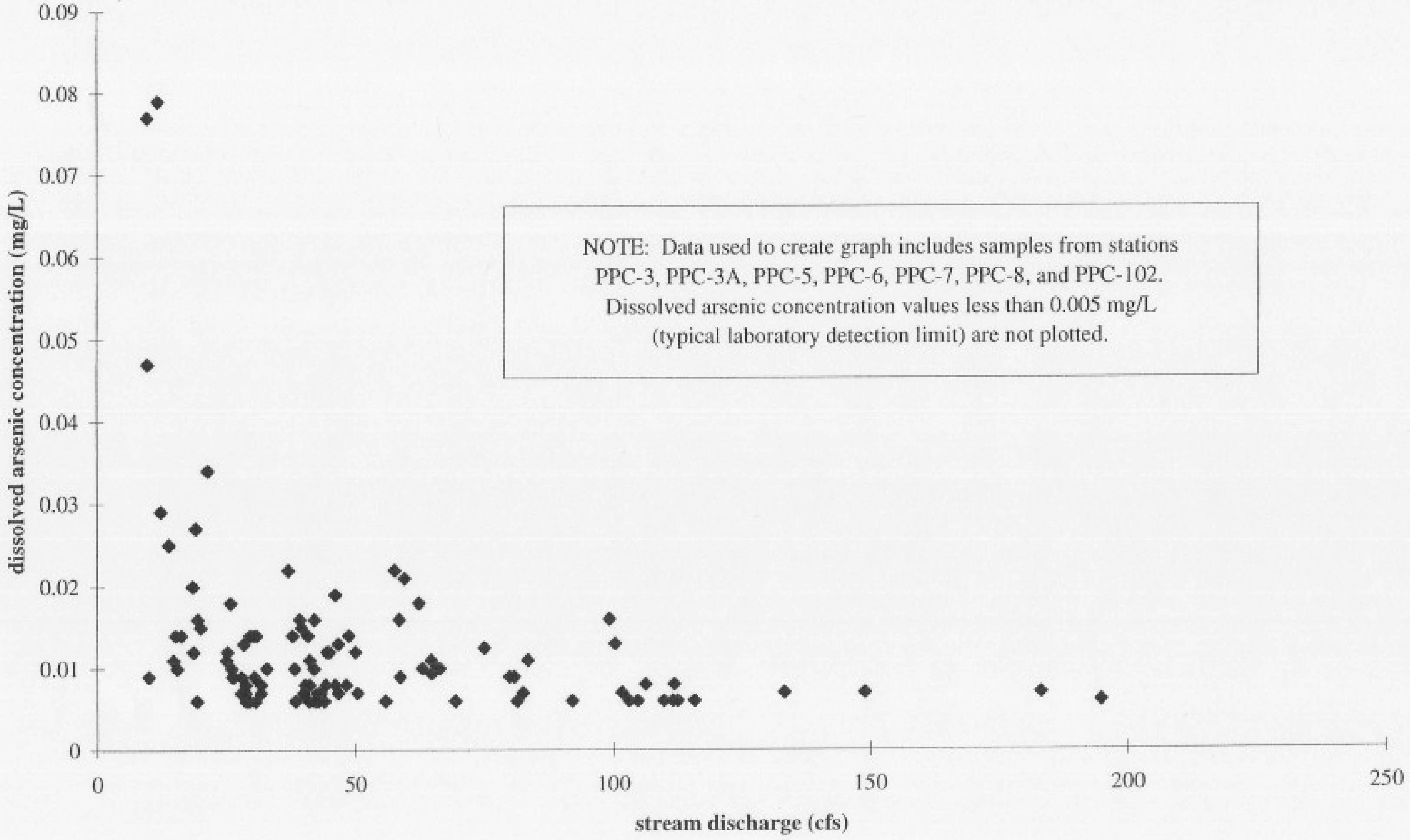
Temporal trends for water quality parameters including arsenic, arsenic speciation ratio, cadmium, copper, lead, zinc, iron, manganese, sulfate, chloride, total dissolved solids, pH, and dissolved oxygen for Prickly Pear Creek monitoring stations are presented in Appendix 4-3-1. Water quality statistics for Prickly Pear Creek sites are in Appendix 4-3-2. The temporal plots also show mean values and a range of one and two standard deviations around the mean for arsenic and other selected water quality constituents. Prickly Pear Creek stations that have been monitored since the completion of the Comprehensive RI/FS include:

- PPC-3/PPC-3A, PPC-5, PPC-7, and PPC-8, sampled seasonally under the Post-RI monitoring plan;
- PPC-4 and PPC-6, sampled along with PPC-3, PPC-5, and PPC-7 in 1995 and 1996 under the terms of EPA Clean Water Act Section 308 and 309 Requests for Information; and
- PPC-101, PPC-102, and PPC-103, new stations established adjacent to Lower Lake, and sampled with PPC-3 and PPC-5 as part of the Lower Lake Remediation Project beginning in 1994.

Examination of temporal trend plots for these stations shows that there are few consistent long-term trends apparent in Prickly Pear Creek water quality constituents. The most consistent water quality trend is the increase in dissolved zinc concentrations that has occurred since about 1995; prior to 1995, dissolved zinc concentrations in the creek ranged from about 0.02 to 0.06 mg/L, while recent concentrations have been slightly higher, from about 0.06 to 0.14 mg/L. The increase in dissolved zinc is apparently unrelated to the East Helena plant site, since monitoring stations both upstream and downstream of the plant site have shown the trend.

