

**Mining Sites on the National Priorities List  
NPL Site Summary Reports**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Volume V**

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Volume V of the Mining Sites on the National Priorities List contains the following NPL site summary reports: Teledyne Wah Chang, Tex-Tin Corp., Torch Lake, United Nuclear Corporation/Churchrock Site, U.S. Tatanium, Uravan Uranium Mill, Whitewood Creek, and Wayne Interim Storage Facility/W.R. Grace.

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**Mining Waste NPL Site Summary Report**

**Teledyne Wah Chang  
Albany, Oregon**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

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**Prepared by:**

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**TELEDYNE WAH CHANG**

**ALBANY, OREGON**

**INTRODUCTION**

This Site Summary Report for the Teledyne Wah Chang site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on or proposed for the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region X Remedial Project Manager for the site, Howard Orlean.

**SITE OVERVIEW**

Teledyne Wah Chang Albany (TWCA) is a Superfund Site located in Millersburg, Oregon, an industrial suburb 3 miles north of Albany, Oregon (see Figure 1). The Superfund Site consists of two areas, the 110-acre Plant Site property and a 115-acre area approximately .75 of a mile north of the plant site known as the Farm Site. The Plant Site contains numerous buildings and facilities including an extraction area, a fabrication area, a solids storage area, and a parking and recreation area. The Farm Site contains four 2.5-acre solids storage ponds. The remainder of the Farm Site is used primarily for agriculture (Reference 1, Chapter 2, page 1; Reference 2, page 1).

TWCA is an active facility that has been manufacturing primary and mill-product zirconium and hafnium from zircon sand for approximately 30 years. The facility has also produced smaller quantities of tantalum, niobium, and vanadium products. TWCA is a primary producer of zirconium metal. Zircon sand, the principal ore for the manufacturing process, is imported from Australia (Reference 1, Chapter 4, page 1).

Most of the wastestreams from the plant's operations are treated prior to discharge or disposal. Treatment techniques include continuous chemical precipitation and sedimentation of aqueous wastes in the wastewater treatment plant; segregation and disposal of solid wastes; and use of a variety of air contaminant control systems to cleanse emissions. Solids produced in the wastewater treatment plant have been managed over the years at several onsite areas, including the Lower River Solids Pond (LRSP), Schmidt Lake, the Farm Ponds 1 through 4, and the V-2 Pond (Reference 1, Chapter 5, pages 1, 5, and 6).

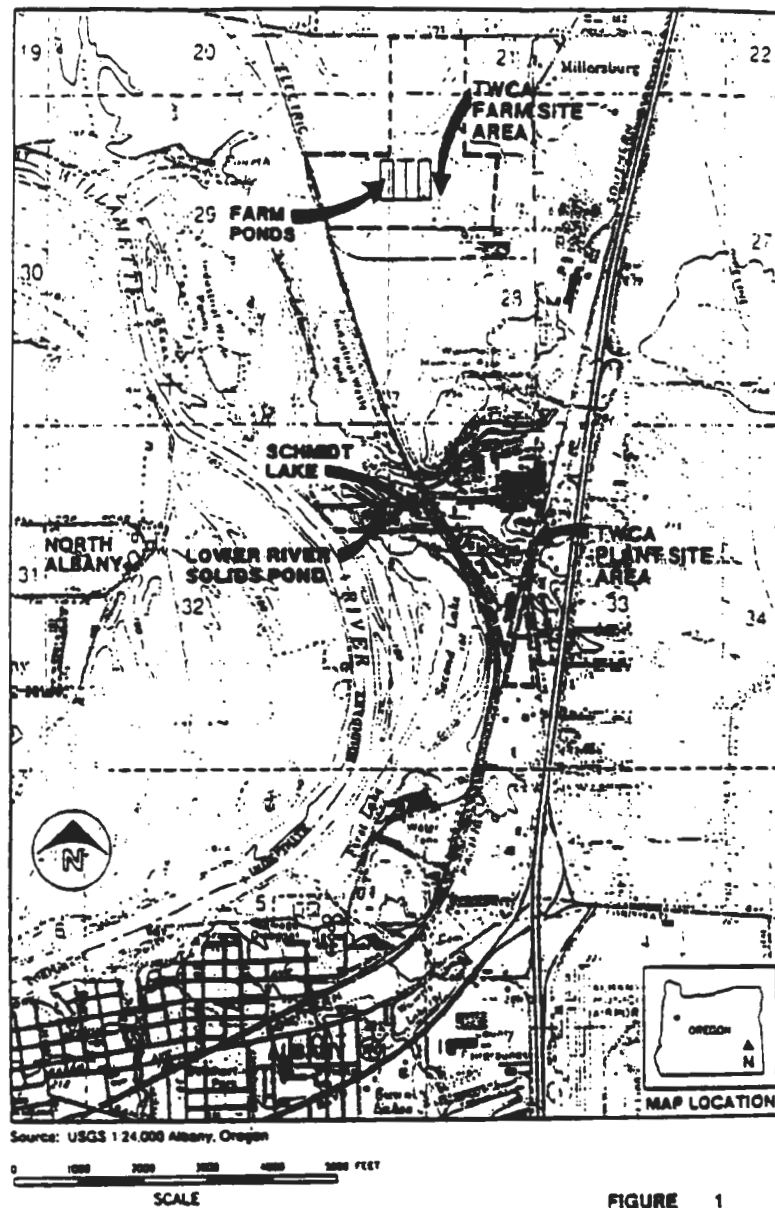


FIGURE 1. LOCATION MAP

TWCA currently has a National Pollutant Discharge Elimination System (NPDES) permit to regulate the discharge of process wastewater. The facility also has an Air Contaminant Discharge Permit that regulates air emissions from the facility. Although the facility submitted a Resource Conservation and Recovery Act (RCRA) Part B Application for the operation of hazardous waste management activities at the site, EPA determined that a Part B RCRA Permit was not necessary. Radioactive wastes are managed under the requirements of a Naturally Occurring Radioactive Materials (NORM) license (Reference 1, Chapter 5, pages 5, 15, 16, and 19).

The TWCA facility has been cited for numerous violations of its NPDES permit, occurring in 1975, 1977, 1978, 1979, 1980, and 1989. The company was fined for illegal burning in 1983. In 1986, TWCA was cited for several violations of the State's hazardous waste management rules (Reference 7, page 10).

Onsite storage of the solid wastes has attracted the attention of regulatory agencies and the public for many years, particularly with regard to the low-levels of radioactive materials found in these wastes (first confirmed by the Oregon State Health Division in 1977). In 1978, TWCA was granted a Radioactive Materials License to transfer, receive, possess, and use zircon sands and industrial byproducts containing licensable concentrations of radioactive materials (Reference 2, page 4). The company applied to the Energy Facility Siting Council (EFSC) in 1981 to obtain a site certificate to close the LRSP sludge pond and to store approximately 120,000 cubic yards of lime solids from the wastewater treatment process. After several years of deliberations, the EFSC ruled (in 1987) that the sludge was not subject to their jurisdiction because the levels of radioactivity were too low. In October 1983, during the EFSC deliberations, the TWCA site was placed on the NPL (Reference 2, page 4).

On May 4, 1987, TWCA signed a Consent Order to conduct the Remedial Investigation/Feasibility Study. As part of this order, EPA and TWCA agreed to address the LRSP, Schmidt lake, and Farm Pond sludges in an expedited fashion prior to the completion of the Remedial Investigation/Feasibility Study for the entire facility. This expedited action resulted from the public's concern of the sludge materials, the location of the sludges in the floodplain, and the potential of the sludges to contribute to ground-water contamination at the site. The Farm Ponds were later dropped from the expedited investigation and are being included as part of the overall site Remedial Investigation because they did not lie within the floodplain, and they contained levels of radioactivity lower than the other locations (Reference 2, page 4; Reference 1, Chapter 5, page 7; Reference 7, pages 1, 5, 10, and A-1).

In 1989, a Record of Decision (ROD) was finalized as an interim response for Operable Unit 1 (i.e., the sludge ponds unit consisting of the LRSP and Schmidt Lake) (Reference 7, page 1). The ROD specified a remedial action consisting of excavation and treatment of the sludges with cement, and

offsite disposal of the sludges in a specially constructed monocell. According to Region X, EPA issued a Unilateral Administrative Order to TWCA in February 1991 that called for the treatment, excavation, and offsite disposal of the LRSF and Schmidt Lake sludges along with long-term operation and maintenance of the offsite monocell.

TWCA is currently conducting the Remedial Investigation/Feasibility Study in response to the May 1987 EPA Order of Consent, Docket No. 1086-02-19-106 (Reference 1, Chapter 5, page 7 and Chapter 7, page 2). The Remedial Investigation is designed to characterize the nature and extent of contamination in various media (e.g., ground water, surface water, and sediments) throughout the site as well as evaluate pathways by which contamination may be leaving the site. At the request of EPA, TWCA has also initiated a baseline human Health Assessment that will consider the risks posed by the site to human health and the environment (Reference 5, pages 1 and 2).

As the Remedial Investigation/Feasibility Study for the entire site is not yet complete or available to the public, much of the information defining the problems at the TWCA site is preliminary. Conclusions about the risks associated with the site have only been summarized for Operable Unit 1 and are reported in the ROD for that unit. This document presents information from the ROD for Operable Unit 1 and describes the available preliminary information for other areas at the site.

## OPERATING HISTORY

The TWCA site has been in operation since 1956, when the Wah Chang Corporation reopened the U.S. Bureau of Mines' zirconium metal sponge pilot plant. New facilities were constructed in 1957, primarily for the production of zirconium and hafnium sponge. Tantalum and niobium pilot facilities were also included. Melting and fabrication operations were added in 1959. Teledyne Wah Chang Albany was established in 1967 after Teledyne Industries, Inc., purchased Wah Chang Corporation of New York (Reference 1, Chapter 4, page 1). The facility is still operating today as a primary manufacturer of zirconium metal. It is also capable of manufacturing hafnium, niobium, and vanadium metals (Reference 1, Chapter 4, page 1).

Zircon sand, the principal ore for the manufacture of zirconium metal, is imported from Australia. At TWCA, the sand undergoes a chlorination process from which zirconium tetrachloride is produced. Silicon tetrachloride is also produced from this process; it is purified and sold as a byproduct (Reference 1, Chapter 4, pages 1 through 3).

Following chlorination, the zirconium tetrachloride completes a separation process using the organic solvent methyl isobutyl ketone (MIBK) to remove the hafnium portion of the zirconium (most

zirconium minerals contain 1 to 5 percent hafnium). The resulting zirconium and hafnium oxides follow similar processes to final metal production, including a second chlorination step; a reduction process using elemental magnesium (magnesium chloride is removed and sold as a by-product); and the consolidation of zirconium sponge into ingots for eventual forming into numerous shapes and sizes (Reference 1, Chapter 4, pages 3 through 6).

Some of the wastes produced from the zirconium and hafnium manufacturing process include sand chlorinator residues (characterized as "radioactive"); MIBK still bottoms (characterized as "ignitable"); magnesium chloride wastes (characterized as a fire hazard); and smokehouse residue (characterized as "Extraction Procedure (EP) toxic waste code D008" according to the facility owner/operator) (Reference 1, Chapter 5, page 13). Slag wastes containing niobium and iron metals are produced from the niobium and vanadium manufacturing processes. Ancillary processes associated with the manufacturing operations include metal forming, painting, maintenance activities, and analytical laboratory Quality Assurance/Quality Control (QA/QC). These ancillary processes produce wastes, including salts, metal fines, waste thinners, MIBK, and 1,1,1-trichloroethane (Reference 1, Chapter 5, page 13)

Because so many processes are involved in the production of nonferrous metals and products, many waste management programs are employed at TWCA, including process wastewater treatment, solid waste management, hazardous waste management, radioactive-material control, Polychlorinated Biphenyls (PCBs) equipment management, and air-quality control (Reference 1, Chapter 5, page 1).

TWCA operates a wastewater treatment system for the handling of industrial wastewaters generated from metals manufacturing operations. The wastewater treatment process, consisting of a continuous chemical precipitation and sedimentation system, generates treated wastewater and sludges. The treated wastewater is discharged to Truax Creek under the guidelines of a NPDES permit that was first issued in March 1975. Sludges produced from TWCA's chemical precipitation and sedimentation processes are collected and placed in storage ponds for additional settling and dewatering. These "ponds" include the LRSP, Schmidt Lake, and Arrowhead Lake (located onsite) and Farm Ponds 1 through 4 (located north of the plant) (see Figure 1). A smaller pond, known as the V-2 Pond, was also used for a short period of time for temporary solids storage and pretreatment (Reference 1, Chapter 5, pages 1 through 6).

The solids produced from the various wastewater treatment processes were stored onsite in the LRSP, Schmidt Lake, and Arrowhead Lake from 1967 to 1978. Arrowhead Lake was dewatered and covered in the early 1980's. The LRSP and Schmidt Lake have not been used to store solids since 1979. TWCA also obtained a solid waste permit to use the sludge as a soil amendment on the TWCA

Farm Site in 1976. The sludge was applied at an average rate of 108 tons per acre; the use of the sludge as a soil amendment was only done in 1976 (Reference 1, Chapter 5, pages 5 through 8).

In 1979, the Farm Ponds came into operation as solids storage ponds for sludge from the wastewater treatment processes. The switch to sludge disposal in the Farm Ponds occurred after production processes for zirconium and hafnium were modified in 1978. The process modification reduced concentrations of radioactive materials in the sludges, and directed the radioactive materials to a separate solid waste referred to as "chlorinator residue" that is managed as a radioactive waste and shipped to Hanford, Washington, for disposal (Reference 1, Chapter 5, pages 5 through 8).

The V-2 Pond, built in 1960, was used for settling the lime solids from the lime-treated zirconium sulfate wet cake filtrate wastewater stream from the zirconium and hafnium separations process. Some of the wastewaters from the niobium and tantalum process used before 1975 were also placed into the V-2 pond. The V-2 pond was operational until the addition of storage tanks and a separations spill treatment system between 1977 and 1980 eliminated any waste or waste-water influent into the V-2 Pond. The contents of the pond, with the exception of approximately 5,400 cubic yards of solids, were removed and transported to an EPA-approved landfill in 1987 (Reference 1, Chapter 5, pages 9 and 10).

TWCA also has an extensive system of solid waste management. All solid wastes generated at the TWCA facility are initially delivered to the Dumpmaster Area, where they are inspected and separated into nonhazardous and hazardous components. According to a 1988 Current Situation Summary for a Remedial Investigation/Feasibility Study prepared by CH2M Hill Northwest, TWCA is disposing of nonhazardous waste materials at a public landfill. Hazardous wastes are temporarily stored onsite until they can be transported offsite to a hazardous materials storage, treatment, or disposal facility (Reference 1, Chapter 5, page 12). Whenever practical, TWCA recycles waste materials.

TWCA has not always practiced offsite disposal for its solid waste process residues. Three onsite areas of the plant have been used for disposal, including the chlorinator residue pile, the magnesium resource recovery pile, and the Truax Creek landfill area. Beginning in 1972, chlorinator residue from the sand chlorination process was stored in a pile north of Schmidt Lake. This disposal practice was discontinued in 1978 and pile contents were transferred to the Hanford radioactive disposal site in Washington (Reference 1, Chapter 5, page 17). Solid residues from the nonferrous metals manufacturing process (primarily magnesium chloride wastes) were placed in the magnesium resource recovery pile until May 1983. In October 1983, TWCA, with the approval of the Oregon Department of Environmental Quality (ODEQ), began operations to recover and beneficially use the contents of the pile (e.g., substituting a magnesium hydroxide slurry for lime in the operation of



TWCA's wastewater treatment system) (Reference 1, Chapter 5, pages 17 and 18). From 1958 to 1973, a portion of the area north of Truax Creek (extending from the area opposite of the V-2 Pond and east to Arrowhead Lake) was used as a landfill. Arrowhead Lake was briefly used as a landfill in 1976 (Reference 1, Chapter 5, page 18).

Radioactive wastes are managed under the requirements of the facility's NORM license issued by the Oregon Health Division (Reference 1, Chapter 5, page 16). Currently, low-level radioactive residues generated by the pure chlorination and sand chlorination processes are collected and transported in special containers to an offsite radioactive waste disposal facility, such as the one located at the Hanford site in Washington (Reference 1, Chapter 5, page 14).

Some of the solid waste disposal activities undertaken by TWCA involve transformers and capacitors containing PCBs. While the majority of electrical transformers used at the TWCA site are owned and maintained by Pacific Power and Light, a few transformers and most capacitors are owned and maintained by TWCA. Some of this equipment holds oil containing PCBs. Spent equipment known to contain PCBs is sent to an EPA-approved PCB facility for proper treatment and disposal. According to TWCA, there have been no known spills of PCBs into soils or waters onsite (Reference 1, Chapter 5, page 15). However, PCBs have recently been detected in sediment samples collected from Truax Creek (Reference 3, pages 2 and 3).

TWCA operates a range of air contaminant control systems to cleanse air emissions from their transition metal refining operations. Some of the air emissions control systems that have been implemented include water and caustic sprays, scrubbers, baghouses, demisters, and wet electrostatic precipitators (Reference 1, Chapter 5, pages 19 and 20).

## **SITE CHARACTERIZATION**

The TWCA site is located in the north-central part of Oregon's Willamette Valley in the community of Millersburg, Oregon. The site is 3 miles north of Albany, approximately 65 miles south of Portland, and 60 miles east of the Pacific Ocean. The Willamette River forms the western boundary of the plant site. Ground surface in the vicinity of the site slopes westward towards the Willamette River (see Figure 1) (Reference 1, Chapter 2, pages 1 through 4; Reference 4, page 9).

The immediate area surrounding the TWCA plant site is primarily industrial, with some land north and west of the site used for agriculture. Residential and commercial activities are located to the east and south of the facility. The population of Albany is approximately 27,000, and Millersburg has a population of 600 (Reference 1, Chapter 2, pages 3 and 4).

### Ground Water

The alluvial deposits of the Willamette River and its tributaries make up the principal aquifer in the Albany area (Reference 1, Chapter 3, page 3). Ground-water levels are generally shallow, with depth to ground water ranging from 3 to 22 feet below ground surface in the LRSP area, and 5 to 9 feet below the extraction and fabrication area (Reference 1, Chapter 3, page 17). The general direction of ground-water flow beneath the site is to the northwest and west towards the Willamette River, with local drainage to Murder and Truax Creeks (Reference 1, Chapter 3, page 4). Approximately 250 domestic wells are located within 3 miles of the facility, all of which are upgradient of the site. There are no known domestic, municipal, industrial, or irrigation wells located between the site and the Willamette River (Reference 1, Chapter 3, page 4; Reference 2, page 3).

Ground-water monitoring has occurred at the Farm Ponds Site and the Plant Site since the early 1980's. At the request of the ODEQ, TWCA began a ground-water monitoring program at the Farm Site in 1980, and it continued quarterly through 1988. In 1982 and 1983, samples were analyzed for MIBK, Total Organic Carbon (TOC), and an array of inorganic parameters. Beginning in 1984, analyses were limited to the indicator parameters of ammonia, nitrate, chloride, sulfate, Total Dissolved Solids (TDS), and conductivity (Reference 1, Chapter 6, pages 2 and 3).

The Current Situation Summary for the site presented analytical data for ground-water samples collected in the area of the Farm Ponds (see Figure 1). These data were presented as concentration ranges reflecting all of the years of sampling data. A comparison of the maximum concentration range for each parameter to the appropriate Federal Drinking Water Standard demonstrates that concentrations of heavy metals (including cadmium, chromium, and lead) exceed the Federal Primary Drinking Water Standards. The maximum concentrations for chloride, iron, manganese, sulfate, and TDS exceeded Federal Secondary Drinking Water Standards (see Table 1) (Reference 1, Chapter 6, page 3).

Volatile organic compounds (including 1,1,1-trichloroethane, 1,1,2-trichloroethane, and 1,1-dichloroethane) were also detected in some ground-water samples in the Farm Ponds area (Reference 1, Chapter 6, page 3). There are no Federal Drinking Water Standards for these constituents; however, a comparison of maximum concentrations to Maximum Contaminant Levels (MCLs) for ground water indicated that no MCL levels were exceeded.

**TABLE 1. GROUND-WATER CONTAMINANTS THAT EXCEED DRINKING WATER STANDARDS**

Constituent	Farm Ponds Area (Concentration Range - mg/l)	Federal Drinking Water Standards (mg/l) (Reference 7) (Primary)
Cadmium	< 0.0003 - 0.092	0.01
Chromium	< 0.01 - 0.09	0.05
Lead	< 0.02 - 0.1	0.05
Nitrate (N)	< 0.01 - 62	10
		(Secondary)
Chloride	0 - 3,100	250
Iron	< 0.01 - 7.5	0.3
Manganese	< 0.05 - 21	0.05
Sulfate	0 - 880	250
TDS	0 - 13,400	500

Source: Reference 1, Chapter 6, page 3

A number of locations at the Plant Site are sampled, including quarterly sampling since 1982 at the LRSP area (including Schmidt Lake, chlorinator residue handling area, and magnesium resource recovery pile); the Arrowhead Lake area (old Truax Creek landfill area); and the ammonium chloride/sulfate storage area. Quarterly sampling has occurred at the metals forming sump area since 1986 (Reference 1, Chapter 6, page 4).

Analytical data for a variety of constituents from the Plant Site were summarized in the Current Situation Summary for the site. These data were presented as concentration ranges reflecting all of the sampling data. When the MCL for each parameter is compared to the Federal Drinking Water Standards, several constituents, from various locations around the Plant Site, were indicated as exceeding the appropriate Drinking Water Standard (see Table 2).

**TABLE 2. GROUND-WATER CONSTITUENTS DETECTED AT PLANT SITE THAT EXCEED DRINKING WATER STANDARDS**

Constituent	LSRP Area	Arrowhead Lake Area	Metals Forming Sump Area	Ammonium Chloride Sulfate Storage Area	Federal Drinking Water Standards (Reference 7) (Primary)
Cadmium	--	0.003 - 0.018	--	<0.003 - 0.02	0.01
Chromium	<0.01 - 0.96	--	--	--	0.05
Lead	<0.02 - 0.28	<0.02 - 0.15	--	<0.02 - 0.07	0.05
Nitrate (N)	--	<0.5 - 160	<1 - 240	<0.5 - 550	0.01
Fluoride	--	1 - 6	<1 - 87	--	4
Selenium	--	--	--	<0.003 - 0.034	0.01
Radium 226	<0.2 - 7.6 pCi/l	--	--	--	5 pCi/l
Radium 228	<0.3 - 11 pCi/l	--	--	0.6 - 11 pCi/l	5 pCi/l
<b>(Secondary)</b>					
Chloride	7 - 68,700	10 - 4,900	--	320 - 2,300	250
Iron	<0.05 - 570	<0.05 - 11	<0.05 - 2.5	<0.05 - 37	0.3
Manganese	<0.03 - 230	<0.05 - 27	<0.05 - 150	<0.05 - 21	0.05
Sulfate	<3 - 1,200	<10 - 1,200	--	<10 - 2,400	250
TDS	11 - 89,500	20 - 8,000	38 - 1,500	320 - 4,900	500
*Fluoride	--	1 - 6	<1 - 87	<1 - 4	2

Concentration ranges are in mg/l unless designated otherwise.

Source: Reference 1, Chapter 6, page 7

Exceedances of the Primary Drinking Water Standard were noted for cadmium, chromium, lead, nitrate, fluoride, selenium, radium 226, and radium 228. Exceedances of the Secondary Drinking Water Standard were noted for chloride, iron, manganese, sulfate, TDS, and fluoride (Reference 1, Chapter 6, pages 5 through 8).

Although Drinking Water Standards were not available for all of the constituents detected in the ground water, a comparison to MCLs for ground water indicated that three volatile organic compounds (1,1-dichloroethane, chloroform, and 1,1,1-trichloroethane) detected in ground-water samples at the plant site exceeded the appropriate MCLs (see Table 3) (Reference 1, Chapter 6, pages 1 through 8).

**TABLE 3. UPPER CONCENTRATION RANGES OF GROUND-WATER CONTAMINANTS AT THE PLANT SITE THAT EXCEED FEDERAL STANDARDS**

Constituent	LRSP Area	Arrowhead Lake Area	Metals Forming Sump	Ammonium Chloride Storage	MCL (Reference 9)
chloroform	< 5 - 230	—	—	—	100
trichloroethane	< 5 - 330	—	—	7 - 400	5
1, 1, 1-trichloroethane	—	310 - 7,561	10 - 18,000	—	200
Concentrations are in $\mu\text{g/l}$					

Source: Reference 1, Chapter 6, pages 5 through 8

Ground-water monitoring data from the metals forming sump area indicated that no constituents exceeded Federal standards. Additional ground-water monitoring data is being collected and analyzed as part of the ongoing Remedial Investigation for the site.

#### Surface Water

The Willamette River is the major regional drainage flowing north through the Willamette Valley and is used for recreational, fishing, agricultural, and industrial purposes. Currently, there are no known communities or individuals downstream of the TWCA that use the Willamette River as a source of drinking water (Reference 1, Chapter 3, page 23).

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Portions of the TWCA (namely the sludge pond units – LRSP and Schmidt Lake) are located in the 100-year and 500-year floodplains of the river. The Farm site is above the 500-year floodplain. The ground surface at the TWCA site slopes westward toward the river at a gradient of approximately 11 feet per mile. Local creeks, drainage ditches, and lakes that receive drainage from the plant site feed into the Willamette River. These waterbodies include four oxbow lakes (Second, Third, and Fourth Lakes, and Conser Slough) and two creeks (Truax Creek and Murder Creek) (Reference 1, Chapter 3, pages 22 and 23; Reference 7, page 1).

The two creeks drain the plant site from east to west. They join northwest of the site and flow northward through Third Lake, Fourth Lake, and Conser Slough, ultimately discharging to the Willamette River. Truax Creek receives discharges from the TWCA process wastewater treatment system (under TWCA's NPDES permit) and from parts of the site's storm-water drainage system. Murder Creek also receives discharges (mainly roof drainage) from the Plant Site storm-water drainage system. The Farm Site is drained by two drainage ditches that enter the area from the east, flowing westward and discharging to Conser Slough and the river (Reference 1, Chapter 3, pages 22 and 23).

Surface-water monitoring of an area drainage ditch north of the Farm Ponds designated as East Boundary (upgradient), West Boundary (downgradient) and the Railroad Culvert (downgradient) occurred quarterly between June 1984 and March 1987. The parameters examined as part of this sampling strategy included nitrate-nitrogen, TDS, conductivity, chloride, calcium, and sulfate. At the plant site, Truax Creek is monitored weekly for ammonia, nitrate, and TOC, as required by the NPDES permit (Reference 1, Chapter 6, pages 9 and 10).

Concentrations of constituents detected in surface water at the Farm Site and at the Plant Site are presented in Tables 6-7 and 6-8 of Reference 1, respectively. These tables list the ranges of constituent concentrations found throughout the monitoring program over the years (Reference 1, Chapter 6, pages 9 and 10). Data for the Plant Site suggest that low levels of volatile and semivolatile organic compounds are found in the surface waters on and around the site.

When the maximum concentrations from the Plant Site data are compared to the appropriate Ambient Water Quality Criteria (AWQC), the following constituents are shown to exceed the criteria:

- Chloroform [maximum concentration of 6 micrograms per liter ( $\mu\text{g/l}$ ) exceeds the surface water AWQC for water and fish ingestion of  $0.19 \mu\text{g/l}$ ]
- 1,2-dichloroethane (maximum concentration of  $7 \mu\text{g/l}$ ) exceeds the AWQC (also for water and fish ingestion) of  $0.94 \mu\text{g/l}$ ]

Surface-water monitoring data for the Farm Site were conducted on a very limited number of parameters, and could not be compared to the AWQC.

Additional surface-water monitoring data is being collected and analyzed as part of the ongoing Remedial Investigation for the site. The Remedial Investigation was not complete or available to the public at the time of this report's preparation.

#### Sediments and Soils

Sediment sampling was conducted from September 19 through October 18, 1989, as part of the Phase 1 Remedial Investigation (Reference 6, pages 1 and 2). The results of these analyses will be provided as part of the Remedial Investigation, which is not yet available for the public. The sediment samples from this sampling episode were analyzed for volatile and semivolatile organic compounds, total metals, pesticides, PCBs, and radionuclides (Reference 3, Memo Page).

There were no analytical data available to characterize potential contamination of the soils at the TWCA site. However, as described previously in this report, TWCA received a permit from ODEQ to use the sludge from the wastewater treatment processes (stored in the Farm Site solids storage ponds) as a soil amendment on the TWCA Farm Site. Although this practice was conducted for only 1 year (1976) the spreading of potentially radioactive material on the land raised many concerns in the Site Investigation Report for the TWCA Site, including concerns about contamination of the food chain and long-term contamination of the soil and land. The Site Investigation recommended that land use in the area be restricted (Reference 1 Chapter 5, page 8; Reference 4, pages 4, 5, and 6).

#### Air

TWCA has been monitoring the ambient air for radon emissions and radionuclide dispersion on and around the site since 1967 under Air Contaminant Discharge Permits (Reference 1, Chapter 6, page 12). Extensive area and point source studies have also been conducted relative to radon emanation and radionuclide dispersion near the LRSP, Schmidt Lake, and Farm Pond areas. Measured radon concentrations averaging 0.26 pico Curies per liter (pCi/l) have been similar to background levels (0.21 pCi/l) in the vicinity of the site (Reference 1, Chapter 6, pages 13, 14, and 15). Airborne particulate studies have indicated no detectable concentrations of alpha emitters; air emissions are considered an unimportant pathway for radionuclide transport. Monitoring of gamma radiation levels at the site boundaries and selected areas in the facility also indicate that levels are below the limits specified by the Nuclear Regulatory Commission (NRC) (Reference 1, Chapter 6, pages 12 through 18).

## ENVIRONMENTAL DAMAGES AND RISKS

The ongoing Remedial Investigation/Feasibility Study, addressing contaminated ground water, surface water, soils, and sediments associated with manufacturing and disposal activities at the TWCA site, is currently being undertaken by TWCA and its consultant, CH2M Hill. Until an Endangerment Assessment is completed, detailed information on environmental damages and risks for the whole site is not available.

A general assessment of risks for the entire TWCA site were provided as part of the Site Investigation report for the facility. Some of the risks identified in the Site Investigation included the following (Reference 4, pages 4 through 7):

- The threat to workers by radon gas
- The potential that flooding could cause widespread contamination of radioactive wastes
- The contamination of the land by the application of radioactive materials
- The potential for ground-water and surface-water contamination.

A more detailed assessment of the environmental risks from the LRSP and Schmidt Lake was provided in the ROD for those units.

Analytical data from the ROD (see Tables 4 and 5) indicated that the LRSP and Schmidt Lake sludge contain metal compounds including zirconium, hafnium, chromium, mercury, nickel, uranium, and radium. Cyanide was also found in the sludges. Several organic compounds were also identified; hexachlorobenzene being the most prevalent (Reference 7, page 13).

Many of the constituents found in the sludge were identified as contaminants of concern in the ROD. The following constituents were specifically identified as contaminants of concern and potential risks to human health:

- Carcinogens - Arsenic, beryllium, bis (ethylhexyl) phthalate, cadmium, chromium-VI, hexachlorobenzene, methylene chloride, nickel, tetrachloroethene, trichloroethane, 1,1-dichloroethane



TABLE 4. CONTAMINANTS IN LRSP SOLIDS

Constituent	Maximum	Minimum <sup>1</sup>	Average <sup>2</sup>	Background <sup>3</sup>
<b>Inorganics</b>				
Arsenic	39	2	10	24
Barium	3,500	33	173	116
Beryllium	1.3	0.5	0.7	0.7
Chromium	220	65	100	20
Copper	77	29	48	12
Mercury	7.6	0.3	1.2	<0.2
Nickel	3,000	25	206	14
Lead	260	38	102	10
Antimony	24	5	11	<20
Selenium	16	1	3	3
Thorium	74 (8.3)	11 (1.2)	31.7 (3.5)	3.5
Uranium	129 (87.8)	12.7 (6.4)	69.2 (46.5)	0.8
Zinc	87	24	40	39
Cyanide	165.0	3.0	16	<2
Radium <sup>4</sup> Activity Concentration	(22.2) 2.30 x 10 <sup>-3</sup>	(3.2) 3.32 x 10 <sup>-6</sup>	(13.2) 1.37 x 10 <sup>-3</sup>	(1.0) 1.04 x 10 <sup>-6</sup>
Zirconium <sup>5</sup>	10.0	3.0	5.1	<1.0
<b>Volatile Organics</b>				
Methylene chloride	22,000	0.006	0.084	—
1,1,1,-Trichloroethane	0.860	0.053	0.155	—
4-Methyl-2-pentanone	1,400,000	0.040	3.929	—
1,1-Dichloroethane	0.860	0.053	0.174	—
Tetrachloroethene	0.970	0.005	0.164	—
<b>Semivolatile Organics</b>				
Hexachlorobenzene	64,000	0.740	6.600	—
bis(2-ethyl-hexyl)phthalate			1.295	—

Note. All concentrations in mg/kg of as received, wet solids  
 Concentrations in parentheses are in pCi/g  
 Only constituents that were detected in 10 percent or more of the samples are shown

<sup>1</sup>Minimum value detected above detection limit

<sup>2</sup>Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limits were included in the average.

<sup>3</sup>From soil samples taken east of the existing Farm Ponds, October 1988. See Remedial Investigation report.

<sup>4</sup>As radium-226

<sup>5</sup>Zirconium is expressed as a percent (Reference 10, pages 6 and 8)

TABLE 5. CONTAMINANTS IN SCHMIDT LAKE SOLIDS

Constituent	Maximum	Minimum <sup>1</sup>	Average <sup>2</sup>	Background <sup>3</sup>
<b>Inorganic</b>				
Arsenic	36	8	16	24
Barium	72	36	39	116
Beryllium	1.1	0.7	0.8	0.7
Cadmium	1.2	0.1	0.3	<0.1
Chromium	13	79	90	20
Copper	72	34	45	12
Mercury	1.4	0.2	0.6	<0.2
Nickel	4,300	1,700	2,600	14
Lead	150	70	103	10
Antimony	14	8	9	<20
Selenium	4	1	2	3
Thorium	59.3 (7.5)	30.8 (3.4)	46.3 (5.1)	3.5
Uranium	237.7 (160.9)	104.6 (70.8)	162.6 (110.1)	0.8
Zinc	97	50	67	39
Cyanide	110	2.5	5.3	<2
Radium <sup>4</sup> Activity Concentration				
Zirconium <sup>5</sup>	28.8	3.9	7.4	<1.0
<b>Volatile Organics</b>				
Methylene chloride	0.090	0.031	0.046	—
1,1,1,1-Tetrachloroethane	0.320	0.073	0.168	—
4-Methyl-2-pentanone	54.000	24.000	32.708	—
1,1-Dichloroethane	3.900	0.170	1.054	—
Tetrachloroethene	0.073	0.073	0.073	—
<b>Semivolatile Organics</b>				
Hexachlorobenzene	25.333	7.300	14.087	—
bis(2-ethyl-hexyl)phthalate				
N-Nitrosodimethylamine		0.190	0.048	—

Note All concentrations in mg/kg of as-received, wet solids  
 Concentrations in parentheses are in pCi/g  
 Only constituents that were detected in 10 percent or more of the samples are shown

<sup>1</sup>Minimum value detected above detection limit.

<sup>2</sup>Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limit were included in the average.

<sup>3</sup>From soil samples taken east of the Farm Ponds, October 1988. See Remedial Investigation report.

<sup>4</sup>As radium-226

<sup>5</sup>Zirconium is expressed as a percent (Reference 10, pages 7 and 9)

- Radionuclides - Uranium, thorium, radium
- Noncarcinogens - Antimony, barium, zirconium (Reference 7, pages 14 through 16).

The LRSP and Schmidt Lake are located on the floodplain of the Willamette River; therefore, contamination by flooding is a potential risk. The two units are also unlined surface impoundments that could be a source of ground-water contamination. Another concern is contamination by airborne dust from the ponds as they dry during the summer months or dust resulting from sludge removal and potential treatment. The last major risk concern potentially resulting from the sludge from these units is direct dermal contact by onsite workers or trespassers (Reference 7, page 13).

The ROD estimates that the risk of developing cancer from the LRSP and Schmidt Lake sludges ranges from 1 in 1,000 to 1 in 3,000 for exposure over a lifetime for people who reside onsite. The greatest cancer risks are from nickel, chromium-VI, arsenic, and hexachlorobenzene. The risk of death from cancer due to exposure from radionuclides if no clean-up action is taken range from 7 in 1 million to 1 in 1,000 (Reference 7, page 17).

#### **REMEDIAL ACTION AND COSTS**

According to EPA, the overall Remedial Investigation/Feasibility Study for the TWCA site is not yet completed and is not expected to be available until 1992. A ROD for Operable Unit 1 (i.e., the LRSP and Schmidt Lake) was finalized in December 1989 as part of an expedited action to address those sludge ponds. Seven clean-up alternatives were developed and analyzed in detail in the ROD. Of these, an action involving the removal, solidification, and offsite disposal of approximately 85,000 cubic yards of material from the LRSP and Schmidt Lake was selected (Reference 7, pages 1, 3, and 4).

The specific remedy for the remediation of Operable Unit 1 begins with the excavation of sludge from the LRSP and Schmidt Lake. Once excavated, the sludge will be mixed with a solidification agent, such as Portland cement, to improve the handling and transportation of the material and to reduce the mobility of the contaminants. The solidified sludge will be transported offsite to a permitted solid waste disposal site. As part of the requirements for this disposal, the waste will be placed in a separate, lined monocell and capped according to State and local requirements. The monocell is also required to have a leachate control system (Reference 7, page 34).

The estimated cost for the remedy is \$10.7 million, with the specific elements and costs of the action defined below:

- Sludge Removal and Hauling - \$590,000
- Solidification Treatment Process - \$1,586,000
- Offsite Disposal - \$6,000,000
- Engineering Design, Bids, Contingencies, etc. - 2,540,000 (Reference 10, page 35).

The long-term operation and maintenance costs (including monitoring) are included as part of the offsite disposal cost.

#### **CURRENT STATUS**

According to EPA Region X, the Remedial Investigation/Feasibility Study is ongoing and expected to be completed in 1992 (Reference 11). TWCA is preparing to remove the LRSP and Schmidt Lake sludges under a February 1991 Unilateral Administrative Order. The monocell will be constructed at the Findley Buttes landfill in Boardman, Oregon.

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3. SAIC Report, Data Validation for Work Assignment C10005, Teledyne Wah Chang Albany, DCN: TZ4-C10005-DV-02775; SAIC; 1990.
4. Potential Hazardous Waste Site, Site Inspection Report for Teledyne Wah Chang, Albany, Oregon; EPA; 1982.
5. Review of CH2M Hill Work Plans for Baseline Risk Assessment Human Health Evaluation and Environmental Evaluation, Remedial Investigation/Feasibility Study, Teledyne Wah Chang Albany, DCN: TZ4-C10005-EP-H0773; Environmental Toxicology International Corporation; 1990.
6. Technical Memorandum Concerning Fall 1989 Sampling Activities, DCN: TZ4-C10005-EP-00568, From Thomas A. Tobin, SAIC, to Neil Thompson, EPA; Undated
7. Record of Decision, Decision Summary, and Responsiveness Summary for Interim Response Action - Teledyne Wah Chang Albany Superfund Site Operable Unit 1 (Sludge Ponds Unit), Albany, Oregon; EPA; December 1989.

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SAIC. SAIC Report, Data Validation for Work Assignment C10005, Teledyne Wah Chang Albany, DCN: TZ4-C10005-DV-02775. 1990.

Tobin, Thomas A. (SAIC). Technical Memorandum Concerning Fall 1989 Sampling Activities, DCN: TZ4-C10005-EP-00568 to Neil Thompson, EPA. 1989.

**Reference 1**

**Excerpts From Current Situation Summary for a  
Remedial Investigation/Feasibility Study for the  
Teledyne Wah Chang Albany (Revision 4);  
CH2M Hill; October 1988**

CURRENT SITUATION SUMMARY  
Revision 4  
October 1988

CURRENT SITUATION SUMMARY  
FOR A  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

TELEDYNE WAH CHANG ALBANY  
ALBANY, OREGON

DRAFT

Prepared for  
Teledyne Wah Chang Albany  
by  
CH2M HILL NORTHWEST, INC.  
Corvallis, Oregon  
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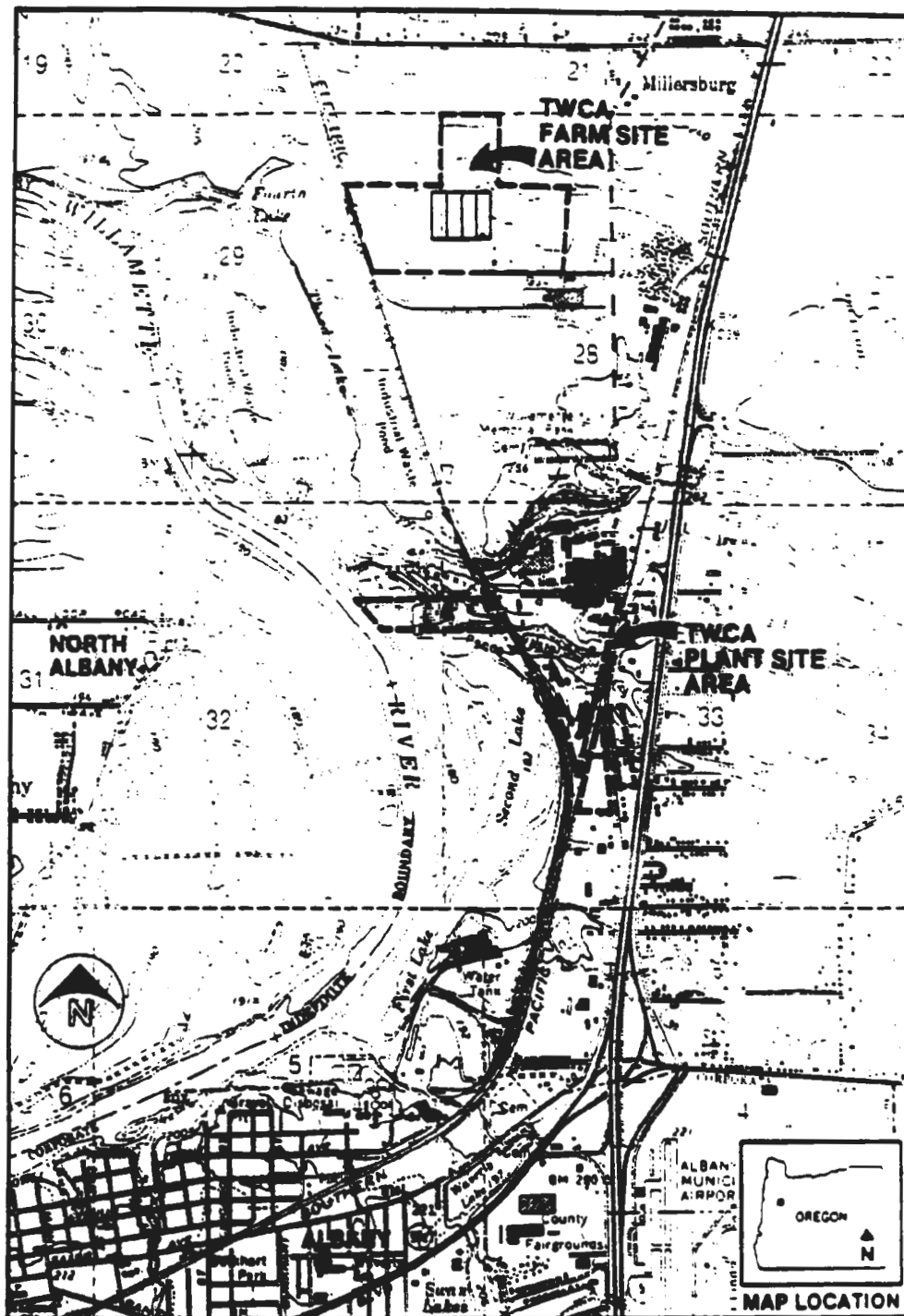
## Chapter 2

### PHYSICAL SETTING

TWCA is in Millersburg, Oregon, an industrially-based community 3 miles north of Albany. The site is predominantly in Sections 21, 28, 32, 33 of Township 10 South, Range 3 West, Willamette Meridian (WM), in the north-central part of the Willamette Valley of western Oregon (Figure 2-1). It is roughly 20 miles south of Salem, 65 miles south of Portland, and 60 miles east of the Pacific Ocean.

Plate 1 shows the site boundaries. The TWCA site consists of two major areas: the plant site area and the farm site area. The 110-acre plant site contains an extraction area south of Truax Creek, a fabrication area north of Truax Creek, a solids storage area west of the Burlington Northern Railroad (Spokane-Portland-Seattle Railroad), and a parking and recreation area east of the Southern Pacific Railroad. The farm site, approximately 115 acres, is 3/4 of a mile north of the plant site and contains four 2-1/2-acre solids storage ponds. The ponds are in the southern portion of the site; the remainder of the site is used primarily for agriculture.

The immediate area surrounding TWCA is primarily industrial (see Plate 1). The industries closest to the sites are:



Source: USGS 1:24,000 Albany, Oregon

0 1000 2000 3000 4000 5000 FEET  
SCALE

Figure 2-1  
LOCATION MAP  
Teledyne Wah Chang Albany  
Albany, Oregon

- o Willamette Industries' Duraflake Division particle board plant, at the northeast corner of the TWCA plant site
- o Willamette Industries' Western Kraft paper mill, including settling and infiltration ponds, north of the TWCA plant site and adjacent to the Willamette River
- o Menasha Corporation's wood flour processing plant, east of Willamette Industries' Duraflake Division
- o Georgia-Pacific Corporation's resin plant, also east of Willamette Industries' Duraflake Division
- o Simpson Timber Company's plywood mill, about 1/2 mile southwest of the TWCA plant site
- o Truax Oil Company, Linn County Plywood Mill, and SRC Incorporated, all between the TWCA plant and farm sites on Arnold Lane
- o Elstor Sales Corp. (formerly Sun Transformer), about 1/4 mile south of the TWCA plant site

The land to the north of the TWCA plant site is used mainly for industrial and agricultural purposes. The land east of

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I-5 and south of the plant site is used mainly for residential and commercial purposes. The land west of the Willamette River, which forms the western boundary of the plant site, is used for farming. The land surrounding the farm site area is agricultural. Albany, the urban area south of the plant site, has a population of approximately 27,000; Millersburg has a population of about 560 people. TWCA employs more than 1,300 people from the area.

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Chapter 3

ENVIRONMENTAL SETTING

The topographic and geologic, climatic, groundwater, and surface water conditions of the TWCA site are described in this chapter.

TOPOGRAPHY AND GEOLOGY

The broad and relatively flat Willamette Valley was formed by the Willamette River as it meandered back and forth between the Coast Range mountains to the west and the Cascades to the east. The ground surface in the vicinity of TWCA slopes westward towards the river with a gradient of approximately 11 feet per mile. Most of the hills within the Willamette Valley consist of relatively resistant volcanic rock.

The uppermost geologic unit in the Albany area is undifferentiated younger and older alluvium deposited by the Willamette River. The upper portions of the alluvium include about 5 to 15 feet of clayey silt mapped as Willamette Silt by Allison (1953). Below the silt is a sandy gravel deposit varying in thickness from a few feet to tens of feet and mapped as Linn Gravel (Allison, 1953). This unit is widespread in the mid-Willamette Valley but is exposed only

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where the silt has eroded. Frank (1974) differentiates the gravel into younger and older alluvium. The younger deposits are limited to the present flood plain of the Willamette River; the gravels beneath the TWCA plant and farm sites are mapped as older alluvium. Younger alluvium may underlie the western half of the Lower River Solids Area.

The alluvium is underlain by a fine-grained silty clayey sandstone (sometimes a sandy, clayey siltstone or sandy, silty shale). This rock unit is part of the Spencer Formation, which probably underlies most of the Albany area (Frank, 1974). In places it is deeply weathered and soft; in others, it is moderately hard. Local erosion and redeposition as a soft silty, clayey sand, or silty clay may also explain some of the unit's variability. Because the Spencer was an erosional surface prior to alluvial deposition, the thickness of overlying alluvium is variable. The Spencer is exposed at the surface about 2 miles west of the site, across the Willamette River.

CLIMATE AND METEOROLOGY

The climate in the Willamette Valley is influenced by moist maritime air masses from the Pacific Ocean. Temperatures are moderate, with maximums seldom reaching 100°F and minimums

rarely reaching 0°F (NUS, 1983). Roughly 70 percent of the 40-inch annual precipitation falls during November through March, while only 6 percent occurs during June, July, and August. There are usually only 3 or 4 days per year with measurable amounts of snow. The average annual potential evapotranspiration rate for the Albany area is about 27 inches. Therefore, there is an average annual moisture surplus of approximately 13 inches. However, there is a substantial seasonal deficit during the dry summer months, resulting in the need to irrigate agricultural lands (NUS, 1983).

The prevailing wind direction is from the south with an average wind speed of about 7 miles per hour.

#### REGIONAL GROUNDWATER

The alluvial deposits of the Willamette River and its tributaries make up the principal aquifer in the Albany area (Frank, 1974). The layers and lenticular bodies of coarse sand and gravel in the alluvium locally yield large quantities of water to wells. The coarse deposits are interbedded with finer deposits of sand and silt that produce considerably smaller quantities of water. The underlying Spencer

Formation has low permeability and yields only small quantities of water to wells. Water wells drilled into this formation locally produce poor quality saline water (Frank 1974).

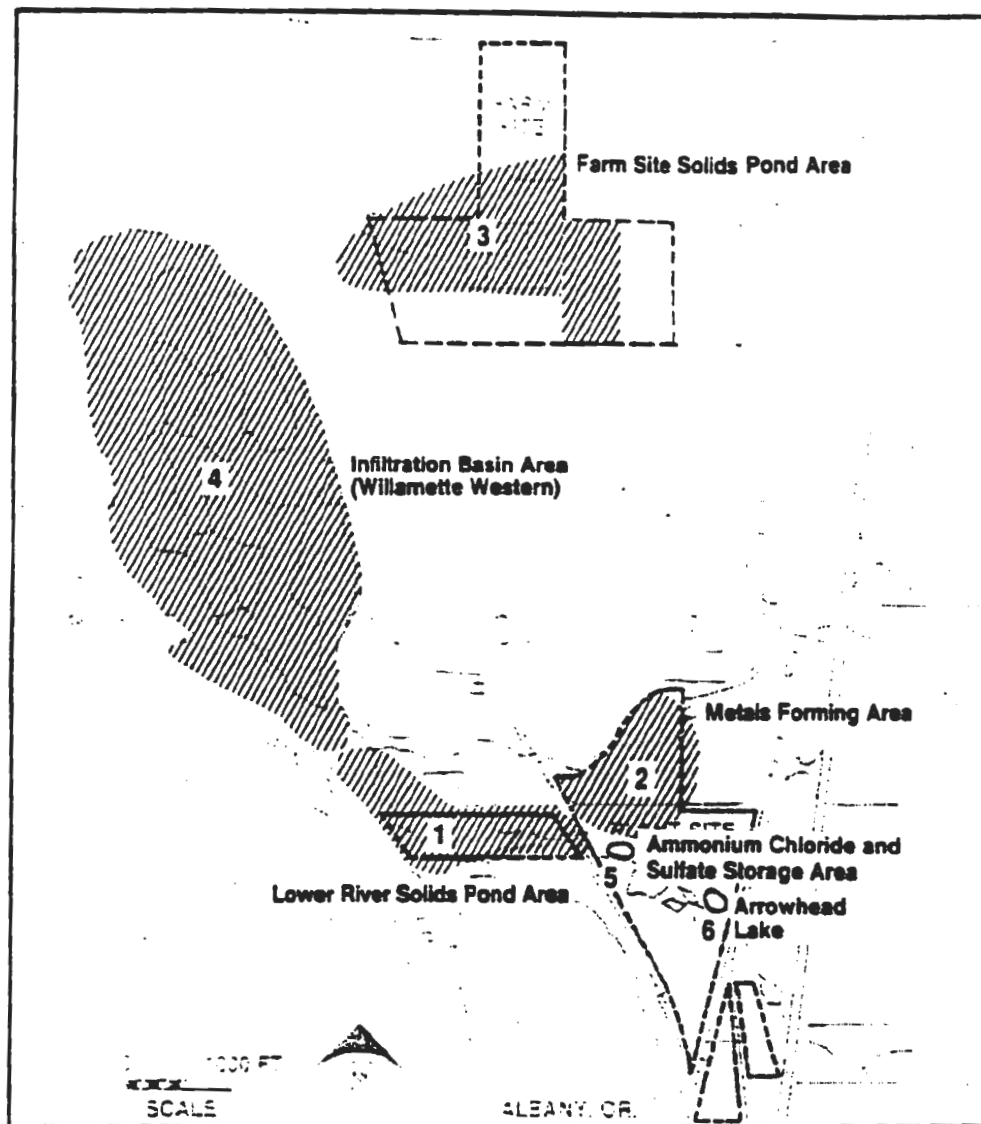
Direct precipitation during late fall and winter is the primary source of aquifer recharge in this area. Regional groundwater flow is to the northwest and west where it discharges to the Willamette River (Frank, 1974) and locally to Truax and Murder Creeks.

All known domestic wells in the TWCA vicinity are upgradient of the site. There are no known domestic, municipal, industrial, or irrigation wells located between the site and the Willamette River.

#### SITE GROUNDWATER

The general hydrogeologic conditions beneath the plant and farm sites have been identified based on specific hydrogeologic data from previous investigations (see Figure 3-1). A few other monitoring wells and numerous geotechnical foundation borings provide additional information.





#### LEGEND

— TWCA Boundaries

- 1 Science Application, Inc. (1981)  
Dames and Moore (1981a)  
CH2M HILL (1982)
- 2 CH2M HILL (1987a)
- 3 Dames and Moore (1979)  
Knoll (1984)  
CH2M HILL (1987b)
- 4 Environmental Geology and Ground Water (1980)
- 5 TWCA installed monitoring wells in 1980/1981
- 6 Dames and Moore (1981b)

Figure 3-1  
**AREAS OF PREVIOUS  
HYDROGEOLOGIC  
INVESTIGATIONS**

Teledyne Wah Chang Albany  
Albany, Oregon

PLANT SITE

The conceptual model of the hydrogeologic system in the plant site area is summarized in Figures 3-2 through 3-11. These figures have been reproduced from CH2M HILL (1982 and 1987a).

The following generalizations can be made about plant-site groundwater conditions based on the CH2M-HILL reports and other reports listed in "References" (Chapter 8):

- o Fill material is present locally across the plant site.
- o Alluvial sediments ranging in thickness from 10 to 20 feet beneath the metals-forming area and up to 60 feet beneath the Lower River Solids Pond (LRSP) form the surficial geological unit at the site.
- o The upper alluvium is composed of flood plain deposits consisting of fine-grained lenses of silt, clay, and some sand (Willamette Silt). These deposits have relatively low permeability and produce little water. Permeabilities are typically less than 1 foot per day ( $3.5 \times 10^{-4}$  cm/sec).

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- o The lower alluvium (Linn Gravels) consists of water-bearing coarse-grained deposits of gravel and sand, often with thin lenses of silt or clay (referred to as "shallow aquifer"). This unit is the uppermost aquifer. Permeabilities are typically between 10 and 100 feet per day ( $3.5 \times 10^{-3}$  to  $3.5 \times 10^{-2}$  cm/sec).
- o Bedrock consisting of a fine-grained silty clayey sandstone, sandy clayey siltstone, or sandy silty shale (the Spencer Formation) underlies the lower alluvium in most of the Albany area. Locally, the unit appears to be either deeply weathered or eroded and redeposited as a soft silty clayey sand or a silty clay.
- o Water levels are generally shallow, ranging between approximately 5 and 9 feet below ground surface in the extraction/fabrication areas and between approximately 3 and 22 feet below ground surface in the LRSP area.
- o Groundwater in the shallow aquifer flows generally westward beneath the plant site toward the Willamette River, with local drainage to Murder and Truax Creeks.

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and sand often with thin lenses of silt or clay (referred to as "shallow aquifer"). This unit, which is 20 to 25 feet thick, is the uppermost aquifer.

- o A blue-gray clay (lacustrine?) underlies the lower alluvium in the farm site.
- o Water levels are generally shallow, generally ranging between approximately 1 to 10 feet below the natural ground surface.
- o Groundwater in the shallow aquifer flows generally westward beneath the farm site towards the Willamette River.
- o Vertical gradients are downward through the upper alluvium to the shallow aquifer. The vertical gradients are most prominent during the winter and less so during the summer, indicating surficial recharge of precipitation.

SURFACE WATER

Local creeks, ditches, and lakes in the vicinity of the TWCA site are shown in Plate 1. The Willamette River is the major

regional drainage flowing north through the Willamette Valley. The headwater of the Willamette River is in the Cascade Mountains about 100 miles southeast of Albany. The mouth of the river is in Portland, where it joins the Columbia River. Summer and winter flows in the Willamette River near TWCA are about 5,500 cubic and 110,000 feet per second, respectively, according to USGS gaging records. Portions of the TWCA plant site are in the 100-year and 500-year flood plains of the river (see Plate 1). Most of the TWCA plant site east of the Burlington Northern tracks was above the 1964 flood elevation. The corridor along Truax Creek, however, experienced significant flooding during this record event. The Farm site is above the 500-year flood plain.

Local surface water drainage is predominantly westward towards the Willamette River. Site surface water consists of bodies that receive drainage from the plant site, including:

- o Second, Third, and Fourth Lakes, and Conser Slough (oxbow lakes formed when the Willamette River abandoned a former channel).
- o Truax and Murder Creeks that drain the plant site from east to west. The creeks join northwest of the plant site and flow northward through Third Lake, Fourth Lake, and Conser Slough, ultimately discharging to the Willamette River.

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The Farm site is drained by two drainage ditches that enter the area from the east and also flow westward, discharging to Conser Slough and the river (see Plate 1).

The Willamette River is used for a variety of purposes, including recreation, fishing, agriculture, and industry. It also serves as a water source for wildlife. No communities or individual residences downstream of the TWCA plant site are known to use the Willamette River as a source of drinking water at the present time.

Truax Creek receives discharges (regulated by NPDES permit) from the TWCA process wastewater treatment system and from parts of the plant site storm drainage system. Murder Creek receives discharges (mostly roof drains) from the plant site storm drainage system. Both creeks and Second Lake are also local groundwater discharge areas for shallow groundwater beneath the plant site.

AIR

Since 1967, air quality monitoring has been in effect and TWCA has been operating under Air Contaminant Discharge Permits. Area and point source studies have been conducted relative to radon emanation and radionuclide dispersion near the LRSP, Schmidt Lake, and the farm site (Scientific Appli-

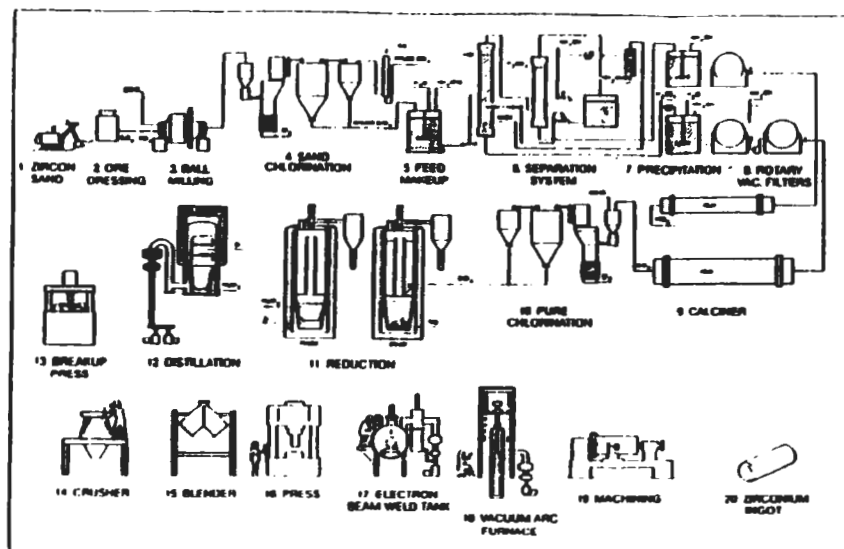
## Chapter 4

### PLANT PROCESSES

The TWCA site has been operating continuously for approximately 30 years. Operations began in 1956 when, under contract with the U.S. Atomic Energy Commission, Wah Chang Corporation reopened the U.S. Bureau of Mines Zirconium Metal Sponge Pilot Plant. Construction of new facilities, at the site of the existing plant, began in 1957. These facilities were established primarily for the production of zirconium and hafnium sponge. However, tantalum and niobium pilot facilities were also included. Melting and fabrication operations were added in 1959. Teledyne Wah Chang Albany was established in 1967 after Teledyne Industries, Inc., purchased Wah Chang Corporation of New York.

#### ZIRCONIUM AND HAFNIUM

TWCA is a primary producer of zirconium metal. (The zirconium manufacturing process is shown in Figure 4-1.) Zircon sand, the principal ore, is imported from Australia. This material is found in deposits that also contain several other important raw materials, including rutile, ilmenite, and monazite. Zircon (zirconium ortho silicate,  $ZrSiO_4$ ) is



#### 1. Zircon Sand

Zirconium is fairly common in the earth's crust being more plentiful than some of the more familiar metals such as iron and copper. Zircon sand is the primary source of zirconium and is produced in large quantities throughout the world. Zirconium is currently the major constituent of zirconium sand.

#### 2. Ore Dressing

Zircon is extracted as a by-product with heavy and complex fluorine, phosphoric, and hydrogen processes are employed to separate these elements.

#### 3. Ball Milling

Crushed sand and electrolytic quantities of carbon in the form of coke are mixed and ground together in a ball mill to provide an intimate mixture with a specified particle size range.

#### 4. Sand Chlorination

The green mixture is reacted with chlorine gas at about 1000° C to produce zirconium tetrachloride (ZrCl<sub>4</sub>) and silicon tetrachloride (SiCl<sub>4</sub>) according to the following chemical reaction:



Zirconium tetrachloride and silicon tetrachloride are subsequently separated by partial condensation of the chlorides at 0° C. Silicon tetrachloride is treated as a by-product of the process.

#### 5. Feed Blending

Zirconium tetrachloride containing approximately 100 percent hydrogen tetrachloride, a major impurity and a water carrier of zirconium is dissolved in water. The feed solution is added to a specific composition and filtered to remove suspended solids (fine sand and carbon). The solution is then transferred to the separation system.

#### 6. Separation System

The separation system is composed of a series of solvent extraction and scrubbing columns which separate the liquid-liquid extraction of zirconium tetrachloride and hydrogen. Although these two elements are very similar chemically, they differ markedly in their reaction properties. Zirconium reacts with a number of chemical reagents while hydrogen absorbs large quantities of moisture. Consequently there is a need for their separation.

#### 7. S.G. Purification and Rotary Vacuum Filter

Solvents containing zirconium and hydrogen are collected in their own storage tanks and handled separately. The zirconium solution is processed with sulfuric acid to form a hydrogen zirconium sulfate. This slurry is filtered on a rotary filter and the filter cake is washed with water containing a small amount of sulfuric acid and is filtered again to remove sulfuric acid.

Hydrogen purification is effected by the addition of propane to an aqueous solution of hydrogen sulfate.

#### 8. Calciner

Hydrogen sulfate from the rotary filter is carried to a gas-fired rotary calciner which operates at a temperature of approximately 1000° C (1800° F). The calcined product, zirconium dioxide (ZrO<sub>2</sub>), is collected in containers at the discharge end of the calciner. Hydrogen is also processed through a calciner to obtain hydrogen oxide (H<sub>2</sub>O).

#### 9. Pure Chlorination

Zirconium oxide and electrolytic quantities of carbon powder are intimately blended and reacted with chlorine according to the following chemical reaction:



Several impurities including aluminum, iron and titanium are reduced during the chlorination process.

#### 10. Reduction

Zirconium tetrachloride is reacted with electrolytic magnesium in a closed, inert atmosphere to produce zirconium metal according to the following chemical reaction:



Hydrogen tetrachloride (H<sub>2</sub>Cl<sub>4</sub>) is treated as a by-product.

#### 11. Distillation

The hydrogen tetrachloride by-product is physically separated from the distillation tank and then product is. The remaining product residue is treated with a distillation tank. After the distillation process is completed, the product is treated with a distillation tank.

#### 12. Breakup Press

The zirconium sponge residue is broken into smaller pieces which are suitable for use in the casting operation. Hand grinding of sponge product is performed during the operation to improve quality.

#### 13. Castor

Sponge is crushed from approximately four to six inches down to about three quarters inch. It may be repeated at this point.

#### 14. Blends

Individual runs of zirconium sponge are blended together to meet product high quality grade requirements.

#### 15. Press

Zirconium sponge and electrolytic aluminum are mixed together and pressed into a 10" diameter x 5" thick compact.

#### 16. Electron Beam Weld Tank

Sponge compacts and scrap bottom and endcap beam welded to form an ingot and ingot mold.

#### 17. Vacuum Arc Furnace

Welded ingot molders are melted into ingots (70" dia x 150000) by the electron beam and melting process. Double melting ensures homogeneity.

#### 18. Machining

Cast ingots are machined to remove surface porosity and melting anomalies.

#### 19. Zirconium Ingot

Final machined ingots are then tested and the resulting product is forged, hot rolled, and cold rolled as required.

Figure 4-1  
ZIRCONIUM  
MANUFACTURING PROCESS  
Telsodyne Walsby Chang Albany  
Albany Oregon



concentrated in Australia by gravity, electrostatic, and magnetic methods to remove all but a small amount of impurities.

#### SAND CHLORINATION

The zircon concentrate is combined with petroleum coke, and milled/mixed in a ball mill before feeding to a chlorination reactor. The chlorination reaction, conducted at a temperature of approximately 1,100°C (2,012°F), is as follows:



The silicon tetrachloride ( $\text{SiCl}_4$ ) and zirconium tetrachloride ( $\text{ZrCl}_4$ ) are separated by fractional condensation. Remaining offgases enter a scrubber where caustic soda ( $\text{NaOH}$ ) removes chlorine and chlorides. The  $\text{SiCl}_4$  is purified and sold as a byproduct.

#### SEPARATIONS

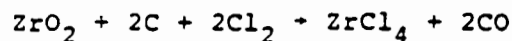
Most zirconium minerals contain 1 to 5 percent hafnium. Hafnium is a sister element of zirconium; their chemical properties are almost identical. The hafnium level in zirconium used in nuclear reactors must be extremely low. Zirconium has a low thermal-neutron-capture cross section and

will allow neutrons to pass through it without appreciable absorption of energy. Hafnium, on the other hand, will absorb appreciable amounts of energy due to its high thermal-neutron-capture cross section. The zirconium-hafnium separation process involves dissolution of the  $Zr(Hf)Cl_4$  in water with subsequent feed to a liquid-liquid extraction unit operation. The feed solution is mixed with an organic solvent, methyl isobutyl ketone (MIBK), containing ammonium thiocyanate ( $NH_4CNS$ ). Hafnium is more soluble in the organic (extract) phase and thus is separated from the aqueous (raffinate) phase. Hafnium is removed from the extract phase by stripping with sulfuric acid, and then formed into a solid by precipitation with ammonium hydroxide ( $NH_4OH$ ); the precipitate is isolated by filtration and calcined to an oxide ( $HfO_2$ ). Zirconium is removed from the raffinate phase by precipitation with sulfate ions ( $SO_4^{2-}$ ). The precipitate is isolated by filtration, repulped with ammonium hydroxide, and calcined to an oxide ( $ZrO_2$ ). The MIBK and thiocyanate materials are purified and recycled.

#### PURE CHLORINATION

Zirconium and hafnium oxides follow similar paths to metal production. Zirconium oxide is mixed with petroleum coke and fed to a chlorination reactor. The chlorination reac-

tion, conducted at a temperature of about 1,100°C (2,012°F),  
is as follows:



Reaction offgases are scrubbed with caustic soda to remove  
chlorine and chlorides.

#### REDUCTION

The final extraction operation involves the reaction of zirconium tetrachloride with elemental magnesium in a classical "Kroll" reduction reaction:



Magnesium chloride ( $\text{MgCl}_2$ ) is physically removed from the zirconium sponge and sold as a byproduct. The zirconium sponge is then heated in a vacuum (distillation) to remove any residual magnesium chloride or elemental magnesium, which is recycled or sold as byproduct.

#### CONSOLIDATION

Consolidation of the zirconium sponge into ingots involves crushing to 3/4-inch minus, blending appropriate quantities,

and pressing into briquettes. The briquettes are then welded together with an electron beam to form an electrode suitable for consumable vacuum arc melting.

#### FORMING

Zirconium and zirconium alloy ingots are processed into numerous shapes and forms such as forgings, plate, sheet, foil, tubing, rod, and wire. The forming operations include forging, rolling, extrusion, drawing, tube reduction, and swaging. Intermediate and final surface conditioning can involve caustic cleaning, degreasing with 1,1,1-trichloroethane (1,1,1-TCA), and pickling with a hydrofluoric (HF)-nitric ( $\text{HNO}_3$ ) acid mixture. Caustic and acid solutions are treated prior to final discharge. The 1,1,1-TCA is sent to a recycler for purification and return.

#### NIOBIUM AND VANADIUM

TWCA can produce niobium metal from an ore, using sequential processes of chlorination, hydrolysis, precipitation, calcination, and aluminothermic reduction. The rate of operation of these processes is variable due to changing demand for the metal. Offgas are scrubbed with caustic soda for removal of chlorine and chlorides.

Chapter 5

WASTE MANAGEMENT PROGRAMS

Waste management programs at TWCA include a wide range of activities because of the many processes involved in production of nonferrous metals and products. These activities include process wastewater treatment, solid waste management, hazardous waste management, PCB equipment management, radioactive-material control, waste minimization through beneficial use, and air quality control programs.

PROCESS WASTEWATER

TWCA operates a wastewater treatment system for management of industrial wastewaters generated from the manufacturing and forming of nonferrous metals of zirconium, hafnium, titanium, niobium, and refractory metals. Domestic wastewater is collected separately and discharged into the sanitary sewage collection system for appropriate treatment by the City of Albany.

The facility's central wastewater treatment system consists of a continuous chemical precipitation and sedimentation

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system. Metals removal is accomplished by neutralization with lime, magnesium hydroxide, or sulfuric acid and carbon dioxide to pH 6 to 8 to form metal hydroxides and sulfates. Fluorides are removed by the formation of calcium fluoride. These compounds are removed in a clarifier by settling. Solids generated from the operation of the clarifier, referred to as "sludge," are placed in storage ponds for additional settling and dewatering (see the discussion that follows on wastewater treatment system solids).

An emergency neutralization system is in place so that the treated wastewater's pH can be kept within acceptable limits should the central wastewater treatment system malfunction before its discharge to ~~Truax Creek~~. Sodium hydroxide, sulfuric acid, or carbon dioxide may be added by the emergency neutralization system.

Other systems used at TWCA located on the upstream side of the central wastewater treatment system include:

- o Dechlorination to remove residual chlorine from the blowdown of air pollution control devices employed for the removal of chlorine and chloride from gaseous emissions

- o Spill collection and treatment to assist in meeting limits for MIBK, ammonia, and thiocyanate from the separations process
- o Thiocyanate regeneration for control and recycle of thiocyanate within the separations process
- o Ammonia recovery
- o Oil separation
- o MIBK steam stripping for control and recovery of MIBK within the separations process
- o Barium sulfate coprecipitation for control of radium
- o Selective uranium precipitation and settling with filtration for solids dewatering
- o Boildown for concentration of a dilute solution of ammonium sulfate for use as fertilizer or recycling in the zirconium/hafnium separations process

Figure 5-1 is a block diagram of the treatment systems and process wastewater sources at TWCA.

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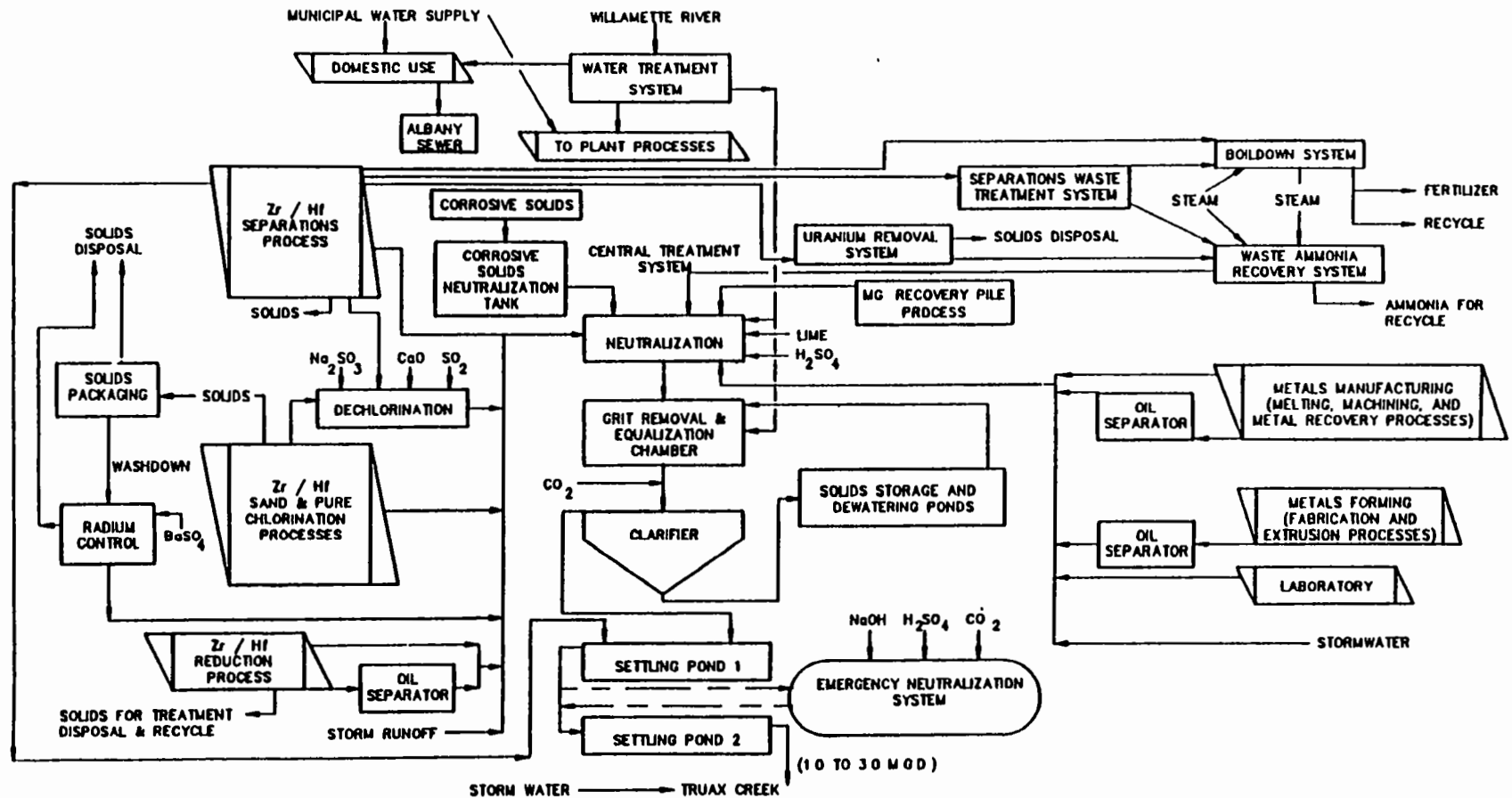


Figure 5-1  
**SCHEMATIC FLOW DIAGRAM  
 OF WASTEWATER SOURCES  
 AND TREATMENT SYSTEMS**  
 Teledyne Wah Chang Albany  
 Albany Oregon



PERMIT STATUS

The process wastewater treatment facility was issued an NPDES permit in March 1975 by the State of Oregon Department of Environmental Quality (DEQ). Two addenda to the permit were subsequently issued. The permit expired in June 1978 and was reissued in October 1978, with an expiration date of July 1981. Application Forms 1 and 2C were submitted on April 10, 1981. DEQ extended the expiration date until a new permit could be issued. Issuance of a new permit was delayed by DEQ until national effluent limitations guidelines could be established (50 FR 38276, September 20, 1985 [nonferrous metals manufacturing phase II], 50 FR 34242, August 23, 1985 [nonferrous metals forming], and 49 FR 8742, March 8, 1984 [nonferrous metals manufacturing Phase I]). A new permit is expected to be issued by the DEQ in 1988.

TWCA has been submitting monthly monitoring reports to DEQ since 1975.

WASTEWATER TREATMENT SYSTEM SOLIDS

Solid residues generated from the operation of waste treatment systems are most often referred to as "sludges." Sludges generated from the facility's central wastewater treatment system are presently stored in a number of surface

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impoundments. Sludges generated prior to 1980 are contained in the Lower River Solids Pond (LRSP), Schmidt Lake, and Arrowhead Lake. Some of the sludge, generated prior to 1976, was used as a beneficial soil amendment under permit on the TWCA farm site located about 1 mile north of the TWCA plant site. Sludge generated after 1980 is contained in one of the four ponds located at the TWCA farm site and referred to as Farm Ponds 1, 2, 3, and 4. Previous wastewater treatment associated with the removal and recovery of ammonia resulted in the construction of an additional pond (V-2 Pond). This pond was used for temporary storage and pretreatment with lime prior to sending it to an ammonia recovery steam stripping system. The use of this pond was abandoned in 1979. Solids remaining in this pond consist mostly of hydrous metal precipitate and unreacted lime solids.

Lower River Solids Pond, Schmidt Lake, and Arrowhead Lake

From 1967 until 1978, the solids produced from various wastewater treatment processes were stored onsite in the LRSP, Schmidt Lake, and Arrowhead Lake.

Arrowhead Lake was dewatered and covered in the early 1980s. The LRSP and Schmidt Lake have not been used to store solids generated since 1979. Supernatant water is returned to the onsite wastewater treatment plant.

In the early 1980s, various agencies and environmental interest groups focused on the solids stored in the LRSP and Schmidt Lake because of their purported low-level radioactive properties. TWCA submitted an application for a site certificate for the maintenance of a radioactive waste disposal facility to the Oregon Energy Facility Siting Council (EFSC) in 1982. A series of public hearings was held. The EFSC ruled in March 1987 that the radioactive level of the LRSP sludge was too low to meet the criteria as a low-level radioactive waste and, therefore, was not under EFSC's jurisdiction. TWCA, on May 1, 1987, announced plans to relocate the sludges approximately 1 mile to remove them from the 500-year flood plain. These plans were placed on hold after it was ruled that the risks and remediation options for the sludges had to be addressed as part of the CERCLA (Superfund) RI/FS process.

#### Farm Site Solids Storage Ponds

In 1978, TWCA modified the process for the production of zirconium and hafnium metal that lowered the trace concentrations of radioactive compounds in the sludge. The process modification directed the radioactive materials into a separate solid waste referred to as chlorinator residue. This residue is managed as a radioactive waste and shipped to Hanford, Washington, for disposal.

Sludge generated since the implementation of this modification has been stored in the four Farmsite ponds. These ponds were placed into operation in October 1979, after approval by the DEQ as part of the NPDES Wastewater Discharge Permit program. A groundwater monitoring program was implemented as a permit condition.

#### Farm Site Soil Amendment Programs

The use of sludge generated by the central wastewater treatment system as a beneficial soil amendment has been implemented in the past by TWCA. A number of studies were conducted by the Department of Soil Sciences of Oregon State University under contract to TWCA before 1976. Additional studies were conducted by OSU in 1979.

TWCA obtained a solid waste permit (No. 1079) from DEQ to use the sludge as a soil amendment on the TWCA farm site in 1976. The sludge was applied at an average rate of 108 tons/acre on the 47.8 acres available for soil amendment. Further use of the sludge as a soil amendment has not been implemented since 1976.

#### V-2 Pond

The name V-2 Pond comes from the major wastewater stream discharged into the pond, which was the lime-treated

zirconium sulfate wet cake filtrate (V-2 filtrate) produced by a rotary vacuum filter used in the zirconium and hafnium separations process. The V-2 Pond was used to settle the lime solids in the treated filtrate. Because processes for the extraction and manufacture of niobium and tantalum were located in the building used for the separations process, some of the wastewaters from the niobium and tantalum process used before 1975 were also placed into the V-2 Pond.

The V-2 Pond was built in 1960 as one large pond. The ammonia recovery treatment system consisting of a steam stripping column, was installed in 1969 to recover ammonia from the treated V-2 filtrate prior to discharging to TWCA's central wastewater treatment system.

A dike constructed of crushed rock was installed in 1975, making one large pond and one small pond. The dike was installed to reduce the level of sulfate ion in the V-2 Pond by directing the discharge of separations process spillage into the small pond and precipitating the sulfate with lime before it entered into the large pond. The contents of the large pond were directed to an ammonia recovery treatment system.

A 200,000-gallon tank and a 400,000-gallon tank were built in 1977 and 1978 to store the V-2 filtrate in a tank rather than in the V-2 Pond. A separations spill treatment system

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was installed in January 1978, and then modified with major improvements by February 1980 to eliminate any waste or wastewater influent into the V-2 Pond.

The contents of the small V-2 Pond were removed and transported to an EPA-approved landfill for disposal in 1987. It is estimated that 5,400 cubic yards of solids are presently contained in the remaining large portion of the pond.

SOLID WASTE

CURRENT MANAGEMENT PROGRAMS

Solid waste management programs at TWCA have been developed and implemented to comply with the requirements of RCRA, TSCA, and CERCLA. These programs include procedures for:

- o Proper management and disposal of brand-name products and items used on the plant site
- o Proper management and disposal of solid wastes generated by different process operations
- o Proper management of transformers and capacitors containing PCB

All materials are initially delivered to the TWCA Dumpmaster Area if they are intended for transportation to and disposal at a public landfill or at a hazardous waste treatment, storage, or disposal facility. Nonhazardous material is inspected by the operator of this area to make sure it does not contain any items prohibited from disposal in a public landfill by federal and state law or by more restrictive disposal policies developed and implemented by TWCA.

Hazardous wastes intended for disposal are also inspected by the operator of the Dumpmaster Area as they are transferred from the generating process area to the Dumpmaster Area for temporary storage. The wastes are inspected to make sure they have been placed in a proper container with correct labeling.

#### Management and Disposal of Brand-Name Products

As part of its solid waste program, TWCA has reviewed all items purchased to determine if they would be RCRA hazardous waste due to ignitability, corrosivity, reactivity, or toxicity; a fire hazard; or an environmental liability if improperly managed or disposed. All of these items have been assigned a disposal code so the material will be disposed of properly if it is no longer needed. This practice, as well as instructions to implement a spill contingency plan in

case of an environmental incident, are formally documented in a written procedure and used at the TWCA site.

#### Solid Process Wastes

Each process area has been evaluated to minimize the generation of waste and make sure it is properly managed. Table 5-1 lists process wastes presently generated on a routine basis at TWCA. This listing describes each waste's characteristic and the waste management option used for recycle, treatment, or disposal.

Written procedures are implemented to make sure that hazardous and radioactive wastes are properly managed and packaged on the TWCA site prior to transportation offsite for treatment and disposal.

Containers of hazardous waste are temporarily stored at the Dumpmaster Area where they are inspected weekly until transported offsite. The Dumpmaster Area includes an asphalt surface and collection sump so as to collect and direct any contaminated rainfall and runoff to the Central Wastewater Treatment System. All liquid wastes, such as solvents, that are forbidden from entering the treatment system are placed in separate steel trays so any spillage may be fully contained and properly managed.



Table 5-1  
PROCESS WASTES GENERATED AT TWCA

Generating Process	Waste	Characteristic	Management Option
Zirconium and Hafnium Manufacturing			
Sand Chlorination	Sand Chlorinator Residues	Radioactive	Radioactive Waste Landfill
	Sand Chlorinator Residues	Nonhazardous	Onsite Corrosive Neutralization Tank
Separations	MIBK Still Bottoms	Ignitable	Hazardous Waste Incinerator
	Uranium Removal Treatment System Solids	Radioactive	Radioactive Waste Disposal Site
Pure Chlorination	Pure Chlorinator Residues	Nonhazardous	Onsite Corrosive Neutralization Tank
	Pure Chlorination Residues	Radioactive	Radioactive Waste Landfill
	Recycled Oxide Chlorinator Residue	EP Toxic (D 008)	Hazardous Waste Landfill
Reduction	MgCl <sub>2</sub> Wastes	Fire Hazard	Beneficial Use of Mg as Magnesium Hydroxide Slurry
	Smokehouse Material (Nonhazardous)	Nonhazardous	Oxidation of Metal Fines in Smokehouse
	Smokehouse Material (Hazardous)	EP Toxic (D-008)	Public Landfill
	Stainless Steel Liners	Nonhazardous	Hazardous Waste Landfill
Niobium Manufacturing	Nb Thermite Slag	EP Toxic (D 005)	Public Landfill
	FeNb Thermite Slag	Nonhazardous	Public Landfill
Vanadium Manufacturing	Thermite Slag	Nonhazardous	Public Landfill
Round Products Forming	Salt Bath Material	EP Toxic (D 005)	Hazardous Waste Landfill
Extrusion Products Forming	Rocker Lube	Nonhazardous (animal fat)	Biological Treatment Lagoon
	Honing Solids	Fire Hazard	Hazardous Waste Landfill
	Al <sub>2</sub> O <sub>3</sub> Blasting Grit	Nonhazardous	Recycle or Public Landfill
	Scrubber Solids (Nonhazardous)	Nonhazardous	Public Landfill
	Scrubber Solids (Hazardous)	EP Toxic (D 008)	Hazardous Waste Landfill
Powder Metallurgy	Isopropyl Alcohol	Ignitable	Ignitable Waste Incinerator
	1,1,1-Trichloroethane	Toxic (F 001)	Recycle at Hazardous Waste Facility
Metal Forming	Metal Grinding Solids	Fire Hazard	Hazardous Waste Landfill
	Abrasive Saw Fines	Nonhazardous	Public Landfill
	Metal Fines	Fire Hazard	Onsite Oxidation in Burnback System
	Burnback Material	Nonhazardous	Public Landfill
Paint Shop and Maintenance Shop	Waste Thinners	Ignitable	Incineration
Analytical Lab	Methyl Isobutyl Ketone	Ignitable	Recycle Onsite
	1,1,1-Trichloroethane	Toxic (F 001)	Recycle at Hazardous Waste Facility

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Low-level radioactive residues are generated by the pure chlorination and sand chlorination processes. They are collected and transported from the process area in specially designed steel collection containers to the residue handling facility. This facility is used to transfer the residues from the special containers into containers for transportation and disposal. The facility includes an impermeable surface sloped so as to collect any contaminated rain water or washdown water for removal of radium in a separate wastewater treatment system. Radioactive residues and solids generated from the treatment system are transported to an offsite radioactive waste disposal site.

Transformers and Capacitors Containing PCB

There are considerable electrical power requirements for operation of the metals manufacturing and forming processes at TWCA. Therefore, a number of transformers and capacitors are used throughout the plant site. Most transformers are owned by Pacific Power and Light as part of the electrical distribution system. A few transformers and most capacitors are owned and operated by TWCA. Some of this equipment holds oil that contains PCB (polychlorinated biphenyl), which is regulated by the EPA and DEQ.

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PCB-containing equipment that is owned and operated by TWCA is managed and inspected as required by specific procedures and training requirements developed by TWCA to ensure compliance with regulatory requirements. Due to environmental concern, any equipment containing PCB that is removed from service is sent to an EPA-approved PCB facility for proper treatment and disposal. As such, TWCA does not have a storage site for PCB waste. Equipment or items containing PCB and designated as waste are only temporarily stored for less than 90 days in drums in the Dumpmaster Area until transported to an EPA-approved facility. Prior to construction of the Dumpmaster Area, waste PCB items were temporarily stored in a specially designed storage facility with a bermed concrete floor.

There are no known spills of PCB into soil or water. As required by EPA, reports are completed annually that document management of PCB items owned by TWCA.

PERMIT STATUS

TWCA has notified the EPA and DEQ that the only hazardous waste activity included at the site is generation.

On February 3, 1984, TWCA submitted a complete RCRA Part B Application for the operation of hazardous waste management

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activities at the site, including thermal treatment of non-ferrous metal fines in the Burnback Area. It also included management of magnesium chloride wastes by the beneficial use of magnesium within these wastes as magnesium hydroxide slurry and thermal treatment of the remaining metal fines in the smokehouse. This application was considered complete by the EPA. However, the EPA concluded that these wastes managed and treated at the facility did not meet the criteria to be classified as an ignitable or reactive waste. Therefore, a Part B RCRA Permit was not deemed necessary for these activities.

Radioactive wastes are managed under the requirements of a Naturally Occurring Radioactive Materials "NORM" license, issued by the State of Oregon Health Division. It was renewed in 1987.

PAST DISPOSAL PRACTICES

TWCA has not always practiced offsite disposal for all of its waste process residues. Three major areas of the plant site have been used in the past for this purpose: the chlorinator residue pile, the magnesium resource recovery pile, and the Truax Creek area landfill.

### Chlorinator Residue Pile

Beginning in 1972 with the startup of the sand chlorination process, chlorinator residues were placed in a separate pile north of Schmidt Lake. This practice was discontinued in 1978, when the contents of the pile were transferred to the Hanford radioactive waste disposal site in Washington. After the contents of the pile were removed, the area was surveyed with a  $\mu$ R meter and visually inspected to ensure that no contamination remained. Powdered barium sulfate was applied over the entire area.

The Chlorinator Residue Handling Facility was constructed in December 1978, on the site where the pile was previously located.

### Magnesium Resource Recovery Pile

Solid residues generated during the development and operation of nonferrous metals manufacturing processes at the plant site were placed in a resource and recovery pile. Due to improvements in process operations and modifications in management of materials, no material has been placed in the pile since May 1983.

Intentions were to later recover the metallic value from the material placed in the pile. Because the major metal of

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value contained in the pile was magnesium, the pile was appropriately named the Magnesium Resource Recovery Pile. The major material placed in the pile was magnesium chloride wastes generated by the zirconium/hafnium reduction process. Other materials included stainless steel liners and thermite slag containing small amounts of niobium.

In October 1983, TWCA notified the DEQ of a proposal for a process to recover and beneficially use the contents of the pile. A small-scale process was approved and placed into operation. It was modified and enlarged in February 1984, and again in October 1984, with the approval of the DEQ. Since the initial startup, over 20,000 cubic yards of material has been processed to produce a magnesium hydroxide slurry used as a lime substitute for operation of the TWCA Central Wastewater Treatment System. In August 1986, a sheetpile wall was installed to eliminate mixing of the LRSP solids with the beneficial portions of the pile. The recovery operation will be completed in June 1988.

Truax Creek Landfill

A portion of the area north of Truax Creek extending from the area opposite of the V-2 Pond and east to Arrowhead Lake was used as a landfill beginning in 1958 until 1973. Arrowhead Lake was used briefly as a landfill in 1976.

AIR

TWCA operates air contaminant control systems to cleanse emissions from the transition metal refining operations under Air Contaminant Discharge Permit No. 22-0547. Table 5-2 lists emission sources, control systems, and air contaminants. Control system blowdowns are directed to the central wastewater treatment system.

CVR153/040

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Table 5-2  
AIR CONTAMINANT CONTROL SYSTEM SUMMARY

Emission Sources	Control System(s)	Air Contaminant
Sand Chlorination Offgas	Water Spray, Caustic Packed Bed	Cl <sub>2</sub> , CL <sup>-</sup> , particulate
Sand Chlorination Area Vent	Caustic Spray, Caustic Packed Bed	Cl <sub>2</sub> , CL <sup>-</sup> , particulate
Feed Makeup Offgas	High Pressure Venturi, Demister	Cl <sub>2</sub> , CL <sup>-</sup> , particulate
Feed Makeup Area Vent	Low Pressure Venturi, Demister	Cl <sub>2</sub> , CL <sup>-</sup> , particulate
Separations Area Vent	Acid Packed Bed	NH <sub>3</sub> , NH <sub>4</sub> <sup>+</sup>
ZrO <sub>2</sub> /HfO <sub>2</sub> Calciner	Cyclone, Med. Pressure Venturi, Demister, Caustic, Packed Bed, Wet Electrostatic Precipitator	SO <sub>2</sub> , SO <sub>3</sub> , particulate
Siltet Purification	High Pressure Venturi, Caustic Packed Bed	Cl <sub>2</sub> , CL <sup>-</sup> , particulate (min)
Pure Chlorination	Caustic Spray, Caustic Packed Bed	Cl <sub>2</sub> , CL <sup>-</sup> , particulate
West Zr Reduction	High Pressure Venturi	CL <sup>-</sup> , particulate
East Zr Reduction	High Pressure Venturi	CL <sup>-</sup> , particulate (min)
Magnesium Recovery	Wet Ionizer, High Pressure Venturi, Demister	CL <sup>-</sup> , particulate
Crucible Handling	High Pressure Venturi	CL <sup>-</sup> , particulate (min)
Nb <sub>2</sub> O <sub>5</sub> Calciner	High Pressure Venturi, Demister	Particulate (min)
Boilers (3)	None	SO <sub>x</sub> , NO <sub>x</sub> , particulate
Metal Pickling Operation	None	F <sup>-</sup> , NO <sub>x</sub>
Crucible Burn Pots	None	Particulate
Raw Material Handling	Scrubbers	Particulate (min)
Fabrications	Scrubber Baghouses	

Reference: DEQ Review Report, January 12, 1987.  
CVR153/009

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## Chapter 6

### ENVIRONMENTAL MONITORING PROGRAMS AND DATA

This chapter summarizes ongoing environmental monitoring programs at TWCA. It briefly describes the sampling locations, periods, and frequencies. Sporadic or one-time grab sample analyses are not included. Summary tables show parameters analyzed and concentration ranges:

This section is organized as follows:

- o Groundwater Quality Monitoring
  - Farm site
  - Plant site (LRSP, metals-forming sump area, Arrowhead Lake, and ammonium hydroxide and sulfate storage area)
- o Surface water quality monitoring
- o Solids Characterization
  - Farm site
  - Plant site (LRSP and V-2)

- o Air Quality Monitoring
- o Treated Process Wastewater Quality Monitoring

#### GROUNDWATER QUALITY MONITORING

##### FARM SITE

At the request of the Oregon Department of Environmental Quality and Oregon Water Resources Department, TWCA implemented a groundwater monitoring program at the farm site. Fourteen wells are routinely sampled (see Plate 3 for locations).

Sampling of most wells began in 1980 and has continued quarterly to date. In 1982 and 1983, samples were usually analyzed for MIBK, TOC and the inorganic parameters summarized in Table 6-1. From 1984 to date, analyses have been limited to the indicator parameters of ammonia, nitrate, chloride, sulfate, total dissolved solids, and conductivity, with periodic additions of other parameters. The Knoll report (1984) presents the initial monitoring program. The CH2M HILL (1987b) report documents the monitoring program for the deep railroad (RRD) well. Table 6-1 summarizes the range of groundwater quality data from these sampling activities.

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Table 6-1  
GROUNDWATER QUALITY  
FARM SITE

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	0 - 1,220 mg/l	Copper	<.005 - 0.28 mg/l
Magnesium	6 - 330 mg/l	Iron	<.01 - 7.5 mg/l
Potassium	0.48 - 8.3 mg/l	Manganese	<.05 - 21 mg/l
Sodium	7.8 - 360 mg/l	Nickel	<.01 - 0.19 mg/l
Ammonia (N)	0 - 10 mg/l	Zinc	<.005 - 0.26 mg/l
Bicarbonate	0.01 - 200 mg/l	Arsenic	<0.2 - <1.0 mg/l
Carbonate	0.001 - 160 mg/l	Barium	<1.0 mg/l
Chloride	0 - 3,100 mg/l	Cadmium	<.0003 - 0.092 mg/l
Fluoride	<1 - <5 mg/l	Chromium	<.01 - 0.09 mg/l
Nitrate (N)	<0.01 - 62 mg/l	Lead	<.02 - 0.1 mg/l
Sulfate	0 - 880 mg/l	Mercury	<.002 - <.01 mg/l
Thiocyanate	<1 - 5 mg/l	Selenium	<.003 - <.005 mg/l
Conductivity	0 - 5,400 umhos/cm	Silver	<.01 - <.02 mg/l
pH	5.2 - 8.2 mg/l	Radium-226	<.4 - <.7 pCi/l
Total Dissolved Solids	0 - 13,490 mg/l	Radium-228	<.1 - <1.2 pCi/l
Thorium	<1.1 pCi/l		
Uranium	0.34 pCi/l		
Methyl Isobutyl Ketone (MIBK)	<1.0 - 4 mg/l		
Total Organic Carbon	<3 - 130 mg/l		
Total Suspended Solids	<5 - 31,700 mg/l		
1,1,1 Trichloroethane	15 ug/l		
1,1,2 Trichloroethane	32 ug/l		
1,1 Dichloroethane	18 ug/l		
Trans-2-Dichloroethene	2 ug/l		
Other Volatile Organics	BMDL		

BMDL=below method detection limit

NOTE: See Table 6-2 for well location numbers  
u = micro

PLANT SITE

Groundwater has been monitored at various areas of the plant site since about 1980. The last area added to the plant site monitoring well network is the metals-forming sump area in 1986. Table 6-2 summarizes the areas monitored and corresponding wells. Plate 3 shows the location of the wells. Tables 6-3 through 6-6 summarize groundwater quality results from each area.