Dissolved arsenic concentrations have not shown any significant long-term increases or decreases in Prickly Pear Creek over the period of record, with the possible exception of PPC-7 (Appendix 4-3-1). Concentrations observed at this site from 1984 through 1988 ranged from 0.01 to 0.05 mg/L, while concentrations observed since 1989 have only occasionally exceeded 0.01 mg/L. The higher concentrations in 1984 and 1985 are presumably related to the low creek flows in those years. Prickly Pear Creek exhibits a typical concentration/discharge relationship for dissolved arsenic, with concentrations decreasing as flows (and dilution) increase. The relationship between dissolved arsenic concentration and discharge for Prickly Pear Creek is shown in Figure 4-3-5.

Figure 4-3-6 shows dissolved arsenic concentrations at Prickly Pear Creek sites PPC-3 (or PPC-3A), PPC-5, and PPC-7 for seasonal high and low flow monitoring events conducted since 1985. Figure 4-3-7 shows total arsenic concentrations for the same sites and monitoring events (note that Figures 4-3-6 and 4-3-7 do not include the entire data set, but rather were prepared from a representative set of seasonal monitoring data from both the RI and post-RI monitoring periods). Figures 4-3-6 and 4-3-7 indicate that, with very few exceptions, arsenic concentrations either do not increase or increase only slightly (0.001 to 0.003 mg/L increase) from station PPC-5 to PPC-7. Concentration increases from PPC-3 to PPC-5, which are the result of seepage from Lower Lake, are typically greater than concentration increases between PPC-5 and PPC-7. No strong seasonal trends in Prickly Pear Creek arsenic concentrations are evident from Figures 4-3-6 or 4-3-7; however, monitoring events showing unusually high arsenic concentrations (e.g., September 1985, August 1987) relative to the entire seasonal data set are apparent on these figures.



NOTE: Data used to create graph includes samples from stations PPC-3, PPC-3A, PPC-5, PPC-6, PPC-7, PPC-8, and PPC-102. Dissolved arsenic concentration values less than 0.005 mg/L (typical laboratory detection limit) are not plotted.

Figure 4-3-5. Dissolved Arsenic Concentration/Stream Discharge Relationship Prickly Pear Creek

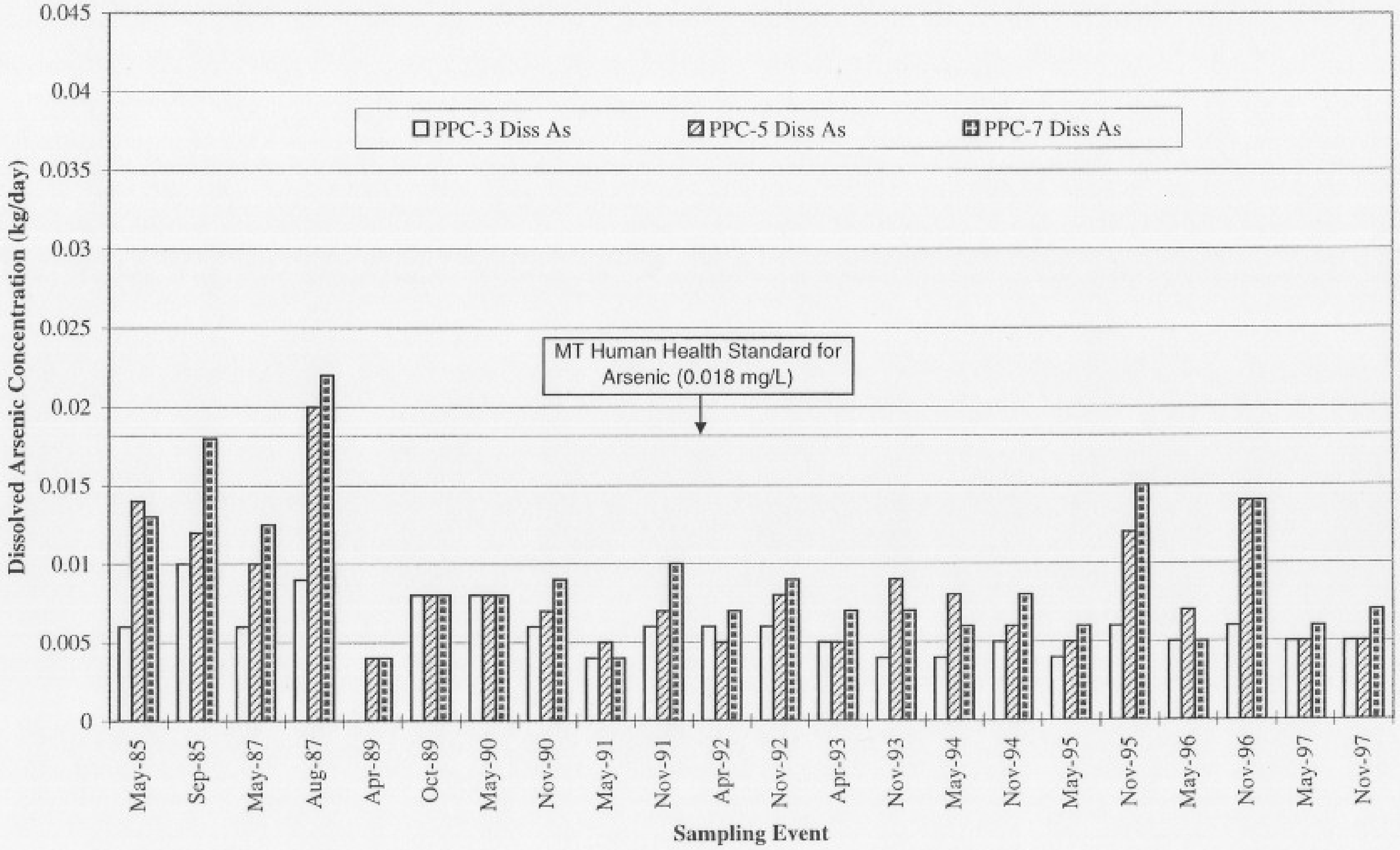


Figure 4-3-6. High and Low Flow Dissolved Arsenic Concentrations in Prickly Pear Creek PPC-3, PPC-5 and PPC-7

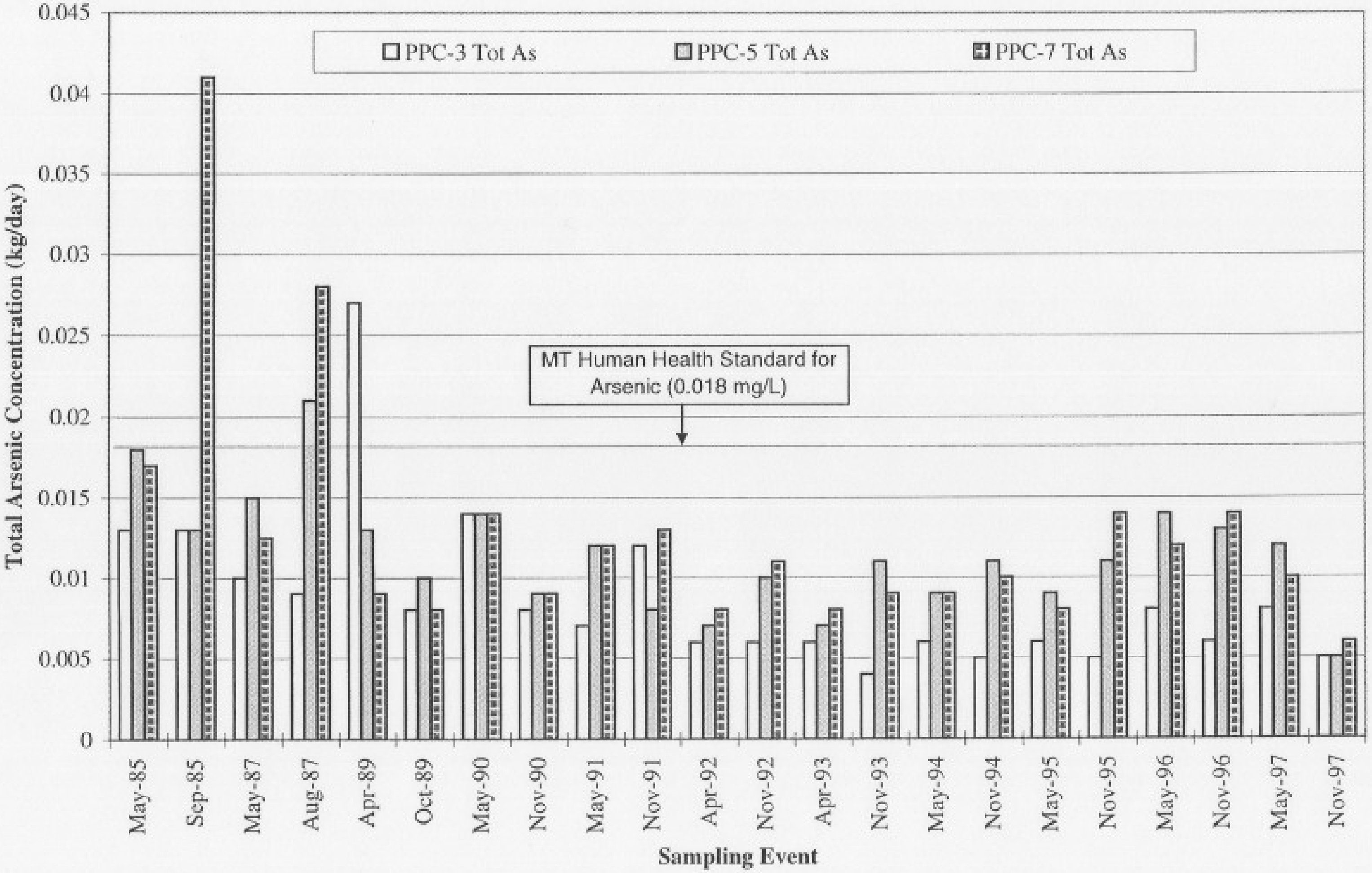


Figure 4-3-7. High and Low Flow Total Arsenic Concentrations in Prickly Pear Creek Sites PPC-3, PPC-5 and PPC-7

Table 4-3-2 shows potentially applicable water quality criteria (both Federal and State criteria) for arsenic, cadmium, copper, lead and zinc. Comparison of the standards in Table 4-3-2 with average and maximum total concentrations for Prickly Pear Creek cited in Table 4-3-1 indicates that freshwater chronic criteria for manganese and lead are typically exceeded both upstream (PPC-3) and downstream (PPC-7) of the plant site. Occasional exceedances of water quality standards for arsenic, cadmium, copper and zinc also occur upstream and downstream of the site.

Comparison of the Montana human health standard for arsenic (0.018 mg/L) with the seasonal Prickly Pear Creek data shown in Figures 4-3-6 and 4-3-7 shows that seasonal dissolved and total arsenic concentrations since 1989 have been below the human health standard at all three monitoring locations (except for total arsenic at PPC-3 in April 1989). Additional infrequent exceedances of the arsenic human health standard at stations PPC-5 and PPC-7 have occurred over the period of record (from 1984 through 1997), primarily during the remedial investigation conducted from 1984-1987. Examination of the complete database, including seasonal monitoring and supplemental monitoring results (Appendix 3-1-1) shows that overall, total recoverable and total arsenic concentrations have exceeded the Montana human health standard at PPC-3 one time (out of 79 samples), at PPC-5 eight times (out of 66 samples), and at PPC-7 six times (out of 55 samples).