Table 6-2  
SUMMARY OF PLANT AND FARM SITE GROUNDWATER MONITORING

Area	Wells	Approximate Frequency
Ammonium Chloride and Sulfate Storage	PW1 - PW3	Quarterly Since 1982
Arrowhead Lake	PW4 and PW5	Quarterly Since 1982
Lower River Solids Pond <sup>a</sup>	PW7 - PW9 W10 PWA - PWE	Quarterly Since 1982
Metals Forming Sump	PW10 - PW14	Quarterly Since 1986
Farm Site	RRD, RRS, WS, WD1 WD2, ND1, ND2, NS ND, ES, HW, SD & SS	Quarterly Since 1984

<sup>a</sup> Includes Schmidt Lake, chlorinator residue handling area, and magnesium resource recovery pile.

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Table 6-3  
GROUNDWATER QUALITY  
AMMONIUM CHLORIDE AND SULFATE STORAGE AREA

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	10 - 920 mg/l	Mercury	<.002 - 2 mg/l
Magnesium	28 - 300 mg/l	Selenium	<.003 - 0.034 mg/l
Potassium	3.7 - 22 mg/l	Silver	<.01 - <.05 mg/l
Sodium	32 - 160 mg/l	Radium-226	<.4 - 2 pCi/l
Ammonia (N)	4 - 3,050 mg/l	Radium-228	0.6 - 11 pCi/l
Bicarbonate	110 - 440 mg/l	Thorium	<.11 - <1.1 pCi/l
Carbonate	0.018 - 0.24 mg/l	Uranium	<.34 pCi/l
Chloride	320 - 2,300 mg/l	Methyl Isobutyl Ketone (MIBK)	<1 - 2 mg/l
Fluoride	<1 - 4 mg/l	Total Organic Carbon	<3 - 54 mg/l
Nitrate (N)	<.5 - 550 mg/l	Total Suspended Solids	<5 - 2,700 mg/l
Sulfate	<10 - 2,400 mg/l	1,1,1 Trichloroethane	<50 - 198 ug/l
Thiocyanate	<1 - 13 mg/l	1,1 Dichloroethane	9 - 120 ug/l
Conductivity	1,010 - 11,800 umhos/cm	Carbon Tetrachloride	<100 ug/l
pH	6.3 - 8.7	Chloroform	<50 - <100 ug/l
Total Dissolved Solids	320 - 4,900 mg/l	Methylene Chloride	<100 ug/l
Copper	<0.005 - 0.12 mg/l	Tetrachloroethene	5 - <100 ug/l
Iron	<.05 - 37 mg/l	Trans-1,2-Dichloroethene	48 - <100 ug/l
Manganese	<.05 - 21 mg/l	Trichloroethene	7 - 400 ug/l
Nickel	<.01 - <.1 mg/l		
Zinc	<.01 - 0.03 mg/l		
Arsenic	<.01 - <.05 mg/l		
Barium	<1 - <10 mg/l		
Cadmium	<.003 - 0.02 mg/l		
Chromium	<.01 - <.05 mg/l		
Lead	<.02 - 0.07 mg/l		

NOTE: u = micro

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Table 6-4  
TYPICAL GROUNDWATER QUALITY  
ARROWHEAD LAKE AREA

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	120 - 1,700 mg/l	Mercury	<.002 - <2 mg/l
Magnesium	32 - 240 mg/l	Selenium	<.003 - 0.01 mg/l
Potassium	13 - 304 mg/l	Silver	<.01 - <.05 mg/l
Sodium	59 - 1,100 mg/l	Radium-226	<.1 - <2 pCi/l
Ammonia (N)	1 - 66 mg/l	Radium-228	<.7 - <3 pCi/l
Bicarbonate	120 - 230 mg/l	Thorium	<.1 - <1.1 pCi/l
Carbonate	0.005 - 0.09 mg/l	Uranium	<.34 pCi/l
Chloride	10 - 4,900 mg/l	Methy Isobutyl Ketone (MIBK)	<1 mg/l
Fluoride	1 - 6 mg/l	Total Organic Carbon	5 - 140 mg/l
Nitrate (N)	<.5 - 160 mg/l	Total Suspended Solids	<5 - 14,700 mg/l
Sulfate	<10 - 1,200 mg/l	1,1,1 Trichloroethane	310 - 7,561 ug/l
Thiocyanate	<1 - 19 mg/l	1,1 Dichloroethane	31 - 480 ug/l
Conductivity	1,160 - 10,200 umhos/cm	Carbon Tetrachloride	<100 ug/l
pH	6.0 - 7.8	Methylene Chloride	<100 ug/l
Total Dissolved Solids	20 - 8,000 mg/l	Tetrachloroethane	<50 - <100 ug/l
Copper	<.005 - 0.12 mg/l	Trans-1,2-Dichloroethene	<50 - <100 ug/l
Iron	<.05 - 11 mg/l	Chloroform	<50 - 100 ug/l
Manganese	<.05 - 27 mg/l	Trichloroethene	<50 - <100 ug/l
Nickel	<.01 - 0.2 mg/l		
Zinc	<.01 - 0.3 mg/l		
Arsenic	<.01 - <.05 mg/l		
Barium	<1 - <10 mg/l		
Cadmium	.003 - 0.018 mg/l		
Chromium	<.01 - <.037 mg/l		
Lead	<.02 - 0.15 mg/l		

NOTE: u = micro

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Table 6-5  
GROUNDWATER QUALITY  
LOWER RIVER SOLIDS POND AREA

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	1 - 11,000 mg/l	Mercury	<.002 - <2 mg/l
Magnesium	0.1 - 19,500 mg/l	Selenium	<.003 - <0.01 mg/l
Potassium	0.8 - 58 mg/l	Silver	<.01 - <.05 mg/l
Sodium	6 - 2,500 mg/l	Radium-226	<.2 - 7.6 pCi/l
Ammonia (N)	<.5 - 840 mg/l	Radium-228	<.3 - 11 pCi/l
Bicarbonate	110 - 500 mg/l	Thorium	<.11 - <1.1 pCi/l
Carbonate	0.006 - <1 mg/l	Uranium	<.34 pCi/l
Chloride	7 - 68,700 mg/l	Methy Isobutyl Ketone (MIBK)	<1 - <50 mg/l
Fluoride	<1 - 160 mg/l	Total Organic Carbon	<3 - 200 mg/l
Nitrate (N)	<.5 - 400 mg/l	Total Suspended Solids	4 - 68,400 mg/l
Sulfate	<3 - 1,200 mg/l	1,1,1 Trichloroethane	<50 - <100 ug/l
Thiocyanate	<1 - 165 mg/l	1,1 Dichloroethane	14 - 100 ug/l
Conductivity	170 - 113,000 umhos/cm	Chloroform	<5 - 230 ug/l
pH	4.5 - 10.0	Methylene Chloride	<5 - <100 ug/l
Total Dissolved Solids	1.1 - 89,500 mg/l	Tetrachloroethane	<5 - <100 ug/l
Copper	<.005 - 0.23 mg/l	Trans-1,2-Dichloroethene	<5 - <100 ug/l
Iron	<.05 - 570 mg/l	Trichloroethene	<5 - 330 ug/l
Manganese	<.03 - 230 mg/l	Other Volatile Organics	BMDL
Nickel	<.01 - 5.2 mg/l		
Zinc	<.01 - 44.6 mg/l		
Arsenic	<.01 - <.05 mg/l		
Barium	<.5 - <10 mg/l		
Cadmium	<.003 - <.004 mg/l		
Chromium	<.01 - .96 mg/l		
Lead	<.02 - 0.28 mg/l		

NOTE: BMDL = below method detection limit  
u = micro

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Table 6-6  
GROUNDWATER QUALITY  
METALS-FORMING SUMP AREA

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	2 - 220 mg/l	Chloromethane	<1 - <100 ug/l
Magnesium	1 - 89 mg/l	Bromoethane	<1 - <100 ug/l
Sodium	6 - 94 mg/l	Dichlorodifluoromethane	<1 - <100 ug/l
Ammonia (N)	<.6 - 29 mg/l	Vinyl Chloride	<1 - <100 ug/l
		Chloroethane	<1 - 540 ug/l
Chloride	<10 - 240 mg/l		
Fluoride	<1 - 87 mg/l	Methylene Chloride	<5 - 1,300 ug/l
Nitrate (N)	<1 - 240 mg/l	Trichlorofluoromethane	<1 - <100 ug/l
		1,1-Dichloroethylene	<1 - 420 ug/l
Sulfate	10 - 130 mg/l	1,1-Dichloroethane	3 - 7600 ug/l
Thiocyanate	<2 - 2 mg/l	Trans-1,2-Dichloroethene	<1 - <100 ug/l
Conductivity	140 - 1,940 umhos/cm		
pH	5.2 - 7.2	Chloroform	<1 - <100 ug/l
Total Dissolved		1,2-Dichloroethane	<1 - 110 ug/l
Solids	38 - 1,500 mg/l	1,1,1-Trichloroethane	10 - 18,000 ug/l
		Carbon Tetrachloride	<1 - <100 ug/l
Copper	<0.1 - 0.04 mg/l	Bromodichloromethane	<1 - <100 ug/l
Iron	<.05 - 2.5 mg/l		
Manganese	<.05 - 150 mg/l	1,2-Dichloropropane	<1 - <100 ug/l
Nickel	<.02 - 0.22 mg/l	Cis-1,3-Dichloropropene	<1 - <100 ug/l
Zinc	<.02 - 0.06 mg/l	Dibromochloromethane	<1 - <100 ug/l
		1,1,2-Trichloroethane	<1 - <100 ug/l
Barium	<1 mg/l		
Cadmium	<.003 mg/l	Trans-1,3-Dichloropropene	<1 - <100 ug/l
Chromium	<.02 mg/l	Trichloroethene	<1 - <370 ug/l
Lead	<.02 mg/l	Bromoform	<1 - <100 ug/l
		1,1,2,2-Tetrachloroethane	<1 - <100 ug/l
Radium-226	<.2 - <2 pCi/l	Perchloroethylene	<1 - <100 ug/l
Radium-228	<4 pCi/l	Chlorobenzene	<1 - <100 ug/l
Thorium	<1.1 pCi/l	1,3-Dichlorobenzene	<1 - <100 ug/l
Uranium	<.34 pCi/l	1,2-Dichlorobenzene	<1 - <100 ug/l
Total Suspended		1,4-Dichlorobenzene	<1 - <100 ug/l
Solids	<10 - 1,900 mg/l		
Total Organic			
Carbon	<3 - 26 mg/l		
4-Methyl-2-pentanone (MIBK)	<1 mg/l		

NOTE: BMDL = below method detection limit  
u = micro



SURFACE WATER QUALITY MONITORING

FARM SITE

Monitoring of the drainage ditch north of the Farm Ponds, designated as East Boundary (upgradient), West Boundary (downgradient), and Railroad Culvert (downgradient), was started in June 1984, continued quarterly through March 1987, and included the following parameters: nitrate-nitrogen, total dissolved solids, conductivity, chloride, calcium, and sulfate. Table 6-7 summarizes Farm site surface water quality.

Table 6-7  
SURFACE WATER QUALITY  
FARM SITE

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	16 - 950 mg/l	Sulfate	21 - 670 mg/l
Chloride	<10 - 2,200 mg/l	Conductivity	236 - 2,900 umhos/cm
Nitrate (N)	<.3 - 6.8 mg/l	Total Dissolved Solids	140-4,500 mg/l

NOTE: u = micro

PLANT SITE

Routine monitoring of Truax Creek is conducted weekly for ammonia, nitrate, and total organic carbon as required by the NPDES permit. Monitoring locations include upgradient and downgradient of the Pond 2 weir on Truax Creek and near the confluence of Truax Creek with Murder Creek. Table 6-8 summarizes surface water quality at the Plant site.

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Table 6-8  
SURFACE WATER QUALITY  
PLANT SITE

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	13 - 680 mg/l	1,1,1-Trichloroethane	<1 - 23 ug/l
Magnesium	4 - 91 mg/l	1,1,2,2-Tetrachloroethane	<2 - 3 ug/l
Ammonia (N)	<.5 - 9.8 mg/l	1,1-Dichloroethane	<1 - 7 ug/l
Chloride	<10 - 1,300 mg/l	1,2-Dichlorobenzene	<1 ug/l
Nitrate (N)	<1 - 16 mg/l	1,2-Dichloroethane	<1 - 7 ug/l
Sulfate	<10 - 450 mg/l	1,1-Dichloroethene	<1 - 4 ug/l
Thiocyanate	<2 - 4 mg/l	1,2-Dichloropropene	<1 ug/l
Conductivity	190 - 3,930 umhos/cm	1,3-Dichlorobenzene	<1 ug/l
pH	6.6 - 7.2	1,4-Dichlorobenzene	<1 ug/l
Total Dissolved Solids	86 - 2,900 mg/l	Bromodichloromethane	<1 - 1 ug/l
Copper .0	0.01 - 0.03 mg/l	Bromoform	<1 ug/l
Iron .3	<.05 - 0.5 mg/l	Bromomethane	<1 ug/l
Manganese .65	<.05 - 1.2 mg/l	Carbon Tetrachloride	<1 ug/l
Nickel	<.02 mg/l	Chlordane	<.02 ug/l
Barium	<1 mg/l	Chlorobenzene	<1 ug/l
Cadmium	<.003 mg/l	Chloroethane	<1 - 4 ug/l
Lead	<.02 mg/l	Chloroform	<1 - 6 ug/l
Methyl Isobutyl Ketone	<1 mg/l	Chloromethane	<1 ug/l
Total Organic Carbon	<3 - 24 mg/l	CIS-1,3-Dichloropropene	<1 ug/l
Total Suspended Solids	8 - 50 mg/l	Dibromochloromethane	<3 ug/l
		Dichlorodifluoromethane	<2 ug/l
		Fluoranthene	<1 - 4 ug/l
		Methylene Chloride	<1 ug/l
		Napthalene	11 - 140 ug/l
		Trans-1,2-Dichloroethene	<1 - 2.0 ug/l
		Trichloroethene	<1 - 3 ug/l
		Trichlorofluoromethane	<1 ug/l

NOTE: u = micro  
Truax and Murder Creeks

SOLIDS CHARACTERIZATION

FARM SITE

The farm site contains four solids ponds denoted as Ponds 1, 2, 3, and 4. Sampling was conducted in 1980, 1983, 1985, 1986, and 1987. Samples were analyzed for total metals and inorganic compounds, Extraction Procedure (toxic) for metals, inorganics, and radiological compounds. A summary showing ponds sampled and analyses performed for each year is in the site chronology. Table 6-9 summarizes the chemical quality of the farm site solids.

Table 6-9  
SOLIDS CHARACTERIZATION  
FARM SITE

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	16 - 22%	Radium-226	1.1 - 7.9 pCi/gm
Magnesium	0.24 - 0.59%	Thorium	14 - 91 ppm
Carbonate	0.72 - 6.0%	Uranium	200 - 610 ppm
Chloride	1 - 2%	Zirconium/Hafnium	14.6 - 36.4%
Fluoride	0.6 - 5.2%	Arsenic	15 - 58 ppm
Sulfate	5.4 - 11%		
Aluminum	1.2 - 2.4%	Barium	200 - 1,000 ppm
Antimony	\$50 - 540 ppm	Cadmium	\$10 - \$20 ppm
Carbon	\$0.05 - 5.26%	Chromium	73 - 610 ppm
Copper	\$10 - 360 ppm	Lead	63 - 180 ppm
Iron	4.9 - 19%	Mercury	\$3 - \$1 ppm
Nickel	80 - 450 ppm	Silver	\$5 - \$50 ppm
Silica	6.9 - 11%		
Titanium	3.0 - 4.4%		
Zinc	96 - 220 ppm		

Note: Concentrations are on a dry weight basis.

PLANT SITE

Samples were collected and analyzed from the LRSP during April 1978, April 1979, April 1982, April 1985, January 1986, April 1986, August 1986, and September 1986. Samples were collected and analyzed from Schmidt Lake in March 1979, April 1979, and February 1987. Table 6-10 summarizes the chemical quality of the LRSP and Schmidt Lake lime solids.

Samples from the V-2 pond were collected and analyzed in January 1987. Table 6-11 summarizes the chemical quality of the V-2 pond solids.

AIR QUALITY MONITORING

Since 1967, air quality monitoring has been in effect and Teledyne Wah Chang Albany has been operating under Air Contaminant Discharge permits. Extensive area and point source studies have been conducted relative to radon emanation and radionuclide dispersion near the Lower River Solids Pond (LRSP), Schmidt Lake (SL), and the Farm Pond Area (Scientific Applications, Inc., 1980, and Battelle Pacific Northwest Laboratories, 1985, 1986).

The Battelle report concludes that the average annual release of radon and particulates from the lime solid wastes will

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meet the air radioactive material pathway exemption criteria of OAR, Section 345-50-035. Over a 10-month period, the TWCA site boundary at five locations had an average radon concentration of 0.26 pCi/l. This value is close to the

Table 6-10  
SOLIDS CHARACTERIZATION  
LRSP AND SCHMIDT LAKE

Parameter	Concentration Range	Parameter	Concentration Range
Calcium	5 - 15.9%	Chloride	0.17 - 8.3%
Magnesium	0.029 - 2%	Fluoride	0.099 - 13%
Potassium	0.02 - 0.58%	Sulfate	0.66 - 10.2%
Sodium	0.05 - 19,900 ppm	Carbon	0.35 - 15.3%
Arsenic	8 - 51 ppm	Nitrogen	5,500 - 23,000 ppm
Barium	<200 - 400 ppm	Radium-226	1.25 - 89 pCi/gm
Cadmium	<1 - 100 ppm	Thorium	0.006 - 0.029%
Chromium	150 - 2,600 ppm	Uranium	0.018 - 0.49%
Lead	87 - 520 ppm	1,1,1-Trichloroethane	<1 - 18 ppb
Mercury	<.5 - 4 ppm	1,1-Dichloroethane	<1 - 15 ppb
Silver	<.5 - <50 ppm	2-Hexanone	<10 - 250 ppb
Aluminum	0.2 - 10%	2-Methylnaphthalene	ND - <30 ppb
Antimony	<100 ppm	Acenaphthene	<30 ppb
Copper	72 - 630 ppm	Acetone	<10 - 17 ppb
Iron	0.005 - 5%	Hexachlorobenzene	4,500 - 5,000 ppb
Manganese	0.015 - 0.58%	Hexachlorobutadiene	<30 ppb
Nickel	0.075 - 1,100 ppm	Hexachloroethane	<30 ppb
Niobium	<.013 - 0.32%	Methylene Chloride	5 - 39 ppb
Selenium	<1 - <5 ppm	Phenanthrene	<30 ppb
Silica	1.5 - 22.3%	Chlorobenzene	4.5 - 14.4 ppb
Tantalum	<.01 - 0.7%	Chloroform	<1 - 6 ppb
Titanium	<100 - 250 ppm	Dichloroethene	<1 ppb
Vanadium	400 - 700 ppm	Tetrachloroethene	<1 - 4 ppb
Zinc	54 - 270 ppm		
Zirconium and Hafnium (O)	5 - 27.0%	Other Volatile & Semivolatile Organics	ND

Note: ND = Not Detected  
Concentrations are on a dry weight basis.

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Table 6-11  
SOLIDS CHARACTERIZATION  
V-2 POND

Parameter	Concentration Range	Parameter	Concentration Range
Antimony	<1.0 ppm	Chlordane	<10 ppb
Copper	0.03 - 0.06 ppm	Chloroform	ND-20 ppb
Nickel	0.39 - 4.43 ppm	Di-N-Butyl Phthalate	376-962 ppb
Selenium	<.05 ppm	Dicamba	<100 ppm
Zinc	0.095 - 0.623 ppm	Dieldrin	<.5 ppb
Arsenic	<0.05 ppm	Endosulfan I	<.5 ppb
Barium	<.05 - 0.132 ppm	Endosulfan II	<.5 ppb
Cadmium	<.002 - 0.033 ppm	Endosulfan Sulfate	<.5 ppb
Chromium	<.005 - 0.009 ppm	Endrin	<.5 ppb
Lead	0.018 - 0.06 ppm	Endrin aldehyde	<.5 ppb
Silver	<.005 - 0.007 ppm	Fluoranthene	ND-499 ppb
Radium-226	1.2 - 120 pCi/gm	Heptachlor	<.5 ppb
Thorium	2 - 619 ppm	Heptachlor Epoxide	<.5 ppb
Uranium	55 - 3,509 ppm	Hexachlorobenzene	ND-12,426 ppb
Thallium	<1 ppm	Lindane	<.5 ppb
2,4,5-TP	<100 ppm	Methoxychlor	<1 ppb
2,4-D	<100 ppm	Methylene Chloride	28 - 66 ppb
4,4-DDD	<.5 ppb	PCBs	<10 ppb
4,4-DDT	<.5 ppb	Pyrene	ND-505 ppb
Methyl Isobutyl Ketone	25 - 143 ppm	Toluene	ND-8 ppb
Acetone	549 - 2,020 ppb	Toxaphene	<50 ppb
Aldrin	<.5 ppb	Trichloroethene	ND-4 ppb
B-BHC	<.5 ppb	Vinyl Acetate	ND-213 ppb
a-BHC	<.5 ppb	Xylenes (O&M)	ND-20 ppb
d-BHC	<.5 ppb		
Benzo (K) Fluoranthene	ND - 439 ppb		
Bis-2-(ethylhexy 1) Phthalate	633 - 1,598 ppb		
Carbon Disulfide	181 - 802 ppb		

NOTE: ND = not detected

Concentrations are on a dry weight basis.

radon concentration measured at eight background locations (0.21 pCi/l). The data show that radon released from the LRSP and SL is diluted to background levels at the site boundary, and is only slightly elevated above background levels on the banks of the LRSP. A MILDOS computer program, developed for the U.S. Nuclear Regulatory Commission, was selected to calculate maximum airborne particulate activity adjacent to the LRSP and SL. Results are shown in Table 6-12.

Table 6-12  
CALCULATED UPPER LIMIT ACTIVITIES  
COMPARED WITH OAR 345-30-035 MPC VALUES

Radionuclide	$^{238}\text{U}$	$^{234}\text{U}$	$^{239}\text{Th}$	$^{226}\text{Ra}$	$^{222}\text{Rn}$	$^{210}\text{Pb}$	$^{210}\text{Bi}$	$^{210}\text{Po}$
Concentration, pCi/m <sup>3</sup>								
MPC-pCi/m <sup>3</sup>	5	4	$8 \times 10^{-2}$	2	$3.3 \times 10^{-2}$	4	200	7
LRSP	$5 \times 10^{-3}$	$5 \times 10^{-3}$	$2 \times 10^{-3}$	$1 \times 10^{-3}$	$3 \times 10^{-3}$	$6 \times 10^{-3}$	$6 \times 10^{-3}$	$6 \times 10^{-3}$
Schmidt Lake	$4 \times 10^{-3}$	$4 \times 10^{-3}$	$2 \times 10^{-3}$	$1 \times 10^{-3}$	$8 \times 10^{-6}$	$5 \times 10^{-3}$	$5 \times 10^{-3}$	$5 \times 10^{-3}$

Airborne-particulate studies by Scientific Applications, Inc., indicated that no detectable concentration of alpha emitters existed, and that the air pathway is considered unimportant as a means of radionuclide transport. TWCA established a monitoring program in July 1978 to quantify gamma levels at the site boundaries and selected areas within the facility. The data are shown in Tables 6-13 and 6-14. All levels are below the limits specified by the U.S. Nuclear Regulatory Commission.

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Table 6-13  
PLANT PERIMETER MONITORING--QUARTERLY BASIS  
PENETRATING/NONPENETRATING

Site <sup>a</sup>	7/01/87- 9/30/87	4/01/87- 6/30/87	1/01/87- 3/31/87	7/01/78- 9/30/78	10/01/78- 12/31/78
1	m/m	m/m	m/m	m/m	10/m
2	m/m	m/m	m/m	m/m	m/m
4	m/m	m/m	---	m/m	m/m
6	m/m	m/m	m/m	m/m	m/m
7	m/m	m/m	m/m	m/m	m/m
8	m/m	m/m	m/m	m/m	31/m
13	m/m	m/m	m/m	m/m	m/m
15	m/m	m/m	m/m	m/m	m/m
16	19/m	m/m	m/m	m/m	m/m
17	m/m	m/m	m/m	m/m	13/m
18	m/m	m/m	m/m	m/m	m/m
19	m/m	m/m	m/m	m/m	m/m
23	m/m	m/m	m/m	m/m	m/m
24	m/m	m/m	m/m	m/m	10/m
31	m/m	m/m	m/m	m/m	m/m
33	m/m	m/m	m/m	m/m	12/m
34	m/m	m/m	m/m	m/m	18/m

<sup>a</sup> Sites located throughout main plant site.

Notes: 1. Acceptable limits specified by the U.S. Nuclear Regulatory Commission.

Whole Body: Quarterly--1250 millirem.

2. m--below measurable detection limits.

3. date expressed as millirem units.



The Farm Ponds contain lime solids generated after a major process change that lowered the radionuclide levels vis-a-vis the material in LRSP and Schmidt Lake. The radium content is approximately 5 pCi/g, compared to a median value of about 40 pCi/g for Schmidt Lake and the LRSP. The lower radium content equates to a marked reduction in radon emanation. Consequently, the Farm Pond solids should pose no risk or threat to the public health and welfare, or to the environment.

Current monitoring programs conducted pursuant to Air Contaminant Discharge Permit No. 22-0547 have generated a significant body of information on plant site emissions such as metals, ammonia, chlorides, sulfates, fluorides, sulfur dioxide, carbon monoxide, nitrous oxides, and particulates.

#### AREA AND POINT SOURCE STUDIES

##### Chlorides, Chlorine, and Ammonia

Ambient air measurements, which were supplied to the Oregon Department of Environmental Quality (DEQ), are typical of the plant site and are presented in Tables 6-15 and 6-16.

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Table 6-15  
Ambient Air Measurements  
January 1986

Period <sup>a</sup>	North ( $\mu\text{g}/\text{m}^3$ )			East ( $\mu\text{g}/\text{m}^3$ )			South ( $\mu\text{g}/\text{m}^3$ )		
	Cl	Cl <sub>2</sub>	NH <sub>3</sub>	Cl	Cl <sub>2</sub>	NH <sub>3</sub>	Cl	Cl <sub>2</sub>	NH <sub>3</sub>
Jan. 2-9	<0.036	<0.014	0.002	<0.059	<0.024	0.017	<0.023	<0.009	<0.014
Jan. 9-16	<0.040	<0.016	<0.017	<0.066	<0.026	<0.015	<0.025	<0.010	<0.011
Jan. 16-23	<0.034	<0.014	<0.024	<0.042	<0.017	0.015	<0.036	<0.014	<0.010
Jan. 23-30	<0.041	<0.020	0.021	<0.050	<0.025	0.016	<0.027	<0.013	

<sup>a</sup> All periods are in 1986.

Notes: Measurements made at the three monitoring stations; measurements shown here are average for the time designated.

TLV-SAX, N. Irving, 4th Edition 1975

Chlorine: 3  $\mu\text{g}/\text{m}^3$

Ammonia: 18  $\mu\text{g}/\text{m}^3$

u = micro

Table 6-16  
Ambient Air Measurements  
January 1987

Period <sup>a</sup>	North ( $\mu\text{g}/\text{m}^3$ )			East ( $\mu\text{g}/\text{m}^3$ )			South ( $\mu\text{g}/\text{m}^3$ )		
	Cl	Cl <sub>2</sub>	NH <sub>3</sub>	Cl	Cl <sub>2</sub>	NH <sub>3</sub>	Cl	Cl <sub>2</sub>	NH <sub>3</sub>
Jan. 2-7	<0.104	<0.042	<0.017	<0.017	<0.007	<0.014	<0.049	<0.019	<0.020
Jan. 7-14	<0.061	<0.024	<0.023	<0.092	<0.037	<0.016	<0.058	<0.023	<0.026
Jan. 16-21	<0.143	<0.057	<0.028	<0.061	<0.025	<0.016	<0.065	<0.026	<0.026
Jan. 21-28	0.031	<0.012	<0.013	0.023	<0.009	<0.017	<0.025	<0.010	<0.12
Jan. 28- Feb. 4	<0.021	<0.008	<0.007	<0.057	<0.023	<0.026	<0.035	<0.014	<0.012

<sup>a</sup> All periods are in 1987.

Notes: Measurements made at the three monitoring stations; measurements shown here are average for the time designated.

TLV-SAX, N. Irving, 4th Edition 1975

Chlorine: 3  $\mu\text{g}/\text{m}^3$

Ammonia: 18  $\mu\text{g}/\text{m}^3$

u = micro

50

GENERAL

<u>Date</u>	<u>Event</u>
1957	Wah Chang Corporation began operation.
Dec. 1964	Plant site flooded to elevation of approximately 209 feet above MSL.
May 1967	Teledyne, Inc., purchased the plant from Wah Chang Corporation.
1969	Termination of zirconium carbide production process.
1972	Installation and startup of sand chlorination process.
Dec. 1982	TWCA placed on National Priorities List.
March 3, 1986	EPA (C. Findley, Region X) made a Section 104 CERCLA request for environmental data and radiation studies conducted since July 1982.
May 1987	TWCA and EPA sign Order on Consent Docket No. 1986-02-19-106.
Aug. 1987	TWCA submitted draft Work Plan for RI/FS.
Feb. 1988	TWCA submitted revision No. 1 to draft Work Plan for RI/FS.



**Reference 2**

**Excerpts From Decision Summary, Interim Response Action,  
Operable Unit 1; EPA; 1989**



DECISION SUMMARY  
INTERIM RESPONSE ACTION  
OPERABLE UNIT #1

TZ4-C10 <sup>V. at</sup> ~~CCS-EP-101086~~ 12118

RECEIVED  
DEF J 4 92  
SAIC TFS  
REGION 1

SITE NAME

Teledyne Wah Chang Albany (TWCA), Albany, Oregon

LOCATION AND DESCRIPTION

The Teledyne Wah Chang Albany facility is located in Millersburg, Oregon (about three miles north of Albany) in the Willamette Valley (see Figure 1). The Superfund site includes the 110 acre plant site property and the 115 acre facility known as the "farm site", which has the plant's wastewater treatment ponds ("Farm Ponds") and is located approximately <sup>3/4</sup> one mile north of the plant site. Operable Unit #1, the unit addressed by this Interim Action, includes the solids in the Lower River Solids Pond and Schmidt Lake which are located between the plant and the Willamette River.

Of the two major site areas, the plant site contains numerous buildings and facilities including an extraction area south of Truax Creek, a fabrication area north of Truax Creek, a solids storage area west of the Burlington Northern Railroad, and a parking and recreation area east of the Southern Pacific Railroad. The farm site is 3/4 of a mile north of the plant site and contains five 2-1/2 acre solids storage ponds. The remainder of the site is used primarily for agriculture. Over 1300 people are employed at the TWCA plant, making it the largest employer in the Albany area.

The Lower River Solids Pond (LRSP) and Schmidt Lake are the two sludge ponds addressed by this Record of Decision. They lie in the western portion

The immediate area surrounding TWCA is primarily industrial, with some land to the north being used for agriculture. The land east of Interstate 5 and south of the plant site is used mainly for residential and commercial purposes, while land west of the Willamette River, which borders the plant site, is used for farming. Albany, the urban area to the south of the site, has a population of approximately 27,000; Millersburg has a population of about 560.

There are about 250 known private drinking water wells within three miles of the facility, all of these wells are upgradient of the site. There are no known domestic, municipal, industrial, or irrigation wells located between the site and the Willamette River. The Willamette River is not used as a drinking water source in this area.

#### SITE HISTORY AND ENFORCEMENT ACTIVITIES

##### Site History

Operations at the TWCA site began in 1956 when, under contract with the U S Atomic Energy Commission, Wah Chang Corporation reopened the U S Bureau of Mines Zirconium Metal Sponge Pilot Plant. Construction of new facilities at the site of the existing plant began in 1957. These facilities were built primarily for the production of zirconium and hafnium sponge. However, tantalum and niobium pilot facilities were also included. Melting and fabrication operations were added in 1959. Teledyne Wah Chang Albany was established in 1967 after Teledyne Industries, Inc., purchased Wah Chang Corporation of New York. In 1971 the plant became a separate corporation - Teledyne Wah Chang Albany.



Because of the many processes involved in production of nonferrous metals and products, waste management programs at TWCA consist of a wide range of activities, including process wastewater treatment, solid waste management, hazardous waste management, PCB equipment management, radioactive material control, waste minimization through beneficial use, and air quality control programs. Discharge of process wastewater is regulated by an NPDES permit. An Air Contaminant Discharge Permit regulates emissions at the facility. Teledyne is currently classified as a hazardous waste generator under the Resource Conservation and Recovery Act (RCRA) program.

The LRSP was constructed and placed into operation in 1967 to receive lime solids (sludge) from TWCA's onsite wastewater treatment plant. Schmidt Lake was constructed for the same purpose in 1974. Sludge was pumped into the two ponds until October 1979 when the farm ponds to the north of the facility were put into operation. The farm ponds were originally part of this operable unit, but because they are outside the flood plain and are not considered an immediate threat, they are now being investigated as part of the overall site RI. The sludge in both the LRSP and Schmidt Lake contains metals, a few organic compounds, and trace levels of some radionuclides. Tables 1-4 present a summary of the contaminants found in the sludge.

In 1978, TWCA modified the process for the production of zirconium and hafnium metal. The process modification directed the radioactive materials into a separate solid waste referred to as chlorinator residue. This residue

is managed as a low specific activity radioactive waste and shipped to Hanford, Washington, for disposal. Sludge generated since the implementation of this modification has been stored in the farm ponds.

#### Enforcement History

The sludge ponds have attracted the attention of regulatory agencies and the public for many years, particularly because of the presence of radioactive materials, which was first confirmed by the Oregon State Health Division in 1977. In March 1978, TWCA was granted a Radioactive Materials License to transfer, receive, possess, and use zircon sands and industrial byproducts containing licensable concentrations of radioactive materials. TWCA took samples from the ponds on several occasions in 1979 and 1980. In 1981, the company applied to the Energy Facility Siting Council (EFSC) for a site certificate to close LRSP; the next year, they made another application to store approximately 120,000 cubic yards of lime solids. The site was listed on the National Priorities List (NPL) in October 1983. After several years of hearings, court actions, and further sampling, EFSC ruled in 1987 that the sludge was not subject to their jurisdiction, the levels of radioactivity being too low. TWCA then submitted a closure plan to the Oregon State Health Division, but EPA and other agencies recommended that closure not take place until after the conclusion of the RI. Meanwhile, the site had been listed on the National Priorities List in 1983, and on May 4, 1987, TWCA had signed a Consent Order agreeing to conduct the RI/FS.

The TWCA facility holds permits for water and air emissions. It was found in violation of wastewater discharge permits in 1975, 1977, and 1978; subsequent process changes reduced the toxicity of the facility's wastewater discharges. TWCA was assessed fines for other water quality permit violations in 1979, 1980 and 1989. The company was fined for illegal open burning in

**Reference 3**

**Excerpts From SAIC Report, Data Validation for Work Assignment C10005,  
Teledyne Wah Chang Albany, DCN: TZ4-C10005-DV-02775;  
SAIC; 1990**

INTER-OFFICE MEMO



TZ4-C10005-DV-02775

RECEIVED

MAR 02 1990

SAIC-TES  
REGION 10

DATE March 1, 1990

TO Tom Tobin

FROM Paul Mills

SUBJECT: SAIC Report, Data Validation Work Assignment C10005, Teledyne Wah Chong<sup>a</sup>

Attached is a summary of the data validation performed on the data from EPA's Case #12741. Metals, volatiles and base-neutral/acid organics by GC/MS, and organochlorine pesticides and PCBs by GC were reviewed, using the EPA's CLP data validation guidelines (1988) to evaluate the completeness and compliance with contract requirements.

The original data you provided us was copied and distributed to specialists in the SAIC Environmental Chemistry Laboratory Division. Ray Martrano, GC/MS Section Manager; Steve Glover, GC Section Manager; and Leta Thomsen, Metals Section QC Specialist, performed the validations of their portions of the data. I have enclosed their summaries as attachments behind my own. Additional supporting data for GC/MS, such as checklists, etc. is also included. We will mail back the original data to you under separate cover. We will maintain our copies in case there are questions, until you have authorized us to either dispose of them or send the copies back to you.

The hours charged by the reviewers are as follows:

Ray Martrano = 18 hours  
Steve Glover = 14 hours  
Leta Thomsen = 25.5 hours

57.5

There will probably be some secretary time thrown in for typing Ray's report. I'll charge my time to TES QA numbers, for oversight/auditing of lab work here, since I think this is appropriate.

If you have any questions, please call me, (619)-535-7493

Attachments

soil matrix, and the standard should be analyzed under the same conditions as samples. It is possible that the reported values for these samples are somewhat high; "hot" purge standards may have produced a larger response, against which the samples' responses would not have generated as high concentrations

Due to surrogate recoveries and spiking errors, several samples required re-extraction for BNAs. These were re-extracted beyond the specified holding time for extractions; since surrogate and matrix spike recoveries on the re-extracts were acceptable, no significant data impact is noted. Where insufficient sample volumes remained for re-extraction with full volumes of samples, 500 ml aliquots were used, which would require an increase in reported detection limits by a factor of 2, since usually 1000 ml are used.

Several non-criteria compounds showed a high RSD in calibration runs. While contractually compliant, the data user is advised to note that samples containing "hits" of these compounds may be considered estimated concentrations. See the tables attached to the GC/MS review section for details concerning which samples, calibrations, and compounds are affected.

Several spectra of hits in these samples were judged by the SAIC reviewer to be poor fits, i.e., not meeting the CLP-specified criteria for matches. These are mostly very low-level (lower than contract required reporting limits) compounds which the lab has self-reported as estimated, using the "J" data qualifier. See the associated table in Section IX of the GC/MS review for details. If these compounds from these samples are of concern, it is recommended that alternate methods be used to identify and quantitate them (e.g., GCs for volatile analysis can more accurately measure low levels)

#### ORGANOCHLORINE PESTICIDES/PCBs

Several samples exceeded the extraction holding time when they were re-extracted. Re-extraction was required due to incorrect surrogate spike amounts. Original results of initial extractions of these samples show the presence of PCBs and it is unlikely PCBs degraded in the few days after holding times expired. The data for the re-extracted samples should be qualified as "estimated" JF069RE, JF069MSRE, JF069MSDRE.

JF076MS and JF076MSD aqueous spiked samples were extracted beyond the holding time; since no compounds were found above reporting limits in the original sample which met holding times, there is no significant impact on data quality.

Although contract-required confirmation criteria were not met, the second-column confirmation runs did show the PCB patterns which in the chemist's judgment confirmed the presence of PCBs.

A method blank showed below-reporting limit levels of PCB-1260, no associated samples showed this PCB at any detectable level. It was judged a laboratory contaminant, and no qualification of data from samples was noted.

Soil sample matrix spike/matrix duplicate recoveries on the re-extracted samples exceeded the advisory control limits, probably due to the interferences from PCBs in the native sample. There is not significant impact on data quality.

SAIC's data reviewer believes that the pattern(s) reported by the original GC chemist as PCB-1248 and PCB-1254 are all PCB-1248. Since identification is made using several peaks common to both Aroclors, there could be some later-eluting peaks of 1248 which may be interpreted to represent PCB-1254. The quantitation of PCB-1248 uses earlier-eluting peaks than PCB-1254 does, so the actual values reported would not be changed much (perhaps 25 percent) if the Aroclors present are considered all 1248 instead of a mixture. If total PCBs are of concern, rather than amounts of specific isomers, there should be no impact from this differing interpretation. PCBs were detected in GC/MS runs of these samples, but SAIC's GC/MS data reviewer was unable to determine whether PCB-1248 and PCB-1254 were both present.

**Reference 4**

**Excerpts From Potential Hazardous Waste Site,  
Site Inspection Report for Teledyne Wah Chang, Albany, Oregon;  
EPA; 1982**

VII SITE RELATED INFORMATION (continued)					
2 Estimate the amount (specify unit of measure) of waste by category mark 'X' to indicate which wastes are present					
a SLUDGE	b OIL	c SOLVENTS	d CHEMICALS	e SOLIDS	f OTHER
AMOUNT	AMOUNT	AMOUNT	AMOUNT	AMOUNT	AMOUNT
					106,000
UNIT OF MEASURE	UNIT OF MEASURE	UNIT OF MEASURE	UNIT OF MEASURE	UNIT OF MEASURE	UNIT OF MEASURE
					cubic yards
<input checked="" type="checkbox"/> (11) PAINT PIGMENTS	<input checked="" type="checkbox"/> (1) OILY WASTES	<input checked="" type="checkbox"/> (1) HALOGENATED SOLVENTS	<input checked="" type="checkbox"/> (11) ACIDS	<input checked="" type="checkbox"/> (11) FLYASH	<input checked="" type="checkbox"/> (1) LABORATORY PHARMACEUTICALS
(12) METALS SLUDGES	(2) OTHER (specify)	(12) NON-HALOGENATED SOLVENTS	(12) PICKLING LIQUORS	(12) ASBESTOS	(12) HOSPITAL
(13) POTW		(13) OTHER (specify)	(13) CAUSTICS	(13) MILLING/MINE TAILINGS	<input checked="" type="checkbox"/> (13) RADIOACTIVE
(14) ALUMINUM SLUDGE			(14) PESTICIDES	(14) FERROUS SMELTING WASTES	(14) MUNICIPAL
(15) OTHER (specify)			(15) DYES/INKS	(15) NON-FERROUS SMELTING WASTES	(15) OTHER (specify)
			(16) CYANIDE	(16) OTHER (specify)	
			(17) PHENOLS		
			(18) HALOGENS		
			(19) PCB		
			(110) METALS		
			(111) OTHER (specify)		

C LIST SUBSTANCES OF GREATEST CONCERN WHICH ARE ON THE SITE (place in descending order of hazard)										
1 SUBSTANCE	2. FORM (mark 'X')			3 TOXICITY (mark 'X')				4 CAS NUMBER	5 AMOUNT	6 UNIT
	a. SOLID	b. LIQ.	c. VAPOR	e. HIGH	b. MED	c. LOW	d. NONE			
Radium chloride		X		X				None		
Radon gas			X	X				None		
Uranium	X	X		X				None		
Thorium		X		X				None		

VIII. HAZARD DESCRIPTION	
FIELD EVALUATION HAZARD DESCRIPTION Place an 'X' in the box to indicate that the listed hazard exists Describe the hazard in the space provided.	
<input checked="" type="checkbox"/> A HUMAN HEALTH HAZARDS A. Radon gas is a serious threat to workers B. In the event of a small flood these would be widespread contamination by radioactive wastes C. Land use must be restricted for thousands of years due to radioactive waste	



☐ P. NON-WORKER INJURY/EXPOSURE

Unknown

☒ C. WORKER INJURY/EXPOSURE

Several citations have been issued.

- A. Fatality: anhydrous ammonia exploded, blasted and burned worker.
- B. March 17, 1976, Citation. HCl exposure
- C. Sept., 1975. Citation. Rupture and explosion of titanium tetrachloride and inhalation, 2nd degree burns.

☒ D. CONTAMINATION OF WATER SUPPLY

Possible. Many domestic wells in the area in the aquifer of concern. Need to sample these wells.

☒ E. CONTAMINATION OF FOOD CHAIN

Food chain crops grown on land spread with radioactive wastes.

☒ F. CONTAMINATION OF GROUND WATER

Wells sampled show 10 of 13 wells had elevated levels of radium chloride and 3 wells exceeded legal levels. Radium chloride levels at 6 pCi found in 40 feet test well.

☒ G. CONTAMINATION OF SURFACE WATER

Sampling at Truax Creek shows higher radionuclide concentrations attributable to TWCA plant.

III HAZARD DESCRIPTION (continued)

☐ H DAMAGE TO FLORA/FAUNA

Unknown

☐ I FISH KILL

Unknown

☒ J CONTAMINATION OF AIR

Radon gas emission from sludge lagoons.

☐ K NOTICEABLE ODORS

None

☒ L CONTAMINATION OF SOIL

Landspreading of radioactive wastes.

☒ M PROPERTY DAMAGE

Land use greatly restricted

## HAZARD DESCRIPTION (continued)

☒ H. FIRE OR EXPLOSION

Several explosions due to magnesium and zirconium.

☒ O SPILLS/LEAKING CONTAINERS/RUNOFF/STANDING LIQUID

Chlorinator residues. Ordered to clean up in 1977. No other spills or hot spots the Health Department is aware of.

☒ P. SEWER STORM DRAIN PROBLEMS

Discharged radioactive materials to sewer but nothing detected in excess of State standards.

☒ Q EROSION PROBLEMS

Water leaching through dikes in past. Not felt to exist at present. Dikes made of rip-rap, not lined.

☒ R INADEQUATE SECURITY

Not fenced on river. Rest of site is fenced. Ponds not under constant guard. Guard at gate.

☒ S. INCOMPATIBLE WASTES

- A. Magnesium and zirconium
- B. Radioactive substances

# VIII HAZARD DESCRIPTION (continued)

☐ T MIDNIGHT DUMPING

None known

☐ U OTHER (specify)

## IX. POPULATION DIRECTLY AFFECTED BY SITE

A LOCATION OF POPULATION	B APPROX NO. OF PEOPLE AFFECTED	C APPROX NO OF PEOPLE AFFECTED WITHIN UNIT AREA	D APPROX NO. OF BUILDINGS AFFECTED	E DISTANCE TO SITE (specify units)
1 IN RESIDENTIAL AREAS	20,000	3 miles	> 5000	3 miles
2 IN COMMERCIAL OR INDUSTRIAL AREAS	3,000	1 miles	> 1000	3 miles
3 IN PUBLICLY TRAVELLED AREAS	> 10,000	2 miles	> 1000	3 miles
4 PUBLIC USE AREAS (parks, schools, etc.)	6 schools 1 park	2 miles	6	2 miles

## X WATER AND HYDROLOGICAL DATA

A DEPTH TO GROUNDWATER (specify unit)	B. DIRECTION OF FLOW WNW	C GROUNDWATER USE IN VICINITY Domestic, industrial
D POTENTIAL YIELD OF AQUIFER	E DISTANCE TO DRINKING WATER SUPPLY (specify unit of measure) < 1 mile	F DIRECTION TO DRINKING WATER SUPPLY all around site
G TYPE OF DRINKING WATER SUPPLY		
<input type="checkbox"/> 1 NON-COMMUNITY < 15 CONNECTIONS	<input checked="" type="checkbox"/> 2 COMMUNITY (specify town) > 15 CONNECTIONS	Albany, from the Santanum River (private domestic wells)
<input checked="" type="checkbox"/> 3 SURFACE WATER	<input checked="" type="checkbox"/> 4 WELL	

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Continued From Page 8

## X. WATER AND HYDROLOGICAL DATA (continued)

H. LIST ALL DRINKING WATER WELLS WITHIN A 1/4 MILE RADIUS OF SITE

1. WELL	2. DEPTH (specify unit)	3. LOCATION (proximity to population/buildings)	4. NON-COM- MUNITY (mark 'X')	5. COMMUN- ITY (mark 'X')
McKibben	----	(See files and maps)	X	
Hofziger	70'	"	X	
Schmidt	55'	"	X	
Schmidt	----	"	X	

## I. RECEIVING WATER

1. NAME  
Willamette and  
Truax Creek☒ 2. SEWERS☒ 3. STREAMS/RIVERS☐ 4. LAKES/RESERVOIRS☐ 5. OTHER (specify) \_\_\_\_\_

## J. SPECIFY USE AND CLASSIFICATION OF RECEIVING WATERS

Willamette is Class I water

## XI. SOIL AND VEGETATION DATA

LOCATION OF SITE IS IN

☐ A. KNOWN FAULT ZONE☐ B. KARST ZONE☒ C. 100 YEAR FLOOD PLAIN☒ D. WETLAND☐ E. A REGULATED FLOODWAY☐ F. CRITICAL HABITAT☐ G. RECHARGE ZONE OR SOLE SOURCE AQUIFER

## XII. TYPE OF GEOLOGICAL MATERIAL OBSERVED

Mark 'X' to indicate the type(s) of geological material observed and specify where necessary, the component parts.

X	A. OVERBURDEN	X	B. BEDROCK (specify below)	X	C. OTHER (specify below)
X	1. SAND				
X	2. CLAY				
X	3. GRAVEL				

## XIII. SOIL PERMEABILITY

☐ A. UNKNOWN☐ B. VERY HIGH (100,000 to 1000 cm/sec.)☐ C. HIGH (1000 to 10 cm/sec.)☒ D. MODERATE (10 to 1 cm/sec.)☐ E. LOW (1 to .001 cm/sec.)☐ F. VERY LOW (.001 to .00001 cm/sec.)

## G. RECHARGE AREA

☒ 1. YES☐ 2. NO

3. COMMENTS

## H. DISCHARGE AREA

☒ 1. YES☐ 2. NO

3. COMMENTS

Discharge to nearby surface water bodies.

## I. SLOPE

1. ESTIMATE % OF SLOPE

2. SPECIFY DIRECTION OF SLOPE CONDITION OF SLOPE ETC.

0.02%

Slope is west towards Willamette River

## J. OTHER GEOLOGICAL DATA

Setting in an alluvial flood plain with lakes in abandoned meanders.

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### XIV PERMIT INFORMATION

List all applicable permits held by the site and provide the related information.

A PERMIT TYPE (e.g. RCRA State, NPDES, etc.)	B ISSUING AGENCY	C PERMIT NUMBER	D DATE ISSUED (mo., day, & yr.)	E EXPIRATION DATE (mo., day, & yr.)	F IN COMPLIANCE (mark 'X')		
					1 YES	2 NO	3 UNKNOWN
RCRA	EPA		3-16-82				X
NPDES	OR DEQ	OR10001112	1-4-78	7-31-81	X		
PSD	EPA	220547					X

### XV PAST REGULATORY OR ENFORCEMENT ACTIONS

☐ NONE ☒ YES (summarize in this space)

1972 - 1979

Numerous failures to comply with NPDES permit requirements for one or more pollutants.

Several citation from Oregon Accident Prevention Division.

NOTE Based on the information in Sections III through XV, fill out the Tentative Disposition (Section II) information on the first page of this form.

**Reference 5**

**Excerpts From Review of CH2M Hill Work Plans for Baseline Risk Assessment:  
Human Health Evaluation and Environmental Evaluation,  
Remedial Investigation/Feasibility Study, Teledyne Wah Chang Albany,  
DCN: TZ4-C10005-EP-H0773; Environmental Toxicology International Corporation; 1990**

DCN# TZ4-C10005-EP-H0773

MEMORANDUM

RECEIVED Environmental Toxicology  
International, Inc.  
MAY 25 1990

To: Pat Cirone, U.S. EPA  
From: Jeanne M. Funsch, ETI  
Date: 16 May 1990  
Subject: Comments on the Teledyne Wah Chang Superfund Site Draft Work Plans

This memo presents the comments on the Teledyne Wah Chang Superfund Site Draft Work Plans for the Baseline Risk Assessment that were discussed by Jeanne Funsch (ETI), Bruce Duncan (EPA), and Pat Cirone (EPA) on 15 May 1990. The comments on the Environmental Evaluation are presented first, followed by comments on the Human Health Evaluation.

**Environmental Evaluation**

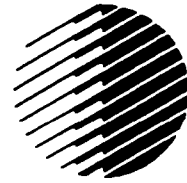
- 1) Using a hazard index approach (i.e., comparing estimated wildlife exposures to water quality criteria or reference values from the scientific literature) may not be a sufficiently-complete assessment of the potential affects to the ecosystems present at the Teledyne site. This approach is useful for screening purposes, however. The results of this screening may warrant examination of certain contaminants and/or exposure pathways in more detail (e.g., bioassays). A discussion of how the screening would be interpreted and used should be included in the Work Plan, including the rationale for either eliminating contaminants from further study or progressing to a more detailed analyses.
- 2) There is a lack of basic site-specific information in the Work Plan. A conceptual site model is needed that includes a representation of critical habitats and exposure pathways. Information on the species and habitat types present on site is also needed *before* any assessment strategies are formulated.

**Human Health Evaluation**

- 1) New EPA Region X guidance is expected in approximately one month. However, the guidance presented by Region X in January of 1991 is more

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South and Stewart, Suite 700  
Seattle, WA 98101 USA  
Telephone (206) 441-6142  
Facsimile (206) 443-1812  
Telex 4947618 ETI UT





current than the guidance used in writing the Human Health Evaluation Work Plan and therefore should be consulted at this time.

- 2) Information regarding the exposure scenarios (i.e., residential, industrial, etc.) and the exposure parameters to be used in the risk assessment should have been submitted prior to the Work Plan (as is outlined in the Region X guidance included as Attachment A of the Work Plan). Current and future scenarios for both residential and industrial exposures are required by Region X guidance. Also, the separation of the site into two source areas should be addressed relative to the exposure scenarios.
- 3) A more illustrative conceptual site model would complement a discussion of exposure scenarios (i.e., instead of a flow chart). The geographic areas of concern should be emphasized in this model. For example, a depiction that supports the elimination of exposure to soil as a pathway of concern and the areas where workers are currently active would both be appropriate.
- 4) Additional risk estimates currently required under Region X guidance to be included in a Baseline Risk Assessment are risk reduction for each of the remedial alternatives selected for detailed review and estimates of risks that may occur during remedial actions. Remedial action goals should also be discussed in the Baseline Risk Assessment (i.e., will cleanup levels be based on established criteria or risk-based concentrations). None of these topics is currently addressed in the Work Plan. These issues were apparently not addressed in the guidance included as Attachment A to the Work Plan. Parts B and C of the Risk Assessment Guidance for Superfund under development by the EPA will discuss these topics in more detail. Until these documents are finalized, EPA Region X should be consulted.
- 5) Risk-based detection limits should be used in the RI/FS process.
- 6) The Uncertainty Section was missing in the Baseline Risk Assessment Process outlined in the Work Plan on page 1-6. This section is discussed later in the document (page 5-1), but should also include discussions of the following: uncertainty in the sampling and analysis procedures, differences in the absorption of contaminants, the degradation of contaminants to more or less toxic compounds, dermal exposure uncertainties, and the chemical form of the contaminants that is expected on site (i.e., trivalent or hexavalent chromium).
- 7) Including the results of Phase I sampling in the Work Plan would be appropriate, particularly if only these data will be used in the risk assessment.
- 8) Plates 2 and 3 are missing from the Work Plans.

cc: John Kane (SAIC)

**Reference 6**

**Excerpts From Technical Memorandum Concerning Fall 1989 Sampling Activities,  
DCN: TZ4-C10005-EP-00568; From Thomas A. Tobin, SAIC, to  
Neil Thompson, EPA; Undated**

## TECHNICAL MEMORANDUM

EPA Contract No. 68-W9-0008, WA No. C10005  
Teledyne Wah Chang Albany RI/FS Oversight  
September/October 1989

## 1.0 Introduction

From September 19 through October 18, 1989 SAIC provided technical oversight for the Phase I Remedial Investigation (RI) sediment, surface water, and ground water sampling effort at the Teledyne Wah Chang (TWCA) facility near Albany, Oregon. The RI, conducted by TWCA's consultant CH2M Hill of Corvallis, Oregon, will assess the presence and extent of chemical contaminants in ground water, sediment, and surface water in and around the TWCA facility. From September 19 through September 29 SAIC provided oversight jointly with the TES-4 contractor, Tetra Tech, Inc.

Tetra Tech provided primary oversight of TWCA's RI sampling activities during the first week of sampling with SAIC in a support role. Conversely, SAIC provided primary oversight during the second week with Tetra Tech in a support role. SAIC alone provided oversight during the remaining three weeks. SAIC provided one field engineer during the initial week of sampling to makeup the two person team. During the second and subsequent weeks of oversight, SAIC provided two field personnel to provide full time oversight of TWCA's sampling procedures.

SAIC documented CH2M Hill's sampling activities and collected duplicate sediment, surface water, and ground water samples concurrently with CH2M Hill as described in SAIC's Sampling and Analysis Plan (SAIC SAP, 1989) and Quality Assurance Project Plan (SAIC QAPJP, 1989). SAIC directly observed the sampling of approximately 80 percent of the ground water monitoring wells and obtained duplicated samples from approximately 10 percent of CH2M Hill's sampling sites. Table 1 summarizes all duplicate samples collected by SAIC and their corresponding traffic report numbers. Table 2 summarizes SAIC's sampling oversight activities and provides additional information applicable to each sample station. Appendix A contains annotated photographs and associated documentation of sampling activities.

Duplicate samples collected by SAIC are currently being analyzed by process laboratories under contract to EPA using EPA Contract Laboratory Program (CLP) protocols. When available, validated results will be submitted under separate cover.

## 2.0 Weekly Activities and Observed Deviations

Following is a week-by-week description of SAIC's sampling and oversight activities. Deviations to CH2M Hill's Field Sampling Plan (CH2M Hill FSP, 1988) or SAIC's SAP, and subsequent consequences, are provided. Except where noted, CH2M Hill followed sampling procedures outlined in their Field Sampling Plan.

September 19-21, 1989

Week 1 Activities

Robert Brockhaus (SAIC) and Kurt Schmeirer (Tetra Tech) oversaw Week 1 surface water and sediment sampling activities. SAIC collected duplicate samples at Truax Creek sampling stations TC-5, TC-6 and at the Murder Creek sampling station, MTC-1. SAIC also prepared two Quality Control (QC) samples -- a field replicate sample (designated TC-9) collected at sample station TC-5 and a transfer blank sample (designated TB-1) collected at sample station MTC-1 (Table 1).

Week 1 Work Plan Deviations and Consequences

1. SAIC proposed collecting a sediment sample at station MTC-1. Only surface water was collected at sample station MTC-1, however because SAIC did not at the time have a sufficient number of sediment sample containers. This inadequacy was caused solely because some of the sediment sample containers had broken in transit from the glassware supplier. Able to obtain CLP-clean sediment sample containers from CH2M Hill, SAIC instead collected a sediment sample at station TC-6.

Consequences: Since all CLP glassware follows a stringent cleaning protocol, the use of CH2M Hill's glassware is not expected to affect QA review of sediment sampling results. There is no consequential change to the level of QA review by substituting one sediment station for another where both samples are subject to comparable analytical tests.

2. SAIC proposed including volatile organic compounds (VOC) trip blanks composed of organic-free water with each set of VOC field samples collected and shipped to the analytical laboratories. SAIC personnel did not include VOC trip blanks with Week 1 VOC field samples because the VOC blanks obtained from the laboratory contained air bubbles.

Consequences: Sample trip blanks are used to assess possible sample container contamination by volatile organic compounds (SAIC QAPjP, 1989). Upon receipt of the unacceptable blanks, SAIC immediately requested, and received within 48 hours, new "bubble-free" VOC trip blanks from the laboratory. Trip blanks were included with sample shipments during all succeeding weeks. The impact of not sending trip blanks with the first week's samples is expected to be minimal to the overall quality of the oversight program as all sample bottles were taped closed and enclosed in a sealed ice chest.

3. CH2M Hill relocated sediment sample station TC-6 from that originally proposed in their FSP because cobbles and gravel in the stream bed made sediment sample collection difficult. As a result, the sediment sample from station TC-6 was collected approximately 50 feet upstream of surface water sample station TC-6. In addition, the sediment sample from TC-6 was

**Reference 7**

**Excerpts From Record of Decision, Decision Summary, and Responsiveness Summary  
for Interim Response Action - Teledyne Wah Chang Albany Superfund Site  
Operable Unit 1 (Sludge Ponds Unit), Albany, Oregon; EPA; December 1989**

RECORD OF DECISION,  
DECISION SUMMARY, AND  
RESPONSIVENESS SUMMARY

FOR

INTERIM RESPONSE ACTION  
TELEDYNE WAH CHANG ALBANY SUPERFUND SITE  
OPERABLE UNIT #1 (SLUDGE PONDS UNIT)  
ALBANY, OREGON

DECEMBER 1989

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
REGION 10  
1200 SIXTH AVENUE  
SEATTLE, WASHINGTON 98101

RECORD OF DECISION  
INTERIM ACTION SELECTION (SLUDGE PONDS UNIT)  
TELEDYNE WAH CHANG ALBANY  
ALBANY, OREGON

Statement of Basis and Purpose

This decision document presents the selected remedial action for the sludge pond unit at the Teledyne Wah Chang Albany (TWCA) site in Millersburg, Oregon, just north of Albany, developed in accordance with CERCLA (42 U S C §9601), as amended by SARA and, to the extent practicable, the National Contingency Plan.

This decision is based on the administrative record for this site. A copy of the administrative record index is attached as Appendix C.

The state of Oregon has concurred in the selected remedy. A copy of the state's letter is attached as Appendix B.

Assessment of the Site

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

Description of the Selected Remedy

The sludge unit addressed by this ROD is the first operable unit to be addressed at the TWCA site. The Remedial Investigation/Feasibility Study (RI/FS) for the unit did not include certain components of a normal RI/FS, such as a complete baseline risk assessment, because these will be part of an overall site RI/FS (currently in the RI stage with the FS scheduled for completion in 1991). The sludge pond unit is being dealt with separately due to the property owners', and the public's, wish for an expeditious cleanup of the sludges, which may be contributing to groundwater contamination at the site.

The remedy consists of:

- ° Digging up and removing the sludge
- ° Partially solidifying the sludge with a solidification agent such as Portland cement, to improve handling and reduce the gross mobility of the solids. A treatment plant will be built for this purpose.
- ° Transporting the sludge mixture to a solid waste landfill and disposing of it offsite.

The wastes being addressed in this Interim Action are not hazardous wastes as defined by the Resource Conservation and Recovery Act (RCRA); therefore, the RCRA Land Disposal Restrictions do not apply.

## SITE NAME

Teledyne Wah Chang Albany (TWCA), Albany, Oregon

## LOCATION AND DESCRIPTION

The TWCA facility is located in Millersburg, Oregon (about three miles north of Albany) in the Willamette Valley (see Figure 1). The Superfund site includes the 110 acre plant site property and the 115 acre facility known as the "farm site", which has the plant's active wastewater treatment sludge ponds ("farm ponds") and is located approximately 3/4 mile north of the plant site. Operable Unit #1, the unit addressed by this Interim Action, includes the solids in the Lower River Solids Pond (LRSP) and Schmidt Lake, which are located on the plant site near the Willamette River and have not been used since 1979.

Of the two major site areas, the plant site contains numerous buildings and facilities including an extraction area south of Truax Creek, a fabrication area north of Truax Creek, a solids storage area west of the Burlington Northern Railroad, and a parking and recreation area east of the Southern Pacific Railroad. The farm site contains four 2-1/2 acre solids storage ponds. The remainder of the site is used primarily for agriculture. The plant is currently operating and employs over 1300 people, making it the largest employer in the Albany area.

The LRSP and Schmidt Lake lie in the western portion of the plant site, next to the east bank of the Willamette River, between Murder Creek to the north and Truax Creek to the south (see Figure 2). The LRSP covers just over 3 acres and holds approximately 75,000 cubic yards of sludge; Schmidt Lake covers roughly 0.6 acre and contains approximately 10,000 cubic yards of material. The sludge in both ponds averages 40 percent solids. Both ponds are diked to contain the sludge, which also allows rainwater to collect on the top of the sludge; the rainwater is collected and pumped back to the plant wastewater treatment facility for treatment. The top few feet of the sludge in both ponds have deep cracks that remain year-round. Most of the surface of the LRSP stays wet throughout the year, but the surface of Schmidt Lake dries to dust during the summer.

Portions of the TWCA site, including the sludge ponds, are in the 100-year and 500-year flood plains of the Willamette River. The ground surface in the vicinity of TWCA slopes westward towards the river with a gradient of approximately 11 feet per mile.

Willamette Valley temperatures are moderate, with maximums seldom reaching 100° F and minimums rarely reaching 0° F. Roughly 70 percent of the 40-inch annual precipitation falls during November through March, while only 6 percent occurs during June, July, and August, fall and winter precipitation is the primary source of aquifer recharge in the area. There are usually on y 3 or 4 days per year with measurable amounts of snow.



The area immediately surrounding the site is primarily agricultural land to the north being used for ag. culture. The land east of the site is and south of the plant site is used mainly for residential and commercial purposes, while land west of the Willamette River, which borders the plant site, is used for farming. Albany, the urban area to the south of the site, has a population of approximately 27,000, Millersburg has a population of about 560.

There are approximately 250 known private drinking water wells within three miles of the facility; all of these wells are upgradient of the site. There are no known domestic, municipal, industrial, or irrigation wells located between the site and the Willamette River. The Willamette River is not used as a drinking water source in this area.

## SITE HISTORY AND ENFORCEMENT ACTIVITIES

### Site History

Operations at the TWCA site began in 1956 when, under contract with the U.S. Atomic Energy Commission, Wah Chang Corporation began operation of the U.S. Bureau of Mines, Zirconium Metal Sponge Pilot Plant. Construction of new facilities at the existing plant began in 1957. These facilities were built primarily for the production of zirconium and hafnium sponge. However, tantalum and niobium pilot facilities were later included. Melting and fabrication operations were added starting in 1959. TWCA was established in 1967 after Teledyne Industries, Inc., purchased Wah Chang Corporation of New York.

Because of the many processes involved in the production of nonferrous metals and products, waste management programs at TWCA consist of a wide range of activities, including: process wastewater treatment; solid waste management; hazardous waste management; PCB equipment management; radioactive material control; waste minimization through beneficial use; and air quality control programs. Discharge of process wastewater is regulated by a National Pollutant Discharge Elimination System (NPDES) permit. An Air Contaminant Discharge Permit regulates air emissions at the facility. Teledyne is currently classified as a hazardous waste generator under the Resource Conservation and Recovery Act (RCRA) program.

The LRSP was constructed and placed into operation in 1967 to receive lime solids (sludge) from TWCA's onsite wastewater treatment plant. Schmidt Lake was constructed for the same purpose in 1974. Sludge was pumped into the two ponds until October 1979, when the farm ponds to the north of the facility were put into operation. The farm ponds were originally part of this operable unit, but because they are outside the flood plain and contain lower levels of radioactivity, they are not considered an immediate threat and are now being investigated as part of the overall site Remedial Investigation (RI). The sludge in both the LRSP and Schmidt Lake contains heavy metals, a few organic compounds, and trace levels of some radionuclides. Tables 1-4 summarize the contaminants found in the sludge.

In 1978, TWCA modified the process for the production of zirconium and hafnium metal such that radioactive materials were directed into a separate solid waste referred to as chlorinator residue. This residue is managed as a low specific activity radioactive waste and shipped to Hanford, Washington, for disposal. Sludge generated since the implementation of this modification has been stored in the farm ponds.

### Enforcement History

The sludge ponds have attracted the attention of regulatory agencies and the public for many years, particularly because of the presence of low-grade radioactive materials which was first confirmed by the Oregon State Health Division in 1977. In March 1978, TWCA was granted a Radioactive Materials License to transfer, receive, possess, and use zircon sands and industrial byproducts containing licensable concentrations of radioactive materials. TWCA took samples from the ponds on several occasions in 1979 and 1980.

Table -  
INORGANIC CONTAMINANTS IN LRSP SOLIDS

	Detects/ Samples	Maximum	Minimum <sup>a</sup>	Average <sup>b</sup>	Background <sup>c</sup>
Arsenic	40/40	39	2	10	24
Barium	39/40	3,500	33	173	116
Beryllium	20/40	1.3	0.5	0.7	0.7
Chromium	39/40	220	65	100	20
Copper	40/40	77	29	48	11
Mercury	36/40	7.6	0.3	1.2	<0.2
Nickel	40/40	3,000	25	206	14
Lead	40/40	260	38	102	10
Antimony	29/40	24	5	11	<20
Selenium	35/40	16	1	3	3
Thorium	40/40	74 (8.3)	11 (1.2)	31.7 (3.5)	3.5
Uranium	40/40	129 (87.8)	12.7 (6.4)	69.2 (46.5)	0.3
Zinc	40/40	87	24	40	39
Cyanide	28/40	165.0	3.0	16	<2
Radium <sup>d</sup>					
Activity	40/40	(22.2)	(3.2)	(13.2)	(1.0)
Concentration		$2.30 \times 10^{-5}$	$3.32 \times 10^{-6}$	$1.3 \times 10^{-5}$	$1.04 \times 10^{-6}$
Zirconium <sup>e</sup>	40/40	10.0	3.0	5.1	<1.0

Note: All concentrations in mg/kg of as-received, wet solids.

Concentrations in parentheses are in pCi/g.

Only constituents that were detected in 10 percent or more of the samples are shown.

<sup>a</sup> Minimum value detected above detection limit.

<sup>b</sup> Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limits were included in the average.

<sup>c</sup> From soil samples taken east of the existing Farm Ponds, October 1988. See RI report.

<sup>d</sup> As radium-226.

<sup>e</sup> Zirconium is expressed as a percent.

Table 2  
INORGANIC CONTAMINANTS IN SCHMIDT LAKE SOLIDS

	<u>Detects/ Samples</u>	<u>Maximum</u>	<u>Minimum<sup>a</sup></u>	<u>Average<sup>b</sup></u>	<u>Background<sup>c</sup></u>
Arsenic	10/10	36	8	16	24
Barium	10/10	72	36	39	116
Beryllium	10/10	1.1	0.7	0.8	0.7
Cadmium	7/10	1.2	0.1	0.3	<0.1
Chromium	10/10	13	79	90	20
Copper	10/10	72	34	45	12
Mercury	4/10	1.4	0.2	0.6	<0.2
Nickel	10/10	4,300	1,700	2,600	14
Lead	10/10	150	70	103	10
Antimony	10/10	14	8	9	<20
Selenium	7/10	4	1	2	3
Thorium	10/10	59.3 (7.5)	30.8 (3.4)	46.3 (5.1)	3.5
Uranium	10/10	237.7 (160.9)	104.6 (70.8)	162.6 (110.1)	0.8
Zinc	10/10	97	50	67	39
Cyanide	4/10	110	2.5	5.3	<2
Radium <sup>d</sup>					
Activity	10/10	(26.4) <sub>-5</sub>	(14.9) <sub>-5</sub>	(19.2) <sub>-5</sub>	(1.0) <sub>-7</sub>
Concentration		2.54x10 <sup>-5</sup>	1.44x10 <sup>-5</sup>	1.85x10 <sup>-5</sup>	9.64x10 <sup>-7</sup>
Zirconium <sup>e</sup>	10/10	28.8	3.9	7.4	<1.0

Note: All concentrations in mg/kg of as-received, wet solids.  
Concentrations in parentheses are in pCi/g.  
Only constituents that were detected in 10 percent or more of the samples are shown.

<sup>a</sup>Minimum value detected above detection limit.

<sup>b</sup>Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limit were included in the average.

<sup>c</sup>From soil samples taken east of the Farm Ponds, October 1988. See RI report.

<sup>d</sup>As radium -226.

<sup>e</sup>Zirconium is expressed as a percent.

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Table 3  
ORGANIC CONTAMINANTS IN LRSP SOLIDS

<u>Volatiles</u>	<u>Detects/ Samples</u>	<u>Maximum</u>	<u>Minimum<sup>a</sup></u>	<u>Average<sup>b</sup></u>
Methylene chloride	36/40	22.000	0.006	0.084
1,1,1,-Trichloroethane	7/40	0.860	0.053	0.155
4-Methyl-2-pentanone	23/40	1,400.000	0.040	3.929
1,1-Dichloroethane	12/40	0.860	0.053	0.174
Tetrachloroethene	19/40	0.970	0.005	0.164
<u>Semivolatiles</u>				
Hexachlorobenzene	39/40	64.000	0.740	6.600
bis(2-ethyl-hexyl) phthalate	5/40	1.700	1.000	1.295

Note: All concentrations in mg/kg dry weight.  
Only compounds that were detected in 10 percent or more of the samples are shown.

<sup>a</sup> Minimum value detected above detection limit.

<sup>b</sup> Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limit were included in the average.

Table 4  
ORGANIC CONTAMINANTS IN SCHMIDT LAKE SOLIDS

<u>Volatiles</u>	<u>Detects/ Samples</u>	<u>Maximum</u>	<u>Minimum<sup>a</sup></u>	<u>Average<sup>b</sup></u>
Methylene chloride	10/10	0.090	0.031	0.046
1,1,1,-Trichloroethane	4/10	0.320	0.073	0.168
4-Methyl-2-pentanone	3/10	54.000	24.000	32.708
1,1-Dichloroethane	5/10	3.900	0.170	1.054
Tetrachloroethene	4/10	0.073	0.073	0.073
<u>Semivolatiles</u>				
Hexachlorobenzene	10/10	25.333	7.300	14.087
bis(2-ethyl-hexyl) phthalate	1/10	1.000	1.000	1.000
N-Nitroso-di-n- propylamine	2/10	0.590	0.190	0.048

Note: All concentrations in mg/kg dry weight.

Only compounds that were detected in 10 percent or more of the samples are shown.

<sup>a</sup> Minimum value detected above detection limit.

<sup>b</sup> Geometric average. Duplicates were averaged to obtain one value that was then included in the geometric average. No values below detection limit were included in the average.

In 1981, the company applied to the state of Oregon's Emergency Response Siting Council (EFSC) for a site certificate to close LRSP and to store approximately 120,000 cubic yards of lime solids. The TWCA facility was listed on the National Priorities List (NPL) in October 1983. After several years of hearings, court actions, and further sampling, EFSC ruled in 1987 that the sludge was not subject to their jurisdiction, the levels of radioactivity being too low. TWCA then submitted a closure plan to the Oregon State Health Division, but EPA and other agencies recommended that closure not take place until after the conclusion of the RI. On May 4, 1987, TWCA signed a Consent Order agreeing to conduct the Remedial Investigation/Feasibility Study (RI/FS).

The TWCA facility holds permits for water and air emissions. It was found in violation of wastewater discharge permits in 1975, 1977, and 1978, subsequent process changes reduced the toxicity of the facility's wastewater discharges. TWCA was assessed fines for other water quality permit violations in 1979, 1980, and 1989. The company was fined for illegal open burning in 1983. In 1986, TWCA was cited for several violations of the state's hazardous waste management rules.

## SUMMARY OF SITE CHARACTERISTICS

### Contaminants Present

The sludge in the LRSP and Schmidt Lake was sampled and contains metal compounds produced by the various onsite processing units, including zirconium, hafnium, chromium, mercury, nickel, uranium, and radium, cyanide has also been found. Of organic compounds detected, the most prevalent one is hexachlorobenzene, which is probably a byproduct of plant operations (Tables 1-4).

TWCA's wastewater treatment system consists of a continuous chemical precipitation and sedimentation system. Metals are treated by neutralization with lime, magnesium hydroxide, or sulfuric acid and carbon dioxide to a pH range between 6 and 8 to form metal hydroxides and sulfates which will precipitate. Fluorides are removed by the formation of calcium fluoride. These compounds are removed in a clarifier by settling. Lime solids, referred to as "sludge", generated from the operation of the clarifier are placed in sludge ponds for additional settling, dewatering and storage.

### Potential Routes of Migration

The LRSP and Schmidt Lake are unlined impoundments constructed on native soils in the Willamette River flood plain; thus, flooding is one potential cause of contaminant migration. Because the ponds are unlined, they could also be a source of groundwater contamination. Another possible route is dermal contact with the sludge by onsite workers or trespassers. A fourth potential route, dust, is a major concern because the dried sludge material can be spread by wind. Some dust is created when the surface of Schmidt Lake dries during the summer, and more could be created by sludge treatment or removal activities. Fortunately, most of the sludge contains a high percentage of water, which limits its migration as a dust.



## SUMMARY OF SITE RISKS

The following assessment is based on the data generated and presented in the TWCA Operable Unit Remedial Investigation (OURI) report and deals only with the potential hazards associated with exposure to the sludges in the ponds. Any potential hazards associated with contaminated soils beneath or surrounding the sludges or with groundwater associated with the ponds will be evaluated as part of the overall site RI/FS. A baseline risk assessment is a part of the overall RI/FS.

### Identification of Contaminants of Concern

During the OURI, sludges in the LRSP and Schmidt Lake were found to contain inorganic elements, organic compounds, and radionuclides. In estimating average concentrations, a value of one-half the method detection limit (MDL) was assumed for cases where no detectable contaminant quantities were found. Of all the chemicals measured in the sludges, the inorganic elements, particularly zirconium, were found in the highest concentrations.

Thirty-four chemical substances were detected and positively identified in the LRSP and Schmidt Lake sludges during the RI. In addition, several tentatively identified compounds were also detected. Of the 34 positively identified chemicals, 26 are chemicals of concern and potential contributors to public health risk.

For carcinogens, since there is no safe dose, an estimate of the likelihood of developing cancer is derived from the average daily dose over a lifetime multiplied by the potency factor for that particular chemical. The potency factor is the plausible upper bound estimate of the probability of a response per unit intake of a chemical over a lifetime. EPA has developed a classification system (A-E) for chemicals which have been evaluated as potential carcinogens. The system is based on a weight of evidence scheme, with those chemicals being known human carcinogens considered as A carcinogens and those for which there is no evidence of carcinogenicity in the E category.

For non-carcinogens, the average daily dose over the period of exposure is compared to a reference dose or other toxicity constant. A reference dose is an estimate (with a safety factor of 10 to 1000) of a daily exposure level for the human population that could occur without producing harmful health effects. Non-carcinogenic effects include behavior changes, nervous system disorders, birth defects, and damage to kidneys, blood, liver and lungs.

### Carcinogens

Twelve ~~non-radionuclide~~ (radionuclide) chemicals found in the pond sludges may cause cancer. Three elements--arsenic, chromium, and nickel--are known to have the potential for causing cancer in humans when inhaled. Analyses done at TWCA were for total chromium, with the type unspecified, in order to be more protective of public health, this risk assessment is based on chromium VI (the most toxic form). Eight chemicals are probable human carcinogens through either ingestion or inhalation (Group B) and one is a possible human carcinogen (Group C). Potency estimates and EPA classification for these chemicals are provided in Table 5.

TABLE 5

TELEDYNE WAH CHANG  
OPERABLE UNIT NUMBER ONE  
HUMAN HEALTH RISK ASSESSMENT

CONTAMINANT	CANCER	POTENCY	EPA CLASSIFICATION
	ORAL	INHALATION	
	(mg/kg/d) ^ (-1)	(mg/kg/d) ^ (-1)	
=====			
Arsenic	1.50E+00	1.50E+01	A
Beryllium	4.80E+00	8.40E+00	B2
Bisethylhexylphthalate	1.40E-02		B2
Cadmium		6.10E+00	B1
Chromium VI		4.10E+00	A
Hexachlorobenzene	1.67E+00		B2
Methylene chloride	7.50E-03	1.40E-02	B2
Nickel		8.40E-01	A
Tetrachloroethene	5.10E-02	3.30E-03	B2
Trichloroethene	1.10E-02	1.30E-02	B2
1,1 Dichloroethane		9.10E-02	C

### Radiological

The presence of uranium, thorium, and radium isotopes in the sludges from Schmidt Lake and the LRSP presents the potential for radiation induced cancer. In the Teledyne Wah Chang Endangerment Assessment (part of the Operable Unit Feasibility Study), the committed dose equivalent was converted into an estimate of cancer risk using conversion factors from the "Effects on Populations of Exposure to Low-Levels of Ionizing Radiation" NAS, (1980), ranging from 67 to 227 cancer deaths per million-man-rem. These factors suggest that if one million individuals were each to receive one rem, then 67 to 227 excess cancer deaths would be observed. These conversion factors may be translated into estimates of individual cancer risk. The individual cancer death risk is  $6.7 \times 10^{-4}$  per rem. Recent information indicates that the maximum number of cancer deaths per million-man-rem should be 400 instead of 227. The new number of 400 cancer deaths per million-man-rem was used in the supplementary assessment to estimate maximum cancer deaths from radiation exposure. Radiation induced cancer is assumed to be fatal and chemically induced cancer may or may not be fatal.

### Non-Carcinogens

For the non-carcinogens, antimony is likely to produce the most severe effect from the ingestion exposure route, barium from the inhalation route. Zirconium, which occurs at the highest concentration, is not acutely toxic, but accumulates in the body and may produce chronic effects.

### Exposure Assessment

Under current and future operating conditions, if no cleanup actions are undertaken at the site, the most likely exposures are for workers and trespassers coming into direct contact with the chemicals in the sludge. In addition, if land use patterns change and the sludge site is opened to residential development, onsite residents may be exposed to contaminated sludges.

In order to estimate potential health risks from contact with the sludge, four exposure scenarios were evaluated in the risk assessment. Two scenarios were used to describe operations continuing at the facility with no corrective action. Under these two scenarios workers were assumed to come into direct contact with pond sludges for an average of 10 years and a maximum period of 40 years. For future risks, if the sludge site should become residential, it was assumed that the average resident would live on the site for 35 years and would be in direct contact with the sludges for 22 to 365 days per year. For the highest residential exposure, it is assumed that an individual would be in direct contact with the pond sludges for his or her entire lifetime (75 years) for 66 to 365 days per year.

Exposure estimates (total dose over a lifetime for carcinogens and over the exposure period for non-carcinogens) for ingestion of contaminated sludges and skin absorption of chemicals were based on average and maximum concentrations of chemicals measured in pond sludges. If the ponds dry, the sludges could be dispersed into the atmosphere by the wind or man's actions. In order to complete the assessment for inhalation of chemicals, maximum particulate concentrations were assumed to be equivalent to the federal particulate standard of 150 ug/cubic meter (National Ambient Air Quality

Standards, 40 CFR 50, part 101, particulate matter less than or equal to 10 microns (24 hour average). A particulate concentration of 50 ug/cubic meter is used as an average exposure condition. In addition, contaminant concentrations were assumed to be the same in the airborne particulates as they are in the sludges, with particles being 100 percent respirable.

### Risk Characterization

A summary of risk estimates for exposure to contaminated sludges is given in Table 6. As this is only a preliminary assessment for a portion of the TWCA facility, the summary risk estimates should not be viewed as a statement about health risks to residents in the vicinity of the site. The risk estimates presented in this report are representative of long term exposures to chemicals in the ponds (from 10 to 75 years) for average and maximum worst case scenarios. Future residential development on the sludge site without cleanup of the contaminants in the ponds is clearly the maximum worst case scenario. The purpose of evaluating this unlikely event is to provide EPA and the public with sufficient information to make a decision regarding the necessity for cleanup of toxic materials in the environment.

Another scenario which is viewed as a potential for the movement of contaminants into the Willamette River due to flooding. The probability of a flood is estimated at a one in 500 year event. Due to the low likelihood, and difficulty in predicting how such an event should occur, risk estimates for this exposure pathway. However, one can assume that provides a measure of what health effects would contaminants should occur over a long period of flooding should not exceed those which are for exposure to 2 ug/L in MCL but if PQL is 10 then RURA won't make cleanup to 2 ug/L.

### Cancer Risk Estimates

The risk of developing cancer ranges from one in one million to greater than one chance in one length of exposure. For onsite workers, the risk of cancer is under maximum exposure conditions (40 years) for chromium VI, arsenic, and hexachlorobenzene are the major contributors to increased cancer risk. The potential risk of developing cancer for people who may reside onsite in the future if no action is taken, ranges from an additional cancer risk of one in one thousand to three in one thousand for exposure over a lifetime. Nickel, chromium VI, arsenic and hexachlorobenzene are also the major chemicals contributing to the cancer risk for this scenario. *location*

The risk of death from cancer due to exposure to radionuclides if no cleanup action is taken is equivalent to those from other chemicals, ranging from seven in one million to one in one thousand. The greatest risk is for residents under maximum exposure conditions (75 years direct contact with contaminated sludges).

### Non-cancer Risk Estimates

Under current or future operating conditions, risks of health effects other than cancer are only expected for the highest worker exposure (40 years).

## THE SELECTED REMEDY

Based upon consideration for the requirements of CERCLA, the detailed analysis of the alternatives, and public comments, both the EPA and the state of Oregon have determined that **Alternative 7 (removal, solidification, and offsite disposal)** is the most appropriate remedy for Operable Unit #1 at the TWCA site. It has been selected because it consistently ranked among the best choices under all the ranking criteria except cost. It effectively reduces the likelihood of contact with the sludges and ensures that contaminants are not transported into groundwater, surface water or air. Human health and environmental risks associated with the identified routes of exposure will be eliminated or controlled by this remedial action.

Approximately 85,000 cubic yards of sludge will be excavated from the LRSP and Schmidt Lake. The sludge will be mixed with a solidification agent such as Portland cement. This will improve handling characteristics, reduce mobility of contaminants, and increase the structural strength for landfilling and capping. The mixture will then be transported to an offsite permitted solid waste disposal site. The mixture would be placed in a separate monocell (adequately protected from coming into contact with other wastes) and capped in accordance with state and local disposal requirements, applicable permit conditions, and EPA approval. The sludge mixture can be taken to a solid waste landfill because it is not a RCRA hazardous waste. The monocell must have a liner and a leachate control system. This Interim Action, including the removal and relocation of the sludges, is scheduled to be completed within three years of the signing of the Consent Decree.

The sludge relocation removes all of the sludge materials from Schmidt Lake and the LRSP, both areas which could be impacted by a one in 500 year flood. The sludge material must go to a permitted solid waste disposal facility which by definition cannot be in a floodplain. No location or facility is specified by this ROD, but two facilities were identified in the FS which meet the state requirements for a disposal facility. There are also out of state permitted landfill disposal facilities available.

The disposal facility must not commingle the TWCA waste sludge materials with any other waste; i.e., it must be a monofill. This is to facilitate compliance with any monitoring requirements that may differ from those for other wastes. A suitable cap must be placed which prevents sludge exposure to people or the environment outside of the disposal unit. The cap must also protect people from the release of radon contained or created from contaminants in the sludge.

A ~~treatment~~ step is part of this remedy. Prior to relocation in the permitted landfill, the sludges will undergo partial treatment by using a solidification agent like Portland cement. The object of this partial solidification treatment process is to reduce the free water content of the sludges, make the sludges easier to handle using conventional equipment, and reduce the mobility of contaminants by chemical and physical processes. Although this treatment process will not make the sludges into rigid solids, it will improve the final handling characteristics and provide a level of treatment to the sludge materials. The FS identified onsite treatment as one of the recommended alternatives. Offsite treatment (e.g., at the disposal facility) may be considered during the design phase. If EPA can be assured it will be performed in accordance with CERCLA and meet ARARS.

The risk reduction by this remedial action is from an estimated 3 excess cancers in a population of 1000 without any future control actions (assuming an extreme residential use scenario of the actual sludge pond area) to acceptable risk levels of less than 1 excess cancer in a population of 1 million by permanently removing the routes of exposure. Additional environmental risk assessment data is being developed during the overall site investigation. Because the existing sludge ponds are unlined, there is a future risk of contaminated groundwater being exposed to the environment. Relocation of the sludges reduces this risk.

Long term monitoring of the solidified wastes is required and may be the responsibility of the permitted landfill facility. Monitoring and management of the facility are specified in the applicable permit and state laws. EPA must approve the use of any disposal site prior to its accepting the TWCA sludge material.

The estimated cost of the remedy is \$10.7 million. The major cost elements as presented in the FS are listed below.

Sludge removal and hauling	\$ 590,000
Solidification treatment process	1,586,000
Offsite disposal	6,000,000
Engineering design, bids, contingencies, etc.	<u>2,540,000</u>
Total Costs	\$ 10,716,000

The long-term O&M costs, including monitoring, are included as part of the offsite disposal cost. O&M and monitoring are the responsibility of the disposal facility. The cost estimates may change based on final engineering, design, disposal costs, etc. This decision does not specify the treatment process, disposal site or engineering designs. These activities are part of the design phase of this action which occurs during the ROD implementation process.

Performance standards for the ROD include the ARARs for excavation, treatment, transportation, and disposal processes. Partial treatment of the sludge material is required to reduce the water content, to improve handling characteristics, and to reduce contaminant mobility. The degree of solidification will be determined during the design phase. Special landfill cap requirements to prevent radiation release are necessary (4' of cover material plus 1' of clay). Long-term monitoring of any disposal site selected must be consistent with the state of Oregon's minimum requirements.

Date \_\_\_\_\_

RESPONSIVENESS SUMMARY  
TELEDYNE WAH CHANG ALBANY  
OPERABLE UNIT #1 INTERIM ACTION

Overview

The Teledyne Wah Chang Albany (TWCA) facility is located in Millersburg, Oregon (about 3 miles north of Albany) in the Willamette Valley of western Oregon. The TWCA Superfund site includes a 110 acre plant site property and the 115 acre facility known as the "farm site". The entire facility was placed on the Environmental Protection Agency's (EPA) National Priorities List (NPL) in 1983. A Remedial Investigation and Feasibility Study (RI/FS) is underway for the entire facility. This responsiveness summary addresses public comments made regarding a proposed Interim Action at the facility.

This Interim Action addresses cleanup of the Lower River Solids Pond (LRSP) and Schmidt Lake which are unlined surface impoundments that previously received process wastewater from the various operations at the site.

The facility has been operating since 1956 when the Wah Chang Corporation began operation of the U.S. Bureau of Mines Zirconium Metal Sponge Pilot Plant. New facilities have been added at the site which now include the production of zirconium and hafnium-sponge from zircon sands, melting and fabrication operations and facilities for the production of other specialty metals. Solids generated from the process wastewater treatment system have been stored in a number of surface impoundments, including the LRSP and Schmidt Lake prior to 1980.

Since 1980 wastewater sludges have been stored in the farm ponds which were originally part of this Interim Action, but will be addressed under the investigation of the entire facility. The TWCA sludges have been the subject of several ballot initiatives, regulatory control processes, and environmental group attention since the early 1980's primarily because of the small amounts of radioactive materials and the location of two of the ponds in the floodplain of the Willamette River. In 1979, TWCA modified their production process to significantly reduce the concentration of radioactive compounds in their wastewater sludges.

In May 1987 TWCA signed an agreement (Consent Order) with EPA to investigate the nature and extent of the contamination problems at the facility and develop alternatives for cleanup where necessary. This work is called a Remedial Investigation and Feasibility Study and is currently underway. As part of this Order, EPA and TWCA agreed to address the LRSP, Schmidt Lake, and Farm Pond sludges prior to completion of the RI/FS for the entire facility. This action was due to concern over the sludges potential contribution to groundwater contamination, public concern over the materials, and their location in the floodplain.

**Mining Waste NPL Site Summary Report**

**Tex Tin Corporation  
Texas City, Texas**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

**Science Applications International Corporation  
Environmental and Health Sciences Group  
7600-A Leesburg Pike  
Falls Church, Virginia 22043**



#### **DISCLAIMER AND ACKNOWLEDGEMENT**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Ruth Izraeli of EPA Region VI [(214) 655-6735], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**TEX TIN CORPORATION**

**TEXAS CITY, TEXAS**

**INTRODUCTION**

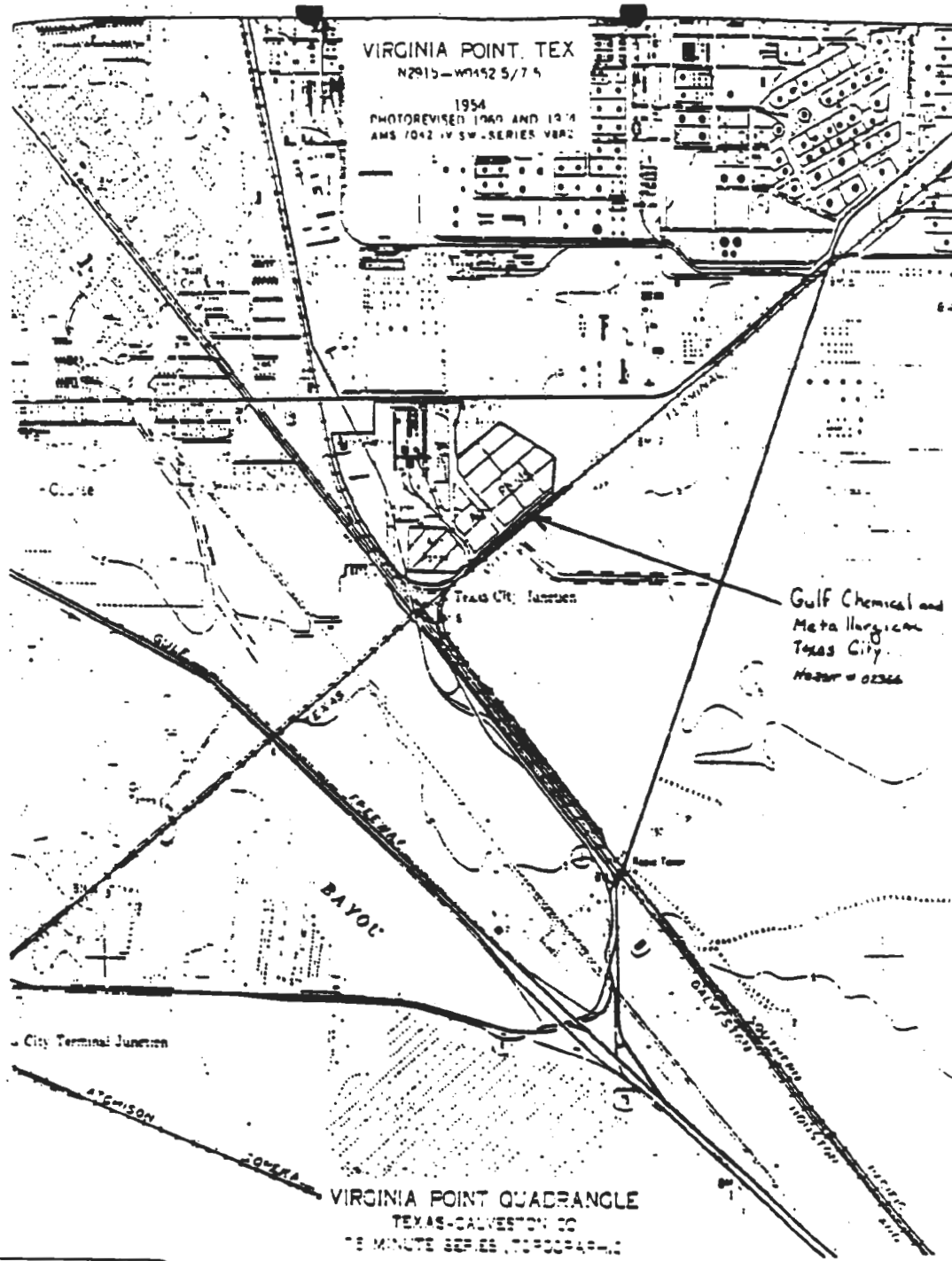
This Site Summary Report for Tex Tin Corporation is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review by the EPA Region VI Remedial Project Manager for the site, Ruth Izraeli.

**SITE OVERVIEW**

Tex Tin Corporation is an active secondary copper smelting facility that was originally operated by the U.S. Government during World War II as its primary tin smelting operation. It was subsequently sold to private investors (Reference 3, page 2). Formerly known as Gulf Chemical and Metallurgical Company (GC&M), the Tex Tin site was added to the NPL in August 1990 (Reference 10). The site is included on the NPL due to the presence of heavy metals such as arsenic, tin, lead, and nickel found in onsite surface water and ground water, and in ambient air sampled on and off the site (Reference 3).

The Tex Tin facility is situated on approximately 175 acres located in an area of mixed land use. Commercial businesses, residential areas, and petrochemical complexes are all located within .25 mile of the site (see Figures 1 and 2). Swan Lake, a saline lake, is located approximately 2 miles from the site. This lake is used primarily for recreational fishing and crabbing. A principal concern is the potential environmental contamination of surface waters through the transport of heavy metals into the Chicot Aquifer, and drainage of contaminated water into Galveston Bay (Reference 3, pages 6 and 7).

The Tex Tin site has been inspected on many occasions by representatives of the Texas Department of Water Resources (TDWR) and EPA, and was placed under an Enforcement Order in 1976 by TDWR for unauthorized water-discharge violations. The Order was referred to the Texas Attorney General's Office in 1978 (Reference 2). Some remedial activities have been undertaken at the facility, including deep-well injection of the contents of an acid pond (Reference 3, page 2).