Comparison of total and total recoverable of cadmium, copper, and zinc to Montana human health standards generally shows no exceeedences for these parameters. Lead concentrations are higher than Montana human health criteria upstream and downstream, with 15 exceedances (out of 81 samples) at PPC-3, 26 exceedances (out of 68 samples) at PPC-5 and 24 exceedances out of 55 samples at PPC-7.

TABLE 4-3-2. FEDERAL AND STATE WATER QUALITY CRITERIA

Parameter	Montana Human Health Standard	Montana Freshwater Aquatic Life Standard		Federal MCL/Action Level
		Chronic	Acute	
Arsenic	0.018	0.190	0.360	0.05
Cadmium	0.005	0.0011(1)	0.0039(1)	0.005
Copper	1	0.012(1)	0.018(1)	1.3
Lead	0.015	0.0032(1)	0.082(1)	0.015
Manganese	0.05	none	none	0.05(2)
Zinc	5.0	0.11(1)	0.12(1)	5.0(2)

MCL = maximum contaminant level
(1) Hardness-dependent parameter. Value shown is for 100 mg/L hardness as $CaCO_3$.
(2) Secondary MCL (unenforceable guideline).

Of the parameters sampled in Prickly Pear Creek, arsenic shows the most obvious or measurable increases in Prickly Pear Creek; primarily between stations PPC-3 and PPC-5. The dissolved arsenic load in Prickly Pear Creek (concentration times flow) can be calculated from concentrations and associated stream discharge rates for various sampling events. Figure 4-3-8 shows dissolved arsenic loads in Prickly Pear Creek calculated for sites PPC-3 (or PPC-3A), PPC-5, and PPC-7 for a number of high and low flow monitoring events conducted since 1985 (note that fewer events are shown in Figure 4-3-8 than in Figure 4-3-6, due to a lack of flow data for loading calculations for some monitoring events). Several ~~For some~~ monitoring events (e.g., May 1985, November 1993, May 1994, and November 1996)~~,~~ show increases in loading between the upstream site (PPC-3) and the site adjacent to the Asarco plant (PPC-5) ~~are apparent~~; in these cases, no appreciable dissolved arsenic loading occurs between PPC-5 and the further downstream site PPC-7. In other cases (e.g., April 1993, May 1997, and November 1997), dissolved arsenic loading shows little or no increase from PPC-3 to PPC-5, and a small increase from PPC-5 to PPC-7. No consistent large loading increases from PPC-5 to PPC-7, however, are apparent. The data indicate, as described in the 1990 Comprehensive RI/FS, increases in arsenic loading have typically

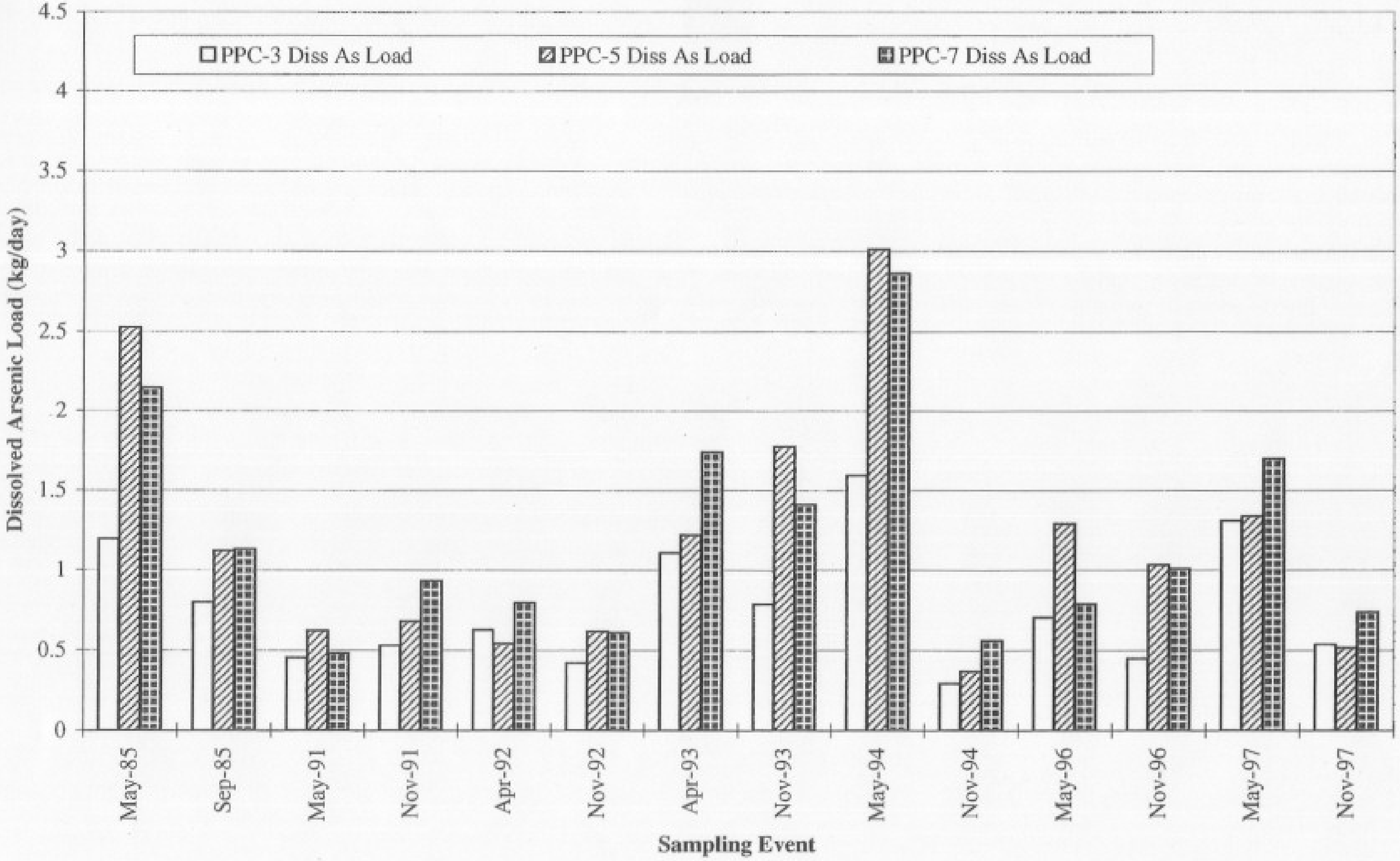


Figure 4-3-8. High and Low Flow Dissolved Arsenic Loading in Prickly Pear Creek PPC-3, PPC-5 and PPC-7

occurred in the stream reach near PPC-5, immediately downstream of adjacent Lower Lake. The very low loading increase between PPC-3 and PPC-5 in 1997 may also be the result of the significantly improved water quality in Lower Lake since 1993 (see Section 4.2.3.1).

Examination of total arsenic data and loading~~s~~ in Prickly Pear Creek were generally similar to dissolved arsenic relationships between sites PPC-3, PPC-5, and PPC-7 (see Figure 4-3-9~~7~~). For one particularly high runoff event (May 1994), however, an apparent increase in total arsenic loading ~~was observed~~ between PPC-3 and PPC-5~~ (primarily due to a dissolved arsenic load increase, as shown on Figure 4-3-5)~~, and again between PPC-5 and PPC-7. ~~(where dissolved arsenic load did not increase, so the increase can be attributed to particulate phase arsenic only).~~ The apparent load increase from PPC-5 to PPC-7 during the May 1994 event is anomalous (i.e., no other increases of similar magnitude during Post-RI monitoring events have been observed). The increase shown on Figure 4-3-9 for May 1994 is probably affected by the decreased accuracy of flow measurements during periods of high stream flow.

The relationship between Prickly Pear Creek and Lower Lake is important, due to the proximity of Lower Lake to Prickly Pear Creek and the historic use of Lower Lake as a storage pond for excess plant water. Lower Lake is in the southeast corner of the plant site, with Prickly Pear Creek immediately to the east (Exhibit 3-2-1). The lake was formed about 50 years ago (in the 1940s) by dividing the northern portion of Upper Lake with a berm of fill, for the purpose of storing plant process recirculation water.

Surface water and groundwater elevation data collected during the post-RI period show that Lower Lake is sometimes as high as five feet above Prickly Pear Creek upstream of the dam (at PPC-103), and approximately fifteen feet higher than the creek below the dam (at PPC-105). Therefore, Lower Lake water has the potential to seep through bottom sediments and adjacent soils into Prickly Pear Creek.

Figure 4-3-10 shows dissolved arsenic concentration trends for Lower Lake, PPC-5, and PPC-7. Lower Lake has shown improvement in water quality over time due to various