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FIGURE 1. VIRGINIA POINT QUADRANGLE

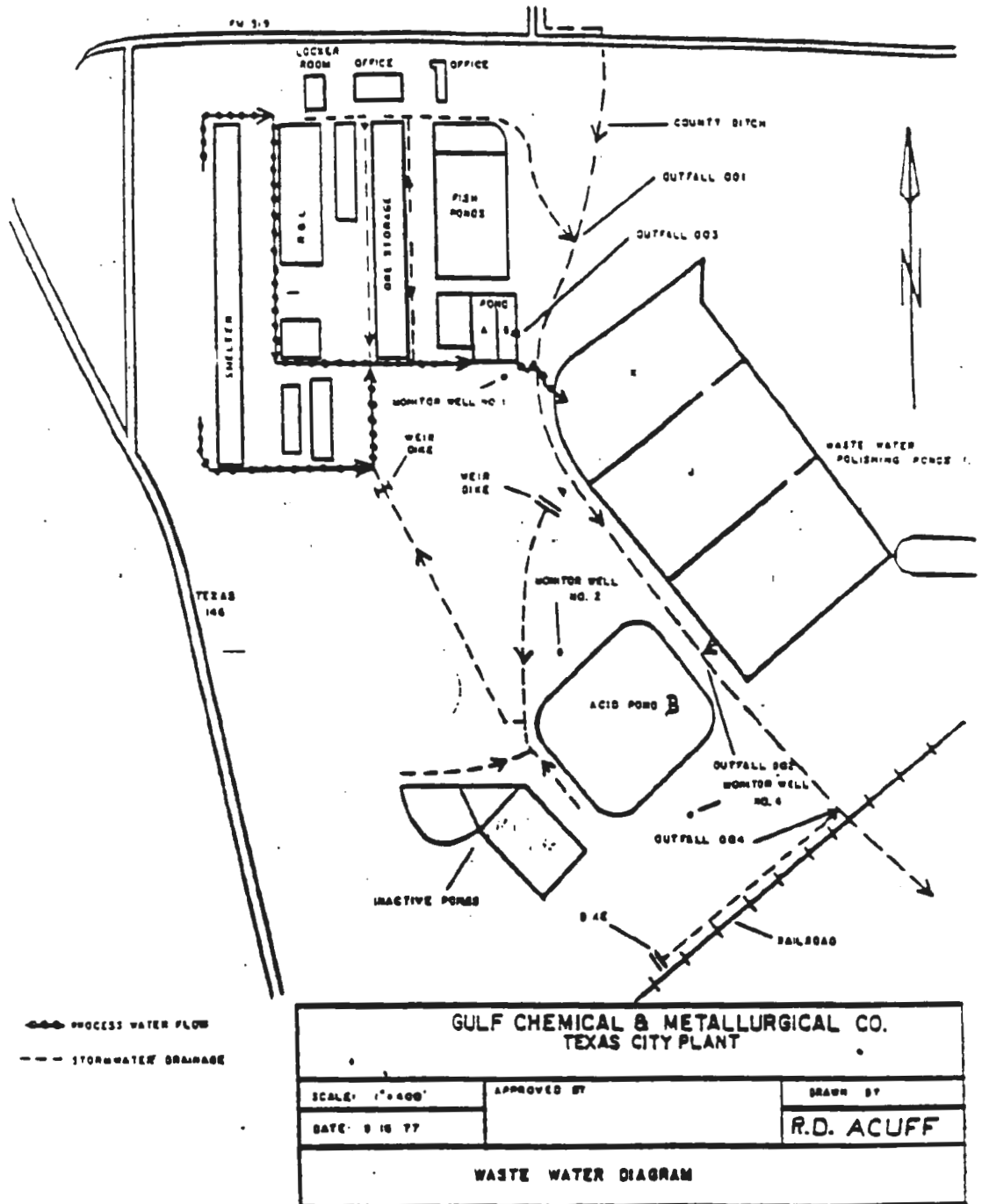


FIGURE 2. GULF CHEMICAL AND METALLURGICAL COMPANY, TEXAS CITY PLANT

## OPERATING HISTORY

The facility was initially operated by the U.S. Government as a tin smelter during World War II (Reference 1, Cover Sheet). It was subsequently acquired by the Associated Metals and Minerals Corporation from the Wah Chang Corporation in 1970, and became known as GC&M (Reference 2). Since 1985, the company has been known as the Tex Tin Corporation. At one time, the facility was operated as an iron recovery facility (iron recovery from ferric chloride). It is currently engaged in the secondary smelting of copper (Reference 3, page 2).

In 1977, Tex Tin was described as having three metals reclamation circuits: nickel sulfate, ferric chloride, and tin. The nickel circuit was described as "nickel sludge is stored in drums in the north end of the smelter building. After smelting, 'waste sludge' is sold for other metal recovery. A small quantity removed during vessel cleaning is dumped with the slag from the tin process." The ferric chloride circuit was described as "GAF sells the company iron sludge contaminated with the herbicide Amiben. The material is stored in the two areas (not clearly designated in the references). Runoff would supposedly flow through the plant to the pond system. A small quantity removed from the settling-tank is disposed of in acid pond B." Finally, the tin ingots circuit was described as: "product is received in the following forms: ore sacks from Bolivia stored on pallets by Ponds A and B, tin residues in 55-gallon drums stored in ore storage building, and tin ore piled along Highway 519. After primary smelting, rich slag is stored onsite. End slag is produced after the electrolyte process GC&M is planning to install a new rotary furnace for tin smelting. This new process will further remove tin from the end slag" (Reference 4, pages 1 and 2).

In 1979, it was reported that the nickel circuit had been "torn down" and that nickel sludges were no longer generated. Ferric chloride production had also decreased due to the loss of the principal buyer; causing GC&M to cease buying Amiben-contaminated iron sludge for use in this circuit. In addition, GC&M stopped disposing of the settling-tank sludge in the acid pond. It was also noted that a rotary furnace had been added to the tin circuit. As a result, "end slag now generated has an obsidian-like appearance. The material is dumped north of the acid pond. The company has hopes of reclaiming additional tin from the slag in the future" (Reference 5, pages 1 and 2).

Tex Tin is situated on approximately 175 acres that contain various active and inactive structures reflective of its past and present industrial activities. Waste areas identified at the site have included wastewater treatment ponds, a gypsum slurry pond, an acid pond once containing ferric chloride and hydrochloric acid, several drained acid ponds, slag, sludge, and ore piles. One of the slag piles is contaminated with the herbicide Amiben (Reference 6, page 1). The facility also stored approximately 4,000 drums containing radioactive material (Reference 3, page 2). At one time, the facility stored piles of spent catalyst in the anticipation of building a plant to extract metals such as

tungsten (Reference 7, page 3, Item 2). An inactive, licensed, low-level radioactive landfill, containing uranium/antimony slag, is also located onsite. The slag is from a pilot study on the extraction of bismuth from a bismuth-uranium catalyst (Reference 7, page 3, Item 2).

## **SITE CHARACTERIZATION**

Ground water, surface water, and soil sampling has detected various metals such as antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc. In addition, ambient-air samples collected offsite have detected concentrations of arsenic, cadmium, chromium, lead, nickel, and tin. The remnant acid ponds are considered a potential source of ground-water and surface-water contamination. The pond is documented as being poorly constructed and maintained (Reference 1, page 2a). Contamination has also been attributed to the onsite slag piles that are uncovered and have no containment or diversion systems (Reference 1, page 4).

"One other area of possible contamination, an abandoned oil-processing facility, has been identified on the Tex Tin property. The Morchem Resources facility was located on the northwestern portion of the site (then owned by GC&M) from 1982 to 1983. Morchem processed Luwa bottoms (high boiling-point glycols with 1% molybdenum) and waste oil from chemical and refining companies. The facility was abandoned in 1984" (Reference 3, page 3). No other information is known about this facility.

### **Ground Water**

The Aquifer of concern underlying the site is the Chicot Aquifer. The Aquifer extends from 60 feet to approximately 1,000 feet below the land surface. The flow of the Aquifer is generally in a southeasterly direction towards Galveston Bay. The Chicot Aquifer is underlain by the Evangeline Aquifer (Reference 1, page 2b).

Tex Tin monitored ground water in the vicinity of the acid pond from 1975 to 1980 (Reference 3, page 5). The monitoring wells were screened at 37 to 47 feet below the ground surface (Reference 1, page 2a). The contaminant concentrations detected were significantly higher in the samples taken from the two downgradient wells as compared to the samples taken from the upgradient well. A Preliminary Health Assessment prepared by the Texas Department of Health in 1989 concluded that the concentrations of 12 metals exceeded drinking-water standards and long-term health advisories.

(Reference 3, page 5). The metals of concern detected in the ground-water samples and the concentration ranges are described in Table 1 (Reference 3, Table 1, page 4).

**TABLE 1. CONTAMINANTS IN GROUND WATER**

Contaminant	Range of Concentrations (in ppm)
Arsenic	< 0.02 - 0.198
Barium	1.9 - 6.5
Cadmium	0.01 - 7
Chromium	0.03 - 0.25
Copper	0.08 - 390
Lead	0.25 - 200
Manganese	6.3 - 357
Mercury	< 0.0002 - 0.011
Nickel	0.02 - 7
Silver	0.07 - 1.02
Tin	0.018 - 100
Zinc	0.11 - 140

#### Surface Water

Tex Tin obtained a National Pollutant Discharge Elimination System permit in March 1976 for the discharge of wastewater from the facility. However, it was believed by an EPA inspector (during a Preliminary Site Investigation in February 1980) that the facility had been noncompliant with the issued permit (Reference 6, Section XIV, page 10). Inspections by the Texas Water Quality Board concluded that dikes designed to prevent discharges from two old outfalls and the acid pond were seeping, allowing contaminated water to enter Wah Chang Ditch (Reference 4, page 1). The Wah Chang Ditch is currently pumped into the Texas City Industrial Channel, which enters Galveston Bay.

Twelve surface-water samples were collected from various locations at the facility between 1975 to 1988. Constituents of concern and the concentration ranges are detailed in Table 2 (Reference 3, Table 1, page 4).

TABLE 2. CONTAMINANTS IN SURFACE WATER

Contaminant	Range of Concentrations (in ppm)
Arsenic	0.05 - 0.94
Chromium	< 0.02 - 81
Copper	0.03 - 60
Mercury	0.00024 - 0.02
Nickel	0.083 - 535
Zinc	0.175 - 42.7

### Soil

Possible soil contamination is not well characterized. In 1980, EPA conducted a Potential Hazardous Waste Site Inspection. At this time, it was the opinion of the investigator that it was "inevitable" that soil contamination was occurring after viewing the site. Piles of tin slag, iron ore, and crushed empty barrels were noted to be in abundance at the rear of the plant. A reddish material (possibly iron) was noted in a drainage ditch located close to the area of the material piles (Reference 8, Section VIII, page 6-L).

A single soil sample was collected by the Texas Department of Health's Bureau of Radiation Control near the low-level radioactive landfill in December 1984. Four metals were detected at significantly elevated concentrations; they are detailed in Table 3 (Reference 3, Table I, page 4).

TABLE 3. CONTAMINANTS IN SOIL

Contaminant	Concentration (in ppm)
Antimony	2,590
Arsenic	720
Copper	130
Lead	980



## Tex Tin Corporation

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According to the reference, the level of copper in the soil was not sufficiently elevated to represent a health concern. The reference further indicated that the concentrations of antimony, arsenic, and lead did constitute a health concern.

### Ambient Air

In January 1986, the Texas Water Commission contracted with the Texas Air Control Board to conduct air-quality monitoring of the Tex Tin site. The samples were obtained along the site perimeter using high-volume particulate samplers. The conclusion reached after the sampling was that heavy metals and arsenic were being carried offsite by the wind (Reference 6, page 7). The maximum values of the detected contaminants are provided in Table 4 (Reference 3, Table 2, page 5).

**TABLE 4. CONTAMINANTS IN AMBIENT AIR**

Contaminants	Maximum Value Detected (in $\mu\text{g}/\text{m}^3$ )
Arsenic	2.34
Cadmium	0.64
Chromium	0.40
Lead	4.42
Nickel	0.21
Tin	103.6

### Radioactivity

Low levels of radioactivity have been detected onsite in association with the tin, copper, and antimony slags and with the company roads that have been graded with tin slag. According to the Bureau of Radiation Control, the radiation levels are well below Federal occupational exposure limits, but are approaching the upper limits of the range of levels generally considered safe for the general public (Reference 3, page 8).

## ENVIRONMENTAL DAMAGES AND RISKS

In general, drinking water is supplied to the communities within the 3-mile radius of the site by the Galveston County Municipal System rather than by private wells. However, a drinking water-well survey conducted in 1985 identified a small beach house community, located approximately 1 mile southwest of the Tex Tin facility, that uses private water wells. The community, consisting of approximately 60 homes, is supplied by 25 wells. While most of the wells are more than 200 feet deep, at least three of the wells are less than 105 feet deep and are in the aquifer of concern (Reference 9, page 2).

In early 1989, the Texas Department of Health undertook a Preliminary Health Assessment of the Tex Tin Corporation Site for the Agency for Toxic Substances and Disease Registry. The Department of Health found numerous physical hazards at the site, particularly due to the lack of adequate security, enclosure of the site, and inadequate containment of industrial materials and treatment ponds (Reference 3, page 5).

The report concluded that potential environmental exposure pathways include ground water, surface water, soil, and air contaminated with a variety of metals including antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc. Possible human routes of exposure were noted as ingestion, inhalation, and dermal contact with the contaminated media. Inhalation and incidental ingestion of airborne particles of Tex Tin emissions or entrained dust also were cited as potential pathways of concern. However, more sampling is needed to assess the potential risks (Reference 3, page 12).

## REMEDIAL ACTIONS AND COSTS

Due to the failure of Tex Tin to achieve compliance with recommendations made by the Texas Water Quality Board regarding ground-water and surface-water violations, the case was referred to the Texas Attorney General in 1978 for legal action. A suit was filed on June 1, 1982, by the State of Texas (Reference 2), but was dismissed for want of prosecution on December 12, 1984 (Reference 10, page 1).

The Tex Tin corporation has made several attempts at remediation including the construction of a deep well for injection of the contents of the acid pond, a major contributor of contamination at the facility (Reference 7, Item 1, pages 1 and 2). According to the Preliminary Health Assessment, the contents of the acid pond were disposed of in the well over a 2-year period beginning in 1985 (Reference 3, page 2). Also, the 4,000 drums containing radioactive material were removed from the site (Reference 3, page 2).

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**CURRENT STATUS**

According to EPA, a Remedial Investigation/Feasibility Study was initiated in the last week of November 1990. At this time, no Record of Decision has been issued, nor are estimated costs for remediation available.

## REFERENCES

1. Tex Tin Hazard Ranking System Package; EPA; March 6, 1987.
2. Facility Management Plan; EPA, Undated.
3. Preliminary Health Assessment, Tex Tin Corporation; Texas Department of Health; Undated.
4. Internal Memo Concerning Tex Tin Corporation; From K. Macko, District 7 Representative, to George Green, TDWR; September 26, 1977.
5. Internal Memo Concerning Tex Tin Corporation; From K. Macko, District 7 Representative, to Steve Cook, TDWR; March 26, 1979.
6. Air Quality Monitoring at Tex Tin Corporation, Final Report; Texas Air Control Board; February 12, 1987.
7. Letter Concerning Tex Tin Corporation; From H.L. Newman, Tex Tin Corporation, to Martha McKee, EPA Region VI; January 25, 1985.
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10. Letter Concerning Tex Tin Corporation; From Robin Morse, Esq., Baker and Botts, to Bob Hanneschlager, EPA Region VI; July 15, 1985.

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Texas Water Quality Board. Solid Waste Disposal Compliance Survey. September 21, 1977.

Texas Water Quality Board. Solid Waste Disposal Compliance Survey. March 5, 1979.

**Reference 1**

**Excerpts From Tex Tin Hazard Ranking System Package;  
EPA; March 6, 1987**

Facility Name: Tex-Tin Corporation

Location: Texas City, TX

EPA Region: VI

Person(s) In Charge of the Facility: Mr. Harold Newan (as of 1980)

P.O. Box 2130

Texas City, TX

Name of Reviewer: R. Roblin

Date: 3/6/87

General Description of the facility:

(For example landfill, surface impoundment, pile, container; types of hazardous substances; location of the facility; contamination route of major concern; types of information needed for rating; agency action, et

The site is an active tin smelting operation that was originally operate  
by the U.S. Government during W.W.II. It was then sold to private inves  
ors. The site is situated on approximately 128 acres with waste handlin  
facilities that include five wastewater treatment ponds, Gypsum slurry  
ponds, open and closed acid ponds, three inactive impoundments, slag pil  
and the inactive and permitted landfill containing radioactive wastes.

The groundwater route is the migration pathway of primary concern.

Specifically, three onsite monitoring wells that are associated with the  
closed acid pond are evaluated and scored. Inorganic contamination has  
been documented and is characterized by elevated levels of lead, mangan-  
ese and copper.

Scores:  $S_M = 38.43$  ( $S_{gw} = 30.61$   $S_{sw} = 4.36$   $S_a = 58.85$

$S_{FE} = N/A$

$S_{DC} = N/A$

FIGURE 1  
HRS COVER SHEET

QA  
David E. Egan  
11-6-87

01/20/87

Attachment A  
Groundwater Rationale

High levels of copper and tin have been detected in groundwater samples taken from on-site monitoring wells which are screened at an interval of 37-47 ft. below the ground surface. (Ref. 12, Ref. 18) The concentrations detected are significantly higher in the samples taken from the down-gradient wells (MW-2, MW-4) as compared to the samples taken from the up-gradient well (MW-1) (Ref. 10, Ref. 05). The monitoring well locations are shown in Ref. 11. The contaminants can be directly attribute to remnant acid ponds that have been documented as being poorly constructed and maintained by facility operators (Ref. 04). Although the facility is still active, the company is exempt from RCRA regulations due to the ore and mineral processing exclusion set forth in 40 CFR Part 261.4(b)(7). (Ref. 14).

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11-6-87



Attachment B

Description of Aquifer of Concern

The Houston District consists of all of Harris, Waller, and Fort Bend Counties and parts of Galveston, Montgomery, Brazoria, Chambers, and Liberty Counties. Within the district, groundwater is primarily drawn from geologic formations composed of sedimentary deposits of gravel, sand, silt and clay. The hydrologic units are: the Catahoula Sandstone and Fleming Formation of Miocene age; the Goliad Sand of Pliocene age; the Willis Sand, Bentley and Montgomery Formations, and Beaumont Clay of Pleistocene age; and alluvium of Quaternary age. (Ref 21) Because of their origin and method of deposition, the sand and clay beds grade into each other both laterally and vertically within short distances; consequently, differentiation of geologic formations based on drillers' or electric logs is almost impossible (Ref. 22).

In the area of the site, water is predominantly drawn from the Chicot aquifer. The Chicot aquifer is composed of the Willis Sand, Bentley formation, Montgomery formation, Beaumont Clay, and any overlying Quaternary alluvium. This aquifer includes all overlying Quaternary alluvium. This aquifer includes all deposits from the land surface to the top of the Evangeline aquifer. In the area of the site, the aquifer can be separated into an upper and lower unit. Where the upper unit of the Chicot aquifer is undifferentiated, the areal extent of the upper unit roughly corresponds to the areal extent of the Beaumont Clay. (Ref. 21). The Chicot maintains a thickness of approx. 1000 to 1100 ft in the area of the site, while the Evangeline has about 3900 to 4000 ft. of thickness (Ref. 16).

Throughout most of Galveston County and southeast Harris County, the base of the Chicot aquifer is formed by a massive sand section with high hydraulic conductivity. This sand unit is known locally as the Alta Loma Sand. The city of Galveston has an established well field drawing from the Alta Loma Sand. The Chicot aquifer is underlain by the Evangeline aquifer everywhere except where salt domes pierce it. The Evangeline aquifer is underlain by the Burkeville confining layer. (Ref. 22)

Water levels in Chicot wells have risen 10 to 20 feet from 1975 until 1980. Corresponding subsidence has been 4 to 5 feet from 1943 until 1978 and 0.25 to 0.5 feet from 1973 until 1978 centered in surface subsidence through near the site. No significant surface faulting occurs within 20 miles of the site. (Ref. 4).

For the purposes of this HRS package, the aquifer of concern will be considered to be the upper unit of the Chicot Aquifer. In the area of the site, this aquifer extends from the surface to a depth of approx. 100 ft.

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11-6-87

### 3 CONTAINMENT

#### Containment

Method(s) of waste or leachate containment evaluated:

N/A

Method with highest score:

N/A

### 4 WASTE CHARACTERISTICS

#### Toxicity and Persistence

Compound(s) evaluated:

Copper - 18

Lead - 18

Mercury - 18

Ref. 5

Compound with highest score:

The above contaminants were detected in samples taken from the acid pond on June 1, 1964. (Ref. 01, Ref. 05)

HRS Value = 18

#### Hazardous Waste Quantity

Total quantity of hazardous substances at the facility, excluding those with a containment score of 0 (Give a reasonable estimate even if quantity is above maximum):

An estimated 19 million gallon surface impoundment that has no liner and has visible seepage from dikes. Monitor wells have documented a release of contaminants to the shallow aquifer below the site. (Ref. 10). In addition, three slag piles are located within the site boundaries with a total estimated waste volume of 13,636.74 cubic yards. These piles have no cover or containment/diversion system. (Ref. 19, Ref. 20) HRS Value = 8. (Ref. 1) Basis of estimating and/or computing waste quantity:

\*See Attachment C\*

\* \* \*

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11-6-87

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**Reference 2**

**Excerpts From Facility Management Plan;  
EPA; Undated**

Gulf Chemical and Metallurgical  
TX 02364

Introduction

On April 20, 1984, Ms. Karen Friebus, Texas Department of Water Resources (TDWR) District 7 office, made an inspection of the Gulf Chemical and Metallurgical (GCM) facility in Texas City. Also present at the inspection was Ms. Pat Fotenot, TDWR District 7, and Mr. Harold Newman with GCM. The inspection consisted of an interview with Mr. Newman, file review, site surveillance, and sampling activities.

Background

The site consists of 128 acres, which was originally started as a tin smelter by the U. S. government during World War II. GCM bought the facility in 1970 from the Wah Chang Corporation. Waste handling facilities include five wastewater treatment ponds, gypsum slurry ponds, acid pond, closed acid ponds, three inactive impoundments, amiben contaminated iron sludge, slag piles, 20,000 drums of spent catalyst, and a landfill containing radioactive waste. On August 10, 1978, the TDWR referred GCM to the Texas Attorney General's office for surface and ground water pollution offenses. On June 1, 1982, a petition and application for temporary injunction were filed against GCM for violations relating to their wastewater permit. The TDWR has documented ground water contamination from the acid pond. Leaks in the acid pond have also been documented by sampling liquid coming from the pond's dikes. Contaminated runoff from the slag piles; closed impoundments and drum storage area have also been documented. Drums in the drum storage area are badly corroded and leaking.

Recommendation

Though GCM considers their waste piles and drum storage area to contain potential raw material, the material is presenting an unknown threat to the environment. Further, the acid pond is contaminating ground water as well as surface runoff. The dikes of the acid pond are unstable and in poor condition. For these reasons, a high level of seriousness is assigned to this site. A ranking package will be developed to determine if this site can be included on the National Priorities List for remedial action under Superfund.

**Reference 3**

**Excerpts From Preliminary Health Assessment,  
Tex Tin Corporation; Texas Department of Health; Undated**

**PRELIMINARY HEALTH ASSESSMENT**

**Tex Tin Corporation**

**CERCLIS No. TXD062113329**

**Texas City, Texas**

**Prepared by the Texas Department of Health**

**Prepared for:**

**Division of Health Assessment and Consultation  
The Agency for Toxic Substances and Disease Registry  
U.S. Public Health Service**

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## SUMMARY

The Tex Tin Corporation facility, formerly Gulf Chemical and Metallurgical Corporation, is a proposed National Priorities List site located in Texas City, Galveston County, Texas. Tex Tin previously operated as a primary tin smelter, but currently operates as a copper smelter. Significant concentrations of metals (antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc) have been detected on-site in surface water, groundwater, and soil. Significant concentrations of metals (arsenic, cadmium, chromium, lead, nickel, and tin) have also been detected in ambient air samples collected off-site. Some remediation activities have occurred on-site including the closure of a 19-million-gallon ferric chloride pond and the removal of approximately 4,000 drums containing radioactive material. The Tex Tin site poses a potential public health concern for on-site workers, residents living in nearby neighborhoods, and possibly for a limited number of residents on private wells located within approximately one mile of the site.

## BACKGROUND

The Tex Tin Corporation, formerly the Gulf Chemical and Metallurgical Corporation, was proposed for inclusion on the National Priorities List in June 1988. The 128-acre site is located at the intersection of State Highway 146 and Farm to Market Road 519 in Texas City, Galveston County, Texas. Tex Tin previously operated as a tin smelter, but currently operates as a copper smelter. The materials managed at the site are primarily inorganic and mineral in nature and also include low-level radioactive material.

Industrial waste areas that have been identified on-site include five wastewater treatment ponds, slag and ore piles, and several inactive acid ponds. An inactive, licensed, low-level radioactive landfill, which contains uranium/antimony slag, is located on the southwest portion of the site. Previous site inspections had identified three primary areas of concern: a 19 million gallon ferric chloride pond, a storage area which held approximately 4,000 drums containing radioactive material, and the slag and ore piles. The original contents of the acid pond were disposed of in a permitted waste disposal well located onsite over a two-year period beginning in 1985 (1). The drums that contained radioactive material have also been removed from the site (2). The slag and ore piles, which have no cover or containment/diversion system, remain onsite. One of the slag piles is contaminated with the herbicide Amben

Numerous metals, including antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc have been detected at elevated levels onsite in groundwater, surface water, and soil samples. Ambient air sampling has detected significant concentrations of arsenic, cadmium, chromium, lead, nickel, and tin offsite.

One other area of possible contamination, an abandoned oil-processing facility, has been identified on the Tex Tin property. The Morchem Resources facility was located on the northwestern portion of the site (then owned by Gulf Chemical and Metallurgical) from 1982 to 1983. Morchem processed Luva bottoms (high boiling-point glycols with 1% molybdenum) and waste oil from chemical and refining companies. The facility was abandoned in 1984 (4). No information was available concerning the extent of closure activities or the current status of the site.

#### ENVIRONMENTAL CONTAMINATION AND PHYSICAL HAZARDS

Limited soil, surface water, and groundwater sampling results were available for review. The samples collected at the Tex Tin site were typically analyzed for metal content only, although radioactive content was measured in selected samples. An analysis for organic contaminants was apparently not conducted for the samples. No quality assurance/quality control information was available for any of the sampling.

Table 1 summarizes the contaminants of concern detected onsite, the media in which they were found, and a range of concentrations for each contaminant.



TABLE 1  
ON-SITE CONTAMINANTS

MEDIA	CONTAMINANT	RANGE OF CONCENTRATIONS in ppm
Soil	Antimony	2,590 *
	Arsenic	720 *
	Copper	130 *
	Lead	980 *
Surface Water	Arsenic	0.05 - 0.94
	Chromium	<0.02 - 81
	Copper	0.03 - 60
	Mercury	0.00024 - 0.02
	Nickel	0.083 - 535
	Zinc	0.175 - 42.7
Groundwater	Arsenic	<0.02 - 0.198
	Barium	1.9 - 6.5
	Cadmium	0.01 - 7
	Chromium	0.03 - 0.25
	Copper	0.08 - 390
	Lead	0.25 - 200
	Manganese	6.3 - 357
	Mercury	<0.0002 - 0.011
	Nickel	0.02 - 7
	Silver	0.07 - 1.02
	Tin	0.018 - 100
	Zinc	0.11 - 140

\* one sample analyzed

The single soil sample which was available for review was collected in December 1984 by the Texas Department of Health Bureau of Radiation Control in the vicinity of the low-level radioactive landfill (5). Four metals were detected at significantly elevated concentrations including antimony, arsenic, copper, and lead. Although the 130 ppm of copper detected in the soil is significantly elevated over typical background concentrations of copper, it is not sufficiently elevated to the point it would represent a health concern. The concentrations of antimony, arsenic, and lead were sufficiently elevated to raise potential health concerns. The elevated copper concentration, however, is one more indication of a possible soil contamination problem.

The analytical results of 12 surface water samples collected from 1975 to 1988 from various locations on the Tex Tin property were reviewed (5, 6, and 7). Arsenic, chromium, copper, mercury, nickel, and zinc were detected at elevated concentrations in some of the samples. Information on the sampling protocols used for sample collection, preparation, or

The groundwater samples reviewed were collected from three on-site monitoring wells from 1975 to 1980 (6). No recent groundwater monitoring data were available for review. Results of the 1975-1980 groundwater sample analyses indicate that concentrations of 12 metals were significantly elevated, exceeding drinking water standards and long-term health advisories. The metals of concern detected in the groundwater samples are arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc. The monitoring wells are screened at 37-45 feet with the two wells located on the southern half of the site showing higher levels of contamination than the one well located on the northern portion of the site.

Ambient air samples collected around the perimeter of the Tex Tin facility in 1986 detected several metals at levels of concern. Samples were collected for an eight-hour period. Table 2 lists the contaminant and the maximum concentration detected.

TABLE 2  
OFF-SITE AIR CONTAMINANTS

CONTAMINANT	MAXIMUM VALUE DETECTED (ug/m <sup>3</sup> )
Arsonic	2.34
Cadmium	0.64
Chromium	0.40
Lead	4.42
Nickel	0.21
Tin	103.6

No off-site samples were available for soil, groundwater, or surface water.

Numerous physical hazards were evident on the site. The large acid pond which had previously been drained is currently filled with 3-6 feet of water contributed from infiltration and precipitation. Other hazards include the wastewater treatment ponds, slag and ore piles, and other hazards which are typically associated with an active industrial site such as heavy machinery, discarded pipe, etc. These materials, along with the low-level radioactive landfill, would pose a hazard to children playing on the site. Although the entire site is currently fenced, portions of the fence are in disrepair and access to the site is still possible through breaches in the fence.

## POTENTIAL ENVIRONMENTAL AND HUMAN EXPOSURE PATHWAYS

Potential environmental pathways include contaminated groundwater, surface water, soil, and air. Potential human exposure pathways include ingestion, inhalation, and dermal contact with contaminated groundwater, surface water, and soils. Inhalation and incidental ingestion of airborne particles from plant emissions or entrained dust are also potential pathways of concern.

## DEMOGRAPHICS

Land use in the vicinity of the Tex Tin facility is mixed, with commercial businesses, residential areas, and petrochemical complexes all located within a quarter mile of the site. The nearest residential community, with several hundred homes, is located approximately a quarter of a mile northwest of Tex Tin, within the city limits of Texas City. Other homes are scattered to the west and east, some also within a quarter of a mile. The majority of the City of La Marque and Texas City, as well as the western section of Hitchcock and all of Bayou Vista, lie within a three-mile radius of Tex Tin. Population estimates were not available for the area included in the three-mile radius. According to 1986 U.S. Census estimates, however, the total population of these four cities is estimated to be 65,300 (8). Several unincorporated areas also lie within the three-mile radius. Drinking water for each of the cities is supplied by the Galveston County Municipal System. The result of a U.S. Environmental Protection Agency (EPA) drinking water well survey conducted in 1985 identified a small, unnamed beach community that uses private wells approximately one mile south of the site (6). The community, which consists of 60 homes, relies on 25 private wells for drinking water. Three of the 25 wells are screened between 84-104 feet, within the aquifer of concern.

Swan Lake, a saline lake, is the nearest surface water body used for recreational activities. The lake is located approximately two miles southeast of the site and is used primarily for recreational fishing and crabbing. Commercial fishing and recreational activities also take place in Galveston Bay, which is located approximately three miles southeast of the Tex Tin site.

Tex Tin is an active copper smelting facility that currently employs 80 people. The petrochemical industry, in general, is a major employer in the Texas City-La Marque area.

## EVALUATION AND DISCUSSION

The primary environmental pathway of concern is groundwater. The aquifer of concern underlying the site is the upper unit of the Chicot which extends from approximately 50 feet below the land surface to approximately 900 feet below the land surface. The flow of water is generally in a southeasterly direction towards Galveston Bay. The three groundwater monitoring wells located onsite are screened at 37-47 feet and have all shown evidence of contamination with metals. The two monitoring wells on the southern half of the site have shown significantly higher levels of contamination than the one well located on the northern half of the site. One investigation report concluded that the groundwater contamination detected could be attributed directly to the remnant acid ponds located at the site. Reportedly, these ponds were poorly constructed and maintained (6).

The majority of residents living in the vicinity of the Tex Tin facility are on municipal systems which do not draw water from the aquifer of concern. Residents in the unnamed beach community located approximately one mile south of the site rely on 25 private wells for drinking water. The majority of the wells in the beach community are screened in the Chicot at depths of approximately 200 feet. Three wells, however, are screened in the upper unit of the Chicot at depths between 84-104 feet. No groundwater samples from these wells were available for review. Concentrations of metals which significantly exceed drinking water standards and long-term health advisories were detected in on-site monitoring wells. These metals include arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, silver, and zinc. The concentrations of these metals found in the monitoring wells, if present in potable water supplies, could pose a threat to human health. Surface water samples collected onsite since 1975 also revealed high levels of several metals including arsenic, chromium, copper, mercury, nickel, and zinc. The elevated metal concentrations could potentially impact downstream surface water bodies used for recreation and fishing. The surface water drainage pathway from the site bypasses Swan Lake, but eventually empties into Galveston Bay. Contaminants in surface water could also infiltrate and contaminate the shallow groundwater at the site.

Possible soil contamination was not well characterized either onsite or offsite. The one soil sample collected on-site which was analyzed detected sufficient concentrations of antimony, arsenic, copper, and lead to raise concerns about the potential for leaching of the metals into groundwater, contributions to surface run-off contamination, re-entrained dust blowing off-property, and direct human contact with the soils.

Ambient air monitoring conducted in 1986 detected high levels of metals in the samples. The values listed in Table 2 indicate that the potential exists for excessive particulate emissions from the Tex Tin property. No ambient air monitoring has been conducted to date in residential areas, the nearest of which is approximately a quarter mile northwest of the Tex Tin site.

Low levels of radioactivity have been detected onsite in association with the tin, copper, and antimony slags and with the company roads which have been graded with tin slag. The Texas Department of Health Bureau of Radiation Control (BRC) has instituted a radiation monitoring program at the Tex Tin site (2). Initial reports from monitoring conducted during the first quarter of 1989 indicate elevated radiation levels are present at the site. The radiation levels, according to BRC staff, are well below federal occupational exposure limits, but are approaching the upper limits of the range of levels generally considered safe for the general public. The BRC currently has no plans to recommend immediate removal of the radioactive material (primarily the tin and antimony slag), due to the apparent lack of consistent exposure opportunities by the general public. The BRC has stressed, however, the need for eventual removal. Since the radioactive material is intimately associated with the chemical contamination at the site, the BRC has also stressed that any remedial activities at the site should include contingencies for dealing with the mixed waste. The BRC plans to continue a monitoring program at the Tex Tin facility (3). [The BRC monitoring results were not available for review at the time of this report. Information concerning the results was supplied by BRC staff. The monitoring data will be furnished to the preparers of this report at a later date.]

Tin and copper slag piles are located in the open on the Tex Tin property, without cover or a containment/diversion system. These slag piles, in addition to being a source of radiation, may also be major contributors to the surface water, soil, and atmospheric contamination previously detected. The area previously used for drum storage and the copper sulfate piles are also probable contributors to the contamination.

The potential effects of exposure to any of the 13 metals detected at the Tex Tin facility would depend on a variety of factors such as the route of exposure (inhalation, ingestion, skin absorption), the concentration of the metal (dose), and the toxicity of the metal. The toxicity of the metal may be determined by the chemical form of the metal (organic, inorganic, valence state) and the route of exposure.

Four of the metals are of particular concern because they have been listed by the EPA as known or probable human carcinogens. Arsenic and certain forms of chromium and nickel have been classified by EPA as Group A, known human carcinogens. Cadmium has been designated as a Group B1, probable human carcinogen by the inhalation route of exposure.

Arsenic was detected at elevated concentrations in the soil, surface water, and groundwater samples collected onsite and in the ambient air samples collected at the perimeter of the site. Exposure to arsenic has been associated with an increase in lung cancer by the inhalation exposure route and also an increase in the incidence of skin cancer by the ingestion exposure route. Should people on or offsite be exposed to the maximum levels of arsenic detected in the environmental media at the Tex Tin site, they would be at an increased risk of lung and skin cancer (9, 10).

In addition, a number of non-cancer effects may result from arsenic exposure. The principal acute effect of arsenic ingestion is irritation of the gastrointestinal tract which may cause pain, nausea, vomiting, and diarrhea. Long-term ingestion may also affect the liver, kidney, cardiovascular system, skin, and nervous system. Inhalation of inorganic arsenic dusts or aerosols may cause irritation of the respiratory tract, as well as symptoms similar to those following ingestion. Finally, dermal contact with arsenic-containing compounds may also result in skin irritation (9).

Given the limited environmental sampling data, it is difficult to assess the non-cancer health risks posed by arsenic either on or offsite. In a worst-case exposure scenario, in which a person is exposed to the maximum concentrations of arsenic found in the air, soil, groundwater, and surface water, adverse health effects may be expected, particularly in children. In a more reasonable exposure scenario based on the available data, however, the adverse effects would be unlikely given that the heavily contaminated groundwater found at the site is reportedly not used as a drinking water source. Additional environmental sampling data is needed, especially off-site data, before the potential health risks may be more accurately assessed.

Elevated levels of chromium were found in groundwater, surface water, and ambient air samples. The three major valence states (forms) of chromium differ in toxicity with the hexavalent [chromium (VI)] form generally considered to be most toxic. Trivalent chromium [chromium (III)] is believed to be an essential nutrient in small quantities, but large doses may result in adverse effects. Metallic chromium [chromium (0)] has not been well characterized in terms of human exposure or potential health effects (11).

Long-term exposure of industrial workers to chromium compounds has been associated with increased lung cancer. Chromium (VI) was implicated through epidemiologic studies and laboratory studies as the form of chromium which is most likely responsible for increased lung cancer. The available sampling data for Tex Tin does not identify the form(s) of chromium detected in the environmental media (11).

Inhalation exposure to high levels of chromium compounds, particularly chromium (VI), may also result in adverse effects on the nasal mucosa (including irritation and in severe cases perforation of the nasal septum), kidney, liver, nervous system, and immune system. Dermal exposure may lead to skin irritation and sensitization to chromium. Based on the available data, the concentrations of chromium detected in the environmental media at Tex Tin would not be expected to produce the non-cancer effects (10, 11).

Nickel was detected in surface water, groundwater, and ambient air samples at elevated levels. Certain nickel compounds, particularly nickel subsulfide, have been associated with an increased risk of lung cancer (12).

nickel refinery dust workers. Occupational exposure to nickel metal has not been associated with an increase in cancer. In animal studies, however, nickel metal and other nickel compounds have produced tumors. In general, all nickel-containing compounds should be considered potentially carcinogenic (12).

The most prevalent non-cancer effect following nickel exposure in humans is contact dermatitis. Inhalation exposure may produce an allergic asthma. Researchers have estimated that 2.5 to 5.0 percent of the general population may be sensitive to nickel (12). Once sensitized, even minimal exposure may result in an allergic reaction. Animal studies have also indicated that nickel exposure may adversely affect the immune system (increased susceptibility to pulmonary infections), kidney, reproductive system, and the hematological and hematopoietic systems (10, 12).

Elevated concentrations of cadmium were detected in groundwater and air samples. EPA classifies cadmium as a probable human carcinogen by the inhalation route of exposure. An increase in lung cancer has been associated with cadmium exposures in both occupational and animal studies. There is currently insufficient data to consider cadmium to be carcinogenic by the oral route of exposure (13).

In extremely high doses, cadmium may cause gastrointestinal irritation and irritation of the respiratory tract. Exposure to the maximum concentration of cadmium detected in the groundwater samples collected at the Tex Tin site could result in gastrointestinal irritation. The levels of cadmium detected in the ambient air samples collected at the perimeter of the facility would not be expected to produce respiratory irritation. In animal studies, short-term exposures to high levels of cadmium have also resulted in injury to the liver and testes (10, 13).

Long-term exposures to lower doses of cadmium have resulted in effects on the kidneys, such as kidney stone formation, and respiratory effects including emphysema. Animal studies have indicated that low-dose exposure to cadmium over an extended period of time may also cause hypertension and effects on the immune system, nervous system, and reproductive system. The doses at which these types of effects would be expected to occur in humans, if they would occur at all, have not been well characterized (10, 13).

Lead is another metal of particular concern detected at the Tex Tin site. Elevated levels of lead were detected in soil, groundwater, and ambient air samples. Exposure to sufficient quantities of lead may cause damage to the brain and nervous system, the blood, kidneys, digestive system, and reproductive system. Small children are at particular risk for exposure to lead, more so than adults, due to their tendency to consume larger amounts of soil during their routine activities and because their bodies absorb a greater amount of the lead in the soil they consume (14, 15).

In the one soil sample collected on the Tex Tin site, the lead concentration was 980 ppm. According to the U S. Centers for Disease Control, lead concentrations in soil and dust exceeding 500-1000 ppm may contribute to increased blood lead levels in children (15). Children exposed to comparable concentrations of lead in soil in a residential setting such as that found at Tex Tin would be at an increased risk for adverse health effects. Airborne lead and lead in groundwater would also contribute to elevated lead levels in children, further increasing their risks.

Antimony was also detected in the soil sample at an extremely elevated concentration. Normal background concentrations of antimony have been reported as high as 10 ppm, although average background concentrations are considerably lower (16). The antimony concentration detected at the site was 2,590 ppm.

The potential adverse effects of antimony ingestion have not been well characterized. There is, however, information available concerning the effects of inhalation exposure in an occupational setting. The potential effects associated with antimony include dermatitis, irritation of the upper respiratory tract, eye irritation, and irritation of the gastrointestinal tract as well as more serious respiratory effects, such as pneumoconiosis. Reports from the Soviet Union have also indicated that female metallurgic workers exposed to antimony aerosols experienced higher rates of spontaneous late abortions, premature births, and gynecologic problems (17, 18).

Elevated concentrations of mercury were detected in groundwater and surface water samples. Organic forms of mercury are generally considered to be more toxic than inorganic mercury compounds although long-term exposure to both forms may adversely affect the central nervous system and kidney. Adverse development and reproductive effects have also been reported. The severity of the effect will be dependent on the form of the mercury, the route of exposure, and the concentration. Acute exposure to mercury compounds may also result in gastrointestinal disturbances (10, 17, 19).

The maximum concentration of mercury found in the groundwater samples collected at the Tex Tin site significantly exceeds the federal drinking water standard and could pose a threat to public health if the groundwater was used as a potable supply. Potential human exposure to surface water at the site has not been well characterized.

Barium, copper, manganese, silver, tin, and zinc were detected at elevated levels in the groundwater at the Tex Tin site. Elevated levels of copper were also detected in soil and surface water, elevated concentrations of tin in air samples, and zinc in the surface water. These metals, although posing less of a health hazard, do have the potential to cause adverse health effects. The primary effect of each of the metals by the ingestion route of exposure would be gastrointestinal irritation. By the inhalation



route of exposure, the primary effect would be respiratory irritation. In extremely large doses, barium, manganese, and organic tin compounds could also adversely affect the central nervous system (10, 17, 19). Exposure to large doses of silver may result in a permanent discoloration of the skin, conjunctiva, and internal organs known as argyria (20).

As with the other metals detected at the Tex Tin facility in the various environmental media, it is difficult to assess the magnitude of the risks posed by these metals based on the limited environmental sampling data. The presence of barium, copper, manganese, silver, tin, and zinc, along with the other metals, in the groundwater, soil, surface water, and air samples does indicate widespread contamination.

Additional environmental sampling and characterization of the pathways of exposure will help further define the extent of the health risks posed by the contamination.

#### CONCLUSIONS AND RECOMMENDATIONS

The Tex Tin site poses a potential public health concern to on-site workers, residents living in nearby neighborhoods, and possibly to residents using private wells in the unnamed beach community located a mile south of the site.

Potential environmental exposure pathways include groundwater, surface water, soil, and air contaminated with a variety of metals including antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, silver, tin, and zinc. Possible human routes of exposure are ingestion, inhalation, and dermal contact with the contaminated groundwater, surface water, and/or soil. Inhalation and incidental ingestion of airborne particles from Tex Tin emissions or entrained dust are also potential pathways of concern.

Since the majority of the environmental sampling data were collected prior to 1985 using unspecified protocols; more current, systematic, and standardized sampling of air, soil, groundwater, and surface water is needed. Specific recommendations include:

1. Ambient air monitoring should be conducted both onsite and offsite for the contaminants of concern. The offsite ambient air monitoring should be conducted in locations with the greatest potential for human exposure to emissions from Tex Tin (i.e. residential areas, playgrounds, etc.).
2. Off-site surface soil samples (top three inches) should be collected from nearby residential areas and in those areas where contaminant migration by either air or water is suspected. Samples should be analyzed for metal, organic, and radioactive content.

**Reference 4**

**Internal Memo Concerning Tex Tin Corporation; From K. Macko,  
District 7 Representative, to George Green, TDWR;  
September 26, 1977**

# Texas Department of Water Resources

INTEROFFICE MEMORANDUM

TO George Green, Chief, Field Support (file) 9/20/77 22 977  
THRU  
FROM Karen A. Macko, District 7 Representative 2  
SUBJECT Gulf Chemical & Metallurgical, Texas City, ISW #30057

## Introduction:

On 9/20/77, Gulf Chemical & Metallurgical met with agency personnel in Austin to discuss pollution abatement measures and request an extension of the 7/1/77 deadline for attainment of new operational levels. David Hays from District 7's industrial section attended the meeting. The following day, 9/21/77, the writer and Nancy Wolfe inspected the Texas City facilities with Richard Acuff, Environmental Engineer.

## Findings:

1. Dikes at old outfalls 002 and 004 were seeping, and contaminate water was reaching the Wah Chang ditch. (See picture)
2. Dikes on acid pond were also seeping allowing low pH water to enter the ditch. The company is considering plans to construct a trench system around the pond and reroute the water through the neutralization process.
3. Several inactive Metals and Trade ponds exist southwest of the acid pond. No plans have yet been formulated for closure.
4. Volume data for solid waste produced is not easily attainable. Richard Acuff will submit the data in the future and keep more appropriate records.
5. Gulf Chemical & Metallurgical has three production circuits at this time. Products and wastes associated with each are discussed below.

- a. Ni circuit - Nickel sulfate product. Nickel sludge is stored in drums in the north end of the smelter building. After smelting, "waste sludge" is sold for other metal recovery. A small quantity removed during vessel cleaning is dumped with the slag from the tin process.
- b. Fe circuit - Ferric chloride product. GAF sells the company iron sludge contaminated with the herbicide amiben. The material is stored in the two areas designated on the attached map. Runoff would supposedly flow through the plant to the pond system. A small quantity removed from the settling tank is disposed of in acid pond B.
- c. Sn circuit - Tin ingots product. Product is received in the following forms: ore sacks from Bolivia stored on pallets by Ponds A and B, tin residues in 55-gallon drums stored in ore storage building, and tin ore piled along Highway 519. After primary smelting, rich slag is stored onsite. End slag is produced after the electrolyte process. Gulf Chemical & Metallurgical is planning to install a new rotary furnace for tin smelting. This new process will further remove tin from the end slag.

Recommendations:

That the company submit a close-out date for the Metals and Trade ponds as well as plans for closure and reclamation of the metals.

That they submit volume data on the slag, nickel sludge, ferric chloride sludge, and plant trash produced.

That Gulf Chemical & Metallurgical repair the dikes at old outfalls 002 and 004.

That the company continue the pollution abatement plan as discussed on 9/20/77 in Austin.

KAM:tmr

Attachments: Annual Compliance  
Photo

\_\_\_\_\_  
Approved

Signed: \_\_\_\_\_

Date: September 23, 1977

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**Reference 5**

**Internal Memo Concerning Tex Tin Corporation; From K. Macko,  
District 7 Representative, to Steve Cook, TDWR;  
March 26, 1979**

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**Texas Department of Water Resources** ENFORCEMENT AND  
INTEROFFICE MEMORANDUM FIELD OPERATIONS

TO Steve Cook, Enforcement Support Section DATE March 26, 1979  
THRU George Green, Chief, Field Support Section  
FROM Karen A. Macko, District 7 Representative  
SUBJECT Gulf Chemical & Metallurgical Company, I.S.W. No. 30057,  
Texas City

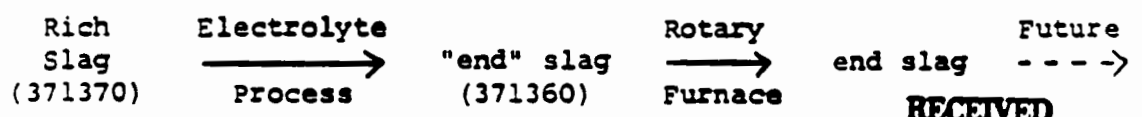
Introduction:

Gulf Chemical & Metallurgical was referred to the Attorney General's office on August 10, 1978, for surface and groundwater pollution offenses. An annual inspection of the tin smelter was made on March 5, 1979, with Ms. Nancy Worst, District 7 Representative, and Mr. Richard Acuff, Environmental Engineer for the company.

Findings:

Gulf Chemical & Metallurgical had been reclaiming metals in three primary circuits.

1. Ni Circuit - This unit was torn down 1 1/2 years ago. Nickel sludges are no longer generated.
2. Fe Circuit - Due to the loss of the principal buyer (City of Houston), ferric chloride production has decreased. The company no longer buys amiben (a herbicide) contaminated iron sludge from GAF Corporation for this circuit. Disposal of settling tank sludge in the acid pond ceased last August.
3. Sn Circuit - The tin circuit has been modified with the addition of a rotary furnace.



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Chemical & Metallurgical Company

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March 26, 1979

End slag now generated has an obsidian-like appearance. The material is dumped north of the acid pond. The company has hopes of reclaiming additional tin from the slag in the future.

The acid pond continues to leak as evidenced by visual seepage and monitor well reports. (Refer to monitor well results in IOM dated November 17, 1978.) On the day of the inspection, an upstream sample at FM 519 had a pH of 6.8. Downstream of the acid pond, the pH had dropped to 4.0.

The metals and trade ponds have not been closed out. Contaminated runoff enters the southern drainage ditch along the railroad track and thence flows to the Wah Chang Ditch.

Company officials and agency personnel met with Mr. Tom Aubry of the Attorney General's staff on March 8, 1979. A final injunction will be proposed incorporating a time schedule for the closure of the acid pond, collection of contaminated runoff, and construction of dikes.

KAM:tmr  
Enclosure

Signed: Kevin A. Macke

Approved: Merton J. Colston

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**Reference 6**

**Excerpts From Air Quality Monitoring at Tex Tin Corporation, Final Report;  
Texas Air Control Board; February 12, 1987**



Tex Tin Corporation  
Air Quality Monitoring  
Final Report

TEXAS AIR CONTROL BOARD  
Sampling and Analysis Division  
February 12, 1987

## INTRODUCTION

The Tex Tin Corporation (Tex Tin) sampling project was the second in a series performed by the Texas Air Control Board (TACB) under a contract with the Texas Water Commission (TWC). Ambient air sampling for particulate matter was conducted at Tex Tin to determine heavy metal and elemental composition.

The Tex Tin Corporation (formerly Gulf Chemical and Metallurgical) is a tin smelter, located in La Marque, Galveston County. The facility is located at the intersection of State Highway 146 (SH 146) and Farm-to-Market Road 519 (FM 519). The site is a 128-acre tract and has several industrial solid waste areas. These industrial solid waste areas include: five wastewater treatment ponds, a gypsum slurry pond, an acidic ferric chloride pond, several closed acid ponds, three inactive impoundments, an area of iron sludge contaminated with Ambien (a pesticide), several slag piles, and approximately 20,000 drums of spent catalyst. Surface water, soil, and shallow ground water contamination have been documented at the site.

In April, 1986, two TACB staff members and a staff member from the TWC traveled to Tex Tin to conduct a preliminary site survey. During this site survey, nine soil samples, a water sample, and a vegetation sample were collected. Analysis of the samples by the TACB Laboratory indicated the presence of heavy metals in all the samples collected.

In August, 1986, the Tex Tin facility was sampled by staff members from the TACB and TWC for particulate matter including heavy metals. Metals, primarily lead, tin, and cadmium, and arsenic were detected in some of the samples. Some problems with the sampling were found during the quality assurance process, so a third sampling trip was made to Tex Tin in late October, 1986. Arsenic was found in the samples taken the second day of this sampling trip.

## RESULTS

Tex Tin was first sampled on April 23, 1986. Nine soil samples, one water sample, and one vegetation sample were taken. (See Map 1) The soil samples were collected from the top one inch to one and one-half inches of soil because this layer of the soil is assured to contain the material which would be reentrained in windy conditions. The water sample was collected from the Wan Chang ditch on the southeast side site, and the vegetation sample was taken from the west side of the property.

Analysis was performed using the X-ray fluorescence spectrometer (XRF) system in the TACB laboratory. Since this analysis was for screening purposes, values were reported as relative peak size and not as concentrations. Large and very large peaks of lead, iron, nickel, and tin were detected in many of the samples (see analytical report SS 45-1, Appendix 2).

The second set of samples were collected in August. These samples were standard high volume particulate samples except that quartz filters were used in place of glass fiber filters. The samples were equilibrated, weighed, and analyzed by XRF. Results of the analysis indicated the presence of lead and arsenic in many of the filters (see analytical report SS 45-2, Appendix 2). The values for arsenic ranged from 0.07 to 2.34 micrograms per cubic meter of air sampled, with a minimum detectable limit of 0.07. The lead values ranged from 0.24 to 4.42 micrograms per cubic meter, with a minimum detection limit (MDL) of 0.14. Accuracy of the analysis was 97% based on the analysis of standards as unknown samples. The precision of analysis (average percent difference of 35 values for two analyses each from two different filters) was -3.1%.

Due to some questions raised during the quality assurance review of the August samples, resampling of Tex Tin for particulate matter was performed during October, 1986. These samples were similar to the previous ones except that glass fiber filters were used instead of quartz filters. The samples were equilibrated, weighed, and analyzed on the XRF (see analytical report SS 45-3, Appendix 2). These samples did not indicate the presence of the heavy metals reported in the August samples. The samples were then extracted with nitric acid and analyzed for arsenic using inductively-coupled plasma emission (ICP) spectrometry. This analysis indicated the presence of arsenic in several of the samples which was not detected by the XRF. The concentrations of arsenic ranged from 0.036 to 0.094 micrograms per cubic meter with a minimum detectable level of 0.014. Accuracy of the XRF analysis was reported as 99.8% with an average precision of 12.6%. The accuracy of the ICP analysis was reported as 98%, with a precision of -4%.

The August set of filters were analyzed for arsenic by ICP in November, 1986. Results of this analysis confirmed the presence of arsenic in this set of samples. The arsenic concentrations ranged between 0.016 and 2.23 micrograms per cubic meter with an MDL of 0.014. The accuracy of the analysis was reported as 98%, and a precision value of 0% difference between duplicate analysis.

## FIELD SAMPLING

The first sampling trip to Tex T. was a preliminary site survey. Messrs. Tom Driscoll and Perry Krauss of the TACB and Mr. Guy Tidmore of the TWC participated in the survey. The sampling team collected the samples from the perimeter of the site, never actually going on-site. The soil samples were collected along the fence lines on the west and north boundaries of the facility and along the railroad tracks paralleling the southeastern border. The water sample was collected from a county ditch that crosses the property. Outfalls from the plant, the ore storage area, and the waste water treatment ponds, as well as overflows from the acid ponds feed into this ditch. The vegetation sample was collected along the western fence line near soil sample #6. (See map 1)

The soil samples were collected from the upper one to one and one-half inch of soil based on the assumption that this layer is subject to reentrainment during strong winds. In addition, it is assumed that this layer is representative of the particulate deposition from the facility. The vegetation sample was collected to determine what elements were associated with plants in the area. The dry grass collected is representative of the vegetation that surrounds the facility on all sides. The county ditch that traverses the facility empties into a canal that forms the southern boundary of the facility. The canal empties into Galveston Bay.

The results of the preliminary survey samples indicated that ambient sampling for particulate matter was necessary. The sampling was performed during the week of August 4-8, 1986. The sampling team was headed by Mr. Tom Driscoll (TACB) with assistance from staff of the TACB Regional Office in Houston and the Galveston County Health Department. Mr. Guy Tidmore and Ms. Kate Arthur (TWC) acted as oversight personnel.

The sampling began on August 5, 1986 at 4:05 p.m. The high volume air samplers (hi-vols) were located along the boundaries of the facility as shown on Map 2. The upwind sampler was located on the south side of the canal (off the property). The winds were predominantly from the south at 4 to 10 m.p.h. The plant/smelter was in operation and emissions were observed coming from the stack and fugitive emissions were observed coming from the plant building. The sampling was terminated at 8:20 p.m., after 255 minutes of sampling, because of darkness.

Sampling began on August 6 at 7:55 a.m. The samplers were located as shown on Map 3. The winds were again from the south at 2 to 7 m.p.h. Sampling continued for 480 minutes, terminating at 3:55 p.m. Between 8.20 and 8.50 a.m. there was a light rainshower. However, the rain was so light that sampling was continued with no interruptions. The plant was operating normally and fugitive emissions were observed coming from the plant/smelter buildings.

The sampling on August 7 was similar to the previous two days. The samplers were located as shown in Map 4. The winds continued from the south at 4 to 8 m.p.h. Sampling began at 7:45 a.m. and continued for 480 minutes, terminating at 3:45 p.m. Once again the plant/smelter was operational, with fugitive emissions observed coming from the facility.

After the sampling team returned to Austin, a quality assurance audit was made on the samples and sampling equipment. The hi-vols used as the collocated pair did not have gaskets around the filter hold-down rings. As evidenced by the appearance of the filters, the lack of gaskets allowed particulate matter in the air to bypass the filters and not be collected. After a review of the audit information and filters, it was decided that resampling was necessary to ensure representative results.

The resampling was scheduled for the week of October 13-17, 1986. However, heavy rains in the Houston-Galveston area during the previous week had soaked the grounds and the sampling was postponed until the week of October 27-31.

The sampling team returned to Texas City-La Marque on October 27, 1986. The hi-vols had been recalibrated in Austin the week of October 6-10. The sampling team used the first day to check out the portable generators, coordinate the sampling with the Galveston County Health District, and choose suitable sampling sites. The plant appeared to be operating normally, with visible emissions (both particulates and liquid water) coming from the smokestack.

On October 28 sampling began at 10:15 a.m. The start of sampling was delayed because the upwind site was located on the Tex Tin property and permission to sample on the property was required. The hi-vols were located as shown on Map 4. The winds were predominantly from the east with a slight southeast component. Several large areas of standing water were noticed close to the fence on the western boundary of the facility, indicating that the ground was still very wet from the rains the previous two weeks, and there appeared to be some run-off from the facility into the bar ditch along SH 146. Sampling continued for 480 minutes, terminating at 6:15 p.m. During the hi-vol set-up, the emissions from the stack were getting noticeably weaker, and by the end of the day's sampling, had almost completely disappeared.

On October 29, the sampling began at 8:45 a.m. The hi-vols were located as shown on Map 5. The winds were again from an easterly direction. The sampling continued for 480 minutes, terminating at 5:45 p.m. There were only very weak visible emissions from the smokestack and no liquid water was present with the visible particulate emissions. There was some site work in progress during the afternoon. A dumptruck was dumping loads of what appeared to be slag from the smelter, and a bulldozer was working on other piles of slag at a separate location on-site.

On October 30 the hi-vols were located along SH 146 near the bridge over the canal. However, as the hi-vols were being loaded with the filters the winds shifted to a more northerly direction and were blowing parallel to SH 146. The sampling was discontinued and the team began to relocate the hi-vols along the railroad tracks across the canal, the southern boundary of Tex Tin. As the hi-vols were being reloaded to begin sampling, the winds shifted back to the east. The hi-vols were reloaded into the sampling van and once again located along SH 146 as shown on Map 6. Sampling began at 1:15 p.m. and continued for 240 minutes, terminating at 5:15 p.m. During the sampling, there were no emissions visible from the smokestack and there was no sitework on the facility. A break in the

"border="1">border" bar along the fence on the west boundary was noticed. At this break there was an area where runoff from the facility had killed all vegetation, and there was an oily film/scur floating on the water in the bar ditch. No water samples were collected since the team did not have any suitable collection jars.

The sampling team returned to Austin on October 31. As the sampling team was leaving Texas City-La Marque, it was noticed that Tex Tin had started normal operations again. There were substantial emissions coming from the smokestack, both particulate and liquid water (no visible emissions determination was made). The samples were given to the TACB Laboratory for analysis by both XRF and ICP (arsenic only).

## QUALITY ASSURANCE

The high volume air samplers used in the Tex Tin sampling were calibrated in Austin during the week prior to the two sampling trips. The samplers were audited within one week of their return from sampling. It was during the post-sampling audit that questions were raised concerning the August hi-vol sampling. Without gaskets on the filter hold-down plates, substantial air leaks could exist around the filter. These leaks would allow particulate matter in the air to bypass the filter and not be collected. However, the air would pass through the throat of the hi-vol and be measured as total volume of air sampled. A check of the filters indicated that this had indeed happened. The filters indicated that high-volume air samplers #2531 and #5980 did not have gaskets around the filter hold-down plates. Post-sampling audit of the flow rate indicated that all samplers were within the 15% flow rate error as required by the sampling plan.

The results of the QA audit of the August sampling trip led to the decision to resample Tex Tin. Glass fiber filters were substituted for the quartz filters, after it was determined that the glass fiber filters contained no contaminants that would interfere with the analysis.

As stated above, all hi-vols to be used at Tex Tin were calibrated prior to their being taken to the field. Results of the post-sampling audit of the flow rates from the October sampling indicated that all samplers were well within the 15% error limit as specified in the sampling plan.

## DISCUSSION

The results of both sampling trips to Tex Tin indicate that heavy metals and arsenic are being carried off-site by the wind. The concentrations being borne off-site vary widely depending on the state of the ground and plant operations.

The August sampling was performed during dry weather with the plant at normal production. The production status was determined from the amount of activity at the facility, the emissions from the smokestack, and the fugitive emissions from the buildings on the facility. The only rainfall was the short shower reported on the second day. The winds reported were normal for the summer months along the Texas coast. The analytical results should be considered as representative of what would be found in the air in the vicinity of a tin smelter. The samples are basically fugitive emissions from the buildings and wind-blown dust stirred-up from the ground during normal plant operations. The emissions from the smokestack had little effect on the results due to the close proximity of the samplers to the property lines of the facility and the height of the smokestack emission point above the ground.

The lack of filter gaskets on the collocated hi-vols lowered the amount of particulate matter collected on the filters while the total air volume sampled was not affected. This means that the concentration of a reported contaminant was at least as great as that reported and probably higher. The lack of gaskets on the filter rings allowed air to leak around the filters and the particulate matter to bypass the filters and not be caught. However, both the air passing through the filter and the air leaking around the filter would pass through the throat of the hi-vol and be measured as the total flow through the hi-vol. This would result in a greater amount of air reported sampled than was actually the case. Since there is no way to accurately estimate the amount of air that leaked past the filter, the results reported should be considered as minimum values.

The problem of filter gasket leak and resultant minimum-level determination of emissions led to a decision to resample Tex Tin. As was stated in the field sampling section, heavy rains in the area postponed the sampling for two weeks. The two-week delay was not sufficient for the ground to dry to the level that existed during the August sampling. There were large pools of standing water covering portions of the facility, and there was also the appearance of water draining from some of the piles of slag visible from the sampling van location. Also, as stated previously, the smelter appeared to have shut down during the sampling period since there was little evidence of plant operations except for a dumptruck off-loading what appeared to be slag from the smelter into the spoils area. The reason for this shut-down has not been determined. The emissions from the smokestack on the second and third sampling days appeared to be natural draft emissions caused by wind flow across the stack exit.

This change in sampling conditions from the August conditions should be considered advantageous to the project. The August sampling results should be considered the base or low point emissions from a facility that is fully operational, i.e., the emissions are at least this high. The October results should be considered as representative of a facility that is not operating and are the minimum emissions which would come from the facility. With the above in mind, the results from the October sampling indicate that there is an ongoing release of arsenic into the air.



# COMPARISON OF ARSENIC LEVELS IN AUGUST AND OCTOBER

The TACB Laboratory used inductively-coupled plasma (ICP) spectrometry to analyze the particulate samples from Tex Tin for arsenic. The ICP method is more sensitive for arsenic as shown by the detection limit.

The results of the sampling at Tex Tin on different dates will be compared using the arsenic results as a basis for comparison. All values are reported in micrograms per cubic meter of air. The minimum detectable level (MDL) for all samples was 0.014 micrograms per cubic meter of air.

Sample ID	Location	CONC
August 5, 1986 (Day 1)		
2981	Upwind	<MDL
2982	Along SH 146, S of FM 519 Intersection	<MDL
2983	Along FM 519, E of office	0.016
2984	Collocated along FM 519	0.031
2985	Collocated along FM 519	0.032
August 6, 1986 (Day 2)		
2986	Upwind	<MDL
2987	Located along SH 146 near FM 519 Intersection	<MDL
2988	Northwest Quadrant	<MDL
2989	Collocated along FM 519, North of smelter	2.23
2990	Collocated along FM 519, North of smelter	0.51
2991	Along FM 519, E of office	0.042
August 7, 1986 (Day 3)		
2992	Upwind	<MDL
2993	Northwest Quadrant	<MDL
2994	Along FM 519, near SH 146 Intersection	0.078
2995	Collocated along FM 519, North of smelter	0.23
2996	Collocated along FM 519, North of smelter	0.38
2997	Along FM 519, East of office	0.056
2998	Upwind	<MDL
October 28, 1986 (Day 1)		
U1	Upwind, along FM 519 at County Ditch	<MDL
D1/1	Along SH 146, West of slag piles	<MDL
D1/2	Collocated along SH 146, West of slag piles	<MDL
D1/3	Collocated along SH 146, West of slag piles	<MDL
D1/4	Along SH 146, west of slag piles	<MDL
October 29, 1986 (Day 2)		
U2	Upwind, along FM 519 at County Ditch	<MDL
D2/1	Along SH 146, West of smelter building	0.094
D2/2	Collocated along SH 146, West of slag hopper	0.042
D2/3	Collocated along SH 146, West of slag hopper	0.036
D2/4	Along SH 146, West of slag piles	0.048

October 30, 1986 (Day 3)

03	Upwind, along FM 519 at County Ditch	<MDL
03/1	Along SH 146, west of slag piles	<MDL
03/2	Collocated along SH 146, west of slag piles	<MDL
03/3	Collocated along SH 146, West of slag piles	<MDL
03/4	Along SH 146, west of slag piles	<MDL

The August samples were collected during dry weather with the plant operating normally. The October samples were collected after heavy rains had fallen over the area and there were several large pools of standing water on the plant grounds. Also, the October samples were collected when the plant was shut down.

None of the upwind samples had arsenic concentrations at or above the minimum detectable level. This indicates that there is little or no background contribution of arsenic to the air entering the Tex Tin facility. Similarly, there were no downwind arsenic concentrations reported above background levels on two of the October sampling days. Most probable causes are that (a) the ground was wet from previous rains; (b) the plant was not operating, and (c) there was no work going on on-site.

With dry weather and the plant under what appeared to be normal operating conditions, arsenic was released to the air from the Tex Tin facility. Arsenic was detected in samples collected downwind of the facility on each of the three sampling days in August. The sampling teams noted that there were substantial fugitive emissions coming from the smelter building on the second sampling day. Also, there was vehicle traffic on the plant all three days. Probable sources for the arsenic are the smelter building and the plant grounds. As vehicles traverse the plant, they could reentrain arsenic that has settled out of the air onto the ground. In the October sampling, arsenic was seen in the downwind samples after vehicles had been driving on-site.

# COMPARISON OF LEAD, TIN, AND CADMIUM LEVELS IN AUGUST AND OCTOBER

The TACB Laboratory used X-ray fluorescence (XRF) spectroscopy to analyze the August and October samples for lead, tin, and cadmium. All values are reported in micrograms per cubic meter of air. The minimum detectable levels (MDL) for all samples were 0.14 (Pb in Aug), 0.09 (Sn in Aug), 0.10 (Cd in Aug), 0.27 (Pb in Oct), and 0.16 (Sn in Oct). The higher MDLs in the October sampling result from the difference in volumes of air sampled. Sample locations are as indicated on the maps in Appendix 1. (NOTE: A blank space indicates that the element was not detected in that particular sample.)

Sample #	Lead (Pb)	Tin (Sn)	Cadmium (Cd)
August 5, 1986 (Day 1)			
2981			
2982	0.24		
2983		0.31	
2984		1.25	
2985		1.56	
August 6, 1986 (Day 2)			
2986			
2987			
2988			
2989	4.42	103.6	0.64
2990	1.20	27.5	0.15
2991	1.22	1.35	
August 7, 1986 (Day 3)			
2992			
2993			
2994	0.29	5.96	
2995	2.01	13.9	
2996	3.61	25.4	0.17
2997	0.68	2.05	
2998			
October 28, 1986 (Day 1)			
No Pb, Sn, or Cd detected on any samples.			
October 29, 1986 (Day 2)			
Up 2	0.35		
D 2/1		1.85	
D 2/2		1.52	
D 2/3		1.51	
D 2/4		1.85	
October 30, 1986 (Day 3)			
D 3/4		0.18	
No Pb, Sn, or Cd detected in any other samples.			

Several conclusions may be drawn from the data presented above.

1. The lead found on August 5 could be automobile exhaust lead because of the location of the sampler and because the XRF does not distinguish exhaust lead from process lead.
2. The tin found on August 5 probably comes from Tex Tin due to sampler location and lack of tin in the upwind sample.
3. The high lead and tin levels found on August 6 result from Tex Tin emissions. This is based on sampler location, comparison to other sample results, and sampler operator comments concerning fugitive emissions from the smelter building.
4. The lead and tin levels found on August 7 are representative of typical plant emissions. The collocated pair of samplers (2995 and 2996) give comparable results for both lead and tin. These samplers were located in the area of greatest emissions and are substantially higher than the other two samplers located downwind of the plant. Also no lead or tin were detected upwind.
5. The lead detected in the upwind sample in October could be automobile lead.
6. The tin detected in the downwind samples comes from the slag piles on ground at Tex Tin. The tin was stirred up by the operations of the dumptruck and/or bulldozer operating on the slag piles.

As stated in the Field Sampling section, the Tex Tin facility was operating normally during the August sampling and was shut down during the October sampling. Also, the ground was dry in August and wet in October.

The presence of the lead in the emissions during the August sampling indicates that the lead is being emitted from the smelter during the smelting process. This is borne out by the fact that lead was not detected during the October sampling when the smelter was shut down. Furthermore, the tin found in all the samples indicated that the tin comes from both the smelter (primary source) and from tin that has settled out of the air and is reentrained by vehicle traffic or winds.

**Reference 7**

**Letter Concerning Tex Tin Corporation;  
From H.L. Newman, Tex Tin Corporation,  
to Martha McKee, EPA Region VI;  
January 25, 1985**

# TEX TIN CORPORATION

HIGHWAY 519 - P. O. BOX 2130

TEXAS CITY, TEXAS 77592-2130

TELEX 509411

EPA 33  
345-4

January 25, 1985

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Martha McKee, Chief  
Compliance Section  
USEPA, Region VI  
1201 Elm Street  
Dallas, Texas 75270

Re: Site Inspection Report of April 20, 1984; EPA Site  
Number TX 02364

Dear Ms. McKee:

Tex Tin Corporation, formerly Gulf Chemical and Metallurgical Company, is concerned with the bias in and created by the above report. The Company must by this correspondence protest the colored report submitted by the site inspector. Please accept the following comments offered in a spirit of cooperation with the Agency.

The report of subjects that are not environmental threats, omission of details concerning present and past environmental corrective actions by the Company and utilization of outdated, misinterpreted information, failed to give an accurate account of current environmental conditions at the Texas City Plant.

In particular those items concerning: (1) The acid pond, (2) Radioactive Burial site, (3) Catalyst Storage, (4) Slags, (5) Rainfall run-off and surface water contamination, (6) Emptied ponds, (7) Ground water, (8) Amiben contaminated iron, (9) Threats to public health, (10) Contamination of railroad borrow ditch, (11) Inadequate security, and (12) Emphasis of 1979-1977 reports.

ITEM 1: The report emphasized "the acid pond" and leads one to the opinion that the pond is creating gross environmental damage while the Company makes no efforts to alleviate the condition. Nothing could be further from the truth. The Company has been actively pursuing the disposal of the liquid and closure of the pond. At the time of the inspector's visit and to her knowledge, the Company in full cooperation with the Enforcement Division of the Texas Department of Water Resources had:

- A. Commencing in 1979 the Company spent in excess of \$300,000 to construct an evaporation system to concentrate the product in the acid ponds in an attempt to be able to sell the resulting ferric chloride. This plant was unsuccessful despite efforts made by the company over an 18 month span and the expenditure of at least \$200,000 in operating costs.
- B. Researched, developed and submitted a plan to neutralize the acid pond. The plan was ultimately discarded with the concurrence of the TDWR because of the volume of sludge generated.
- C. Compiled and submitted an 800 page deepwell injection application to the TDWR. The application was encouraged by the Enforcement Division, accepted and approved by the U.I.C. and acted upon by GCMC. The deepwell is to be totally devoted to the closure of the acid pond.

GCMC had previously made efforts to mitigate the impact of the acid pond by

- (A) Routing plant side pond leakage through the plant drainage system and treating it in the NPDES line and settle treatment system.
- (B) Damming and recirculating contaminated Wah Chang ditch water through the plant NPDES system. The dam was left in place until obvious flooding of FM 519 necessitated removal. The Company has offered to Jerry Saunders, E.P.A., Region VI, to install a new dam and treat the ditch waters until the contents of the acid pond have been injected.

Claims of erosion and berm instability by the inspector were subjective and untrue. Aerial pictures taken years ago show virtually the same degree of erosion as exists today. The berms were stable enough to withstand undiminished hurricane winds and rain in both 1961 and 1983 without loss of the contents or structural integrity.

All the above was known by the inspector who neglected for unknown reasons include them in the report. Contrary to the impression given by the report GCMC has and continues to seek a satisfactory solution to the acid pond. The Company has contracted Golden Strata Services and McClellan Engineering for the detail engineering and installation of the deep well facility. The estimated project cost of 1.2 million dollars should demonstrate the seriousness of the commitment the Company has made to an environmentally acceptable solution to the acid pond.

ITEM 2: The report raises the spectre of an uncontrolled radioactive landfill which is patently untrue. The landfill is fully licensed by the Texas Department of Health under License No. 8-1270. The glassy bismuth-silicate slag is from a pilot study on the extraction of bismuth from a bismuth-uranium catalyst. Production operations were never attempted. The slag from the pilot was buried in a manner that met or exceeded TDH requirements. Approximately 10.3% of the allowable uranium content is so buried. The site is properly capped with clay, marked above ground with four feet of vertical granite marker and duly recorded in the proper deed. The site has been inspected by TDH personnel several times and meets all criteria. All of the above was made known to the inspector but was neglected in the content and summation of the report.

ITEM 3: The report notes spent catalyst and metallic solids in association with toxicity and contamination. GCMC stockpiled catalyst in anticipation of building a plant to extract valuable metals, i.e. tungsten. GCMC performed E.P. toxicity tests on the catalyst even though the material was not considered a waste. The RCRA tests affirmed the nontoxic nonreactive nature of the catalyst, therefore the material was considered safe for outside storage.

GCMC realized the TDWR was concerned with the catalyst storage and submitted data to Mr. Bob Lee, Enforcement, TDWR. The data clearly shows that the problem of the catalyst is visual impact rather than environmental impact. GCMC made further efforts to alleviate TDWR concern by moving 11,266,000 pounds of catalyst to inside storage for future use and disposing of 6,500,000 pounds of low grade material. The disposal was at Chem-Waste Management's Port Arthur secure landfill. Marketable remaining catalysts have been retested to RCRA standards. RCRA analyses attached.

The catalysts have always been stored inside the diked plant area where all contact and noncontact rainfall is collected and directed to the NPDES system.

The inspector was aware of the test results submitted to the TDWR, Company efforts to remove catalyst from outside storage, disposals, and the diking with drainage to the NPDES system.

ITEM 4: The report noted slag materials generated by the nonferrous smelting operations and implied toxicity and water contamination. The TDWR has collected and analyzed the slags from the operations on numerous occasions but have never notified the Company of any adverse results. The Company submits the attached analyses on the old and new slags as proof of the inert nonextractable nonharmful nature of the material. The analyses are for total content, E.P. toxicity and the deionized water leachate. The inspector was aware that the material was inert and disposed on Company property under the Texas Solid Waste Code number of 371370.

ITEM 5: The report claimed contamination of surface water and rainfall runoff. The report led one to assume uncontrolled runoff from all areas of the plant to adjacent surface waters. To reiterate, the inspector was aware that the total plant was bermed, all water collected and pumped to the NPDES



**Reference 8**

**Excerpts From Potential Hazardous Waste Site Inspection Report,  
Gulf Chemical and Metallurgical Company;  
EPA; February 21, 1980**



POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT

COUNTY SITE NUMBER (to be filled by HQ)  
6

GENERAL INSTRUCTIONS: Complete Sections I and II through IV of this form as completely as possible. Then use the information of this form to develop a Tentative Disposition (Section II). File this form in its entirety in the regional Hazardous Waste File. Be sure to include all appropriate Supplemental Reports in the file. Submit a copy of the forms to U.S. Environmental Protection Agency, Site Tracking System; Hazardous Waste Enforcement Task Force (EN-53), 401 M St., SW, Washington, DC 20460.

I. SITE IDENTIFICATION

A. SITE NAME  
GULF CHEMICAL AND METALLURGICAL CO.  
B. STREET (or other identifier)  
HIGHWAY FM 519  
P.O. BOX 2130  
C. CITY  
TEXAS CITY  
D. STATE  
TEXAS  
E. ZIP CODE  
77590  
F. COUNTY NAME  
GALVESTON

G. SITE OPERATOR INFORMATION

1. NAME  
GULF CHEMICAL AND METALLURGICAL CO.  
A DIVISION OF ASSOCIATED METALS AND MINERALS CORPORATION  
2. TELEPHONE NUMBER  
(713) 945-4411  
3. STREET  
HIGHWAY FM 519  
P.O. BOX 2130  
4. CITY  
TEXAS CITY  
5. STATE  
TEXAS  
6. ZIP CODE  
77590

H. REALTY OWNER INFORMATION (if different from operator of site)

1. NAME  
2. TELEPHONE NUMBER  
3. CITY  
4. STATE  
5. ZIP CODE

I. SITE DESCRIPTION

J. TYPE OF OWNERSHIP

☐ 1. FEDERAL ☐ 2. STATE ☐ 3. COUNTY ☐ 4. MUNICIPAL ☒ 5. PRIVATE

II. TENTATIVE DISPOSITION (complete this section last)

A. ESTIMATE DATE OF TENTATIVE DISPOSITION (mo., day, & yr.)  
B. APPARENT SERIOUSNESS OF PROBLEM  
☐ 1. HIGH ☒ 2. MEDIUM ☐ 3. LOW ☐ 4. NONE

C. PREPARER INFORMATION

1. NAME  
VICTOR H. GARCIA  
2. TELEPHONE NUMBER  
(713) 226-5761  
3. DATE (mo., day, & yr.)  
2/21/80

III. INSPECTION INFORMATION

A. PRINCIPAL INSPECTOR INFORMATION

1. NAME  
Victor H. Garcia  
VICTOR H. GARCIA  
2. TITLE  
ENVIRONMENTAL ENGINEER  
3. ORGANIZATION  
ENVIRONMENTAL PROTECTION AGENCY  
4. TELEPHONE NO. (area code & no.)  
(713) 226-5761

B. INSPECTION PARTICIPANTS

1. NAME	2. ORGANIZATION	3. TELEPHONE NO.
VICTOR H. GARCIA	ENVIRONMENTAL PROTECTION AGENCY	(713) 226-5761

C. SITE REPRESENTATIVES INTERVIEWED (include one official & workers' representative)

1. NAME	2. TITLE & TELEPHONE NO.	3. ADDRESS
T. K. THUMMALA	DIRECTOR, ENVIR. AFFAIRS (713) 945-4411	P.O. BOX 2130 TEXAS CITY, TEXAS 77590

REVIEWED BY: (6ASASC) Victor H. Garcia 3/5/80

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☐ B. NON-WORKER INJURY/EXPOSURE☐ C. WORKER INJURY/EXPOSURE☒ D. CONTAMINATION OF WATER SUPPLY

GULF CHEMICAL AND METALLURGICAL CO. HAS TWO SOURCES OF WATER: CROSSLINK WELLS WATER (INDUSTRIAL USE) AND COMPANY WELL WATER (INDUSTRIAL USE AND DRINKING) - COMPANY WATER WELL IS LOCATED ON THE NORTH SIDE OF THE PLANT COMPLEX AND, ACCORDING TO USGS WELL RECORDS, WATER IS DRAWN FROM WELL DEPTHS VARYING FROM 309 FT TO 500 FT. DUE TO LIMITED HYDROLOGICAL INFORMATION, IT IS UNKNOWN IF THE WATER WHICH CONTAMINATED THE MONITORING WELLS REFERENCED IN SECTION F, COULD POSSIBLY AFFECT THE QUALITY OF THE DRINKING WELL. THE WELL WATER LEVEL WAS MEASURED ON 1/15/80, DEPTH 147'

☐ E. CONTAMINATION OF FOOD CHAIN

\* MONITORING WELL DEPTHS TO BE SUBMITTED LATER

☒ F. CONTAMINATION OF GROUND WATER

AT THE REQUEST OF THE TEXAS DEPARTMENT OF WATER RESOURCES, THREE MONITORING WELLS [SHOWN ON ATTACHMENT E] ARE SAMPLED QUARTERLY AND RESULTS SUBMITTED TO TDWR. THE ANALYTICAL RESULTS FOR THE FOURTH QUARTER 1979 ARE SHOWN ON ATTACHMENT F. CONCENTRATIONS OF ZINC, NICKEL, MANGANESE, COPPER AND TIN WERE FOUND. THE LOW PH VALUES SHOWN AT WELLS 2 & 4 INDICATE PROBABLE SEEPAGE FROM THE ACID POND

☒ G. CONTAMINATION OF SURFACE WATER

PRIOR STATE/EPA SAMPLING INSPECTIONS HAVE SHOWN PLANT RUNOFF TO BE OF A LOW PH. FIELD PH MEASUREMENTS TAKEN DURING RECENT EPA RCRA INSPECTION SHOWED A PH OF 4.5 IN THE DRAINAGE SYSTEM AND 5.5 IN A POOL OF STANDING WATER OUTSIDE THE PLANT PROPERTY. METALS SAMPLES WERE COLLECTED DURING THIS INSPECTION. SAMPLES COLLECTED IN THE PAST HAVE FOUND CONCENTRATIONS OF THE FOLLOWING METALS: ZINC, NICKEL, MANGANESE, COPPER AND TIN.

☐ H. DAMAGE TO FLORA/FAUNA☐ I. FISH KILL☐ J. CONTAMINATION OF AIR☐ K. NOTICEABLE ODORS☒ L. CONTAMINATION OF SOIL

GENERAL PLANT APPEARANCE IS MESSY. PILES OF TIN SLAG, IRON ORE, AND CRUSHED EMPTY BARRELS WERE ABUNDANT IN REAR (SOUTHERN) PORTION OF PLANT. CONTAMINATION OF SOIL FROM RUNOFF OFF OF THE PILE APPEARS INEVITABLE. A REDDISH MATERIAL (PRESUMABLY IRON) WAS OBSERVED, ESPECIALLY APPARENT IN SOUTHERN E-W DRAINAGE DITCH. SEE PICTURES, ATTACHMENT A.

☐ M. PROPERTY DAMAGE

inued From Front

# XIV PERMIT INFORMATION

List all applicable permits held by the site and provide the related information.

A. PERMIT TYPE (e.g., RCRA, State, NPDES, etc.)	B. ISSUING AGENCY	C. PERMIT NUMBER	D. DATE ISSUED (mo., day, & yr.)	E. EXPIRATION DATE (mo., day, & yr.)	F. IN COMPLIANCE (mark 'X')		
					1 YES	2 NO	3 UNKNOWN
NPDES	EPA	TX0004055	6/8/76	6/7/81		X	
STATE	TX DEPT OF HEALTH	11-1270	11/07/78	11/30/82	X		
AUTHORIZED DISCHARGE OF DEFLECTED URANIUM WASTE MATERIAL RESULTING FROM THE PROCESSING OF URANIUM CATALYST. WASTE COMPOSED OF 3.7% DEFLECTED URANIUM, 1.7% ANTIMONY, AND 4.9% CALCIUM SILICATE							

## XV. PAST REGULATORY OR ENFORCEMENT ACTIONS

☐ NONE ☒ YES (summarize in this space)

TEXAS DEPARTMENT OF WATER RESOURCES

ENFORCEMENT ORDER ISSUED 1976

REFERRED TO ATTORNEY GENERAL 8/10/78 (UNAUTHORIZED DISCHARGE)

NO LAW SUIT HAS BEEN FILED TO DATE

NOTE: Based on the information in Sections III through XV, fill out the Tentative Disposition (Section II) information on the first page of this form.

\* See Attachment H

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**Reference 9**

**Excerpts From Drinking-water Well Survey at Tex Tin Corporation;  
Ecology and Environment; October 4, 1985**

REF

ECOLOGY AND ENVIRONMENT, INC.  
REGION VI  
MEMORANDUM

TO: Keith Bradley, Region VI - RPO  
FROM: R. Roblin, FIT - Geologist *RR*  
THRU: K.H. Malone, Region VI - RPM *KH*  
DATE: October 4, 1985  
SUBJ: Drinking Water Well Survey at Tex-Tin Corp., Texas City, TX (TX2364)  
TDD#R6-8509-19

FIT member, Ray Roblin, was tasked to conduct a drinking water well survey within a 3 mile radius of Tex-Tin Corp. (AKA Gulf Chemical Metallurgy), in Texas City, Texas. This area includes parts of the cities of Texas City, La Marque, Bayou Vista and the extreme eastern edge of Hitchcock, Texas. The survey was conducted on September 30 and October 1, 1985.

The main purpose of this investigation was to ascertain whether any residents of the area are presently using groundwater for domestic supplies. The main aquifers of concern are the two upper sand units which are associated with the Beaumont Formation of late Pleistocene Age. The Beaumont Formation consists mostly of clay, silt, sand and includes mainly stream channel, point bar, natural levee and backswamp deposits, and to a lesser extent coastal marsh and mud flat deposits. Its thickness is approximately 100' in the investigation area. Lower stratigraphic Pleistocene units that are not water producers are the Montgomery Formation and the Bentley Formation. These units comprise approximately 150' of section. Below those units is the Willis Formation also of Pleistocene Age. This unit consists mostly of clay, silt, sand and minor siliceous gravel of granule to pebble grain size. The Willis is the next lowest water bearing formation below the Beaumont Formation, and its thickness is approximately 75' (Sellers et.al., 1981).

The initial investigation focused on the location and extent of the cities of La Marque and Texas City's water lines in relation to the area of concern. Mr. Ron Fleenor of the cities of La Marque and Texas City's water department was interviewed. He stated that....

- City water lines serve all residents within the city limits inside the three mile radius from the site.
- La Marque has 3 deep (800'-840') water wells that are maintained for emergencies only and at this time only 2 are operational.
- In a recently annexed area, there were 3 private wells. These wells are used for lawn watering only.  
(Fleenor 9/30/85).

The three private wells referred to by Mr. Fleenor are located west of the site approximately 2 1/2 miles. The wells are 30', 40' and 120' in depth respectively. The wells are shown on the attached map to reference 1.

Ms. Fay Fraboni of the Galveston County Municipal Water District was interviewed concerning a beach house community that is located approximately 1 mile south of the site, which is the City of Bayou Vista.

- Bayou Vista is supplied with water from the Galveston County System and uses no ground water (Fraboni 9/30/85).

The community is identified on the attached map as Reference 2. Directly west of Bayou Vista, north of State Road 6, just west of Highland Bayou, is another small beach house community consisting of approximately 60 homes. These homes are supplied by 25 wells. This information was determined by canvassing the community. Most (≈95%) of these homes are used only on weekends and holidays according to resident, Ralph Heintz of 7115 W. Hunter Drive, Hitchcock, Texas. Mr. Heintz stated that his well is 215' deep and that most in this community are also approximately 200' deep. By checking drillers well logs, filed with T.D.W.R. in Austin, at least 3 of these wells are between 97'-105' which is in the aquifer of concern (TDWR). This community is located on the attached map to Reference 3.

Ms. Rose Tellis, City of Hitchcock Water Department was contacted concerning the extent of water lines.

- City water lines extend to their city limits in the western edge of the investigation area.

- Water is supplied by the Galveston County Municipal System (Tellis 10/1/85).

In conclusion, no other industrial or irrigation wells were located within the investigation area. The communities within the 3 mile radius of the site are supplied water by the Galveston County Municipal System. The only domestic wells used for drinking water are the 25 wells located in the unannexed beach house community located west of Highland Bayou. At least three of these wells are in the aquifer of concern.

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**Reference 10**

**Letter Concerning Tex Tin Corporation;  
From Robin Morse, Esq., Baker and Botts,  
to Bob Hanneschlager, EPA Region VI;  
July 15, 1985**

## BAKER &amp; BOTTS

ONE S-EL PLAZA  
HOUSTON TEXAS 77002

TELEPHONE 733 229 1234

TELECOPIER 733 229 730

TELEX 78-2779

701 PENNSYLVANIA AVE N.W.  
WASHINGTON D.C. 20006410 UNITED BANK TOWER  
400 WEST FIFTEEN STREET  
AUSTIN TEXAS 78701

G-36,375

July 15, 1985

Mr. Bob Hanneschlager, Chief  
 Superfund Branch (6AW-S)  
 U. S. Environmental Protection Agency  
 - Region VI  
 1201 Elm Street  
 InterFirst Two Building  
 Dallas, Texas 75270

VIA  
FEDERAL EXPRESS

RE: Tex Tin Corporation - Texas City, Texas

Dear Mr. Hanneschlager:

As counsel for Tex Tin Corporation, we have recently been informed that the Texas Department of Water Resources has forwarded a Superfund ranking package to Region VI with respect to Tex Tin's Texas City, Texas plant. We have been supplied with a copy of the ranking package by TDWR and have reviewed it with company representatives. The purpose of this letter is to inform Region VI that, as explained below, the TDWR assessment appears to be grossly distorted and should not serve as a basis for Superfund action. We would urge Region VI to reject the referral action and are ready to work with EPA in order to obtain a truer understanding of the environmental situation at the plant.

Beginning with Figure 1, the "HRS Cover Sheet", we would first note that there is no formal state enforcement action now pending. The referenced lawsuit was dismissed for want of prosecution on December 12, 1984.

Turning to the next page, entitled "Fact Sheet", there are no "hazardous waste" facilities at the plant. The plant's wastewater is not a listed or characteristic hazardous waste stream under RCRA. As for the referenced acid ponds, including the 18 million gallon pond alleged to contain "highly acidic ferric chloride waste", these units are all exempt from RCRA pursuant to 40 C.F.R. § 261.4(b)(7), the exclusion for wastes resulting from the extraction and processing of ores and minerals. Furthermore, the company has been pursuing an active program of neutralization and removal in connection with the old acid

**Mining Waste NPL Site Summary Report**

**Torch Lake  
Houghton County, Michigan**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

**Science Applications International Corporation  
Environmental and Health Sciences Group  
7600-A Leesburg Pike  
Falls Church, Virginia 22043**

## **DISCLAIMER AND ACKNOWLEDGEMENTS**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Jae B. Lee of EPA Region V [(312) 886-4749], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**TORCH LAKE**  
**HOUGHTON COUNTY, MICHIGAN**

**INTRODUCTION**

This Site Summary Report for the Torch Lake Superfund Site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region V Remedial Project Manager for the site, Jae B. Lee.

**SITE OVERVIEW**

The Torch Lake NPL Site is located on the Keweenaw Peninsula of Upper Michigan (see Figure 1). For over 100 years, the area surrounding Torch Lake was the center of Michigan's copper mining, smelting, and milling activities. Over 10.5 billion pounds of copper were processed in the area between 1868 and 1968 (Reference 2, page 5). Copper-contaminated tailings were pumped, with process wastewater, into Torch Lake or onto property around Torch Lake (Reference 1, page 1-2). An estimated 200 million tons of tailings were pumped into Torch Lake, reducing its volume by at least 20 percent (Reference 2, page 5).

The surface area of Torch Lake is 2,717 acres; it has a mean depth of 56 feet and a maximum depth of 115 feet (Reference 1, page 1-1). Several small creeks and the Trap Rock River discharge into Torch Lake (see Figure 2). The Torch Lake watershed is approximately 77 square miles. The primary land use in the watershed is farming of northern hardwoods and a few dairy and potato farms. The communities of Lake Linden (population 1,181) and Hubbell (population 1,278) are located on the west side of Torch Lake (Reference 1, page 1-2). Torch Lake feeds into the northeastern arm of Portage Lake and then into Lake Superior, via the Portage River. The Portage Lake and River are part of the Keweenaw Waterway, a shipping channel across the Keweenaw Peninsula. Torch Lake is 14 miles from Lake Superior (Reference 2, page 1).