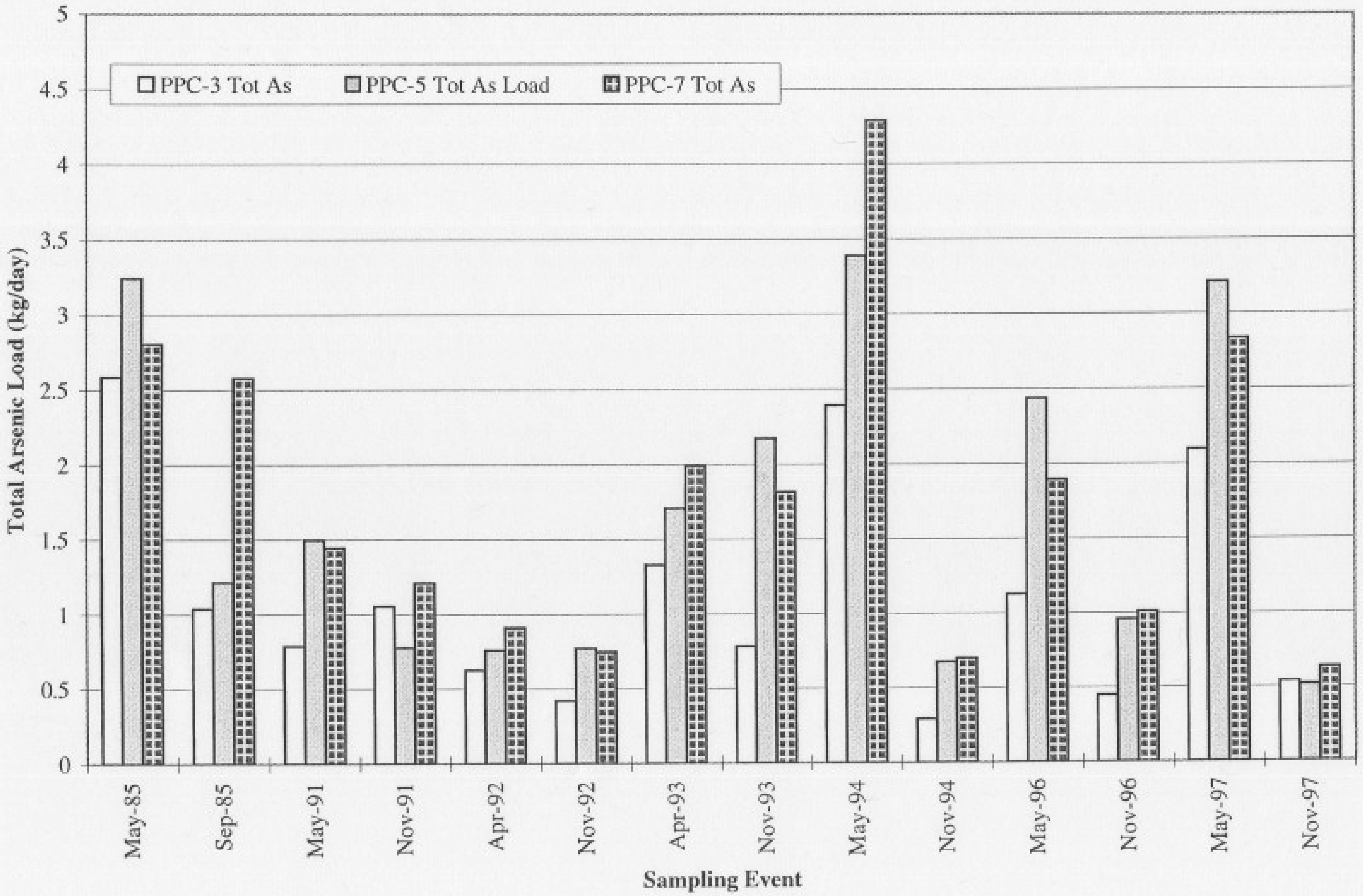


Figure 4-3-9. Total Arsenic Loading in Prickly Pear Creek Sites PPC-3, PPC-5 and PPC-7

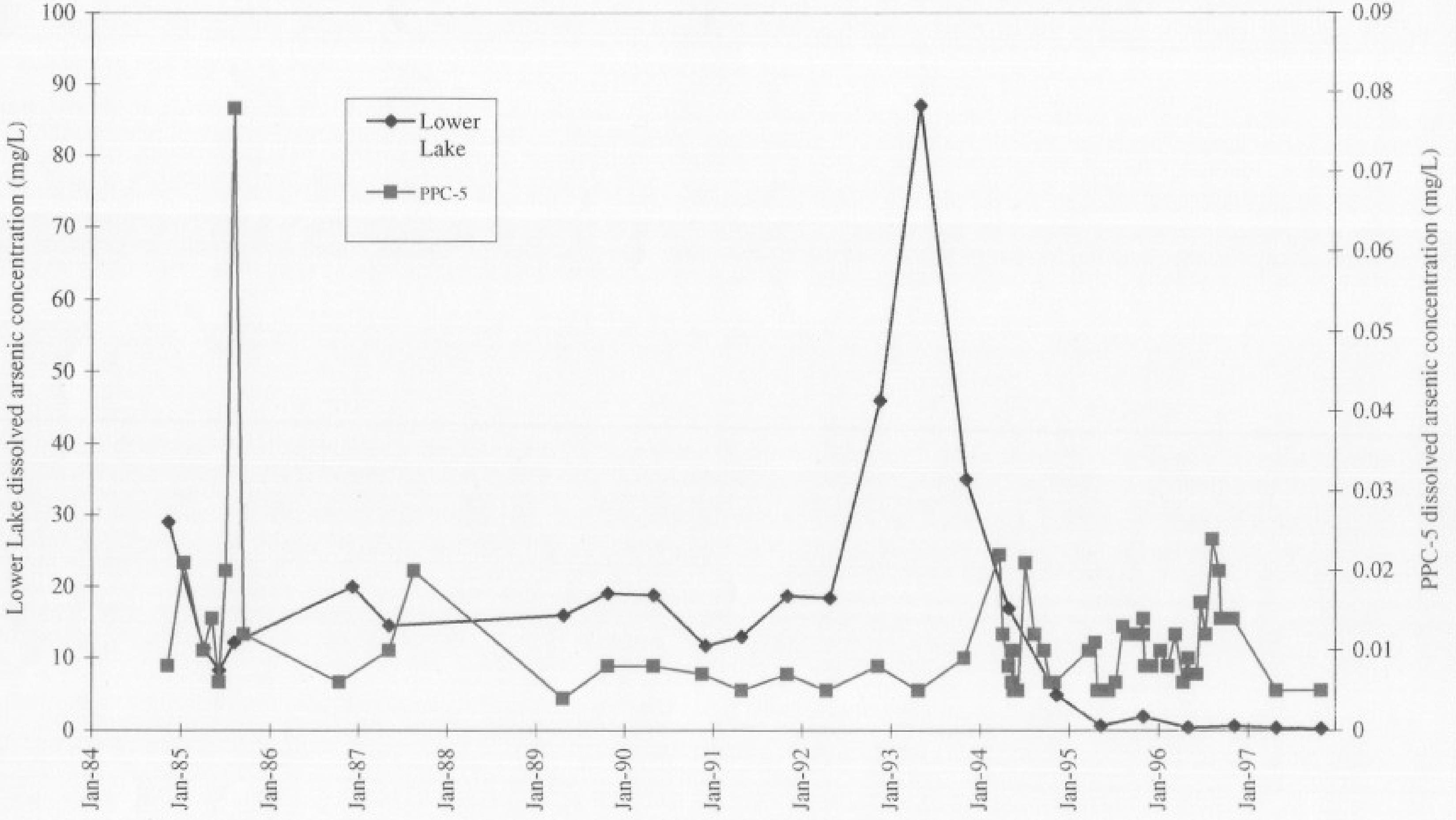


FIGURE 4-3-10. ARSENIC CONCENTRATION TRENDS FOR LOWER LAKE AND PRICKLY PEAR CREEK (PPC-5)

process controls and water treatment strategies. Arsenic concentrations have decreased from greater than 10 mg/L (prior to 1993) to an average of 0.42 mg/L (based on 1996 and 1997 seasonal monitoring data). The large spike in arsenic concentration in 1992 and 1993 resulted from routing of high-arsenic process water (scrubber blowdown) directly to Lower Lake during the change over to the new Acid Plant Water Treatment Facility (see Section 4.2.3 - Process Fluid Chemistry, and Section 5.0 - Release Assessment). Arsenic concentrations at PPC-5, as discussed previously, have changed little over the period of record, and did not show a similarly large spike in concentration, although a very minor concentration increase (0.01 mg/l to 0.025 mg/l, see Figure 4-3-10) was apparent at the site in early 1994. A similar low concentration increase occurred in 1996 (Figure 4-3-10), suggesting that the fluctuation in 1994 may be seasonal rather than attributable to the Lower Lake spike. A review of the time trend plots for arsenic at PPC-5 in Appendix 4-3-1 shows that highest arsenic concentrations observed were at about one standard deviation (0.025 mg/l) from the data mean, clearly indicating the concentrations are within the normal range of variability.