In 1983, the Michigan Department of Public Health (MDPH) issued a fish consumption advisory on all Sauger and Walleye caught in Torch Lake (Reference 1, page 1-6). Also in 1983, the International Joint Commission's (IJC) Water Quality Board designated Torch Lake as a Great Lakes

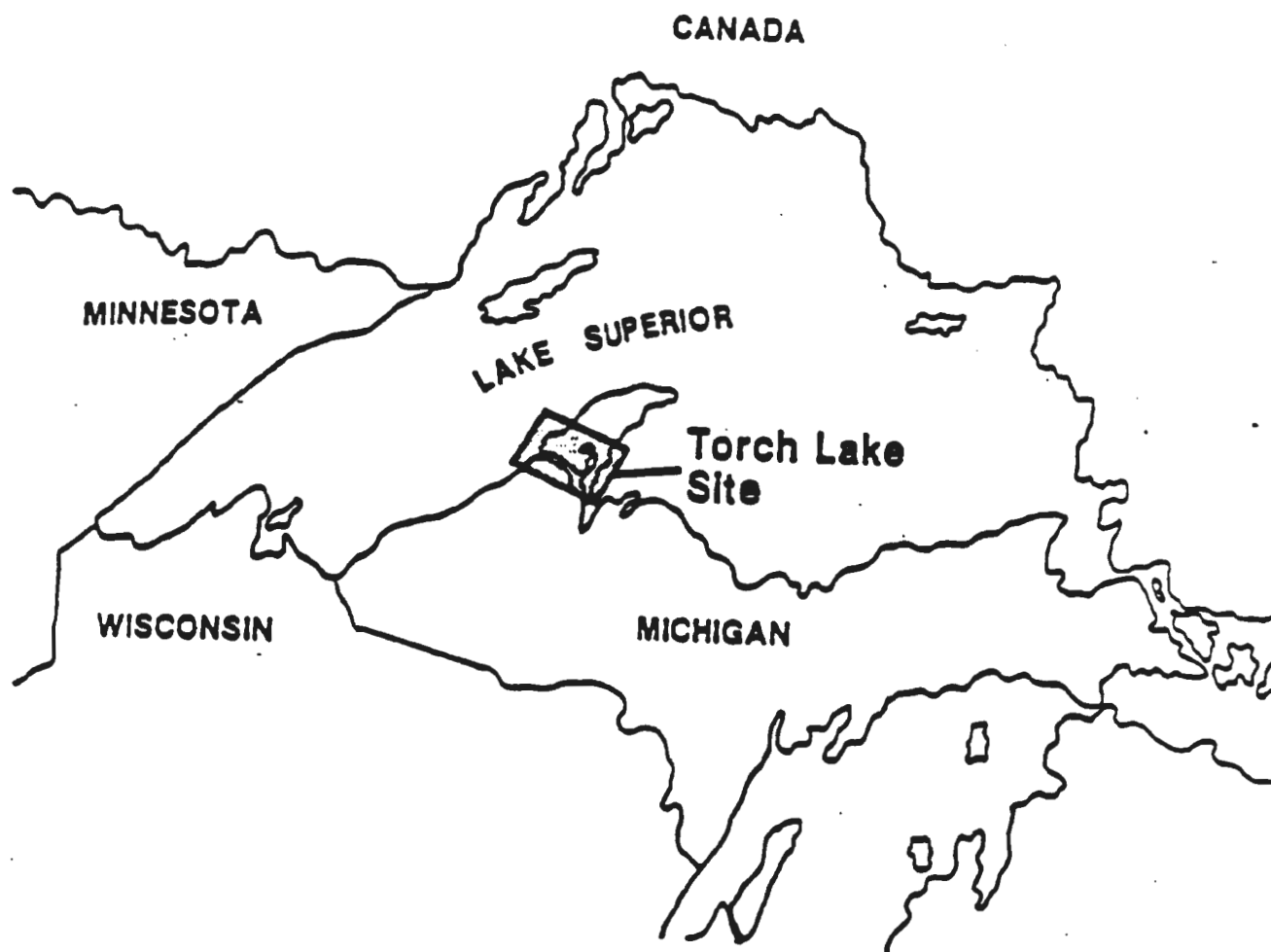


FIGURE 1. SITE LOCATION MAP

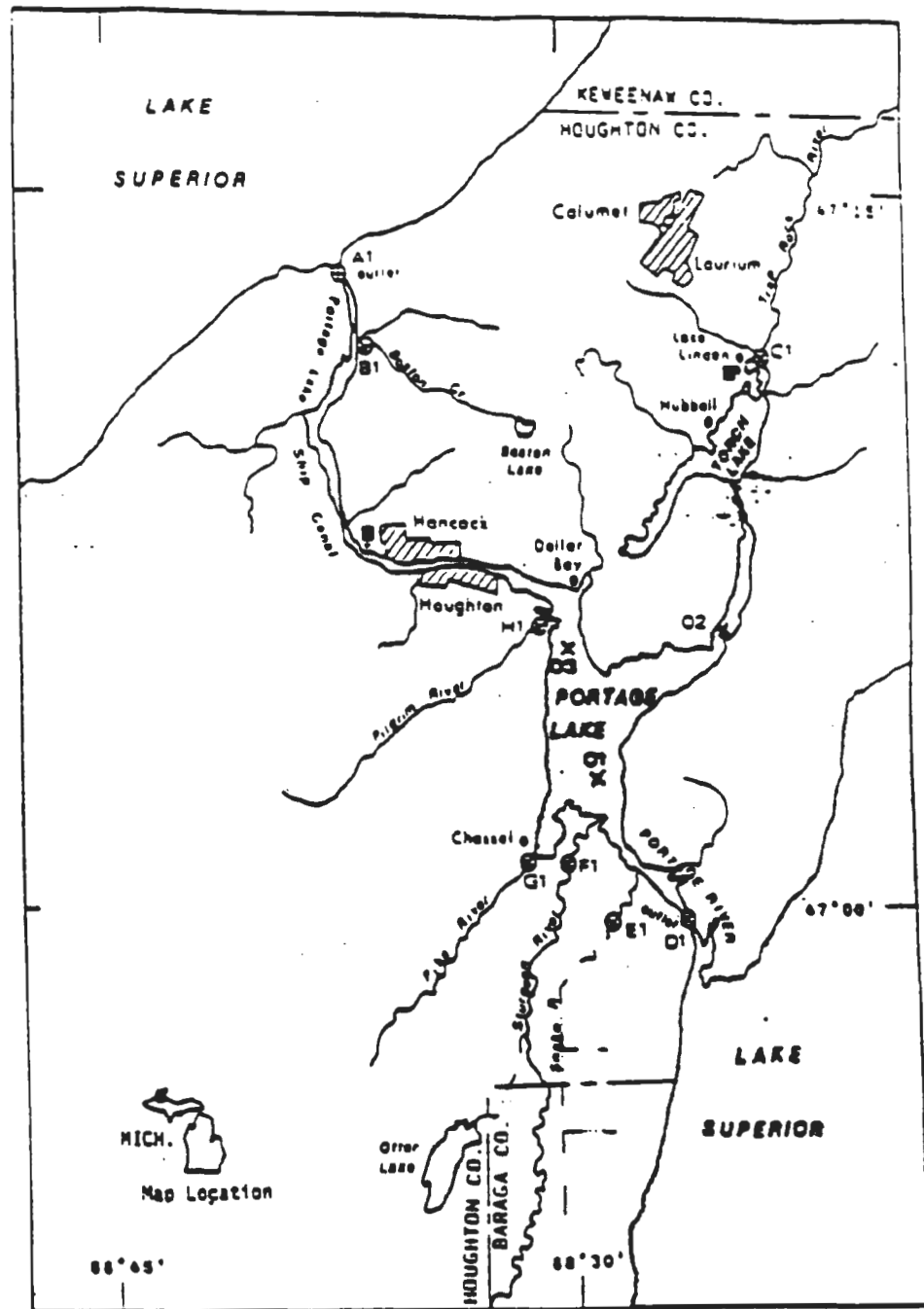


FIGURE 2. TORCH LAKE AND PORTAGE LAKE (HOUGHTON COUNTY, MICHIGAN)

## Torch Lake

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Area of Concern (AOC). This designation was based on MDPH's fish consumption advisory, the frequency of tumor occurrences in fish, the presence of metal-contaminated sediments, and the history of mining and disposal practices in the Torch Lake area (Reference 1, page 1-7).

Torch Lake was listed on the NPL in June 1988 (Reference 2, page 6). The Torch Lake Superfund Site has three Operable Units. Operable Unit 1 includes surface tailings and the contents of buried and submerged drums along the western shore of Torch Lake. Operable Unit 2 includes the potentially contaminated media in and around Torch Lake. The media to be investigated include soil, ground water, Torch Lake sediments, surface water, and the biota (Reference 1, page 1-10). Operable Unit 3 includes other tailings sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas (Reference 1, page 1-11). In September 1988, a Remedial Investigation and Feasibility Study were initiated, by EPA, for Operable Unit 1 (Reference 2, page 6). The Remedial Investigation for this Operable Unit was completed, and the report was submitted to EPA in November 1990. Remedial Investigations for Operable Units 2 and 3 are currently in progress.

## OPERATING HISTORY

Mining of an elemental copper belt extending from the northern tip of Keweenaw Peninsula (100 miles to the southwest of the site) began in the 1860's. The first copper mill along the shore of Torch Lake opened in 1868. At the mills, copper was crushed, grinded, and driven through successively smaller meshes. Copper and crushed materials were separated by gravity in a liquid medium. The recovered copper was sent to a smelter, and tailings were disposed of with process wastewaters into Torch Lake or on land around Torch Lake. Mining activities in the Torch Lake area peaked between the early 1900's and 1920 (Reference 1, page 1-2; Reference 3, page 2).

Beginning in 1916, technological innovations allowed for the recovery of copper from previously discarded tailings in Torch Lake. The submerged tailings were collected, screened, recrushed, and gravity-separated at one of three reclamation plants (Reference 1, page 1-3). These plants included the Calumet and Hecla (1916), the Tamarack (1925), and the Quincy (1943) (Reference 5, page 2). Initially, an ammonia-leaching process was used to recover copper and other metals from the tailings (Reference 1, page 1-3). By 1917, a flotation process that agitated ore, water, oil, and chemical reagents became economically feasible. The flotation process created a froth that would support copper-bearing particles. Typically, the reagents consisted of 50 percent coal tar, 15 percent pyridine oil, 20 percent coal tar creosote, and 15 percent wood creosote. In 1926, xanthates were added to the process. After the flotation process, the tailings were discharged into Torch Lake (Reference 5, page 2).



During the 1920's, copper mining had decreased, and processing of mine tailings had increased. Beginning in the 1930's and continuing until the 1960's, mills operated mainly to recover copper from tailings piles. The last mill closed in 1968. In the 1970's, copper recovery plants again began operating in the Torch Lake area. The only discharge to Torch Lake from the copper recovery plants was noncontact cooling water. By 1986, only one small copper recovery plant was still operating (Reference 1, page 1-3).

An estimated 5 million tons of copper were produced in the Keweenaw Copper District of Michigan from the 1860's to 1968. More than half of this was processed along the shores of Torch Lake. Between 1868 and 1968, an estimated 200 million tons of tailings were discharged into Torch Lake, reducing the Lake's volume by 20 percent and dramatically changing the shoreline (Reference 1, page 1-3).

#### **SITE CHARACTERIZATION**

Copper-ore tailings are present in and around Torch Lake and other areas of the Keweenaw Peninsula. The sources of contamination in Operable Unit 1 are: (1) tailings and associated debris and flotation chemicals; (2) drums in the tailings; (3) drums in Torch Lake; and (4) industrial chemicals. The potential pathways for the transport of contaminants to receptors include air, ground water, surface water, and sediments. Humans, terrestrial organisms, and aquatic life may be exposed to contaminants through ingestion, inhalation, and direct contact. The contaminants may become more concentrated in fish and fauna through bioaccumulation (Reference 1, page 1-9).

Mine tailings are divided into two categories. The first category involves tailings resulting from crushing and gravitational separation process. The contaminants of concern in this tailings category are arsenic, copper, lead, and zinc. The second category of tailings includes tailings that were reprocessed using the flotation process. The contaminants of concern in the reprocessed mine tailings include arsenic, copper, lead, zinc, and the industrial chemicals used in the flotation process (lime, pyridine oil, coal tar creosotes, wood creosote, pine oil, and exanthates) (Reference 1, page 1-8).

Drums have been visibly observed in tailings piles on land and identified by geophysical investigations of submerged tailings in Torch Lake. The contents of the drums are not documented, but it is rumored that striking mine workers may have placed explosives in some of the drums and buried them in tailings piles (Reference 1, page 1-9).

## **Torch Lake**

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Debris from an electrical materials/copper reclamation facility is mixed with tailings in areas of Operable Unit 1. The contaminants of concern associated with this reclamation facility are asbestos, metals, and Polychlorinated Biphenyls (PCBs) (Reference 1, page 1-9).

### **Drums**

In 1989, magnetometry and Ground Penetrating Radar were used to detect buried and submerged drums in tailings piles (Reference 1, page 2-1). EPA Technical Assistance Team (TAT) personnel collected samples from eight drums exposed on the surface of tailings in Operable Unit 1 (Reference 1, page 4-2). The sampling analysis indicated that seven of the drums had very low hazardous constituent concentrations as measured by Extraction Procedure (EP) Toxicity tests. None of the drum samples were considered hazardous based on Resource Conservation and Recovery Act characteristics of EP Toxicity. PCBs and pesticides were not found above detection limits in any of the samples. The eighth drum contained 4,000 parts per million (ppm) of trichloroethylene. It is suspected that the contents of the drum are not related to mining activities, but rather to illegal dumping (Reference 1, page 4-2).

The TAT assessment did not indicate that immediate removal of the drums was necessary (Reference 1, page 4-2). Drum identification and sampling was to continue in 1990, but the results were not included in the November 1990 Remedial Investigation Report for Operable Unit 1 (Reference 1, page 4-1).

### **Tailings**

The western shore of Torch Lake is lined with mine wastes from mining and associated activities. The tailings piles in Operable Unit 1 are subdivided into nine sectors based on historic mining practices, location, and field reconnaissance work (Reference 1, page 3-2). Surface and subsurface samples were collected from tailings samples in all sectors (Reference 1, page 2-2). Tailings samples were analyzed for inorganic and semivolatile organic compounds, moisture content, grain-size distribution, Atterberg Limits, and cation exchange capacity (Reference 1, page 2-3).

Fifty eight surface samples were collected from a 0- to 6-inch depth and a density of 1 sample per 10 acres. Surface samples were collected to assess the risk from inhalation and ingestion of fugitive dust particles (Reference 1, page 2-3). Twelve subsurface samples were collected from a depth of 0 to 3 feet and at a density of 1 sample per 20 acres. Subsurface samples were collected to obtain the necessary data to evaluate remedial action alternatives, particularly revegetation and dust control (Reference 1, page 2-3).

Analytical data for the tailings samples from Operable Unit 1 are presented in Table 1. The table contains the ranges from surface and subsurface samples and background concentrations for the chemicals of concern.

**TABLE 1. SUMMARY OF INORGANIC CHEMICALS OF POTENTIAL CONCERN DETECTED IN OPERABLE UNIT 1 TAILINGS (in mg/kg)**

Compound	Tailings Concentrations		Native Soil Concentrations <sup>1</sup>
	Surface	Subsurface	
Aluminum	5,190 - 37,200	5,410 - 27,200	10,000 - 300,000
Antimony	3.4U <sup>2</sup> - 11.7	3.5 - 7.3	—
Arsenic	0.37U <sup>2</sup> - 8.3	0.47 - 14.4	1.0 - 40
Barium	5.5 - 135	5.1 - 68	100 - 3,500
Beryllium	0.18U <sup>2</sup> - 1.7	0.18U <sup>2</sup> - 1.0	0.1 - 40
Boron	NA	NA	—
Chromium	10.7 - 46.3	13.6 - 42.7	5.0 - 3,000
Cobalt	5.4 - 52.6	8.5 - 32.8	1.0 - 40
Copper	72.3 - 3,020	699 - 5,540	2.0 - 100
Lead	1.5 - 104	0.38U <sup>2</sup> - 82.8	2.0 - 200
Manganese	103 - 1,080	217 - 703	100 - 4,000
Mercury	0.08U <sup>2</sup> - 1.1	0.09U <sup>2</sup> - 0.24	0.01 - 0.08
Nickel	12.6 - 57.3	20.2 - 115	5.0 - 1,000
Silver	1.5U <sup>2</sup> - 8.2	1.5U <sup>2</sup> - 22.8	0.1 - 5.0
Titanium	NA	NA	1,000 - 10,000
Vanadium	19.2 - 159	25.5 - 121	20 - 500

NA - Not analyzed

<sup>1</sup>The source of naturally occurring soil concentrations is Dragun, 1988.

<sup>2</sup>Indicates the concentration was below the detection limit and was estimated.

Source: Reference 1, Table 4-1

## **Torch Lake**

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Based on the sampling analysis, the Remedial Investigation concludes that the concentration and distribution of metals appeared to be similar in surface and subsurface samples. Concentration ranges from subsurface samples were within or below the range of concentrations found at the surface. Copper concentrations in tailings samples were elevated above background soil concentrations. In summary, neither organic nor inorganic compound levels in tailings samples from Operable Unit 1 were found to be dramatically higher than background soil concentrations (Reference 1, page 4-3).

In 1989, the U.S. Bureau of Mines sampled mine-tailings leachate and water quality and concluded that leachate from Torch Lake mine tailings was extremely low in comparison to leachate from 30 other sites. The U.S. Bureau of Mines analysis indicated that very little metal is being released from Torch Lake tailings (Reference 1, page 1-6).

### **Soils**

The soils in the Torch Lake area are primarily sand and silty loams with some localized clays. The soils in the area have fragipans that develop 19 to 24 inches below the surface. The fragipans resist root penetration and water infiltration, directing surface-water flows laterally before penetrating into the ground-water system (Reference 2, page 4).

A limited soil-sampling program was conducted to determine if particulates are being transported from tailings piles to nearby residential locations. Nine composite soil samples were collected. Each composite soil sample consisted of four subsamples representing the corners of the property sampled. Although contamination was not apparent in the samples, traces of tailings and slag were noted (Reference 1, page 2-4). Complete characterization of the Torch Lake Superfund Site soils and a Risk Assessment of soils was not in the scope of the Remedial Investigation for Operable Unit 1 (Reference 1, page 4-3).

Table 2 compares soil-sampling ranges with typical background soil concentrations for the contaminants of concern. Chromium, copper, lead, nickel, and vanadium were measured in most soil samples. Copper concentrations exceeded background levels in all but one of the samples. Mercury levels exceeded background concentrations in four of the samples. Arsenic was at levels typical of background concentrations at eight of the sampling sites (Reference 1, page 4-4).

Soil samples from residential locations generally had concentrations of inorganic compounds an order of magnitude higher than background concentrations (Reference 1, page 4-4).

**TABLE 2. SUMMARY OF INORGANIC CHEMICALS OF POTENTIAL CONCERN  
DETECTED IN OPERABLE UNIT 1 SOIL SAMPLES (in mg/kg)**

Compound	Range of Concentrations	Native Soil Concentrations <sup>1</sup>
Aluminum	3,140 - 7,600	10,000 - 300,000
Antimony	U <sup>2</sup>	—
Arsenic	U <sup>1</sup> - 7.00	1.0 - 40
Barium	U <sup>1</sup> - 101.00	100 - 3,500
Beryllium	U <sup>2</sup>	0.1 - 40
Boron	U <sup>2</sup>	—
Chromium	5.90 - 20.10	5.0 - 3,000
Cobalt	U <sup>2</sup>	1.0 - 40
Copper	58.30 - 459.0	2.0 - 100
Lead	6.10 - 329.0	2.0 - 200
Manganese	91.40 - 357.0	100 - 4,000
Mercury	0 - 0.47	0.01 - 0.08
Nickel	0 - 33.70	5.0 - 1,000
Silver	1.5U <sup>2</sup>	0.1 - 5.0
Titanium	U <sup>2</sup>	1,000 - 10,000
Vanadium	11.40 - 26.30	20 - 500

<sup>1</sup>The source of naturally occurring soil concentrations is Dragun, 1988.

<sup>2</sup>Indicates the concentration was below detection limits and was estimated.

Source: Reference 1, Table 4-2

The EPA TAT also collected three soil samples from the east side of Torch Lake during the Torch Lake Site Assessment. All the metals detected in the soil samples were within typical soil background concentrations and below maximum concentrations for EP Toxicity, as regulated under 40 Code of Regulations Part 261 (Reference 1, page 4-4).

## **Torch Lake**

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### **Surface Water**

Water enters Torch Lake from the Trap Rock River, and Hammell, Dover, McCallum, and Sawmill Creeks. The Trap Rock River is the largest discharger into Torch Lake, and the Trap Rock River Watershed covers approximately 58 percent of the Torch Lake Drainage Basin. An estimated 2,000 kilograms per year of dissolved copper is transported through Trap Rock River and its tributaries into Torch Lake (Reference 2, page 1). Contamination of the surface water was not addressed in the Remedial Investigation for Operable Unit 1 but will be addressed during the Remedial Investigation for Operable Unit 2.

### **Ground Water**

The U.S. Geological Survey sampled well water in 1968 and 1977. Analysis of the 35 wells in Houghton County indicated that only 3 had specific conductance greater than 500 micromhos per centimeter. Sampling results from these two sampling periods indicated a high-quality water source for general use (Reference 2, page 4).

All ground-water wells drilled on the west and north sides of Torch Lake are set in bedrock. Many Torch Lake communities and seasonal residents now get their potable water from municipal well systems or from an independent supplier. Some communities, like Hubbell, receive their water supply from Calumet, a larger community to the northwest (Reference 2, page 4).

In July 1989, TAT personnel sampled seven private wells and two municipal wells (Reference 2, page 10). Only one sampling location had a concentration of either organic or inorganic compounds in excess of the Maximum Contaminant Levels (MCL) or above removal action levels (Reference 2, page 20). The sample collected from the Lake Linden municipal well had an iron concentration of 0.33 ppm. This is slightly greater than the Secondary MCL of 0.3 ppm for iron (Reference 2, page 15). A detailed assessment of the ground-water contamination will be addressed during the Remedial Investigation for Operable Unit 2.

### **Air**

The Michigan Department of Natural Resources (MDNR) collected air samples from four sampling locations (based on wind and population profiles) to monitor likely exposure points, emissions sources, and background conditions. Total Suspended Particulates (TSP) samples were collected for 1 month (from August 14, 1989, to September 13, 1989). Samples were collected for 24-hour periods every other day, resulting in 62 filters samples (Reference 1, page 2-4). The two filters with the

greatest concentration of TSP were further analyzed for arsenic, chromium, copper, nickel, lead, and zinc (Reference 1, page 2-5). The sampling analysis indicated that mean ambient-air concentrations at the two selected monitoring stations exceeded mean background ambient-air concentrations for aluminum, arsenic, barium, copper, magnesium, iron, manganese, and TSP (Reference 6, Table 2).

## ENVIRONMENTAL DAMAGES AND RISKS

By the 1970's, a century of mining waste deposition into Torch Lake had created an environmental concern. In response to a 1972 discharge of cupric ammonium carbonate leaching liquor from the Lake Linden Leaching Plant, MDNR reported the discoloration of several acres of lake bottom (Reference 1, page 1-3). In its investigation, MDNR found 15 water-quality parameters within ranges commonly encountered in similar Michigan lakes. Heavy metal concentrations in lake sediments were within the ranges measured at 28 background locations, except for arsenic, chromium, zinc, and copper, all of which had elevated levels. Plant and benthic invertebrate analysis did not indicate any water-quality changes (Reference 1, page 1-4).

Three months after the spill, researchers from Michigan Technical University (MTU) cited the spill as the cause for a temporary depletion of oxygen, elevated copper levels, increased pH, and increased carbonate alkalinity. Bioassays indicated that portions of the Lake were toxic to macroinvertebrate amphipod species (Reference 1, page 1-4).

Torch Lake has supported a diverse fish population; although the fish biomass has remained the same, there has been a change in the dominant predator fish species. The change in dominant species may be a result of changes in turbidity or lake chemistry (Reference 1, page 1-4).

In 1973, an MTU graduate student observed abnormalities and lesions in Sauger and Walleye, and reported this finding to the MDNR. Subsequent pathological tests revealed that these two species were affected by three types of neoplasms (including hepatomas, dermal fibromas, and gelatinous masses) (Reference 1, page 1-4). In 1983, MDPH issued a consumption advisory for Saugers and Walleyes caught in Torch Lake (Reference 4, page 1). This fish-consumption advisory was still in effect as of November 1990.

Solely on the basis of the fish-consumption advisory, the IJC's Water Quality Board, in 1985, designated Torch Lake as a Great Lakes AOC. In 1987, MDNR presented the IJC with Phase I of a Remedial Action Plan for Torch Lake. The plan called for the annual stocking of Walleye and Sauger and a 1988 sampling of these species (Reference 4, page 1). In March 1990, MDNR reached

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the conclusion that the 1988 sampling data did not support the continued fish-consumption advisory for these species (Reference 4, page 3). MDNR reached this conclusion for the following reasons:

- Only 4 of the 56 fish samples had mercury concentrations that exceeded 0.5 milligrams per kilogram (mg/kg) consumption advisory action limit, and none exceeded 1.0 mg/kg. The fish from Torch and Portage Lakes were among the least contaminated fish in Michigan's Fish Contaminant Monitoring Program (Reference 4, page 1).
- No internal or external growth abnormalities were observed on 458 fish collected. Cancerous growths were not found on any fish livers during either the 1988 or 1985 fish collection and sampling periods. MDNR acknowledges that liver neoplasms (cancerous growths) have declined to near background levels, but additional studies need to be conducted to determine the background frequency of liver cancer in fish (Reference 4, page 1).
- Saugers have been in steady decline in Torch Lake since the 1960's, and this has been attributed to a decrease in lake turbidity. Saugers are a turbid-water species and when the Lake water cleared after mining operations ceased, the Saugers lost their competitive advantage over other fish species. Torch and Portage Lakes are no longer considered important Sauger sports fisheries (Reference 4, page 3).
- Bioassays of Torch Lake surface water and sediments have not indicated the presence of carcinogenic substances (Reference 4, page 3).

In a study of heavy-metal concentrations in Torch Lake sediments and mining wastes, it was concluded that, although the tailings are directly contaminated with arsenic, chromium, copper, lead, tin, and zinc, the water in Torch Lake is not directly contaminated with heavy metals. Furthermore, heavy metals may be entrained in wind currents, but they do not represent a serious human health risk (Reference 1, page 1-5).

The copper and hydrologic budgets were calculated for Torch Lake to determine the amount and sources of copper entering Torch Lake. Over 96 percent of the copper input is from surface runoff, 3 percent is from precipitation, and 1 percent is from ground-water inflow. Copper loss occurs by outflow into Portage Lake. The copper budget indicates an annual net loss of dissolved copper. However, copper concentrations have been relatively stable for the past 14 years. Therefore, it was determined that precipitation, complexation, dissolution, absorption, and diffusion control dissolved copper concentrations (Reference 1, page 1-5).

In a 1988 Preliminary Health Assessment for Torch Lake, the Agency for Toxic Substances and Disease Registry (ATSDR) concluded that the site is a potential public health concern because of



possible exposure to unknown etiological agents that may create adverse health effects over time. Although Torch Lake is currently contaminated with mine tailings, there are no known health effects linked to this contamination. The incidence of cancer deaths from 1970 to 1981 was cited at or below the State average for age-adjusted stomach-cancer mortality. Furthermore, ATSDR concluded that there was no indication that human exposure is currently occurring (or has occurred in the past) (Reference 1, page 1-6).

According to the EPA Region V Remedial Project Manager, the Risk Assessment section that accompanies the Remedial Investigation for Operable Unit 1 is still under review and will be forwarded to EPA in June 1991. Quantification of the ground- and surface-water pathways were not included in the scope of work for the Operable Unit 1 Remedial Investigation. Ground-water contamination from Operable Unit 1 tailings is being addressed in the Operable Unit 2 Remedial Investigation. Likewise, surface-water and sediment contamination are being addressed in the Operable Unit 2 Remedial Investigation. The potential contamination from the drums in the tailings of Operable Unit 1 will only be addressed after additional drums are located and sampled (Reference 1, page 5-1).

#### REMEDIAL ACTIONS AND COSTS

The Torch Lake area has undergone a number of remedial actions since the closing of the last mill in 1968. Previous remedial actions include:

- Since the 1960's, attempts have been made to establish vegetation on tailings deposits on the shoreline of Torch Lake (Reference 1, page 1-8)
- The Portage Lake Water and Sewage Authority has sprayed sewage sludge on the tailings to promote vegetative growth on the southwest end of the Lake (Reference 1, page 1-8)
- As per the Torch Lake Remedial Action Plan, annual restocking and periodic sampling of Saugers and Walleyes have been accomplished (Reference 1, page 1-8)
- The wastewater treatment facilities in the communities surrounding Torch Lake have been upgraded (Reference 1, page 1-8).

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Remedial actions for the Torch Lake Superfund Site are still under development. None of the three Operable Units have documented a remedial action in either a Record of Decision or a Feasibility Study. The Feasibility Study for Operable Unit 1 is still under development, and will be completed in fiscal year 1991.

### **CURRENT STATUS**

The Remedial Investigation for Operable Unit 1 was completed and submitted to EPA in November 1990. The Feasibility Study is still under development and should be available by the end of fiscal year 1991. Field investigations for Operable Units 2 and 3 were completed in 1990, and as of May 20, 1991, the data was being reviewed. The Remedial Investigation for Operable Unit 2 will be submitted to EPA in June 1991. The Remedial Investigation for Operable Unit 3 should be completed by the end of fiscal year 1991.

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5. Technical Memorandum Number 1; From Jeffrey D. Maletzke, Donahue & Associates, Inc., to Lori Ransome, Donahue & Associates, Inc.; July 28, 1989.
6. Technical Memorandum Number 7; From Lori Ransome, Donahue & Associates, Inc., to Project Files; February 9, 1990.

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**Reference 1**

**Excerpts From Final Remedial Investigation Report, Operable Unit 1:  
Torch Lake, EPA Contract No. 68-W8-0093; Prepared for EPA  
by Donahue & Associates, Inc.; 1990**

# EPA REGION V ARCS PROGRAM



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VOLUME 1

FINAL REMEDIAL INVESTIGATION REPORT  
OPERABLE UNIT I

TORCH LAKE  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
BOUGHTON COUNTY, MICHIGAN

NOVEMBER 1990

*U.S. EPA Contract*  
*68-W8-0093*

Donohue & Associates, Inc.

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OPERABLE UNIT I  
TORCH LAKE  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
BOUGHTON COUNTY, MICHIGAN

NOVEMBER 1990

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Work Assignment No.: 02-5LS8  
Donohue Project No.: 20011

VOLUME 1

FINAL REMEDIAL INVESTIGATION REPORT  
OPERABLE UNIT I

TORCH LAKE  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
BOUGHTON COUNTY, MICHIGAN

NOVEMBER 1990

Prepared for:

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Emergency and Remedial Response Branch  
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## 1.0 INTRODUCTION

### 1.1 PURPOSE OF REPORT

Donohue & Associates, Inc. (Donohue) is submitting this Remedial Investigation (RI) Report for Operable Unit I (OU I) for the Torch Lake Superfund Site. This RI Report is submitted to the U.S. Environmental Protection Agency (EPA) in response to Work Assignment No. 02-5LS8 under Region V ARCS Contract No. 68-W8-0093.

The rationale and scope of work for the Torch Lake Remedial Investigation/Feasibility Study (RI/FS) is described in the Torch Lake RI/FS Final Work Plan (Revision 1) (Donohue, 1989a). The Torch Lake RI/FS will be conducted as three operable units. OU I includes the primary contaminant sources of surface tailings and drum contents in the primary study area, on the western shore of Torch Lake. This OU has been identified as possibly requiring separate and earlier remediation than other media, from a human risk perspective. OU II includes other potentially contaminated media in the primary study area. These comprise soil, air, surface water, and Torch Lakes's submerged tailings, sediment, groundwater, and biota. OU III includes other tailings contaminant sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas.

This report summarizes the RI performed for OU I which includes primary contaminant sources in surface tailings on the western shore of Torch Lake. The RI was performed to collect and evaluate data to supplement existing data and form the basis for assessing: (1) physical characteristics of OU I, (2) type and extent of contamination of OU I, (3) environmental and human health risks associated with OU I, and (4) the need for and methods to remediate OU I. Activities documented in this report include waste characterization of OU I tailings and drums, characterization of dust emissions, air pathway exposure modeling, limited characterization of soil, and assessment of human health impact.

This introductory chapter presents site background and history, a summary of the RI/FS Work Plan rationale and approach including the division of the site into three operable units, and the organization of the remaining chapters of the RI Report for OU I.

### 1.2 SITE BACKGROUND

#### 1.2.1 Site Location and Description

The location of the Torch Lake Superfund Site is shown on Figure 1-1. It is located on the Keweenaw Peninsula in Houghton County, Michigan, at 47°N latitude, 88°W longitude. Torch Lake is tributary to Portage Lake, which is part of the Keweenaw Waterway that flows to Lake Superior. Torch Lake is about 14 mi by water from Lake Superior. Torch Lake has a surface area of 2,717 acres, a mean depth of 36 ft, a maximum depth of 115 ft, and a volume of  $5.2 \times 10^9$  ft<sup>3</sup>. The Trap Rock River and several small creeks discharge into

Torch Lake. Its watershed is approximately 77 mi<sup>2</sup>. The watershed is forested with second-growth northern hardwoods, and supports a few dairy and potato farms. Only a small percentage of the watershed is residential or commercial. The communities of Lake Linden (pop. 1181), Hubbell (pop. 1278), and Mason are located on the west side of Torch Lake. Torch Lake is used for fishing, boating, limited contact recreation (swimming), non-contact cooling water supply, treated municipal waste assimilation, and wildlife habitat (Michigan Department of Natural Resources, 1987).

#### 1.2.2 Site History and Response Actions

The following sections describe industrial history, environmental problems and studies, regulatory actions, and response actions pertaining to the Torch Lake Superfund Site.

##### 1.2.2.1 Industrial History

Torch Lake is located in Michigan's copper mining district. For 100 years, the lake was the site of milling and smelting facilities, a repository for copper mining and milling wastes, and a part of the waterway used for transportation to support the industry. PRC Engineering, Michigan Technological University (MTU) (Rose, W.I., et al, 1986), and MDNR (Michigan Department of Natural Resources, 1987), have compiled chronologies of Torch Lake's copper industry. The following summary of the chronology is relevant to the types of hazardous materials potentially impacting the environment.

Deposits of native (elemental) copper are found in a belt extending from the tip of the Keweenaw Peninsula southwest over a distance of 100 miles. Copper mined in the region was native copper, found as a metal. Copper mining operations had begun on the Keweenaw Peninsula by the 1860s. The first mill opened on Torch Lake in 1868. At the mills, copper was extracted by crushing or "stamping" the rock into smaller pieces, grinding the pieces, and driving them through successively smaller meshes. The copper and crushed rock were separated by gravimetric sorting in a liquid medium. The copper was sent to a smelter. The crushed rock particles, called "tailings" or "stampands", were discarded with mill processing water, typically by pumping into the lake or waterway. The milling process was not efficient, and copper was lost in the discarded tailings.

Mining output, milling activity, and tailings production peaked in the Torch Lake area in the early 1900s to 1920. Mining company records from this time describe how mill tailings were pumped out into Torch Lake and deposited on property around Torch Lake. All of the mills were located on the west shore of the lake.

In about 1916, advances in technology allowed recovery of copper from tailings previously deposited in Torch Lake. Dredges were used to collect submerged tailings, which were then screened, recrushed, and gravity-separated. An ammonia leaching process involving cupric ammonium carbonate was used to recover copper and other metals from conglomerate tailings. A flotation process made it economically feasible to recover copper from old tailings in

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Torch Lake and was used for reclamation at Torch Lake mills by 1917. The flotation process involved agitating ore, water, oil, and chemicals to produce a froth that would support copper-bearing particles. During the 1920s, chemical reagents were used to further increase the efficiency of the flotation process. The chemical reagents included lime, pyridine oil, coal-tar creosotes, wood creosote, pine oil, and xanthates. These were used in various combinations depending on the ore and process water. After leaching or flotation at reclamation plants, chemically treated tailings were returned to the lake, resulting in increased turbidity.

During the 1920s, mining activities decreased, whereas tailings processing per mine increased over the previous decade. In the 1930s and 1940s, the Torch Lake mills operated mainly to recover tailings in Torch Lake. In the 1950s copper mills were still active, but by the late 1960s copper milling had ceased. The last mill closed in 1968.

Over 5 million tons of native copper were produced from this area, and more than half of this was processed along the shores of Torch Lake from the 1860s until 1968. Between 1868 and 1968 at least 200 million tons of tailings were dumped into Torch Lake, filling at least 20 percent of the lake's original volume. These deposits resulted in drastic changes to the shoreline.

In the early 1970s, exploratory research was conducted in the Centennial Mine, resulting in a devatering discharge into Slaughterhouse Creek, a Trap Rock River tributary. A small copper recovery plant continues to operate in Hubbell, and discharges non-contact cooling water into Torch Lake (Science Applications International Corp., 1986).

#### 1.2.2.2 History of Environmental Problems and Studies

In the 1970s, environmental concern developed regarding the century-long deposition of tailings into Torch Lake. High concentrations of copper and other heavy metals in Torch Lake water or sediments, toxic discharges, and fish abnormalities prompted many investigations into long- and short-term impacts attributable to mine-waste disposal.

The academic and regulatory communities have produced an extensive amount of data, research, scientific literature, and reports regarding Torch Lake's complex environmental problems (Michigan Department of Natural Resources, 1987; Rose, W.I., et al., 1986; Warburton, 1986; Michigan Water Resources Commission, 1973; Wright et al., 1973; Black et al., 1982; U.S. EPA, 1987; Spence, 1988a).

In 1972, cupric ammonium carbonate leaching liquor was discharged into the north end of Torch Lake from storage vats at the Lake Linden Leaching Plant. The Michigan Water Resources Commission (MWRC) investigated the spill (MWRC, 1973) and reported that discoloration of several acres of lake bottom indicated previous discharges. No deleterious effects to surface water quality, algae, fish, or benthic macroinvertebrates were detected three months after the discharge. To assess effects from the spill, MWRC compared results from its 1972 investigation to data from a 1970 MWRC investigation. Except for

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chloride and copper, 15 water quality parameters surveyed were within ranges commonly encountered in Michigan lakes of this type. Chloride concentrations had decreased because of the termination of mine dewatering and the effect of natural lake flushing. Dissolved copper concentrations remained high, similar to 1970 levels. Heavy metal concentrations in Torch Lake sediments were within ranges measured at 28 background locations in Michigan, except for elevated levels of arsenic, chromium, zinc, and copper. Plant and benthic invertebrate analyses did not indicate changes in water quality. Copper concentrations in Torch Lake fish were found to be less than those measured in 1970. Mercury was found in fish in 1972, but this was attributed to the use of analytical techniques that were more sensitive than those previously available.

MTU researchers also examined the alteration of Torch Lake water quality after the 1972 discharges (Wright et al., 1973). The cupric ammonium carbonate spills were cited as factors in temporary water quality changes, namely the depletion of oxygen through the conversion of ammonia to nitrate, elevated copper levels, increased pH, and increased carbonate alkalinity. Bioassays suggested that portions of the lake were toxic to a macroinvertebrate amphipod species.

A diverse fish population has occupied Torch Lake and supported productive food and sport fishing. Although game fish biomass has remained constant, changes in the dominant larger predator species, from sauger to walleye and northern pike, and lack of sauger reproduction and juveniles have been reported. Impacts to dominant fish predator species may have been due to lake chemistry or turbidity/habitat changes. In 1973, abnormalities and lesions in Torch Lake sauger and walleye were documented by an MTU graduate student and reported to the MDNR. Subsequent pathological research was conducted in 1979, 1980, and 1982, and indicated that these two species from Torch Lake were commonly affected with three types of neoplasms including hepatomas, dermal fibromas, and gelatinous masses. No virus particles were observed, and the livers were found to be frequently atrophic. Pug-headedness in perch has also been observed at an incidence of greater than 1 percent, which is significant for fish.

Benthic communities have been reduced in areas of copper tailings, and bioassays have shown the tailings to be toxic (MDNR, 1987).

MTU researchers, under contract with the MDNR, have conducted numerous studies to determine possible impacts of copper mining wastes on the environment of the Torch Lake area. Five studies are discussed in the 1986 Project Completion Report (Liddy, 1986) and are summarized here.

A four-month tumor induction study was conducted in the laboratory to examine the effect on fish liver histology following static exposure to creosote and xanthate flotation agents in the presence of Torch Lake sediments. Causal relationships with liver abnormalities or tumor occurrence were not concluded.

The environmental fate of xanthates and creosotes was examined using library and laboratory studies. Xanthate fate was studied by following the degradation of pure compounds in the laboratory. The rate and mechanism of degradation was related to pH, and it was concluded that xanthates would not be expected to persist in the environment beyond one year. Torch Lake sediment extracts were analyzed for ten typical creosote polycyclic aromatic hydrocarbon (PAH) components. Eight of these compounds were not detectable in the sediment extracts. Chrysene and benzo[a]pyrene were detectable, but the sources could not be determined. Airborne particulates from fuel combustion as well as mining pollutants may have contributed to the PAH content of Torch Lake sediment.

A study regarding tumor incidence and parasite surveys of perch, walleye, and sauger from Torch Lake reported that parasite species and tumors were observed in the three fish species, and abnormalities were observed in perch, but no direct relationship between parasites and tumors was found.

In a study of heavy metals in Torch Lake sediments and mining wastes, sediment, tailings, and airborne dust samples were analyzed for metals and mineral composition. It was concluded that though the sediments were enriched with arsenic, chromium, copper, lead, tin, and zinc, Torch Lake water is not directly contaminated with heavy metals, and though winds stir up dust from stamp sands, it is unlikely that airborne heavy metals represent a serious human health problem. The chromium, lead, tin, and zinc enrichment of sediments in the vicinity of Hubble is anomalous in reference to local mineral deposits, and is attributed to contamination from electrical debris and associated slag at the reclamation plant near Hubble.

The copper budget for Torch Lake was calculated with the hydrologic budget to determine the amount and sources of copper entering Torch Lake. Over 96 percent of the copper input is from surface runoff, 3 percent is from precipitation, and less than 1 percent is from groundwater. Copper loss occurs by outflow through Portage Lake. Considering external factors only, the budget indicates an annual net loss of dissolved copper. However, no significant changes in copper concentrations have occurred in the past 14 years. It was therefore concluded that internal processes (precipitation, complexation, dissolution, adsorption, and diffusion in sediment pore water) control dissolved copper concentrations.

In 1988, MTU researchers conducted a magnetometry investigation of a small area of stamp sands. The investigation indicated the presence of buried metallic objects near an area where many barrels are rumored to have been buried (Spence, 1988b).

In 1988, MDNR collected 455 fish, including 18 species, from Torch Lake and Portage Lake (Michigan Department of Natural Resources, 1989). No sauger were captured, and this rarity was attributed to the fact that turbidity in the waters has decreased. No suspicious growths were observed, either externally or internally, during fish collection or liver preparation. Livers from 32 walleye and bullheads were analyzed. One walleye from Portage Lake had abnormal liver cell development, but this was not confirmed as a tumor. The

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other 31 livers were normal. The MDNR report compared these data to previous studies and concluded that these data strongly suggest that liver tumor inducing agents above background concentrations no longer exist in the Torch Lake - Portage Lake fishery. Low contaminant levels in fish flesh further suggest reconsideration of the fish consumption advisory.

In 1988, the Agency for Toxic Substances and Disease Registry (ATSDR) released its Preliminary Health Assessment for Torch Lake (MDPH, 1988). Site background, previous investigations, site visit, potentially contaminated media, potential environmental and human exposure pathways, and demographics were evaluated and discussed.

Based on the information reviewed, it was concluded that the site is of potential public health concern because of possible exposure to presently unknown etiologic agents at levels that may result in adverse health effects over time. Although Torch Lake is polluted with copper and other contaminants, no known health effects were linked to the problem. The incidence of cancer deaths over the period 1970-1981 was cited as at or below the state average for age-adjusted cancer mortality except for stomach cancer. Stomach cancer in the locale was linked with the predominantly Scandinavian descent of the population.

The ATSDR report recommended additional investigations regarding: (1) rumors about dumping of chemicals and barrels into the lake; (2) contents of barrels found in and around the lake; (3) private well sampling and analysis; (4) fish population reproduction and tumor incidence; (5) causative agent of fish tumors; (6) human health risk from fish consumption. The ATSDR report also recommended cleanup of abandoned buildings and industrial scrap materials which constitute physical hazards on the shoreline of Torch Lake.

The ATSDR concluded that although there is currently a potential for human exposure to contaminants, there are no indications in the review conducted for the ATSDR Health Assessment that human exposure is actually occurring at the present time or has occurred in the past. Therefore the site is not being considered for followup health studies at this time. ATSDR will reevaluate the site for followup if data become available suggesting human exposure is occurring or has occurred.

In 1989, the Bureau of Mines (U.S. Department of Interior, 1990) performed laboratory evaluations of tailings and water samples from Torch Lake to determine the potential for metals to adversely affect Torch Lake. In general, metal concentrations of leachates from Torch Lake tailings samples were concluded to be extremely low when compared to tailings at over 30 other sites. Bureau of Mines results indicated that very little metal is being released from the Torch Lake tailings.

#### 1.2.2.3 History of Regulatory Actions

Because of the incidence of fish tumors, in 1983 the Michigan Department of Public Health (MDPH) announced an advisory against the consumption of Torch Lake sauger and walleye. Although no human health effects were associated

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with fish consumption, MDPH issued the advisory as a preventive measure until the causative factors of fish tumors and the potential risks to humans could be identified. The advisory is still in effect.

In 1984, the Hazard Ranking System was applied by EPA to score the Torch Lake Superfund Site. The site was defined as Torch Lake, the northern end of Portage Lake, and the North Entry to Lake Superior, because at these locations copper concentrations were significantly above background values. The background samples were obtained from the southern end of Portage Lake and the South Entry.

In 1985, the U.S. EPA initiated a responsible party search for the Torch Lake waste disposal site. Three potentially responsible parties (PRPs) were identified and issued notice letters. In August 1988, negotiations with these three PRPs were concluded. In June 1988, the Torch Lake Superfund Site was placed on the U.S. EPA National Priority List (NPL) for funding under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). A federal-lead RI/FS was initiated at the site in October 1988.

Torch Lake is on the Act 307 Michigan Sites of Environmental Contamination Priority List. In 1985, MTU researchers were awarded funds from the MDNR through Act 307 to study fish tumor problems in Torch Lake.

In 1983, the International Joint Commission Water Quality Board designated Torch Lake as a Great Lakes Area of Concern (AOC). An AOC is defined as an area with known impairment of a designated use. The AOC is confined to Torch Lake and its shores on the basis of the fish consumption advisory, tumor frequency, metal-contaminated sediments and their impact on biota, and the history of mining waste disposal. In 1985, the State of Michigan designated Torch Lake as a Category 2 AOC based on the information base available and programs underway. In the case of the Torch Lake AOC, the causative factors were unknown and an investigation was underway. The site can be removed from the AOC list when evidence is presented that the designated uses have been restored.

The MDNR completed a Remedial Action Plan (RAP) for Torch Lake in 1987. The primary goal of the RAP was stated as the removal of the fish consumption advisory "on the basis of its issuance". The objectives of the RAP were to assemble and summarize all existing data, identify impaired designated uses, identify problem sources, identify data gaps, propose further investigations, and propose alternatives to restore designated uses.

The impaired uses of Torch Lake were identified as: (1) fish consumption because of the MDPH advisory affecting sport fishery for sauger and walleye, and (2) the reduced benthic macroinvertebrate community in locations where mine tailings have been deposited. In the RAP, the MDNR recommended that the AOC be reclassified because: external fish tumors have been associated with viral infections; fish tumors are common in Great Lakes populations; all other fish in the community did not exhibit abnormal growths and can be used for food; the fish move freely to Portage Lake and Lake Superior; although not aesthetically pleasing, tumors from fish do not transmit cancer to humans; bioassays of Torch Lake sediment and water have been negative for mutagenic activity; tumor-inducing agents have not been identified in Torch Lake.

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In September 1988, the State of Michigan issued a letter of assurance to enable the EPA to conduct an RI/FS for the Torch Lake Superfund Site. This letter recommended continuation of MTU's previous studies.

#### 1.2.2.4 History of Response Actions

Attempts to establish vegetation on stampsand deposits on the shorelines of Torch Lake have been conducted since the 1960s (Laddy, 1986, and Science Applications International Corp., 1986). The objectives of stampsand vegetation include stabilizing the shoreline and reducing airborne particulates. The Portage Lake Water and Sewage Authority has spray-irrigated sewage sludge on tailings to promote vegetation at the southwest end of the lake.

The Village of Lake Linden has been developing recreational facilities with a bathing beach, camping area, park, and boat ramps at the north end of Torch Lake.

In Hubbell and Lake Linden, debris around the smelters and from the shoreline has been removed.

Proposed actions include restocking and monitoring sauger or walleye in Torch Lake, monitoring Torch Lake water and fish tissue, and natural transportation and burial of copper-enriched sediments in Torch Lake (MDNR, 1987). MTU researchers disagreed with MDNR's restocking proposal, monitoring plan, funding level, and natural sedimentation processes proposal, and proposed other research to identify alternatives for remedial action. In the 1987 RAP, the MDNR stated that other remedial actions for the fish consumption impairment cannot be proposed since causes of fish tumors have not been determined; other remedial actions for the contaminated sediment problem have not been proposed because of the expanse and volume of the sediments. Other reviewers oppose the restocking plan because it would encourage fishing and consumption, and because it may not be logistically possible.

Wastewater treatment is being upgraded in the surrounding communities.

### 1.3 INITIAL SITE EVALUATION AND DESIGNATION OF OPERABLE UNITS

A detailed initial evaluation of the site is contained in the Final Work Plan (Revision 1) (Donohue, 1989a).

#### 1.3.1 Types and Volume of Waste Present

The types and approximate amounts of waste present in OU I and the potential contaminants associated with each are summarized in Table 1-1. Copper ore tailings are present in and around Torch Lake and at other locations on the Keweenaw Peninsula in tremendous quantities. The estimated total of 200 million tons of ore tailings which were discharged into the lake can be divided into two categories. The first includes tailings resulting from the stamping/gravimetric separation process. Contaminants of concern in tailings from this process include copper, arsenic, chromium, lead, and zinc. The second category includes tailings reprocessed using the flotation process. The flotation process used lime, pyridine oil, coal tar creosotes, wood creosote, pine oil, and xanthates.



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Drums are present in the tailings and submerged in Torch Lake. The presence of exposed drums has been confirmed visually. The presence of buried and submerged drums has been indicated by geophysical investigations conducted by EPA Technical Support Unit and Emergency Response Team personnel. A brief geophysics survey conducted by researchers at MTU also showed an anomaly which may indicate additional buried drums (Spence, 1988b). The nature of the material disposed of in drums is not documented. Because explosives were used in large quantities during mining operations, and because workers, angry over local area strikes were rumored to have put explosives in drums, one or more drums could contain explosives.

Debris associated with an electrical materials copper reclamation facility is mixed with tailings over a portion of the site. Some scrap material was burned, and some was disposed near the facility. The contaminants of concern associated with electrical material reclamation include PCBs, metals, and asbestos.

#### 1.3.2 Potential Migration Pathways

Contaminant sources and potential migration pathways are shown on Figure 1-2, the Conceptual Site Model. Primary contaminant sources include (1) tailings with associated debris and flotation chemicals, (2) drums in the tailings, (3) drums in Torch Lake, and (4) industrial chemicals. Industrial chemicals are included as a possible contaminant source because of a reported discharge of leaching liquor directly to the lake (MWRC, 1973).

Primary release mechanisms include dust emissions, infiltration, runoff, and erosion from tailings; leaks from drums in the tailings and in the lake; and spills and discharges of industrial chemicals. These release mechanisms result in secondary contaminant sources including contaminated soil, surface water, and sediments. Secondary release mechanisms include dust emissions and infiltration from soil, and infiltration through sediments.

Potential contaminant transport pathways to receptors include air for dust emissions, groundwater flow to water supplies, and surface water and sediments.

Receptors include humans via ingestion, inhalation, and dermal contact, and terrestrial and aquatic environmental species through ingestion, inhalation, and direct contact. Through bioaccumulation, fish and other fauna can serve as sources to both human and environmental receptors through ingestion.

#### 1.3.3 Identification of Operable Units

The Hazard Ranking System scoring package defined the Torch Lake Superfund Site to include Torch Lake, the North Entry (to Lake Superior), and the northern portion of Portage Lake, where copper concentrations are significantly above the background established by the southern portion of Portage Lake and the South Entry. This area is shown on Figure 1-3.

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During project scoping meetings, representatives from EPA, Donohue, MDNR, the U.S. Fish and Wild Life Service, and the Bureau of Mines reached consensus that operable units (OU) will be defined for the site for the following reasons:

- o The Torch Lake Site as defined in the Hazard Ranking System is large and complex.
- o The most important waste sources and the receptors are in close proximity over a relatively small portion of the site.
- o Remediation of contaminant sources, if necessary, will be expedited by completing the RI/FS and ROD for the tailings adjacent to the lake.
- o Information obtained from a relatively small portion of the site, containing serious sources and important receptors, can be used to determine the need for additional information throughout the rest of the site and to help develop and focus the scope of work for collecting additional information.
- o There is a substantial amount of background information available for the site as a whole that must be reviewed. In addition there are on-going studies concerning the site as a whole that, when completed, will help determine the scope for the remaining work. This background information can be reviewed while work proceeds on the smaller area.

The primary study area includes Torch Lake and its surrounding shore. The boundaries of the primary study area, shown on Figure 1-4, are the Keweenaw Fault line along the northwest side of the lake, Hammell Creek to the north, the topographic ridge line on the east, and a line extending from Gooseneck Creek in the southwest corner of Torch Lake eastward along Upper Point Mills Road and Baulman Road to the eastern boundary on the south. Included in this area are the towns of Lake Linden, Hubbell, and Mason on the west side of Torch Lake. The primary study area was delineated because the environmental problems here are more readily defined, and focusing on this area will provide earlier information on potential remedial action alternatives. This approach will prevent delays in remedial action for Torch Lake and will provide background information for planning for the remainder of the site.

OU I includes the primary contaminant sources of surface tailings and drum contents in the primary study area, on the western shore of Torch Lake. This OU has been identified as possibly requiring separate and earlier remediation than other media, from a human risk perspective.

OU II includes other potentially contaminated media in the primary study area. These comprise soil, air, surface water, and Torch Lakes's submerged tailings, sediment, groundwater, and biota.

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OU III includes other tailings contaminant sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas.

OU II or III may be divided into additional operable units if data indicate that separate study and remediation will be most effective. OU III may be integrated with OU I for later stages of the RI/FS if evaluations performed in early RI/FS tasks indicate that this is appropriate.

#### 1.4 OPERABLE UNIT I ACTIVITIES AND ORGANIZATION OF REPORT

Remedial investigation activities associated with OU I were conducted to evaluate the elements of the Conceptual Site Model highlighted on Figure 1-5. Specific activities included waste characterization of OU I tailings, geophysical investigations for drums in OU I tailings, sampling of drums that were accessible from the surface, characterization of dust emissions from OU I tailings, characterization of soil in the immediate vicinity of receptors, air pathway exposure modeling, and assessment of human health impacts. Waste characterization activities included investigation of parameters needed to evaluate potential remedial actions.

Chapters 2 through 6 of this RI Report for OU I present details of the OU I study area investigation, and discussions of the physical characteristics of the study area, the nature and extent of OU I contamination, contaminant fate and transport, and the OU I baseline risk assessment. In general, results and conclusions from OU I RI activities are discussed and integrated in the text of the Report, while media-specific data and evaluations are presented in Technical Memoranda. Chapter 7 presents conclusions and discussion of uncertainties. Technical Memoranda are included in Appendix A. The Baseline Risk Assessment Report for OU I is presented in Appendix B (found in Volume 2 of this report).

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## 2.0 STUDY AREA INVESTIGATION

This chapter describes field activities and physical and chemical monitoring associated with site and waste characterization of OU I. The remedial investigation for OU I included a review of the mining archives at Michigan Technological University (MTU), field reconnaissance, drum investigation including geophysical surveys for locating drums, drum sampling to determine drum contents, surface tailings sampling, subsurface tailings sampling, soil sampling in the immediate vicinity of human receptors, and air sampling and meteorological monitoring. This chapter summarizes these activities which are discussed in more detail in the referenced Technical Memoranda (Appendix A).

### 2.1 MICHIGAN TECHNOLOGICAL UNIVERSITY ARCHIVE SEARCH AND FIELD RECONNAISSANCE OF TAILINGS

Donohue conducted a search of mining company records at the MTU archives to better understand the industrial activities that impacted the Torch Lake Superfund Site and OU I in particular. Information obtained in the archive search and from field reconnaissance is presented in Technical Memorandum Number 1 (TM 1) in Appendix A. Information documented in TM 1 was used to divide the OU I tailings along the west side of the lake into sectors based on homogeneity of tailings type and source. Nine sectors were identified for separate sampling.

General locations of these sectors are shown in Figure 2-1. Surface features and past and present land use in the vicinity of OU I are discussed further in TM 1 and Chapter 3 of this report.

### 2.2 DRUM INVESTIGATION

Geophysical surveys to detect buried and submerged drums and sampling and analysis of exposed drums on the surface of OU I tailings were performed in 1989 to locate buried drums and characterize drum contents. Additional drum investigation activities are planned for 1990.

#### 2.2.1 Geophysical Investigations

Geophysical survey activities for OU I are discussed in detail in TM 2 (Appendix A). Geophysical survey activities were conducted by Donohue, Region V EPA Technical Support Unit, and Great Lakes National Program Office (GLNPO) staff. The purpose of the geophysical investigations was to delineate suspected drum disposal areas within OU I tailings piles and off-shore in Torch Lake. Magnetometry and ground penetrating radar (GPR) investigations were conducted on OU I tailings piles to locate buried drums. GPR and sub-bottom profile (seismic) investigations were conducted in Torch Lake to locate submerged drums.

As described in TM 2, magnetometer and GPR surveys were conducted at the Centerline Apartments area in Lake Linden, the stampmill site in Tamarack City, and the sewage settlement pond site. Reference baseline and a 100- by 50-foot grid were surveyed at each location. Survey grid markers labeled with

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north and east grid coordinates were placed along the survey lines. Details concerning the geophysical survey investigations are explained in TM 2. Results are discussed in Section 4.1.1.

The marine GPR system consisted of recording equipment and a GPR antennae. The location of the boat was determined with Loran C Navigation and marked on a strip chart recorder. The marine GPR was not effective in locating submerged drums because the depth of water penetration was limited to approximately 20 feet.

The subbottom profiler system consisted of recording equipment with a seismic source and receiver. The location of the boat during this survey was determined with Loran C Navigation and marked on a strip chart recorder. The subbottom profiler mapped several near-shore areas and conducted several transects across the lake, both north-south and east-west. Technical difficulties terminated the survey without a complete coverage of the lake as proposed in the Final Work Plan.

#### 2.2.2 Drum Sampling

In June 1989, EPA Technical Assistance Team (TAT) sampling personnel collected samples from eight surface drums and five surface soil locations along the northern and western shoreline of Torch Lake. Drum and soil samples collected, the matrix of each sample, and the analytical parameters analyzed for each sample are summarized in Table 2-1. Details of the sampling program, including maps showing general sample locations, are presented in TM 3 (Appendix A).

### 2.3 TAILINGS SAMPLING

#### 2.3.1 Introduction

Tailings in OU I were sampled and analyzed to characterize their potential as a contaminant source, for risk assessment purposes, and to provide data needed to evaluate remedial action alternatives.

Tailing samples were collected from all nine sectors delineated in TM 1. Approximate sampling locations are shown on Figures 2-2, 2-3, and 2-4. Survey locations of sampling points are presented in TM 4. Samples were collected from the surface (0- to 6-inch) and subsurface (0- to 3-foot) depths. Sampling procedures for surface tailings and subsurface tailings are reported in TM 4 and TM 5, respectively. Details of tailings sampling procedures are also presented in the RI/FS Field Sampling Plan (Revision 1) (Donohue, 1989b). Deviations from procedures described in the Field Sampling Plan are recorded in TM 4 and TM 5. Also included in TM 4 is a summary of visual descriptions for each sector.

In addition to tailings sample collection activities, field monitoring for alpha/beta/gamma radiation was completed using a Monitor 4 detector. Measurements were recorded for composite subsamples. Tailings samples were

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analyzed for inorganic and semivolatile organic compounds, which comprise all compounds on EPA's Target Compound List with the exception of cyanide, as well as for the physical parameters of moisture content, grain size distribution, Atterberg Limits, and cation exchange capacity (TM 8).

#### 2.3.2 Surface Samples

Surface tailings samples were collected to assess risk by exposure from dermal contact and inhalation of fugitive dust. A total of 58 surface tailings sample composites were collected from the 0- to 6-inch depth at a density of one composite sample per 10 acres. As described in TM 4, the surface tailing sampling and decontamination procedures were conducted in accordance with the Torch Lake RI/FS Field Sampling Plan, Quality Assurance Project Plan, and Health and Safety Plan (Donohue, 1989 b,c,d). Descriptions of texture, Munsell color, vegetation, debris, and special features were recorded. Samples were collected from areas that contained tailings. Grab samples were obtained from "slime" deposits (very fine grain size material), crushed slag, and the slag pile to further characterize these materials.

#### 2.3.3 Subsurface Samples

Subsurface tailings samples were collected to obtain data necessary to evaluate remedial action alternatives, particularly stabilization and dust control by vegetation. Twelve subsurface tailings composite samples were collected from the 0- to 3-foot depth at a density of one sample per 20 acres. Procedures used and observations recorded during collection of subsurface tailings samples are presented in TM 5.

A total of 23 subsurface excavations were conducted during the sampling program. Prior to intrusive work, excavation locations were checked for buried metallic objects with a metal detector. Radiation measurements were taken from composite samples at each location. Each excavation was also screened with an EMU photoionization detector upon completion of the excavation. Photographs were taken at each sample location.

Subsurface conditions encountered at Sector 3 prevented excavation to 3 feet. Construction debris and gravel sized slag allowed digging with a shovel to only 2 feet below grade. Therefore, the composite sample was collected from a depth of 0 to 2 feet at this location.

Observations during subsurface tailings sampling at Sector 8 suggested that the two sampling locations were located in tailings materials derived from different sources. Although both areas consisted of amygdaloidal basalt tailings, the sample collected at Location 2 was coarser-grained with a lower percentage of fine-grained tailings than the sample from Location 4. Therefore, separate samples and decontamination procedures were conducted at both locations.

## 2.4 SOIL SAMPLING

Limited soil sampling was performed to obtain preliminary information regarding whether air-borne particulate materials are being transported from OU I tailings sources to residential yards in the primary study area. Soil samples were collected from nine residential yards in Lake Linden, Hubbell, Tamarack City, and Mason, as well as from the Lake Linden football field. Each sample was composited from four subsamples collected from the 0- to 4-inch depth. Sample locations and procedures are described in detail in TM 6. Soil samples were analyzed for semivolatile organic and inorganic compounds.

Ten composite soil samples were collected, each comprised of four subsamples representing the corners of the property sampled. Samples were collected using an 18-inch, 3/4-inch diameter silt probe driven to a depth of 0 to 4 inches. Samples were analyzed for Routine Analytical Services (RAS) inorganic compounds and extractable compounds.

In general, the soil cores obtained consisted of various hues of grayish- and brownish-brown, dry to damp silty sand. In most cases, a 1- to 2-inch root zone and darker topsoil was evident. Although signs of contamination were not apparent, traces of tailings and/or slag were noted. Descriptions were recorded on soils data forms.

Additional details of the soil sampling and sample handling procedures are recorded in TM 6 (Appendix A). Deviations from the Field Sampling Plan (Donohue, 1989b), are documented in TM 6.

Additional soil samples were also collected by EPA TAT personnel, and these procedures and results are reported in TM 3.

## 2.5 AIR SAMPLING

Ambient air samples were collected at Torch Lake to provide data to support an air pathway analysis as a component of the baseline risk assessment for OU I. Air monitoring and modeling data were obtained to characterize the airborne transport of fugitive dust from tailings, and to estimate emission rates and concentrations of air contaminants to assess actual or potential receptor exposure to air contaminants.

Michigan Department of Natural Resources (MDNR) personnel conducted the Torch Lake air sampling program according to the procedures described in the Torch Lake RI/FS Field Sampling Plan (Donohue, 1989b) and the Quality Assurance Project Plan (Donohue, 1989c). Four sampling locations were selected based upon wind and population profiles to monitor likely exposure points, emissions sources, and background conditions. Total suspended particulate (TSP) high volume samplers were operated over a 1-month period from August 14 to September 13, 1989. Samples were collected for 24-hour periods every other day, resulting in collection of 62 filters of TSP, including five field blanks and five duplicates. Filters were analyzed for TSP at EPA's Region V Central

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Regional Laboratory. The two samples with the highest TSP from each sampler and the highest TSP from the duplicate sampler were analyzed for 26 metals including arsenic, chromium, copper, nickel, lead, and zinc.

Further details concerning the air sampling and meteorological monitoring program are provided in TM 7 (Appendix A). TM 7 includes MDNR's documented report.

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Jacobsville Sandstone occur along the northwest margin of Torch Lake. Immediately adjacent to Torch Lake, bedrock crops out in large areas beneath a thin cover of glacial drift. The Portage Lake Lava Series consists of basalt and andesitic lava flows with interbedded conglomerates and sandstones. The Jacobsville Sandstone is a light red to bleached white, fine- to coarse-grained feldspathic sandstone.

#### 3.1.1.4 Historic Mining Practices

In addition to the tailings piles, abandoned mine works including stamp mills and smelters are a prominent surface feature throughout the region. The tailings were often processed near a waterway. Therefore, many of the shorelines of the lakes and rivers of the region are dotted with the ruins of former stamp mills and smelters. The greatest concentration of these ruins is along the western shore of Torch Lake.

#### 3.1.2 Tailings Surface Features

The western shore of Torch Lake is lined with tailings piles and the associated stamp mill and smelter ruins attributable to past copper mining practices. This section provides detailed descriptions of surface features of OU I tailings, which are themselves the prominent surface feature in the primary study area. OU I tailings were divided into nine sectors as shown on Figure 2-1 based on information obtained in a search of MTU archives and field reconnaissance work as reported in TM 1.

In the following sections, each sector is described in detail. Surface feature physical and locational information for all sectors are summarized in Table 3-1, and additional descriptive information is provided in TM 1 and TM 4 (Appendix A).

##### 3.1.2.1 Sector 1

Sector 1 (Figure 2-2) encompasses approximately 110 acres of red conglomerate tailings. The tailings consist of primarily dusky red to reddish brown, fine, and medium silty sand. In addition to being one of the largest tailings piles along the west shoreline of Torch Lake, Sector 1 exhibits the greatest relief of any of the sectors. Relief in the north-central portion of the sector is on the order of 20 to 30 feet. As is the case with many of the sectors, Sector 1 has little or no relief along its perimeter. Vegetation is sparse except along the northern perimeter adjacent to the Trap Rock River and in those areas where vegetation has been actively encouraged through the addition of topsoil and planting of pine trees. Vegetation is primarily confined to an area surrounding the sewage ponds and public campground. Areas of stressed vegetation are also evident. Surface features unique to Sector 1 include an abandoned landfill and associated miscellaneous surface debris, sewage ponds, a public beach, campground, and park. Sampling and analysis to characterize the abandoned landfill or the sewage ponds were not within the scope of the field activities conducted for the OU I remedial investigation. Slime patches consisting of broken chips resembling weathered shale and dry powder-like fine clayey silt are apparent at the surface. Slime is the mining engineering term for the fine-grained material produced during the copper reclamation process.

#### 4.0 NATURE AND EXTENT OF CONTAMINATION

This chapter presents the results of OU I site and waste characterization for both natural chemical components and contaminant compounds, for the media sampled in OU I RI field investigation activities. These media include drums, OU I tailings, soil, and air. This chapter emphasizes the chemicals of potential concern for this site which were identified in data evaluation performed for the Baseline Risk Assessment (Appendix B).

##### 4.1 DRUMS

The 1989 drum investigation included both a geophysical survey to attempt to define the extent and location of drums buried in OU I tailings, and sampling and analysis of surface drums to determine the nature of their contents. RI activities related to identifying the nature and extent of drum wastes will continue in 1990 when additional exposed, buried, and submerged drums will be staged and sampled. Therefore, this report presents the results of initial activities only. Evaluation of the nature and extent, fate and transport characteristics, or risk associated with drum-related contamination will be performed and presented after additional drum investigation activities are conducted.

##### 4.1.1 Geophysical Survey

The results of the geophysical survey of OU I tailings are discussed in detail in TM 2 and in TM 9. The ground penetrating radar data from the three tailings sites investigated were difficult to interpret because of the complex appearance of the signal reflection. This was attributed to the extensive metallic debris in OU I tailings fill areas. Also, radar target data did not correspond to magnetic data.

The radar record from the Stampmill Site indicated radar targets that may include buried drums or other cylindrical metallic objects. The Stampmill Site radar targets did not correspond to magnetic anomalies indicating that the buried objects are non-ferrous (not iron or steel). Only a few radar targets were recorded at the Centerline Apartments Site, and these did not correspond to the magnetic anomalies. This indicates that these targets are also non-ferrous materials. The non-magnetic radar targets may be attributable to large boulders of copper which did not go through crushers in the stampmills, and were often thrown into the tailings piles.

Radar targets were not found at the Stampmill and Centerville Apartments Sites at the locations of magnetic anomalies, suggesting that (1) scrap iron or steel may also be found at these locations, or (2) the magnetic anomalies are outside of the spacing of the radar lines.

The radar targets at the Sewage Pond Site did correspond to magnetic anomalies. These targets have the best chance to be buried drums. However, not all magnetic anomalies were associated with radar targets.

Test pit excavations are required to verify whether the radar targets or magnetic anomalies represent buried drums. Test pit excavations and drum sampling are scheduled for 1990.

#### 4.1.2 Analysis of Surface Drum Contents

As discussed in Section 2.2.2, EPA TAT personnel sampled the contents of eight drums found exposed at various locations on the surface of OU I tailings. The analytical data reported in TM 3 indicate that for seven of the drums, the concentration of hazardous constituents was very low as measured by the EP toxicity test. None of the drum waste material sampled is considered hazardous based on RCRA characteristics of EP toxicity. PCBs and pesticides were not found above method detection limits in any drum. In general, only traces of volatile and semivolatile organic compounds were found. One overturned and leaking drum from a Hubbell sampling location contained 4,000 ppm of trichloroethylene (TCE). It is suspected that this drum is not related to past site operations, but rather to a recent unauthorized disposal.

The TAT assessment did not indicate that immediate removal of the drums was necessary.

#### 4.2 TAILINGS

Radiation readings above background were not measured for any tailings sample (TM 4).

Analytical chemistry data for OU I tailings samples are presented and discussed in TM 10. A summary of the ranges in concentration of chemicals of potential concern measured in surface and subsurface tailings samples is shown in Table 4-1. This table also presents naturally occurring, native soil concentrations. The data and discussion in TM 10 provide the following conclusions regarding the distribution of chemicals in OU I tailings.

Detectable amounts of semivolatile organic compounds were measured in surface (0 to 6 inch) tailings samples in all sectors. Bis(2-ethylhexyl)phthalate (BEHP) was the most widespread, and was measured in all sectors except Sectors 4, 7, and 9. The highest concentrations and the largest number of semivolatile organic compounds were measured in Sectors 3 and 8. Fifteen base/neutral extractable compounds, primarily polycyclic aromatic hydrocarbons, were detected in Sectors 3 and 8. The highest concentrations of semivolatile organic compounds measured were for benzo(b)fluoranthene or benzo(k)fluoranthene in Sector 8.

Semivolatile organic compounds were also measured in subsurface tailings samples taken from the 0 to 3 foot depth in all sectors except Sectors 4 and 9. The largest number of subsurface semivolatile organic compounds and the highest concentrations were also found in Sectors 3 and 8.

The distributions and concentrations of semivolatile organic compounds were similar for surface and subsurface tailings samples. Sectors 3 and 8, where semivolatile organic compounds were detected, were the same sectors where

TABLE 4-1

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN  
DETECTED IN OPERABLE UNIT I TAILINGS  
TORCH LAKE RI/FS  
AUGUST, 1989

	<u>Range of Concentrations, mg/kg</u>		<u>Native Soil</u>
	<u>Surface Tailings</u>	<u>Subsurface Tailings</u>	<u>Concentrations,</u> <u>mg/kg</u>
<u>Organic Compounds</u>			
bis(2-Ethylhexyl) phthalate	0.038J - 1.2	0.11 - 1.1U	150 - 925
<u>PAHs</u>			
Naphthalene	0.050J - 0.44U	0.08J - 0.43U	1 - 5
2-Methylnaphthalene	0.069J - 0.44U	0.12J - 0.43U	
Acenaphthylene	0.037J - 0.44U	0.35U - 0.43U	
Phenanthrene	0.049J - 0.44U	0.073J - 0.43U	
Fluoranthene	0.039J - 0.44U	0.048J - 0.43U	0 - 0.04
Pyrene	0.047J - 0.44U	0.06J - 0.43U	0 - 0.015
Benzo(a)anthracene	0.054J - 0.44U	0.022J - 0.43U	0 - 0.01
Chrysene	0.046J - 0.44U	0.025J - 0.43U	0 - 5
Benzo(b)fluoranthene	0.057J - 0.56	0.066J - 0.43U	0 - 0.03
Benzo(k)fluoranthene	0.067J - 0.56	0.066J - 0.43U	0 - 0.015
Benzo(a)pyrene	0.048J - 0.44U	0.02J - 0.43U	0 - 8
Indeno(1,2,3-cd) pyrene	0.091J - 0.44U	0.140J - 0.43U	0 - 0.015
Dibenzo(a,h) anthracene	0.044J - 0.44U	0.066J - 0.43U	
Benzo(g,h,i) perylene	0.099J - 0.44U	0.160J - 0.43U	0 - 0.02
<u>Inorganic Compounds</u>			
Aluminum	5,190 - 37,200	5,410 - 27,200	10,000 - 300,000
Antimony	3.4U - 11.7	3.5 - 7.3	
Arsenic	0.37U - 8.3	0.47 - 14.4	1.0 - 40
Barium	5.5 - 135	5.1 - 68	100 - 3,500
Beryllium	0.18U - 1.7	0.18U - 1.0	0.1 - 40
Boron	N/A	N/A	
Chromium	10.7 - 46.3	13.6 - 42.7	5.0 - 3,000
Cobalt	5.4 - 52.6	8.5 - 32.8	1.0 - 40
Copper	72.3 - 3,020	699 - 5,540	2.0 - 100
Lead	1.5 - 104	0.38U - 82.8	2.0 - 200
Manganese	103 - 1,080	217 - 703	100 - 4,000

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railroad ties, tar roofing, or coal debris were documented in the field sampling logs (see Table 3-1). Sectors 3 and 8 were the only sectors where the presence of coal at sampling locations was documented. All of the semi-volatile polycyclic aromatic hydrocarbon chemicals of potential concern are documented as being derived from coal, coal-tar, wood preservative sludge, or petroleum sources (Verschuere, 1983).

Inorganic compounds of potential concern including chromium, cobalt, copper, lead, nickel, and vanadium were found in most sectors at varying concentrations.

Arsenic was found in Sectors 1, 3, 5, 6, and 7. Arsenic was found in subsurface samples for Sectors 3 and 6. Arsenic levels in slag samples exceeded typical native soil levels. Mercury was detected in all samples from Sectors 3 and 8 at concentrations exceeding typical soils.

The concentration and distribution of metals appeared to be similar in the surface and subsurface samples. For inorganic constituents, the majority of the subsurface tailings concentrations are within or below the range of concentrations found at the surface.

In general, copper concentrations measured in tailings are elevated above the range generally found in soils. This is expected because of the occurrence of native copper in the Keweenaw Peninsula.

Slime material, the fine-grained tailings material deposited in layers in the tailings, contained higher concentrations of chromium than tailings samples. The concentrations of other inorganic compounds such as arsenic, copper, and lead are similar in slime samples and tailings samples.

Slag material, produced by smelting high copper concentrate produced in the stamping and flotation processes, exhibited higher concentrations of arsenic, chromium, copper, and lead than the concentrations measured in the tailings samples.

In summary, neither organic nor inorganic compound levels measured in OU I tailings are dramatically higher than those found in naturally-occurring soils.

#### 4.3 SOILS

Soil chemistry analytical results are presented and discussed in TM 11. Ten composite residential soil samples were collected and analyzed during OU I RI activities to assess contaminant distribution from tailings sources. The results are discussed here although neither complete characterization of Torch Lake Superfund Site soils nor assessment of risk attributable to soils was within the scope of OU I RI activities. A summary of the ranges of chemicals of potential concern measured in soil samples and naturally occurring soil concentrations are shown in Table 4-2.

TABLE 4-2  
SUMMARY OF CHEMICALS OF POTENTIAL CONCERN  
DETECTED IN SOIL SAMPLES  
TORCH LAKE RI/FS  
AUGUST, 1989

	Range of Concentrations, mg/kg	Native Soil Concentrations, mg/kg
<u>Organic Compounds</u>		
bis(2-Ethylhexyl) phthalate	0.800 - 3.8	150 - 925
<u>PAHs</u>		
Naphthalene	U - 0.071J	1 - 5
2-Methylnaphthalene	U - 0.054J	
Acenaphthylene	U - 0.13J	
Phenanthrene	0.049J - 1.900	
Fluoranthene	U - 0.092J	0 - 0.04
Pyrene	0.045J - 2.600	0 - 0.015
Benzo(a)anthracene	U - 1.500	0 - 0.01
Chrysene	U - 1.600	0 - 5
Benzo(b)fluoranthene	U - 1.500	0 - 0.03
Benzo(k)fluoranthene	U - 0.670	0 - 0.015
Benzo(a)pyrene	U - 1.600	0 - 8
Indeno(1,2,3-cd)pyrene	U - 0.630	0 - 0.015
Dibenzo(a,h)anthracene	U - 0.290J	
Benzo(g,h,i)perylene	U - 0.670J	0 - 0.02
<u>Inorganic Compounds</u>		
Aluminum	3,140 - 7,600	10,000 - 300,000
Antimony	U	
Arsenic	U - 7.00	1.0 - 40
Barium	U - 101.00	100 - 3,500
Beryllium	U	0.1 - 40
Boron	U	
Chromium	5.90 - 20.10	5.0 - 3,000
Cobalt	U	1.0 - 40
Copper	58.30 - 459.0	2.0 - 100
Lead	6.10 - 329.0	2.0 - 200
Manganese	91.40 - 357.0	100 - 4,000

TABLE 4-2

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN  
DETECTED IN SOIL SAMPLES  
TORCH LAKE RI/FS  
AUGUST, 1989  
(continued)

	Range of Concentrations, mg/kg	Native Soil Concentrations, mg/kg
Mercury	0 - 0.47	0.01 - 0.08
Nickel	0 - 33.70	5.0 - 1,000
Silver	1.5U	0.1 - 5.0
Titanium	U	1,000 - 10,000
Vanadium	11.40 - 26.30	20 - 500

**Notes:**

- o U indicates compound was not detected and the numerical value indicates the contract required quantitation limit, adjusted for dilution and percent moisture (organics) or the instrument detection limit (inorganics).
- o N/A indicates chemical not analyzed for in this medium.
- o J indicates this value is estimated.
- o PAH denotes polycyclic aromatic hydrocarbon compounds.
- o Source of naturally occurring native soil concentrations is Dragun (1988).

A/R/TORCHLRI/AB4

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Torch Lake RI/PS  
Final RI Report - OU I  
EPA Contract No. 68-W8-0093

Section No.: 4  
Revision No.: 0  
Date: November 1990

Semivolatile organic compounds were measured in most of the ten soil samples. Base/neutral extractable and TIC hydrocarbons were the most widely distributed. Semivolatile organic compounds detected at levels higher than naturally-occurring levels in soils include: fluoranthene, pyrene, benzo(a) anthracene, benzo(b) fluoranthene, benzo(k) fluoranthene, indeno (1,2,3-cd) pyrene, and benzo(g,h,i) perylene.

Inorganic compounds of potential concern, including chromium, copper, lead, nickel, and vanadium were measured in most of the soil samples. Copper, lead, and mercury were detected at concentrations exceeding native soil concentrations. The measured copper concentrations were higher than typical native soil levels for all soil samples except for that from the football field. High concentrations of lead and mercury were measured in one soil sample from Lake Linden. The sampling team did not observe anything that might explain the high lead and mercury concentration in this sample. High mercury levels were also measured in four samples from Lake Linden and Mason. Arsenic was measured in 8 of 11 soil samples, at levels typical of naturally occurring soils.

EPA Technical Assistance Team (TAT) personnel also collected soil samples during a Torch Lake Site Assessment (TM 3). Three samples from locations of suspected contamination in Hubbell and Mason and a background soil sample from the east side of Torch Lake were analyzed for volatile and semivolatile organic compounds, EP toxicity metals, total metals, and cyanide. Methylene chloride, phenanthrene, fluoranthene, pyrene, chrysene, and di-n-octyl phthalate were detected from a soil sample collected directly underneath a drum. No pesticides or PCBs were detected. EP toxicity metals concentrations were below maximum concentrations (40 CFR 261). All of the metals detected were within the typical concentration ranges of metals in soils.

The inorganic compounds measured in the ten residential soil samples collected for the RI field investigation (TM 11) are generally an order of magnitude higher than concentrations measured in the TAT background soil sample collected from the east side of Torch Lake (TM 3).

#### 4.4 COMPARISON OF TAILINGS AND SOIL CHEMISTRY

In general, semivolatile organic compound levels were orders of magnitude higher in soil samples than in tailings samples. Arsenic, chromium, and copper concentrations are generally similar in soil samples and tailings samples. The highest level of lead measured was detected in a soil sample.

For both tailings and soil samples, contaminant compounds were distributed in a non-homogeneous manner. There was no pattern of distribution which suggested impact of tailings-derived compounds to residential soils. The sporadic distribution, the lack of geographical proximity, and the concentrations measured suggest that detected compounds are unrelated between these media.



## 5.0 CONTAMINANT FATE AND TRANSPORT

This chapter addresses potential routes of contaminant migration and contaminant persistence and mobility for chemicals of potential concern in OU I tailings.

### 5.1 POTENTIAL ROUTES OF MIGRATION

The remedial investigation and risk assessment for Operable Unit I address the potential routes of migration highlighted in Figure 1-5. Contaminant migration from OU I tailings could occur by generation of particulate material, or by infiltration, runoff, or erosion. Contaminant migration could also occur from secondary sources such as soil.

Particulate generation may occur when fugitive dust is generated by wind erosion of exposed tailings. Vehicular travel over contaminated tailings also creates dust and may be a source of airborne contaminants. Evaluation of the air exposure pathway was conducted by emissions and air modeling as part of the Baseline Risk Assessment (Chapter 6 and Appendix B).

Quantification of other migration pathways was not part of the scope of this investigation. Contaminant infiltration from OU I tailings will be addressed by collection and analysis of groundwater samples from beneath OU I tailings during the OU II RI, and by leaching tests conducted by the Bureau of Mines. Contaminant runoff and erosion will also be addressed after collection of surface water and sediment samples in the OU II RI. The potential for contaminant migration from drums in OU I tailings will be addressed after additional investigations to locate and sample drums to determine the nature and extent of drum-derived contamination.

The significance of contaminant migration by infiltration, runoff, or erosion routes is limited by the persistence and mobility of the contaminant types detected in OU I tailings. Contaminant persistence and mobility are discussed below for OU I chemicals of potential concern.

### 5.2 CONTAMINANT PERSISTENCE AND MOBILITY

There are several mechanisms that can affect contaminant fate and transport in the environment. These include transformation mechanisms (such as biotransformation, hydrolysis, oxidation, and precipitation); phase change mechanisms (such as volatilization, sorption, ion exchange, and dissolution); and transport mechanisms (such as advection, diffusion, complexation/chelation, and particle-facilitated transport). These mechanisms can cause loss, movement, change, or retardation of contaminants in the environment. The potential for these mechanisms to contribute to contaminant fate or transport in OU I tailings is determined by the chemical and physical properties of the tailings and of the compounds of interest. The chemicals of potential concern identified for OU I tailings include primarily polycyclic aromatic hydrocarbons (PAHs) and inorganic compounds. The fate and transport characteristics of these classes of compounds are discussed in the following sections.

**Reference 2**

**Excerpts From Site Assessment for Torch Lake,  
Houghton County, Michigan, Report, EPA Contract No. 68-01-7367;  
Prepared for EPA by WESTON-Major Programs TAT;  
1990**

**SITE ASSESSMENT**  
**FOR**  
**TORCH LAKE**  
**HOUGHTON COUNTY, MICHIGAN**

**Prepared for:**  
**U.S. Environmental Protection Agency**  
**Region V**  
**230 South Dearborn Street**  
**Chicago, Illinois**

**CONTRACT NO. 68-01-7367**

**TAT-05-G2-01666**

**TDD# 5-8906-06 and 06A**

**Prepared by:**  
**WESTON-Major Programs**  
**Technical Assistance Team**  
**Region V**

**FEBRUARY 1990**

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## **1.0 SITE DESCRIPTION**

Torch Lake is located on the Keweenaw Peninsula in Houghton County, Michigan (Figure 1). At its southern end, it feeds into Portage Lake, which is part of the Keweenaw Waterway that opens into Lake Superior. Torch Lake is located approximately 14 miles north of the Keweenaw Bay. The lake has a surface area of 2,717 acres, a mean depth of 56 feet, and a maximum depth of 115 feet. The towns of Hubbell (population 1,278), Lake Linden (population 1,200), Quincy (population approximately 10) and Mason (population approximately 50), are located on the west side of Torch Lake (Figure 2).

The Torch Lake area is a remnant boom town from the late nineteenth and early twentieth centuries, when the local copper mining industry was at its peak. Although populations have declined, the Torch Lake area is still maintained as a habitat for wildlife and a recreational area for fishing, boating, and swimming. Many people currently own cottages at or near the lake which they use on a seasonal basis. Torch Lake is also used for a non-contact cooling water supply and for treated municipal wastewater assimilation.

### **1.1 Topography**

The topography of Torch Lake is governed primarily by the various rock lithologies and faulting processes of the area. Within three miles west of Torch Lake, the relief ranges from 600 feet to 1,200 feet. To the east, relief is considerably lower due to the more easily eroded bedrock. Also noted to the east are numerous lakes and wetlands which are characteristic of a recently glaciated plain.

### **1.2 Surface Water**

The major sources of inflow to Torch Lake are Trap Rock River, and Hammell, Dover, McCallum, and Sawmill Creeks. The largest is Trap Rock River which discharges directly into the north end of Torch Lake. The Trap Rock River watershed covers approximately 46 square miles and 58% of the total Torch Lake Basin. As a result of the mining industry, tributaries to the Torch Lake Basin transport an abundance of stored mine tailings. It is estimated that 2,000 kilograms per year of dissolved copper is transported through tributaries into Trap Rock River and eventually deposited into Torch Lake. Transport of these tailings during high magnitude discharge is expected during the winter thaw flooding events.

### **1.3 Geology**

Most of the western shoreline of Torch Lake is composed of variable sized tailing material. The material ranges from pebbles to coarse sand to fine silt. The remaining constituents of the shoreline sediments are conglomerate and basaltic rock indigenous to the Upper Peninsula.

The Keweenaw Peninsula is underlain by Precambrian rocks over which glacially transported deposits are lain. Multiple advances and retreats during glacial episodes have scoured the resistant bedrock and infilled many of the alluvial valleys. The various types of glacial deposits that are found in the region include till, lacustrine, and outwash.

#### 1.4 Soils

The soils in the area consist primarily of sandy and silty loams. These types of soils develop from till, outwash, Holocene alluvium, and reddish clays. In local areas, the reddish clays are deposited between the ground surface and the bedrock. Soils in the glacial deposits are spodosol, which develop under forest vegetation and tend to concentrate iron and aluminum oxides within the reddish clay "B" horizon. The soils in the area tend to have fragipans which develop 19 - 24 inches below the surface. The fragipans resist root penetration and water infiltration, directing the flow of water laterally before penetrating into the ground water system.

#### 1.5 Ground Water

The U.S. Geological Survey conducted well water sampling in 1968 and 1977. Analysis of those samples indicate that of 35 wells in Houghton County, only three had a specific conductance greater than 500 micromhos per centimeter (umho/cm) (EPA, 1981). The data from the analysis of the Houghton County well water samples also showed most of the wells contained very low levels of chloride, sulfates and dissolved solids. The pH ranged from 5.0 - 9.0 for the 35 wells. During the time of these tests, analysis of the data indicated a good quality water source for the general area.

All ground water wells drilled on the north and west side of Torch Lake are set in bedrock due to the bedrock's high stratigraphic position. Many of the Torch Lake communities and seasonal residents have converted their homes to a municipal well water system or the Gregorie water system, an independently owned well water supplier. Other communities, such as Hubbell, receive their water supply from larger cities, such as Calumet to the northwest.

#### 2.0 SITE BACKGROUND

Torch Lake is located in the copper mining district of the upper peninsula of Michigan. Deposits of native copper extend 100 miles southwest, in a belt beginning at the tip of the Keweenaw Peninsula. Copper mining began on the Keweenaw Peninsula in the 1860s with the first mill opening on Torch Lake in 1868. Milled copper was extracted by crushing or "stamping" the rocks into smaller pieces. The extracted copper was then sent to a smelter and melted. The remaining crushed rock particles, called "tailings" or "stampsands", were discarded with the mill processing water into Torch Lake or the Keweenaw waterway. Mining output,

milling activities and tailings production peaked in the Torch Lake area in the early 1900s to 1920. All of the mills were located on the north shore of the lake. Records from the mills describe pumping of tailings into Torch Lake as well as deposition of tailings on property around Torch Lake.

In around 1916 and 1917, new technology was introduced to extract copper which utilized lime, pyridine oil, coal-tar creosotes, wood creosote, pine oil, cupric ammonia and xanthates. After the extraction, the chemically contaminated water was returned to the lake.

In the Torch Lake area over 10.5 billion pounds of native copper were processed. Between 1868 and 1968 at least 200 million tons of tailings were dumped into Torch Lake, filling at least 20 percent of the original volume of the lake, resulting in drastic changes in the geography of the shoreline.

In the 1920s, workers angry during local mill strikes were rumored to have concealed explosives in drums. Information from local residents indicates that the explosive drums may have been left along the shores of Torch Lake, and may have eventually been placed in the Lake.

In the 1970s, the Michigan Water Resources Commission (MWRC) collected baseline data on the chemical profile of the water and the biota of Torch Lake. In 1972 a large volume of cupric ammonium carbonate was discharged from storage tanks located at the Lake Linden Leaching Plant into Torch Lake. The MWRC investigated the spill and determined that no significant deleterious effects from the spill had occurred to the surface water quality, algae and fish, based on comparisons to the data from the 1970 study.

Michigan Technical University (MTU) researchers have contributed numerous studies on the impact copper mining wastes have had on the water quality and biological integrity of the Torch Lake area. Some examples of studies conducted by MTU are: "Tumor Induction Study" of fish liver histology; the "Environmental Fate of Xanthates and Creosotes"; the "Tumor Incidence and Parasite Survey of Perch, Walleye, and Sauger from Torch Lake, Houghton County Michigan"; and the "Copper Budget for Torch Lake".

Torch Lake presently receives industrial discharge from mining and non-mining industry. In 1980 the Peninsula Copper Industry Recycling Plant, owned by the Venture's Group, began operations which includes discharging its non-contact cooling water into Torch Lake. Exploratory research at the Centennial Mine in 1980 resulted in a dewatering discharge into the Slaughterhouse Creek, a tributary of Trap Rock River which flows into Torch Lake.

In 1983, the Michigan Department of Public Health (MDPH) issued an advisory against the consumption of all sauger and walleye from Torch Lake because of the number of fish that had dermal tumors. The advisory was issued as a precautionary measure until the causative factor(s) of the fish tumors and the potential risk to humans could be identified. The advisory was still in affect at the time of Technical Assistance Team (TAT) sampling in July 1989. In 1983, the International Joint Commission Water Quality Board designated Torch Lake as a Great Lakes Area of Concern (AOC). An AOC is defined as an area with a known impairment of a designated use. The AOC is confined to Torch Lake and its shores on the basis of the fish consumption advisory, tumor frequency, metal-contaminated sediments, the impact on biota, and the history of mining waste disposal. In 1986 a study by the MNDR determined that the lake sediments are heavily contaminated with heavy metals such as copper, zinc, tin, and lead. On June 10, 1988, Torch Lake was placed on the National Priorities List (NPL), under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and on September 28, 1988 a Remedial Investigation/Feasibility Study (RI/FS) was initiated by the U.S. Environmental Protection Agency (U.S. EPA), with Jae Lee as U.S. EPA Remedial Project Manager (RPM).

### 3.0 SITE INSPECTION

On June 21, 1989, TAT was tasked by the U.S. EPA to perform a site assessment and collect samples from abandoned drums and visually contaminated soils along the northern perimeter of Torch Lake. On July 17, 1989, TAT was additionally requested to collect residential and municipal well water samples.

#### 3.1 Drum and Soil Sampling

On June 21, 1989, TAT members Steve Renninger, Frank Beodray, and Louise Raimondo were met by U.S.EPA On-Scene Coordinator (OSC) Walter Nied and RPM Lee in the town of Lake Linden located on the shores of Torch Lake. TAT conducted sampling of drums and potentially contaminated soils along the shoreline of Torch Lake.

Eight drum and five soil samples were collected along the northern and western shoreline of Torch Lake (Table 1). Air monitoring was conducted in the sampling areas with a photoionization detector (HNU - 10.2 ionization potential probe) and radiation meter. TAT sampled two locations at Lake Linden. At the first sample location, which was situated along the debris-covered shoreline of Torch Lake (Figure 3), three drum samples were collected (S-57, S-58, S-59). A soil sample (S-65) was collected from a man-made tailings island covered with stunted conifer vegetation. Sample S-60 was collected near an abandoned building from corrugated material used for roofing which had weathered and fallen to the ground (Figure 4). The TAT documented the presence of unidentified drums containing wastes, steamlines with deteriorated insulation,

and two storage tanks within the abandoned warehouse. No ambient air readings exceeded background levels at the Lake Linden sampling locations.

TAT then collected samples from drums located in the southern extent of the city of Hubbell, which is locally referred to as Tamarack City. Drums were sampled in three separate areas in Hubbell (Figure 4). The first drum sampling area was located along the debris-covered shoreline of Torch Lake. One drum sample (S-61) was collected because it was believed to be representative of all the drums. TAT photodocumented the drums scattered along the shoreline and into the shallows of Torch Lake. The second drum sampling area in Hubbell was located away from the shoreline in a heavily vegetated area. Sample S-62 was collected from an overturned drum which was observed to contain a black, tar-like waste that had partially spilled onto the soil. Two samples, S-63 and S-64, were collected at the third sampling location from the soils adjacent to two transformer pads, where local residents had previously reported fluid spills. No readings were recorded above background during air monitoring at the Hubbell sampling locations.

The final sampling locations were near the town of Mason (Figure 5). TAT conducted air monitoring in the sampling areas recording no ambient air readings above background levels. Two locations were sampled by TAT in a wooded area containing randomly dispersed 55-gallon drums. A total of four samples were collected: one solid (S-67), from an overturned, uncovered drum; one soil (S-68), collected directly underneath a drum; and two liquid (S-66 and S-69), from drums that contained liquids.

A background sample (S-70) was collected on the east side of Torch Lake. Analytical parameters are summarized in Table 1. The samples were analyzed by National Contract Laboratory Program (CLP) Laboratories and ATEC Associates, Inc.

### 3.2 Ground Water Sampling

On July 18, 1989, TAT members Beodray and Anne Anderson returned to Houghton, Michigan, to conduct water sampling of residential and municipal wells in or around Torch Lake. The purpose of the well water sampling was to determine whether the potential contamination of Torch Lake had affected ground water quality. Air monitoring with the HNU was conducted on a sample-by-sample basis.

TAT sampled the water of six private residential wells, two municipal wells and one well providing water to 40 renters in the town of Mason (Table 2). All private well water samples were collected along the northern shore of Torch Lake along State Route #1 (Bootjack Road) and Trap Rock Road (Figures 6 and 7). The following objectives were used in determining the well locations to be sampled: wells which were located in close proximity to suspected sources of contamination; were of shallow depth; were screened in suspect formations; were located in close proximity to the lake; and/or serve a large number of people (>30 individuals)



Samples were collected from the spigot located closest to the well and prior to any water treatment system or holding tank. All samples were analyzed for volatile organic compounds (VOCs) and hazardous substance list (HSL) metals, and two samples were additionally analyzed for acid and base/neutrals (ABN) and cyanide, under TAT Analytical Services TDD#5-8907-L4, by Weston-Gulf Coast Labs.

#### 4.0 ANALYTICAL RESULTS

The analytical results from the TAT sampling are summarized in Tables 3-7.

##### 4.1 Drum and Soil Sampling

The EP toxicity metals data, summarized in Table 3, indicates that none of the material sampled is considered hazardous based on the RCRA characteristics of EP toxicity (all levels were below the maximum concentrations established in 49 CFR Part 261).

Analytical results of the RCRA/asbestos analysis are summarized in Table 4. The material sampled for RCRA parameter analysis was not considered to be hazardous based on RCRA characteristics. Asbestos analysis indicates that the roofing tile material contains 30-40 percent chrysotile asbestos.

Organic analysis of the samples is summarized in Table 5. None of the samples contained pesticides or PCBs above method detection limits. The sample from Hubbell-Drum #2 (S62) contained 4000 ppm trichloroethene (TCE) and 34 ppm bis(2-ethylhexyl)phthalate. Samples S-58 and S-66 contained methylene chloride at 5 ppm and 3 ppm respectively, but methylene chloride was also detected in the background sample. Contaminants detected at estimated levels include: acetone, benzene, 2-hexanone, xylene, tetrachlorethene, benzoic acid, phenanthrene, fluoranthene, pyrene, chrysene, di-n-octylphthalate, naphthalene and 2-methylnaphthalene. Additional tentatively identified organic compounds for the samples are summarized in Attachment A. The analytical results of the total HSL metals and cyanide analysis for the background soil sample are summarized in Table 6. All of the levels detected were within the typical concentration ranges of metals in soil. Total metals and cyanide analytical results for the remaining samples were not available at the time of writing.

##### 4.2 Ground Water Sampling

Analytical results of the TAT well water sampling are summarized in Table 7. The sample collected from the Village of Lake Linden Municipal Well (S-77) contained iron levels (0.33 ppm) greater than the secondary maximum contaminant level (SMCL) of 0.3 ppm. None of the organics detected in the samples were at levels above the MCL or removal action level (RAL).

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**TABLE 7**  
**ANALYTICAL RESULTS OF TAT WELL WATER SAMPLING\***  
**TORCH LAKE, HUBBELL, MI**  
**JULY 18, 1989**

<b>Parameter</b> <b>(results in ug/l)</b>	<b>Jolly</b> <b>8-11</b>	<b>Sturvia</b> <b>8-11</b>	<b>LaCrosse</b> <b>8-11</b>	<b>Mason</b> <b>8-11</b>	<b>Blank</b> <b>8-11</b>	<b>Lake</b> <b>Linden</b> <b>8-11</b>	<b>Destramps</b> <b>8-11</b>	<b>Warners</b> <b>8-11</b>	<b>St. John</b> <b>8-11</b>	<b>Removal Action Level<sup>1</sup> or</b> <b>Maximum Concentration</b> <b>Level<sup>2</sup> (1° or 2°)</b>
Aluminum	.043	.034	.047	.033	.044	.030	.093	.18	.064	--
Barium	.076	.058	.23	.20	ND	ND	.069	.039	ND	1.8
Calcium	31.3	30.4	36.2	32.8	.11	23.3	18.1	29.6	4.6	--
Copper	ND	.021	ND	ND	ND	ND	ND	ND	.031	1.0 (2°)
Iron	.20	.064	.25	.19	ND	.33	.045	.019	.084	.3 (2°)
Lead	ND	.0019	.0092	.0013	.0023	ND	ND	ND	.0034	.03 (At cap)
Magnesium	9.1	9.4	8.7	10.3	ND	8.9	8.9	7.9	1.9	--
Potassium	1.3	1.4	.90	3.3	ND	1.8	2.3	1.0	2.0	--
Sodium	3.3	3.7	2.8	10.3	ND	14.1	3.3	2.9	1.3	--
Vanadium	ND	ND	ND	.010	ND	ND	.012	ND	ND	--
Zinc	.33	.022	.10	1.1	.010	.031	.030	.015	.10	5.0 (2°)
<b>(results in ug/l)</b>										
Chloromethane	2J	ND	ND	ND	ND	ND	ND	ND	ND	--
Methylene Chloride	3JB	3JB	2JB	4JB	4JB	48	4JB	2JB	2JB	48
Acetone	ND	ND	8JB	ND	7JB	ND	ND	ND	ND	--
Bis(2-ethylhexyl) Phthalate	NA	NA	NA	4JB	3JB	NA	NA	NA	NA	--
1,4-Dichlorobenzene	NA	NA	NA	ND	2J	NA	NA	NA	NA	173

NA = Not Analyzed

-- = Not Available

J = Estimated Value

B = Detected in lab blank

ND = Not detected at method detection limits

\*Samples analyzed by Weston-Gulf Coast under TAT Analytical Service TDD85-8907-L4

<sup>1</sup>OSWER Directive 9360.1-10

<sup>2</sup>Safe Drinking Water Act

**Reference 3**

**Excerpts From Superfund Fact Sheet:  
Torch Lake Superfund Site, Houghton County, Michigan;  
EPA Region V; 1989**

## ■ Background continued from Page 1

Torch Lake's western shore, the larger communities of Houghton, Hancock, and Calumet lie 10-15 miles further to the west. **Wetlands** bound the lake on the east. Torch Lake is used for fishing, boating, swimming, non-contact cooling, water supply, and wildlife habitat. In addition, treated wastewater from the regional sewage lagoon system is discharged into Torch Lake.

### History of Mining Operations at the Site

For approximately 100 years, from 1868 to the late 1960s, Torch Lake was the site of copper milling and smelting facilities and was a dumping ground for copper mining and milling wastes. All of the mills were located on the west side of the lake. Copper was extracted by crushing or stamping the rock into smaller pieces, grinding the pieces, and driving them through successively smaller meshes. Until the early 1900s, the copper and crushed rock were then separated using gravity. The copper was subsequently sent to the smelter, and the crushed rock particles, called "**tailings**" or "**stamp sands**," were discarded with the mill processing water, typically into the lake or waterway. Because of the inefficiency of this early milling process, substantial amounts of copper remained in the discarded tailings.

By 1916, reclamation plants were using new processes to recover additional copper from the discarded tailings. One of

these processes involved dredging up the tailings, combining them with water and oil, and agitating the mixture to produce a froth upon which copper-bearing particles would float. During the 1920s, a variety of chemicals were used to further increase the efficiency of this process. After the process was completed, the chemically treated tailings were once again dumped back into Torch Lake.

By the time the last copper mill had closed in 1968, over 10.5 billion pounds of native copper had been produced from this area. More than half of this amount had been processed along the shores of Torch Lake. Between 1868 and 1968, approximately 200 million tons of tailings were dumped into Torch Lake, filling in at least 20 percent of the lake's original volume. These deposits created small tailings "peninsulas" in the lake and resulted in other changes to the original shape of the shoreline.

### Environmental Actions to Date

Environmental concern about the century-long deposition of tailings into Torch Lake began in the early 1970s. High levels of copper and **heavy metals** (such as **arsenic** and **chromium**) found in Torch Lake water, **sediments**, and **tailings**, chemical spills and other toxic discharges, and fish tumors have prompted many investigations into the possible impacts of mine-waste disposal. Numerous regulatory actions have been

taken by state, national, and international agencies. For example, in 1972 the Michigan Water Resources Commission studied the impact of a chemical spill into the northern end of Torch Lake at the Lake Linden Leaching Plant. In 1983, the Michigan Department of Public Health announced an advisory against consuming Torch Lake sauger and walleye because of reported abnormalities and lesions in the fish. (A full chronology of significant regulatory agency activities at the Torch Lake site is presented on page 4.) However, the causes and full extent of the environmental problems related to Torch Lake remain unclear.

In 1984, U.S. EPA designated Torch Lake as a **Superfund** site, adding it to the **National Priorities List**, a roster of uncontrolled hazardous waste sites eligible for federal investigation and cleanup funds. U.S. EPA took this action based on: (1) the elevated levels of copper and heavy metals found in Torch Lake water, sediments, and tailings; (2) the 1972 chemical spill into the north end of Torch Lake; and (3) the 1983 fish consumption advisory. In 1985, U.S. EPA began a search for **Potentially Responsible Parties (PRPs)** and has so far identified and concluded negotiations with three PRPs. In 1988, the State of Michigan issued a letter of assurance enabling U.S. EPA to conduct a long-term RI/FS. Specifics about the EPA investigation to begin later this month are presented in the following section.

## ■ RI/FS Activities Planned for the Torch Lake Site

As mentioned earlier, the entire Torch Lake Superfund site is quite large, encompassing all of Torch Lake, the northern half of Portage Lake, the North Entry to Lake Superior, and tributary areas. Furthermore, nine different kinds of samples may need to be collected and analyzed: (1) **tailings**, (2) **surface water**, (3) **ground water**, (4) **drums**, (5) **soil**, (6) **wetlands**, (7) **sediments**, (8) **air**, and (9) **biota**, especially the fish population (see Figure 2).

Because of the magnitude of the site and the diversity of sampling and analysis that may be necessary, U.S. EPA has divided the site into three segments, called **Operable Units (OU)** (Figure 3). Operable Unit I (OU I) includes the surface tailings on the western shore of Torch Lake. Operable Unit II (OU II) includes other areas of potential contamination in and around Torch Lake, including soil, ground water, submerged tailings, sediment, surface water, and

biota. Operable Unit III consists of other tailings sources in the mid-Keweenaw Peninsula, including the North Entry, the northern portion of Portage Lake, and tributary areas. Separate RI/FSs will be conducted for each Operable Unit.

The RI/FS for OU I will begin first and is discussed in more detail on the next page.

Continued on page 5

**Reference 4**

**Excerpts From Fish Growth Anomalies in Torch and Portage Lakes,  
1974-1988, Houghton County, Michigan, MI/DNR/SWQ-90/029;  
MDNR, Surface Water Quality Division;  
1990**

MICHIGAN DEPARTMENT OF NATURAL RESOURCES  
SURFACE WATER QUALITY DIVISION  
MARCH 1990

## STAFF REPORT

FISH GROWTH ANOMALIES IN TORCH AND PORTAGE LAKES  
1974-1988  
HOUGHTON COUNTY, MICHIGAN

Following the report and description of several anomalous growths in old sauger and walleyes from Torch Lake (Black et al; 1982), the Michigan Department of Public Health (MDPH) issued a fish consumption advisory for Torch Lake walleye and sauger in 1983. In 1984, the lake (Figure 1) was designated as a 307 site under the Michigan Environmental Response Act, Act 307 of 1982. Also in 1984, the U.S. EPA designated Torch Lake, as well as other locations in the area having mining wastes, as a Superfund site. Site evaluation by EPA is ongoing. In 1985, the International Joint Commission's (IJC) Water Quality Board designated Torch Lake as a Great Lakes Area of Concern (AOC), solely on the basis of the fish consumption advisory limited to sauger and walleye (IJC, 1985). A remedial action plan (RAP) was completed for Torch Lake by the Michigan Department of Natural Resources (MDNR) Surface Water Quality Division and presented to the IJC in 1987 (Evans 1987).

In the RAP, several activities were to be undertaken by the MDNR. Walleye or sauger were to be stocked annually for a period of years and water and fish were to be sampled in 1988 in Torch Lake, as well as the adjoining Portage Lake. Walleyes have since been stocked annually, except for one year when sauger were stocked. Fish were collected in 1988 as planned and analyzed for contaminants and tumors. The purpose of this report is to present the fish contaminant and tumor data and compare it to other data where appropriate.

## FINDINGS AND CONCLUSIONS

1. Organic contaminants were at trace levels in tissues from fish collected in Torch and Portage Lakes. Only four (4) of the 56 fish samples analyzed for mercury had concentrations that exceeded the 0.5 mg/kg consumption advisory action limit and none exceeded 1.0 mg/kg. Overall, the fish from these lakes are among the least contaminated fish encountered in the Michigan Fish Contaminant Monitoring Program.
2. No internal or external growth anomalies were observed among the 458 fish collected in 1988. No liver neoplasms (cancerous growths) were found among the 47 walleyes collected in 1988 nor in 25 walleyes collected in 1985. The incidence of liver neoplasms has apparently declined and may now be near normal background levels, however, additional study is needed to more accurately determine normal or background tumor frequencies, especially in older and larger fish

3. Saugers were not collected in 1988 following an extended period of population decline which began in the 1960's. Sauger are a turbid water fish and once the waters cleared, as copper ore milling decreased and then stopped, sauger were apparently no longer able to out-compete other game fish. Sauger, for all practical purposes, are no longer important to the sports fishery of Torch and Portage Lakes.
4. Bioassays of the water and sediments of Torch Lake, have not indicated the presence of a carcinogenic substance. The data do not support the basis for the continuance of this specific fish consumption advisory.

#### BACKGROUND

Torch Lake, located on the Keweenaw Peninsula and tributary to Portage Lake and Lake Superior, came to the national forefront in 1982 when abnormal or tumorous growths were described from the liver, spleen, and mesenteries of the lake's old sauger and walleye. The highly visible external tumors on these species have been associated with viral infections and are common in Great Lakes populations. Other fish in the diverse fish communities of Torch and Portage Lakes have not exhibited either external or internal growths considered abnormal.

The Michigan Department of Public Health issued a fish consumption advisory on Torch Lake sauger and walleye in 1983 even though these fish move freely into Portage Lake and Lake Superior. The advisory was issued as a precaution, until the causative agent or agents, if present, in Torch Lake could be determined. No tumor inducing agents have been identified, either by chemical analysis or bioassays, at levels that would cause the high incidence of liver tumors.

Consumption of fish with tumors or abnormal growths, while aesthetically displeasing, is not known to transmit tumors to humans. Since Torch Lake was the center of an outstanding sauger fishery for many years prior to the closing of the riparian copper mills and smelter, it seemed reasonable to concentrate considerable study effort on Torch Lake and the copper industry for possible fish tumor inducers. Several studies were completed and have been summarized in the RAP (Evans, 1987). Tumor induction studies of the appropriate copper flotation chemicals have not been completed.

Torch Lake received approximately 200 million tons of copper ore tailings between the late 1860's and the 1960's (Markham 1986). Over 20 percent of this 1100 hectare lake (present mean depth 17 meters) was filled with tailings, and relatively small amounts of industrial and municipal trash. Raw sewage and mine pumpage were also discharged to the lake. Similar types of waste were discharged to Lake Superior and Portage Lake.

Stamping the copper ores and recovering the native copper was a relatively inefficient process initially, and considerable copper was known to exist in the coarse tailings (stamp sands) in the lake. In 1915, leaching of conglomerate tailings and ores with cupric ammonium

**Reference 5**

**Technical Memorandum Number 1;  
From Jeffrey D. Maletzke, Donahue & Associates, Inc., to Lori Ransome,  
Donahue & Associates, Inc.; July 28, 1989**



### General

The history of copper mining in this region and subsequent deposition of tailings in Torch Lake, spans a period of approximately 100 years, from the late 1860's to the late 1960's. The copper mined was found in conglomerate and amygdaloid forms. Conglomerate is formed by compaction and cementation of river-deposited gravel, with copper in interstitial spaces. Amygdaloid is derived when vesicles formed in cooling lava become filled with copper.

Once mined, the ore was transported to mills along the western shore of Torch Lake (Figure 1) where the ore was crushed (or stamped). The copper and crushed rock were separated by gravimetric sorting in which the difference in specific gravity between the copper and the crushed rock permitted the copper to be concentrated and extracted. The waste sands (tailings) produced from these operations were discarded, typically by pumping into Torch Lake. Values equal to one-fourth of the total copper were lost in the waste sands.

Beginning about 1916, spurred by war time economy and advances, in metallurgy, the tailings were dredged from the lake, screened, recrushed, and gravity separated at one of three reclamation plants. From oldest to youngest these plants included the Calumet and Hecla (1916), the Tamarack (1925), and the Quincy (1943) (Figure 1). At these plants, an ammonia leaching process was used to recover copper from conglomerate tailings, and a flotation process was used to extract copper from both conglomerate and amygdaloid tailings.

The leaching process involved the dissolution of metallic copper in a cupric ammonium solution containing an excess of ammonium carbonate. With the copper dissolved as either cuprous or cupric ammonium carbonate, steam distillation was employed to cool and condense the carbon dioxide and ammonia, thereby facilitating recovery of the copper. Leaching accounted for 40 percent of the copper reclaimed from the original stamp sands.

The flotation process involved agitation of ore, water, oil, and chemicals to produce a froth, supporting copper-bearing particles. Typical reagents consisted of 50 percent coal tar, 15 percent pyridine oil, 20 percent coal tar creosote, and 15 percent wood creosote. In 1926, xanthates were introduced. Prior to the use of xanthates, only conglomerate tailings were treated by flotation. Approximately 0.05 pounds of potassium and sodium xanthate were used per ton of ore in combination with 0.15 pounds of pine oil per ton of ore. Pine oil contained wood creosote. Flotation accounted for 10 percent of the copper reclaimed in the original stamp sands.

After reclamation, the chemically treated tailings were returned to Torch Lake. The present location and extent of the tailings presumably reflects the final placement after processing by the respective reclamation plants.

The following discussion stems directly from maps and descriptions found in the MTU archives, as well as from field reconnaissance. During field reconnaissance the location and extent of the tailings, as well as other notable features, were mapped on air photos (Figures 2 through 6). Tailings were then assigned to sectors as indicated on the air photos and Figure 7. Each sector

**Reference 6**

**Technical Memorandum Number 7;  
From Lori Ransome, Donahue & Associates, Inc., to Project Files;  
February 9, 1990**

**TABLE 2**  
**DETECTED INORGANIC COMPOUNDS (ug/m<sup>3</sup>)**  
**AIR TSP SAMPLES**  
**TORCH LAKE RI/PS**  
**August 1989**

	<b>Hubbell</b>		<b>Lake Linden</b>		<b>Mason</b>			<b>Background</b>	
	<b>AA01</b>	<b>AA01</b>	<b>AA02</b>	<b>AA02</b>	<b>AA03</b>	<b>FD AA03</b>	<b>AA03</b>	<b>AA04</b>	<b>AA04</b>
	<b>8/18/89</b>	<b>8/26/89</b>	<b>8/18/89</b>	<b>8/26/89</b>	<b>8/18/89</b>	<b>8/18/89</b>	<b>8/26/89</b>	<b>8/26/89</b>	<b>9/5/8</b>
<b>Aluminum</b>	0.227	0.201	0.266	0.132	0.345	0.405	0.179	0.127	0.219
<b>Arsenic</b>		0.0017		0.0016	0.0005		0.0013	0.0013	0.001
<b>Boron</b>	0.110	0.0517	0.0625	0.0294	0.0788	0.0944	0.0346	0.035	0.080
<b>Barium</b>	0.00191	0.002	0.0032	0.00151	0.00282	0.00315	0.00206	0.00165	0.002
<b>Calcium</b>	0.744	0.799	1.0553	0.620	0.975	1.11	0.840	0.964	1.05
<b>Cadmium</b>		0.00977	0.0276						
<b>Chromium</b>			0.00192		0.00369				
<b>Copper</b>	0.151	0.201	0.100	0.0858	0.117	0.173	0.0795	0.0808	0.075
<b>Magnesium</b>	0.230	0.238	0.266	0.153	0.336	0.380	0.233	0.190	0.183
<b>Iron</b>	0.291	0.237	0.316	0.169	0.451	0.516	0.254	0.164	0.170
<b>Manganese</b>	0.00447	0.00406	0.00564	0.00221	0.00915	0.0104	0.00488	0.00184	0.002
<b>Nickel</b>		0.00427							
<b>Tin</b>									0.009
<b>Titanium</b>	0.0145	0.00805	0.0149		0.0353	0.0374	0.00976		
<b>Zinc</b>	0.0322	0.0544	0.0555	0.0526	0.102	0.121	0.0575	0.0488	0.061
<b>TSP</b>	20	22	21	21	30	32	25	18	14

FD - Field Duplicate

Space - Analyzed for but not detected

AA - Ambient Sample

TSP - Total Suspended Particulates

**Mining Waste NPL Site Summary Report**

**United Nuclear Corporation  
Churchrock Site  
Gallup, New Mexico**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

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## **DISCLAIMER AND ACKNOWLEDGEMENTS**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Ricky McCoy of EPA Region VI [(214) 655-6730], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**UNITED NUCLEAR CORPORATION**

**CHURCHROCK SITE  
GALLUP, NEW MEXICO**

**INTRODUCTION**

This Site Summary Report for the United Nuclear Churchrock Site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review by the EPA Region VI Remedial Project Manager for the site, Ricky McCoy.

**SITE OVERVIEW**

The United Nuclear Corporation (UNC) Churchrock Site is an inactive uranium mill and tailings-disposal site located in an isolated area of McKinley County, 15 miles northeast of Gallup, New Mexico. The Mill was operational from 1977 to 1982. The Mill, designed to process 4,000 tons of ore per day, used the conventional acid-leach solvent-extraction method to extract uranium. The waste tailings were pumped to a 100-acre tailings-disposal area (see Figure 1). According to radioactive materials license records, between 3.4 and 3.6 million tons of acidic tailings were disposed of at the site. In May 1982, UNC closed the Mill to await better uranium market conditions; the market did not improve, and UNC announced that the Mill would not reopen (Reference 1, pages ES-1, ES-3, 1-4, and 1-5). In 1987, UNC submitted a closure plan for decommissioning the Mill to the Nuclear Regulation Commission (NRC).

Arsenic, cadmium, lead, molybdenum, cobalt, manganese, chromium, and radionuclides (including uranium and thorium) are the constituents of concern at the site. Although no people reside within the site boundary, adjacent land includes the Navajo Indian Reservation to the north and land to the east and south held in trust for the Navajo Tribe and administered by the Bureau of Indian Affairs. Ten wells are located in slightly over a 3-mile radius of the site; the closest is 12,000 feet northeast of the site. Four of these wells are operational, and are used for both livestock and domestic purposes. Land use is primarily grazing for sheep, cattle, and horses (Reference 1, pages ES-1 through ES-3, 2-15, and 2-16). Contaminants in the Alluvial Aquifer and/or deeper aquifers at concentrations exceeding clean-up standards include aluminum, arsenic, cadmium, cobalt, manganese, molybdenum,

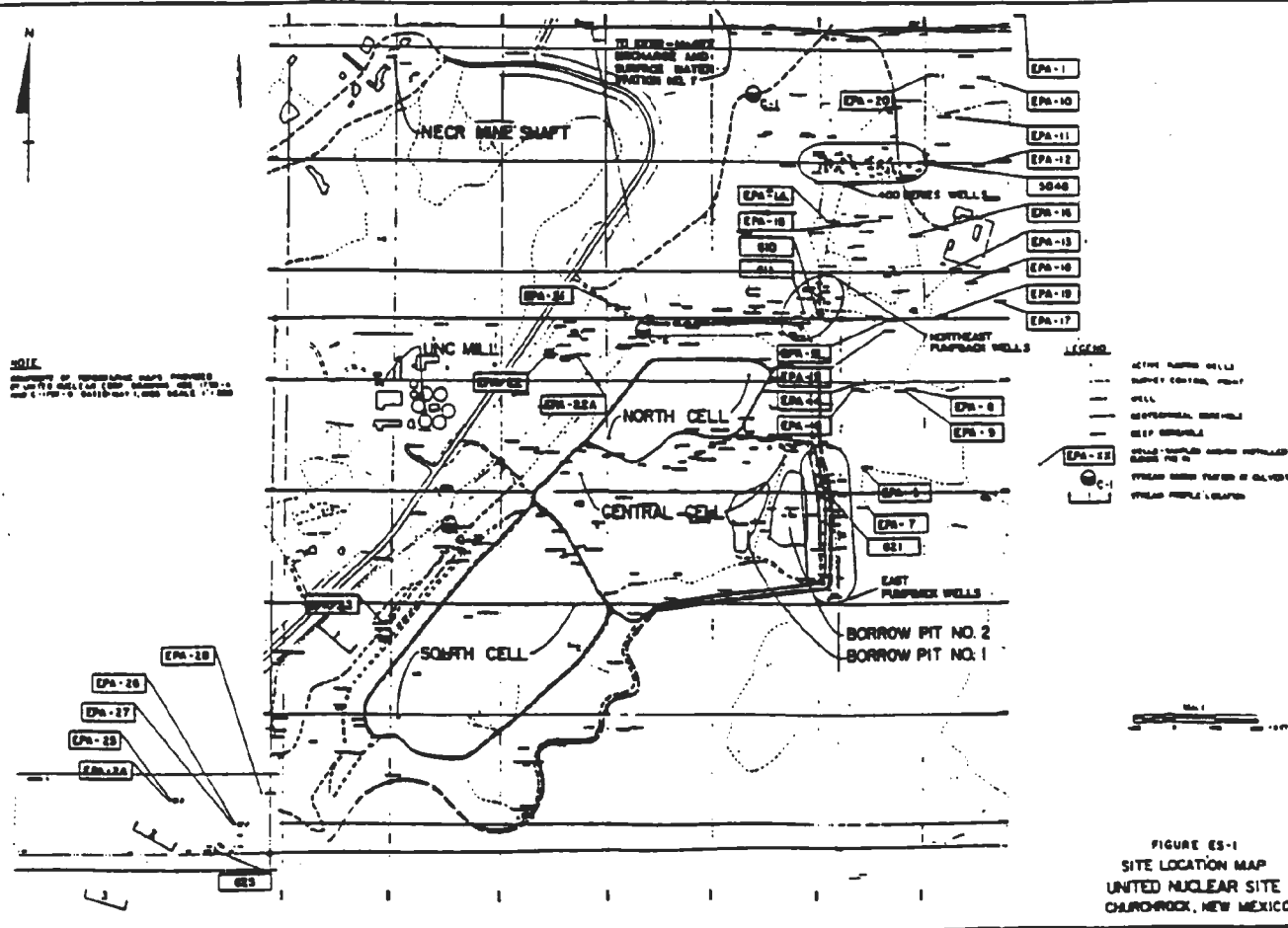


FIGURE 1. SITE MAP

nickel, selenium, nitrate, Total Dissolved Solids (TDS), radium 226 and radium 228, and gross alpha (Reference 2, Table 6).

In October 1979, the New Mexico Environmental Improvement Division (NMEID) ordered UNC to implement a discharge plan to control contaminated tailings seepage which was responsible for ground-water contamination. Ground-water pumping and evaporation was initiated in 1981. From 1979 to 1982, UNC neutralized tailings with ammonia and/or lime (Reference 1, page 1-4).

In 1983, the Churchrock site was placed on the NPL. In early 1987, UNC submitted a reclamation plan to the NRC for decommissioning the mill and began to address monitoring, tailings-seepage control, and general decontamination. A Memorandum of Understanding (MOU) between EPA Region VI and NRC Region IV was signed in August 1988, this MOU provided that EPA would address ground water outside the disposal site, while NRC would address surface reclamation and source control.

Remedial Investigation efforts were initiated by EPA Region VI in 1984 (Reference 2, page 5). In 1988, a Record of Decision (ROD) describing the remedy at the site, selected in accordance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and local applicable or relevant and appropriate requirements (ARARs), was signed by EPA Region VI in concurrence with the State of New Mexico and NRC. The ROD estimates the present value costs of future remedial actions, using a 10 percent discount rate, to be approximately \$17 million dollars over a 10-year period (Reference 2, Declaration, page 1 and Summary, page 41).

## OPERATING HISTORY

The Churchrock Uranium Mill was licensed under a radioactive-materials license in May 1977, and began milling operations in June 1977. The Mill was designed to process 4,000 tons of ore per day using conventional crushing, grinding, and acid-leach solvent-extraction methods to produce uranium. The ore processed at the site (average ore grade 0.12 percent uranium oxide) came from UNC's Northeast Churchrock and Old Churchrock mines as well as the nearby Kerr-McGee Quivera mine. The crushing, grinding, and milling process produced an acidic waste of ground ore and fluids referred to as tailings. Tailings waste was pumped to a 100-acre disposal area where between 3.4 and 3.6 million tons of tailings were disposed (Reference 1, pages 1-1 and 1-4; Reference 2, page 4).

UNC's tailings-disposal area is located directly east of Pipeline Canyon. The tailings-disposal area was subdivided by cross-dikes into cells identified as the South Cell, Central Cell, and North Cell areas. Two soil-borrow pits are in the Central Cell area (Reference 2, page 1) (see Figure 1)



(Reference 4). In July 1979, the dam on the South Cell breached, releasing approximately 93 million gallons of tailings and pond water to the Rio Puerco River. The dam was repaired and clean-up actions were taken (Reference 1, page 1-4; Reference 2, page 4).

In October 1979, NMEID ordered UNC to implement a discharge plan to control tailings seepage that was responsible for ground-water contamination. In 1981, UNC implemented a ground-water pumping system that withdrew ground water and returned it to a lined pond for evaporation (Reference 1 page 1-4; Reference 2, page 4). In response to NMEID concerns that acid solutions in tailings were major factors in mobilizing contaminants, UNC added lime or ammonia to the tailings from 1979 to 1982 (Reference 1, page 1-4).

In May 1982, UNC announced that it was going to temporarily close the Churchrock Uranium Mill due to depressed uranium market conditions. The market did not recover, and UNC closed the facility. In 1987, UNC submitted a closure plan to NRC to decommission the Mill (Reference 1, page 1-4; Reference 2, page 4).

## **SITE CHARACTERIZATION**

EPA conducted a Remedial Investigation, completed in August 1987, to determine the nature and extent of ground-water contamination in aquifers present at the site. EPA concluded that three primary aquifers of concern existed, the Alluvial Aquifer and the Zone 1 and Zone 3 Aquifers of the Upper Gallup Sandstone (Reference 1, page ES-6). The Alluvial Aquifer has been contaminated by mine discharges and tailings seepage. Several distinct plumes exist, the major one extending southwest from the South Cell for at least 1,000 feet downgradient. Other plumes extend to the north. Numerous contaminants exceeded National Primary and Secondary Drinking Water Standards (DWSs) (Reference 1, page ES-9).

### **Source Characterization**

Tailings solids are believed to be the main source of contamination on the Churchrock site. Tailings solids- and liquids-source sampling was not conducted during the Remedial Investigation. However, analytical results characterizing these materials were obtained from previous investigations conducted by UNC in February 1986 and by NRC in April 1987 (Reference 1, page 5-1). Tailings fluids were characterized as acidic, high dissolved solids water with sulfate, ammonia, and sodium as the principal ions. Metal concentrations, particularly aluminum and iron, were very high [each over 1,000 milligrams per liter (mg/l)]. Radioactivity (thorium 230) was also high [10,000 to 50,000 pico Curies per liter (pCi/l)]. Additional data offered by NMEID suggested ammonia concentrations as

high as 4,000 mg/l; nitrate as high as 17 mg/l; and arsenic as high as 1.87 mg/l. NRC's 1987 sampling showed a pH of 3.34, TDS over 58,000 mg/l, ammonia over 5,800 mg/l, thorium 230 of 13 pCi/l, iron of 2,700 mg/l, lead of 3.34 mg/l, and radium 226 of 24 pCi/l. The Remedial Investigation suggested that the tailings-liquor chemistry may have been variable throughout its discharge history (Reference 1, pages 5-1 through 5-3).

### Surface Water

The original goal of the Remedial Investigation's surface-water studies was to determine the amount of infiltration occurring along Pipeline Canyon at the tailings-disposal area. This data was to be used to understand the recharge characteristics of the aquifers present at the Churchrock site, as well as to determine the quality of the surface water. At the time of the Remedial Investigation studies, Pipeline Canyon had a perennial flow since 1968 as a result of mine dewatering from the Kerr-McGee and UNC mines. During active periods of dewatering, surface-water gauging indicated a loss of nearly 200 gallons per minute (gpm) of perennial flow along Pipeline Canyon over a distance of less than 1 mile through the study area due to evaporation and seepage. Following the cessation of mine dewatering by UNC in 1983 and Kerr-McGee in 1986, the Canyon returned to its natural, ephemeral-drainage patterns. This has resulted in a substantial decrease in the volume of water that can infiltrate into ground water (Reference 1, pages ES-5, 5-3 through 5-5).

Surface-water sampling was conducted prior to the cessation of mine discharges (i.e., before reversion to ephemeral flow). Water quality was governed by mine discharges, precipitation, and upgradient surface water. TDS concentrations were approximately 500 mg/l. The major anions were bicarbonate and sulfate, and the prominent cations were calcium and magnesium. Contaminants detected in surface water are listed in Table 1 (Reference 1, page 5-6).

Low metal concentrations were believed to be a function of the pH. It was also noted that, because infiltrating surface waters would dissolve constituents as they pass through the alluvium and bedrock, surface-water quality would not necessarily reflect ground-water background quality. Radiological analyses indicated the presence of radionuclides, which were attributed to the source rock in the mines (Reference 1, pages 5-6 and 5-7).

**TABLE 1. CONCENTRATION OF CONSTITUENTS IN SURFACE WATER**

Constituent	Concentration (mg/l)
pH	7.6 to 8.6
Aluminum	0.73
Barium	0.48
Iron	0.19
Manganese	0.03
Nickel	0.06
Vanadium	0.05
Zinc	0.04

#### **Ground Water**

Complex ground-water flow patterns exist on the site. This is partly due to numerous fractures and fissures present in the bedrock units. In addition, Zone 2 of the Upper Gallup Sandstone is a shale in some areas, acting as a barrier between Zones 1 and 3, which otherwise are hydraulically connected with each other and with the Alluvial Aquifer. The Mancos Shale, located beneath Zone 1 of the Upper Gallup Sandstone, acts as a barrier to mitigate vertical migration into the lower aquifers (Reference 1, page ES-7). To analyze contaminant migration in the ground-water, a total of 33 test borings were drilled on the site (29 monitoring wells, and four observation wells). The borings ranged from 62 to 263 feet deep with an average depth of 160 feet (Reference 1, page 3-5).

The aquifers of concern include the Alluvial and Zones 3 and 1 of the Upper Gallup Sandstone, all of which are hydraulically connected. These Aquifers were sampled and analyzed in March, May, and August 1985 and were identified and characterized as described below.

#### **Alluvial Aquifer**

The Alluvial Aquifer receives water from surface-water infiltration through Pipeline Canyon and from recharge from precipitation and seepage from the tailings ponds (as noted, surface-water infiltration would be substantially lower since the cessation of mine discharges in 1986). Overall, flow direction is to the southwest along the axis of Pipeline Canyon (although seepage from the ponds had caused a

mound in local ground-water levels). EPA has identified several distinct, high-TDS plumes in the Alluvial Aquifer that may be the result of mine water, tailings, or other sources. The major plume extends southwest of the South Cell of the tailings ponds at least 1,000 feet downgradient of the site. TDS values up to 20,000 mg/l were found. The plume extent downgradient has not been determined. Other plumes extend north of the tailings ponds.

In 1985, the alluvial plumes contained numerous contaminants above the Primary and Secondary DWSs. Maximum pollutant concentrations found in alluvial ground water included nitrate (greater than 300 mg/l), sulfate (greater than 8000 mg/l), selenium (0.4 mg/l), manganese (20 mg/l), molybdenum (0.28 mg/l), and cadmium (0.125 mg/l). Gross-alpha activity exceeded Primary DWSs in six wells, with levels ranging from 16 to 45 pCi/l, compared to the Maximum Contamination Level (MCL) (after subtracting uranium and radon activity) of 15 pCi/l. Water from one alluvial well had a gross-beta activity in excess of 50 pCi/l. The radium 226 and 228 standard of 5 pCi/l was exceeded in two wells. Concentrations of thorium and uranium isotopes indicated little migration away from the tailings ponds (Reference 1, pages ES-7, ES-9, and 6-4).

### Zone 3 Upper Gallup Sandstone

The major flow system in the Zone 3 Aquifer is to the northeast from the North Cell of the site. In 1985, the Zone 3 Aquifer had been severely impacted by contaminants leached from the north tailings cell. A large, elongated plume had migrated more than 2,000 feet from the tailings-disposal site at a rate of 337 to 450 feet per year from 1979 to 1985. TDS concentrations near the source were greater than 15,000 mg/l with pH values of less than 3. Major ions affecting water quality included ammonia (100 mg/l), sulfate (8000 mg/l), and nitrate (35 mg/l). Radionuclides (radium 226 and 228, thorium 230, uranium 238, and gross alpha and beta) were present at very high levels onsite and much lower (but still elevated) levels offsite. Metals concentrations also decreased with distance from the source (Reference 1, pages 5-46, 5-48, 5-49, 6-5, and 6-6).

Maximum metal concentrations exceeding Primary and Secondary DWSs in EPA monitoring wells on tribal lands to the east included manganese (55 mg/l), arsenic (1.8 mg/l), cadmium (0.277 mg/l), chromium (0.135 mg/l), and beryllium (0.254 mg/l). Radionuclides were also found in water from Zone 3 Wells on tribal lands 800 feet from the pond (Reference 1, page 6-5).

### Zone 1 Upper Gallup Sandstone

The Zone 1 Aquifer exhibited predominant flow to the north and received water from the same sources as Zone 3. Contamination in Zone 1 was less extensive than in Zone 3. Contaminants were

migrating from the North Cell to the northeast and east. A second plume from Soil-borrow Pit 2, located within the Central Cell, had moved downgradient to tribal grounds to the east. TDS concentrations ranging from 6,000 to 7,000 mg/l, pH values from 4 to 5, and high nitrate concentrations exceeding 100 mg/l were measured in monitoring wells on tribal lands (Reference 1, pages ES-12, 6-7, and 6-8).

#### Fate and Transport of Mobile Contaminants

- Arsenic - Arsenic is mobile in an aqueous systems at moderately acidic pHs. Low arsenic concentrations (on the order of 0.1 to 0.6 mg/l) are present in the tailings area because at very low pH, the arsenate adsorption on iron oxyhydroxide is at its highest level. This creates an arsenic "reservoir" of adsorbed arsenic. As the pH increases, some of the arsenic is released and is mobile. As the oxidation-reduction decreases, most of the arsenic previously adsorbed were into solution and can be transported. Arsenic was found in onsite Zone 1 and 3 Wells at levels over the 0.05 mg/l DWS (at levels up to 2.5 mg/l). The 1985 arsenic distribution was a combination of oxidation-reduction and ground-water flow (Reference 1, pages 5-62 and 5-63).
- Molybdenum - In ground water, molybdenum travels (in solution) as an anion, and is not as easily attenuated as arsenic. Leachate characterization of the tailings for molybdenum was not available; however, values along the tailings embankment northeast of the North Cell indicated molybdenum values of 0.2 to 0.7 mg/l. Wells further downgradient had much higher molybdenum values (up to 59 mg/l in Zones 1 and 3 Wells). This increase in molybdenum concentration with distance could not be explained at the time (another natural or anthropogenic source or an earlier "slug" load from the tailings area were suggested as possible explanations) (Reference 1, pages 5-65 and 5-66).
- Manganese - Manganese is relatively mobile because it typically remains in solution until the Ph reaches 8.0 and above. Manganese was typically present at the outer edge of the contamination plumes. Manganese is present in the tailings; and wells in all three Aquifers throughout the study areas exhibited manganese concentrations above the Secondary DWS (Reference 1, page 5-66).
- Cadmium - Cadmium, like manganese, is relatively mobile. Sorption onto sediments and manganese oxide occurs as Ph increases. Adsorption onto organic materials and minerals, coprecipitation with metal oxides, and substitution in carbonates also control cadmium mobility. In 1985, cadmium was not present above the 0.005 mg/l detection limit in wells near the tailings ponds with low Ph values. Downgradient wells exhibited sporadic concentrations above the source concentration, suggesting that the cadmium may be inherent to natural geologic media or reflective of a previous slug loading (Reference 1, pages 5-68 and 5-69). Historic sampling by NMEID indicates a different cadmium distribution: cadmium was rarely found away from the tailings ponds. Away from the ponds, cadmium was reportedly absorbed or precipitated (Reference 1, page 5-69).

- **Radionuclides:**

- **Radium 226 and 228** - No measurement of radium activity in the Zone 1 Aquifer exceeded the Clean Water Act standard of 5 pCi/l. Only two of eight Alluvial wells exceeded the standard. Eleven of 15 Zone 3 Wells had levels ranging up to 47.6 pCi/l; radium activity levels decreased rapidly downgradient of the tailings ponds (Reference 1, pages 5-72 through 5-75).
- **Thorium 230** - Mobility of thorium at the site was a function of pH. Thorium can remain in solution at pH values below 5 (as is the case near the ponds); at higher pH (as is the case downgradient of the ponds), thorium precipitates and is immobile. High thorium levels were found only in Zone 3 Wells, from 41,000 pCi/l near the North Cell to about 0.2 to 0.4 pCi/l near the edge of the pond. Thorium was determined not to be migrating far from the ponds (Reference 1, page 5-76).
- **Uranium 238** - Most wells showed uranium 238 activity over 15 pCi/l (an "arbitrary" value selected in the Remedial Investigation to reflect the alpha activity standard). Uranium 238 activity was found to decrease rapidly away from the core of the contaminant plume (Reference 1, pages 5-76 and 5-77).
- **Gross Alpha** - Gross alpha readings (without subtracting radon) above 15 pCi/l were found throughout the site and in all aquifers of concern. Zone 3 Wells had the highest gross alpha concentrations. up to 3,000 pCi/l in areas where TDS concentrations exceeded 10,000 mg/l. Downgradient, near the fringe of the plume, values decreased to about 100 pCi/l. Outside the plume, activities were in the vicinity of 50 pCi/l. Generally, Zone 1 activity levels decreased significantly downgradient from the source (Reference 1, page 5-77).

## ENVIRONMENTAL DAMAGES AND RISKS

In July 1979, the dam on the South Cell breached, releasing 93 million gallons of tailings and pond water to Rio Puerco River. In October 1979, the State ordered UNC to implement a discharge plan to control the tailings seepage deemed responsible for ground-water contamination. In 1981, UNC implemented a ground-water pumping system that withdrew ground water from site aquifers and returned it to Borrow Pit 2 for evaporation (Reference 2, page 4).

UNC began tailings neutralization (in late 1979) to reduce the mobilization of contaminants; this continued until early 1982. Neutralization involved the addition of ammonia or lime to the tailings. In 1983, EPA designated the Churchrock site an NPL Site and initiated a Remedial Investigation effort (Reference 2, page 4).

A Risk Assessment, based on ingestion of ground water contaminated at 1985 levels, estimated excess lifetime cancer risks for arsenic and radionuclides (the only carcinogens among the contaminants). The excess lifetime cancer risk from arsenic ingestion was estimated as  $1 \times 10^{-1}$  (based on a maximum arsenic concentration) to  $1.2 \times 10^{-3}$  (average concentrations).

For radionuclides, the excess cancer risks was estimated to be  $1.8 \times 10^{-1}$  to  $6.5 \times 10^{-5}$ . In addition, estimated daily intakes of cadmium, manganese, and nickel were estimated to exceed health-based standards for noncarcinogens (Reference 3, pages ES-6, 4-13, 4-19, and 4-20). These estimates were all based on a "future-use scenario," in which it was assumed that wells would be constructed for domestic use in each of the clean-up target areas (Reference 3, page ES-6). However, EPA has found no current exposure from ground-water ingestion from currently operating domestic and livestock wells within 4 miles of the site (Reference 2, page 23).

## REMEDIAL ACTIONS AND COSTS

As noted previously, UNC cleaned-up a 1979 release of tailings and pond water, and conducted activities to neutralize tailings from 1979 to 1982 (Reference 1, page 1-4). In addition, UNC implemented a ground-water pumping system in 1981 that withdrew contaminated ground water for treatment and evaporation in a lined pond (Borrow Pit 2) (Reference 1, page 1-4). As of August 1987, a total of 27 wells were actively pumping ground water for neutralization and return to Borrow Pit 2. The average pumping rate was 30 gpm (43,200 gallons per day) (Reference 1, page 5-24).

In 1981, EPA conducted a preliminary evaluation of the UNC Churchrock Site by assessing existing data and conducting Site Assessment Inspections. In 1982, an additional sampling inspection was conducted, and in 1983, EPA included the site on the NPL. EPA conducted a Remedial Investigation from March 1984 to August 1987 (Reference 2, page 4). The Feasibility Study Report was released in August 1988. A ROD, describing the final EPA remedy at the site, was signed in September 1988 by the Region VI Administrator, and verbal concurrence was given by the State of New Mexico (Reference 2, page 5). The final remedy, as well as available cost data, are described below.

Remedial actions addressing source-control and onsite surface reclamation will be implemented by UNC, as directed by NRC. These activities are to be integrated and coordinated with remedial action for the Ground-water Operable Unit (described below) (Reference 2, Declaration, pages 1 and 4).

The selected remedy for the Ground-water Operable Unit is intended to prevent further offsite migration of contaminants by containing, removing, and evaporating contaminated ground water. The

remedy for the Ground-water Operable Unit is comprised of the following elements (Reference 2, Declaration, pages 2, 3, and 4):

- Installation of a monitoring-well system in all three aquifers to detect increases in extent or concentrations of ground-water contaminants at (and outside of) the tailings-disposal area
- Continued operation of existing seepage (i.e., ground water) extraction systems in Zone 1 and 3 Aquifers
- Containment and removal (by extraction wells to be installed) of contaminated ground water from the Upper Gallup Zone 3 and southwest Alluvium Aquifers
- Evaporation of ground water removed from Aquifers using lined evaporation ponds and spray equipment to enhance evaporation
- Implementation of a performance monitoring and evaluation program to allow a determination to be made of the adequacy of the remedial action outside of the disposal area.

According to the ROD, the capital cost of the ground-water remedy was estimated to be \$12 million; the present-worth estimate (using a 10 percent discount rate) was estimated to be \$17 million over a 10-year period. These costs were estimated "without detailed engineering data," so actual costs were reported to depend on a number of factors, including direct and indirect remedial action start-up costs; size of evaporation system; well-system performance; duration of pumping; and future changes in such factors as clean-up criteria (Reference 2, pages 41 and 42).

## CURRENT STATUS

Remediation of the Churchrock site is on-going. UNC submitted a 1989 review of ground-water corrective action to EPA and NRC. This report describes the corrective-action program. This report, based on limited monitoring data, (third and fourth quarters of 1989), stated that the extraction wells in Zone 3 are operating (as intended) by removing seepage from the target area and creating a hydraulic barrier to further migration of tailings seepage. Eighteen Zone 3 Wells were extracting an average combined total of about 51 gpm (about 8 gpm, prior to start-up of 12 new wells in August). Water was sent to the lined evaporation ponds. Additional Zone 3 Wells are to be installed in 1991 (Reference 4, pages 2, 3, and 9).

Data (second, third, and fourth quarters of 1989) for the Zone 1 Aquifer showed corrective action will be a long-term process. Although Borrow Pit 2 was dewatered, ground-water and pH levels had remained stable, and the plume had migrated about 150 feet downgradient (Reference 4, pages 4 and 10).



Data for the Southwest Alluvium Aquifer was collected during the fourth quarter of 1989, immediately prior to (and following) the initiation of pumping. Data were said to provide a preliminary indication that the ground-water withdrawal system was working as planned (by beginning to reverse water-level gradient and creating a hydraulic barrier to flow). Three Extraction Wells began pumping (extracting ground water) from Zone 1 in August 1989, and had an average combined total flow rate of about 20 gpm (Reference 4, pages 5 and 10).

Two 5-acre lined evaporation ponds began operation in January 1989. Misters installed in 1988 were used in the summer, both to control wind-blown tailings and to dispose of extracted ground water (Reference 4, page 5).

Although not part of the Ground-water Operable Unit remedy, UNC also began source-control activities. In 1989, UNC reported that the North Cell had been regraded and covered with an interim soil cover to eliminate ponded water and minimize infiltration in the Zone 3 Aquifer (Reference 4, pages 5, and 6).

EPA, NRC, the State Authority (NMEID), and the Navajo Tribe have analyzed the annual review and have included some modifications in the remediation plan. These modifications, including the addition of ground-water monitoring wells, have been completed. According to EPA, the agencies and the Navajo are currently reviewing UNC's 1990 review of ground-water corrective action to assess the effectiveness of remedial activities and modify them as necessary.

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2. Record of Decision, United Nuclear Corporation Ground-water Operable Unit, EPA Region VI; September 30, 1988.
3. Public Comment Draft, United Nuclear Corporation Churchrock Site Operable Unit, Feasibility Study, Gallup, New Mexico; EPA Region VI; August 1988.
4. Ground-water Corrective Action, Churchrock Site; Prepared for UA/C Mining and Milling by Canonic Environmental Annual Review; 1989.

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**Reference 1**

**Excerpts From Draft Final, Remedial Investigation Report,  
United Nuclear Corporation Churchrock Site;  
Prepared for EPA Region VI by CH2M Hill  
(under Contract 68-01-7251); August 1988**

# KEIM IV

Selected Uncontrolled  
Hazardous Waste Sites - Zone



Environmental Protection Agency  
Hazardous Site Control Division

Contract No. 68-017211

DEPT. OF COMMERCE

U.S. DEPT. OF COMMERCE

## CH2M HILL

Mark J. Vanden

IC

PC

Ecology and Environment

## EXECUTIVE SUMMARY

The Churchrock uranium mill and tailings disposal site is the subject of this Remedial Investigation (RI). The mill and associated disposal site is owned by the United Nuclear Corporation (UNC). The facility was in operation from 1977 to 1982. In 1983, it was placed under the interim National Priorities List (NPL). This RI is part of the Superfund process to investigate sites placed on the NPL by the U.S. Environmental Protection Agency (U.S. EPA). Since commencement of the study, UNC has decided to permanently close the facility due to a poor uranium market and has submitted a reclamation plan to the Nuclear Regulatory Commission (NRC).

The objectives of the RI are to determine the nature and extent of groundwater contamination in three aquifers at the site. The ultimate goal of the RI is to collect sufficient data in order to prepare a feasibility study to address the contaminated groundwater. Data collected during this RI form the principal data base for the RI. Previous UNC and New Mexico Environmental Improvement Division (NMEID) investigations, and the closure plan have been used to refine EPA collected data. The non-EPA data is used qualitatively because it was not collected with the same QA/QC requirements.

## SITE DESCRIPTION

The Churchrock site is located in northwestern New Mexico about 15 miles northeast of Gallup, New Mexico. The site is in Section 2, Township 16 North, Range 16 West, in McKinley County, New Mexico (Figure ES-1). The Churchrock site is in an isolated area. There are no people living within the

site boundary. Adjacent land ownership includes the Navajo Indian Reservation to the north and Bureau of Indian Affairs trust land to the east and south. The closest public use well is about 12,000 feet northeast of the site. Ten wells are located in slightly more than a 3-mile radius of the site. Four of these wells were operational and sampled. The wells are used for livestock and domestic purposes. The area is semiarid and receives between 10 to 11 inches of rain per year. The mean temperature is about 48°F.

#### SITE HISTORY

The uranium mill facility was licensed under a radioactive materials license in May 1977. Milling operations began in June 1977. The mill, designed to process 4,000 tons of ore per day, used the conventional acid leach, solvent extraction method to extract uranium. The waste product, tailings, was pumped to the 100-acre tailings disposal area. According to the license records, between 3.4 and 3.6 million tons of tailings were disposed of at the site.

In May 1982, UNC announced a temporary closure of the Churchrock uranium mill to await better market conditions. The mill did not reopen because market conditions did not improve. During the early part of 1987, UNC submitted a reclamation plan to the NRC for decommissioning the mill. UNC's current onsite activities at Churchrock are limited to the following:

- o Compliance monitoring activities
- o Seepage collection system operation at the tailings impoundment
- o Tailings dust control
- o Decontamination and sale of selected mill equipment
- o Operation of an enhanced spray evaporation system of water contained in Borrow Pit No. 2

## SITE PHYSICAL DATA

### SURFACE WATER

Drainage from the site is through Pipeline Canyon. As a result of discharge from the UNC and Kerr-McGee mines, this stream contained year-round flow. Pipeline Canyon is now an ephemeral drainage due to the cessation of mine discharges in February 1986.

During the RI fieldwork, the surface water gaging study indicated that there was about a 200-gallon-per-minute loss of perennial flow along Pipeline Canyon over a distance of less than a mile through the study area. This loss was attributed to evaporation and seepage.

### GEOLOGY

The stratigraphy at the site is divided into two main components: the surficial unconsolidated deposits (Quaternary alluvium) and the underlying consolidated bedrock units. The Quaternary alluvium is the major surficial unconsolidated deposit at the site. This deposit consists of a mixture of sand, silt, clay, and to a lesser amount, gravel. Thicknesses are in excess of 120 feet with an average of 50 feet. The deposit's general stratigraphic sequence in places consists of finer material at the top with coarser material at the bottom.

The main bedrock units of concern at the site are the Upper Gallup Sandstone (Zones 1, 2, and 3), and the Upper D-Cross Tongue member of the Mancos Shale. All bedrock units are of Cretaceous age. Zone 3 of the Upper Gallup Sandstone, which is up to 90 feet thick, contains a medium- to coarse-grained sandstone. Zone 2 (10 to 20 feet thick) contains a carbonaceous shale and coal with thin sandstone lenses. Zone 1 is



sandstone similar to Zone 3, but somewhat finer in grain size with thicknesses of up to 90 feet. A carbonaceous, fissile shale represents the Mancos at the site.

There are three principal structural zones at the site: Pipeline Canyon lineament, Fort Wingate lineament, and Pine-dale monocline. These structural features impact the site hydrogeology by affecting groundwater flow directions.

#### HYDROGEOLOGY

There are three aquifers of concern identified at the site:

- c Alluvium
- o Zone 3 of the Upper Gallup Sandstone
- o Zone 1 of the Upper Gallup Sandstone

The alluvial aquifer received water from losses through Pipeline Canyon, recharge from precipitation, and seepage from the tailings ponds. The overall flow direction is to the southwest along the axis of Pipeline Canyon. The results of U.S. EPA pump tests indicate that the aquifer has transmissivities and storage coefficients of up to 6,575 gallons per day per foot and 0.09, respectively. Groundwater velocities in the alluvium along Pipeline Canyon are about 2 feet per day.

The Zone 3 aquifer receives water from the same sources as the alluvial aquifer. Where Zone 3 is in contact with the alluvium, the alluvium also directly provides water to the Zone 3 aquifer. The flow direction of the Zone 3 aquifer is north and easterly. The results of the U.S. EPA pump tests indicate that the aquifer has average transmissivities and storage coefficients of 1,032 gallons per day per foot and 0.02, respectively.

The Zone 1 aquifer receives water from sources similar to the Zone 3 aquifer. In some areas, these three aquifers have the same piezometric surface and are assumed to be hydraulically connected. The flow direction of the Zone 1 aquifer is north. The results of the pump tests from other studies indicate that the aquifer has transmissivities and storage coefficients of about 150 gallons per day per foot and 0.05, respectively.

Groundwater flow directions at the site are complex. The area contains numerous fractures and faults which may affect flow direction and velocity in the bedrock more than the dip of the rocks. In portions of the site, the Zone 2 shale unit, may provide an effective barrier to communication between the two sandstone aquifers. In places, all three aquifers of concern are in hydraulic connection, indicating they are not hydraulically isolated units. The Mancos Shale, located beneath the Zone 1 sandstone, is considered a barrier to further vertical migration into lower aquifers.

Figure ES-2 summarizes the flow paths described above.

#### ALLUVIAL AQUIFER CONTAMINATION

The depiction of groundwater contamination in the alluvium, Zone 1, and Zone 3 aquifers is addressed in the RI by the reporting of analytical values collected during the RI and other investigations. The plumes identified in the RI may be the result of mine water, tailings or other sources. In the feasibility study, EPA will address target areas for groundwater cleanup. These target areas will look at exceedances of Applicable or Relevant and Appropriate state and federal public health and environmental Requirements (ARARs) and pathways from the tailings ponds to the target areas. ARARs will also be developed in the feasibility study. The RI will serve as a data base for these assessments.

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The alluvial aquifer at the site has been impacted by mine discharges and tailings seepage. Several distinct, high total dissolved solids (TDS) plumes have been found in the site alluvium (Figure ES-3). The major alluvial plume extends southwest of the southern cell a minimum of 1,000 feet downgradient of the site. The limit of this plume, which has TDS values up to 20,000 mg/L, has not been determined. Another alluvial TDS plume extends about 800 feet north of the ponds. Another plume is found north and upgradient of the tailings pond. The alluvial plumes contain numerous contaminants above National Primary and Secondary Drinking Water Standards. Concentrations of nitrate (>300 mg/L), sulfate (>8,000 mg/L), selenium (0.4 mg/L), manganese (20 mg/L), and cadmium (0.125 mg/L) have been found in the site alluvial groundwater.

Radionuclides in the groundwater of the alluvial aquifer are primarily represented by gross alpha activity. Values above the gross alpha primary drinking water standard were found in the water from six of the alluvial wells. These waters exhibited gross alpha activities ranging from 16 to 45 pCi/L. Water from one alluvial well had a gross beta activity in excess of the 50 pCi/L standard. The radium-226 and -228 standard of 5 pCi/L was exceeded in the water from two alluvial wells. Concentrations of thorium and uranium isotopes in the alluvial groundwater indicate little migration away from the ponds.

### ZONE 3 CONTAMINATION

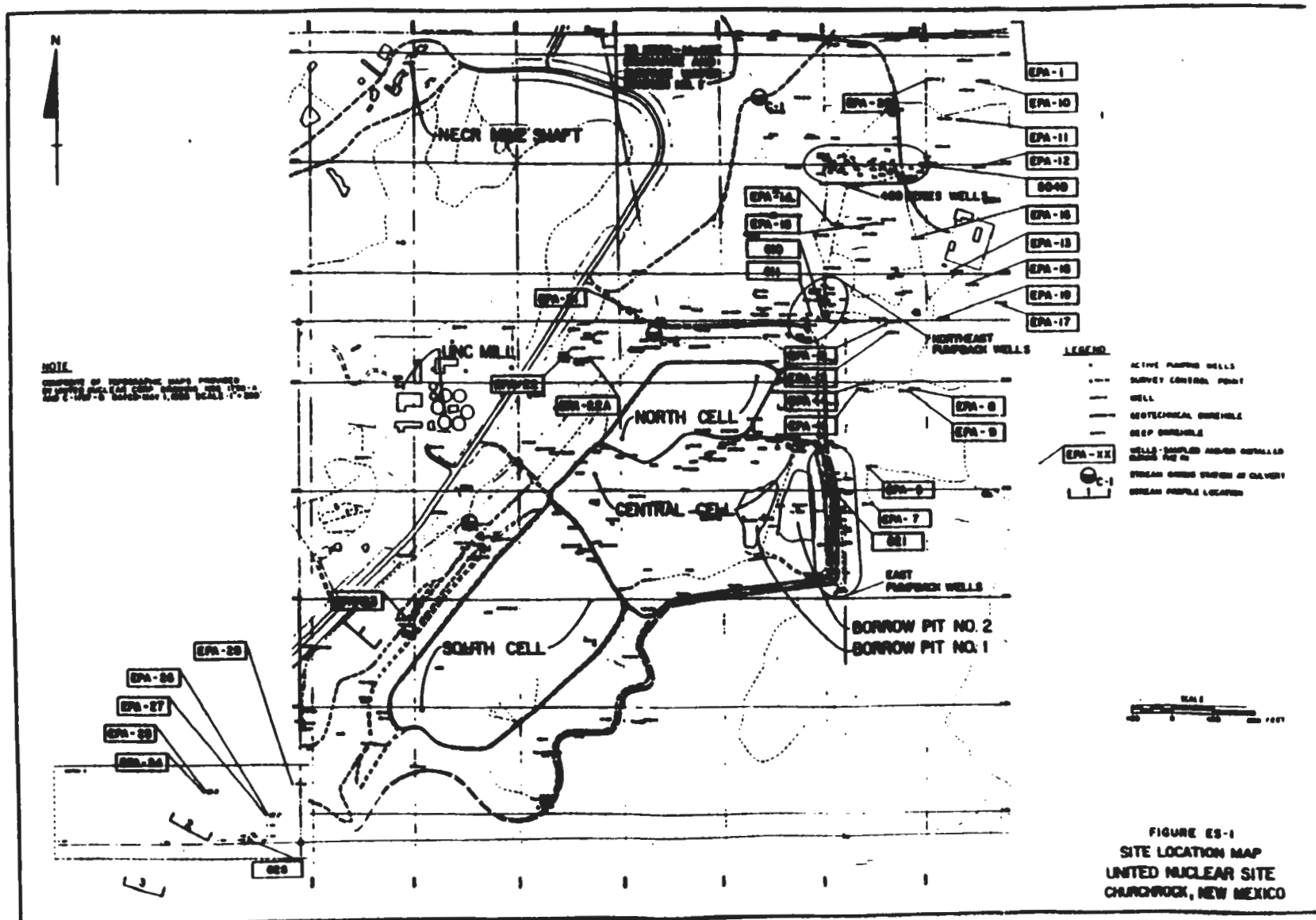
The Zone 3 aquifer has been severely impacted by contaminants that have leached from the northeast portion of the north tailings cell (Figure ES-4). An elongate TDS plume has migrated more than 2,000 feet from the disposal site. This contaminant plume migrated at a historic rate of between

337 and 450 feet per year from 1979 to 1985. TDS concentrations near the source are above 15,000 mg/L with pH values below 3.0. High ammonia (100 mg/L), sulfate (8,000 mg/L), and nitrate (35 mg/L) are the major ions that affect water quality. Metal concentrations in the Zone 3 plume exceed primary and secondary water quality standards; however, these concentrations typically decrease with distance from the source. Contaminants have migrated toward the tribal lands east of the site. Table ES-1 summarizes elevated single observation contaminant levels in groundwater on tribal lands. These data are a compendium of UNC, NMEID and EPA sampling.

Radionuclide distribution in the Zone 3 aquifer indicates that activity levels decrease with distance from the source. Thorium and uranium activities decrease from 41,000 and 7,000 pCi/L to less than 1 and 55 pCi/L, respectively, over a distance of 800 feet. Radionuclides have also been found on tribal lands in water from Zone 3 wells, Table ES-1.

#### ZONE 1 CONTAMINATION

The extent of contamination in Zone 1 is not as extensive as in Zone 3 (Figure ES-4). TDS plumes for the Zone 1 aquifer indicate that contaminants are leaving the site from the northeast section of the north tailings cell and migrating to the northeast and east (Figure ES-5). Another plume is migrating eastward from borrow pit No. 2 and has moved to the tribal lands east of the site. Contaminant velocities, as determined by TDS distribution, have been estimated at 100 feet per year during the 1979-1985 timeframe.



Section 1  
INTRODUCTION

The remedial investigation of the United Nuclear Corporation (UNC) uranium mill facility in Churchrock, New Mexico, was conducted from March 1984 to October 1987. This report presents the work performed, the data gathered and the conclusions for the RI.

An RI is part of the Superfund process. This introductory section defines the Superfund process, describes the Churchrock site and the site's background, provides an overview of previous investigations at the site, presents the objectives and goals of RI activities, and depicts the organization of the remainder of the report.

SITE BACKGROUND

The UNC Churchrock site is located in northwestern New Mexico about 15 miles northeast of Gallup, New Mexico, (Figure 1-1). The site is in Section 2, Township 16 North, Range 16 West, in McKinley County, New Mexico.

The Churchrock uranium mill facility (Figure 1-2) was licensed under a radioactive materials license in May 1977. Milling operations began in June 1977. The mill, designed to process 4,000 tons of ore per day used the conventional acid leach, solvent extraction method to extract uranium. The ore processed at the site primarily came from two of UNC's nearby mines: Northeast Churchrock and Old Churchrock. Ore was also obtained from the nearby Kerr-McGee mine. The average ore grade processed at the mill was approximately 0.12 percent uranium. The acid leach process produced a wet,

acidic waste, commonly referred to as tailings. The wet tailings were pumped to the tailings disposal area. An estimated 3.4 to 3.6 million tons of tailings were disposed in the ponds.

In July 1979, the dam on the south cell breached releasing approximately 93 million gallons of tailings and pond water to the Rio Puerco. The dam has since been repaired. The resulting spill clean up was conducted according to criteria imposed by state and federal agencies at that time. This event led to closer examination of the site.

In October 1979, the the New Mexico Environmental Improvement Division (NMEID) ordered UNC to implement a discharge plan to control contaminated tailings seepage which was deemed responsible for groundwater contamination. In 1981, UNC implemented a groundwater pumping system that withdrew groundwater for treatment and evaporation in a lined pond.

This offsite migration of radioactivity and chemical constituents into the groundwater, in addition to surface water and air emissions, prompted the inclusion of Churchrock onto the National Priorities List of Superfund sites.

NMEID suggested that UNC investigate neutralization of the tailings because the acid solutions with the tailings were believed to be a major factor governing contaminant transport. UNC began tailings neutralization with ammonia in late 1979. In early 1982, neutralization with lime was initiated. Tailings neutralization ceased later that year.

In May 1982, UNC announced that they were going to temporarily close the Churchrock uranium mill because of depressed uranium market conditions. The market did not recover and UNC decided to permanently close the facility. During the early part of 1987, UNC submitted a closure plan to the Nuc-

lear Regulatory Commission (NRC) for decommissioning the mill. UNC's current onsite activities at Churchrock are limited to the following:

- o Compliance monitoring activities
- o Seepage collection system operation at the tailings impoundment
- o Tailings dust control
- o Decontamination and sale of selected mill equipment
- o Operation of an enhanced spray evaporation system that sprays water from Borrow Pit No. 2 and wells from the seepage collection system

#### SUPERFUND PROCESS

Under Section 104(a) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (42 U.S.C. >9004(a), 1982), called CERCLA or Superfund and the Superfund Amendments and Reauthorization Act (SARA) of 1986, the United States Environmental Protection Agency (U.S. EPA) is authorized to respond to an actual or threatened release into the environment of a hazardous substance or a release or substantial threat of release of a pollutant or contaminant that may present an imminent or substantial endangerment to the public health or the environment.

U.S. EPA has developed the Superfund process to identify potentially hazardous sites of concern; to evaluate the extent of the release and threatened release of hazardous substances, pollutants, or contaminants; and to develop and implement measures to contain these hazards. This process consists of the following five steps:



With the exception of the breach of the south cell embankment in 1979, there are no direct surface water discharges from the tailings ponds to the stream in Pipeline Canyon (U.S. EPA, 1985). Flow around the tailings ponds is diverted by ditches and the embankments formed by the tailings ponds. One major drainage east of the site in Section 1 contains several stock ponds and dams. These ponds currently contain no water. In fact, the westernmost pond which has a 400-foot-long embankment is breached from a failure during a storm event.

#### CLIMATE

Meteorological data indicate that rainfall averages between 10 and 11 inches in the Gallup, New Mexico, area. The major precipitation events occurs between July and August and December and February. Summer precipitation events are characterized by local and sometimes violent afternoon and early evening thunderstorms. Lake evaporation rates for the area are about 50 inches per year. Based on the precipitation and evaporation rates, the climate is classified as semiarid (Raymond and Conrad, 1983).

The mean annual temperature, according to the United States Weather Bureau at Gallup, New Mexico, is 48.5°F. Daytime highs usually are between 80° and 90°F in the summer and 40° to 50°F in the winter. Winter lows below 0°F are not uncommon in the Gallup area (Raymond and Conrad, 1983).

#### DEMOGRAPHY AND LAND USE

The Churchrock site is in an isolated area. There are no people living within the site boundary. The closest down-gradient public-use well (No. 15K-303) is about 2,700 meters to the northeast (Figure 1-2). This well is owned by the

Bureau of Indian Affairs (BIA) and is used for culinary water and watering stock. This well is completed in the Upper Gallup Sandstone and is downgradient of the site. It is not clear whether it intersects Zone 3 or both Zones 1 and 3. Other closer wells are UNC monitoring or industrial use wells (Rogers and Associates, 1985).

There are 10 wells within a slightly more than 3 mile radius of the site. Four of these wells are in use and have been sampled. These wells are for livestock and domestic use. The U.S. EPA Mitre Model rating lists well No. 15K-303 as the closest well.

UNC owns Section 2 which contains the mill and disposal facilities (Figure 1-2). In addition, UNC owns Section 36, northeast of the disposal site. This section contains many of the pumpback wells and the Kerr-McGee mine offices. The remaining land that surrounds the mill and disposal ponds include Sections 1, 3, 11, and 35. These lands are held in trust for the Navajo Tribe and administered by the BIA. Land north of Sections 35 and 36 (Figure 1-2) is within the exterior borders of the Navajo Indian Reservation, owned by the Navajo Tribe, held in trust by the federal government, and managed by the BIA.

With the exception of the mine and mill activity, the land use is primarily grazing for sheep, cattle, and horses.

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4 observation wells or piezometers (Figure 3-1). Water levels were measured in the monitoring and observation wells.

#### TEST BORINGS

A total of 33 test borings were drilled at the site to install 29 monitoring wells (Nos. EPA-1 through EPA-28 and EPA-22A) and 4 observation wells (Nos. EPA-15A, EPA-15B, EPA-15C, and EPA-15D). The drilling was conducted from November 11, 1984 through February 12, 1985. These borings were advanced by air and mud rotary techniques. The initial eight borings were drilled using mud rotary techniques. Subsequent drilling was performed by air rotary techniques which proved to be quicker and less expensive.

A total of 5,312 feet of drilling was completed for the installation of the monitoring and observation wells. The borings ranged in depth from 62 to 263 feet deep with an average depth of about 160 feet. Figure 3-1 depicts the monitoring and observation well locations. Table 3-1 summarizes depth, hole diameter, and other pertinent data regarding the borings and wells. Boring logs are contained in Appendix B.

Table 3-1 reflects the aquifer in which the well was screened. In two wells, over drill of the boring resulted in extension of the sand pack below the screened interval. At well No. EPA-06, the screen and the sand pack extend into Zone 2, but do not penetrate Zone 1. Because Zone 2 is an aquitard, water levels and quality from well No. EPA-06 should reflect Zone 3. Well No. 19 was screened in Zone 3, however, the borehole was drilled through Zone 2 and 5 feet into Zone 1. The annulus below the screen was backfilled with fine sand. The annulus in the screened zone was backfilled with coarse sand and gravel. At this location, Zone 1 is not saturated

Section 5  
DISCUSSION OF RI FINDINGS

In Section 2 the regional setting and some of the pre-RI studies were described. These data, additional data sources from Section 4, and the RI field studies were combined to understand the characteristics of the site. These site-specific characteristics are described in this section and are divided into four main subsections: source characterization, surface water, geology, and hydrology.

SOURCE CHARACTERIZATION

Source sampling of tailings solids or liquids was not conducted by EPA during the RI. Analytical results of tailings liquids presented in this section represent analyses from previous investigations. UNC has provided EPA with tailings liquid analyses based on samples from well Nos. 633 and 635 in 1987. The UNC data exhibit high nitrate values, but the predominant nitrogen species is ammonia. These data are portrayed in Table 5-1. Also, in this table is an example of a one-time tailings liquid sample from well No. 633. This well, completed in the south cell, and the UNC data may be used to characterize the resident tailings fluids.

From these analyses, the tailings fluids are characterized as an acidic, high dissolved solids water with sulfate, ammonia and sodium as principle ions. Metal analyses particularly aluminum and iron are very high (over 1,000 mg/L). Radioactivity as represented by Th-230 is also very high (10,000 to 50,000 pCi/L). NRC sampled tailings liquor in April 1987 in order to identify hazardous constituents present in the ponds. Table 5-1 depicts these data. Analytical results are consistent with UNC and other available data.

Table 5-1  
PROBABLE TAILINGS LIQUID CHEMISTRY

Parameter	Units	UNC (1) Summary	Well (2) No. 633 2/26/86	NRC Sample April 1987
pH	S.U.	1 - 3	1.71	3.34
TDS	mg/L	38,462 - 61,932	46,793	58,860
Aluminum	mg/L	1,167 - 2,906	2,880	2,100
Manganese	mg/L	100	100	210
Ammonia	mg/L	1,450 - 5,500	438	5,860
Nitrate	mg/L	75.5 - 282	1.84	<50
Th-230	pCi/L	1,064 - 277,733	-	13
Conductivity	umhos/cm	-	17,718	-
Calcium	mg/L	-	240	460
Magnesium	mg/L	-	287	1,100
Sodium	mg/L	-	526	890
Potassium	mg/L	-	4	-
Bicarbonate	mg/L	-	0	<1
Chloride	mg/L	-	253	580
Sulfate	mg/L	24,813 - 43,581	28,209	41,000
Arsenic	mg/L	0.024 - 0.208	0.65	<0.60
Selenium	mg/L	0.001 - 0.161	0.29	<1.2
Iron	mg/L	-	4,350	2,700
Lead	mg/L	-	0.6	3.34
Cadmium	mg/L	-	0.013	0.24
Zinc	mg/L	-	10	20
Molybdenum	mg/L	<0.05 - 0.15	-	<0.24 (3)
Ra-226	pCi/L	13	-	24
Ra-228	pCi/L	2.6	-	

(1) Range for 3 samples collected and analyzed by UNC.

(2) One-time sampling event. Analytical data is also presented in Appendix G.

(3) Total Radon (226 + 228)

No source sampling of the tailings solids was conducted by U.S. EPA. U.S. EPA has contacted UNC to determine if leachate tests of tailings solids analyses have been performed.

NMEID data suggest ammonia concentrations as high as 4,000 mg/L; nitrate as high as 17 mg/L; and arsenic as high as 1.87 mg/L. These supplemental data indicate that the tailings liquor chemistry may have been variable throughout its discharge history.

#### SURFACE WATER

The original goal of the surface water studies was to determine the amount of infiltration that was occurring along Pipeline Canyon at the tailings disposal area. This data was to be used to understand the recharge characteristics of the aquifers of concern at the Churchrock site. Following collection of the RI field work, the mine discharges to Pipeline Canyon ceased. The stream reverted to its premining ephemeral condition and the amount of recharge available to the aquifer decreased significantly.

In order to factor out the water added to the surface water system by the Kerr-McGee discharge, the outflow was subtracted at each location from the Kerr-McGee discharge to calculate net loss or gain. These data are presented in Table 5-2. Values that are negative, theoretically indicate loss of water through evaporation or seepage into the alluvial or bedrock systems.

The data in Table 5-2 also indicates that other sources, such as runoff, have contributed partially to flow in Pipeline Canyon. For example, flow typically increased at the first measuring point downstream of the mine discharge.

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C

Table 5-2  
NET LOSS OR GAIN OF FLOW AT SURFACE WATER SAMPLE POINTS

LOCATIONS								
<u>Date</u>	<u>A</u>	<u>B</u>	<u>C/D*</u>	<u>E</u>	<u>F/G*</u>	<u>H</u>	<u>I</u>	<u>J</u>
May 4, 1985	0	-	99	352	-	-	-	-
May 5, 1985	0	-	-	-	-63	-160	-358	-394
May 10, 1985	0	-	203	529	197	13	-31	-466
May 11, 1985	0	-135	-	-	-	-	-	-
June 8, 1985	0	-	-414	-	-369	-	-	-
June 17, 1985	0	632	-253	-507	-289	-161	-112	-201
June 18, 1985	0	729	649	1751	212	115	-213	-342

NOTE: All flow values are in gallons per minute.

Locations

A = Kerr-McGee outflow  
 B = Sample Point below Kerr-McGee discharge  
 C = Culvert No. 1 Inflow  
 D = Culvert No. 1 Outflow  
 E = Culvert No. 2 Inflow  
 F = Culvert No. 3 Inflow  
 G = Culvert No. 3 Outflow  
 H = Stream Profile 1  
 I = Stream Profile 2  
 J = Stream Profile 3

\* Reflects average of inflow and outflow.

This location had an average increase of 409 gpm, which is attributable to upgradient runoff. All flow measurements downstream of culvert No. 3 indicated that there was a loss through evaporation or seepage into the alluvium and rock systems. The average of the last three sample points (H, I, and J) indicate an average loss of 193 gpm. These results compare favorably with calculations made by Raymond and Conrad (1983) using UNC data. In their study of the flow in Pipeline Canyon, they reported an average loss of 250 gpm along the stream from a point just upstream of the tailings ponds to one downstream of the UNC property.

Pipeline Canyon has had a perennial flow since 1968 as a result of mine dewatering from the Kerr-McGee and UNC mines (Raymond and Conrad, 1983). Prior to the dewatering, the stream was an ephemeral drainage. Following cessation of dewatering by UNC in 1983 and Kerr-McGee in 1986, the stream has made a return to its natural state. Field visits in August 1987 (1 year following the termination of Kerr-McGee's discharge), revealed that there was no flow in the stream. This, of course, has resulted in a decrease in the volume of water that can infiltrate into the groundwater system.

Although not a part of the RI, determination of the flow volume through the canyon may be required in assessing remedial actions in an FS. Canonie (1987b) used the probable maximum flood (PMF) as the basis to calculate flow in the channel for the UNC reclamation plan. Through the use of the Soil Conservation Service Synthetic Triangular Unit Hydrograph method, the peak flow rate was calculated as 25,000 cfs. For reference, the maximum flow measured along Pipeline Canyon during the field investigation was 7.4 cfs or 0.03 percent of the PMF.

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The surface water samples collected along Pipeline Canyon represent water quality that is available for recharge to the aquifers. The quality of the water is governed by the quality of the mine discharges, natural precipitation, and upgradient surface water.

Because these surface waters will dissolve constituents as they pass through the alluvium and bedrock, the surface water quality does not necessarily indicate background water quality of the aquifers. Tables D-5 and D-6 in Appendix D depict the water quality of these samples.

The surface water samples are characterized by TDS concentrations of approximately 500 mg/L. As was the case with groundwater, the major anions are bicarbonate and sulfate and the predominant cations are calcium and magnesium. The waters were near neutral to slightly alkaline (pH of 7.6 to 8.6). Metal concentrations were low which may be a function of the pH. Average metal concentrations of the four surface water samples collected by U.S. EPA were:

Aluminum	0.73 mg/L	Nickel	0.06 mg/L
Barium	0.48 mg/L	Vanadium	0.05 mg/L
Iron	0.19 mg/L	Zinc	0.04 mg/L
Manganese	0.03 mg/L		

Antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, selenium, silver, thallium, and tin were not detected in the surface water samples collected during the Phase I field investigation. Detection limits were according to CLP requirements.

Radiological analyses performed on two surface water samples do indicate the presence of radionuclides. Their presence is largely a function of the source rock in the mines.

Radionuclides with the exception of radium decreased in concentration from culvert No. 1 downstream to stream profile No. 1. The distribution between the two sampling points were:

	<u>Culvert No. 1</u>	<u>Stream Profile No. 1</u>
Radium-226	0.94 pCi/L	7.99 pCi/L
Thorium-230	0.402 pCi/L	0.297 pCi/L
Uranium-238*	432 pCi/L	71 pCi/L
Gross Alpha	207 pCi/L	90 pCi/L
Gross Beta	98 pCi/L	75 pCi/L

\*uncorrected for U-238 and Radon

The decrease, with the exception of radium, downstream may be a function of dilution or attenuation and precipitation along the stream bed.

#### GEOLOGY

As described in Section 3, a total of 33 borings were drilled in the RI for the purpose of installing 29 monitoring wells and 4 observation wells. More than 300 wells and borings had been installed at the UNC property prior to this investigation. Many of the wells were completed across several geologic and hydrogeologic horizons. One of the objectives of the RI was to compliment the studies in areas to the northeast of the facility where contaminant migration was occurring in the Upper Gallup Sandstone (Zones 1 and 3). Because of this, many of the borings exceeded 200 feet in depth and considerable time was required. This resulted in a drilling program that concentrated more on the logging of drill cutting samples every 5 feet rather than continuous coring of the bedrock. As a result, many of the logs cannot provide detailed stratigraphic information on such items as rock characteristics, fractures, and structures.

Zone 1 has very similar recharge relations as Zone 3. In areas where Zones 1, 3, and/or the alluvium have the same piezometric surface (Figures 5-2 through 5-3), the units are assumed to be hydraulically connected. Review of the cross-sections in Figures 5-3 and 5-5, indicate that faulting and fracturing has placed the Zone 1 aquifer in position with Zone 3. In these areas, the Zone 1 aquifer will receive additional recharge from Zone 3.

#### WATER LEVELS AND FLOW DIRECTIONS

Comprehensive groundwater levels were measured by Canonie (1987a) for May 1986. These measurements depict groundwater levels within 3 months after cessation of Kerr-McGee's mine discharge to Pipeline Canyon. In order to determine water level responses following the end of mine water discharges to Pipeline Canyon, piezometric maps were constructed for August 1987. These maps (Figures 5-8, 5-9, and 5-10) show changes that have occurred in about a year following mine discharges. The maps were developed from the August 1987 water level measurements and supplemented by UNC quarterly monitoring reports and trends observed by Canonie data. The predominant flow directions and changes in piezometric surfaces are described below for each of the aquifers of concern.

As a precursor to the discussion of groundwater level measurements, it is necessary to briefly discuss the pumping system at the site. At the time water level measurements were taken in August 1987, a total of 27 wells were actively pumping water from the groundwater systems for neutralization and return to borrow pit No. 2. The average pumping rate was 30 gpm or 43,200 gallons per day. Table 5-3 lists the pumping wells at the site. The effects of the pumping

The following sections address the contaminant plume distribution for the aquifers of concern at the site.

### Zone 3

Figure 5-15 presents the TDS isoconcentration map for the Zone 3 sandstone. Review of this map indicates a lobate plume with widths (as delineated by TDS concentration) of 1,100 to 1,400 feet and a length in excess of 3,500 feet.

The plume originates, as indicated by maximum TDS values, in the northeastern quadrant of the north cell of the tailings disposal area. In the area of maximum contamination (TDS values greater than 10,000 mg/L), specific wells had the following TDS concentrations: No. 613 (15,460 mg/L), No. 610 (11,140 mg/L), No. EPA-06 (11,453 mg/L), and No. TWQ-10D (15,186 mg/L).

Comparison of plume geometry and trend with the groundwater flow directions in August 1987 (Figure 5-9) reveals two important observations. The general trend of the plume is towards the northeast and is identical to the direction of decreasing piezometric surfaces. Additionally, the thin, elongated zone of TDS concentrations between 6,000 and 10,000 mg/L occurs in the same area where the piezometric surface has slight fluctuations in the vicinity of well Nos. EPA-2 and EPA-3. In this area, the piezometric surfaces are lower than would be expected. This may represent increased transmissivity due to fractures or rock lithology. Analysis of the core log reveals that the core recovery was poor and the rock was poorly cemented and friable. These attributes suggest a high transmissivity.

Two wells in the highest concentration of the plume were sampled during the RI field work. These wells include Nos.

610 and EPA-6. Review of the previous water quality tables in Appendix D confirms that these two wells usually contained the highest concentrations of most parameters. Typical water quality for this zone of the plume is:

Ammonia	>100 mg/L
pH	2 to 4
Sulfate	>8,000 mg/L
Nitrate	6 to 35 mg/L

Analysis of changes in parameter concentrations with distance can be made by comparing the above values with the analytical results from wells further downgradient in the plume. For example, well Nos. EPA-10 and EPA-12 are approximately 2,500 to 3,000 feet downgradient of the source of groundwater contamination. Ammonia and nitrate levels in these wells have historically been below 1 mg/L, indicating that through oxidation, dilution, or other form of attenuation, the concentrations have decreased.

For these downgradient wells, pH has increased relative to the center of the plume, but still remains slightly acidic (6 to 6.5). More conservative and readily solubilized species such as sulfate and chloride are lower.

In order to estimate a plume migration rate, the midpoint for the 4,000 to 6,000 mg/L zone of the plume was selected to represent the "extent" as of 1985. This point was chosen to be the vicinity of well No. EPA-12 which is approximately 2,700 feet from the northeast edge of the tailings pond where tailings rest directly on top of the Zone 3 aquifer. Assuming the migration started at the time of tailings disposal (1977) a minimum TDS plume migration rate of about 337 feet per year was obtained. It is likely that migration probably did not start until 1979 when saturation of the

tailings and bedrock occurred. It was also at this time when NMEID first noticed discharges and ordered a seepage control plan for the site. Using the 1979 to 1985 time-frame, the migration rate of the plume would be 450 feet per year. Therefore, based on analytical results, Zone 3 plume migration rates are between 337 and 450 feet per year.

When calculating the migration rates for chemical compounds at this site, several important factors must be considered. First of all, the rates are "average" rates and do not reflect current migration rates. Movement was calculated on the basis of distance travelled versus the time the sample was collected following tailings disposal. Actual migration rates may have been initially faster and slowed at later times, or vice versa. Also of importance is the influence of the pump back wells. These wells were installed after disposal and before the 1985 sampling. This is of importance because the wells have influenced movement as verified by their cones of depression in the piezometric surface maps.

The calculated average migration rates cannot be effectively applied to post-1985 predictions because of the pumping wells. These rates would overestimate the future extent of the plume.

#### Zone 1

Figure 5-16 is the TDS isoconcentration diagram for the Zone 1 sandstone. Review of this figure indicates two separate broad plumes of groundwater contamination. The southern plume emanates from the eastern edge of the central cell and borrow pit No. 2. The shape of this plume suggests a radial flow from the source. The second plume is another

associated with Kerr-McGee is the probable source of this anomaly.. Information requested from Kerr-McGee should provide further insight into the nature of this second source.

The contamination of the southwest alluvium by nitrate is attributed primarily to leaching from the tailings pond. The distribution of high nitrate values is analagous with the TDS plume which is shown to emanate from the southern disposal cell. The argument by Billings that high nitrate in the alluvium comes from natural salts conflicts with the low nitrate levels found in well Nos. EPA-22A and -21. These wells are upgradient of the central, south, and most of the north tailings cell and are therefore not impacted by nitrate.

#### METALS

Review of metal analyses included sampling events during the RI and historical data as presented by NMEID (Appendix G). Table 5-4 lists the maximum metal concentrations for wells sampled by U.S. EPA during the remedial investigation. This table also contains standards which could be used as potential applicable or relevant and appropriate requirements (ARAR's).

From this table, the following parameters were determined to be above the standard.

Arsenic	Manganese
Beryllium	Selenium
Cadmium	Zinc
Chromium	Molybdenum
Iron	

With the exception of iron and manganese, the above metals and their distribution will be discussed in the following subsection. Iron is a secondary drinking water standard. Iron migration rate would be slower than manganese (another secondary drinking water standard); therefore, discussion of manganese characteristics should conservatively represent iron. Zinc was only slightly above secondary drinking water standard. In addition, historic data (Appendix G) for zinc is limited.

#### Arsenic

The primary drinking water standard for arsenic is 0.05 mg/L. Arsenic is mobile in the aqueous system at moderately acidic pH values. However, as pH increases and sediments, clay, or argillaceous material are available, precipitation and/or oxidation with subsequent adsorption will occur. Arsenates have fairly high mobility and are not attenuated easily. One of the major controls on arsenate mobility is the presence of iron hydroxides. As evidenced by high iron concentrations in groundwater, the abundance of iron hydroxides may adsorb much arsenic. Near the tailings ponds arsenic concentrations are in the order to 0.1 to 0.6 mg/L. Wells in this immediate vicinity (Figure 5-18) which represent the range include:

<u>Well No.</u>	<u>Concentration</u> <u>(mg/L)</u>
335	0.42
TWQ-11D	0.52
TWQ-36D	0.06
320	0.2
TWQ-156	0.5
610	0.6
611	0.1



Review of the data indicates that alluvial wells rarely have concentrations above 0.05 mg/L. This may be due to adsorption on the clay minerals and iron hydroxides.

Distribution of arsenic in bedrock wells, both Zone 3 and Zone 1, indicates that transport of arsenic is evident (Figure 5-18). Arsenic has been detected up to 1 mg/L in the following wells:

<u>Well No.</u>	<u>Concentration</u> <u>mg/L</u>
501B	1.91
EPA-13	1.06
EPA-10	2.5
EPA-1	1.6
EPA-3	1.8

Low arsenic concentrations are present in the tailing area because at low pH the arsenate adsorption on iron oxyhydroxide is at its highest level. This creates a arsenic "reservoir" of adsorbed arsenic. As the pH increases, some of the arsenic is released and is mobile. As the Eh (oxidation-reduction) decreases, most of the arsenic previously adsorbed goes into solution and can be transported. The current distribution is a combination of pH-Eh and groundwater flow.

Other wells which have been found to have historical arsenic values above the .05 mg/L drinking water standard. These include well Nos. EPA-5, EPA-6, EPA-11, EPA-16, EPA-18, and 436.

#### Selenium

The primary drinking water standard for selenium is 0.01 mg/L. Selenium usually has a low mobility in groundwater systems.

scope of the RI, but may relate in part to the previously mentioned proto ore pile and associated ponds.

#### Molybdenum

No molybdenum standards have been developed for active uranium processing sites. However, a proposed standard of 0.1 mg/L was proposed in September 1987, for groundwater at inactive sites (40 CFR 192.02). This value was used to discuss potential contamination at the Churchrock site. UNC has analyzed the ore for molybdenum and found concentrations of less than 1 to 70 mg/kg. Leachate characterization of the tailings for molybdenum is not available. Table 5-1 contains data supplied by UNC from wells in the ponds that report values up to 0.15 mg/L.

In groundwater, molybdenum travels as an anion ( $\text{MoO}_4$ ) and is not as easily attenuated as selenium or arsenic. Instead it travels as a conservative species in solution, much like the chloride ion.

Values along the tailings embankment and the pump back wells northeast of the north cell indicate molybdenum values of 0.2 to 0.7 mg/L. However, wells further downgradient have much higher molybdenum values. Maximum values of molybdenum in selected Zone 1 and 3 wells downgradient (Figure 5-18) of the site include:

<u>Well No.</u>	<u>Concentration</u> <u>(mg/L)</u>
EPA-1	42
EPA-11	59
EPA-13	5.6
411	2.4
401	5.9
430	1.6

The occurrence of higher molybdenum values in distant down-gradient wells than in wells close to the site cannot be explained with the current data. One explanation may be the presence of another (presently not identifiable) natural or man-made source. Slug flow from the tailings pond may also be an explanation for the molybdenum distribution. This latter explanation refers to the introduction of a single discrete impulse of contamination into the groundwater system. This contamination could move as a single discrete body downgradient. Current data is not sufficient to refute or prove either of potential explanations.

#### Manganese

The secondary drinking water standard for manganese is 0.05 mg/L. This standard was developed mostly for aesthetic (taste and discoloration) properties. Manganese has a high mobility because when it becomes solubilized it typically remains in solution until the pH reaches 8.0 and above. It is typically at the outer edge of contaminant plumes. Manganese is present in the tailings as exhibited by the concentration of 100 mg/L in well No. 633.

Review of manganese historical data in Appendix F reveals that more than 50 alluvial, Zone 1 and 3 wells have manganese concentrations above the secondary drinking water standard. Values of manganese have been found up to 15 mg/L in Zone 1 well No. EPA-7, and 55 mg/L in Zone 3 well No. EPA-6 east of the site (Figure 5-18). All of the U.S. EPA Zone 1 and 3 wells northeast of the site exceeded the standard.

Alluvial wells throughout the study areas exhibited manganese concentrations above the standard. The southwest alluvial wells had concentrations up to 19.8 mg/L at well No. 630. The northern alluvial wells have historical manganese concentrations of 0.1 to 1 mg/L.

In general, manganese concentrations in alluvium were lower than in bedrock. This is probably due to the generally more alkaline pH and higher adsorptive qualities of the alluvium.

#### Beryllium

Beryllium has a very low aqueous solubility and is quickly precipitated or adsorbed onto solids after entering the aqueous environment (U.S. EPA, 1979). In near neutral pH waters, beryllium will precipitate as  $\text{Be}(\text{OH})_2$ . Beryllium concentrations in fresh surface water are typically less than 1 ppb.

Review of the data base in Appendix G indicates that beryllium was not a routine analytical parameter. Data from U.S. EPA sampling represents the majority of beryllium sampling at the site. No data on beryllium concentrations in the tailings are available.

Based on U.S. EPA sampling results, beryllium was found in several monitoring wells. These wells and their respective concentrations include:

<u>Well No.</u>	<u>Concentration</u> <u>(mg/L)</u>
EPA-3	0.089
610	0.126
611	0.022
EPA-6	0.254

The data suggest that beryllium is present in or has been mobilized by the acidic tailings. It has only been found in wells with acidic pH values. No detectable beryllium was found in alluvial wells. Well No. 611 is the only Zone 1

well which contains detectable beryllium. Therefore, it can be concluded that beryllium has not migrated more than 600 feet in the Zone 1 aquifer. Beryllium in Zone 3 is found farther from the tailings pond as evidenced by its presence at well Nos. EPA-3 (1,200 feet), EPA-6 (900 feet), and 610 (750 feet). In summary, beryllium has been found offsite two wells, at concentrations above the  $10^6$  cancer risk water quality criteria standard.

#### Cadmium

Unlike beryllium, cadmium has been analyzed in the tailings liquids. Well No. 633 exhibited a concentration of 0.013 mg/L. The results of the U.S. EPA sampling is the main data base for cadmium distribution.

In comparison with most heavy metals, cadmium like manganese is relatively mobile. Sorption onto sediments and manganese oxide occurs as the pH increases. Adsorption onto organic materials (coal), minerals, coprecipitation with metal oxides and substitution in carbonates also control cadmium mobility (U.S. EPA, 1979). In carbonate groundwater, cadmium solubility would be about 0.1 mg/L at a pH of 7 and 100 mg/L at a pH of 5.

In the U.S. EPA sampling, cadmium was found above the primary drinking water standard of 0.01 mg/L in the following wells (Figure 5-18):

<u>Well No.</u>	<u>Concentration</u> <u>(mg/L)</u>
EPA-3	0.013
EPA-4	0.143
EPA-5	0.113

EPA-6	0.277
EPA-7	0.033
EPA-11	0.088
EPA-13	0.021
EPA-14	0.045
EPA-20	0.038
EPA-23	0.05
EPA-24	0.099
EPA-25	0.125
625	0.018

The concentrations in well Nos. 610 and 611 which are close to the ponds and have low pH values do not exhibit cadmium concentrations above the 0.005 mg/L detection limit. The sporadic distribution in Figure 5-18 and downgradient concentrations above the source concentrations suggests that the cadmium may be inherent to natural geologic media or the distribution may be reflective of slug flow which is discussed at the end of the "metal" subsection of this report.

Historical sampling by NMEID indicates a different cadmium distribution. MNEID (1987) has indicated that cadmium is rarely found "offsite" (away from the tailings pond). Rather, when found, cadmium has been only in groundwater with acidic concentrations, close to the tailings ponds. Away from the ponds, cadmium reportedly is absorbed on clays or precipitated as a carbonate or with iron oxides and hydroxides.

#### Chromium

Chromium is found in trivalent and hexavalent forms in aqueous systems. However, chromium analyses in the U.S. EPA sampling were reported as total chromium. The trivalent form readily forms an insoluble hydroxide precipitate in neutral waters. However, hexavalent chromium is not easily

sorbed on clays or hydrous metal oxides. At neutral pH, hexavalent chromium will typically be present in greater concentrations than the trivalent form. The major attenuating mechanism for hexavalent chromium is sorption onto carbon (U.S. EPA, 1979).

The historical data base for chromium is mostly from the U.S. EPA sampling events. For these samples, the maximum chromium concentrations that were greater than the primary drinking water standard of 0.01 mg/L include:

<u>Well No.</u>	<u>Concentration</u> <u>(mg/L)</u>
504B	0.03
610	0.268
611	0.014
EPA-6	0.135
EPA-27	0.029

From these data and the chromium distributions shown in Figure 5-18, chromium is not considered a significant offsite contaminant. Chromium appears to be limited to the area of the northeast pumpback system and quickly decreases down-gradient from this area.

#### ORGANIC COMPOUNDS

Organic analyses were performed on three groundwater samples from the following well Nos.: 610, 611, and 625. These samples were collected during the May 1985 sampling. The results of the analyses are contained in Appendix D-4.

Five volatile compounds were found in the three wells. The compounds and range of concentration were: methylene

## RADIONUCLIDES

Samples analyzed for radiological constituents are presented in Tables D-6, D-7 and D-8 in Appendix D. The analytes included Radium-226, Radium-228, Thorium-230, Uranium-238, Gross Alpha, and Gross Beta.

Comparison between U.S. EPA and historical data is not possible for the radionuclides. Historical radiological analyses were typically for uranium concentration as expressed in mg/L. In contrast, U.S. EPA data was measured as activity and expressed in pCi/L. If all uranium isotopes were analyzed, it would be possible to get a rough estimate of uranium concentration from the activity values. However, only U-238 was analyzed. Therefore, no conversions of activity to mass were made. Discussion of radionuclides are based on U.S. EPA data.

Gross alpha discussions represent gross alpha data with U-238 subtracted out. EPA guidelines for gross alpha require subtraction of U-238 and radon activity. Radon was not analyzed by the CLP, therefore, it could not be subtracted.

### Radium-226 and Radium-228

The Clean Water Act (CWA) has a standard which governs the concentration of radium in water. This standard combines the concentrations of Ra-226 and Ra-228. The combined guideline under the CWA is 5 pCi/L. Table 5-5 depicts which samples exceeded this standard. A total of 13 wells with 18 observations over 5 pCi/L were recorded (Figure 5-19).