In addition to dissolved arsenic, sulfate concentration trends were compared for Lower Lake and Prickly Pear Creek, since sulfate is more chemically conservative than arsenic and may act as a better tracer for evaluating potential effects of Lower Lake on Prickly Pear Creek. Figure 4-3-11 shows sulfate concentrations in Lower Lake and at site PPC-5. A pronounced increase in Lower Lake sulfate concentration has occurred since 1994 as a result of the HDS™ plant discharge, from about 600 mg/L to 1600 mg/L; concentrations at PPC-5 do not show an accompanying increase. Time trend plots for sulfate for PPC-5 and PPC-7 in Appendix 4-3-1 show concentrations of sulfates in 1994 through the present have little variability and are near the mean concentration of the period of record.

4.3.1.3 Prickly Pear Creek and Upper Lake Sediment Quality

Bottom sediments from Prickly Pear Creek (sampling locations PPC-3 through PPC-9) and Upper Lake were collected and analyzed in 1984 and 1985 as part of the RI; no subsequent

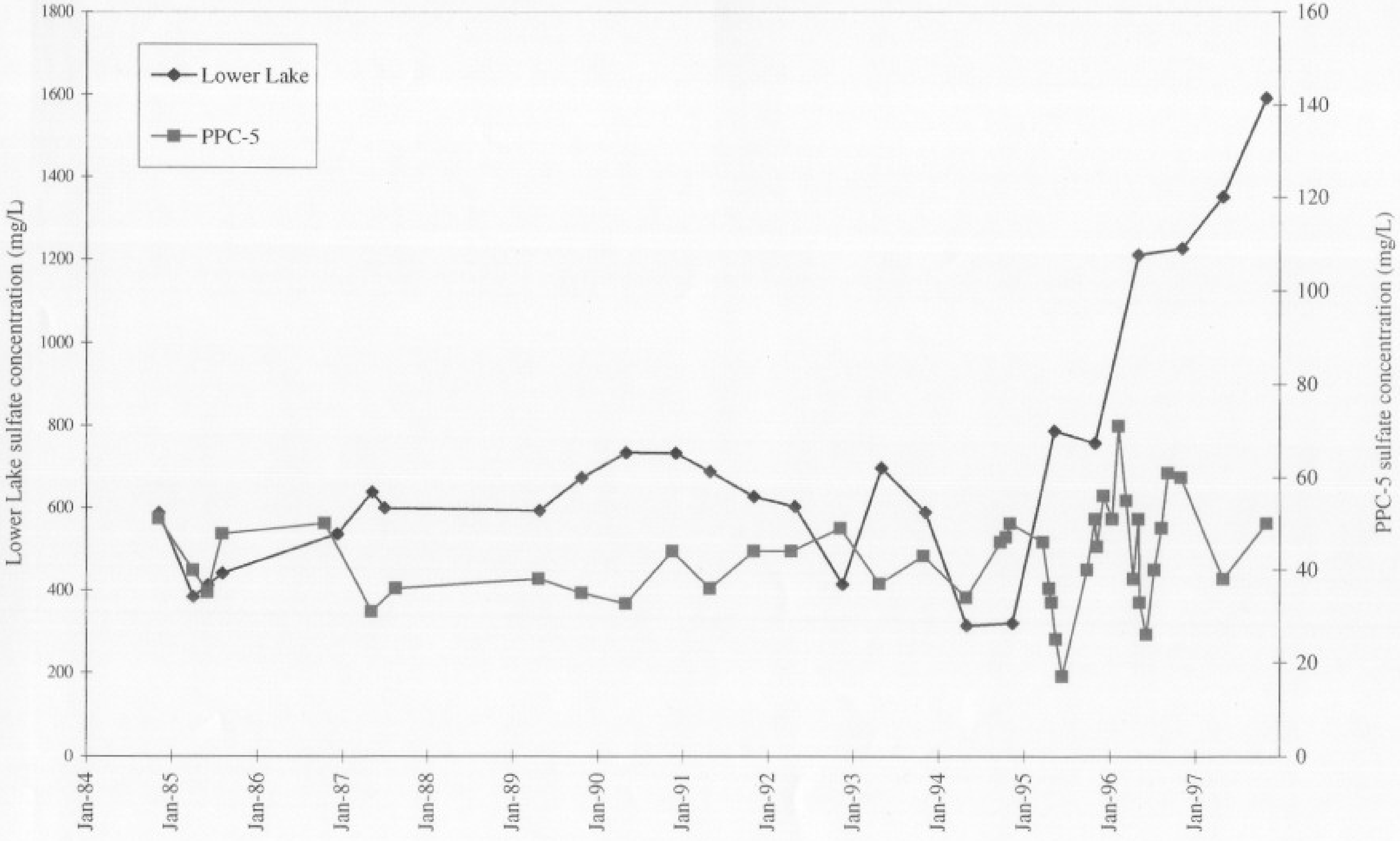


FIGURE 4-3-11. SULFATE CONCENTRATION TRENDS IN LOWER LAKE AND PRICKLY PEAR CREEK (PPC-5)

sediment samples from these locations have been collected. The sediment quality data for Prickly Pear Creek and Upper Lake are in Appendix 3-1-2. Bottom sediments were collected and analyzed as bulk samples (i.e., size fractionation was not performed on sediments).