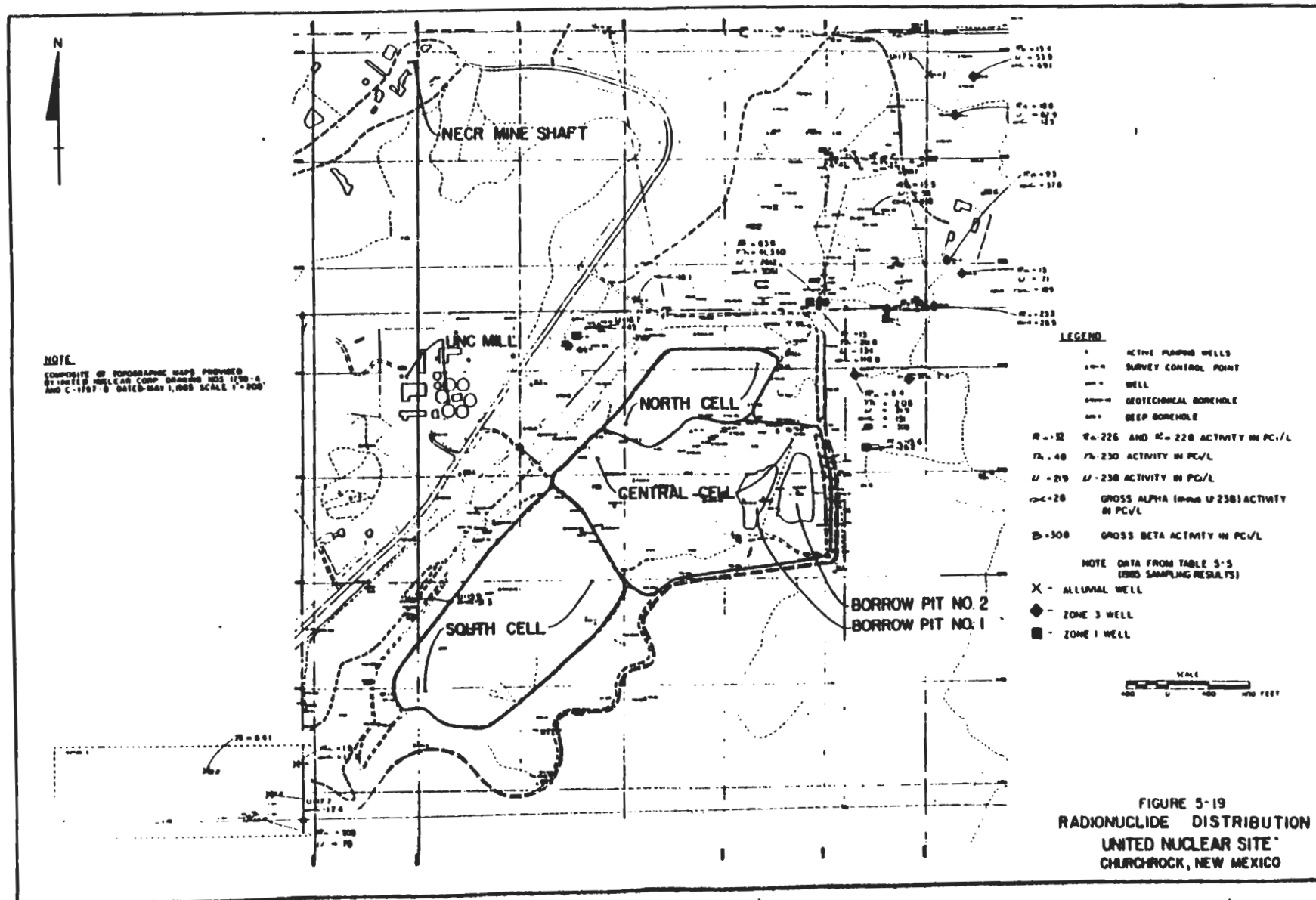
Concentrations of radium-226 (Ra-226) in the March 1985 sampling event ranged from 0.009 pCi/L in well No. EPA-25 to a high of 117 pCi/L in well No. EPA-18 (an alluvial well



**Table 5-5**  
**GROUNDWATER ANALYSES WITH ELEVATED RADIOACTIVITY VALUES**

Well No.	Aquifer	Date	Radium		Th-230		U-238		Gross Alpha <sup>a</sup>		Gross Beta	
			>5 pCi/L	%	>1 pCi/L	%	>15 pCi/L	%	>15 pCi/L	%	>50 pCi/L	%
EPA-3	Zone 3	3/85	-	-	-	-	20.2	12	68	44	-	-
EPA-5	Zone 1	3/85	-	-	-	-	15.6	12	28.2	81	-	-
FPA-5	Zone 1	5/85	-	-	-	-	-	-	21.2	79	-	-
EPA-6	Zone 3	3/85	5.4	10	2.05	35	219	11	151	27	308	28
EPA-9	Zone 3	3/85	7.4	35	-	-	-	-	-	-	-	-
EPA-10	Zone 3	3/85	-	-	-	-	30	16	46.1	39	-	-
EPA-10	Zone 3	5/85	15.4	97	-	-	53.9	17	69.1	36	-	-
EPA-11	Zone 3	3/85	-	-	-	-	68.8	12	150.2	23	-	-
EPA-11	Zone 3	5/85	18.8	71	-	-	82.9	12	125.1	19	-	-
EPA-13	Zone 3	3/85	21.8	19	-	-	-	-	-	-	-	-
EPA-13	Zone 3	5/85	9.3	2	-	-	-	-	37.8	60	-	-
EPA-15	Zone 3	3/85	-	-	-	-	55	13	111.8	20	-	-
EPA-15	Zone 3	5/85	7.5	61	-	-	50.6	11	15.4	31	-	-
EPA-18	Zone 3	3/85	13	5	-	-	71	13	189	24	-	-
EPA-19	Zone 3	3/85	23.3	23	-	-	-	-	26.5	60	-	-
EPA-20	Alluvial	3/85	-	-	-	-	17.3	20	-	-	-	-
EPA-21	Alluvial	5/85	-	-	-	-	-	-	18.1	35	-	-
EPA-22	Zone 1	3/85	-	-	-	-	18.7	12	45	40	-	-
EPA-23	Alluvial	5/85	-	-	-	-	15.9	12	31.3	49	-	-
EPA-25	Alluvial	3/85	-	-	-	-	-	-	-	-	64.1	63
EPA-27	Alluvial	3/85	-	-	-	-	17.7	12	17.4	94	-	-
EPA-28	Alluvial	3/85	-	-	-	-	-	-	15.7	86	-	-
EPA-28	Alluvial	5/85	19	15	-	-	-	-	17.7	81	-	-
610	Zone 3	3/85	47.6	28	41,340	5	7,612	11	-3,061	5	83.6	10
610	Zone 3	5/85	25.4	21	4,243	6	737	13	-	-	584	9
611	Zone 1	3/85	-	-	28.8	12	134	12	116.8	19	113	24
611	Zone 1	5/85	-	-	19.0	14	118	12	148.5	17	108	22
625	Alluvial	3/85	7.05	15	-	-	70	15	-	-	-	-

<sup>a</sup> Value reflects subtraction of U-238, however, radon was not analyzed.



scutthwest of the site). The values for well No. EPA-18 were anomalously high and probably reflect a poor analysis. A duplicate sample at well No. EPA-18 revealed an Ra-226 value of 13 pCi/L. This latter value appears reasonable in consideration of the concentration in wells in this area: well No. EPA-13 (Ra-226 of 11.4 pCi/L) and well No. EPA-9 (Ra-226 of 8 pCi/L). Excluding the anomalously high value at well No. EPA-18, the next highest observation was at well No. 610. This well located in Zone 3 northeast of the north cell had Ra-226 concentrations of 47.6 pCi/L in March 1985. Reanalyses in May 1985 revealed similar findings. The two highest values at the site were well Nos. 610 (25 pCi/L) and EPA-13 (9.5 pCi/L).

Ra-228 concentrations exhibited similar trends to Ra-226. Elevated concentrations of Ra-228 were found in the Zone 1 and 3 well Nos. (EPA-6, EPA-19, EPA-13, and EPA-15) east and northeast of the north cell.

Trends of radium-226 and -228 in groundwater may be determined from Figure 5-19. For Zone 3, the maximum combined radium activity occurs at well No. 610. Here activities as high as 47.6 pCi/L have been measured. This activity decreases rapidly away from this point. For example, all the down-gradient wells are less than 25 pCi/L and many are below to CWA standard. This significant reduction occurs in distances of several hundred feet in some wells.

In Zone 1, no radium activities exceeded the CWA standard. It is concluded that radium activity is not migrating in this unit. Only two alluvial wells exceeded the radium standard. These included well Nos. EPA-28 (19 pCi/L) and 625 (7.05) pCi/L. The occurrence of the anomalously high value at well No. 625 cannot be currently explained.

### Thorium-230

Thorium-230 (Th-230) is a radionuclide that was found in the groundwater in concentrations ranging from less than 1 pCi/L to a maximum of 41,340 pCi/L in well No. 610. Very few wells exhibited concentrations above 1 pCi/L (Table 5-5 and Figure 5-19). These wells were all completed in the Zone 3 aquifer and are in the same region as the elevated Ra-226 and Ra-228 levels. As was the case with Ra-226, the duplicate sample for well No. EPA-18 had anomalously high Th-230 values.

Review of the thorium distribution and comparison with the TDS Zone 3 plume (Figure 5-15) indicates that in the high TDS area around well No. 610 concentrations of thorium are very high (up to 41,000 pCi/L). However, these values significantly decrease to about 0.2 to 0.4 pCi/L at the edge of the plume. It can be concluded that Th-230 is not migrating far from the tailings ponds.

Thorium distribution at the site reflects the control of pH on the solubility of thorium. At pH values below 5.0 (near the ponds), thorium can remain in solution. At near neutral to alkaline pH values, thorium precipitates and is immobile.

### Uranium-238

Analyses for Uranium-238 (U-238) ranged from a high of 7612 pCi/L in well No. 610 to a low of 3.1 pCi/L in well No. EPA-7. Alluvial wells generally had concentrations of less than 20 pCi/L. However, well No. 625 did show concentrations above 70 pCi/L in the first sampling round. No drinking water standard is available for uranium activity. In order to isolate wells with appreciable U-238 activities, a somewhat arbitrary value of 15 pCi/L was chosen. This value reflects the alpha activity standard and uranium-238

is an alpha emitter. Table 5-5 lists the wells that exceeded this value. Fifteen wells were shown to exceed the 15 pCi/L value. These wells also exceeded the radium standard.

Review of Figure 5-19 indicates that U-238 activity rapidly decreases away from the core of the TDS plume. However, U-238 has been found outside of UNC property at elevated concentrations. For example, well No. EPA-6 exhibited a uranium activity of 219 pCi/L.

#### Gross Alpha and Gross Beta

Gross alpha and beta are two parameters for which the CWA does have standards. For gross alpha, the maximum contaminant level after subtracting uranium and radon activity is 15 pCi/L. Radon values were not analyzed; therefore, Table 5-5 depicts groundwater analyses which do not subtract radon activity.

Gross beta is a direct reading. A limit of 50 pCi/L exists under the CWA. Only six occurrences above the value were found in the groundwater analyses. Of these occurrences, only one well was completed in the alluvial aquifer. This well No. 625 is in the southwestern portion of the site.

Gross alpha readings above 15 pCi/L (without subtraction of radon) are ubiquitous throughout the site and in all aquifers of concern. However, in review of Figure 5-19, several trends can be made. Zone 3 wells have highest gross alpha concentrations in the TDS plume where concentrations exceed 10,000 mg/L. Here, activities were up to 3,000 pCi/L. Down-gradient near the fringe of the plume values decreased to about 100 pCi/L. Outside the plume, activities are in the vicinity of 50 pCi/L.

### ALLUVIAL AQUIFER CONTAMINATION

The alluvial aquifer has been impacted by the mine water discharges and tailings leachate. Several distinct high TDS plumes have been found at the site. The major plume extends southwest from the southern cell down the stream valley. This plume extends a minimum of 1,000 feet past the southern cell. The extent of the plume is beyond the furthest down-gradient monitoring well. Post RI field investigations by UNC found TDS levels in excess of 20,000 mg/L in the southwest alluvium. UNC has attributed these concentrations to natural levels in the Mancos Shale beneath the alluvium. Investigations from the RI work indicate anomalously high TDS concentrations in the alluvial aquifer, near the Mancos Shale contact. At this time it cannot conclusively be shown what is the source of these anomalies.

Another plume, as evidenced by TDS concentrations, has been shown to radiate from the north cell. The extent of this plume is smaller (less than 800 feet) than the southwest alluvium plume. The major reason the southwest plume extends further is because of higher groundwater velocities beneath the stream channel.

Alluvial contaminants, in addition to TDS include nitrate (in excess of 200 mg/L), and sulfate (in excess of 8,000 mg/L). Heavy metals have also been found at concentrations above water quality standards. Among these are selenium (0.4 mg/L), manganese (20 mg/L), cadmium (0.125 mg/L), and molybdenum (0.28 mg/L).

Radionuclides in the alluvium are primarily represented by gross alpha activity. Values above the gross alpha primary drinking water standard were found in six alluvial wells. These wells exhibited gross alpha activities ranging from 16 to 45 pCi/L. One well had a gross beta activity in excess

of the 50 pCi/L standard. The radium-226 and -228 standard of 5 pCi/L was exceeded in two alluvial wells. Thorium and uranium isotopes were shown not to migrate away from the ponds in the alluvium.

### ZONE 3 CONTAMINATION

The Zone 3 aquifer has been severely impacted by contaminants that have leached from the northeast portion of the north tailings cell. An elongate TDS plume has migrated more than 2,000 feet from the disposal site. This contaminant plume has migrated at a historic rate of between 337 and 450 feet per year between 1979 and 1985. TDS concentrations near the source are above 15,000 mg/L with pH values below 3.0. High ammonia (100 mg/L), sulfate (8,000 mg/L), and nitrate (35 mg/L) are the major ions that affect water quality. Heavy metal concentrations in the Zone 3 plume exceed primary and secondary water quality standards, however, these concentrations typically decrease away from the source. Heavy metals have migrated into the tribal lands east of the site. Maximum concentrations on tribal lands include: cadmium (up to .277 mg/L) chromium (.135 mg/L), manganese (55 mg/L), arsenic (1.8 mg/L), and beryllium (.254 mg/L). Table 6-1 summarizes typical maximum contaminant levels in groundwater on tribal lands.

Radionuclide distribution in Zone 3 indicates that activity levels decrease very rapidly from the source. Thorium and uranium activities have been shown to decrease from 41,000 and 7,000 pCi/L to less than 1 and 55 pCi/L, respectively, over a distance of 800 feet. Radionuclides have also been found at offsite locations (tribal lands) in Zone 3 wells. Well No. EPA-6 which is about 800 feet from the disposal pond had the following radionuclide activity levels:

<u>Radionuclide</u>	<u>Activity</u> <u>(pCi/L)</u>
Radium-226 and -228	5.4
Thorium 230	2.05
Uranium-238	219
Gross Alpha	151
Gross Beta	308

#### ZONE 1 CONTAMINATION

The Zone 1 aquifer has also been contaminated by site activities. The extent of contamination, however, is not as extensive as in Zone 3. TDS plumes for the Zone 1 aquifer indicate that contaminants are leaving the site from the northeast section of the north tailings cell and migrating to the northeast and east. Another plume is migrating eastward from borrow pit No. 2 and has encroached onto the tribal lands east of the site. Both of the Zone 1 contaminant plumes have traveled at least 800 feet from their sources. Contaminant velocities, as determined by historical TDS distribution, have been estimated at 100 feet per year between 1979 and 1985.

The Zone 1 contaminant plumes, on the tribal lands are characterized by TDS concentrations between 6,000 and 7,000 mg/L, acidic pH (4-5), and high nitrate concentrations (above 100 mg/L). Metal in groundwater on the tribal lands have had concentrations up to 0.143 mg/L of cadmium, 1 mg/L of arsenic and 15 mg/L of manganese (Table 6-1).

Radionuclides activities are highest near the north cell of the tailings pond (well No. 611). Here, thorium (29 pCi/L), uranium (134 pCi/L), gross alpha (117 pCi/L), and gross beta (108 pCi/L) attain maximum Zone 1 levels. Radionuclides do



not, however, travel very far in the Zone 1 aquifer. At the five Zone 1 wells on the tribal lands, only gross alpha activity exceeded water quality standards. Gross alpha activity in these four wells ranged from 10.9 to 28.2 pCi/L.

#### INTERRELATIONSHIPS OF THE AQUIFERS

One of the goals of the investigation was to determine the degree of interrelationship between site aquifers. RI pump tests showed little drawdown in wells within the same unit as the pumping well. Therefore, the aquifers were not "stressed" enough to produce drawdown in lower or upper aquifers and no conclusion can be made on the interconnectivity of the aquifers. Review of previous testing has indicated that, in places, the aquifers are hydraulically connected.

This phenomena is also indicated in hydrogeologic cross-sections where piezometric surfaces for the three aquifers are near identical at some locations. In portions of the site, there appears to be no hydraulic connection between the aquifers. This is evidenced by substantial piezometric head differences between aquifers.

#### RECOMMENDATIONS

The RI was responsible for filling previously identified data gaps and supplementing or verifying information collected to date at the site. The need for additional RI work is dependent upon the scope of the FS. Assuming that the FS applies only to the remediation of the groundwater, the following are potential data gaps and future activities.

The principal data gap for the remediation of groundwater contamination is characterization of the source, the tailings pond. A detailed characterization would include

**Reference 2**

**Excerpts From Record of Decision, United Nuclear Corporation  
Ground-water Operable Unit;  
EPA Region VI; September 30, 1988**

**RECORD OF DECISION  
UNITED NUCLEAR CORPORATION  
GROUNDWATER OPERABLE UNIT  
McKinley County, New Mexico  
SEPTEMBER 1988**

**U.S. ENVIRONMENTAL PROTECTION AGENCY  
REGION VI, DALLAS, TEXAS**

DECLARATION  
FOR THE  
RECORD OF DECISION

SITE NAME AND LOCATION

United Nuclear Corporation  
McKinley County, New Mexico  
Groundwater Operable Unit Remedial Action

STATEMENT OF PURPOSE

This decision document presents the remedial action for the Groundwater Operable Unit of the United Nuclear Corporation (UNC) site selected by the United States Environmental Protection Agency (EPA) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the National Contingency Plan (NCP).

STATEMENT OF BASIS

The decision is based upon the administrative record for the United Nuclear Corporation Superfund Site. The attached index (Appendix E) identifies the items which comprise the administrative record upon which the selection of this remedial action is based.

Remedial action for the Groundwater Operable Unit is part of a comprehensive response action for the United Nuclear Corporation Superfund Site. Remedial activities addressing source control and onsite surface reclamation will be implemented by United Nuclear Corporation under the direction of the U.S. Nuclear Regulatory Commission (NRC), pursuant to the facility's NRC license, and integrated with the Environmental Protection Agency's selected remedy for the groundwater operable unit. Agency responsibilities for remedial action at the United Nuclear Corporation site are delineated in a Memorandum of Understanding (MOU) signed by the EPA and NRC in August 1988. (Appendix I)

The Nuclear Regulatory Commission and the State of New Mexico have reviewed the proposed plan for remedial action, as identified in the remedial investigation/feasibility study (RI/FS), and proposed Plan of Action Fact Sheet, and support the remedy described in this Record of Decision. (Appendices F, G)

## DESCRIPTION OF SELECTED REMEDY

The Operable Unit for the United Nuclear Corporation site addresses high levels of radiological and nonradiological constituents that have seeped from tailings into groundwater outside the tailings disposal site. The hazardous substances of primary concern are arsenic, cadmium, cobalt, nickel, radium-226/228, selenium, and gross alpha. The tailings seepage has contaminated portions of the shallow alluvial groundwater system and underlying Upper Gallup Sandstones.

The selected remedy for this operable unit is designed to contain, remove, and evaporate contaminated groundwater resulting from tailings seepage outside the tailings disposal area thus preventing further migration of seepage into the environment. The remedy is comprised of the following six elements.

1. Implementation of a monitoring program to detect any increases in the areal extent, or concentration of groundwater contamination at, and outside of, the boundary of the tailings disposal area.

Evaluation of geochemical and hydrological information indicates that a tailings seepage mound exists in the tailings disposal area resulting in migration of contaminated groundwater into the alluvium, as well as underlying Zone 1 and Zone 3 Upper Gallup sandstones. Tailings seepage has migrated outside the tailings disposal area in each of these three aquifers, and there is the potential for further downgradient migration. For these reasons, a monitoring program will be established prior to the installation of extraction wells in each aquifer.

The monitoring program will consist of a groundwater monitoring network comprised of a series of wells to measure water levels and water quality. The monitoring points shall be located upgradient, downgradient, and cross-gradient of seepage plumes in order to further define the extent of contamination in Zones 1 and 3 of the Upper Gallup Sandstone, and the southwest alluvium. The extent of contamination in each aquifer, and concentration of contaminants in each well, shall be used to identify the most effective pumping well locations.

2. Operation of existing seepage extraction systems in the Upper Gallup aquifers.

Because seepage from tailings has migrated into underlying Zone 1 and Zone 3 sandstones, the selected remedy includes operation of the East pump-back wells in Zone 1 and the Northeast pump-back wells in Zone 3 until adequate dissipation of the tailings seepage mound has been achieved. Operation of these two pump-back systems will be integrated with active seepage remediation that may be required by the NRC inside the tailings disposal area, and with active seepage collection as required by EPA outside the disposal area.

3. Containment and removal of contaminated groundwater in Zone 3 of the Upper Gallup Sandstone utilizing existing and additional wells.

Active remediation of Zone 3 outside the tailings disposal site will be performed in areas contaminated by tailings seepage. The full extent of the tailings seepage plume will be determined during remedial design, prior to extraction well installation, and will be delineated on the basis of groundwater flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded for hazardous constituents in groundwater.

Seepage collection in Zone 3 will be designed to create a hydraulic barrier to further migration of contamination. Final well locations will be guided by observed saturated thicknesses in Zone 3, and the extent of the tailings seepage plume as defined above. Data obtained during performance monitoring of the extraction system should be used to determine the optimum rate of pumping, and extent and duration of pumping actually required.

4. Containment and removal of contaminated groundwater in the southwest alluvium utilizing existing and additional wells.

Active remediation in the southwest alluvium will be performed in areas contaminated by tailings seepage. The extent of the tailings seepage plume outside the tailings disposal area will be determined prior to extraction well installation. Delineation of alluvial contamination will be based on groundwater flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded for hazardous constituents in groundwater.

Seepage collection in the southwest alluvium will be designed to create a hydraulic barrier to further migration of contamination while the source is being remediated. The number of extraction wells required, and their final locations, will be determined from the observed saturated thicknesses in the alluvium, and the extent of the tailings seepage plume as defined above, during the remedial design phase. Data obtained during performance monitoring of the extraction system should be used to determine the optimum rate of pumping, and extent and duration of pumping actually required.

5. Evaporation of groundwater removed from aquifers outside the disposal area using evaporation ponds supplemented with mist or spray systems to enhance the rate of evaporation.

Tailings seepage extracted in pumping wells will be directed to an evaporation disposal system consisting of lined evaporation ponds and mist or spray evaporation systems. Inflow to the evaporation disposal system will be from current and required extraction wells outside and/or within the tailings disposal area. The evaporation pond system, coupled with mist and

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spray evaporation systems, will be sized and operated in order to provide sufficient evaporative capacity for maintenance of a reasonable operational water balance. Optimization of the evaporation disposal system should occur during the first several months of operation.

6. Implementation of a performance monitoring and evaluation program to determine water level and contaminant reductions in each aquifer, and the extent and duration of pumping actually required outside the tailings disposal area.

In order to evaluate predicted reductions in contaminant concentrations with time in a particular aquifer, and declines in pumping rates, a performance monitoring program shall be implemented. Performance monitoring during active seepage remediation will allow a determination to be made regarding the adequacy of groundwater remedial actions outside the tailings disposal area at the United Nuclear Corporation site.

These elements comprise remedial action in the groundwater operable unit at the United Nuclear Churchrock site. The Nuclear Regulatory Commission has directed United Nuclear Corporation to submit a reclamation plan addressing source control and surface reclamation measures at the site under the Company's Source Material License. Upon approval of a final reclamation plan, both groundwater and source control/surface reclamation remedial actions will be integrated and coordinated to achieve comprehensive reclamation and remediation of the site.

Table 6  
COMPOUNDS EXCEEDING STANDARDS

<u>Contaminant</u>	<u>Zone 3</u>	<u>Zone 1</u>	<u>North Alluvium</u>	<u>South Alluvium</u>	<u>Sec. 36 Alluvium</u>
Aluminum	X	X			
Arsenic	X	X			
Cadmium	X	X		X	X
Cobalt	X	X		X	
Manganese	X	X		X	
Molybdenum	X	X	X	X	
Nickel	X	X		X	
Selenium	X	X		X	
Nitrate	X	X		X	X
TDS	X	X	X	X	X
Ra-226-228	X				
Gross Alpha	X	X	X	X	X



## 1. SITE LOCATION AND DESCRIPTION

The United Nuclear Corporation (UNC) Churchrock site is located approximately 17 miles northeast of Gallup, New Mexico, in McKinley County (Figure 1). United Nuclear Corporation, also referred to herein as the potentially responsible party (PRP), operated the site as a uranium mill facility within UNC-owned Section 2, Township 16 North, Range 16 West (Figure 2). The site includes an ore processing mill and a tailings pond area which cover about 25 and 100 acres, respectively. The tailings pond area is subdivided by cross-dikes into three cells identified as the South cell, Central cell, and North cell. In addition, two soil borrow pits (Pits No. 1 and No. 2) are present in the Central Cell area. Borrow Pit No. 2 is currently used for storage of recovered and neutralized water extracted by three well systems operated by UNC. These pumpback wells are currently used to remove contaminated groundwater from Zones 1 and 3 of the Upper Gallup Sandstone.

The area around the site is sparsely populated and includes Indian tribal and allotted trust land as well as UNC-owned property. Section 36, Township 17 North, Range 16 West, located northeast of the site, is owned by UNC and bounded on the north by the Navajo Indian Reservation. The nearest residence is located approximately 1.5 miles northwest of the site. The nearest groundwater well is located 1.7 miles northeast of the perimeter of the site. Four known operating wells are located within a four mile radius of the site.

## 2. SITE STATUS

### 2.1 Site History

The UNC uranium mill was granted a radioactive materials license by the State of New Mexico in May 1977 and operated from June 1977 to May 1982. The mill, designed to process 4,000 tons of ore per day, used a conventional crushing, grinding, and acid leach solvent extraction method to extract uranium. The ore processed at the site primarily came from two of UNC's nearby mines: Northeast Churchrock and Old Churchrock. Ore was also obtained from the nearby Kerr-McGee (Quivira) mine. The average ore grade processed at the mill was approximately 0.12 percent  $U_3O_8$  (EPA, 1988). The crushing, grinding, and milling processes produced an acidic waste of ground ore and fluid, commonly referred to as tailings. The tailings were pumped to the tailings disposal area. An estimated 3.5 million tons of tailings were disposed in the ponds (EPA, 1988).

Prior to licensing of the UNC mill, uranium mining began in the area north of the present site. In 1968, the northeast Churchrock mine began operating and removed and discharged mine water. Water discharged from this mine, and later the Quivira mine, percolated into the ground and added water to the alluvial and Upper Gallup aquifers underlying much of the site. Limited monitoring of groundwater during the period of mining, and prior to operation of the mill, indicated water quality was variable.

In July 1979, the dam on the south cell breached, releasing approximately 93 million gallons of tailings and pond water to the Rio Puerco (EPA, 1988). The dam was repaired shortly after its failure. Cleanup of the resultant spill was conducted according to criteria imposed by state and federal agencies, including EPA, at that time.

In October 1979, the New Mexico Environmental Improvement Division (NMEID) ordered UNC to implement a discharge plan to control contaminated tailings seepage. The tailings seepage had been deemed responsible for groundwater contamination. In 1981, UNC implemented a groundwater pumping system that withdrew groundwater from the site aquifers and returned it to Borrow Pit No. 2 for evaporation (EPA, 1988).

UNC began tailings neutralization in late 1979, and continued the process until early 1982. Neutralization included the addition of ammonia or lime to the tailings; neutralization has also been conducted several times during the history of the mill operation (EPA, 1988).

In May 1982, UNC announced that they were going to temporarily close the Churchrock uranium mill because of depressed uranium market conditions. The market did not recover and UNC subsequently decided to close the facility permanently (EPA, 1988).

The offsite migration of radionuclides and chemical constituents into the groundwater, in addition to surface water and air emissions, prompted the placement of the UNC site onto the National Priorities List (NPL) of Superfund sites in 1983.

EPA's RI field activities at the UNC site were conducted from March 1984 to August 1987. The objectives of the RI field activities were to determine the nature and extent of groundwater contamination in the three aquifers at the site.

During early 1987, UNC submitted a closure plan to the NRC for reclamation of the mill site. This plan has been under review by the NRC since then and was formally approved in September 1988. On August 26, 1988, EPA and the NRC signed a Memorandum of Understanding (MOU), a copy of which is attached as Appendix I, which provides for the coordination of EPA's remedial action with the U.S. Nuclear Regulatory Commission (NRC) required site reclamation action. UNC's current activities at the site are limited to (1) compliance monitoring activities, (2) an improved seepage collection system operation, (3) dust control, (4) decontamination and sale of selected equipment, and (5) enhanced spray evaporation of water contained in Borrow Pit No. 2.

## 2.2 Response History

In 1981 EPA conducted a preliminary evaluation of the UNC site consisting of an assessment of existing data and a site inspection. The site, then

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regulated by the State of New Mexico under "agreement state" status with the NRC, was subsequently included on the Superfund Interim Priority List. In late 1982 EPA conducted an additional sampling inspection. In 1983 the site was formally placed on the National Priorities List of Superfund sites.

EPA began the RI in August of 1984 and fieldwork began in early 1985 after site access problems were resolved. The RI, which addresses groundwater outside the byproduct materials disposal site, was released in August 1988.

EPA also released a FS report in August 1988 along with a proposed plan of action fact sheet for the UNC site groundwater operable unit. EPA held a 29-day public comment period and a public meeting.

### 2.3 Enforcement History

During 1982 and 1983, EPA and UNC engaged in extensive negotiations with the aim of entering an agreed upon Administrative Order on Consent for conduct of investigative and remedial activities at the site in response to groundwater contamination. In August of 1983, after UNC declined to commit to an Order on Consent to promptly address groundwater concerns, EPA sent notice letters to UNC indicating its plans to conduct its own Remedial Investigation (RI) and Feasibility Study (FS).

In September of 1983 UNC objected to EPA's decision to conduct its own RI/FS, stating that EPA had no authority under CERCLA with respect to the site, and that EPA's work would interfere and be duplicative of UNC's own efforts. EPA continued with development of its plans for a CERCLA RI/FS, but progress was slowed as UNC denied EPA access to the site to conduct RI/FS activities from April through September 1984.

In August 1984 UNC filed suit against EPA for declaratory and injunctive relief in U.S. District Court for the District of New Mexico (No. 84-1163-JB) seeking to prevent EPA conduct of the RI/FS. In September of 1984, EPA obtained and executed an Administrative Warrant to conduct preliminary RI activities. EPA also filed an action in the same District court seeking injunctive relief and an Order in Aid of Access (No. 84-1409-88). During the months of October through December 1984, UNC and the United States filed numerous motions, in relation to both cases no. 1163 and no. 1409. In December of 1984 U.S. District Court dismissed case no. 1163 "without prejudice". UNC also informed the Department of Justice of its intention not to interfere with EPA access to the site to conduct the RI/FS, and work on the study was able to proceed. In April of 1985, the U.S. District Court entered an order granting EPA access to the UNC site for the purpose of conducting the RI/FS. (UNITED STATES OF AMERICA v. UNITED NUCLEAR CORP., 610 F. SUPP. 527 (D.N.M., 1985))

In June of 1986 the State of New Mexico returned its authority to regulate uranium mills back to the NRC. This Regulatory change prompted the develop-

The locations of operating wells sampled by EPA in 1987 are shown in Figure 9. Primary drinking water standards were not exceeded in any of the samples. Well 15K-303 and the Gray Well were the only samples containing radiological activity above 1 pico curie per liter (pCi/L), with 15K-303 containing  $12.0 \pm 2.7$  pCi/L beta and  $1.6 \pm 0.1$  pCi/L radium 226, and the Gray Well containing  $2.5 \pm 3.0$  pCi/L alpha and  $5.6 \pm 3.6$  pCi/L beta. These activities are below the drinking water standards, and related to natural background levels in area groundwater. The state standard for total dissolved solids (1000 mg/L) was exceeded in samples from all four wells, while the state standard for sulfate (600 mg/L) was exceeded in 15K-303. The state standard for iron (1.0 mg/L) was exceeded in wells 16F-606 and 15K-303, and that for manganese (0.2 mg/L) exceeded in well 15K-303. The principal exposure pathways through which humans might potentially become exposed to contaminants in the future are:

- o ingestion of groundwater from wells outside the tailings disposal area in each of the contaminated target areas if water supply wells are ever installed before completion of remedial activity
- o inadvertent ingestion of surficial tailings solids

EPA concluded from its public health assessment in the Feasibility Study that adverse health or environmental hazards could result if no action was taken to prevent exposure to groundwater contaminants found at the site. The public health assessment assumed ingestion of groundwater at contaminant concentrations equal to those measured during the 1985 RI sampling events (Tables 4 and 5). This assumption was conservative since dilution and dispersion expected to occur if seepage were allowed to continue to migrate downgradient from the site would likely further reduce the concentration of contaminants from the concentrations assumed. The remedy selected for the UNC groundwater operable unit is designed to contain and remove groundwater contaminated by tailings seepage thereby preventing continued downgradient migration of seepage and reducing significantly the amount of radiogenic and nonradiogenic constituents released into the environment. Groundwater remediation coupled with source control remedial action required by NRC will allow further improvements in groundwater quality at the UNC site. NRC-required source control measures, which address surficial contamination from windblown tailings solids and control of groundwater evaporation residues, are expected to eliminate significant potential risks to human health and the environment via the direct contact, air emissions, or surface exposure routes.

#### 4. COMMUNITY RELATIONS

On April 6, 1987, EPA held its first community meeting on the UNC site to discuss the status of on-going investigations at the site, and to clarify the respective roles of EPA and NRC in coordinating site reclamation. Navajo translation was provided and NRC was in attendance. Fact sheets

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spray evaporation systems. Inflow to the evaporation disposal system will be from current and required extraction wells outside and/or within the tailings disposal area. The evaporation pond system, coupled with mist and spray evaporation systems, will be sized and operated in order to provide sufficient evaporative capacity for maintenance of a reasonable operational water balance. Optimization of the evaporation disposal system should occur during the first several months of operation, and shall include pilot testing to determine the optimum pH for water evaporation.

6. Implementation of a performance monitoring and evaluation program to determine water level and contaminant reductions in each aquifer, and the extent and duration of pumping actually required outside the tailings disposal area.

In order to evaluate predicted reductions in contaminant concentrations with time in a particular aquifer, and declines in pumping rates, a performance monitoring program shall be implemented. Monitoring well locations shall be chosen at critical points to allow effectiveness evaluations of hydraulic capture zones in collecting tailings seepage.

Performance monitoring during active seepage remediation will allow a determination to be made regarding the adequacy of groundwater remedial actions outside the tailings disposal area at the United Nuclear Corporation site. Monitoring data will also be used to aid in making any modifications in remedial action outside the tailings disposal area, in order to meet CERCLA requirements.

These elements comprise the selected remedy for the groundwater operable unit at the United Nuclear Churchrock site. As previously mentioned the Nuclear Regulatory Commission has directed United Nuclear Corporation to submit a reclamation plan addressing source control and surface reclamation measures at the site under the company's Source Material License. Upon approval of a final reclamation plan, both groundwater and source control/surface reclamation remedial actions will be integrated and coordinated to achieve comprehensive reclamation and remediation of the site.

## 6.2 Cost of Selected Remedy

The estimated capital cost of the selected remedy is \$12 million and the present-worth estimate using a 10 percent discount rate is \$17 million over a 10-year period. This is approximate and made without detailed engineering data. The actual final cost of the selected remedy will depend on a number of factors which include:

- o material and labor costs, extraction well development, competitive market, conditions, and others direct and indirect costs related to the startup of remedial activity;

- o achievable flow rates from extraction wells, and therefore, the size of the enhanced mister/pond evaporation system necessary to accommodate these flows;
- o changes in operation and maintenance costs related to well system performance;
- o changes in contaminant concentrations and pumping rates over time resulting from groundwater extraction and source control activities which may constrain the required duration of pumping; and
- o changes in parameters such as cleanup criterion, should significant additional information on background levels of constituents result in any significant adjustments of such parameters.

### 6.3 Statutory Determinations

Section 121 of SARA requires the selected remedy to be protective of human health and the environment, be cost effective, use permanent solutions and alternative treatment or resource recovery technologies to the maximum extent possible, be consistent with other environmental laws, and have a preference for treatment which significantly reduces the toxicity, volume, or mobility of the hazardous substances as a principle element. EPA believes that the selected remedy best fulfills the statutory and selection criteria as compared to the other solutions evaluated herein.

#### 1. Protective of Human Health and Environment

The selected remedy, by containing and removing tailings seepage, will substantially reduce groundwater contamination in aquifers outside the byproduct materials disposal site. Contaminant concentration in impacted aquifers will be reduced to ARARs to the maximum extent practicable. The selected remedy, in conjunction with NRC-directed source control remedial action should effectively mitigate and minimize potential threats to human health and the environment. Implementation of the selected remedy will not cause unacceptable short-term risks or crossmedia impacts.

#### 2. Cost Effective

The selected remedy offers the lowest cost of all the treatment alternatives. Compared to other treatments alternatives, it is equally effective in removing contaminants in the alluvial and Upper Gallup Zone 3 aquifers, and is equally implementable. As previously mentioned, the characteristics of the Upper Gallup Zone 1 aquifer limit the implementability and reliability of an extraction well network (e.g. Alternative 1) in significantly decreasing contaminant levels in this aquifer.

**Reference 3**

**Public Comment Draft, United Nuclear Corporation  
Churchrock Site Operable Unit, Feasibility Study,  
Gallup, New Mexico; EPA Region VI; August 1988**

PUBLIC COMMENT DRAFT

UNITED NUCLEAR CORPORATION CHURCHROCK SITE  
OPERABLE UNIT FEASIBILITY STUDY  
GALLUP, NEW MEXICO

AUGUST 1988



## CLEANUP CRITERIA

Concentrations of contaminants in each of the aquifers were compared to federal and state standards and background levels. Wells that had groundwater samples with one or more contaminants exceeding standards or background levels were used to develop target areas for groundwater cleanup. Contaminant-specific Applicable or Relevant and Appropriate Requirements (ARARs) identified as cleanup criteria for the UNC site were: Federal Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs); New Mexico Water Quality Act (MNWQA) standards; and Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings. Table ES-3 summarizes the contaminant-specific ARARs.

For the purposes of the OUFS, background levels are based on postmining, pretailings conditions and have been set by EPA and NMEID based on currently available information. Should additional information become available that would significantly alter the estimation of background levels, such information would be evaluated in terms of its impact on remedial actions in each aquifer.

## PUBLIC HEALTH RISK ASSESSMENT

A public health risk assessment was conducted for the no-action alternative following guidelines established in the Superfund Public Health Evaluation Manual (EPA, 1986). Two exposure scenarios were analyzed: current and future use. The current use scenario evaluates exposures from consumption of groundwater from existing domestic and livestock wells. The future use scenario assesses exposures that result from consumption of groundwater from hypothetical domestic use wells located within each of the cleanup target areas.

Results of the public health risk assessment indicate that potential excess lifetime cancer risks from ingestion of arsenic contaminated groundwater at the site range from  $1.0 \times 10^{-1}$  to  $1.2 \times 10^{-3}$ . Potential excess cancer death risks from ingestion of radionuclides at the site range from  $1.8 \times 10^{-1}$  to  $6.5 \times 10^{-5}$ . Evaluation of noncarcinogenic risks at the site indicate that estimated daily intakes for several contaminants exceed established health-based levels.

## SCREENING OF RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

Response actions, technologies, and process options that are potentially suitable for application to the clean-up target areas were developed and screened. The first step in the screening process was the identification of the remedial

The remaining nonradiological contaminants were evaluated on the basis of noncarcinogenic health effects. These contaminants were assessed in terms of toxicological end points such as neurotoxicity, behavioral toxicity, hepatotoxicity, renal toxicity, hematologic toxicity, reproductive toxicity, and teratogenicity.

Table 4-9 presents summaries of toxicity profiles of the 11 indicator chemicals for both carcinogenic and noncarcinogenic effects.

#### TOXICITY SUMMARIES--RADIONUCLIDES

Radium-226, radium-228, thorium-230, and uranium-238 have been detected in the groundwater at the site. Once ingested, each of these radionuclides accumulate to some degree in human bone tissue. The radioactive decay of these materials produces alpha, beta, and gamma radiation, which may deliver significant radiation doses to the bone tissue. Bone cancers have been observed among individuals who were exposed to radium in the course of luminous-dial manufacturing and among patients who received radium medicinally during the early years of this century (Eisenbud, 1987). Leukemia has been observed in increased frequency among groups exposed to ionizing radiation, such as the survivors at Hiroshima and Nagasaki. Also, thorium can be taken up by the liver and uranium by the kidney.

#### RISK ASSESSMENT

Quantitative health risks are calculated using the exposure and toxicity information presented previously. Health risks are presented in terms of both carcinogenic and noncarcinogenic effects.

#### CARCINOGENS--NONRADIONUCLIDES

The methodology used in this risk assessment is based on the Superfund Public Health Evaluation Manual (EPA, 1986). For carcinogenic contaminants via the ingestion pathway, the estimated lifetime cancer risk (R) was calculated using the following model:

$$R = p \times d$$

where:

p = cancer potency (kg-day/mg)  
d = lifetime average intake (mg/kg/day)

The excess lifetime cancer risk is the incremental increase in the probability of contracting cancer over a 70-year period.

the boundary of Section 2 in each of the target areas. The contaminant concentrations that exist under this scenario are assumed to be equal to concentrations measured during the 1985 RI sampling events (Tables 4-1 and 4-2). This assumption is conservative. Dilution and dispersion occurring as the plume migrates downgradient from the site will likely further reduce the concentration of contaminants from the concentrations assumed.

For the future ingestion scenario, the rate of groundwater ingestion is assumed to be two liters per day for a 70-kg adult and one liter per day for a 10-kg child. Daily intakes have been estimated for both the adult and child using the maximum and mean values for each contaminant. The maximum and mean values have been calculated for each target area (north alluvium, south alluvium, Zone 1, and Zone 3). The two northern alluvial target areas have been combined for this public health assessment. The calculated daily intakes of nonradiological contaminants for the future ingestion of contaminated groundwater are presented in Table 4-7.

The 70-year lifetime doses due to ingestion of radionuclides are presented in Table 4-8 for both maximum and mean concentrations for the future use scenario.

#### TOXICITY ASSESSMENT

Some of the general toxicological effects associated with exposure to nonradiological indicator chemicals and radionuclides found at the site are summarized in this subsection. Eleven nonradiological indicator chemicals were selected for discussion of toxicological characteristics. These 11 chemicals were selected based on their frequency of occurrence at the site, concentration, and potential toxic effects. Exclusion of a chemical from this summary does not imply that exposure to these substances is without risk. All chemicals detected may contribute, in varying degrees, to potential risks from the site.

#### TOXICITY SUMMARY--NONRADIOLOGICAL CONTAMINANTS

The metals and inorganics included in this assessment can be divided into two categories based on type of health effect: carcinogens and noncarcinogens. Carcinogens are those contaminants that may cause or induce cancer. EPA has various categories for potential carcinogens that are based on weight-of-evidence. Some metals may cause cancer by one exposure route but not by other routes. Arsenic is the only nonradiological contaminant detected in the groundwater that EPA currently considers carcinogenic via the ingestion route.

The remaining nonradiological contaminants were evaluated on the basis of noncarcinogenic health effects. These contaminants were assessed in terms of toxicological end points such as neurotoxicity, behavioral toxicity, hepatotoxicity, renal toxicity, hematologic toxicity, reproductive toxicity, and teratogenicity.

Table 4-9 presents summaries of toxicity profiles of the 11 indicator chemicals for both carcinogenic and noncarcinogenic effects.

#### TOXICITY SUMMARIES--RADIONUCLIDES

Radium-226, radium-228, thorium-230, and uranium-238 have been detected in the groundwater at the site. Once ingested, each of these radionuclides accumulate to some degree in human bone tissue. The radioactive decay of these materials produces alpha, beta, and gamma radiation, which may deliver significant radiation doses to the bone tissue. Bone cancers have been observed among individuals who were exposed to radium in the course of luminous-dial manufacturing and among patients who received radium medicinally during the early years of this century (Eisenbud, 1987). Leukemia has been observed in increased frequency among groups exposed to ionizing radiation, such as the survivors at Hiroshima and Nagasaki. Also, thorium can be taken up by the liver and uranium by the kidney.

#### RISK ASSESSMENT

Quantitative health risks are calculated using the exposure and toxicity information presented previously. Health risks are presented in terms of both carcinogenic and noncarcinogenic effects.

#### CARCINOGENS--NONRADIONUCLIDES

The methodology used in this risk assessment is based on the Superfund Public Health Evaluation Manual (EPA, 1986). For carcinogenic contaminants via the ingestion pathway, the estimated lifetime cancer risk (R) was calculated using the following model:

$$R = p \times d$$

where:

p = cancer potency (kg-day/mg)  
d = lifetime average intake (mg/kg/day)

The excess lifetime cancer risk is the incremental increase in the probability of contracting cancer over a 70-year period.

The cancer potency factor converts estimated intakes directly to incremental risk. (This factor is based on an upper 95-percent confidence limit on the probability of response per unit intake of a chemical over a lifetime, i.e., only 5 percent chance that the probability of response could be greater than the estimated value on the basis of the experimental data used.) If the exposure assessment is conservative, the resultant health risk that is calculated is also conservative. Consequently, the calculated risk may overestimate the actual risk associated with consuming groundwater at the site.

EPA's cancer potency factor for arsenic, as listed in the Integrated Risk Information System (IRIS), is 15 kg-day/mg. Since EPA published this value, a scientific panel and the Risk Assessment Forum have recommended that it be reduced to 1.5 kg-day/mg. This reduced value has been used to calculate carcinogenic health risks.

The excess lifetime cancer risk from arsenic ingestion has been calculated using both the mean and maximum intake values for the future exposure scenario. The adult intake was used rather than the child intake because the risk conversion number is for 70 years of ingestion. Table 4-10 presents the excess lifetime cancer risks for future ingestion of arsenic from the various groundwater aquifers. Arsenic concentrations detected in samples from Zone 3 have the highest estimated excess lifetime cancer risks: the estimated risk using the maximum concentration is  $1 \times 10^{-1}$ , and the estimated risk using the mean concentration is  $2.5 \times 10^{-2}$ . It should be noted that these estimated lifetime cancer risks are based on arsenic concentrations that range from 0.03 to 2.4 mg/l in Zones 1 and 3. The arsenic MCL of 0.05 mg/l corresponds to an excess lifetime cancer risk of  $2.1 \times 10^{-3}$ .

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Table 4-10  
POTENTIAL EXCESS LIFETIME CANCER RISKS  
FROM INGESTION OF ARSENIC IN GROUNDWATER--  
FUTURE USE SCENARIO

	Excess Lifetime Cancer Risk Maximum Concentrations	Excess Lifetime Cancer Risk Mean Concentrations
Zone 1	$4.3 \times 10^{-3}$	$1.2 \times 10^{-3}$
Zone 3	$1.0 \times 10^{-1}$	$2.5 \times 10^{-2}$

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## CARCINOGENS--RADIONUCLIDES

Radionuclides that are deposited in the body could produce a variety of cancers (EPA 76, NAS 80). EPA's Office of Radiation Programs (ORP) indicates that risks due to radionuclide exposure should be calculated in terms of cancer fatalities. The ORP uses a conversion factor of  $2.8 \times 10^{-7}$  excess risk of death from cancer from whole body exposure to one millirem of radiation. Table 4-11 presents the estimated risk of death from ingestion of radionuclides detected in the various groundwater aquifers under the future use scenario. Zone 3 also has the highest estimated health risk for ingestion of radionuclides: the estimated excess risk from ingestion of thorium-230 is  $1.5 \times 10^{-5}$  using the maximum concentration and  $1.3 \times 10^{-5}$  using the mean concentration. The excess lifetime risk of death from ingestion of radionuclides under the current use scenario is  $1.7 \times 10^{-5}$  and  $7.8 \times 10^{-6}$  based on the maximum and mean Ra-226 concentrations, respectively.

## NONCARCINOGENS

Exposure to noncarcinogens has been assessed by comparing the estimated daily intake of contaminants to reference doses (RfDs) or Acceptable Intakes for Chronic Exposure (AICs). RfDs and AICs are estimates of an exposure level that would not be expected to cause adverse health effects when exposure occurs for a significant portion of the lifespan. For those indicator chemicals selected, RfDs and AICs have been developed for cadmium, manganese, nickel, and selenium. These values are presented in Table 4-12. To assess the overall potential for noncarcinogenic effects posed by ingestion of multiple noncarcinogenic contaminants, a hazard index (HI) approach has been used. For this method, which assumes dose additivity, the ratios of estimated daily intake to the RfD or AIC for each contaminant are summed (EPA, 1986). As the HI approaches a value of one, the concern for possible noncarcinogenic health effects is increased.

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Table 4-12  
RfDs AND AICs USED IN THE RISK ASSESSMENT

<u>Contaminant</u>	<u>RfD or AIC (mg/kg/day)</u>
Cadmium	$0.00029^a$
Manganese	$0.22^a$
Nickel	$0.02^b$
Selenium	$0.003^a$

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<sup>a</sup>AIC from Superfund Public Health Evaluation Manual (EPA, 1986).

<sup>b</sup>RfD IRIS Data Base (EPA, 1987).

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**Reference 4**

**Ground-water Corrective Action, Churchrock Site;  
Prepared for UA/C Mining and Milling by  
Canonie Environmental Annual Review; 1989**

identified as Zone 3 and Zone 1 of the Upper Gallup Sandstone and the Southwest Alluvium. These formations are described in the Geohydrologic Report (GHR) (Canonie, 1987b), the EPA's Feasibility Study (EPA, 1988a), and the EPA's Remedial Investigation (EPA, 1988b).

The corrective action at the Church Rock site described in the RD consists of extraction of tailings seepage from Zone 3 and the Southwest Alluvium. Limited seepage extraction from Zone 1 was to continue until dewatering of Borrow Pit No. 2, which is the source of tailings seepage in Zone 1, is completed. Figure 1-1 is a site orientation map that provides an overview of current site conditions and the target areas where corrective action is being implemented. The remedial action target areas were delineated in the RD (Canonie, 1989). For Zone 3 and Zone 1, acidic pH and calculations of travel distance were used to determine the extent of the target area. For the Southwest Alluvium, chloride concentrations greater than 100 milligrams per liter (mg/l) and calculations of travel distance were used to determine the extent of the target area. A summary of the remedial actions completed in 1989 is presented below.

## 1.2 Remedial Activities

### 1.2.1 Zone 3 Remedial Action

Remedial action in Zone 3 consists of pumping the existing northeast pump-back and new extraction wells located in or adjacent to the target area located northeast of the North Cell of the tailings impoundment. The existing northeast system consists of six wells pumping at an average combined rate of approximately 8 gallons per minute (gpm). Figure 1-1 shows the location of the system. The wells were installed in 1983 as required by the New Mexico Environmental Improvement Division to control migration of tailings seepage. The wells have been pumping continuously since that time and have extracted a portion of the seepage migrating from the North Cell of the tailings impoundment.

The purpose of the new extraction well system is to create a hydraulic barrier to further migration of the plume and to dewater the remedial

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action target area shown on Figure 1-1. The extractable volume of the target area in Zone 3 is estimated to be 200 million gallons or less. The system of wells is designed to remove this volume in 6 1/2 years of operation. However, monitoring of hydrogeologic conditions during remediation will determine the duration and magnitude of pumping actually required.

Figure 1-1 shows the locations of the new extraction wells. As shown, a total of 12 new wells, numbered 701 through 713, were installed in 1989. These wells comprise Stage I of the Zone 3 system described in the RD. The remaining Stage II wells are scheduled to be installed in 1991 with the number and location to be determined based on the performance of the Stage I wells.

Originally, a total of 13 wells was proposed for the first stage of well installation. However, the results of the aquifer test conducted in the first five wells installed (708 through 712) indicated that Well 704 would have a low yield and, by interfering with adjacent extraction wells, could cause a net loss of system capacity by reducing the productivity of surrounding wells. United Nuclear sought and received approval from the NRC and EPA for exclusion of the well from the program in June 1989.

The new Zone 3 extraction wells began pumping on August 7 and 8, after installation of the distribution lines was completed. The wells have pumped continuously since that time with a combined average flow rate of approximately 43 gpm. This rate is less than the rate of 60 gpm assumed during the system design because the hydraulic properties of the formation limit the productivity of the wells. The extraction wells are monitored daily for water level, instantaneous pumping rate, and cumulative volume pumped so that adjustments to system operation can be made as needed. Evaluation of the performance of the system is based on the data collected since the third quarter sampling event in July 1989.

#### 1.2.2 Zone 1 Remedial Action

Tailings seepage in Zone 1 originated from its subcrop in Borrow Pit No. 2 and migrated to the east of the Central Cell of the tailings impoundment.

Figure 1-1 shows the location of Borrow Pit No. 2 in relation to the plume in Zone 1. The remedial action for Zone 1 consists of dewatering Borrow Pit No. 2 and continuation of pumping from the existing north cross dike and east pump-back wells until the pit is dewatered. Additional pumping in Zone 1 has been determined to be infeasible due to the low transmissivity of the formation within the target area (Canonie, 1987b; EPA, 1988a).

In accordance with the schedule presented in the RD, Borrow Pit No. 2 was dewatered in 1989. In fact, dewatering was completed at the end of April 1989, which was approximately 6 months earlier than anticipated at the time the RD was submitted. Since Borrow Pit No. 2 is dry, remedial activities for Zone 1 consist of monitoring water levels and water quality in 10 wells located east and northeast of the pit. Although Borrow Pit No. 2 is dry, the existing pump-back wells continue to operate as required by the NRC License and the EPA in the AO (EPA, 1989). Evaluation of the performance of the Zone 1 remediation is based on the data collected since the second quarter sampling event in April 1989, when Borrow Pit No. 2 was dewatered.

#### 1.2.3 Southwest Alluvium Remedial Action

Remedial action for the Southwest Alluvium consists of pumping three extraction wells comprising a barrier/collection system in the target area shown on Figure 1-1. The system is located downgradient of the southern edge of the South Cell of the tailings impoundment and upgradient of the Points of Compliance (POC) wells designated by the NRC for the Southwest Alluvium. The location, spacing, and pumping rates for the wells were designed to establish a hydraulic barrier to further migration of seepage through the alluvium while the source is being remediated.

Figure 1-1 shows the location of the three extraction wells (801 through 803) and four monitoring wells (804 through 807) that were installed in the Southwest Alluvium. The wells were installed in August 1989 and began pumping on October 16, 1989. The wells have pumped continuously since that time with a combined average flow rate of approximately 20 gpm. This rate is higher than the rate of 17 gpm assumed for development of the system design. As with the Zone 3 system, the extraction wells are monitored



daily for water level, instantaneous pumping rate, and cumulative volume pumped so that adjustments to system performance can be made as needed. Evaluation of the performance of the system is based on the data collected since the fourth quarter sampling event in October 1989.

#### 1.2.4 Evaporation Disposal System

Seepage collected by the extraction wells is being disposed of by evaporation. The evaporation disposal system is designed to dispose of the extracted tailings seepage by the end of 1996. As shown on Figure 1-1 the system consists of two, five-acre lined evaporation ponds equipped with an evaporation mist system and a separate mist or spray evaporation system installed on the surface of the tailings. The evaporation disposal system has been installed and is operating entirely within the tailings disposal area. Details of the design and construction of the system are presented in Amendment I of the Reclamation Plan (Canonie, 1988a), the Technical Specifications (Canonie, 1988b) and the As-Built Report (Canonie, 1989c).

The lined ponds were constructed in October 1988 through January 1989 and began operation on January 3, 1989. The misters were installed in spring 1988 and have been used during the summer months to help control windblown tailings and dispose of the water from the extraction wells and Borrow Pit No. 2.

Between January and April 1989, water discharged to the ponds consisted of water pumped from the existing northeast, north cross dike, and east pump-back well systems and from Borrow Pit No. 2. Since Borrow Pit No. 2 was dewatered in April 1989, only water from the existing and new extraction wells has been discharged to the system.

#### 1.2.5 Source Control - Surface Reclamation

Another component of the remedial action is the surface reclamation of tailings. Surface reclamation activities related to source control began in May 1989 and will continue until October 1997, when reclamation is

scheduled to be completed. Beneficial effects from the reclamation activities are to be realized by placement of a cover over the tailings impoundment to prevent infiltration of precipitation. A description of, and technical specifications for, the surface reclamation activities are presented in the Reclamation Plan (Canonie, 1987a).

As shown on Figure 1-1, the reclamation activities completed in 1989 included regrading and placement of the interim soil cover in the North Cell. Regrading of the North Cell is an important step for source control for Zone 3 because the seepage present in this unit originated from tailings liquids in direct contact with the sandstone exposed in the northeast corner of the North Cell [GHR (Canonie, 1987b)]. The regrading and recontouring of the tailings materials, shown on Figure 1-2, eliminates ponded water and minimizes infiltration. In addition, placement of the compacted soil cover provides a low permeability layer that also minimizes infiltration. Permeability testing of the interim cover material provided values of  $1.4 \times 10^{-6}$  centimeters per second (cm/sec),  $3.9 \times 10^{-8}$  cm/sec, and  $3.5 \times 10^{-8}$  cm/sec. These values confirm that the compacted soil cover serves a barrier to infiltration. As a result, further seepage recharge to Zone 3 is minimized.

### 1.3 Performance Monitoring

A program of performance monitoring was established to evaluate the success of the remedial action in meeting the design expectations. Performance monitoring may indicate that the objectives have been met and the remedy is complete. The results of the monitoring may also indicate that achievement of all cleanup levels in a reasonable time period is technically impractical and that establishment of Alternate Concentration Limits (ACLs) or a waiver to meeting certain contaminant-specific Applicable or Relevant and Appropriate Requirements (ARARs) is necessary. A detailed description of the monitoring program is presented in the RD (Canonie, 1989a). Figure 1-2 presents the locations of the wells included in the performance monitoring program.

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they were collected in mid-July, immediately prior to startup of the system. The fourth quarter data represent conditions after three months of pumping (August through October).

The results of the evaluation indicate that the extraction wells are performing as designed and are successful in:

1. Capturing and extracting seepage in the remedial action target area; and
2. Creating a hydraulic barrier to further migration of tailings seepage.

For example, the saturated thickness of the formation has been reduced by more than 20 feet in the center of the well system. The area where draw-down caused by the wells equals or exceeds 10 feet is approximately 52 acres. This area of intense dewatering incorporates 90 percent of the Zone 3 target area.

Additional confirmation of the performance of the well system is provided by a comparison of actual field conditions and conditions predicted by the computer simulation. The location and configuration of the contours of saturated thickness based on the fourth quarter water level data are similar to those generated by the computer simulation. The similarity of the contour plots indicates the system is operating as predicted in the RD (Canonie, 1989a).

The preliminary pH data provide confirmation that the wells are extracting seepage. Comparison of the data from the third quarter and the fourth quarter sampling events indicates that the areal extent of tailings seepage represented by acidic pH was reduced by half, from approximately 72 acres to 34 acres, during the first three months of system operation.

### Zone 1 - Performance Monitoring Evaluation

The Zone 1 performance monitoring evaluation utilized data collected during the second, third, and fourth quarter 1989 sampling events. The second quarter data represent initial conditions since they were collected at the end of April, immediately prior to dewatering of Borrow Pit No. 2.

The results of the Zone 1 performance monitoring evaluation indicate that water level and pH measurements remained stable for the period between second quarter 1989 (when Borrow Pit No. 2 was dewatered) and fourth quarter 1989. The plume, represented by acidic pH, has migrated approximately 150 feet downgradient from that delineated by the remedial action target area in the RD (Canonie, 1989a). Since the target area was established based on data collected in 1986, this distance is approximately one-third less than would be expected using the velocity of 115 feet per year to 148 feet per year calculated in the RD (Canonie, 1989a). Given the low permeability of Zone 1, dissipation of the mound will be a long-term process and identifiable changes or trends in water level and pH will occur in small increments.

### Southwest Alluvium Performance Monitoring Evaluation

The Southwest Alluvium performance monitoring evaluation utilized data collected during the fourth quarter sampling event in October 1989 and water level readings obtained in December 1989 specifically for this report. The fourth quarter data represent initial conditions since they were collected immediately prior to startup of the extraction wells.

The results indicate that the extraction wells are performing as designed. Because the wells did not start operating until mid-October, the monitoring data provide only a preliminary indication of the effects of the extraction wells. However, review of the water level data indicates that the extraction wells are beginning to cause a reversal of the water level gradient and creating a hydraulic barrier to flow.

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**Mining Waste NPL Site Summary Report**

**U.S. Titanium Superfund Site  
Nelson County, Virginia**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

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## **DISCLAIMER AND ACKNOWLEDGEMENTS**

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**U.S. TITANIUM SUPERFUND SITE**

**NELSON COUNTY, VIRGINIA**

**INTRODUCTION**

This Site Summary Report for the U.S. Titanium site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region III Remedial Project Manager for the site, Kim Hummel.

**SITE OVERVIEW**

The U.S. Titanium NPL Site covers approximately 175 acres of a former titanium dioxide manufacturing plant (milling and ore-processing plant) located within Nelson County, Virginia, in the rural community of Piney River, on the north side of the Piney River. Superfund remedial efforts are specifically directed toward seven locations on the site, comprising a total of about 50 acres (Reference 1, page 5).

The site has had many different owners during its course of operation. According to EPA Region III, P.R. Corporation is the most recent owner, having acquired the property sometime after 1987 (although the exact date was not known). U.S. Titanium was the owner prior to P.R. Corporation. The plant began operation in 1931 under the auspices of the Virginia Chemical Corporation, which owned and operated the facility until July 1944. American Cyanamid Corporation operated the facility from 1944 to 1971. It owned the facility until 1973; the 2 years post-operation (i.e., 1971 to 1973) were spent negotiating facility-closure plans with the State Water Control Board (SWCB). Mr. S. Vance Wilkins purchased the site from American Cyanamid in 1973. He owned it until 1976, when he sold it to U.S. Titanium (Reference 5, page 1).

The American Cyanamid Corporation appears responsible for the majority of waste generated and stored at the facility. During American Cyanamid's 27 years of operating the facility, about 80,000 cubic yards of copperas waste (i.e., ferrous sulfate) was produced. This waste was stored onsite as a stockpile for later sale as a commercial product (the type and purpose of the product was not defined in the available literature) (Reference 5, pages 1 and 2; Reference 2, Volume 1, pages 6 and 7).

However, the copperas waste stockpile was never sold commercially, and in December 1980, the wastes were buried onsite under State orders (Reference 2, Volume 1, page 8). Prior to burying the copperas waste, the facility owner that followed American Cyanamid (S. Vance Wilkins, the owner from 1973 to 1976) attempted to reduce runoff associated with the large stockpile of copperas material by installing a State-permitted temporary leachate-collection and recirculation system (No-Discharge Certificate No. IW-ND-407) (Reference 5, page 1).

Due to these various modes of copperas management prior to its final burial, several separate and distinct areas were identified as possible sources of contamination. These areas, combined with other locations used in the plant's manufacturing and/or wastewater treatment processes (e.g., an evaporation pond, an unreacted ore-waste pile, two sedimentation ponds, a settling pond, and a drainage area that receives the majority of the surface-water runoff from the site) comprise seven distinct and separate areas of concern (see Figure 1). Table 1 provides a brief description of each of these areas (Reference 1, pages 5 through 9; Reference 2, Volume 1, pages 3 through 5).

U.S. Titanium improperly managed the temporary leachate-collection and recirculation system installed by Vance Wilkins. Contaminated runoff from the stockpiled copperas then entered the Piney River and caused six major fish kills (of over 228,837 fish) between July 1977 and June 1981. The 1977 fish kill prompted SWCB to begin enforcement activities on the site. In September 1977, SWCB ordered U.S. Titanium to pay for the fish kill and submit a plan to dispose of the waste copperas. Although the company paid for the fish, it did not provide the requested disposal plan. During deliberations with the company, another serious fish kill occurred in August 1979, which prompted SWCB to request the Circuit Court of Nelson County to order U.S. Titanium to bury the copperas by December 31, 1980. In response to the court order, U.S. Titanium contracted with New Enterprise Construction Co., to dispose of the copperas waste from Area 2. The waste was buried in a clay-lined, capped, burial pit, now referred to as Area 1. Burial was completed on December 12, 1980 (Reference 5, page 2; Reference 1, page 8).

After several site inspections and assessments by EPA, the site was listed on the NPL in September 1983. Following a civil action by the Commonwealth of Virginia against American Cyanamid and others for damages caused by the site, American Cyanamid was found liable for the damages. American Cyanamid signed a stipulation and order with the State establishing a schedule for completion of a temporary source control action, a Supplemental Remedial Investigation, and a Feasibility Study for the site. A Record of Decision (ROD), developed in accordance with Comprehensive Environmental Response, Compensation, and Liability Act, was signed by the Region III Administrator and concurred by the Commonwealth of Virginia in November 1989. The ROD estimated a treatment cost of \$5,895,000 (Reference 2, Volume 1, pages 4 through 8; Reference 1, pages 8 and 9).

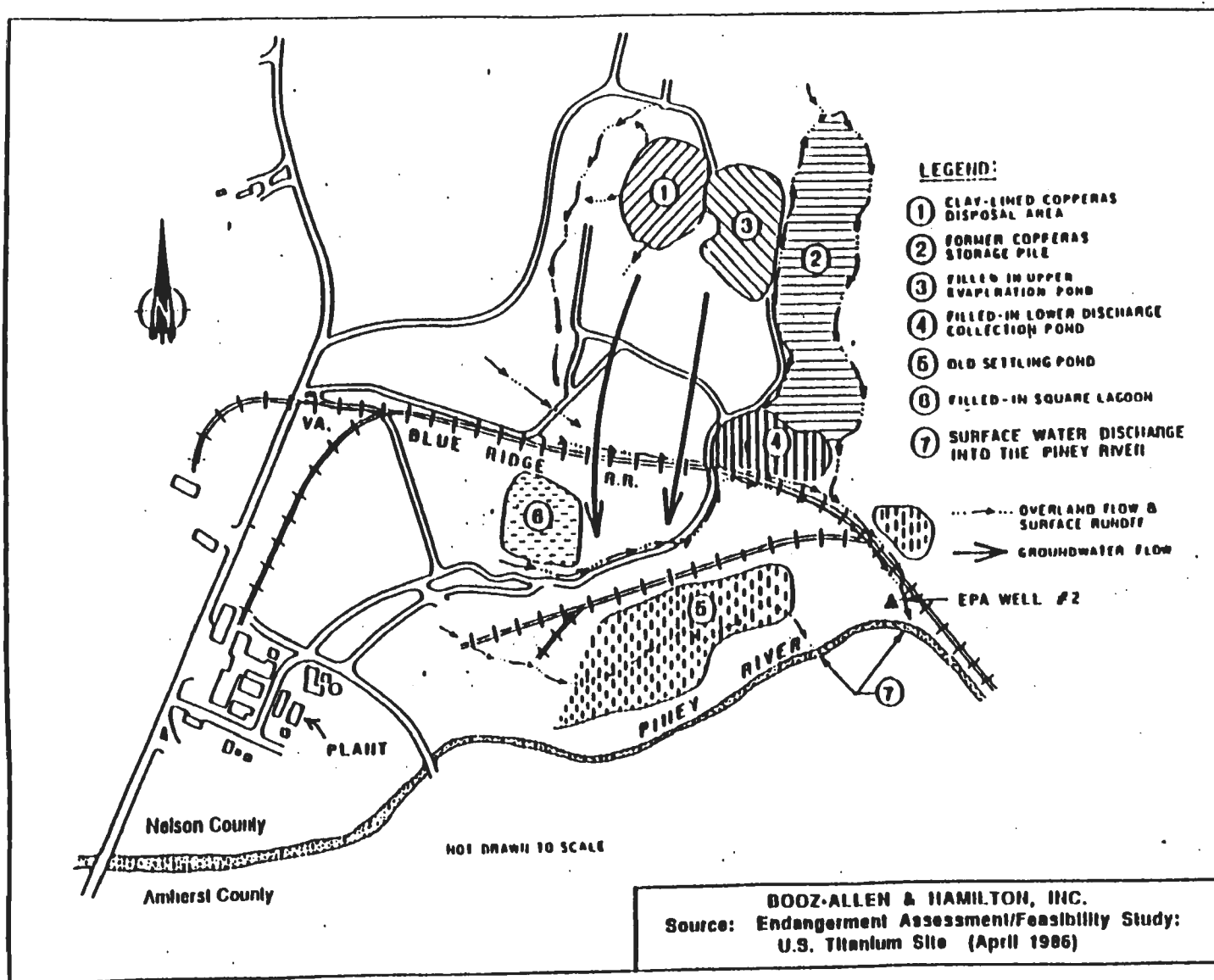


FIGURE 1. MAP OF U.S. TITANIUM SITE

Source: Reference 1, page 7

**TABLE 1. BRIEF SUMMARY OF THE AREAS OF CONCERN FOR  
SUPERFUND REMEDIAL ACTIONS**

NPL Area of Concern	Description
Area 1	Clay-lined, capped, burial pit where copperas from Area 2 was landfilled in 1980. Area 1 encompasses about 2 acres and contains about 16,000 cubic yards of copperas.
Area 2	Former Copperas Stockpile, located on the slope east of Area 3. Area 2 covers approximately 8 acres. Copperas from manufacturing operations was deposited here from 1949 to 1971.
Area 3	Contains the Evaporation Pond operated from 1974 to 1980. The Pond covered about 2 acres and was part of the system to prevent discharges to the Piney River under a State No-Discharge Certificate.
Area 4	Unreacted Ore-waste Pile. The Pile is about 1 acre and consists of clean outs from reactor vats used in the titanium dioxide process and dredge materials from the Sedimentation Ponds in Area 5.
Area 5	Contains 2 Sedimentation Ponds used to remove settleable solids from plant wastewater prior to discharge to the River. The approximately 7-acre area lies in the 100-year floodplain of the Piney River.
Area 6	Settling Pond used to recover phosphate ore, a by-product from titanium dioxide production. The Pond covers about 1 acre.
Area 7	Drainage area receiving most of the surface-water runoff from the site and flow from the tributaries. The area covers about 1 acre and lies within the 100-year floodplain of the Piney River.

Source: Reference 1, page 5

## OPERATING HISTORY

The Piney River plant began operations in 1931 under the ownership of the Virginia Chemical Corporation. Operations at the site by Virginia Chemical included the production of titanium dioxide pigment from native ilmenite ore (using the sulfate process) and production of phosphate through the digestion of native apatite ore with sulfuric acid (Reference 2, Volume 1, page 3). Titanium ore for the titanium dioxide production was obtained from mining operations directly south of the Piney River (Reference 1, page 8). The source of the apatite ore for phosphate production was not specified in the references. The wastestream resulting from these early operations at the site consisted of spent

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sulfuric acid, hydrated ferrous sulfate (copperas), diatomaceous earth filter cake, gypsum (from the phosphate process only), and unreacted apatite and titanium ore. From 1931 to 1944, this wastestream was discharged directly to the Piney River (Reference 2, Volume 1, page 3).

American Cyanamid Company purchased the site from Virginia Chemical in 1944. American Cyanamid discontinued phosphate production and operated the facility for titanium dioxide production only; wastestreams were still discharged directly to the Piney River. Beginning in 1947, American Cyanamid constructed a State-permitted Settling Pond to remove settleable solids from the wastewater. This Settling Pond is now referred to as Area 5. In the early 1950's, the company employed partial neutralization of the wastewater; and by 1955, it had eliminated suspended solids from the effluent and had significantly reduced sulfuric acid discharges. A Neutralization Lagoon was installed and became operational in 1957. By 1961, wastewater was being neutralized to a pH of at least 5; flow- and pH-monitoring equipment had been installed on the effluent stream; and a sulfuric acid recovery plant was being operated continuously (Reference 2, Volume 1, pages 3 and 4).

American Cyanamid ceased all operations in 1971. At the time of closure, American Cyanamid undertook a study to determine what could be done to reduce the acidic discharges from the Copperas Stockpile which had accumulated between 1949 and 1971 (approximately 80,000 cubic yards of the material had been stored for sale as a commercial product). The area where the copperas had been stored is now referred to as Area 2. The SWCB approved American Cyanamid's plans for the excavation and subsequent burial of the copperas in a clay-lined landfill on the south side of the Piney River on April 5, 1973 (Reference 2, Volume 1, page 4).

Prior to plan implementation, however, American Cyanamid sold the site to Mr. S. Vance Wilkins (in 1973) with the stipulation that he complete its plan (American Cyanamid paid him \$100,000 as part of the sales agreement to do this). Rather than implement American Cyanamid's plan, Mr. Wilkins opted to install a temporary copperas leachate-collection and recirculation system consisting of a lower collection lagoon located in the southern portion of what is now referred to as Area 2; an upper Evaporation Pond in an area now referred to as Area 3; and a pumping system for transferring the leachate from the lower Collection Pond to the Evaporation Pond. The leachate-collection and recirculation system installed by Mr. Wilkins was granted a 3-year State No-Discharge Certificate (No. IW-ND-407) on December 23, 1974. Mr. Wilkins never implemented the State-approved plan for burial (Reference 2, Volume 2, page 7).

Mr. Wilkins sold the site to U.S. Titanium Corporation in March 1976. U.S. Titanium failed to operate and maintain the leachate-collection and recirculation system installed by Mr. Wilkins. This failure resulted in the first of six major fish kills, in 1977 (Reference 1, pages 1 and 2). The failure of U.S. Titanium to maintain this "no-discharge" system led SWCB to take enforcement actions

against the facility, as described above. In summary, the State ordered U.S. Titanium to develop a disposal plan for the copperas. Actual burial of the copperas (as defined in the plan) began on October 2, 1980, and was completed by December 12, 1980. Final grading, channel improvements, and seeding and mulching were completed by January 16, 1981. (This disposal area is now referred to as Area 1) (Reference 2, Volume 2, page 8).

Concurrent with the copperas burial, EPA began preliminary investigations of the site. These ultimately resulted in the placement of the site on the NPL in December 1982.

### **SITE CHARACTERIZATION**

The site is located in the Piedmont physiographic province, about 5 miles east of the Virginia Blue Ridge Mountains. The elevation ranges from 618 feet in the Piney River near the drainage area (Area 7) to 726 feet on top of the copperas burial pit in Area 1. The bedrock under the site is igneous and metamorphic. Two distinct sets of nearly vertical fractures are present in the bedrock and have approximately northwest-southeast and northeast-southwest orientations (Reference 2, Volume 2, pages 42 through 46; Reference 1, page 12).

### **Characterization of Contamination**

NUS Corporation, under contract with EPA, prepared a Site Inspection Report of the U.S. Titanium site, dated July 27, 1983. NUS used available sampling and monitoring data as the basis for its conclusions. An initial Toxicological Impact Assessment (January 1983) of the site was based on data collected by EPA Region III (Central Regional Lab) on August 4, 1982, and data collected by SWCB on January 7, 1982. The conclusions reached in the early assessment were later confirmed by additional sampling and analysis performed by Ecology and Environment (in November 1982). Both of these investigations indicated the following: (1) high concentrations of toxic metals in leachate (arsenic, cadmium, chromium, lead, and nickel); (2) high sulfate and low pH in surface waters originating from the site; (3) contamination of ground water with metals, sulfate, and high acidity; and (4) probable (but undetermined) impacts on the nearby Piney River (Reference 3, page 1; Reference 4, pages 1-1' through 1-2).

EPA and the State considered these Site Inspections and other data (e.g., the Supplemental Remedial Investigation) when compiling the October 1989 ROD. In the ROD, they concluded that problems from the site were associated with acidified soils throughout the site and the buried copperas, both resulting from the titanium dioxide operation; no conclusions were made about damages from the phosphate operation. Leaching of these areas caused high levels of iron and acidity and metal

contamination (aluminum, cadmium, chromium, copper, nickel, and zinc) in ground and surface waters. These reported levels of contamination in both media violated surface-water criteria (see Table 2) (Reference 1, page 13). Table 3 provides a description of the acid-related problems at the site.

### Soils

Two soil groups exist at the site, one associated with the more upland areas, and the other characteristic of the floodplain. In the upland areas, the site is underlain by a soil of residuum (saprolite) derived from the weathering of the underlying parent bedrock material. It is composed primarily of clay and silty clay of the Cullen Association. The soils of the floodplain are heterogeneous alluvial deposits of gravel, sand, silt, and clay. The approximate boundary between the saprolite and alluvial soils lies along the base of the hill where Areas 1, 2, and 3 are located (Reference 1, page 12; Reference 2, Volume 2, page 34).

Soil surveys conducted as part of the 1983 Site Inspection indicated that, "in most cases soil metals were elevated but generally unremarkable." The highest metal concentrations found at the site occurred in samples collected from the copperas pile, which revealed very high levels of iron — nearly 50 percent by weight, or 496,000 milligrams per kilogram (mg/kg) (Reference 3, page 3). Metals that warrant toxicological concern were not detected in soil samples at unusually high levels. Lead, for example, was detected in one sample at a concentration of 190 mg/kg. The Site Investigation stated that lead occurs in all soils with a mean total concentration of 15 mg/kg and a range of from 2 to 200 mg/kg. Similarly, levels of arsenic, chromium, and other metals were found in some soil samples at the high end of the range normally found in uncontaminated soils (Reference 3, page 3).

Soil acidity at the site is a problem, however. Soil samples taken from the Copperas Pile and a soil sample taken from the eroded face of the treatment lagoon demonstrated very acidic solutions, ranging in pH from 2.6 to 3.6, when diluted with distilled water. Leaching or percolation of runoff into these soils, which are rich in ferrous salts (iron content ranged from 320,000 to 496,000 mg/kg), results in unusually high acidity, as is evidenced by the low pH of several surface- and ground-water samples from the site. High acidity, in turn, results in dramatic increases in the solubilities of most metals in water. This increased leaching potential also is reflected in several of the aqueous samples examined (Reference 3, page 3). The data presented in the ROD further demonstrated that leaching and runoff from the site affects ground- and surface-water quality in the area, as levels of pH and certain metals in both media were in violation of established water-quality criteria (see Table 2). Table 3, provides additional information on the acidity problems of the site (Reference 1, page 14).

**TABLE 2. MEAN CONTAMINANT CONCENTRATIONS IN SURFACE-WATER DISCHARGE AND GROUND WATER AT THE U.S. TITANIUM SITE**

UNITS [in milligrams per liter (mg/l)]			
Contaminants	Surface-water Discharge <sup>1</sup>	Ground Water <sup>2</sup>	Surface-water Criteria <sup>3</sup>
Aluminum	200	200	0.087 <sup>4</sup>
Arsenic <sup>5</sup>	<0.01	0.028	0.190
Cadmium	0.013	0.047	0.0003
Chromium	0.355	0.084	.011 <sup>6</sup>
Copper	1.355	0.45	0.0025
Nickel	0.692	2.67	0.023
Zinc	1.56	19.27	0.047
Iron	267	698	1.0
pH	2.4	3.1	6 to 9
Acidity	1,446	2,090	—

<sup>1</sup>Report by J. Novak, Virginia Tech; 1984.

<sup>2</sup>Morris, Ph.D. Thesis, Virginia Tech; 1984.

<sup>3</sup>Virginia Water Control Board.

<sup>4</sup>EPA Ambient Water Quality Criteria; 1988.

<sup>5</sup>NUS; 1983.

<sup>6</sup>Cr(VI) (total recovery).

Source: Reference 1, page 14



TABLE 3. ACID-RELATED PROBLEMS AT THE U.S. TITANIUM SITE

NPL Area of Concern	Acid-Related Problems
Area 1	The cap system on the burial pit has not functioned properly, allowing water to infiltrate the unit. The resultant acidic and high-iron leachate has acidified soils under the pit and contaminated ground water. This area causes about 65 percent of the total acidic discharge at the site. Ground-water samples downgradient of the pit have had a pH as low as 3.66 and concentrations of iron up to 2,190 mg/l.
Area 2	The soil under the former Copperas Stockpile is acidified, and ground-water seepages at the base of the slope have shown a pH as low as 2.66 and a total dissolved iron concentration of up to 17,720 mg/l. Total acid contribution from the area is 11 percent.
Area 3	The soil under the former Evaporation Pond is acidified down to the water table. The pH of ground water in the area is 3.32, with dissolved iron measured at 4,360 mg/l. This area contributes about 7 percent of the total acidity.
Area 4	The unreacted Ore-waste pile contains residual acidity from processing. The soil beneath this area also is acidified (levels were not given). The area contributes about 4 percent of the total acidity.
Area 5	The two Sedimentation Ponds in this area contain residual acidity from processing. Storm-water runoff from this area has caused a lowering of pH in the Piney River. Ground water flowing through this area also becomes acidified. pH readings from wells in the area have been as low as 3.42, with total dissolved iron concentrations of up 1,840 mg/l. This area contributes about 12 percent of the site's total acidity.
Area 6	This area has no detectable acidity or copperas problems.
Area 7	The soil under this Drainage Area has become acidified. A well downgradient of the area showed a pH as low as 3.09 and total dissolved iron of up to 570 mg/l. The area contributes about 1 percent of the site's total acidity.

Source: Reference 1, pages 12 and 13

### Ground Water

The hydrogeology at the site is typical of the Piedmont of Virginia. Ground water primarily occurs in the porous, unconsolidated material of the saprolite and, to a much lesser extent, in the fractures that run through the igneous and metamorphic bedrock. These two units are hydraulically connected over large distances, although local heterogeneities such as changes in clay content of the saprolite across a bedrock contact may produce local, partially confined conditions in the bedrock (Reference 2, Volume 2, page 49).

The depth to ground water is about 44 feet on the south side of Area 1. Downhill from Area 1, the water table becomes shallower, intersecting ground surface in the streambeds and springs along the base of the hill (Reference 1, page 12). Ground water eventually discharges into the Piney River either directly or via tributaries along the base of the hill containing Areas 1, 2, and 3. Observations during dry periods when the water table is low showed that ground water stopped discharging into the tributary along the southern base of Areas 1 and 3. During the same dry periods, the stream along the base of Area 2 continued to receive ground-water discharge, albeit at a much lower rate (Reference 2, Volume 2, page 59). Ground-water flow within the site originates in the upland area where Areas 1 and 3 are located and flows in a radial pattern downhill toward the streams surrounding the base of the hill and to the Piney River (Reference 1, page 12).

Analyses of samples from onsite monitoring wells revealed significantly reduced and variable pH values which ranged between slightly over 6 (in the deeper wells) to 2.5 (in the shallow and most contaminated well). Wells downgradient of the former Copperas Pile Storage Area (Well 7) and Burial Pit and Settling Pond (Wells 1, 2, and 6) revealed the following:

- Very high concentrations of certain metals [iron up to 5,570,000 micrograms per liter ( $\mu\text{g/l}$ ), nickel up to 6,300  $\mu\text{g/l}$ , manganese up to 1,000,000  $\mu\text{g/l}$ , zinc up to 12,000  $\mu\text{g/l}$ ]
- Concentrations of other toxic metals (arsenic, chromium, lead, selenium, and thallium) several times greater than National Interim Primary Maximum Contaminant Levels or Ambient Water Quality Criteria
- Enormous amounts of sulfate (up to 18,092,000  $\mu\text{g/l}$  or 1.8 percent in Well 7) (Reference 3, page 7).

Tabular results of the ground-water monitoring and analysis are presented in Table 4. The locations of sampling sites are given in Figure 2.

TABLE 4. GROUND-WATER MONITORING DATA FOR THE U.S. TITANIUM SITE<sup>1</sup>

Parameter	Sample Date <sup>3</sup>	(Dr. Smith) UST-R1	(Mrs. Hilbish) UST-R2	UST-W5 or Well #5	UST-W8 or Well #8	Well #1	UST-W2 or Well #2	UST-W6 or Well #6	UST-W7 or Well #7
pH	1/7/82 8/4/82	---- ----	---- ----	6 0 6 35 (6 2)	6 0 6 05	3.6 ----	4 7 4 45 (4 3)	4 6 3 4° (3 7)	2 5 2 8 (2 6)
Sulfates <sup>2</sup> (mg/l SO <sub>4</sub> )	1/7/82 8/4/82	---- ----	---- < 5	12 8 < 5	2,223 < 25	15,000 ----	6,626 > 2,500	2,279 > 2,500	18,092 > 2,500
As (µg/l)	1/7/82 8/4/82	< 5 < 5	< 5 < 5	1 < 5	3 < 5	200 ----	31 39 ppb	1 37	10 52
Cd (µg/l)	1/7/82 8/4/82	---- < 10	---- < 10	4 < 10	2 60	160 ----	80 190	[9] 120	---- 65
Cr (µg/l)	1/7/82 8/4/82	---- < 10	---- < 10 <sup>1</sup>	20 < 10	200 < 10	320 ----	200 35 ppb	[170] 75	530 280
Cu (µg/l)	1/7/82 8/4/82	---- ----	---- 65	< 10 < 10	20 20	100 ----	370 150	[200] 3,100	1,500 600
Fe (µg/l)	1/7/82	----	----	15	2.7	3000	3.7	[11] 5,570	----
Pb (µg/l)	1/7/82 8/4/82	---- < 5	---- < 5	2 < 5	2 110	---- 200	2 120	[78] 150	200 100
Mn (µg/l)	1/7/82	----	----	.13	32	1000	467	[19]	119
Ni (µg/l)	1/7/82 8/4/82	---- < 20	---- < 20	10 < 20	70 < 20	---- ----	4,600 6,300	[390] 3,800	2,800 2,300
Zn (µg/l)	1/7/82 8/4/82	---- 760	---- 130	730 50	2,100 12,000	---- ----	1,700 3,800	[1,400] 3,800	5,900 4,900

<sup>1</sup>Data from samples collected after well systems were purged<sup>2</sup>Note that the concentrations of sulfates, iron, and manganese are in mg/l<sup>3</sup>Values shown for January 7, 1982 were samples collected and analyzed by Virginia SWCB

° Results of pH paper, calibration of pH meter suspect

[] Results of samples collected before purging, no sample collected after purging

() Values determined in laboratory 17 days beyond allowable holding time

Source Reference 4, page 101288



Data summarized in the ROD supported the above findings by also showing a low mean pH (3.1) in ground-water samples and elevated concentrations of certain metals. The data from the ROD were presented in this report as Table 2 (Reference 1, page 14).

The two closest, private drinking-water wells also were sampled for the Site Investigation. However, both wells are hydraulically upgradient of the U.S. Titanium site, and the parameters tested (mostly inorganic) were present at low levels or were not detected. Other wells also are hydrologically isolated from the U.S. Titanium site; therefore, the investigation concluded that no drinking-water wells appear to be in any imminent danger of contamination (Reference 3, page 7).

### Surface Water

The U.S. Titanium site lies within the Piney River Drainage Basin, which is part of the larger James River Drainage Basin. The Piney River flows in an easterly direction, forming the southern boundary of the site. Areas 1, 2, 3, and 4 lie on the upland area, while Areas 5, 6, and 7 lie within the floodplain of the Piney River.

Surface water runs off the site primarily via a drainage channel along the bottom of Area 2 and a small stream that originates along the western side of Area 1. These two channels merge south of Area 2 and discharge into the Piney River through a culvert at the downstream end of the property. A third stream originates to the west of the Sedimentation Ponds in Area 5, flows through the Sedimentation Ponds, and discharges into the Piney River through a breach in the dike at the southeastern end of the Sedimentation Pond (Reference 2, Volume 2, page 61).

As discussed previously, runoff from the site resulted in six fish kills from 1971 to 1981. In June 1982, remedial measures were taken to improve conditions at the former Copperas Storage Area (Area 2) and the final Disposal Area (Area 1). The available documentation for the site states that no fish kills have occurred since these improvements.

Sampling and analysis conducted for the Site Investigation prior to the June remediation demonstrated the effects of the site on Piney River water quality. The results of these analyses are presented in Table 5. Figure 2 provides a map of sampling locations. A comparison of upstream and downstream locations shows an increase in metal concentrations at the downstream location (iron increases from 10  $\mu\text{g/l}$  upstream to 510  $\mu\text{g/l}$  downstream; manganese increases from 10 to 130  $\mu\text{g/l}$ ; chromium increases from 10 to 40  $\mu\text{g/l}$ ; sulfates increase from 1,900 to 13,800  $\mu\text{g/l}$ ; and pH falls from 6.7 to 5.1) (Reference 3, page 5; Reference 4, pages 101287 and 101295).

TABLE 5. SURFACE-WATER MONITORING DATA FOR THE U.S. TITANIUM SITE

Parameter	Stations									
	. 1	5	6	7	9	10	18	19	UST-L1	UST-L2
pH	6.7	3.0	3.0	3.0	3.0	2.9	5.1	6.6	---	2.9
Alk./Acid (mg/l calcium carbonate)	12/5	Acid/745	Acid/700	Acid/1,270	Acid/1,445	Acid/1,755	4/22	Alk/33	---	---
Sulfate (mg/l)	1.9	1,658.5	1,459.4	1,813.6	2,240.5	2,700.7	13.8	21.4	----	----
As (mg/l)	0.001 -	---	0.073	0.01 -	0.15	0.1 -	0.0 -	0.001 -	0.52	0.042
Cd (mg/l)	0.001 -	----	0.004	0.003	0.004	0.008	0.001 -	0.001 -	0.91	0.024
Cr (mg/l)	0.01 -	---	0.11	0.14	0.08	0.09	0.04	0.01 -	2.7	0.085
Cu (mg/l)	0.01 -	----	0.15	0.19	0.08	0.11	0.01 -	0.01 -	3.9	0.110
Fe (mg/l)	0.01	----	100	230	320	410	0.51	3.3	----	---
Pb (mg/l)	0.002 -	----	0.002	0.1	0.1	0.1	0.002 -	0.002 -	0.97	0.070
Ni (mg/l)	---	---	---	----	----	----	----	----	15.5	92
Mn (mg/l)	0.01	----	6.7	12	45	570	0.13	0.76	----	---
Zn (mg/l)	0.01 -	----	0.11	0.97	1.1	1.4	0.01 -	0.02	61.0	1.59

Source. Reference 4, page 101287

Surface-water samples taken in November 1982 suggest that a potentially serious leaching problem may still exist, despite the remedial measures taken in June 1982. A surface-runoff sample, taken from a culvert as it enters Piney River, revealed high levels of iron (424,000  $\mu\text{g/l}$ ), manganese (115,000  $\mu\text{g/l}$ ), zinc (2,270  $\mu\text{g/l}$ ), chromium (55  $\mu\text{g/l}$ ), nickel (1,278  $\mu\text{g/l}$ ), copper (170  $\mu\text{g/l}$ ), and silver (24  $\mu\text{g/l}$ ). Another surface-water sample taken downstream of the site in November (the location was not given) also demonstrated that the metals and related contaminants are adversely affecting Piney River water quality through runoff or infiltration. The downstream sample showed substantial increases in iron (from less than 50  $\mu\text{g/l}$  in the upstream sample to 5,960  $\mu\text{g/l}$ ) and manganese (from less than 10 to 390  $\mu\text{g/l}$ ). The pH decreased from 6.6 to 5.5. Sulfate was not measured (Reference 4, pages 4-1 and 4-2).

A sampling episode documented in the Supplemental Remedial Investigation also supports the assertion that runoff from the site may still pose a threat to Piney River water quality. The pH measurements before and after a "light" (intensity not measured) rain showed a drop in pH from 6.65 to 4.93 as a result of rain-induced site runoff (Reference 2, Volume 2, page 153).

The ROD also documented the contamination potential of the site, presenting data showing that the acidic nature of the site has led to metal leaching. Data compiled by the State for the ROD showed that concentrations of metals in surface water at the site exceed surface-water criteria (see Table 2). The downstream extent of contamination was not well documented in the ROD, although the results of SWCB sampling (the most recent sampling was in the fall of 1988) demonstrated that the aquatic invertebrate community in the Piney River has not completely recovered, even at a distance of 3.5 miles downstream (Reference 1, page 15).

#### **Fate and Transport**

Copperas is the primary source of acidity, dissolved iron, and sulfate in discharges from the site. Copperas is not acidic, but subsequent to dissolution, it produces acidity as the result of a sequence of reactions (that include oxidation of the ferrous iron to ferric iron and the hydrolysis of the ferric iron to ferric oxyhydroxides). The net effect of these reactions is that for every mole of copperas dissolved, 2 moles of excess hydrogen ion are produced, resulting in acidic leachate (Reference 2, Volume 2, page 159). The highly soluble nature of copperas [15.65 grams per liter (gm/l) in cold water] inhibits its reprecipitation once it is dissolved by percolating water. After the copperas leachate is formed in the Burial Pit (Area 1), the dissolved iron, sulfate, and acidity are transported along two possible pathways. The first pathway is from the Burial Pit down to the water table and hence with the ground water to points of discharge. The second pathway is via surface-water runoff from the Burial Pit and subsequently to the Piney River. In either case, the pathway taken by any

particular dissolved ion from the Burial Pit may involve both intermittent surface- and ground-water transport (Reference 2, Volume 2, page 168).

In the past, runoff from the U.S. Titanium site (following an unusually heavy precipitation event) resulted in fish kills in the Piney River that were attributed to a substantial influx of ferrous sulfate and a reduction in pH. During periods of low precipitation, water enters streams primarily as subsurface infiltration through granular or porous material. Low pH was noted in a downstream sample during a time when no leachates were observed discharging into Piney River, possibly reflecting the substantial contribution of affected ground waters to the River (Reference 3, page 8).

#### ENVIRONMENTAL DAMAGES AND RISKS

Initial interest in the site was prompted by the 1979 fish kill, although two previous and significant fish kills also occurred (Reference 1, page 8). Table 6 is a summary of significant documented fish kills.

**TABLE 6. FISH KILLS IN PINEY RIVER**

Date	Number of Fish Killed
July 1977	73,056
August 1977	8,940
August 1979	26,136
July 1980	53,980
May 1981	20,482
June 1981	46,243
Total	228,837

This initial interest led to a number of enforcement and legal actions, as documented earlier in this report. Ultimately, the site was placed on the NPL in September 1983.



The area surrounding the site is populated by approximately 200 people, most of whom live within a 1-mile radius of the site. The closest residence is approximately 2,000 feet to the west of the site along State Route 151, across from the former plant building site. The community uses ground water for its potable water supply. However, the residential wells are hydrologically isolated from the contaminated ground water found on the site. Residential wells to the north and west are upgradient (ground-water flow is south-southeast), while wells south of the Piney River and east of the site are hydraulically isolated by the ground-water discharge boundaries associated with the Piney River, and the unnamed tributary on the eastern side of the boundary. No residential wells exist between the site and the Piney River (Reference 2, Volume 2, page 31).

Surface-water drainage from the site flows south to the Piney River, which, in turn, flows southeastward to the Tye River, and subsequently to the James River. The Piney River is not used for a municipal water supply, but is used for recreation and fishing upstream of the site. The closest diversion for drinking water is approximately 40 miles downstream on the James River, and is not subject to adverse impacts from the site (Reference 2, Volume 2, page 32).

The results of the 1983 Site Investigation tend to support those of the Supplemental Remedial Investigation, as it also concluded that, "[t]hreats of a direct nature to human health appear to be minimal" (Reference 3, page 1).

The greatest impact of the site is the past and potential contamination of surface water. The elevated levels of metals and acidity in the Piney River water resulting from the site can have toxic effects on aquatic life. For example, the Site Investigation cited a study documenting the effects of low pH on Fathead Minnows: a pH value of 6.6 was marginal for vital life functions, while a lower pH reduced egg production and hatchability. At pH levels below 5.2, the fish exhibited abnormal behavior and deformities. Reported pH levels on the Piney River downstream of the site averaged 5.1 (Reference 3, page 8). Also, the oxidation of large amounts of ferrous ions in water can deplete dissolved-oxygen supplies. The oxidation process causes the precipitation of ferric hydroxide, which can settle out of suspension and produce a choking sediment layer on the River's bottom. These two phenomena (oxygen depletion and sedimentation) can also have deleterious affects on the River ecology (Reference 3, pages 8 and 9).

The precipitation of ferric hydroxide has been a problem in the Piney River, as summarized in the ROD: "[t]hese [ferric hydroxide] sediments are still present today and have disrupted the benthic community in the river. This in turn has resulted in a decrease in the number and diversity of the fish population in the river adjacent to and downstream of the site. Low pH discharges can be toxic to aquatic organisms. Based on sampling as late as fall 1988, the SWCB has concluded that the

aquatic invertebrate community has not completely recovered in the Piney River even at a distance of 3.5 miles downstream" (Reference 1, page 15).

## REMEDIAL ACTIONS AND COSTS

American Cyanamid began preliminary efforts to address water-quality problems from the site (in 1947) by installing a sedimentation pond to remove settleable solids from the wastewater. Subsequent activities, completed by 1961, included neutralization of all wastewater to a pH of 5; installation of flow and pH monitoring equipment on the effluent stream; and continuous operation of a sulfuric acid recovery plant. American Cyanamid's efforts focused on wastewater discharges. The site's subsequent owner, Vance Wilkins, began addressing the acidic-leachate problem associated with the Copperas Stockpile by installing a temporary copperas leachate-collection and recirculation system (permitted by the State on December 23, 1974). U.S. Titanium purchased the site from Mr. Wilkins in March 1976. In September 1977, SWCB ordered U.S. Titanium to submit a plan for the disposal of the copperas waste. After several delays and subsequent judicial proceedings, U.S. Titanium completed burial of the copperas on December 12, 1980. Final grading, channel improvements, and seeding and mulching were completed by January 16, 1981. Reclamation work and runoff control on the former Copperas Stockpile area was contracted on May 27, 1982. The recent status of this reclamation work was not provided in the available information (Reference 2, Volume 2, pages 5 through 9).

A 1979 fish kill spurred regulatory interest in the site. A number of ensuing enforcement and regulatory activities resulted in the placement of the site on the NPL in September 1983. A ROD describing the final EPA remedy at the site was completed and signed by the EPA Regional Administrator and the Commonwealth of Virginia in November 1989. The primary goal of the remedial action was to control risks posed by acidic discharge to ground water and the Piney River by eliminating the sources of acidic discharge from the six areas of the site found to be major sources of contamination. The final EPA remedy, as conveyed in the ROD, and the available cost data are described in Table 7 (Reference 1, pages 16, 17, 30, and 31).

## CURRENT STATUS

The ROD was signed in November 1989. According to EPA Region III, the Potentially Responsible Party, EPA, and the Commonwealth of Virginia completed the negotiation of a Consent Decree for implementation of the remedial design and remedial action in September 1990. The Consent Decree was lodged in Federal Court on December 4, 1990, and entered on February 18, 1991. The Consent

Decree does not become effective, however, until the State dismisses a Nuisance Action it currently has pending against American Cyanamid. This dismissal is expected in the near future.

**TABLE 7. SELECTED EPA REMEDIAL ACTIONS FOR THE U.S. TITANIUM SITE**

Treatment Component	Approximate Cost
<b>Ground Water</b>	
Collection: Passive Collection System <sup>1</sup>	\$173,000
Treatment: Passive Treatment System <sup>2</sup>	\$431,000
Area 1 - Dissolution and Treatment <sup>3</sup>	\$3,962,000
Area 2 - Surface Repair of Unvegetated Areas	\$147,000
Area 3 - Improve Surface Drainage	\$106,000
Area 4 - Drainage Control and Revegetation	\$202,000
Area 5 - Drainage Control and Revegetation	\$874,000
Area 6 - No Action	0
Area 7 - Above-grade Dry Neutralization (in combination with wetland)	0
<b>Total</b>	<b>\$5,895,000</b>

<sup>1</sup>Ground water would be intercepted by a series of subsurface drains and/or trenches installed below the water table along the base of the hill containing Areas 1, 2, 3, and 4. Gravity flow would feed the collected water to the ground-water treatment system.

<sup>2</sup>The treatment system would include an oxidation/settling pond, a constructed wetland, and a limestone neutralization bed. All residual wastes would undergo Extraction Procedure (EP) Toxicity testing to determine their waste classification before disposal. Waste determined to be hazardous (as per Resource Conservation and Recovery Act Subtitle C) would be managed accordingly.

<sup>3</sup>According to EPA Region III, the major steps included in the ROD for this procedure are: (1) dissolution of copperas inside the burial pit; (2) recovery of resulting leachate from the pit; (3) complete treatment of the leachate using physical and chemical processes; and (4) sludge disposal. An explanation of significant differences (dated September 26, 1990), allows for an alternate method of dissolution to be considered during design. Steps 1 and 2 above may be substituted with: (1) excavation of the soil and copperas mixture from the burial pit; and (2) dissolution of the copperas from the soil.

## U.S. Titanium Superfund Site

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### REFERENCES

1. Record of Decision, U.S. Titanium Superfund Site, Nelson County, Virginia; EPA; October 1989.
2. Supplemental Remedial Investigation, U.S. Titanium Site, Piney River, Virginia, 5 Volumes; Prepared for American Cyanamid Company by Hydrosystems, Inc.; September 17, 1987.
3. A Toxicological Impact Assessment of the U.S. Titanium Corporation Property; NUS Corporation; January 6, 1983.
4. Site Inspection of U.S. Titanium; NUS Corporation; July 27, 1983.
5. Letter Concerning Status Report of the U.S. Titanium Mine Site; From R.V. Davis, SWCB, to J. Kenneth Robinson, House of Representatives; August 26, 1980.

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NUS Corporation. A Toxicological Impact Assessment of the U.S. Titanium Corporation Property. January 6, 1983.

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Prepared for American Cyanamid Company by Hydrosystems, Inc. Supplemental Remedial Investigation, U.S. Titanium Site, Piney River, Virginia, 5 Volumes. September 17, 1987.

Sitler, Jeffrey A. (Hydrosystems, Inc., Executive Vice President). Letter and Attachment Concerning U.S. Titanium Superfund Site to Dr. Tim Lange, Virginia Department of Waste Management. July 18, 1989.

Virginia Department of Waste Management. U.S. Titanium Superfund Site, Nelson County, Virginia, Record of Decision. October 1989.

**Reference 1**

**Excerpts From Record of Decision,  
U.S. Titanium Superfund Site, Nelson County, Virginia;  
EPA; October 1989**

**RECORD OF DECISION**

**U. S. TITANIUM SUPERFUND SITE  
NELSON COUNTY, VIRGINIA**

**PREPARED BY  
VIRGINIA DEPARTMENT OF WASTE MANAGEMENT  
OCTOBER, 1989**

## DECISION SUMMARY

### SITE NAME AND LOCATION

The U. S. Titanium Site is located at the southern border of Nelson County along the north bank of the Piney River and east of Virginia Route 151, about 40 miles south of Charlottesville, in west central Virginia. The center of the site is located approximately at longitude 79° 01' 00" West and latitude 37° 42' 30" North. The site lies just east of the rural community of Piney River, Virginia. Figure 1 shows the general location of the site on the USGS Piney River 7.5' quadrangle topographic map.

The U. S. Titanium site lies on 175 acres of a former titanium dioxide manufacturing plant. Superfund remedial efforts are concerned with approximately 50 acres of the site. This acreage contains seven separate and distinct areas which were identified as possible sources of contamination and are described below. A site map is shown in Figure 2.

Area 1 is a clay lined, clay capped burial pit where copperas (ferrous sulfate) from Area 2 was landfilled in 1980. It encompasses approximately two acres and contains about 16,000 cubic yards of copperas.

Area 2 is the former copperas stockpile area located on the slope east of Area 3. It covers approximately eight acres. Copperas from manufacturing operations was deposited here from 1949 to 1971. The copperas was buried in Area 1 in 1980.

Area 3 contained the evaporation pond operated between 1974 and 1980 and is located between Area 1 and Area 2. This pond, which covered about two acres, was part of a system to prevent discharges to the Piney River operated under a No-Discharge Certificate issued by the Virginia Water Control Board (VWCB). Surface water run-off and some groundwater discharges were collected in a containment pond and pumped up to the evaporation pond.

Area 4 is an unreacted ore waste pile located south of Area 2. It covers about one acre and consists of clean-outs from reactor vats used in the titanium dioxide process and dredged material from the sedimentation ponds in Area 5.

Area 5 contains two sedimentation ponds located along the Piney River used to remove settleable solids from plant wastewater prior to discharge to the river. The ponds cover an area of approximately seven acres and contain an extremely fine-grained sediment composed of unreacted ore, filter cake, and gypsum. This area lies within the 100-year floodplain of the Piney River.

Area 6 contains a settling pond used to recover phosphate ore, a by-product from titanium dioxide production. It covers about one acre and is located north of Area 5.

Area 7 is the drainage area receiving most of the surface water run-off from the site and the flow from tributaries. This area is located in the southeast corner of the site and covers about one acre. This area lies within the 100-year floodplain of the Piney River.





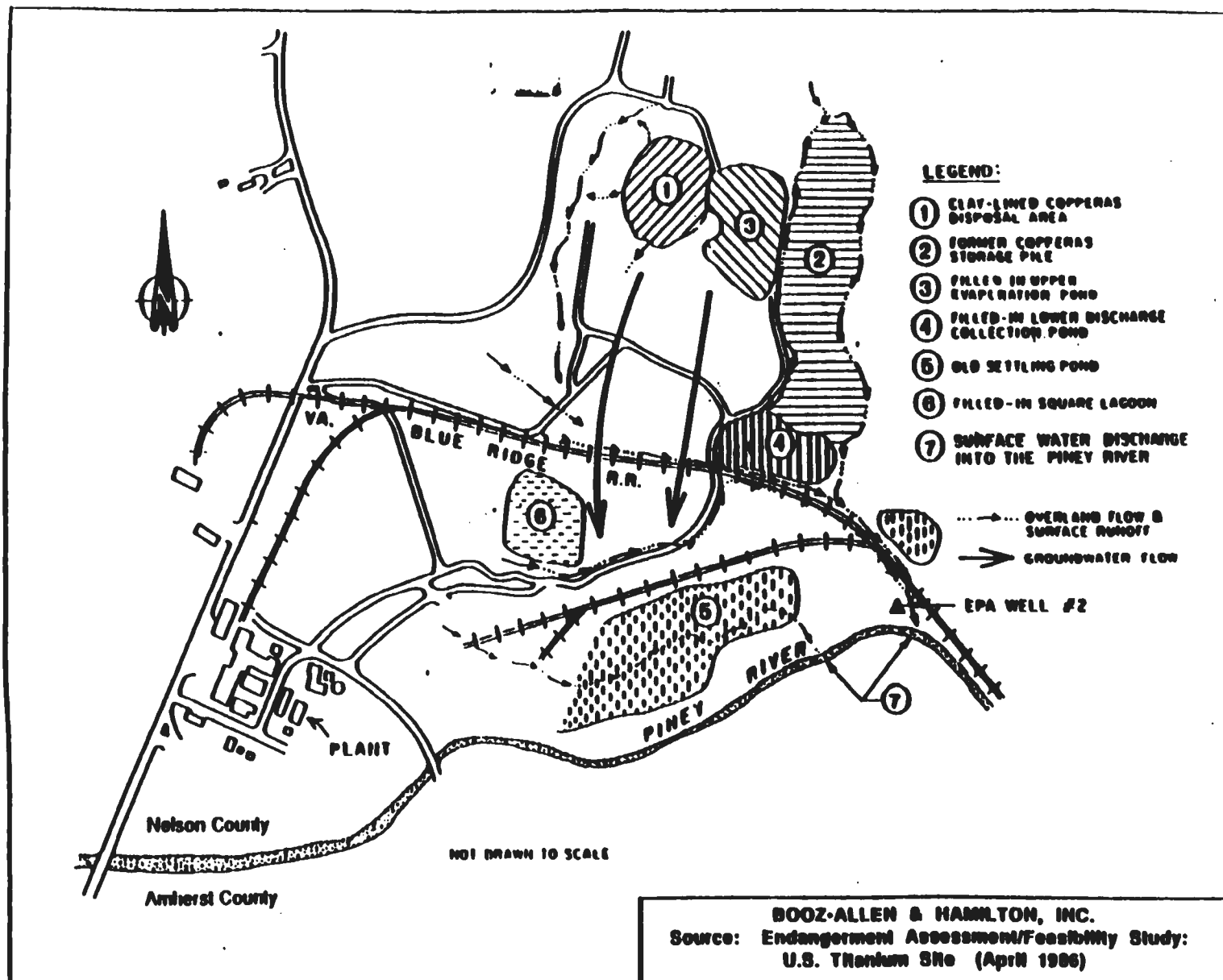


Figure 2: U. S. Titanium Site

### SITE HISTORY AND ENFORCEMENT ACTIVITIES

In 1931, the Virginia Chemical Corporation began producing titanium dioxide from ilmenite ore using the sulfate process at the site. The ore was obtained from mining operations directly south of the Piney River. In the sulfate process, the ilmenite ore is treated with sulfuric acid to dissolve the titanium dioxide product. Waste streams from this process include acid contaminated unreacted ore, spent sulfuric acid, and solid ferrous sulfate, called "copperas."

In July 1944, American Cyanamid Corporation purchased the Virginia Chemical Corporation and operated the plant until it closed in June 1971. Following the plant closure, the site passed through various ownerships including the U.S. Titanium Corporation from which the site received its name.

Six major fish kills occurred in the Piney River between 1977 and 1981, as documented by the VWCB, which were attributed to contamination from the site:

DATE	NUMBER OF FISH KILLED
July 1977	73,056
August 1977	8,940
August 1979	26,136
July 1980	53,960
May 1981	20,482
<u>June 1981</u>	<u>46,243</u>
TOTAL	228,837

The 1979 fish kill prompted the VWCB to request the Circuit Court of Nelson County to order U. S. Titanium to bury the copperas by December 31, 1980. In response to the court order, U. S. Titanium Corporation contacted New Enterprise Construction Co. to dispose of the copperas waste. The copperas waste from the storage pile (Area 2) was collected and then buried in Area 1.

Under contract with EPA, Ecology and Environment submitted a Preliminary Assessment report of the site on August 3, 1980. The burial of Copperas in Area 1 was completed on December 12, 1980. A report of a screening Site Inspection conducted by EPA on August 3-4, 1982, was released on November 19, 1982. In December 1982, the U. S. Titanium site was proposed for inclusion on the National Priority List pursuant to Section 105(8) of CERCLA. The site was finally listed on the NPL in September, 1983.

On February 1 and 2, 1983, NUS Corporation, under contract with EPA, conducted a site inspection as part of a Remedial Action Master Plan which was released in August, 1983. GCA Corporation, under contract with EPA also conducted a Focused Feasibility Study on the nature and extent of the acidic discharges from the site and evaluated alternative remedial actions. The report was released by EPA on October 8, 1985.

Following a civil action filed by the Commonwealth of Virginia against American Cyanamid Company and others in State Court, based on a nuisance action for fish kills and environmental degradation resulting from the site, a liability judgement was rendered against American Cyanamid on November 7, 1985.

On April 30, 1986, the Attorney General for the Commonwealth of Virginia and American

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Cyanamid Company signed a Stipulation and Order establishing a schedule for completion, by American Cyanamid Company, of a temporary source control action for the copperas burial pit, a Supplemental Remedial Investigation (SRI), and a Feasibility Study (FS) for the site. The SRI and FS were conducted by Hydrosystems under contract with Cyanamid Company and submitted in November 1988 and April 1989 respectively. The SRI characterized the nature and extent of contamination at the site. The FS described various cleanup technologies and how remedial alternatives were developed, screened, and evaluated based on these technologies.

### HIGHLIGHTS OF COMMUNITY PARTICIPATION

While the U.S. Titanium site is located in a predominantly rural area, there has been considerable interest among residents since the late 1970's, when fish kills began to occur. The local Blue Ridge Chapter of the Sierra Club was formed in response to site events. In addition, the local media have followed the site activities consistently.

The post-RI/FS community participation activities began in April, 1989, when a fact sheet describing the Remedial Investigation/Feasibility Study was mailed to a list of residents, officials, and media. In addition, informal meetings were held with local officials and Sierra Club representatives on May 18. The Community Relations Plan (CRP) was revised at this time, and a repository for the Administrative Record File and other information was established at the Nelson County Memorial Library and the County Administration office. The Proposed Plan was formally released to the public on July 31. A notice announcing the availability of the Proposed Plan, the public comment period, and the Administrative Record File was published in the Charlottesville Daily Progress on July 31. The Virginia Department of Waste Management (VDWM) also cosponsored an informal workshop for Sierra Club members and other interested citizens on July 31, to explain the Superfund process, resources available to the public, and outline the Proposed Plan.

The public comment period extended from July 31 through September 29, after a 30-day extension was granted at the request of American Cyanamid. A public meeting was held on August 9, where VDWM and EPA representatives reviewed the Proposed Plan and Superfund public participation opportunities in detail. The meeting lasted four and a half hours, and the interest level of the community was very high. A formal response to questions and comments put forth during the public meeting and comment period can be found in Part III of this document, the Responsiveness Summary. Community participation activities will continue through remedial design and remedial action.

A detailed outline of community relations activities undertaken with the U.S. Titanium site community can be found in the Responsiveness Summary (Appendix A). All studies and documents pertaining to this site can be found in the Administrative Record Files, upon which the decision for choosing remedial alternatives was based.

### SITE CHARACTERISTICS

Based on the findings of the SRI and previous site investigations, the following conclusions can be made regarding the site, the types of contamination, and affected media.

The site is located in the Piedmont physiographic province, about five miles east of the Virginia Blue Ridge. The elevation ranges from 726 feet on top of the copperas burial pit in Area 1 to 618 feet in the Piney River near the drainage area (Area 7). The bedrock underlying the site consists of igneous and metamorphic rocks. Two distinct sets of nearly vertical fractures are present in the bedrock and have approximately northwest-southeast and northwest-southwest orientations.

Two soil groups exist at the site. In the upland areas, the soil is a residuum (saprolite) derived from the weathering of the underlying parent bedrock material. It is composed predominantly of clays and silts. Within the floodplain, the soil consists of heterogeneous alluvial deposits of gravel, sand, silt, and clay. In general, the soil depth decreases from near 60 feet at the top of the slope in Area 3, to less than one foot near the stream at the base of Area 2.

Groundwater occurs primarily in the porous, unconsolidated granular material of the saprolite and, to a much lesser extent, in the fractures that run through the dense, hard igneous and metamorphic bedrock. These two units are hydraulically interconnected over larger distances. The depth to water table is about 44 feet on the south side of Area 1. Coming down the valley, the water table becomes shallower, intersecting ground surface in the stream beds and springs along the base of the hill. Groundwater flow within the site originates in the upland area containing Areas 1 and 3, flows in a radiating pattern down hill toward the streams surrounding the base of the hill and to the Piney River.

The site lies within the Piney River drainage basin, a part of the larger James River drainage basin. Areas 5 through 7 lie within the floodplain of the Piney River. Surface water drainage runs off the site primarily via three drainage channels into the Piney River.

In Area 1, the copperas burial pit, the cap system has not functioned properly allowing water to infiltrate the pit. The resultant acidic and high iron content leachate has acidified soils underneath the pit and contaminated groundwater. Acidic seepages from the burial pit have killed trees and other vegetation down-gradient from Area 1. This area accounts for about 65 percent of the total acidic discharge at the site. Analysis of groundwater samples down-gradient of the burial pit have shown a pH as low as 3.68, and concentrations of total dissolved iron of up to 2190 mg/l, sulfate of up to 14,000 mg/l, and acidity of up to 10,050 mg/l as calcium carbonate.

The soil under the former copperas stockpile area, Area 2, is acidified and groundwater seepages at the base of the slope have killed the grass stand and formed iron sulfate deposits. The acidic contribution from this area is 11 percent. Analyses of samples from seeps at the base of Area 2 have shown a pH as low as 2.68, and concentrations of total dissolved iron of up to 17,720 mg/l, sulfate of up to 45,000 mg/l, and acidity of up to 41,000 mg/l as calcium carbonate.

The soil under Area 3, the former evaporation pond, is acidified up to the water table. Total acidic contribution from this area is about 7 percent. The most recent analysis of groundwater from a well located within Area 3 has shown a pH of 3.32, and concentrations of total dissolved iron of 4,360 mg/l, sulfate of 54,000 mg/l, and acidity of 40,500 mg/l as calcium carbonate.

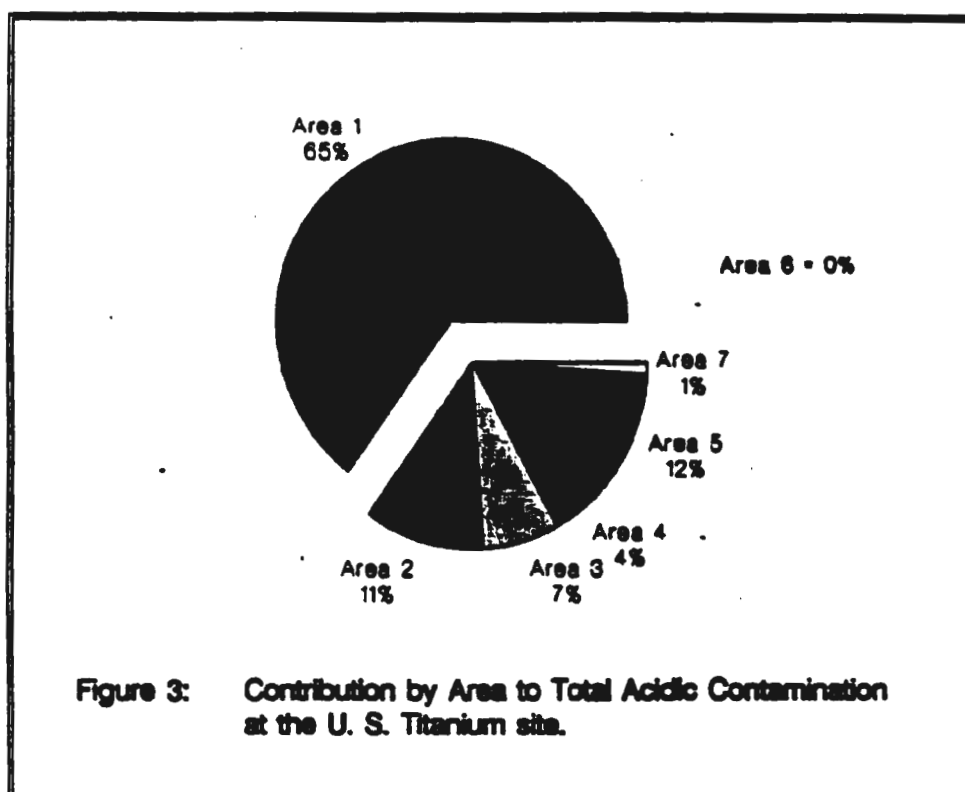
Area 4, the unreacted ore waste pile area, contains residual acidity from processing. The soil underneath this area is also acidified. Four percent of total acidity at the site is attributable to this area.

Area 5, which contains the two sedimentation ponds, contains residual acidity from processing. During storm events, erosion of sediments by storm run-off has resulted in a significant lowering of the pH in the Piney River. In addition, groundwater flowing through this area is acidified by contact with the waste prior to discharge to the Piney River. Area 5 accounts for 12 percent of the total acidity at the site. Analyses of samples from wells located on the northeastern edge of this area have shown a pH as low as 3.42, and concentrations of total dissolved iron of up to 1,840 mg/l, sulfate of up to 5,400 mg/l, and acidity of up to 3,220 mg/l as calcium carbonate.

Area 6, the settling pond used to recover phosphate ore has no detectable copper or acidity problem. There is also no groundwater contamination.

The soil under Area 7, the drainage area receiving most of the surface run-off from the site, has become acidified and contributes about one percent to total site acidity. Analysis of samples from a well down-gradient of Area 7, have shown a pH as low 3.09, and concentrations of total dissolved iron of up to 570 mg/l, sulfate of up to 2,400 mg/l, and acidity of up to 1,542 mg/l as calcium carbonate.

The acidic nature of the site has also led to the leaching of other metals such as aluminum, copper, zinc, cadmium and nickel from on site soils. The concentration of these metals in surface water and groundwater at the site, as well as that of iron, exceed surface water criteria (Table 1). Figure 3 shows the percentage contribution by area to acidic contamination at the site.



**TABLE 1: MEAN CONCENTRATION IN SURFACE WATER DISCHARGE &  
GROUNDWATER AT THE U. S. TITANIUM SITE**

Units in mg/l

<u>Contaminants</u>	<u>Surface<sup>a</sup> Water Discharge</u>	<u>Ground<sup>b</sup> Water</u>	<u>Surface<sup>c</sup> Water Criteria</u>
Al	200.	200.	0.087 <sup>d</sup>
As <sup>e</sup>	<0.01	0.028	0.190
Cd	0.013	0.047	0.0003
Cr	0.335	0.084	.011 <sup>f</sup>
Cu	1.355	0.45	0.0025
Ni	0.692	2.67	0.023
Zn	1.56	19.27	0.047
Iron	267.	698.	1.0
pH	2.4	3.1	6-9
Acidity	1446	2090	-

a. Source: Report by J. Novak, Virginia Tech (1984)

b. Source: Morris, Ph.D. Thesis, Virginia Tech (1984)

c. Source: Virginia Water Control Board

d. Source: USEPA Ambient Water Quality Criteria (1988)

e. Source: NUS (1983)

f. Cr(VI) (total recovery)



### SUMMARY OF SITE RISKS

Without remedial action, the site will continue to contaminate groundwater and surface water in the Piney River sub-basin. Acidified soils and buried copperas wastes will continue to leach contaminants into the groundwater. The dissolution of copperas produces acidity as the result of a sequence of reactions that include oxidation, of the ferrous iron to ferric iron, and hydrolysis of the ferric iron to ferric oxyhydroxide. The net effect of these reactions is that for every mole of copperas dissolved, two moles of excess hydrogen ion ( $H^+$ ) are produced resulting in the acidic leachate. Groundwater eventually discharges into the Piney River either directly or by way of two site tributaries. Surface water run-off from the site erodes acidic sediments and discharges them into the river.

These discharges can contain high iron concentrations and have low pH values. The high iron concentrations have resulted in the deposition of ferric hydroxide sediments at the bottom of the river. These sediments are still present today and have disrupted the benthic community in the river. This in turn has resulted in a decrease in the number and diversity of the fish population in the river adjacent to and downstream of the site. Low pH discharges can be toxic to aquatic organisms. Based on sampling as late as fall 1988, the State Water Control Board has concluded that the aquatic invertebrate community has not completely recovered in the Piney River even at a distance of 3.5 miles downstream.

Actual or threatened releases of pollutants from this site, if not addressed by implementing the response action selected in this ROD, may present substantial endangerment to aquatic life in the Piney River.

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### DESCRIPTION OF ALTERNATIVES

Several alternatives were evaluated in detail to determine which would be most effective in achieving the goals of CERCLA, and in particular, achieving the remedial objective for the site. The detailed analyses of remedial alternatives for the various areas of the site are briefly described below.

#### NO ACTION

Capital Costs:	\$ 21,000*
Annual O & M:	\$156,000*
Five Year Review:	\$133,000*
Months to Implement:	3*

The Superfund program is required to evaluate the "No Action" alternative. Under this alternative, no remedial action would be taken to prevent contamination from entering groundwater or the Piney River. Site access controls, deed restrictions, and maintenance of on site roads would be performed. In addition, monitoring of the groundwater and surface water would be performed along with a formal review of the site condition every five years. ARAAs associated with surface water and groundwater would not be attained.

The remedial objectives for the site would not be met by the no action alternative and impacts on the benthic community in the Piney River would continue. The no action alternative does not meet SARA's preference for permanent treatment.

#### GROUNDWATER COLLECTION SYSTEM

##### Alternative GW-2: Passive Groundwater Collection

Capital Costs:	\$142,000*
Annual O & M Costs:	\$2,000*
Months to Implement:	3*

Groundwater would be intercepted by a series of subsurface drains and/or trenches installed below the water table along the base of the hill containing Areas 1, 2, 3, and 4. Gravity flow would be used to feed the collected water to the groundwater treatment system. Measures would be taken to prevent the formation of iron salt deposits in the collection system during periods of low flow. Uncontaminated surface water run-off would be diverted away from the collection system.

Groundwater would be collected for treatment until the groundwater quality achieves a level which allows it to be discharged directly into the Piney River. The discharge limits for this site necessary to meet water quality standards in the Piney River and so comply with the Clean Water Act (CWA) and Virginia Water Control Board (VWCB) regulations have been determined by VWCB and are presented in Appendix I.

\* All costs and implementation times are estimated.

## GROUNDWATER TREATMENT SYSTEM

### Alternative WT-2: Passive Water Treatment

Capital Costs: \$119,000\*  
Annual O & M Costs: \$20,000\*  
Months to Implement: 6\*

The components of the treatment system would include an oxidation/settling pond, a constructed wetland, and a limestone neutralization bed.

The oxidation/settling pond would be capable of complete removal of iron and sulfur elements from the collected groundwater. Its design would utilize existing knowledge of acid mine drainage treatment where the use of oxidation/settling ponds is a standard technique. Such treatment systems often utilize alkaline chemicals to raise the pH of the water and cause metals to precipitate. The sulfur element would also be precipitated. The oxidation/settling pond would make up for any loss in the performance of the wetland.

Wetland vegetation works in conjunction with anaerobic bacteria to remove iron and sulfur species from the water; an increase in the pH can also be expected. The wetland would be protected from a 100-year flood by constructing a berm around it.

Should the presence of other metals in the effluent from the wetland make the discharge requirements set by the VWCB non-attainable and thus prevent direct discharge into the Piney River, additional physical or/and chemical treatment steps would be installed.

The limestone bed would act as a final polishing step for pH adjustment before discharge of the effluent to the Piney River.

An eight-foot high, locked chain-link fence would be installed around the wetland for the protection of the community, on site workers, and game and wildlife. Routine maintenance of the entire groundwater system would include restocking of the wetland with new plants, dredging of the oxidation pond and wetland, periodic effluent and influent monitoring. The monitoring program for groundwater treatment is presented in Appendix I.

All residual wastes would have to undergo Extraction Procedure Toxicity (EP Tox) testing to determine their classification before disposal. Wastes that fall under RCRA Subtitle C (Hazardous Waste) would be managed according to the Virginia Hazardous Waste Management Regulations (VHWMR) and applicable RCRA Land Disposal Restrictions (LDRs). Wastes that are classified as RCRA Subtitle D (Solid Waste) would be managed according to the Virginia Solid Waste Management Regulations (VSWMR). The oxidation/settling pond, the wetland and the neutralization bed would be constructed and operated according to VHWMR or VSWMR (including minimum technology requirements). The Commonwealth of Virginia is a RCRA delegated State. All RCRA authority has been delegated to the Commonwealth of Virginia except those under the 1984 Hazardous and Solid Waste Amendments (HSWA).

\* All costs and implementation times are estimated.

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### SELECTED REMEDY

Based upon consideration of the requirements of CERCLA, the detailed analysis of the alternatives, and public comments, both EPA and the Commonwealth of Virginia have determined that the following combination of alternatives is the most appropriate remedy for cleaning up the site

TREATMENT COMPONENT	ESTIMATED COST
Groundwater:	
Collection: Passive Collection System (GW-2)	173,000
Treatment: Passive Treatment System (WT-2)	431,000
Area 1: In-situ Dissolution and Treatment (A1-10)	3,962,000
Area 2: Surface Repair of Unvegetated Areas (A2-4)	147,000
Area 3: Improve Surface Drainage (A3-3)	106,000
Area 4: Drainage Control and Revegetation (A4-4)	202,000
Area 5: Drainage Control and Revegetation (A5-4)	874,000
Area 6: No Action (A6-1)	0
Area 7: Above-grade Dry Neutralization (A7-7) (in combination with wetland)	0
<b>TOTAL:</b>	<b>5,895,000</b>

The selected remedy consists of dissolution and treatment of copperas waste in Area 1. Drainage controls and revegetation would be implemented in Areas 2, 3, 4 and 5. Area 6 requires no remedial action. Acidified soil in Area 7 would be mixed with lime to neutralize any leachate. Groundwater would be collected by using subsurface drains and trenches with treatment in a constructed wetland. The wetland treatment would be supplemented with active treatment processes necessary to meet set discharge requirements.

Some changes may be made to the selected remedy as a result of the remedial design and construction processes.

#### Remediation Goals

The purpose of this response action is to control risks posed by acidic discharge into groundwater and the Piney River. By eliminating most of the sources of acidic discharge into the river, the remedial action will prevent future fish kills and stop further leaching of metals and continued degradation of the Piney River. This remedy will address all the six areas of the site that have been

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found to be the sources of contamination.

Since no Federal or State ARARs exist for soils, the action level for the in-situ dissolution and leachate collection remedy for Area 1 would be determined using fate and transport modeling to determine the level to which acidic producing potential of the soil should be reduced in order to ensure that the leaching of contaminants to groundwater and surface water above levels protective of the Piney River as determined by the SWCB would not continue. At a minimum, the leaching shall not cause the Piney River to exceed State Water Quality Standards.

The termination of in-situ dissolution and leachate collection would be determined using the results of soil boring tests, and fate and transport modeling to estimate the potential of groundwater contamination that could result from the migration of residual contaminants in the soil. The leaching process shall be stopped when (1) soil boring tests show that no significant amount of copperas remains in the pits, and (2) the residual acidity in the formation is such that if leached into groundwater and discharged into the Piney River would not violate the ARARs for the river.

Discharge from Area 1 into the wetland would only be allowed when the water to be discharged is comparable to the quality of influent water into the wetland and provided such additional discharge capacity would not adversely affect the performance of the wetland. In any case, no discharge would be allowed until the dissolution process is near completion. Any discharge into the Piney River must meet the discharge limits set forth in Appendix I.

All solid wastes generated during the remediation process would be subjected to EP Tox testing and then disposed of according to VHWMR and RCRA-LDRs (Federal) or the VSWMR.

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**Reference 2**

**Excerpts From Supplemental Remedial Investigation,  
U.S. Titanium Site, Piney River, Virginia, 5 Volumes;  
Prepared for American Cyanamid Company by Hydrosystems, Inc.;  
September 17, 1987**

VOLUME 1 OF 5  
SUPPLEMENTAL REMEDIAL INVESTIGATION  
U.S. TITANIUM SITE  
PINEY RIVER, VIRGINIA

EXECUTIVE SUMMARY

SEPTEMBER 17, 1987

PREPARED FOR:

AMERICAN CYANAMID COMPANY  
ONE CYANAMID PLAZA  
WAYNE, NJ 07470

PREPARED BY:

HYDROSYSTEMS, INC.  
PO BOX 348  
DUNN LORING, VA . 22027

301026

Volume 1



## EXECUTIVE SUMMARY

### 1.0 PURPOSE

The purpose of the Supplemental Remedial Investigation (SRI) is to augment the existing data base relating to the nature and extent of the acidic discharges at the U.S. Titanium Site in Piney River, Virginia (referred to as the "Site").

Numerous data gaps were identified in previous studies. Several of these data gaps were of major importance to the understanding of the extent of the problem, while other data gaps were important to the evaluation of alternative remedial actions. The previous site investigations did not provide a comprehensive investigation of the surface water and groundwater quality impacts. No previous study was conducted to estimate the relative contribution of each area to the contamination of surface- and groundwater. The previous studies did not address the pathways of contamination or the geochemical controls on leachate production and migration.

The SRI is intended to supplement the previous studies by filling gaps in the existing data base according to the following objectives:

- Characterize the extent and nature of contamination in each of the seven areas and groundwater.
- Characterize the hydrogeology to provide data for evaluation of the significance of the groundwater contamination component to acidic discharges and for the

## 2.2 SITE HISTORY

The Piney River plant commenced operations in 1931 under the ownership of the Virginia Chemical Corporation. Those operations included: (1) the production of titanium dioxide pigment from native ilmenite ore via the sulfate process and (2) production of phosphate through the digestion of native apatite ore in sulfuric acid. As a result of the titanium dioxide and phosphate operations, the plant produced a waste stream consisting of dilute sulfuric acid, hydrated ferrous sulfate (copperas), diatomaceous earth filter cake, gypsum (from the phosphate process only), and unreacted apatite and titanium ore. From 1931 until 1947, the wastewater stream was discharged directly to the Piney River.

In July of 1944, American Cyanamid Company acquired the plant and property. American Cyanamid Company operated the plant for the production of titanium dioxide only.

In 1947, American Cyanamid Company constructed a State permitted settling pond to remove settleable solids from the wastewater. This settling pond is now referred to as "Area 5." In the early 1950's, American Cyanamid Company employed partial neutralization of the wastewater, and by 1955 had eliminated suspended solids from the effluent and had significantly reduced sulfuric acid discharges. This was followed by the installation of a neutralization lagoon which became operational in 1957.

By 1961, American Cyanamid Company had achieved the following results:

1. All wastewater was neutralized to a pH of at least 5.0.
2. Flow and pH monitoring equipment were installed on the effluent stream.
3. A sulfuric acid recovery plant was in continuous operation to reduce sulfuric acid discharges.

In 1971, American Cyanamid Company ceased all operations at the Piney River plant. Also in 1971, American Cyanamid Company commissioned a study of the acidic discharges from the copperas stockpile, where an estimated 80,000 cubic yards of copperas had been stored between 1949 and 1971 for sale as a commercial product. This area is now referred to as "Area 2". The study concluded that acidic discharges attributable to the copperas could be eliminated by moving the copperas to a new clay-lined landfill on the south side of the Piney River.

On October 31, 1972, American Cyanamid Company submitted plans to the State Water Control Board (SWCB) for excavation and subsequent burial of the copperas in a new landfill to be located on the south side of the Piney River. Approval for this plan was granted by the Executive Secretary of the SWCB on April 5, 1973.

In 1973, Mr. S. Vance Wilkins purchased the property from American Cyanamid Company. As part of the sales agreement, American Cyanamid Company paid Mr. Wilkins \$100,000 for the stipulated purpose of implementing the State-approved plan for burial of the copperas on the south side of the Piney River.

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Rather than implementing the State-approved plan developed by American Cyanamid Company, Mr. Wilkins constructed a temporary copperas leachate collection and recirculation system consisting of a lower collection lagoon located in the southern portion of what is now referred to as "Area 2", an upper "evaporation" pond in an area now referred to as "Area 3", and a pumping system for transferring the leachate from the lower collection pond to the "evaporation" pond.

In March of 1976, Mr. Wilkins sold the Site to the U.S. Titanium Corporation. U.S. Titanium Corporation's purchase of the Site was financed by The Stone Foundation, which held a mortgage on the property.

In September of 1977, the SWCB ordered U.S. Titanium Corporation to submit a plan for disposal of the copperas. U.S. Titanium Corporation failed to submit the required disposal plan, and the SWCB filed suit in the Circuit Court of Nelson County seeking a temporary injunction to require U.S. Titanium Corporation to apply to the State Department of Health for a landfilling permit for the copperas.

After further judicial proceedings, U.S. Titanium Corporation and/or The Stone Foundation contracted with Geonics, Inc. to prepare a permit application for disposal of the copperas. This application was submitted to the SWCB and State Department of Health on October 3, 1979 and approved by that department on March 11, 1980.

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On October 2, 1980, New Enterprise Construction Company began full-scale burial of the copperas under contract to U.S. Titanium Corporation and/or The Stone Foundation. Burial was completed on December 12, 1980, and final grading, channel improvements, and seeding and mulching were completed by January 16, 1981. The burial area is now referred to as "Area 1".

During the U.S. Titanium Corporation and/or The Stone Foundation sponsored burial of the copperas, the U.S. Environmental Protection Agency, Region III (EPA), contracted with Ecology and Environment, Inc. to conduct a preliminary assessment of the U.S. Titanium Site. The resulting report was submitted to the EPA on August 3, 1980.

On April 7, 1982, the Executive Director of the SWCB disapproved a site improvement plan for reclamation of the former copperas storage area submitted by U.S. Titanium Corporation and/or The Stone Foundation. As a result, Benton G. Tinder was appointed receiver of the U.S. Titanium Corporation property at Piney River. On May 27, 1982, Mr. Tinder contracted with R.M. Cash and G. Burley of Amherst, Virginia, to complete reclamation and runoff control for the former copperas stockpile area. This reclamation work was funded from the Governor's Contingency Fund.

In December 1982, the EPA ranked the U.S. Titanium Site 332nd out of 418 sites on the National Priorities List published pursuant to Section 105(8)(B) of CERCLA. On February 1 and 2, 1983, NUS Corporation, under contract with the EPA, conducted a site

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inspection as part of the development of a Remedial Action Master Plan (RAMP). The RAMP was released in August of 1983.

In June of 1983, the SWCB authorized the Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, to conduct studies relating to the U.S. Titanium Site.

In 1985, EPA contracted with GCA Corporation to conduct a focused feasibility study (FFS) on the nature and extent of the acidic discharges from several specific areas on the Site and to evaluate alternative remedial actions. On October 8, 1985, the EPA released a draft FFS prepared by GCA Corporation and dated July 23, 1985. Comments on the draft FFS were submitted by American Cyanamid Company on November 20, 1985.

On November 7, 1985, a liability judgment was rendered against American Cyanamid Company, U.S. Titanium Corporation, Ronald Penque and Henry A. Williams, III, principals of U.S. Titanium Corporation, and Penque-Williams, Inc. in Commonwealth of Virginia v. U.S. Titanium Corporation, et al., a nuisance action seeking abatement of conditions at the site. In early 1986, the U.S. Titanium Corporation transferred its Piney River property to the P.R. Corporation of Piney River, Virginia. One of the principals of the P.R. Corporation is Mr. Robert Desmond.

On April 30, 1986, the Attorney General for the Commonwealth of Virginia and American Cyanamid Company signed a Stipulation and Order establishing a schedule for completion, by American Cyanamid Company, of a temporary source control action for the

copperas burial pit, a supplemental remedial investigation, and a feasibility study for the Site.

On August 12, 1986, American Cyanamid Company, through a contract with HYDROSYSTEMS, Inc. of Dunn Loring, Virginia, completed a temporary source control remedial action at the copperas burial pit to inhibit leachate production.

### 2.3 NATURE AND EXTENT OF PROBLEM

Conditions at the U.S. Titanium Site include the chronic discharge of acidic surface- and groundwater into the Piney River, the presence of a soil/copperas mixture in the burial pit, and acidified soil and sediment in other areas of the Site. The acidic groundwater and surface water do not contain hazardous constituents and do not present any risk to human health. The chronic acidic discharges to the Piney River have resulted in impacts to the aquatic community immediately downstream of the Site. Recent benthic surveys indicate, however, that the river recovers below about 1,000 feet downstream and is showing signs of recovery in the immediate vicinity of the Site.

Due to the inadequate burial of the copperas by the U.S. Titanium Corporation in 1980, infiltrating water has dissolved copperas, causing collapse depressions to form in the surface of the burial pit. The resulting leachate formed by the dissolution of the copperas discharges to the surface via seeps around the circumference of the burial pit and percolates to the groundwater.

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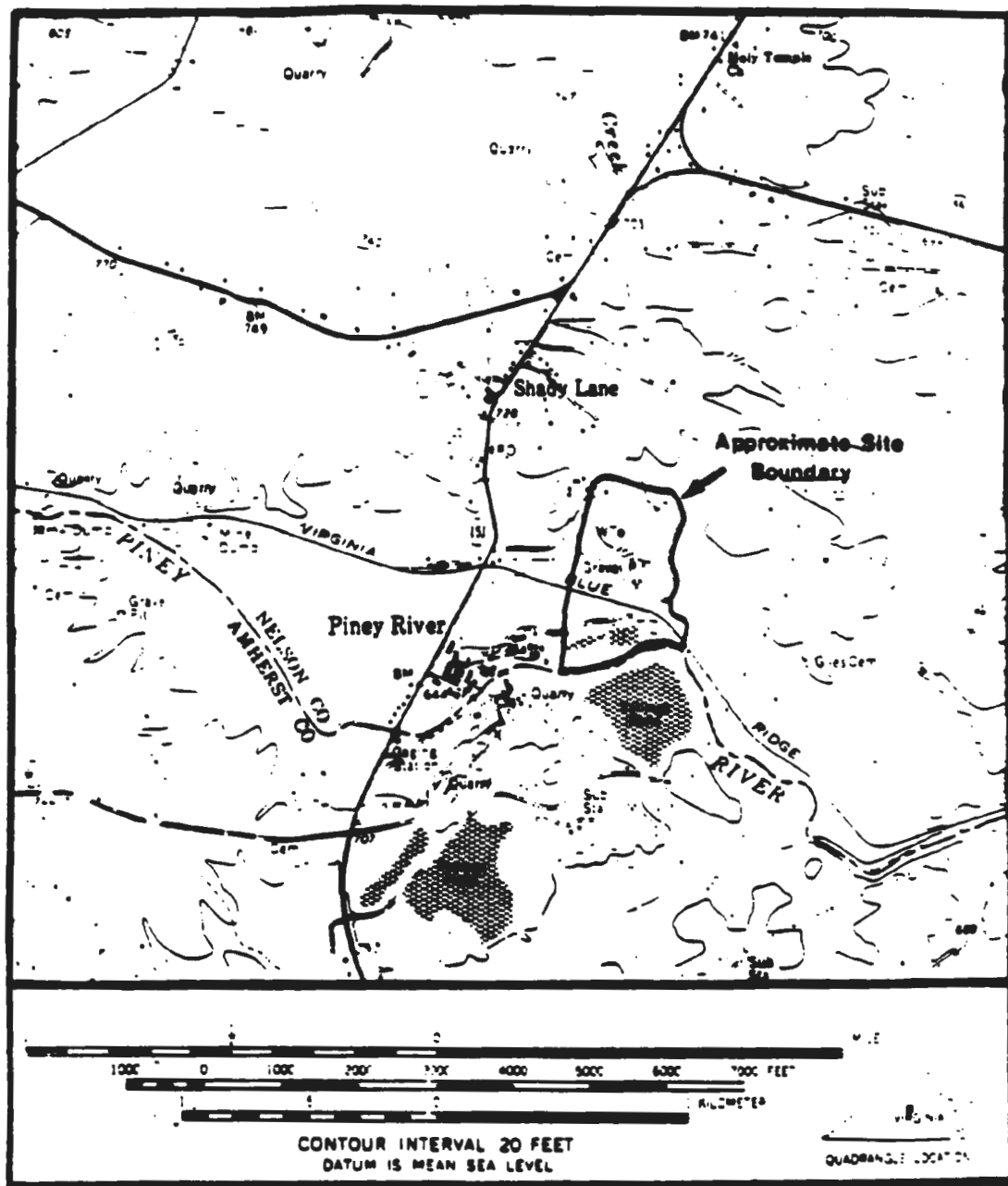


Figure 1.1. Location map for the U.S. Titanium Site in Piney River, Virginia.

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As a result of the titanium dioxide and phosphate operations, the plant produced a waste stream consisting of dilute sulfuric acid, hydrated ferrous sulfate (copperas), diatomaceous earth filter cake, <sup>CaSO<sub>4</sub> H<sub>2</sub>O</sup> gypsum (from the phosphate process only), and unreacted apatite and titanium ore. From 1931 until 1947, the wastewater stream was discharged directly to the Piney River.

In 1947, American Cyanamid Company constructed a sedimentation pond to remove settleable solids from the wastewater (NUS, 1983, p. A-2). In April of 1947, the State Water Control Board (SWCB) issued to American Cyanamid Company, pursuant to Section 1514-b17 of the State Water Control Law, Waste Discharge Certificate No. 34 for the Piney River plant effluent (NUS, 1983, p. 2-7). This sedimentation pond is now referred to as "Area 5".

In the early 1950's, American Cyanamid Company employed partial neutralization of the wastewater, and by 1955 had eliminated suspended solids from the effluent and reduced sulfuric acid discharges from 120 tons/day to 90 tons/day (NUS, 1983, p. 2-11). This was followed by the installation of a neutralization lagoon which became operational in 1957 (NUS, 1983, p. A-5).

By 1961, American Cyanamid Company had achieved the following results:

1. All wastewater was neutralized to at least a pH of 5.
2. Flow and pH monitoring equipment were installed on the effluent stream.

3. A sulfuric acid recovery plant was in continuous operation to reduce sulfuric acid discharges. (NUS, 1983, p. 2-12)

On March 21, 1961, the SWCB issued to American Cyanamid Company Waste Discharge Certificate No. 1312 in replacement of Certificate No. 34 for the Piney River plant effluent. This new discharge certificate was issued to reflect improvements instituted by American Cyanamid Company in the waste handling operations. (NUS, 1983, p. 2-8)

In 1971, American Cyanamid Company closed down all operations at the Piney River plant. Also in 1971, American Cyanamid Company commissioned a study of the acidic discharges from the copperas stockpile where an estimated 80,000 cubic yards of copperas had been stored between 1949 and 1971 for sale as a commercial product (NUS, 1983, pp. ES-1 and 2-6). This area is now referred to as "Area 2".

The study, conducted by Geraghty & Miller, Inc., concluded that acidic discharges attributable to the copperas could be eliminated by moving the copperas to a new clay-lined landfill on the south side of the Piney River (Geraghty & Miller, Inc., 1972).

On October 31, 1972, American Cyanamid Company submitted plans to the SWCB for excavation and subsequent burial of the copperas in a new landfill to be located on the south side of the Piney River (NUS, 1983, p. 2-8). On April 5, 1973, American Cyanamid Company obtained approval from the Executive Secretary of the SWCB for

the plan to bury the copperas in the proposed new landfill (NUS, 1983, p. 2-8).

In 1973, Mr. S. Vance Wilkins purchased the property from American Cyanamid Company. As part of the sales agreement, American Cyanamid Company paid Mr. Wilkins \$100,000 for the stipulated purpose of implementing the State-approved plan for burial of the copperas on the south side of the Piney River (NUS, 1983, p. 2-3).

Rather than implementing the plan developed by American Cyanamid, Mr. Wilkins constructed a temporary copperas leachate collection and recirculation system consisting of a lower collection lagoon located in the southern portion of what is now referred to as "Area 2", an upper retention pond in an area now referred to as "Area 3", and a pumping system for transferring the leachate from the lower collection pond to the upper retention pond. The SWCB issued a three-year duration State No Discharge Certificate No. IW-ND-407 on December 23, 1974, to permit operation of the leachate collection and recirculation system installed by Mr. Wilkins (NUS, 1983, p. 2-8 and personal communication with Tedd Jett, SWCB).

In March of 1976, Mr. Wilkins sold a portion of the property north of the Piney River to the U.S. Titanium Corporation, retaining ownership of that part of the property on the south side of the river and portions of the property on the north side. U.S. Titanium Corporation's purchase of the Piney River property

was financed by The Stone Foundation, which held a mortgage on the property.

In September of 1977, the SWCB ordered U.S. Titanium Corporation to submit a plan for disposal of the copperas. U.S. Titanium Corporation failed to submit the required disposal plans, and the SWCB filed suit in the Circuit Court of Nelson County seeking a temporary injunction to require U.S. Titanium Corporation to apply to the State Department of Health for a landfilling permit for the copperas. (NUS, 1983, p. 2-9)

After further judicial proceedings, U.S. Titanium Corporation and/or The Stone Foundation contracted with Geonics, Inc. to prepare a permit application for disposal of the copperas. This application was submitted to the SWCB and State Department of Health on October 3, 1979 and approved by the State Department of Health on March 11, 1980. (NUS, 1983, p. 2-9)

By May 30, 1980, U.S. Titanium Corporation and/or The Stone Foundation completed the burial of copperas in a test cell, and, on October 2, 1980, New Enterprise Construction Company began full-scale burial of the copperas under contract to U.S. Titanium Corporation and/or The Stone Foundation. Burial was completed on December 12, 1980, and final grading, channel improvements, and seeding and mulching were completed by January 16, 1981. (NUS, 1983, p. 2-13). The burial area is now referred to as "Area 1".

During the U.S. Titanium Corporation and/or The Stone Foundation sponsored burial of the copperas, the U.S. Environmental Protection Agency, Region III (EPA), contracted with Ecology and

Environment, Inc. to conduct a preliminary assessment of the U.S. Titanium Site. The resulting report was submitted to the EPA on August 3, 1980 (NUS, 1983, p. 2-13).

On April 7, 1982, the Executive Director of the SWCB disapproved a site improvement plan for reclamation of the former copperas storage area submitted by U.S. Titanium Corporation and/or The Stone Foundation. As a result, Benton G. Tinder was appointed receiver of the U.S. Titanium Corporation property at Piney River (NUS, 1983, p. A-12). On May 27, 1982, Mr. Tinder contracted with R.M. Cash and G. Burley of Amherst, Virginia, to complete reclamation and runoff control for the former copperas stockpile area. This reclamation work was funded from the Governor's Contingency Fund. (NUS, 1983, p. 2-10)

In December 1982, the EPA ranked the U.S. Titanium Site 332nd out of 418 sites on the National Priorities List published pursuant to Section 105(8)(B) of CERCLA (NUS, 1983, p. 2-11). On February 1 and 2, 1983, NUS Corporation, under contract with the EPA, conducted a site inspection as part of the development of a Remedial Action Master Plan (RAMP). The RAMP was released in August of 1983. (NUS, 1983, pp. A-13 and 1-1)

In June of 1983, the SWCB authorized the Department of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, to conduct studies relating to the U.S. Titanium Site (VPI, 1984, p. 1).

In 1985, EPA contracted with GCA Corporation to conduct a Focused Feasibility Study (FFS) on the nature and extent of the acidic

## 2.0 SITE FEATURES INVESTIGATION

### 2.1 DEMOGRAPHY

The U.S. Titanium Site is located on the Piney River flood plain and the adjoining hill north of the river and east of State Route 151 near the town of Piney River. The town is primarily zoned for industrial development. Industries in the area have included mining, mineral processing, and lumber. Currently, there is at least one operating rock quarry and two saw mills in the Piney River area. Since American Cyanamid Company closed the titanium processing plant, titanium minerals are no longer mined from the local deposits.

The area is populated by approximately 200 people, with most of these people living within a one-mile radius of the Site. The closest residence is approximately 2000 feet to the west of the site along State Route 151, across from the former plant building site.

The community utilizes groundwater for its potable water supply. However, the residential wells are hydrogeologically isolated from the contaminated groundwater found on the Site. The wells to the north and west are upgradient, while wells south of the Piney River and east of the Site are hydraulically isolated by the groundwater discharge boundaries associated with the Piney River, and the unnamed tributary on the eastern side of the boundary. No residential wells exist between the Site and the Piney River.

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Surface drainage from the Site flows south to the Piney River, which, in turn, flows southeastward to the Tye River, and subsequently, to the James River. The Piney River is not used as a municipal water supply, but is used for recreation and fishing upstream of the site. The closest diversion for drinking water is approximately 40 miles downstream on the James River (NUS RAMP, 1983), and is not subject to possible adverse impacts from the Site. Recent biologic surveys have shown that the Piney River is fully recovered above its confluence with the Tye River. The point of recovery is between 1000 feet and four miles downstream of the Site.

## 2.2 LAND USE

The U.S. Titanium Site is an abandoned mining and ore processing facility that was used for titanium dioxide and yellow ferric oxide manufacturing during the American Cyanamid Company ownership (NUS RAMP, 1983). The processing plant, the associated settling ponds, and a copperas stockpile area were located on the north side of the Piney River in an area covering approximately 100 acres.

Predominant land use in areas adjacent to the site include rock quarry operations, logging, and farming. Route 151 and several railroad right-of-ways lie adjacent to the Site, and the land in the surrounding area is zoned for industrial use (NUS RAMP, 1983).

The railroad right-of-ways belong to the Blue Ridge Railroad, which is no longer in business, and the tracks have been removed.



### 3.0 PHYSICAL SETTING

#### 3.1 SOILS

In the upland areas, the Site is underlain by clay and silty clay of the Cullen soil association (NUS, 1983, p. 3-2). The soil is a residuum (saprolite) derived from the weathering of the underlying parent bedrock material. It is a dark reddish clay loam near the surface, but grades into the parent bedrock at variable depths across the Site. These residual soils typically have a pH of 5.1 to 6.0 (GCA, 1985, p. 3-9). Within the flood plain, the soils consist of heterogeneous alluvial deposits of gravel, sand, silt, and clay. The approximate boundary between the residual and alluvial soils lies along the base of the hill containing Areas 1, 2, and 3 (see Plate 2).

##### 3.1.1 DISTRIBUTION AND THICKNESS OF SOILS

Numerous borings and wells were drilled at this Site by HYDROSYSTEMS, Inc. (plotted on Plate 2) and investigators from VPI (Morris, 1984, and Moslehi, 1984). These borings and wells were used to delineate the thickness of soils throughout the Site. On Site, the residual soils range in thickness from just a few inches near the stream bed east of well 7 in Area 2, to approximately 60 feet along the southern edge of Areas 1 and 3. Plate 2 presents the soil thickness data, while logs of the soil borings are presented in Appendix E.

i.e., less than 0.5 in/hr (Bureau of Reclamation, 1978, p. 41). Only six tests had final saturated K values greater than 0.5 in/hr. Those values, ranging from 0.63 to 0.80 in/hr fall within the range for silty clay to silty clay loam.

As can be seen in the graphs presented in Appendix I about 13 of the 21 infiltrometer tests produced fair to good results which could be fit with an exponential curve with confidence. The other test results are judged poor due to inadequate data to produce a curve fit with confidence. However, even the results for the tests with poor data fall within two standard deviations of the mean, indicating the results are reasonable.

### 3.2 GEOLOGY

#### 3.2.1 PHYSIOGRAPHY

The Site is located in the Piedmont physiographic province about five miles east of the Virginia Blue Ridge. The Site is located on the Piney River Quadrangle 7.5 minute series topographic map (U.S. Geological Survey, PR 1984). In the general vicinity of the Site, elevations (datum is mean sea level) range from 2218 feet at England Ridge 4.5 miles to the northwest of the Site, to just under 600 feet about one mile downstream of the Site on the Piney River. Within the boundaries of the Site, the elevation ranges from 726 feet on top of the copperas burial pit in Area 1 to 618 feet in the Piney River near the drainage area in Area 7.

### 3.2.2 LITHOLOGY

The bedrock underlying the Site consists of the igneous and metamorphic rocks shown in Figure 3.1. Few detailed studies have been completed on the geology near the Site, except for a study by Hillhouse (1960) on the mineralogy and petrology of the area. Exposures are so few and poor that petrologic and structural relationships have been difficult to determine. However, based on the work of Hillhouse (1960), a general description of the geology is possible.

Underlying all of Areas 1 and 3 and the northern two-thirds of Area 2 is a pegmatitic anorthosite, a complex assemblage of sills (tabular intrusive bodies parallel to the intruded body) and dikes (tabular intrusive bodies cutting across the intruded body) (Hillhouse, 1960). The anorthosite is a coarse-grained, igneous rock consisting of more than 90% plagioclase, a calcium-sodium aluminum silicate with the mineral formula  $(Ca,Na)(Al,Si)AlSi_2O_8$  (Mason and Berry, 1968). The anorthosite is also referred to as the Roseland anorthosite (Hillhouse, 1960).

Underlying the southern end of Area 2, and all of Areas 4, 5, and 6 is what Hillhouse (1960) termed the border gneiss, a complex unit containing feldspathic gneisses, altered augen gneiss, garnet gneiss, graphite gneiss, and lenses of pyroxenite, amphibolite, and pegmatitic anorthosite.

Underlying a small area of the Site just east of Area 5 is Nelsonite, which, on the south side of the river, was the

titanium-ore body. The general term Nelsonite has been given to rocks in Nelson County that consist of apatite and one or more of the iron and titanium oxides: ilmenite ( $\text{FeTiO}_3$ ), rutile ( $\text{TiO}_2$ ), or magnetite ( $\text{Fe}_3\text{O}_4$ ). The Nelsonite that occurs at the Site principally contains ilmenite and apatite, with minor amounts of magnetite, rutile, plagioclase, quartz, hornblende, biotite, and chlorite. The Nelsonite is medium grained, equigranular, and has a distinct, sugary texture (Hillhouse, 1960). The Nelsonite contains up to 60% and, in some cases, as high as 90% ilmenite (Hillhouse, 1960).

Underlying the southeastern corner of the Site in Area 7 is an altered hypersthene granodiorite, which is medium-grained, gray-green in color, and characteristically has a gneissic, or layered mineralogy. The granodiorite has a complex mineralogy consisting of biotite, amphiboles, pyroxenes and numerous metamorphic reaction products (Hillhouse, 1960).

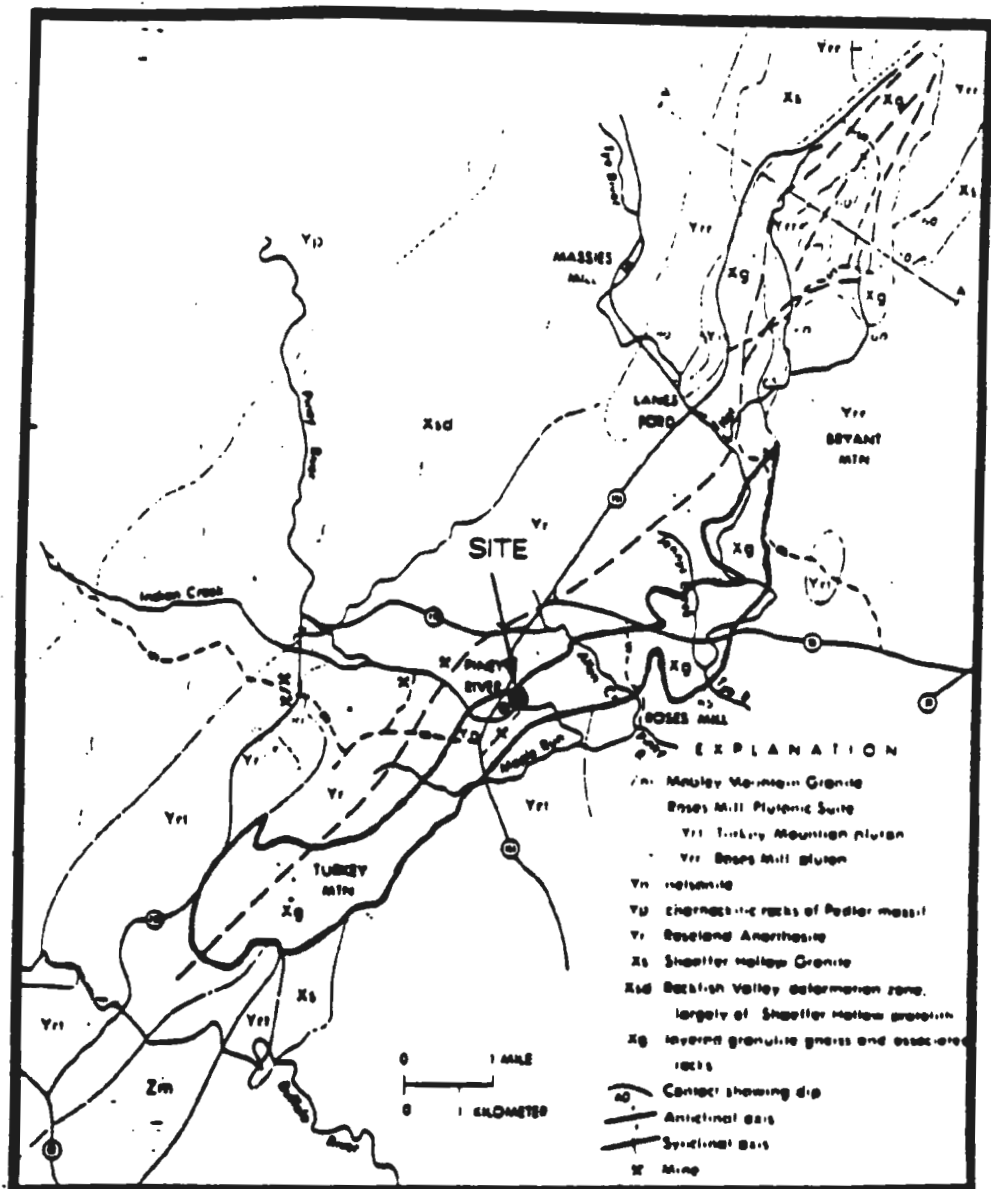


Figure 3.1. Generalized geologic map for the U.S. Titanium Site, Piney River, Virginia (from Hillhouse, 1960).

### 3.2.3 STRUCTURAL GEOLOGY

The structural geology of the region is dominated by the Roseland dome, a doubly plunging anticline. All the rocks exhibit a northeasterly striking, southeasterly dipping gneissosity, or layered mineralogy (Hillhouse, 1960).

Fractures occur in the bedrock at the Site and are visible in the outcrops of bedrock in the bottom of the Piney River and the drainage channel at the base of Area 2. Two distinct sets of nearly-vertical fractures are present and have approximately northwest-southeast and northeast-southwest orientations. Field measurements of strike and dip on 17 fractures at the Site were completed. Analysis of this data indicates an apparent primary fracture orientation (13 out of 17 fractures) that averages approximately North 21° West, and is approximately perpendicular to the strike of the Roseland Dome anticline. An apparent secondary fracture orientation averages approximately North 68° East, paralleling the strike of the Roseland Dome. These fractures are nearly vertical. Table 3.2 and Figure 3.2 present the fracture orientation data and analysis.

These two, nearly-vertical fracture sets oriented at right angles are indicative of the horizontal tension caused by the uplift of the Roseland Dome (Spencer, 1969, p. 64).

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### 3.3 HYDROLOGY

#### 3.3.1 GROUNDWATER HYDROLOGY

##### 3.3.1.1 OCCURRENCE OF GROUNDWATER

The hydrogeology at the Site is typical of the Piedmont of Virginia. Groundwater primarily occurs in the porous, unconsolidated granular material of the saprolite and, to a much lesser extent, in the fractures that run through the dense, hard igneous and metamorphic bedrock. These two units are hydraulically interconnected over larger distances. However, local heterogeneities such as changes in the clay content of the saprolite across a bedrock contact may produce local, partially confined conditions in the weathered, fractured bedrock.

Typically, 80% of the wells in the Piedmont region of south-central Virginia yield less than 20 gallons per minute (gpm) (Davis and DeWiest, 1970, p. 325). For the Piedmont in general, 90% of the total yield possible is obtained within the upper 300 feet, 85% within the upper 200 feet, and 50% within the upper 135 feet (LeGrand, 1967, p. 5). This is due to the fact that the fractures become tighter, and the number of fractures decreases with increasing depth.

However, at the Site, observations of fracture aperture indicate the fractures are very tight even at the surface. Fractures in the bed of the stream at the southern base of Area 2 allow very little seepage of water from above the water fall to below the water fall.

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The hydraulic conductivity for clayey saprolite in Table 3.4 is estimated from the permeameter tests reported by Moslehi (1984, p. 73).

#### 3.3.1.4 RECHARGE AND DISCHARGE AREAS

Groundwater recharge to the Site occurs over the entire surface as precipitation infiltrates into the soil and percolates to the water table. Groundwater discharges into the tributaries along the base of the hill containing Areas 1, 2, and 3 and into the Piney River. Based on field observations during drought periods, when the water table is low, groundwater ceases to discharge into the tributary along the southern base of Areas 1 and 3, passes beneath the tributary and continues to flow towards the Piney River. During those same drought periods, however, the stream along the base of Area 2 continued to receive groundwater discharge, albeit at a much reduced rate.

#### 3.3.1.5 GROUNDWATER-FLOW PATHS

Groundwater flow within the Site originates in the upland area containing Areas 1 and 3, flows in a radiating pattern down hill towards the streams surrounding the base of the hill and to the Piney River. Figure 3.5 presents groundwater flow directions (arrows) superimposed on the groundwater contours taken from Plate 1.



### 3.3.2 SURFACE WATER HYDROLOGY

#### 3.3.2.1 SURFACE DRAINAGE CONFIGURATION

The Site lies within the Piney River drainage basin, which is part of the larger James River drainage basin. The Piney River flows in an easterly direction forming the southern boundary of the Site. Areas 1 through 4 lie on the upland area, while Areas 5 through 7 lie within the flood plain of the Piney River.

Surface water drainage runs off the Site primarily via the drainage channel along the bottom of Area 2 and a small stream that originates along the western side of Area 1. These two channels merge south of Area 2 and discharge into the Piney River through a culvert at the downstream end of the property. A third stream originates to the west of the sedimentation ponds in Area 5, flows through the sedimentation ponds, and discharges into the Piney River through a breach in the dike at the southeastern end of the sedimentation pond. Figure 3.6 illustrates the general surface drainage pattern that currently exists at the U.S. Titanium Site.

#### 3.3.2.2 SURFACE WATER FLOW CHARACTERISTICS

The Piney River flow has been gauged at the Route 151 bridge by the U.S. Geological Survey (approximately 0.5 miles upstream of the Site). The area of the Piney River basin above this gauge is 47.6 sq. mi. The mean flow of the Piney River for the period 1951 to 1986 was 94.7 cfs, while the maximum flow was 38,000 cfs on 8/20/69, and the low flow was 1.1 cfs on 9/13/66.

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quality limits established by the Federal and State governments, even during extremely low river flow. This contradicts previous studies of the Site which suggested that groundwater discharges during low flow periods would be sufficient to cause water quality violations.

ORIGINAL  
(red)

Another objective of this study was to examine the impacts that heavy rainfall events, which normally occur in the summer months, have on river water quality. Specifically, the intent was to observe the impacts on the river due to weather conditions similar to those which are thought to have produced earlier fish kills in the Piney River. Those earlier storms were reported as being relatively intense summer thunderstorms occurring after a few weeks of dry weather.

Unfortunately, the summers of 1986 and 1987 turned out to be severe drought periods. The only significant rainfall event that occurred during the summer of 1986 was a light rain on August 20. That rainfall, however, was enough to produce runoff from the Site both through the culvert and from Area 5.

During that rainfall event, chemical data were collected for three stations along the river, stations 1, 5, and 6, and from the culvert, station 7. These data are presented below in Table 4.13. As can be seen, there was a substantial reduction in pH at station 5. The river water was gray in color, indicating significant runoff and erosion from Area 5 upstream. This pH value of 4.93 was the lowest pH value recorded during this SRI.

## 5.0 TRANSPORT AND FATE OF CONTAMINANTS

### 5.1 GEOCHEMISTRY OF COPPERAS

Copperas is the primary source of acidity, dissolved iron, and sulfate in discharges from the Site. As stated previously copperas is not acidic, but, subsequent to dissolution, copperas produces acidity as the result of a sequence of reactions that include oxidation of the ferrous iron to ferric iron and hydrolysis of the ferric iron to ferric oxyhydroxides. This series of reactions is shown in Figure 5.1. The net effect of these reactions is that for every mole of copperas dissolved, two moles of excess hydrogen ion ( $H^+$ ) are produced resulting in the acidic leachate.

The solubility of copperas is essentially infinite. Krauskopf (1967, p. 516) lists the solubility of ferrous sulfate as >1.0 moles/liter in a solution with just 0.01 moles/liter of sulfate. The theoretical ratios of sulfate to total dissolved iron to net hydrogen ion concentration, based on the reactions presented in Figure 5.1 are 1:1:2.

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### 5.3 CONTAMINANT TRANSPORT

The highly soluble nature of copperas inhibits reprecipitation once it is dissolved by percolating water. After the copperas leachate has been formed in the burial pit in Area 1, the dissolved iron, sulfate, and acidity are transported along two possible pathways. The first pathway is from the burial pit down to the water table and, hence, with the groundwater to points of discharge. The second pathway is via discharge immediately to the surface of the burial pit with subsequent transport in surface water to the Piney River. In either case, the pathway taken by any particular dissolved ion from the burial pit may involve both intermittent surface- and groundwater transport.

These pathways are summarized in Figure 5.3 and are discussed in the following sections under the categories of transport through the unsaturated zone, transport in the saturated zone, and transport in surface water.

#### 5.3.1 UNSATURATED ZONE TRANSPORT

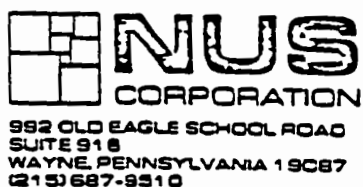
##### 5.3.1.1 WATER MOVEMENT THROUGH UNSATURATED ZONE

In each area of contamination on the Site, initial transport of the contamination is through the unsaturated zone, i.e., the soil above the water table. Due to the nature of the stratigraphy within the saprolite, it is believed that the movement of

**Reference 3**

**Excerpts From A Toxicological Impact Assessment  
of the U.S. Titanium Corporation Property;  
NUS Corporation; January 6, 1983**

ORIGINAL  
(Red)



A Toxicological Impact  
Assessment of the  
U.S. Titanium Corporation Property  
TDD No. F3-8212-16  
EPA No. VA-111

Preparation Date: January 6, 1983

Presented To: Linda Y. Boornazian, DPO  
EPA Region III

Prepared By: Kenneth G. Symms, Ph.D. Toxicologist

Don Senovich, FIT III Manager

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U.S. Titanium Corporation Property  
TDD No. F3-8212-16  
EPA No. VA-111

SUMMARY

Results of U.S. Titanium sample analyses indicate: 1) a high content in leachates of toxic metals (As, Cd, Cr, Pb, Ni), 2) high sulfate and low pH in emanating surface waters, 3) contamination of the groundwater underlying the site with metals, sulfate and high acidity, and 4) probable but undetermined adverse impacts on the nearby Piney River.

No metals of toxicological concern were found above analytical detection limits (5 to 20 ug/l) in the two residential wells sampled. Both wells, however, appear to be hydraulically upgradient from the site; the closest private well is more than 1,000 feet to the north of the copperas burial pit. Local groundwater flow is likely to be intercepted by the Piney River, and distant residential wells are at remote risk.

Threats of a direct nature to human health appear to be minimal. The major concern is the potential for adverse impacts from entry of run-offs low in pH and high in ferrous sulfate and other metals into Piney River via surface run-offs as well as subsurface infiltration. Piney River is protected for water-contact recreation, fish, and wildlife. Several incidents of fish kills have occurred in the past; two, subsequent to burial of the copperas material on-site.

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U.S. Titanium Corporation Property  
TDD No. F3-8212-16  
EPA No. VA-111

SURFACE WATER SAMPLES

Data provided by sample results of an extensive surface water monitoring survey conducted by the SWCB, May 5, 1982, and two leachate samples collected by EPA/CRL, August 4, 1982, are included as attachments to this report (Table F; please note corrections). Seeps taken near or on the Piney River, directly south of the former copperas storage area, (sample station numbers 6,7,9,10, and UST-L2), were found to be highly acidic (pH 2.9-3.0). Enormous amounts of sulfate were also detected (up to 2,700,000 ug/l).

Subsequent to the removal and burial of the copperas material in January of 1981, run-off from the poorly stabilized area of the previous copperas storage resulted in two fish kills in May and June, 1981. In June, 1982, remedial measures were taken to improve conditions of the former copperas storage and final disposal areas (See Site Inspection Report). Surface water samples taken by the SWCB prior to this remedial action indicate substantial contamination in leachates emanating from the previous copperas storage area. A combined drainage sample from two intermittent streams in this same area taken by EPA/CRL, subsequent to the June, 1982 remedial action, suggests that a leaching problem may still exist (compare results of EPA/CRL sample UST-L2 and SWCB samples 6,7,9, and 10). Additional analytical information may be required to make this determination.

Comparison of upstream and downstream samples (cf. sample stations 1 and 18, Table F) taken by the SWCB, May 1982, from the Piney River appears to indicate site-related contamination of the river. The downstream sample showed increases in iron (from 10 ug/l upstream to 310 ug/l), manganese (from 10 ug/l upstream to 130 ug/l), chromium (from 10 ug/l upstream to 40 ug/l), sulfates (from 1,900 ug/l upstream to 13,800 ug/l), and significant reduction in pH (from 6.7 to 5.1). It is noteworthy that these parameters are the same as those noted in the seeps sampled near or on the Piney River, as discussed above. Downstream levels of iron, manganese, and pH are in excess of those recommended in Ambient Waters Quality Criteria and mandated by Secondary MCL Standards for public water systems. The potential may also exist for pollution of the river by arsenic, chromium, and other metals in this flood-prone area.

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(Red)

U.S. Titanium Corporation Property  
TDD No. F3-8212-16  
EPA No. VA-111

### EFFECTS ON AQUATIC SYSTEMS

Past run-off from the U.S. Titanium site following unusually heavy precipitation has resulted in fish kills in the Piney River (documented by Va. SWCB 7/11/77, 8/19/77, 8/24/79, 7/11/80, 6/22/81) attributed to a substantial influx of ferrous sulfate and reduction in pH. In periods of low precipitation, water enters streams primarily as sub-surface infiltration through granular or porous material, and the low pH noted in the downstream sample during a time when no leachates were observed discharging into Piney River may reflect the substantial contribution of affected groundwaters.

Ferrous sulfate, which comprises the bulk of the copperas material stored and then buried on-site, is frequently present in underground waters. Some springs and many mine areas contain fairly large amounts, with the result that the streams to which they give rise are at first completely free of oxygen, low in pH and quite lifeless.

Large amounts of ferrous salts can produce serious pollution in rivers. Waters contaminated by ferrous ions are usually acid; as ferrous ions are oxidized, ferric hydroxide (ochre) is precipitated. In the process, dissolved oxygen is consumed, carbon dioxide is markedly elevated from natural bicarbonate, and the ferric hydroxide formed can settle out of inert suspension and produce a choking sediment over areas in river beds that are critical for the support or progeneration of various freshwater life. According to Hynes, (The Ecology of Running Waters, University Toronto Press, 1970), it is possible that the presence of the deposit and the depletion of dissolved oxygen in the water caused by the rapid oxidation of ferrous ions (immediate oxygen demand) are at least as important in eliminating species as is the low pH.

Downstream sampling of the Piney River revealed a pH value of 5.1. Studies of chronic pH effects on fathead minnows indicated that a pH value of 6.6 was marginal for vital life functions (Mount, D.L., 1973, Water Res. 7, 987). Below this pH, egg production and hatchability were reduced and at pH values below 5.2, fish exhibited abnormal behavior and deformities. A pH range of 6.5 to 9.0 is considered suitable to provide protection for the life of freshwater fish and bottom-dwelling invertebrate fish-food organisms (Quality Criteria for Water, U.S. EPA, 1976).

**Reference 4**

**Excerpts From Site Inspection of U.S. Titanium;  
NUS Corporation; July 27, 1983**

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FAX TRANSMISSION			
TO:	SUE McCarter		
Ph #:	734-3187	Mail Code:	
Fm:	Kim Hummel	Ph #:	215-597-1727
Date:	6/17		
# of Pgs:	28	Confirm:	
Time:	5 00		

ORIGINAL  
(Red)

SITE INSPECTION OF  
U.S. TITANIUM  
PREPARED UNDER

R-585-2-3-18

TDD NO. F3-8212-41  
EPA NO. VAD 980705401  
CONTRACT NO. 68-01-6699

FOR THE  
HAZARDOUS SITE CONTROL DIVISION  
U.S. ENVIRONMENTAL PROTECTION AGENCY

JULY 27, 1983

NUS CORPORATION  
SUPERFUND DIVISION

SUBMITTED BY

C.K. Lee  
C.K. LEE

APPROVED BY

Donald Senovich  
DONALD SENOVIICH  
MANAGER, FIT III

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## 1.0 INTRODUCTION

### 1.1 Authorization

NUS Corporation performed this work under Environmental Protection Agency Contract No. 68-01-6699. This specific report was prepared in accordance with Technical Directive Document No. F3-8212-41 for U.S. Titanium located in Nelson County, Virginia.

### 1.2 Scope Of Work

NUS Corporation was tasked to review information collected by Ecology and Environment during a site inspection, sampling, and well drilling project performed in November, 1982, under EPA project task number F3-8108-17A. NUS did not conduct a site visit.

### 1.3 Summary

The U.S. Titanium site is an abandoned milling and ore processing plant. The facility changed ownership several times during the operation. During its operation, the facility produced about 80,000 cubic yards of copperas (ferrous sulfate) wastes. Several waste handling procedures were utilized over the years (surface piles, lagoons, etc) until December 1980, when the wastes were buried on-site under state orders. (Please see EPA report numbers F3-8008-03 and F3-8108017A for further background information.)

Prior to burial on-site, six fish kills occurred, 1977-1981, in Piney River. The Virginia Water Control Board investigated these fish kills and has attributed them to run-off from the copperas waste pile. Presently, surface water run-off from the site is controlled through existing drainage ways toward the south into the Piney River. (See Plate 8 in Section 5.)

PLATE 5

U. S. Titanium Site, Pinay River, Va.  
Surface Water Monitoring Data

Parameter	Stations									
	<u>1</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>9</u>	<u>10</u>	<u>18</u>	<u>19</u>	<u>UST-L1</u>	<u>UST-L2</u>
pH (S.U.)	6.7	3.0	3.0	3.0	3.0	2.9	5.1	6.6	-----	2.9
Alk./Acid (mg/l CaCO <sub>3</sub> )	12/6	Acid/745	Acid/700	Acid/1270	Acid/1445	Acid/1755	4/22	33/Alk	-----	-----
Sulfates (mg/l)	1.9	1650.5	1459.4	1813.6	2240.5	2700.7	13.8	21.4	-----	-----
As (mg/l)	0.001-	-----	0.073	0.1-	0.15	0.1-	0.0-	0.001-	<del>0.52</del>	<del>0.042</del>
Cd (mg/l)	0.001-	-----	0.004	0.003	0.004	0.008	0.001-	0.001-	<del>0.91</del>	<del>0.024</del>
Cr (mg/l)	0.01-	-----	0.11	0.14	0.08	0.09	0.04	0.01-	2.7	<del>0.085</del>
Cu (mg/l)	0.01-	-----	0.15	0.19	0.08	0.11	0.01-	0.01-	3.9	<del>0.110</del>
Fe (mg/l)	0.01	-----	100	230	320	410	0.51	3.3	-----	-----
Pb (mg/l)	0.002-	-----	0.002	0.1	0.1	0.1	0.002-	0.002-	0.97	<del>0.070</del>
NI (mg/l)	-----	-----	-----	-----	-----	-----	-----	-----	15.5	.92
Mn (mg/l)	0.01	-----	6.7	12	45	570	0.13	0.76	-----	-----
Zn (mg/l)	0.01-	-----	0.11	0.97	1.1	1.4	0.01-	0.02	61.0	1.59

From TUD # F3-2212-16 Report  
Locations see Plate 4

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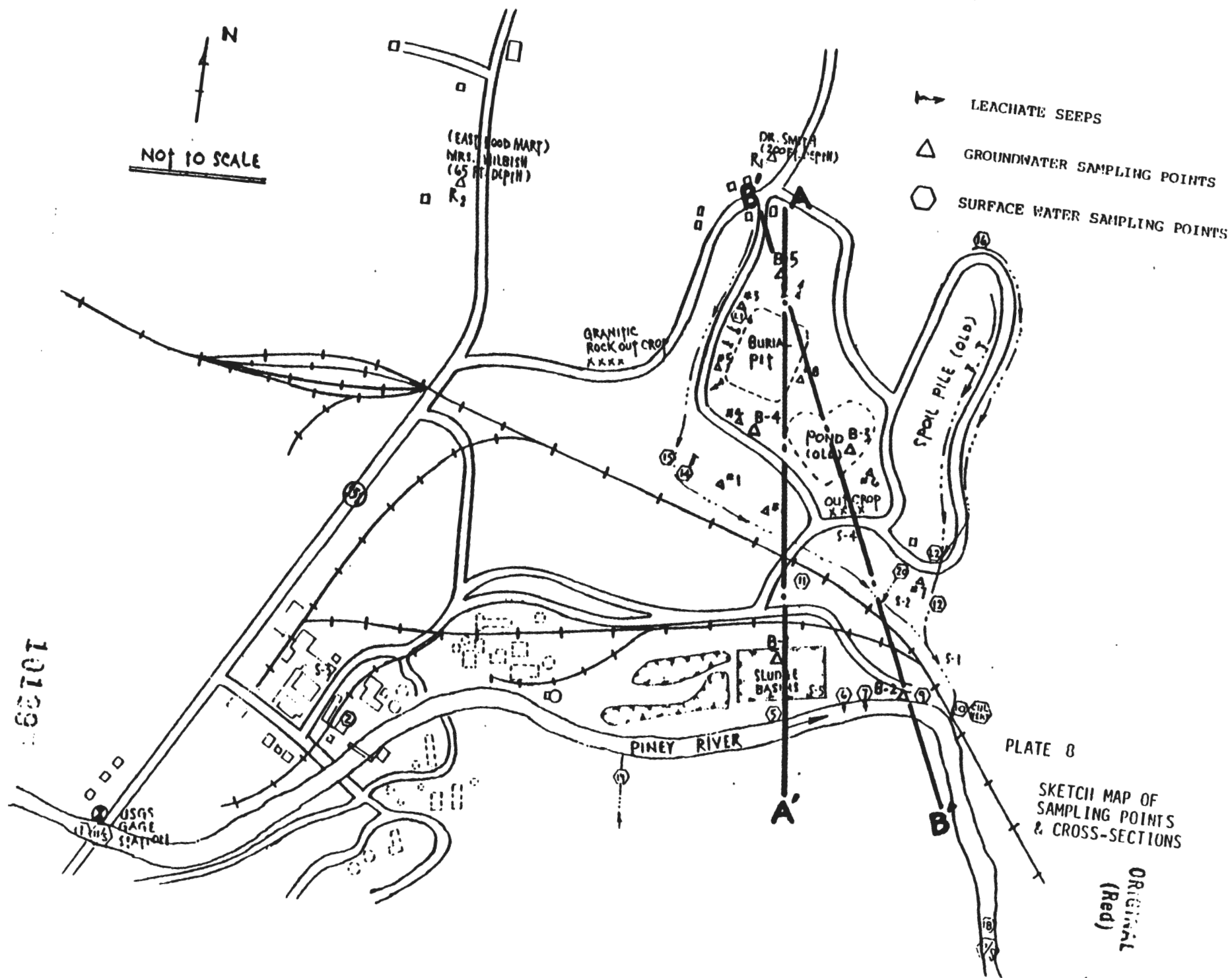
#### 4.0 TOXICOLOGICAL IMPACT ASSESSMENT

A Toxicological Impact Assessment of the U.S. Titanium site was recently prepared under TDD No. F3-8212-16 based on results of samples obtained on August 4, 1982 by EPA Region III and Central Regional Laboratory (EPA/CRL), and samples collected by the Virginia State Water Control Board on January 7, 1982. Subsequently, Ecology and Environment was contracted to have additional monitoring wells installed. FIT III sampled these wells and surface waters on the site in November of 1982 under TDD No. F3-8121-41.

Results of the November sampling confirmed previous findings of elevated iron, manganese, and other metals in ground and surface waters. The toxicological impacts of the inorganics identified are addressed in the initial Toxicological Impact Assessment of the U.S. Titanium Corporation Property, which is included as an attachment to this report for purposes of reference. (Please see Appendix A - 1.0)

Groundwater samples from newly installed wells indicate lower levels of iron and other metals than were found in previous samples taken in late summer by EPA/CRL from existing wells. It may be noted that concentrations of iron and other metals in groundwater can fluctuate with changes in weather conditions. Levels of iron appear, nevertheless, very high in some aqueous samples taken from the recently installed monitoring wells (up to 579,000 ug FE/l in MW B-2).

Surface water samples taken in November suggest that a potentially serious leaching problem may still exist, despite the remedial measures (copperas buried, regrading, and other repair) taken in June of 1982. A surface run-off sample, taken from a culvert as it enters Piney River, revealed high levels of iron (424,000 ug/l), manganese (115,000 ug/l), zinc (2,270 ug/l), chromium (55 ug/l), nickel (1,278 ug/l), copper (170 ug/l), and silver (24 ug/l).



**Reference 5**

**Letter Concerning Status Report of the U.S. Titanium Mine Site;  
From R.V. Davis, SWCB, to J. Kenneth Robinson, House of Representatives;  
August 26, 1980**





ORIGINAL  
(Rec)

# COMMONWEALTH of VIRGINIA

STATE WATER CONTROL BOARD

2111 Hamilton Street

R. V. Davis  
Executive Secretary

Office Box 11143  
Richmond, Virginia 23230  
(804) 257 0056

AUG 26 1980

RECEIVED

OCT 7 1980

VALLEY REGIONAL  
OFFICE

BOARD MEMBERS  
Chairman  
Vice Chairman

John H. Allen  
Charles Lee R. III  
William L. ...  
C. M. Co.  
Harold B. ...

Honorable J. Kenneth Robinson  
House of Representatives  
Washington, D. C. 20515

Re: U.S. Titanium Corporation, Piney River, Virginia

Dear Mr. Robinson:

Thank you for your letter of 18 August 1980 concerning the referenced situation in Nelson County. Hopefully, this will bring you up to date on the status of our efforts to resolve this persistent problem.

As you may recall, U. S. Titanium Corporation is the owner of property located in Piney River, Virginia on which is located a stockpile of waste material known as copperas or ferrous sulphate, which was deposited there by a previous owner, American Cyanamid Corporation. The Board has been involved with U.S. Titanium in a regulatory capacity since 1976 and an enforcement capacity as well, since 1977. U.S. Titanium took possession of two abandoned mine sites and the old American Cyanamid plant site in 1976. American Cyanamid had operated a titanium dioxide manufacturing plant at Piney River for many years, finally closing its operation in 1971. During its operation, American Cyanamid deposited vast amounts of waste copperas adjacent to the Piney River. Prior to the closure of the Piney River Plant, American Cyanamid submitted to the State Water Control Board staff for approval, a proposal to dispose of the waste copperas by burial. Prior to implementing this disposal plan, however, Mr. S. Vance Wilkins bought the property. As part of the sale agreement, American Cyanamid paid Mr. Wilkins a sum of money (\$100,000) to dispose of the waste copperas in accordance with the Board approved plan. Mr. Wilkins, prior to implementing the disposal plan, constructed a Board approved no discharge facility to collect and contain contaminated runoff from the waste copperas pile by utilizing a catchment basin, pumps, and a larger evaporation pond. This facility eliminated the discharge of acidic runoff and seepage from the copperas pile to the river which had persisted since stockpiling was begun by American Cyanamid. It was Mr. Wilkins' intention to try to sell the waste copperas before implementing the approved disposal plan. This proposal was agreed to by the Board's staff, however, Mr. Wilkins was given only until December 1977 to pursue the option of selling the copperas. Beyond that date the Board required that the copperas be properly disposed of in an approved manner. In the interim, Mr. Wilkins was required to maintain and operate the no discharge facilities to prevent discharge of contaminated wastewater to the Piney River in accordance with a certificate issued by the Board.

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- 3 -

Mr. Charles J. Bennett, Jr.

to contain runoff from the copperas pile. Although the staff's investigation is not yet complete, it appears that heavy rains on July 10, 1980 resulted in runoff from the copperas pile entering the Piney River and killing fish in both the Piney and Tye Rivers once again. This most recent fish kill exemplifies the urgency in carrying out the approved burial operation. Both the Department of Health and the Board have jurisdiction over all aspects of the burial operation and propose to enforce their appropriate authority under the law and their respective permits to ensure that the copperas is buried as expeditiously as possible. Should the investigation currently underway determine that U.S. Titanium is responsible for the July 10, 1980 fish kill, the staff will proceed to collect from the company replacement costs for the fish killed and investigative costs incurred by the Commonwealth. Please be advised that the company has paid the Commonwealth in full for the fish destroyed as a result of the past two fish kills.

The staff wishes to assure you that the Commonwealth is doing everything it can to ensure that this waste is properly disposed of this year. You should also be assured that while this waste, due to its acidic nature, is very toxic to fish, it does not appear to represent a hazard to people or wildlife. Unfortunately, the staff must also relay to you that damage to the river from past discharges of American Cyanamid and U.S. Titanium is long term, and despite our best efforts, it will take the river some years to return to a near normal condition. Once these discharges are fully abated and the river begins to recover, the monies collected to replace the fish killed will be available to begin a restocking program.

Should you have any specific questions concerning the copperas disposal program, please do not hesitate to contact Mr. Tedd H. Jett of the State Water Control Board's Valley Regional Office (703/828-2595). Mr. Jett is the engineer in charge of overseeing the Board's responsibility for maintaining the no discharge facility. The actual burial of the waste copperas is the responsibility of the State Department of Health. Mr. Robert H. Forman, Division of Solid and Hazardous Wastes Management (703/825-6772) should be contacted relative to the Department's responsibilities.

Sincerely,



R. V. Davis  
Executive Secretary

/jf

cc: BAT, Richmond  
Bureau of Enforcement, Richmond  
John Butcher, Attorney General's Office  
VRO File #20-1147,  
Mr. Robert H. Forman, R.S.  
State Department of Health  
Div. of Solid & Hazardous Wastes Management  
102 North Main Street  
Culpeper, VA 22701

R. Bradley Channing  
James A. Preston

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**Mining Waste NPL Site Summary Report**

**Uravan Uranium Mill  
Uravan, Colorado**

**U.S. Environmental Protection Agency  
Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

**Science Applications International Corporation  
Environmental and Health Sciences Group  
7600-A Leesburg Pike  
Falls Church, Virginia 22043**

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## **DISCLAIMER AND ACKNOWLEDGEMENTS**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Gene Taylor of EPA Region VIII [(303) 293-1640], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**URAVAN URANIUM MILL**

**URAVAN, COLORADO**

**INTRODUCTION**

This Site Summary Report for the Uravan Uranium Mill is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VIII Remedial Project Manager for the site, Gene Taylor.

**SITE OVERVIEW**

The Uravan Uranium mill complex is located approximately 90 miles southwest of Grand Junction along State Highway 141 in Montrose County, Colorado (see Figure 1). The mill was built at Club Mesa, west of the San Miguel River canyon (Reference 1, page 1).

Standard Chemical Company began radium milling and extraction operations at the site in 1915 and shifted to vanadium production in 1928. In 1936, Union Carbide Corporation purchased the operation (Reference 2, page 3). Production shifted again in the early 1940's to uranium processing (Reference 3, Volume 2, page 2-1; Reference 2, page 3). Operations continued on and off at the facility until 1984, when they were suspended (Reference 2, page 1).

Over the course of its operation, the mill generated and disposed of millions of cubic yards of both solid and liquid wastes. These wastes have potentially hazardous concentrations of radioactive material (including uranium, radium, and thorium); metals (including selenium, aluminum, arsenic, zinc, etc.), and inorganic materials (including ammonia, nitrate, sulfates, etc.).

Mining, milling, and waste disposal activities have resulted in:

- Wind and surface-water dispersal of the tailings materials and the uncontrolled release of radon from the Tailings Piles

- Seepage of contaminated liquids into soils and ground water from several areas in the mill complex and waste disposal areas
- Concentrations of large quantities of wastes in locations that pose a risk to public health and the environment, based on considerations of the potential for release of hazardous materials to the environment (Reference 4, page 7).

Disposal practices included the use of solid waste tailings piles and unlined ponds for liquid waste; most waste management areas are located along the San Miguel River. Seepage from these storage areas flows toward the river.

The finely ground nature of the tailings makes them particularly susceptible to dispersion through both air and water media. Because of the high potential for dispersion by wind and seepage into the San Miguel River, these piles represent a threat to human health at the Uravan site (Reference 2, page 5).

Other exposure routes threatening the health of human populations include inhalation or consumption of contaminated media and consumption of food items that have been previously contaminated (Reference 2, page 20). Several small communities and three larger population centers are within 50 miles of the site (Reference 2, page 23). (According to EPA, the 50 residents of Uravan were moved from company residences, beginning in 1985. The buildings were demolished in 1988.)

A Remedial Action Plan, developed jointly by the State, Union Carbide Corporation, and Umetco, describes a 10- to 15-year action schedule for site remediation. The cost of these activities is estimated to be over \$40 million. Remediation activities may include removal of contaminated solids and liquids from the area (Reference 1, page 2).

## OPERATING HISTORY

Standard Chemical Company began operating the Uravan Mill facility in 1915 to recover uranium, vanadium, and radium from mined ores. Ore was received at the Uravan Mill from approximately 60 different underground mines in the Uravan mineral belt, most of which were within 35 to 40 miles of the mill. Union Carbide bought the facility from Standard Chemical through the U.S. Vanadium Company in 1936 and continued to process uranium and radium at the site. While in operation, the mill processed approximately 1,000 tons of ore per day (Reference 2, page 3).

Stockpiled ore was crushed, ground, and then processed onsite. Processing at the mill included hot, strong acid leaching in a two-stage circuit followed by the recovery of pregnant solutions in

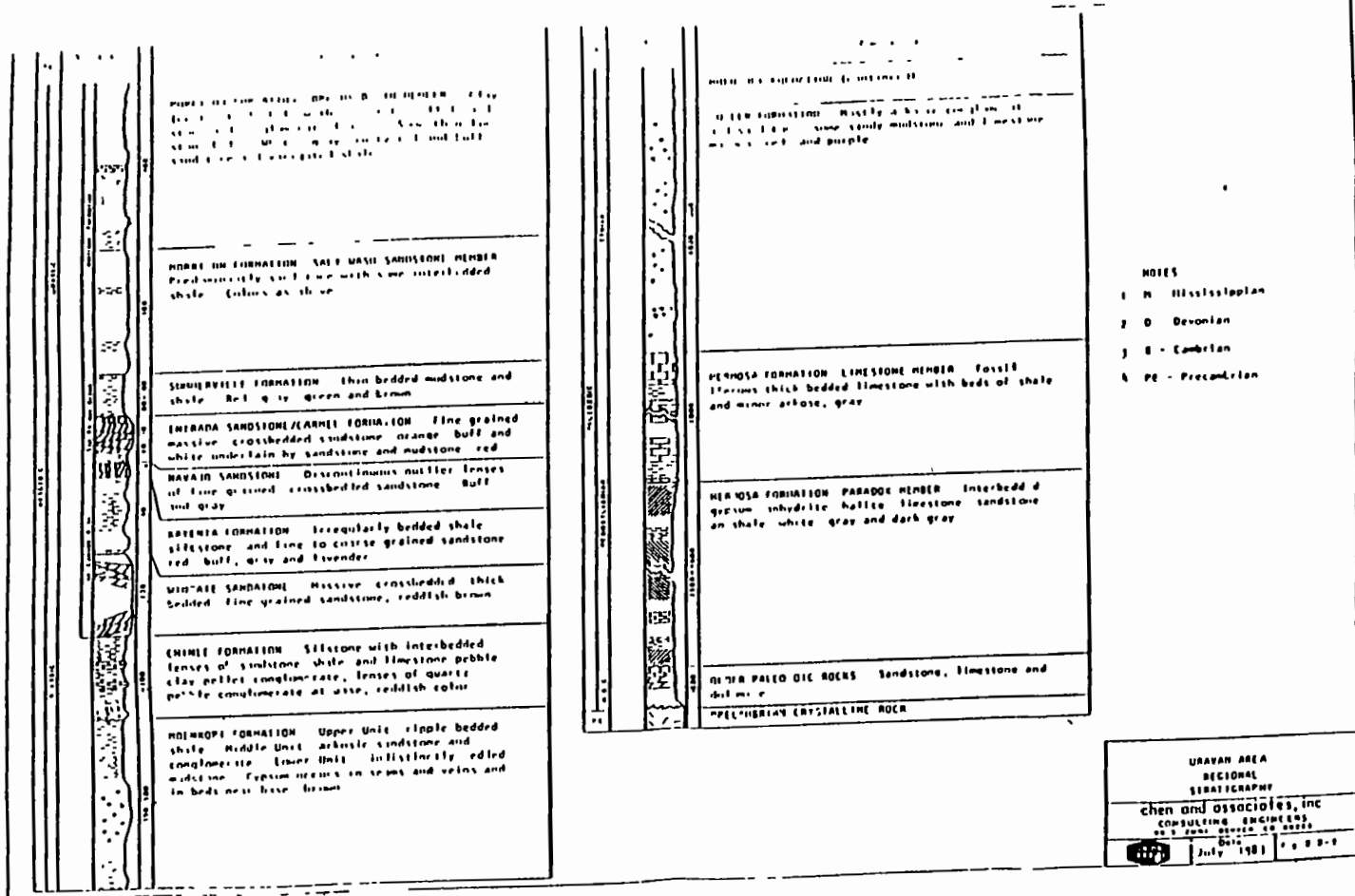
The principal waste management areas onsite and in associated areas are:

- Atkinson Creek Crystal Disposal Area - Unlined storage pit along the San Miguel River containing 200,000 cubic yards of raffinate crystals (Reference 3, Volume 2, page 2-27).
- Club Ranch Ponds - Six unlined ponds covering 32 acres located along the San Miguel River that contain 30 million gallons of liquid raffinate and 560,000 cubic yards of raffinate crystals.
- River Ponds - Seven unlined ponds constructed in old tailings piles containing 200,000 cubic yards of neutralized mill sludge and contaminated soils. The seven ponds are located along both sides of the San Miguel River. These were used as holding areas for liquid waste collected in the mill area before they were discharged into the San Miguel River (Reference 3, Volume 2, page 2-30).
- Tailings Piles - About 10 million tons of mill tailings contained in three piles (at two sites) that are located on the Club Mesa, 400 feet above and west of the mill site.
- Club Mesa Area - Disposal area on Club Mesa consisting of two clay-lined sludge storage areas, storage ponds, raffinate spray evaporation area, and associated contaminated soils; contains 250,000 cubic yards of raffinate crystals, 150,000 cubic yards of neutralized sludge, 40,000 cubic yards of contaminated pond material, and 44,000 cubic yards of contaminated soil.
- Plant Areas - Two plant locations with surficial contamination including containment structures, ore stockpile area, equipment and auxiliary wastes, and heap leach sites containing 15,000 tons of ore.
- Town and Adjacent Areas - Several small communities and three larger population centers located along the San Miguel River are within 50 miles of the site (Reference 2, page 23). Old tailings and contaminated soil have been found in these areas (Reference 2, page 6).