Sediment quality in Prickly Pear Creek differs upstream of the Asarco plant site (PPC-3 and PPC-4) and downstream of the plant site (PPC-5 through PPC-9). In general, downstream sediment arsenic and metals concentrations are higher than those upstream of the plant site. For most metals, the greatest observed change is between PPC-3 and PPC-5, with variable or decreasing trends further downstream. Zinc, however, shows a progressive increase in concentration downstream. Figure 4-3-12 shows the downstream trend in average sediment metals and arsenic concentrations.

Upper Lake sediments also are relatively elevated in concentrations of arsenic and metals, and concentrations are higher than those in Prickly Pear Creek both upstream and downstream of the plant site (Figure 4-3-12). Upper Lake sediment lead concentrations ranged from 494 to 4150 mg/kg in 1984-1985 samples. As stated in the RI, potential causes of arsenic and metal concentrations in Upper Lake sediment compared to Prickly Pear Creek include:

- The quiescent conditions in Upper Lake allow settling and accumulation of fine sediments from upstream of the plant site. As noted in the RI, historical mining impacts are well documented and are a major source of arsenic and metals to Prickly Pear Creek. The fine sediment component, in particular, is likely to exhibit higher concentrations of arsenic and metals. These fine sediments have accumulated in the slow velocity conditions of ~~Lower~~Upper Lake.
- Historic deposition of arsenic and metals from air emissions at the adjacent plant site.

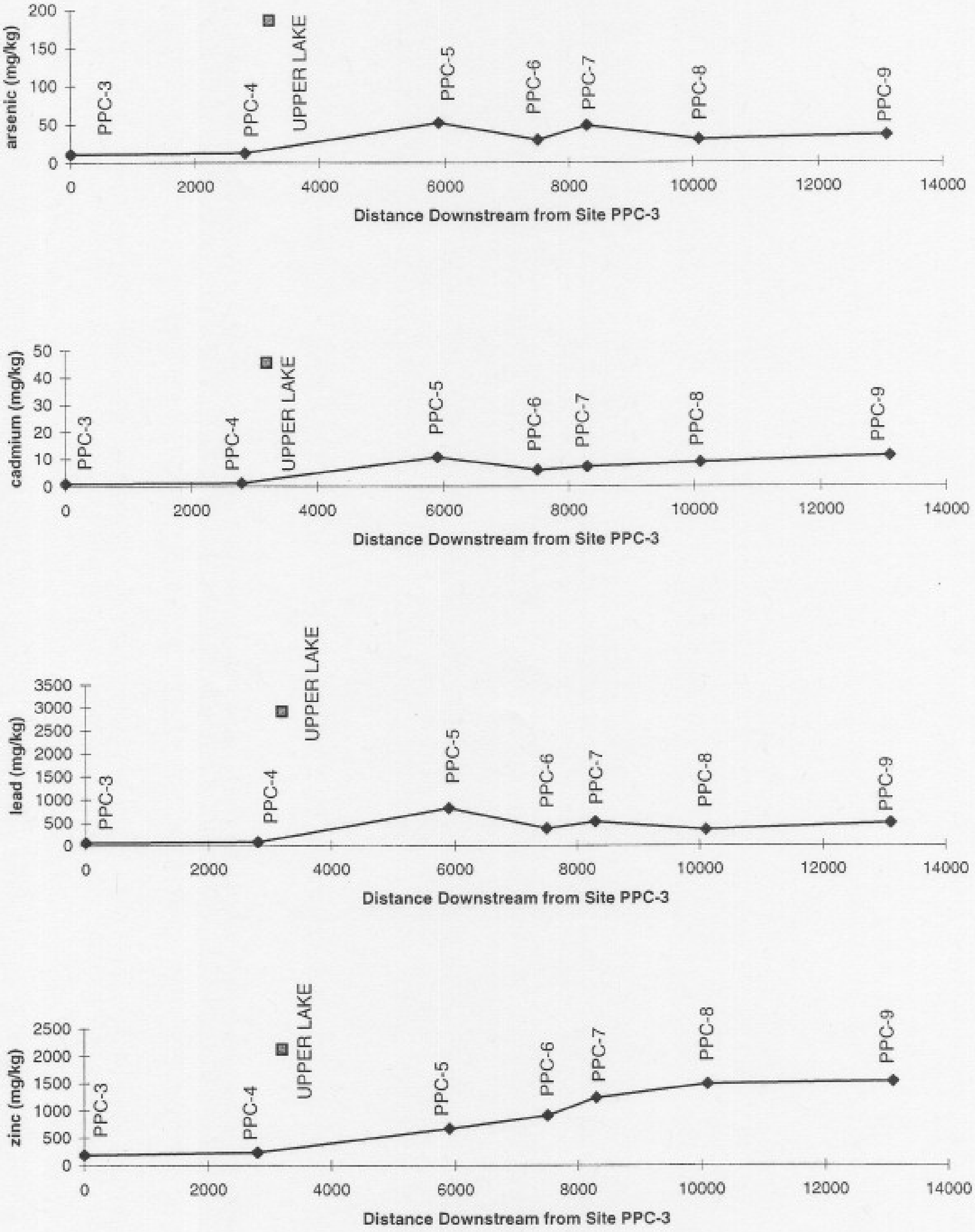


Figure 4-3-12. **Average Sediment Arsenic and Metals Concentrations Upper Lake and Prickly Pear Creek**