#### **SITE CHARACTERIZATION**

Potential transport mechanisms for each contaminant source are summarized in Table 2. Below is a discussion of media contaminated by these mechanisms.

FIGURE 2. URAVAN AREA REGIONAL STRATIGRAPHY





**TABLE 3. GROUND-WATER QUALITY AT URAVAN COMPARING  
GROUND-WATER SAMPLE RESULTS FOR CRP-4 (BACKGROUND  
WELL) AND CRP-2 (CONTAMINATED WELL)**

Parameter	Units	CRP-2	CRP-4	LLD's
Date		11/15/84	10/18/84	
Sample Type		Pumped	Pumped	
Top Casing Elev	feet	4941 980	4995 650	0 001
B Casing Elev.	feet	4891 980	4935 650	0 001
Phreatic Elev.	feet	4927.880	4959 950	0 001
Temp.	C	14	14	-2 000
Cond @ 25° C	umhos	17,136	365	10 000
pH	Units	6.64	7 58	0 100
TDS	mg/l	27,090	272	10 000
Sol. Sulfates	mg/l	18,560	28	10 000
Sol. Chlorides	mg/l	1,420	4	10 000
Sol. Sodium	mg/l	783	19 6	0 100
Sol. Calcium	mg/l	494	45 4	10 000
Sol. Potassium	mg/l	378	10 1	0 100
Sol Nitrite/N	mg/l	0 02	<0.02	0 100
Sol Nitrate/N	mg/l	2	<0 04	0 100
Sol Ammonia	mg/l	1,610	0 2	1 000
Sol Zinc	mg/l	0 208	<0 02	0 020
Sol. Selenium	mg/l	<0 250	<0.01	0 010
Sol Magnesium	mg/l	1,202	22 1	0 100
Sol. Manganese	mg/l	6 63	0.028	0 050
Sol Iron	mg/l	26.8	0 059	0 025
Sol Carbonate	mg/l	< 1	< 1	1.000
Sol. Bicarbonate	mg/l	1,960	258	1 000
Sol U-Nat	pC/l	470	<3	0 200
Sol Th-230	pC/l	0 20±0 50	0 00±0 40	3 100
Sol. Ra-226	pC/l	2 40±0 50	1.10±0 40	0 310
Sol. Pb-210	pC/l	0 40±0 90	13 00±2 00	4 800
Sol. Po-210	pC/l	0 10±0 60	-0 05±0.90	1.000
Zinc <sup>1</sup>	mg/l	0 63	<0 01	0.01
Copper <sup>1</sup>	mg/l	0 07	<0 01	0.01
Arsenic <sup>1</sup>	mg/l	<0 01	<0 01	0.01
Mercury <sup>1</sup>	mg/l	<0 0003	<0 0003	0.0003
Cadmium <sup>1</sup>	mg/l	<0 01	<0 01	0 01
Chromium <sup>1</sup>	mg/l	<0.01	<0.01	0.01
Lead <sup>1</sup>	mg/l	<0 01	<0 01	0.01
Silver <sup>1</sup>	mg/l	<0 01	<0 01	0.01

LLD = Lower Limits of Detection

pC/l = pico Curies per liter

<sup>1</sup>CRP-2 sample 10/6/83, CRP-4 sample 10/5/83

Source. Reference 4, page 90

It is conservatively estimated that contaminated soil erosion accounts for the following contamination in the river, although seep water from tailings piles and ponds was also observed to be contaminating the River system:

- 2.6 to 543 grams per acre per year (g/a-y) of arsenic
- 2.4 to 17 g/a-y of lead
- 0.2 to 0.9 g/a-y of cadmium
- 4.6 grams to 34.6 kilograms/acre-year of vanadium
- 8.4 to 729 (g/a-y) of zinc (Reference 3, Volume 1, page 5-40).

Analyses of seep water, precipitates, and dry wash alluvium from the general area of the mill indicate that these are the likely sources of contamination to the San Miguel and Dolores River ecosystems. Contaminants found in these were elevated; they were also the same as those found in the ecosystem and in sources such as tailings, raffinate storage areas, and onsite soils (Reference 3, Volume 1, page 2-5).

Healthy communities of algae and macroinvertebrates were found in the San Miguel River downstream of the facility, despite high concentrations of metals in their systems. Although fish populations were not sampled, water quality in the area is below the State of Colorado's standards for fish, due to the presence of contaminants (Reference 3, Volume 1, page 2-5). Studies conducted as early as the 1950's noted poor water quality in the area. Incidences of oil patches, high levels of suspended solids, high water turbidity, and reduced fish catches were pointed out by previous researchers, including Tsivoglou (1955) and Nolting (1956) (Reference 3, Volume 2, page 5-90).

#### Air

Air contamination at the Uravan site was not addressed in the Remedial Action Plan. However, provisions for monitoring for radioactive particles during and after site reclamation are discussed.

**TABLE 5. EXPOSURE ROUTES TO HUMAN POPULATION FROM  
CONTAMINANTS AT THE URAVAN SITE**

<b>Indirect Exposure Routes</b>
1. Inhalation of radon gas and both radiologically and nonradiologically contaminated dusts which become airborne.
2. Ingestion of contaminated sediments and soils.
3. Consumption of surface water.
4. Consumption of well water.
<b>Indirect Exposure Routes</b>
1. Consumption of fish from San Miguel or Dolores River.
2. Consumption of produce from private garden harvests.
3. Consumption of milk from dairy cows.
4. Consumption of meat from livestock

Source: Reference 2

vegetation. These contaminants will bioaccumulate as a result of consumption by either animals or humans that are primary or secondary consumers. The high dispersion of contaminants in the area is attributed to wind transport of contaminated particles (Reference 3, Volume 1, page 2-3 and 2-4)

#### **REMEDIAL ACTIONS AND COSTS**

On December 9, 1983, the State of Colorado brought suit against both Union Carbide Corporation and Umetco for response costs and natural resources damage under the Comprehensive Environmental Response, Compensation, and Liability Act (Reference 1, page 1). Specifically, Union Carbide Corporation and Umetco were required to pay between \$3.5 and \$4.0 million to the State of Colorado over a 7-year period. This fine included a reimbursement of the State for fees accumulated as a result of its prosecution of Union Carbide Corporation/Umetco and its future oversight of the Uravan facility, as well as compensation for damage to the State's natural resources as a result of the Uravan facility. Union Carbide Corporation/Umetco were also required to give a 200-acre (\$80,000) pristine area to the State for use as a natural area by the people of Colorado, and \$388,000 of senior water rights on the San Miguel River to the State and a water trust (Reference 1, page 4). Union Carbide Corporation/Umetco have also agreed to donate a part of the Uravan facility to act as a low-level

## REFERENCES

1. Executive Summary of the Remedial Action Plan and Consent Decree, State of Colorado vs. Union Carbide Corporation and Umetco Minerals Corporation (83C2384); Author Not Provided; 1986.
2. Qualitative Health Risk Assessment, Uravan Uranium Mill, Uravan, Colorado; RA Consultants; July 1986.
3. Final Report, Winter Baseline Investigation of Surface Media in the Vicinity of the Uravan Uranium Mill, Uravan, Colorado, Volumes I and II; ERI Logan, Inc.; August 11, 1986.
4. Remedial Action Plan, State of Colorado vs. Union Carbide Corporation and Umetco Minerals Corporation (83C2384); Author Not Provided; 1986.

**Reference 1**

**Excerpts From Executive Summary of the Remedial Action Plan  
and Consent Decree, State of Colorado vs. Union Carbide Corporation  
and Umetco Minerals Corporation (83C2384); Author Not Provided; 1986**

## EXECUTIVE SUMMARY OF THE REMEDIAL ACTION PLAN AND CONSENT DECREE

### STATE OF COLORADO V. UNION CARBIDE CORPORATION AND UMETCO MINERALS CORPORATION, 83C2384

Umetco's Uravan uranium-vanadium mine and mill complex is located approximately ninety (90) miles southwest of Grand Junction along State Highway 141. The facilities occupy a portion of Club Mesa, to the west of the San Miguel River canyon and the river canyon floor. During its seventy (70) years of operation the facility has processed millions of tons of ore and disposed of millions of cubic yards of solid and liquid wastes. Waste disposal practices have resulted in wind and water dispersal of contaminated solids (tailings) and liquids (mill process wastes and seepage) from the disposal areas. These solid and liquid wastes contain hazardous concentrations of radioactive material (uranium, radium, and thorium), heavy metals (selenium, aluminum, arsenic, cadmium, zinc and others) and inorganic contaminants (ammonia, nitrate, sulfates and others).

#### I. THE REMEDIAL ACTION PLAN

Prompted by an awareness of Uravan's impact on the natural resources of the state, legal action was brought against Union Carbide Corporation (UCC) and Umetco Minerals Corporation (Umetco) by the State of Colorado for response costs and natural resource damages pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 ("CERCLA"), which is also known as "Superfund." The state's pleadings also contained causes of action under Colorado law for nuisance, negligence, and strict liability in tort.

Representatives of the state, UCC, and Umetco, together with their expert consultants and counsel, began meeting in March 1985 to develop a program for environmental clean-up at the Uravan Facility. The product of these lengthy negotiations is a 350 page document entitled "Remedial Action Plan" (RAP). The RAP contains a 12-15 year schedule of remedial actions. The cost of the remedial program, as estimated by defendants, exceeds \$40 million.

Stipulated penalties in the amount of \$2500-\$10,000 per day are imposed for environmentally sensitive violations of the RAP, which are: a discharge to surface water or ground water, and the failure to notify the state of such actual or threatened discharges. (See the discussion of this subject as an innovation in Part III below.)

**D. Dispute Resolution.**

The defendants shall pay the state's reasonable costs for adjudication of disputes unless the state's position was unreasonably taken or maintained.

**E. Response Costs, Natural Resource Damages, and Contributions.**

\$3.5-\$4.0 million will be received by the state from UCC/Umetco during the next 7 years. The cash payments are allocated in such a way as to reimburse the General Fund for expenditures made in prosecution of this matter, to pay the costs of the state's future oversight at the Uravan Facility, and to compensate the state by a damage award for injury to its natural resources. Additionally, defendants are transferring a 200 acre parcel of pristine land to the state for preservation as a Natural Area, valued by defendants at \$80,000. Moreover, the defendants will convey to the state and to a water trust certain senior water rights on the San Miguel River, having an approximate value of \$388,000. Finally, the defendants have agreed to make a portion of the Uravan Facility available for disposal of low-level radioactive wastes from the Denver Radium Site and Colorado School of Mines. It must be emphasized, however, that this part of the agreement is only an option from the state's perspective; the public will have an opportunity to comment on the disposal location of these waste materials once a site is actually selected by the state.

**F. Subsequent Enactments.**

Any subsequent statutory enactments or promulgations of regulations will become incorporated only if they are determined to be applicable and their inclusion is deemed appropriate by the Special Master and/or U.S. District Court.

**G. Release and Recopeners.**

The mutual release between the parties extends to civil liability for all environmental claims arising out of the factual circumstances of this case. The release will not apply in the

**Reference 2**

**Excerpts From Qualitative Health Risk Assessment,  
Uravan Uranium Mill, Uravan, Colorado;  
RA Consultants; July 1986**



QUALITATIVE HEALTH RISK ASSESSMENT

Uravan Uranium Mill

Uravan, Colorado

Prepared for:

State of Colorado

Department of Law

Office of Attorney General

CERCLA Litigation Section

Under subcontract to:

GeoTrans Inc.

3300 Mitchell Lane

Boulder, Colorado 80301

Prepared by:

RA Consultants

26050 E. Jamison Circle

Aurora, Colorado 80016

July 1986

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## 1.0 INTRODUCTION

Umetco Minerals Corporation (Umetco), a subsidiary of Union Carbide Corporation (UCC), has operated a uranium mill and tailings disposal site at Uravan in Montrose County, Colorado. Milling and extraction operations for radium first started at this site in 1915, and continued more recently for vanadium and uranium extraction until late 1984; since then operations at the mill have been temporarily suspended. Operations at the Uravan site have resulted in the disposal of a large quantity of milling, radionuclide extraction, and other wastes at the site. These wastes consist of mill tailings, and raffinate as liquid and crystals. During active operations air emissions occur from ore crushing, milling, metals extraction and yellowcake preparation. The wastes contain materials, primarily metals and radionuclides, which in high concentrations and large amounts can constitute a hazard to the health and welfare of human populations.

This assessment for the Uravan site presents the results of a qualitative human health risk analysis. This risk analysis determines the source of contaminants by types and characteristic, location and amount, and an evaluation of human health effects. The hazards posed from the contaminants are evaluated for the potential to release contaminants, and the pathways and transport mechanisms for the contaminants after release. Human populations at risk from the released contaminants are determined from the location, numbers, habits and resource uses in the region around the site. The final step in the risk analysis is to estimate the likelihood and extent of health effects based on the potential for exposure and dose to the population at risk.

This potential health risk will be assessed using three time references. The first time reference assumes the present conditions at the site exist into an indefinite time frame and no remediation occurs. The second reference examines risks during the period of active site remediation which is expected to occur from 1987 until approximately the year 2005. The third time frame is post remediation, with health risks assessed in the short-term (for 200 years) and long-term (beyond 200 years).

4/6/84

vanadium to the tetravalent state. The ion exchange circuit utilized fixed-bed ion exchange columns.

Uranium-barren solution from the ion exchange passed to the vanadium recovery circuit, and after the vanadium was extracted, to final disposal by evaporation in ponds dispersed apart from the regular tailings disposal area. Pregnant solution containing about 20 grams of uranium per liter passed to the precipitation circuit.

In order to precipitate the uranium, pregnant solution was fed through tanks in series and heated by direct steam injection to about 120°F. Ammonia was added to the two tanks, the precipitated yellow cake slurry was thickened, and the overflow solution passed through filter presses to recover any fine product. Filter cake was repulped and fed to a multiple-hearth skinner roaster. The dry yellow cake was loaded into drums using an automatic device to shut off feed when the drum was filled.

#### 3.1.4 Tailings and raffinate disposal

- Plant tailings from the thickener circuit were pumped to either of two available tailings areas alternately to allow settling and recovery of solutions for return to the plant. The tailings ponds are located on a hillside on Club Mesa adjacent to the mill and are somewhat limited in size. As of late 1984, the tailings area encompassed approximately 80 acres containing an estimated 10 million tons of tailings. The Uravan Mill site constitutes a large uranium mill tailings disposal repository. Consequently, the radiological and non-radiological contaminants in the tailings area represent the source or origin of the greatest potential health hazard associated with the Uravan Mill (PERLS 1984). The tailings materials are finely ground, acidic and retain metallic and radioactive contaminants in a mobile state. The tailings material also retained waste liquids within the tailings piles. Raffinate is the waste liquid from the milling and extraction process, and contains ammonium-aluminum salts, with dissolved elements from the ore and spent reagents from the process. Two principal areas were used for disposal of this liquid: storage ponds in the San Miguel River Valley and an evaporation spray area on Club Mesa. Raffinate crystals, a solid

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3. River Ponds. Seven unlined ponds constructed in old tailings piles containing 200,000 cubic yards of mill wastes and contaminated soils that are located along both sides of the San Miguel River.
4. Tailings piles. About 10,000,000 tons of mill tailings waste contained in three piles in two sites that are located on Club Mesa 400 feet above and west of the mill site.
5. Club Mesa area. Disposal area on Club Mesa consisting of two clay lined sludge storage areas, storage ponds, raffinate spray evaporation area and associated contaminated soils; contains 250,000 cubic yards of raffinate crystals, 150,000 cubic yards of neutralized sludge, 40,000 cubic yards of contaminated pond material and 44,000 cubic yards of contaminated soil.
6. Mill areas. Two plant locations with surficial contamination; contain structures, ore stockpile area, equipment and ancillary wastes; heap leach site containing 15,000 tons of ore.
7. Town and adjacent areas. Located along San Miguel River in valley northwest of mill; contain old tailings and contaminated soil.

#### 3.4 TOXICITY EVALUATION

- Data for various locations at the Uravan site, (Tables 3.1 through 3.3), indicate the presence of both non-radiological and radiological contaminants. Table 3.1 (GeoTrans/ERI 1986b) lists the chemical composition of solid waste materials from several source locations. Table 3.2 lists the chemical composition of liquid wastes onsite and contaminated groundwater compiled from historical and current data (GeoTrans/ERI 1986a). Table 3.3 is a summary of concentration of materials in water seepage that has been contaminated with tailings solution and raffinate seepage. The non-radiological and metallic contaminants are discussed in Section 3.4.1.

Due to the locations of the contaminants, potential hazards exist via suspended particulates as a result of windblown releases from the extensive tailings pile area, from the ore pad or storage area, and via liquid releases from the tailings ponds. Consequently, it is necessary to evaluate the toxicity of the contaminants in order to assess potential health risks. The following toxicological data were obtained primarily from the following sources: Casarett and Doull's Toxicology

is also a possibility. The potential for livestock to receive a sufficient dose to pose a health threat to humans eating meat under present levels is low and will remain low during remediation provided livestock is excluded from contaminated areas on site. After remediation, the long-range risks will remain low unless heavily contaminated groundwater reaches the surface as seeps which, in turn, are then used to water the livestock. In a study of cattle and sheep which drank water contaminated from a uranium mine, elevated levels of Pb-210 and Po-210 (up to 710 pCi/kg) were measured in the liver and kidney tissue of the cattle (Ruttenber, et al 1984).

During the remediation period, the RAP (1986) specifies drainage diversion ditches and surface runoff control structures for trapping sediment on all the major facilities being reclaimed during this period. In addition, dewatering wells will be installed in groundwater zones previously contaminated by seepage on Club Mesa and in the San Miguel River Valley. This contaminated water will be evaporated or treated. Also during the remediation period, quality control, and performance evaluation will direct construction and cleanup activities, and will be used to insure effectiveness of the design and engineering.

In this qualitative estimate of the health risk involved in this remediation programs, it is assumed that design and engineering specifications, required to be developed by the RAP (1986) are adequate to control the hazardous materials onsite. It is further assumed that the containment facilities are constructed and perform as designed.

## 5.0 POPULATION AT RISK

### 5.1 HUMAN COMMUNITY AT URAPAN

Since the closing of the Uravan Mill, the population of Uravan has decreased from 497 in 1984 to approximately 50 at the present time. The current population consists of 40 family members and 10 single construction workers (JTRC 1986). It is assumed that this population will increase periodically to approximately 100 persons during the remediation process. Thereafter, the population would then decrease to a maintenance crew of around five persons and eventually the site will be serviced from Grand Junction. There is also the possibility that the

into surface and groundwater and will constitute a low but definite hazard to humans. In time, the movement of these contaminated materials into pathways and subsequent exposure to human will reach a low equilibrium state which in the long-term risk should be insignificant.

In the long-term, the two containment structures, the tailings piles and the Burbank Quarry, will remain onsite as low risks. This is due to the large amounts of contaminated materials, both radioactive and metals, contained in them. The conditions, in particularly the tailings piles, will permit the slow movement of toxic metals and radionuclides into surrounding media. The tailings piles will remain acidic so that metals will be in a soluble state, and an unlined foundation will allow a low rate of seepage into groundwater. There is also the low probability that erosion processes may cause a breach in the slopes, causing a release of solid tailings into Hieroglyphic Canyon or the San Miguel River.

In summary, the overall potential risks to human health is moderate if present conditions at the Uravan site were to be maintained. If unremediated, the probability under present conditions of an eventual failure with an ensuing significant release to the environment is high and the risk to human health moderate due to a small population actually at risk in the area. During the short 15 to 20 year period of remedial activities, risks are slightly higher due to transport and placement of contaminated materials, and to open exposed surfaces. In the short-term following remediation, low levels of risk may exist from residual contaminated surfaces and groundwater. In the long-term, the two containment structures, the tailings piles and the Burbank Quarry, will remain a low risk potential due to the chemical and physical characteristics of the wastes, and to their somewhat exposed topographic position on Club Mesa.

**Reference 3**

**Excerpts From Final Report, Winter Baseline Investigation of Surface Media  
in the Vicinity of the Uravan Uranium Mill, Uravan, Colorado, Volumes I and II;  
ERI Logan, Inc.; August 11, 1986**

FINAL REPORT

WINTER BASELINE INVESTIGATION OF  
SURFACE MEDIA IN THE VICINITY OF  
THE URAVAN URANIUM MILL  
URAVAN, COLORADO

Volume I

Results of January 1986  
Field Investigation

Prepared for

The State of Colorado  
Department of Law  
Office of the Attorney General

Prepared by

ERI Logan, Inc.  
975 South State Highway  
Logan, UT 84321

August 11, 1986

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ERI

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Results of analyses for mesa top soils indicated significant inverse relationships between distance from the Uravan mill site and soil contaminant concentrations for arsenic, barium, cadmium, lead, nickel, vanadium, zinc, and gross beta in the ENE sector, for barium, cadmium, lead, vanadium, and zinc in the NNW sector, for arsenic, cadmium, nickel, vanadium, and zinc in the WNW sector, and various combinations of one to four metals in the other five sectors. Significant inverse relationships between distance and vanadium concentration exist for all sectors. Regression analyses also indicated significant inverse relationships between distance along the river valley from the mill and soil concentrations for Cd, Pb, V, and gross alpha in river bench soils. The most widespread contaminant is vanadium. Further analyses indicate that the Uravan mill has had a greater effect on soil concentrations of these contaminants than geologic parent material or mine workings in the area.

Widespread soil contamination on the mesa tops is inferred to be the result of contaminant transport by winds reflecting regional wind patterns. The effect of local valley wind patterns and strong inversions is reflected in soil contamination of bench and riparian soils.

Soil contamination above levels known to be toxic to plants extends to a distance of 7000 feet from the Uravan mill site. Concentrations of contaminants in soil at levels above background were detected to a distance of 28,000 feet from the site (points of farthest data collection). It is inferred that in areas where soil contamination levels exceed levels toxic to vegetation that plants will exhibit toxic symptoms and reduced productivity. It is also inferred that the vegetation will contain elevated levels of metals and radionuclides due to increased exposure in contaminated areas. Data from past studies (Section 4.2.2 in Volume II of this report)

cadmium, lead and nickel in sediments showed large increases adjacent to the Club Ranch Ponds.

Diverse and apparently healthy communities of algae and macroinvertebrates were found in the San Miguel River upstream and downstream of Uravan. Concentrations of metals in these organisms were higher downstream of Uravan in the San Miguel River than upstream. These include cadmium, copper, nickel, zinc, aluminum, silver, lead, vanadium, and strontium. These increases indicate that sources of contaminants to the San Miguel River occur at Uravan and that bioaccumulation of these is taking place in the aquatic organisms. Increases in most of these same contaminants were noted in the Dolores River organisms downstream from the confluence with the San Miguel River. Macroinvertebrate densities observed in this study indicate dramatically improved environmental conditions over those in the 1960's and early 1970's when macroinvertebrates densities were extremely low.

Fish populations were not assessed for this study. Water samples collected in the San Miguel River in and below Uravan contained levels of aluminum, cadmium, copper, lead, silver, and zinc that exceeded the existing State of Colorado standards for fish. Aluminum was found to exceed standards for the entire region of river from just below Naturita to the confluence with the Dolores River.

Analyses of seep water, precipitates and dry wash alluvium indicate that these are the likely sources of contamination to the San Miguel and Dolores River ecosystems. Contaminants found in these were elevated and were the same as those found in the ecosystem and in sources such as tailings, raffinate storage areas and on-site soils. Direct releases of contaminated water from the Club Ranch and River Ponds into the San Miguel River were also observed and sampled by ERI during the study.

FINAL REPORT

WINTER BASELINE INVESTIGATION OF  
SURFACE MEDIA IN THE VICINITY OF  
THE URAVAN URANIUM MILL  
URAVAN, COLORADO

Volume II

Summary of Historical Information

Prepared for

The State of Colorado  
Department of Law  
Office of the Attorney General

Prepared by

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August 11, 1986

ERI

## 2.0 SOURCE CHARACTERISTICS

### 2.1 General Process Information

Mineral recovery operations started at the Uravan site in 1916. The Standard Chemical Company processed ores there for recovery of radium. This operation was closed in 1922.

In 1928, a subsidiary of Union Carbide Corporation, U.S. Vanadium Company, purchased the mill and began processing ore for vanadium. Uranium and radium were discarded in the tailings material. In 1935, U.S. Vanadium built a new mill and established the town of Uravan to provide housing for workers.

In the early 1940's, the U.S. Army Corps of Engineers began processing the discarded tailings for recovery of uranium for the Manhattan Project. This processing continued until 1945 when the market for uranium declined and the mill was closed. The mill reopened in 1948 to produce uranium under a Radioactive Materials License issued by the Atomic Energy Commission.

In 1956, Union Carbide added a solvent extraction process for vanadium to the uranium process. The mill continued to process ores for uranium and vanadium until it shut down in November 1984 (Dames and Moore 1978, PERLS 1984).

The ore processed at the Uravan mill contained .15 to 0.25%  $U_3O_8$  and .5 to 2%  $V_2O_5$  (Fischer and Hilpert 1952). Other components of the ore included clays, sandstone, limestone, shale, and small amounts of pyrite, molybdenite, and copper minerals (Momeni 1981). Reagents used in the various mill processes included sulfuric acid, anhydrous ammonia, sodium chlorate, hydrogen peroxide, tertiary amine, sulfites, barium chloride, soda ash, Malco, Polyox, and kerosene (Dames and Moore 1978). Radionuclides present in the ore include radon gas, radium, thorium, polonium, lead and others in the uranium-238 decay series (Figure 2.1-1).

Table 1.5-1. Raffinate crystal composition (James and Moore 1982).

Parameter	Content % Dry Basis	Parameter	Content % Dry Basis
U <sub>2</sub> O <sub>3</sub>	0.0002	Cl	0.06 - 0.10
V <sub>2</sub> O <sub>5</sub>	0.003	SO <sub>4</sub>	28 - 40
NH <sub>3</sub>	3 - 12	C	0.09 - 2.
H <sub>2</sub> O	11 - 36	Hg	<0.0001
Li	1.6 - 5.5	Cu	0.001 - 0.015
Fe	0.02 - 0.45	Pb	Nd
Na	0.01 - 0.13	Mo	0.0004
Ca	0.005 - 0.22	Mn	0.036
Ag	<0.0001	Zn	0.108
Si	0.005 - 0.06	Ti	.008
K	<0.5	Sr	<0.005
Ce	0.002 - 0.007	Ni	0.12
Organic	0.02	Co	0.02
Ra-226	17.04 pCi/g	Cd	Nd(a)

(a) Nd = Not detectable.

about 27 feet deep. The crystals are underlain by about 5 feet of gravel over sandstone bedrock.

### 2.8 River Ponds

The River Ponds include seven impoundments located along the San Miguel River below the mill site (Figure 2.2-1). Five of the ponds are on the mill side of the San Miguel River and 2 ponds on the opposite bank. The ponds were constructed on old tailings piles by excavating into, and in some cases through, the tailings materials (Chen and Associates, 1983). The excavations were mantled with soil. The ponds on the mill side of the river have been used as settling basins for waters collected within the mill area prior to discharge into the San Miguel River. The two ponds on the opposite side of the river have been used to store neutralized sludge prior to disposal on Club Mesa. It has been estimated that about 200,000 cubic yards of contaminated material is contained in the River Ponds (Chen and Associates, 1983).

The River ponds are situated immediately adjacent to the San Miguel River below the level of the potential maximum flood (Chen and Associates 1983). Storm events and runoff will cause windborne and precipitated compounds to enter the San Miguel River system. This periodic loading may amount to a substantial input.

### 2.9 Liquid Mill Effluents

Liquid discharge from the mill has occurred at several points including 3 permitted discharge points, the sewage plant outfall, seepage from the Club Ranch Ponds and tailings ponds and a number of process solution spills (PELRS 1984).

**Reference 4**

**Excerpts From Remedial Action Plan,  
State of Colorado vs. Union Carbide Corporation and  
Umetco Minerals Corporation (83C2384); Author Not Provided; 1986**

APPENDIX I

REMEDIAL ACTION PLAN

State of Colorado vs.  
Union Carbide Corporation and  
Umetco Minerals Corporation  
83-C-2384



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Table 1.1-1 cont.

PARAMETER, mg/kg	Tailing Pond 2					Tailing Pond 3		
	NEUTRALIZATION							
	POND SLUDGE	SLIMES	BEACH	SLIMES	BEACH	SPRAY AREA 2	SPRAY AREA 4	SPRAY AREA 8
	ST101	ST102A	ST102B	ST103C	AVE. ST13A,B	CRYSTALS	CRYSTALS	CRYSTALS
SO <sub>4</sub>						180000	410000	330000
Cl <sup>-</sup>						--	27	84
NH <sub>3</sub>						8000	9300	6200
NO <sub>3</sub>						0.6	6	0.6
HCO <sub>3</sub> + CO <sub>3</sub>						ND	ND	ND
Gross alpha, pci/g	1080	3200	1320	4600	830	520	120	1040
Gross beta, pci/g	360	3000	1050	4400	620	290	100	560
Th-230, pci/g	890							
U-nat, pci/g	22	21	45	73	64	1.6	1.9	4.7

Data from ERI 1986 Baseline Study



## 2.4 HYDROGEOLOGY

The regional ground water hydrogeology of the Uruan area has been described in studies done for Union Carbide by Dames and Moore (1978), International Engineering Company (1981) and Envirollogic Systems, Inc. (1983b). These reports may be referred to for additional discussion. This summary includes a description of water-bearing zones, aquitards or confining layers, and their characteristics and interrelationships and draws upon the geologic descriptions given in Section 2.3.

Aquifers in the Uruan area are generally limited to the hydrostratigraphic units which have sufficient permeability to transmit ground water. These sandstone units generally have variable permeabilities due to grain size, fracturing, sorting and secondary cementing. Ground water in the region is transmitted via secondary (joint) permeability and primary (intergranular) permeability. Secondary permeability in the region tends to be directional and highly variable. Mesozoic Formations capable of transmitting water in economic amounts include the Dakota and Burro Canyon Formations, the Salt Wash member of the Morrison Formation, and the Entrada, Kayenta, and Wingate Sandstones (Figure 2.3-1). Mesozoic strata which are not capable of transmitting water in economic amounts and which are therefore considered aquitards include the Brushy Basin member of the Morrison Formation, the Summerville, Chinle, and Moenkopi formations (Figure 2.3-1).

### 3.3 CONCEPTUAL AQUIFER MODELS AND AQUIFER CONTAMINATION

#### 3.3.1 Conceptual Aquifer Models

The following discussion describes a conceptualization of the hydrogeologic model for Uruvan based upon data generated in the January 1986 BBRI field investigation. While the following discussion focuses on the hydrologic characteristics of the Kayenta and Wingate stratigraphic units, it is important to recognize that the Kayenta and the Wingate are in direct hydraulic connection and they form a single aquifer unit. Key features of the hydrogeologic model are: 1) a low-permeability Kayenta-Wingate sequence beneath Club Mesa, and 2) a Kayenta-Wingate sequence in the River Valley which has a high-permeability in its upper portion (fractured Kayenta) and generally has low-permeability at depth (less-fractured Wingate). The sandstones beneath Club Mesa and at depth beneath the river valley are not extensively fractured and water is transmitted through the sandstones by primary porosity and permeability. These sandstones contain groundwater in storage but generally release only small amounts of groundwater to properly constructed wells. In contrast, the highly fractured Kayenta Formation in the River Valley yields relatively large amounts of ground water. Aquifer tests of wells V-768, V-769 and CRP-15 support this general model. Observation wells CRP-15, -16, -17 and -18 were drilled to test the aquifer properties of the Kayenta and the Wingate and to collect water samples from the aquifer in these locations. The data from

program may be feasible.

Contaminants in the river valley occur in the fracture voids in the Kayenta-Wingate sequence and to some extent in the sandstone rock matrix. Studies by Chandra (1981) for Union Carbide, revealed that within the zone of contamination from the Club Ranch Ponds, calcium carbonate-sulfate crystals have formed along the fractures. The significance of these crystal growths on the fractures is that the bleed rate of contaminants into the fractures from the matrix may be relatively slow. However, no extensive study has been made to confirm the extent or significance of crystal growth in the fractures. Monitoring of the groundwater remedial action will provide the best information on this issue.

In this type of regime, a groundwater restoration plan can concentrate on removing contaminants from the fractures of the sandstones and rely on a slow bleed rate from the matrix to remove additional contaminants. The sandstone matrix itself produces very little water relative to the production from the fractures. Thus, constructing pumping wells in the area of contamination in the vicinity of the Club Ranch Ponds, will remove most if not all of the contamination that can flow freely to the well within a relatively short period of time.

Spray Area. Infiltration travels into the underlying sedimentary rocks and exits along the mesa rim in seeps and vertically down toward the underlying aquifers. In the area of the Club Ranch Ponds, raffinate infiltrated the surficial materials and the Kayenta Formation directly from the bottoms of the ponds. In time this contamination ultimately discharges to the San Miguel River.

Chemical analyses from perched liquid on Club Mesa indicate that some of the raffinate seepage has been neutralized by reactions with the sedimentary rocks (Envirologic Systems, Inc., 1983a). These analyses also show that the perched liquid contains elevated levels of sulfate, chloride, potassium, sodium, magnesium, ammonia, nitrate, zinc, vanadium, selenium, uranium, arsenic, and mercury. Water quality information from the past monitoring program has shown that the total dissolved solids concentrations of fluids in the Salt Wash on Club Mesa range from 1,388 to 48,914 milligrams per liter (mg/l), sulfate concentrations ranged from 308 to 17,305 mg/l, ammonia concentrations ranged from less than 0.5 to 890 mg/l, and the pH ranged from 3.4 to 8.2. Elevated levels of sulfates, magnesium, chlorides, metals, radionuclides, and other inorganic constituents are present. Wells in the Salt Wash on Club Mesa from which UCC/Unetco has collected these data include wells V-763S, V-764S, V-765 and H-7.

Water quality sampling completed on V-768 and V-769 show

groundwater quality are available. The data indicate that leakage from the Club Ranch Ponds has migrated into the Kayenta Formation and is moving generally in a down-valley direction. Water levels in observation wells also indicate that the direction of ground water flow is generally down-valley and towards the river. Total dissolved solids (TDS) concentrations in the observation wells range from less than 15,000 milligrams per liter (mg/l) to as much as 170,000 mg/l in wells downgradient from the Club Ranch Ponds. Radionuclides, dissolved metals, and inorganic contaminants are also present at elevated levels in the aquifer as shown by monitoring well analyses downgradient of the Club Ranch Ponds (see Table 3.3-1). Background (uncontaminated) groundwater in the Kayenta Formation has TDS concentrations in a range from 200 to 500 mg/l as shown in wells CRP-1, CRP-4, G-block, and F-block.

TABLE 3.3-1 GROUNDWATER QUALITY AT URAVAN COMPARING GROUNDWATER  
SAMPLE RESULTS FOR CRP-4 (BACKGROUND WELL) AND CRP-2  
(CONTAMINATED WELL)

PARAMETER	UNITS	CRP-2	CRP-4	LLD'S
Date		11/15/84	10/18/84	
Sample Type		Pumped	Pumped	
Top Casing Elev.	ft.	4941.980	4995.650	0.001
B. Casing Elev.	ft.	4891.980	4935.650	0.001
Phreatic Elev.	ft.	4927.880	4959.950	0.001
Temp.	C.	14	14	-2.000
Cond. @25 C	umhos	17,136	365	10.000
pH	Units	6.64	7.58	0.100
TDS	mg/l	27,090	272	10.000
Sol. Sulfates	mg/l	18,560	28	10.000
Sol. Chlorides	mg/l	1,420	4	10.000
Sol. Sodium	mg/l	783	19.6	0.100
Sol. Calcium	mg/l	494	45.4	10.000
Sol. Potassium	mg/l	378	10.1	0.100
Sol. Nitrite/N	mg/l	0.02	<0.02	0.100
Sol. Nitrate/N	mg/l	2	<0.04	0.100
Sol. Ammonia	mg/l	1,610	0.2	1.000
Sol. Zinc	mg/l	0.208	<0.02	0.020
Sol. Selenium	mg/l	<0.250	<0.01	0.010
Sol. Magnesium	mg/l	1,202	22.1	0.100
Sol. Manganese	mg/l	6.63	0.028	0.050
Sol. Iron	mg/l	26.8	0.059	0.025
Sol. Carbonate	mg/l	<1	<1	1.000
Sol. Bicarbonate	mg/l	1,960	258	1.000
Sol. U-Nat.	pC/l	470	<3	0.200
Sol. Th-230	pC/l	0.20±0.50	0.00±0.40	3.100
Sol. Ra-226	pC/l	2.40±0.50	1.10±0.40	0.310
Sol. Pb-210	pC/l	0.40±0.90	13.00±2.00	4.800
Sol. Po-210	pC/l	0.10±0.60	-0.50±0.90	1.000
Zinc*	mg/l	0.63	<0.01	0.01
Copper*	mg/l	0.07	<0.01	0.01
Arsenic*	mg/l	<0.01	<0.01	0.01
Mercury*	mg/l	<0.0003	<0.0003	0.0003
Cadmium*	mg/l	<0.01	<0.01	0.01
Chromium*	mg/l	<0.01	<0.01	0.01
Lead*	mg/l	<0.01	<0.01	0.01
Silver*	mg/l	<0.01	<0.01	0.01

\*CRP-2 sample 10/6/83, CRP-4 sample 10/5/83)

LLD = Lower Limits of Detection  
pC/l = picoCuries per liter



**Mining Waste NPL Site Summary Report**  
**Whitewood Creek Site**  
**Lawrence, Meade, and Butte Counties, South Dakota**

**U.S. Environmental Protection Agency**  
**Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

**Prepared by:**

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## **DISCLAIMER AND ACKNOWLEDGEMENTS**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-W0-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Michael McCeney of EPA Region VIII [(303) 293-7169], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

## WHITEWOOD CREEK SITE

### LAWRENCE, MEADE, AND BUTTE COUNTIES, SOUTH DAKOTA

#### INTRODUCTION

This Site Summary Report for Whitewood Creek is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and on a review of the summary by the EPA Region VIII Remedial Project Manager for the site, Michael McCeney.

#### SITE OVERVIEW

The Whitewood Creek Superfund Site is a mine tailings contaminated site located in Lawrence, Meade, and Butte Counties, South Dakota, on an 18-mile stretch of Whitewood Creek that begins at the Crook City bridge south of the Town of Whitewood and ends at the confluence of Whitewood Creek and the Belle Fourche River. From the 1870's to 1977, tailings and untreated wastewater from gold mining and milling operations were discharged into Whitewood Creek and were subsequently deposited along the creek's floodplain. Twenty-five to 37 million tons of tailings were deposited over an area 50 to 300 feet wide on each side of the creek, and to thicknesses ranging from less than 1 to 15 feet (Reference 1, page 1, Reference 2, pages 1-8 and 1-23). (See Figure 1.)

Arsenic and cadmium are the contaminants of greatest concern at the site (Reference 1, page 19). Copper and manganese have also been reported at concentrations exceeding background levels, but which are too low to be of concern to human health (Reference 1, page 12). Elevated levels of arsenic, cadmium, and other metals have been found in the tailings deposits, the alluvial materials underlying the tailings deposits, and the surface soils on some of the irrigated lands within the floodplain adjoining the tailings deposits. Contaminants have been detected in the alluvial ground water under the tailings deposits, surface water, surface soils, and vegetation (Reference 2, pages 1-22 and 1-23; Reference 1, page 14).

The total land area of the site is approximately 2,018 acres. The site is mainly woodlands; but the land that is not wooded is used for agricultural purposes and residences. The residences are scattered along both sides of Whitewood Creek. Based on 1988 data, 22 households and 5 vacant residential

properties are located within, or in close proximity to, the site, with a population totaling 85 (63 adults and 22 children). Eighty households, with a population of 283, are within 1 mile of the site located on either side of the creek, and 168 households, with a population of 647, exist within 3 miles of the site. The town of Whitewood, located 1 mile west of the site, has a population of 821 (Reference 2, page 1-16; Reference 1, page 1).

## OPERATING HISTORY

Homestake Mining Co. (Homestake) first began gold mining near Lead, South Dakota, in the late 1870's. Approximately 1 billion tons of ore were produced during the operating history of the site. Mining operations extend to a depth more than 8,000 feet below the land surface. The first milling operations used crude methods to crush ore and recovered gold by gravity or by amalgamation with mercury. By 1880, more than 1,000 stamp mills were employed to crush the ore to a coarse sand size. In the 1920's, ball and rod mills were brought into use at the mine. The ball and rod mills created finer-grained tailings, or "slimes."

Mercury amalgamation was used primarily until 1971, when cyanide began to be used exclusively. It is estimated that between 1/8 and 1/2 ounce of mercury per ton of ore crushed was lost, with 50 percent of this being discharged in the wastestream (Reference 3, pages 1-1 and 1-4)

Tailings and untreated wastewater were continuously discharged into the creek during the 100-year operating history of the site, excluding a 5-year period during World War II when the mine was closed. In 1963, up to 3,000 tons of tailings and 12,500 tons of water were being discharged per day into Whitewood Creek. Tailings were discharged directly into Whitewood Creek or its tributaries from a number of mine operators until approximately 1920, after which Homestake was the only source of tailings discharge (Reference 3, pages 1-1 and 1-4).

After 1935, sand-sized tailings were typically used to backfill mined areas, and the "slimes," as well as some course-grained sands, were discharged into Whitewood Creek. This practice continued until 1977 (Reference 1, page 3). In 1977, Homestake constructed a tailings impoundment in the upper reaches of the Whitewood Creek watershed at Grizzly Gulch, to treat residual slimes and process waters. In December 1984, a wastewater treatment system was put into operation to treat waters from the tailings impoundment and the mine. The plant utilizes rotating biological contractors to remove cyanide and ammonia; iron precipitation and sorption to remove metals, and sand filtration to remove suspended solids. The solids are returned to the tailings pond and the water is discharged into Gold Run Creek, which runs into Whitewood Creek between the towns of Lead and Deadwood. This discharge is monitored to meet requirements of the Clean Water Act (Reference 1, page 3).

adjoining tailings deposits; surface soils in residential yards, gardens, and driveways; alluvial ground water under the tailings deposits; surface water, and vegetation (Reference 1, page 14)

### Ground Water

Three primary aquifers exist in the vicinity of the site: a shallow alluvial aquifer and two deep bedrock aquifers. The bedrock aquifers are separated from the shallow aquifer by up to 1,000 feet of relatively low permeability shale. Hydraulic connection between the alluvial and bedrock aquifers is believed to be limited. Water supply wells in the bedrock aquifers tested during the Remedial Investigation did not contain contaminants from the tailings deposits (Reference 1, page 12)

Within the shallow aquifer, the water table generally exists in the natural alluvium except during wet periods of the year when it may rise into the tailings. For most of the year, ground water flows from the alluvial aquifer into the creek. During high creek flow, lasting from 2 to 8 weeks each spring, flow is reversed and water flows from the creek as far as 200 meters into the alluvium (Reference 1, page 12).

Ground water in the tailings deposits, and in the alluvial deposits beneath the tailings, is of greatest concern at the site. The alluvial aquifer and shallow shale bedrock within the floodplain but outside the immediate influence of the tailings, and the alluvial terrace deposits that are upland from the tailings and the floodplain, appear to be uncontaminated (Reference 1, page 12).

Studies completed by Homestake, the results of which were published in "Mineral and Energy Resources" in 1986, showed that arsenic in the tailings is very immobile and is being released and transported very slowly and in very small amounts into the downgradient alluvial aquifers, the only ground water to exhibit elevated levels of contaminants (Reference 2, page 1-68). Levels exceeding the primary drinking water standards and the South Dakota Drinking Water Standards (DWS) have, however, been recorded [with a maximum arsenic concentration of 0.78 milligrams per liter (mg/l), which is above background levels] (Reference 1, page 16). Movement of arsenic from the tailings to the ground water results from dissolution of arsenic during those times of the year when the water table rises into the tailings; dissolution of arsenic from precipitation passing through the tailings, and incorporation of tailings particles into the alluvium, which probably occurs as the tailings are deposited. The current slow movement of contaminants could continue for thousands of years (Reference 1, page 16)

material; importation of tailings material for use as driveway base, and/or overbank sedimentary deposition of tailings material during past flood events.

#### Air

Preliminary calculations in the Remedial Investigation/Feasibility Study completed for the Whitewood Creek site indicated that the concentrations of contaminants and the potential for exposure through the air pathway was too low to be of concern (Reference 1, page 19).

### **ENVIRONMENTAL DAMAGES AND RISKS**

Systematic studies of the Whitewood Creek area by the South Dakota Department of Health (begun in 1960) quantified the solids and cyanide loading to the creek and recommended further studies. In 1965, a study by the South Dakota Department of Game, Fish and Parks determined that aquatic bottom organisms were not present in Whitewood Creek downstream from the waste discharges. Several additional studies, which focused on the possible serious environmental hazard created by mercury contamination, led to the discontinuance of mercury in gold recovery operations in December 1970 (Reference 1, page 4).

In the winter of 1974-1975, approximately 50 cattle in a dairy operation adjacent to Whitewood Creek died of unknown causes. A later study concluded that the cattle had died of arsenic toxicosis resulting from the consumption of corn silage accidentally contaminated by mining wastes that had been incorporated into fodder during silo-filling operations. A study published in 1978 found arsenic concentrations ranging from 2.5 to 1,530 micrograms per liter ( $\mu\text{g/l}$ ) in ground water from areas with large tailings deposits (Reference 1, page 4). As a result of these studies, it was concluded that the Whitewood Creek area would remain highly contaminated until the discharge of tailings was discontinued. This resulted in the construction of the Grizzly Gulch Tailings Disposal Project by Homestake, which became fully operational on December 1, 1977, producing a dramatic improvement in the physical appearance and quality of the creek waters (Reference 2, Volume 1, page 1-9, Reference 1, page 4).

The potential life-time excess carcinogenic risks from exposure to arsenic through ingestion of soils and ground water within the site (for both the representative and maximum exposed site resident) were determined to be unacceptable. For the representative and maximum exposed site resident, ground-water risks were determined to be  $1.9 \times 10^{-4}$  and  $4.4 \times 10^{-3}$ , and soil risks were determined to be  $2.4 \times 10^{-4}$  and  $2.6 \times 10^{-3}$ , respectively, all of which are greater than the acceptable Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) level of  $1 \times 10^{-4}$  (Reference 2,

properties) within the contaminated fringe areas (Reference 1, pages 32 and 40) The major components of the selected remedy include:

- Cover and/or remove soils in the existing residential areas containing arsenic levels of 100 mg/kg or greater.
- Restrict future development in the 100-year floodplain and tailings deposits as provided through the county ordinance
- Prohibit excavation of tailings deposits for other uses and prohibit excavation of remediated areas through the county ordinance, however, mining would be allowed subject to the regulations of the State of South Dakota.
- Refine knowledge of the extent of contamination and delineate the 100-year floodplain. Provide detailed maps to define site boundaries and specify activities to support county ordinances.
- Set up an educational program to inform people about hazards presented at the site and ways to decrease their personal exposure.
- Continue enforcement of the ban on installation of water supply wells within the 100-year floodplain (this is already prohibited by a state regulation)
- Continue monitoring the surface waters of Whitewood Creek for significant releases of hazardous substances.
- Resample remediated residential areas after major flood events (Reference 1, pages 28 through 32).

The estimated net present worth cost for the selected remedy is \$882,813, with capital costs totaling \$1,028,000 (\$581,000 of which will be spent during start-up and \$447,000 of which will be incurred over the 30-year period). Annual operation and maintenance costs are estimated at \$12,000 (Reference 1, page 40).

**REFERENCES**

1. Record of Decision for the Whitewood Creek Superfund Site, James J. Scherer, Regional Administrator EPA Region VIII; March 30, 1990.
2. Feasibility Study, Whitewood Creek, South Dakota; EPA Region VIII, December 8, 1989.
3. Whitewood Creek Study, South Dakota Department of Water and Natural Resources; EPA and Homestake Mining Company; November 1984.



**Reference 1**

**Excerpts From the Record of Decision,  
Whitewood Creek Superfund Site;  
James J. Scherer, Regional Administrator  
EPA Region VIII; March 30 1990**

**RECORD OF DECISION  
ATTACHMENT A**

**WHITEWOOD CREEK SUPERFUND SITE  
DECISION SUMMARY**

**MARCH 30, 1990**

**RECORD OF DECISION  
MARCH 30, 1990  
DECLARATION STATEMENT**



**SITE NAME AND LOCATION**

Whitewood Creek Site  
Lawrence, Meade, and Butte Counties, South Dakota

**STATEMENT OF BASIS AND PURPOSE**

This decision document presents the selected remedial action for the Whitewood Creek site in Lawrence, Meade, and Butte Counties, South Dakota. This document was developed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the National Contingency Plan (NCP) (40 CFR Part 300).

This decision document explains the factual and legal basis for selecting the remedy for this site. The information supporting this remedial action decision is contained in the administrative record for this site and is summarized in the attached decision summary. This decision is based on the administrative record for this site.

The State of South Dakota concurs with the selected remedy. The State, however, does not concur on the boundaries of the site.

**ASSESSMENT OF THE SITE**

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision (ROD), may present an imminent and substantial endangerment to public health, welfare, or the environment.

**DESCRIPTION OF SELECTED REMEDY**

The remedial action selected by EPA for the Whitewood Creek Superfund site consists of covering and/or removal of contaminated soils at existing residential properties and establishment of institutional controls to restrict access to tailings deposits. Implementation of these measures will reduce the risk to public health presented by residential soils, tailings deposits and alluvial groundwater contaminated with arsenic.

The major components of the selected remedy include:

- Cover and/or remove soils in the existing residential areas containing arsenic levels of 100 milligrams per kilogram or greater.


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- Restrict future development in the 100-year floodplain and tailings deposits as provided through county ordinance.
- Prohibit excavation of tailings deposits for other uses and prohibit excavation of remediated areas through county ordinance, however, mining would be allowed subject to the regulations of the State of South Dakota.
- Refine knowledge of the extent of contamination and delineate the 100-year floodplain. Provide detailed maps to define site boundaries and specify activities to support county ordinances.
- Set up an educational program to inform people about hazards presented at the site and ways to decrease their personal exposure.
- Continue enforcement of the ban on installation of water supply wells with the 100-year floodplain (this is already prohibited by a state regulation).
- Continue monitoring the surface waters of Whitewood Creek for significant releases of hazardous substances.
- Resample remediated residential areas after major flood events.

#### DECLARATION OF STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with most Federal and State requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost effective. A waiver is invoked for complying with maximum contaminant levels for arsenic under the Safe Drinking Water Act and the water quality criteria for protection of human health by consumption of fish because of the technical impracticability of meeting these requirements. This remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable for this site. However, because treatment of the principal threats posed by the site was not found to be practicable, this remedy does not satisfy the statutory preference for treatment as a principal element. Treatment is impracticable because of the large volume of contaminated soils and tailings deposits, the lack of appropriate treatment technologies, and the potential for adverse environmental impact.

Because this remedy will result in hazardous substances remaining on site above health-based levels, reviews of the remedial action will be conducted no less often than each five years after initiation of the remedial action, to ensure that human health and the environment are being protected by the remedial action being implemented.

  
James J. Scherer  
Regional Administrator  
EPA Region VIII

March 30, 1990  
Date

**RECORD OF DECISION  
ATTACHMENT A**

**WHITEWOOD CREEK SUPERFUND SITE  
DECISION SUMMARY**

**I. SITE NAME AND LOCATION**

The Whitewood Creek Superfund site, a National Priorities List site, is located in Lawrence, Meade and Butte Counties, South Dakota (Figure A-1). The site is situated in west central South Dakota on the northern perimeter of the Black Hills, 40 miles northwest of Rapid City on Interstate 90. The site lies within portions of Township 6, 7 and 8 North, Range 4, 5 and 6 East and is mapped on the Rapid City (1:250,000) quadrangle at a latitude of 44°-45°N and longitude 102°-104°W.

The Whitewood Creek site, a mine tailings contaminated site, encompasses approximately 2,018 acres along 18 miles of Whitewood Creek floodplain from the Crook City Bridge to the confluence with the Belle Fourche River. From the 1870s to 1977, tailings were discharged into Whitewood Creek from upstream gold mining and milling operations. These tailings were deposited along the floodplains of Whitewood Creek and the Belle Fourche and Cheyenne Rivers.

The primary concerns for potential harm to human health and the environment presented by the site are exposure to arsenic-rich tailings deposits, and alluvial soil, residential soil, and alluvial groundwater contaminated with arsenic.

The dominant land use within the site is woodlands. The remaining land within the site is used for agriculture and residences. The agricultural lands are located in somewhat discontinuous sections along the edge of the floodplain in areas adjoining and occasionally overlapping the tailings deposit areas.

The residences are scattered along both sides of Whitewood Creek. Based on 1988 data, 22 households and five vacant residential properties are situated within or in close proximity to the site with a population totaling 85 (63 adults and 22 children). Eighty households, with a population of 283, are within a mile of the site on either side of the creek and 168 households, with a population of 647, exist within three miles of the site. The Town of Whitewood, located about one mile west of the site, has a population of 821.

## II. SITE HISTORY AND ENFORCEMENT ACTIVITIES

### History of Operations

1877 to 1977. The Homestake Mining Company, located in Lead, South Dakota, began gold mining operations in the Whitewood Creek watershed in the late 1870s, following development of gold deposits discovered prior to 1850. Mining operations over the last century have produced about one billion tons of ore from both open pit and subsurface shafts which currently extend to a depth exceeding 8,000 feet below the surface. The processing of the ores has changed over the years, resulting in changes in the characteristics of the waste stream. Methods have become progressively more efficient, so that earlier tailings were coarser and contained more metal than those resulting from present operations.

The first milling methods were primitive and non-mechanized. Gold was recovered by gravity or by amalgamation with mercury. By 1880, the early crude methods of milling were replaced with more than 1,000 stamp mills which crushed the ore to a coarse sand size. The tailings were then discharged to Whitewood Creek or its tributaries. Prior to the turn of the century, much of the ore consisted of red-colored minerals which were the near surface residual oxidation products of the original unoxidized ore bodies.

After the turn of the century, the black and green-colored reduced ores from deeper in the mine, below the zone of oxidation, were the focus of mining activity. The use of ball and rod mills, brought into service in the 1920s, created finer-grained tailings referred to as "slimes." After 1935, much of the sand-sized portion of the tailings was returned to the mine to backfill mined areas. The "slimes" as well as some coarse-grained sands continued to be discharged directly into Whitewood Creek until 1977, with the exception of five years during World War II when the mine was closed. Mercury amalgamation was discontinued in 1970.

Tailings, consisting of finely ground rock, residual metallic and nonmetallic compounds not extracted from the ore, and trace compounds used in the extractive processes, were transported away from the mine by the water of Whitewood Creek. These tailings were deposited downstream from the mine with the largest deposits along the banks of Whitewood Creek between the Crook City Bridge and the confluence with the Belle Fourche River. The tailings remain along much of this reach of Whitewood Creek and continue to leach metals to surface and subsurface waters.

1977 to Present. Presently ore is milled in crushers and rod and ball mills. The material from the milling process is separated into two size fractions, sand and slimes. These fractions are treated separately by cyanide leach and carbon filter methods. Residual sand material is used to backfill within the mine. Residual slimes and process waters are piped to the Grizzly Gulch tailings impoundment in the upper reaches of the Whitewood Creek watershed.

A wastewater treatment plant now treats water from the tailings impoundment and the mine. [This plant utilizes rotating biological contactors to remove cyanide and ammonia; iron precipitation and sorption to remove metals; and sand filtration to remove suspended solids. Solids are returned to the tailings pond.] Water enters Gold Run Creek which discharges into Whitewood Creek between the towns of Lead and Deadwood. This discharge is monitored to meet requirements of the Clean Water Act.

## History of Site Investigations

The first systematic studies of the Whitewood Creek area were undertaken by the South Dakota Department of Health in 1960. This work quantified the solids and cyanide loading to Whitewood Creek, recommended further study, and reported that a comprehensive water pollution control program was needed, if any beneficial use was to be made of Whitewood Creek. A study by the South Dakota Department of Game, Fish and Parks in 1965 determined that aquatic bottom organisms were not present in Whitewood Creek downstream from the waste discharges. In 1970-71, a series of studies by the U.S. Environmental Protection Agency (EPA) and the U.S. Food and Drug Administration (FDA) were undertaken to document and characterize the discharge of tailings to Whitewood Creek and to determine the magnitude and extent of the resultant pollution. These studies, together with one prepared by the University of South Dakota, focused on the possible serious environmental hazard created by mercury contamination. In December 1970, results of these studies led to the discontinuance of mercury in gold recovery operations.

In the winter of 1974-75, about 50 Holstein cattle that were part of a dairy operation located adjacent to Whitewood Creek, died of unknown causes. Later, a study by the South Dakota State University Department of Veterinary Science concluded that the cattle had died of arsenic toxicosis due to consumption of corn silage that had been contaminated by the accidental incorporation of mining wastes with fodder during silo-filling operations. A joint study, conducted by the South Dakota Geological Survey and Water Resources Division between May 1975 and July 1978, investigated the presence of arsenic in surface and groundwaters along Whitewood Creek and the Belle Fourche River and portions of the Cheyenne River. This study, published in 1978, found arsenic concentrations ranging from 2.5 to 1,530 ug/L in groundwater from areas with large tailings deposits.

One common conclusion of all these pollution investigations was that Whitewood Creek would remain highly contaminated until the discharge of tailings was discontinued. To comply with new environmental laws, including the Ore Mining and Dressing Effluent Guidelines, Homestake Mining Company implemented the Grizzly Gulch Tailings Disposal project, an impoundment area for tailings storage. The tailings disposal system became operational on December 1, 1977, and no discharge of tailings to Whitewood Creek has occurred since then.

In 1981, at the request of the governor of South Dakota, the Whitewood Creek site was placed on the "Interim National Priorities List." Subsequently, on September 8, 1983, the site was placed on the National Priorities List (NPL).

Following the initial placement of the site on the Interim National Priorities List, EPA, the South Dakota Department of Water and Natural Resources (DWRN), and Homestake Mining Company (Homestake) entered into a three-party study agreement in 1982 to conduct a comprehensive study of the site. The study, funded by Homestake and conducted by Fox Consultants, Inc. of Denver, Colorado, was supervised by a project advisory committee composed of representatives of each of the three parties. The Fox study investigated the quality of surface waters, groundwaters, soils, sediments aquatic life and vegetation in the study area, on an 18 mile segment of the floodplain of Whitewood Creek above its confluence with the Belle Fourche River. The study used 14 target substances as indicators of potential public health and environmental threat. The conclusions, published in a multi-volume report in December 1984, indicated that arsenic was the contaminant of most significant environmental concern throughout the media under evaluation.

The report also indicated that, although mercury and cyanide had originally been contaminants of concern in tailings discharged from Homestake Mine, concentrations of these contaminants at the Whitewood Creek Superfund site were near background levels and therefore not of environmental concern at this time.

Simultaneously with the Fox study, two related studies were conducted. Homestake assembled a group of consultants led by J.A. Cherry to assist the project advisory committee. These consultants studied the hydrogeochemistry of the site and prepared a report completed in 1985. This report, titled "Hydrogeochemistry of sulfide and arsenic-rich tailings and alluvium along Whitewood Creek, South Dakota" was published in 1986 in Mineral and Energy Resources. The second study, an extensive investigation of the surface water in Whitewood Creek, was initiated in 1982 by hydrologists from the U.S. Geological Survey. The U.S. Geological Survey published a draft report in 1985. Subsequent published reports and unpublished data are currently available from the U.S. Geological Survey.

Homestake and the State of South Dakota submitted a request to EPA in 1983 to initiate proceedings to delete Whitewood Creek from the NPL, and resubmitted the request in 1985. This request was supported by a human health exposure assessment performed by Homestake's contractor, Environ Corporation, which concluded that the site posed no risk to human health. EPA, believing that it was premature to discuss deletion until the studies were completed, did not pursue delisting further.

Homestake also funded several additional studies which included: 1) an evaluation by Industrial Waste Management Inc. of the water quality sampling results collected by the U.S. Geological Survey in Whitewood Creek before and after the installation of the wastewater treatment system upstream from the CERCLA site; 2) an analysis of the age of trees growing on the tailings deposits along Whitewood Creek (for the purpose of dating these deposits) conducted by Pope and Talbot, Land Forester; 3) an assessment of the sources, occurrences and mobility of selenium in the Whitewood Creek Basin and a re-analysis of the selenium concentrations in existing water supply wells along Whitewood Creek, both performed by Geochemical Engineering Inc. Another study by Geochemical Engineering Inc. in October 1988, incorporated additional groundwater quality data and soil characterization data. For this study, the population residing within the site was interviewed regarding their habits with respect to the intake of drinking water and locally grown food crops. The study included testing of water supply wells.

In December 1988, an Administrative Order on Consent was signed by EPA and the Homestake Mining Co. This order concluded that the Fox study constituted the functional equivalent of a remedial investigation, as prescribed by the National Contingency Plan. The order required that Homestake conduct a feasibility study (FS) in order to identify and evaluate alternatives for the appropriate extent of remedial action to prevent or mitigate the migration, release or threatened release of hazardous substances, pollutants or contaminants from the site.

In 1989, an FS was conducted by ICF Technology Inc. on behalf of Homestake. Soil data collected in May, June and July 1989 by Homestake and analyzed by Geochemical Engineering Inc. was incorporated into this study, along with a report prepared by Morrison Knudsen Engineers, on the feasibility of removing tailings.

Remedial action objectives for the FS were based on EPA's endangerment assessment. EPA contracted with Battelle Pacific Northwest Laboratory to perform an endangerment assessment. The first draft was released in January 1988 and comments were provided by Homestake in April 1988. A second draft was released by EPA in March 1989 and



The shallow groundwater at the site appears in four units which act as a single aquifer. It is useful to describe the four units separately in order to understand the movement of contaminants within the various media.

- Tailings deposits are generally coarse-grained material, with some fine layers (Unit 1 in Figure A-3).
- Alluvial aquifer materials underneath the tailings, which are most directly influenced by water moving through the tailings, are referred to as the downgradient aquifer (Unit 2 in Figure A-3).
- Alluvial aquifer materials and shallow bedrock shale within the floodplain outside the immediate influence of the tailings are referred to as the upgradient aquifer (Unit 3 in Figure A-3).
- Upland alluvial aquifer terrace deposits are upland away from the tailings and floodplain alluvial materials (Unit 4 in Figure A-3).

The water table along Whitewood Creek occurs mainly in the natural alluvium underlying and adjacent to the tailings. During wet periods of the year, the water table may rise into the tailings. Some recharge of the shallow aquifer may occur then, as precipitation infiltrates through the terrace materials and tailings deposits.

In general, the water table slopes toward the floodplain, and during most of the year, there is a net flow of groundwater from the alluvium into the creek. During high creek flow, lasting from two to eight weeks each spring, the flow is reversed and water flows from the creek as far as 200 meters into the alluvium.

Migration of contaminants from the tailings to the alluvium and groundwater occurs at a slow rate because of the chemistry of the contaminants and tailings deposits (see page 14). The upgradient alluvial aquifer and upland alluvial aquifer appear to be uncontaminated by tailings materials. Groundwater in the tailings deposits and the downgradient alluvial aquifer are of greatest concern to human health.

The bedrock aquifers are separated from the shallow aquifer by up to 1,000 feet of relatively low permeability shale. The thickness of the shale and the lack of continuous porous zones in the shale both serve to limit the connection between the alluvial and bedrock aquifers. Water supply wells in the bedrock aquifers tested in the RI did not contain contaminants from tailings deposits materials.

### **Sources and Types of Contaminants**

The initial RI studies completed by Fox in 1984 identified the tailings deposits as the source of contamination in the study area. Fourteen target substances were investigated as indicators of potential public health and environmental threat (Table A-1). Arsenic was considered to be the contaminant of most significant environmental concern throughout the media under evaluation. Cadmium, copper and manganese were detected at concentrations above background levels but too low to be of concern to human health. The remaining substances were either determined to be naturally occurring (sulfate, selenium) or present at concentrations near background levels (chromium, silver, nickel, iron, mercury, lead, zinc and cyanide).

## Affected Media

The RI/FS documented that hazardous substances are present in a variety of media at the site including:

- . Tailings deposits;
- . Alluvial materials underlying tailings deposits;
- . Surface soils in some of the irrigated lands adjoining tailings deposits;
- . Surface soils in residential yards, gardens, and driveways;
- . Alluvial groundwater under the tailings deposits
- . Surface water; and
- . Vegetation.

Potential health impacts and risk assessments are presented in Chapter V. The media posing the greatest potential risk to human health and the environment are listed below. The potential for contaminants migrating between the media as demonstrated by remedial investigations, especially the Cherry study, is also summarized below.

### Surface Soils in the Tailings Deposit and Fringe Areas

Tailings Deposits (Medium 2, Figure A-2). It is estimated that 21.6 million tons of tailings exist within the site. The tailings deposits contain concentrations of arsenic (maximum 42,500 milligrams per kilogram or mg/kg) and cadmium (maximum 180 mg/kg) which are significantly above levels in uncontaminated alluvial soils at the reference site on the Belle Fourche River above the confluence with Whitewood Creek (12 mg/kg and 1.5 mg/kg, respectively).

The tailings have been determined to be the major source of the contamination found in other affected media. The ore body from which the tailings are derived is a metamorphic iron magnesium carbonate. The gold is found in veins along with quartz, calcite, iron and arsenic sulfides and other minor metals.

Oxidation of the iron and arsenic sulfides in the tailings produces a weak sulfuric acid. In most cases, this acid is buffered by calcium in the carbonates in the ore and from the exposed sedimentary rocks. In this buffered environment, the contaminants are relatively immobile. Isolated pockets having an acid environment occur within the tailings and alluvium, where some arsenic may be mobilized.

Most of the substances are transported in their solid form, rather than in solution. At present, the contaminants contained in the tailings deposits are being released very slowly into the alluvial aquifers. Small amounts are being transported into the underlying alluvium. It is anticipated that these contaminants will continue to be released through both chemical and physical processes at these slow rates for many years.

In all but a few locations (estimated at 25% of the area for purposes of estimating costs of potential remedial action), the tailings deposits support vegetation including grasses, shrubs and trees. Most unvegetated areas have a thin gypsum crust at the surface. This cover provides some stability for these deposits. The tailings exhibit some instability at the creek

bank edges and where cover is absent. Some of the tailings with their contaminants are released to the surface waters of Whitewood Creek. It is estimated that 7,000 kg of arsenic may be added to the surface waters from normal erosion, heavy rainfall and seepage during a normal year. Periodic flooding events may introduce an additional 35,000 kg in a single event.

The potential risk to human health through inadvertent ingestion of tailings was evaluated as part of the soil exposure pathway.

Alluvial Materials Underlying Tailings Deposits (Medium 1, Figure A-2). It is estimated that at least 10 million tons of alluvium underlie the tailings deposits within the site. The alluvium underlying the tailings deposits consistently exhibits elevated levels of arsenic (maximum 700 mg/kg).

While the contaminants within the alluvium are relatively immobile, they are being released very slowly to alluvial aquifers, and transported in small amounts to the surface waters of Whitewood Creek. There may be some scouring of alluvial materials from the bank into the creek during high river flows. In most instances, the alluvium is covered by tailings and the contaminants within it are insulated from, and not available to, surface transport processes, such as erosion or runoff. Because of the covering tailings deposits, no human health exposure pathways exist.

Irrigated Soils (Media 3, 4, and 5, Figure A-2). Approximately 83 acres of irrigated cropland are located within the site. About one-fourth of the water used for irrigation comes from upgradient alluvial or bedrock aquifers, one-fourth from Whitewood Creek and one-half from the Belle Fourche River. Only some portions of the total irrigated croplands are contaminated by arsenic. Overbank flooding and windblown tailings materials probably contributed most of the contamination, although Whitewood Creek surface water may have contributed small amounts of arsenic to the soil where it is used for irrigation.

Arsenic levels are elevated in samples of irrigated soils taken at different locations throughout the site (maximum 600 mg/kg). There is no indication that contaminants in the irrigated soils are migrating into the alluvial groundwaters because of the relative immobility and low concentrations of arsenic in these soils. Contaminant uptake by crops occurs to varying degrees, depending on the contaminant. The potential risk to human health through inadvertent ingestion of contaminated soil was evaluated as part of the soil exposure pathway. The potential risk due to ingestion of crops is discussed below in the section on vegetation.

Surface Soils in Residential Yards, Gardens and Driveways (Medium 6, Figure A-2). The contamination in the residential areas is from windblown tailings materials and from tailings materials inadvertently transported in by dirty work boots etc. or imported for use as a soil conditioner and driveway base. Three residential properties within the site have been found to have surface soil arsenic contamination (maximums: lawn 520 mg/kg, garden 540 mg/kg, driveway 2400 mg/kg). In these samples, maximum concentrations were reported in the 0-6" samples. Concentrations of arsenic in the 18" and 24" depth samples were above background for the area but less than 100 mg/kg. Other residential properties within the site have not been sampled. Approximately 12 residences were estimated in the feasibility study to have arsenic concentrations greater than 100 mg/kg. The total number of affected residences and amount of contaminated material will be determined during the remedial design phase of the Superfund work.

There is no indication that contaminants contained in these soils are migrating into the alluvial groundwaters because of the relative immobility and low concentration of arsenic in these soils.

The potential risk to human health through inadvertent ingestion of contaminated soil was evaluated as part of the soil exposure pathway.

Downgradient Alluvial Groundwater. The water from the downgradient alluvial aquifer (Unit 2, Figure A-3) is the only groundwater to exhibit elevated levels of contaminants. Concentrations of arsenic (maximum: 0.78 mg/l) are detected above background levels. These concentrations exceed primary drinking water standards and the South Dakota Drinking Water Standards.

The water table along Whitewood Creek occurs mainly in the natural alluvium underlying the tailings. During wet periods of the year, the water table may rise into the tailings. Some recharge of the shallow alluvial aquifer may occur then, through infiltration of precipitation moving through the terrace deposits and the tailings deposits. In general, the water table slopes toward the floodplain and, during most of the year, there is a net flow of groundwater from the alluvium into the creek. During high creek flow, lasting from two to eight weeks each year, this flow is reversed. The effect of recharge from the stream may be seen as much as 200 meters from the stream. In the areas where the tailings deposits are fine-grained with low permeability, localized perched zones produce small seeps and springs along the bank of the creek. Gypsum crusts form in places at the surface of the tailings and at the seeps.

Three mechanisms appear to act in movement of arsenic from the tailings to the groundwater: 1) dissolution of arsenic during those times of the year when the water table is in the tailings, 2) dissolution of arsenic when precipitation infiltrates downward through the tailings and 3) incorporation of tailings particles into the alluvium, which probably occurred as the tailings were being deposited. Movement of contaminants presently continues at a slow rate, and could continue for thousands of years.

The potential risk to human health occurs through ingestion of contaminated groundwater.

Surface Waters of Whitewood Creek. The concentrations of contaminants (Table A-1) in surface waters of Whitewood Creek comply with water quality standards established by South Dakota for Whitewood Creek and EPA water quality criteria for chronic toxicity to aquatic life. Concentrations of arsenic at the U.S. Geological Survey Vale sampling station, downstream of the site, occasionally exceed the water quality criteria for the protection of human health from the consumption of fish. These exceedances are due in part to upstream sources and to the additional contributions from the tailings deposits along the creek within the site.

The upstream sources include minor unquantified discharges of municipal and industrial wastewaters from the communities of Lead, Deadwood and Whitewood. Minor additional contamination may be attributed to the few tailings deposits between the Homestake Mine and the beginning of the Whitewood Creek Superfund site at the Crook City Bridge.

Homestake mine discharge also contributes to the upstream loading. Prior to the installation of the Grizzly Gulch Tailings Impoundment and Homestake's wastewater treatment plant, the surface water in Whitewood Creek below the mine was substantially degraded and incapable of supporting aquatic life. Following completion of the treatment plant, Homestake has been discharging to Whitewood Creek under a draft permit from the State of South Dakota. The allowable discharge concentrations for arsenic (0.184 mg/L,

daily maximum; 0.105 mg/L, daily average) in the treatment plant effluent were developed to be protective of a cold water fishery usage of Whitewood Creek between Lead and the Superfund site using ambient water quality above the discharge, and wasteload allocation calculations. The present arsenic concentrations in the effluent at the discharge point located near the town of Lead average 0.03 mg/L with maximums of 0.06 mg/L.

The water quality of Whitewood Creek is different as it leaves the site from that entering the site. Groundwater seeping through the tailings and alluvium into the creek adds an average of 365 kg/year of arsenic to the creek. Normal erosion of tailings along Whitewood Creek contributes on the average of 300 kg/year of arsenic and heavy rains may contribute another 6,000 kg/year. During periodic flood events up to 35,000 kg of arsenic is added to Whitewood Creek from the erosion of the tailings. This added load of contaminants to the surface water across the site results in an increase of arsenic concentrations which varies with the amount of flow in the creek and time of year.

The levels of dissolved arsenic at the downstream end of the site exceed water quality criteria for the protection of human health from the consumption of fish. The levels also periodically exceed the National Primary Drinking Water Standards for arsenic of 0.05 mg/L and have approached the criteria established by the EPA for chronic toxicity to aquatic life of 0.190 mg/L. The observed changes in water quality are related to the uncontrolled releases from the site throughout the year as well as the processes which lead to removal of contaminants from the water column to the sediment of the stream bed. Consequently, the range of observed percent change in arsenic concentrations in Whitewood Creek reported between 1985 and 1987 was from a loss of 80 percent in September 1985 to an increase of 490 percent in July 1985.

Preliminary calculations in the RI/FS indicated that the potential risk to human health of ingesting contaminated water is too low to be of concern, in part because there is no current or anticipated future use of Whitewood Creek surface water for drinking. The National Primary Drinking Water Standards for arsenic are therefore neither applicable relevant or appropriate as a requirement for Whitewood Creek. There are no applicable standards for toxicants in the reach of Whitewood Creek within the site. However, the EPA, 1986 Quality Criteria for Water document established arsenic levels for preventing chronic toxicity of 0.190 mg/L which may be considered as a relevant and appropriate level for protection of the semi-permanent warmwater fishery designated by the State for Whitewood Creek within the site. Due to the potential for exceedances of the national chronic toxicity criteria, coupled with the uncertain future rates of release of arsenic from the tailings deposits, EPA has determined that continued monitoring of Whitewood Creek water quality is needed.

Vegetation. Certain native plants growing on the tailings deposit areas contain concentrations of arsenic (maximum 240 mg/kg, Table A-1) above that of vegetation from the reference area. Some cultivated crops (alfalfa, for example) contained concentrations of arsenic elevated above background, but below levels cited as producing reduction in crop productivity or causing toxic effects in livestock. Arsenic levels were not elevated in crops for direct human consumption. During the endangerment assessment, consumption of vegetation was not considered as a transport pathway, because of the low arsenic levels and because arsenic does not accumulate in tissue or increase in concentration as it progresses up the food chain.

## Contaminants

The media most contaminated by arsenic and cadmium, the contaminants of greatest concern for this site, are the downgradient alluvial aquifer, tailings deposits, irrigated cropland soils and residential soils. Each of these media contribute a portion of the dose ingested by the exposed population depending upon the concentrations of contaminants in the media and the individuals exposure to the media. Section V discusses the volume and mobility of contaminants in these media in greater detail. See Table A-2 for average concentrations of all substances assessed in the EA. The discussion which follows outlines assumed exposure patterns for a variety of exposure scenarios.

## Pathways

There are a number of pathways by which contaminants from the tailings deposits may reach individuals living within or visiting the site. EPA's EA for the site concluded that the pathways which present the highest risk are ingestion of groundwater and ingestion of contaminated soil media (tailings deposits, irrigated cropland soils and residential soils).

The existing ranches and potential ranch sites in the Whitewood Creek area could be expected to utilize groundwater from the upgradient alluvial aquifer. Ranches could also hypothetically use the downgradient alluvial aquifer in the future (See Figure A-2 and A-3)

Some of the ranches exist near tailings deposits and/or contaminated irrigated soils. Inadvertent soil ingestion could occur at these ranches during an individual's lifetime from such activities as playing, hunting, fishing, cutting wood, gardening, and working in the yards and fields. Furthermore, household dust might contain arsenic blown in or mechanically transported (e.g., dirty work boots) from tailings and cropland soils. Most large dust particles which are breathed into the lungs are removed from the lungs by the lung's self cleaning action. Contaminants can become incorporated into mucus and swallowed, in a pathway referred to as incidental soil ingestion.

Additional pathways were also considered, but risk calculations were not developed. Risks for the consumption of homegrown foodstuffs, the air pathway (through inhalation of respirable particles) and the surface water pathway were not calculated in the endangerment assessment because preliminary calculations in the RI/FS indicated concentrations of contaminants and the potential for exposure through these pathways were too low to be of concern.

## Population Exposure Scenarios

The exposure to the potential carcinogen, arsenic (Table A-2), and non-carcinogenic metals in soil and groundwater via ingestion was evaluated for four exposure scenarios. These include 1) a representative adult site resident, 2) a representative child site resident, 3) a recreational visitor, and 4) a hypothetical future (maximum exposed) site resident. Assumptions for ingestion rates are included in Appendix A.

### **Alternative 1: No Action**

The No Action alternative would consist of no remedial activities.

The current State of South Dakota ban on construction of water supply wells within the 100-year floodplain of Whitewood Creek between the Crook City Bridge and the confluence with the Belle Fourche River would continue to be enforced (South Dakota Water Rights Rules, Section 74:02:04.26). This regulation prohibits construction of wells that supply water to the public or supply water for household domestic use or for agricultural purposes. A variance is also provided for in this regulation which may be granted, if it is shown that a well in this location will not be contaminated from tailings deposits and will not cause groundwater pollution. A public health and environmental evaluation would be conducted every five years.

### **Alternative 4: Institutional Controls with Covering and/or Removing Surface Soils at Residential Properties (Including the Restriction of Future Development)**

Two activities required to refine knowledge of the extent of site contamination and define site boundaries would be completed during remedial design. A survey would be conducted to define the limits of the 100-year floodplain. Soil would be sampled both at the surface and at depth to define the tailing deposit areas and parcels of land with surface soils arsenic concentrations greater than 100 mg/kg. Maps compiled during these activities will be used to support the county ordinances regarding use of tailings deposits and fringe areas. All residential properties within the site which potentially contain soils with arsenic concentrations greater than 100 mg/kg as defined by this initial sampling of soils would also be sampled.

To define the boundaries of the tailings deposit areas on both sides of the creek, transect lines perpendicular to and at selected intervals along a baseline connecting the Crook City Bridge to the point where Whitewood Creek joins the Belle Fourche River would be laid out on a map and in the field. Parallel baselines may be utilized as needed to accommodate local obstructions. Surface soil measurements of, or samples for the analysis of, total arsenic would be taken along each of these transect lines near the approximate boundaries of the tailings deposit areas on either side of the creek and at intervals as required to identify the extent of soils with arsenic concentrations greater than 100 mg/kg. The sample locations and associated analytical results would be plotted on a map to define the boundaries of the tailings deposit areas.

Tailings deposits will be identified by a statistically significant change in the physical and chemical characteristics of the surface solids. These parameters may include, but not be limited to, color, particle size, grain size distribution and arsenic concentration.

To define the locations and boundaries of those parcels of land outside and on the fringes of the tailings deposit areas that have surface soils arsenic concentrations greater than 100 mg/kg, sample measurements or samples of the top one inch and at six inches below the surface of soils would be taken along (or parallel to) each of the transect lines described in the previous subsection. These arsenic measurements or soil samples would be taken at intervals beyond the apparent boundary of the tailings deposit areas until arsenic concentrations at or below 100 mg/kg were detected.

The survey to define the limits of the 100-year floodplain would start with ground truthing of existing aerial photographs and maps including Federal Emergency Management Authority (FEMA) maps. The objective of this task is to analyze the potential for

redistribution of existing tailings deposits during major flood events by identifying segments where flood events may result in significant erosion and/or deposition.

Areas around the residential properties with greatest potential exposure to arsenic concentrations exceeding 100 mg/kg in the surface soils would be remediated as subsequently described. If the arsenic level exceeds 100 mg/kg within a defined parcel around each of the potentially affected residences, the property would be subjected to remediation as described below.

The parcel around each of the residences will be based on the most actively used portion of the property including the immediate yard (non-garden) around the residence, the driveway and garden areas. The boundaries of each of the residential parcels and the subareas within each parcel would be determined during RD/RA, and must be coordinated with the current resident(s). These areas would be detailed on a residential site map as part of the site plan for each property. It is assumed that the residential parcels will be approximately two acres, and that gardens will be approximately 90 feet by 180 feet. If use patterns exceed this area, then up to 8 acres and 2 acres respectively will be remediated. If the residential property is less than two acres, the entire parcel, regardless of size, would be remediated if the arsenic levels as determined from the sampling exceed 100 mg/kg.

A limited number of random samples would be collected from driveways and residential soils at any of the twenty-two residences which were within the RI study area but are outside the 100 mg/kg isopleth. If any sample contains surface soil concentrations greater than 100 mg/kg arsenic, then a residential parcel would be selected for sampling as outlined above and remediated as required.

At the residential parcel subject to potential remediation, a garden area designated for food production would be identified on the residential site map along with driveways, buildings and other physical features. The residential area would be divided into a grid with the line spacings set at 30 feet. Each of the 900 square foot areas defined by the grid lines would be sampled to determine the arsenic level at the surface and the six inch depth. The two samples for analysis from each 900 square foot area (surface and subsurface) would be a composite of the less than 2 mm size fraction from each of the four quadrants of the area. If any of the samples from the surface or subsurface exceed the 100 mg/kg arsenic level, then that 900 square foot area would be subjected to remediation.

Samples collected during the RI/FS indicate that where residential soils are contaminated, arsenic concentrations are above 100 mg/kg in the top twelve inches of soil. Samples taken from eighteen and twenty-four inch depths were at background levels. It is assumed that in the non-garden areas where no invasive activities occur, twelve inches of cover will provide sufficient protection for the residents.

The remediation of those non-garden yard areas which exceed the 100 mg/kg arsenic level, therefore would involve some combination of the following actions to minimize exposure of the residents to contaminated surface soils. 1) If topography, building foundation level and resident permit, 12 inches of soil cover would be placed. 2) If it is possible to maintain topography consistent with immediately adjacent areas, or if the resident requests, the removal of twelve inches of soil and replacement with twelve inches of clean soil may be required. 3) If surface soil arsenic concentrations of less than 100 mg/kg can be achieved by removing 6 inches or less of existing soil, this would be done, and sufficient clean soil (20 mg/kg arsenic) would be placed on the excavated areas. In any of these cases, the areas would be restored to their former vegetated conditions. As noted below, excavation



below areas remediated would be prohibited by county ordinance, unless the soil is demonstrated to contain less than 100 mg/kg arsenic.

In garden areas, the invasive and mixing activities associated with gardening could result in elevated levels of arsenic below that found in the adjacent soils. Twenty-four inches of soil would therefore be removed and replaced with clean soil from off-site sources (< 20 mg/kg arsenic).

Roadways and driveways at existing residential properties are paved with gravel or other non-asphaltic, non-cement materials. Where the surface soil arsenic concentrations exceed 100 mg/kg, these gravels would be cleaned up. Six inches of existing gravel would be removed and replaced with clean imported gravel or road base (< 20 mg/kg arsenic).

Contaminated soil and gravel will be disposed of at an off-site facility approved by EPA, such as the Grizzly Gulch tailings impoundment near Lead, South Dakota. Under section 121(d)(3) of CERCLA, any off-site disposal facility used must be operating in compliance with all applicable Federal law and State requirements. The disposal will be undertaken in compliance with EPA policy and/or regulations governing off-site disposal of CERCLA waste.

Following removal and/or covering activities, composite soil samples would be taken at one inch and at one-half the depth of soil or gravel cover from all remediated areas in the manner previously described, and analyzed for total arsenic concentrations. Sampling density will be similar to that required for pre-remediation sampling. This confirmation sampling would confirm that arsenic levels have been brought to below 100 mg/kg. Similar sampling and analysis would also be performed after any flood event that resulted in inundation of any residential property within the site.

The arsenic analysis of soils and other material at the site may be performed using an EPA-approved laboratory or by a combination of laboratory and field analysis using a portable X-ray fluorescence (XRF) instrument. The use of field-portable instruments will be acceptable after development of EPA-acceptable quality assurance/quality control and calibration at an acceptable detection limit for the concentrations being analyzed. If samples are analyzed by XRF in the field, 15 percent of the initial characterization and confirmational samples will be split and sent to an EPA-approved analytical laboratory to confirm the field results and, for confirmational samples, that the arsenic levels are less than 100 mg/kg.

The three counties involved, Meade, Butte and Lawrence, have all expressed a willingness to enact controls similar to those outlined in Appendix D of the Feasibility Study. These institutional controls would include:

- County zoning and building permit regulations would be adopted prohibiting residential and commercial development within the tailings deposit areas and prohibiting residential development of properties that exhibit surface soil arsenic concentrations exceeding 100 mg/kg.
- County regulations would be adopted prohibiting the removal and use of tailings soils from the tailings deposit areas and prohibiting disturbing remediated areas below the depth of soil removal/cover unless the soil is demonstrated to contain less than 100 mg/kg arsenic. Mining of the tailings deposits would be allowed subject to pertinent regulations of the State of South Dakota.

- . Excavation below areas remediated would be prohibited, unless the soil is demonstrated to contain less than 100 mg/kg arsenic.
- . An education program would be conducted annually to acquaint site residents with the potential health hazards associated with exposure to the tailings soils and downgradient alluvial groundwaters within the site. This education would also include methods residents can use to minimize incidental ingestion of contaminated materials. A mechanism to inform potential property owners of the potential health hazards will also be included in the education program.

In the event of a flood where contaminated materials potentially were redistributed, the flooded areas would be resampled. Action would be taken to return any newly contaminated or re-contaminated areas to post-remediation conditions.

The surface water quality of Whitewood Creek would be monitored at the U.S. Geological Survey sampling stations near Whitewood and Vale four times a year. These sampling events would be conducted in late winter before major snow-melt runoff; during peak runoff in spring; during the low flow period in late summer; and once immediately following a major precipitation event. Continued monitoring of Whitewood Creek water quality is needed to evaluate the effect of uncertain future rates of release of arsenic from the tailings deposits on the environment. These data will be reviewed during the five-year review.

The rules of the Occupational Safety and Health Act would apply to the construction-type activities carried out to remove and/or cover contaminated soils. It is estimated that it would take 9 to 18 months to implement the covering and/or removal component of this alternative.

A review of site conditions (five-year review) would be required every five years to ensure that human health and the environment are being protected by the remedial action being implemented. This would include, but not be limited to:

- . Verification sampling within the remediated residential areas.
- . A review of development activity within the site. If development has taken place which is inconsistent with specifications as described in EPA's ROD, these properties would be required to be remediated in a manner consistent with the ROD.
- . A review of the effectiveness of the education program in alerting present and potential property owners to concerns related to the contamination which remains on site.
- . A review of compliance with the monitoring well ban in the floodplain.
- . A review of the surface water quality data collected from Whitewood Creek to assure that levels protective of human health and aquatic life are being maintained.

#### **Alternative 4a: Institutional Controls with Covering and/or Removing of Surface Soils of Existing Residential Properties (Allowing Future Development)**

This alternative would involve the same activities as Alternative 4, but would allow future development within the contaminated fringe areas of the 100-year floodplain outside of the tailings areas, following remediation to provide conditions protective of human health. The county ordinances to be enacted as additional institutional controls would allow for a variance in which an approval of plan for cover and/or removal of soils of greater than 100 mg/kg would be required by the South Dakota Department of Natural Resources prior to development of the land.

- A variance procedure allowing development on lands within the site (but outside the tailings deposit areas), following appropriate remediation, would be adopted. A variance procedure allowing public works developments on land inside the tailings deposit areas, following appropriate remediation, would also be adopted.
- A potential developer must sample the surface soils of any parcel in the fringe area determined to contain contaminated soils. The sampling program would be similar to that outlined for residential remediation in Alternative 4 to identify which portions of the parcel contain concentrations of arsenic greater than 100 mg/kg. The developer then would submit sample results and a remedial plan to the South Dakota Department of Natural Resources. This remedial plan would describe removal, cover or other procedures for bringing all surface soils to 100 mg/kg and would include plans for confirmatory sampling.
- After approval of the plan, the developer may perform the work and confirmatory sampling. The developer would also assume the obligation of complying with a county regulation prohibiting the removal or impairment of any covers placed on the parcel under the plan unless pre-approved by the State.

#### **Alternative 5: Institutional Controls with Fencing of Tailings Deposit Areas and Covering and/or Removing of Surface Soils of Existing Residential Properties**

This alternative would involve the same activities as Alternative 4 with the addition of installation of fencing around the perimeter of the tailings deposit areas. A three-strand barbed wire fence, or equivalent, would be installed, using existing fencing where available. The purpose of the fence would be to reduce current exposures of site residents to the elevated surface soil arsenic concentrations by discouraging access to the tailings deposit areas. ARARs would be the same as for Alternative 4.

#### **Alternative 7: Institutional Controls with Partial Soil Cover of Tailings Deposit Areas and Covering and/or Removing of Surface Soils of Existing Contaminated Residential Properties**

This alternative would involve the same activities as Alternative 4 with the addition of placement of soil cover over barren areas (i.e., devoid of vegetation) in the tailings deposit areas. Barren areas would be identified based on field observations and review of aerial photographs. In the places where these bare areas form steep banks along the creek, these banks would be peeled back to create banks having slopes of no more than 1 horizontal to 3 vertical. The peeled-back tailings materials would be placed in layers on the adjoining tailings deposits before placement of the soil cover. Six to 12 inches of native soils imported from off-site sources would be spread over the barren and/or stabilized tailings deposits. This cover would be vegetated with native grasses to stabilize it and minimize

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The estimated cost for Alternative 4 to remove/cover contaminated soils at existing residences is \$638,392 (\$581,000 capital costs, \$11,000 annual O&M cost). Alternative 4a adds testing and removal/cover at 15 additional residences. Costs are estimated to be \$882,813 (\$1,028,000 capital costs and \$12,000 annual O&M cost). Alternative 5, which is similar to 4 with the addition of fencing, is estimated at \$1,345,841 (\$981,000 capital costs and \$31,000 annual O&M cost). Alternative 7, which is alternative 4 with the addition of a partial soil cover, is estimated at \$5,605,254 (\$5,471,000 capital costs and \$16,000 annual O&M cost). Alternative 9 is estimated at \$75,054,923 (\$107,575,000 capital costs and \$36,000 annual O&M costs).

#### Criterion 8: State Acceptance

The State of South Dakota concurs with the selection of Alternative 4a.

#### Criterion 9: Community Acceptance

Public comments that were received indicated that there is no consensus on what presents the best remedial alternative for the arsenic-contaminated mill tailings along Whitewood Creek. Some citizens expressed the opinion that the tailings appeared to present no health hazard and that the No Action alternative was the best solution. An equal number felt that the tailings pose a hazard to human health and the environment that can only be mitigated by complete removal (Alternative 9). Other people were in favor of the remedy proposed by EPA, with reservations about the potential effect of the remedy on the economics of the community.

## VIII. THE SELECTED REMEDY

### **Alternative 4a: Institutional Controls with Covering and/or Removing of Surface Soils of Existing Residential Properties (Allowing Future Development).**

Based upon a review of information contained in the site Administrative Record, EPA has decided that the most appropriate remedy for the Whitewood Creek Superfund site is to remove and/or cover contaminated residential soils and restrict access to contaminated tailings and groundwater by use of institutional controls. As described in Section IX below, this remedy is the most protective alternative which would not have adverse effects to the environment. It also provides the greatest protection in the most cost-effective manner.

It is estimated that it would take approximately 18 months to implement institutional controls and remove/cover surface soils of existing residential properties. It is also estimated that 15 additional properties will be developed through variance from county ordinance over the thirty year period.

The estimated net present worth for the selected remedy is \$882,813 (Table A-7). Capital costs total \$1,028,000, \$581,000 of which will be spent during start-up, \$447,000 which will be incurred over the thirty year period. Annual O&M costs are estimated to be \$12,000.

At existing residences exhibiting greater than 100 mg/kg arsenic in surface soils, these soils would be removed and/or covered in garden, non-garden and roadway areas. All material removed would be placed in a disposal facility approved by the State and EPA which is designed and constructed to hold wastes that are similar in nature and concentration of contaminants. Soil sampling would be conducted both on the surface and at depth following this remedial action to confirm that remedial action goals have been met. Any properties developed under variance would be sampled and remediated in a similar fashion. If remediated areas should be flooded these areas would be resampled and appropriate action taken to return any contaminated areas to post-remediation contaminant levels. A five-year review would be performed five years after remediation is completed. South Dakota Water Rights Rules (Section 74:02:06:26) ban on water wells in the Whitewood Creek 100-year floodplain would also be continued.

The scope and performance of the remedy selected in this ROD are consistent with the remedy proposed at the start of public comment because the elements of remedial action to be implemented are the same. In response to comments received from citizens during the public comment period, EPA has decided warning signs and notice in deed are not necessary because the proposed educational program is deemed to be sufficient.

### **Response Objectives**

The response objectives for soil remediation at Whitewood Creek are to control exposure through ingestion of contaminated tailings deposit soils, alluvial soils and residential soils, or downgradient alluvial groundwater. Target cleanup objectives for groundwater are the Maximum Contaminant Levels. Target clean-up objectives for soils were developed based on soil concentrations which correspond to carcinogenic health risks of  $1 \times 10^{-4}$ . Acceptable contaminant levels for the chemical of concern (arsenic) in residential soils are 100 mg/kg, based on the  $1 \times 10^{-4}$  target risk levels derived in the endangerment assessment. This action level would also reduce non-carcinogenic risk to an acceptable level. A summary of these calculations are provided in Appendix A of this document.

**Reference 2**

**Excerpts From the Feasibility Study,  
Whitewood Creek, South Dakota;  
EPA Region VIII; December 8, 1989**

**FEASIBILITY STUDY**  
**for**  
**WHITEWOOD CREEK, SOUTH DAKOTA, CERCLA SITE**  
**VOLUME I**  
**December 8, 1989**

**Prepared by**  
**ICF Technology**

**for**  
**Homestake Mining Company**

**for submission to**  
**U.S. Environmental Protection Agency**  
**Region VIII**

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pp 5 and 6), from the 1870's to the end of the century, many gold mining companies discharged tailings into Whitewood Creek or its tributaries. During that period, a substantial portion of these tailings were deposited on and in the alluvial materials of the floodplain because the creek was a small meandering stream with insufficient capacity to transport the large quantities of discharged tailings. The deposited tailings and some alluvial material filled in the meanders of the creek and thereby straightened its channel and increased its gradient. This, in turn, caused the creek to downcut its channel to or near to the resistant shale which today forms the channel bottom for most of the length of the 18-mile stretch. In addition, during flooding events, tailings were deposited in overbank areas throughout the floodplain. Except at the Sheeler site, which is discussed below, it is believed that very little deposition of tailings occurred after the turn of the century because the increased sediment carrying capacity of the transformed creek channel enabled the transport of these tailings downstream of the Site. In 1977, the discharge of tailings into Whitewood Creek was terminated when Homestake put its tailings impoundment at Grizzly Gulch into operation.

#### 1.3.1 Tailings Deposits

The tailings deposits laid down over 80 years ago have remained very stable since the turn of the century as evidenced by a study of the age of the trees that, today, are growing on



the deposits (Cherry, et.al 1986a at p 6 and Blatt 1988) and as further evidenced by aerial photographs. The areas covered by these deposits are shown on the map at the end of this document. The stratigraphy of the tailings deposit areas generally consists of (1) an upper deposit of tailings ranging from approximately one to fifteen feet thick and 50 to several hundred feet wide on each side of the creek along its full 18-mile length within the Site, (2) an underlying strata of natural alluvium consisting of sandy to sandy silt materials with variable amounts of intermixed tailings, and (3) the thick shale strata that forms the floor of the valley (see Figure 4 of Cherry, et.al 1986b at p 2). It is estimated that approximately 25 to 37 million tons of tailings were deposited in the floodplain within the Site.

At the Sheeler site, the deposition history and mechanics were slightly different. Sometime during the 1930's, a diversion channel was constructed along Whitewood Creek near its confluence with the Belle Fourche River. Sometime after its construction, Whitewood Creek breached the channel and deposited tailings over adjacent areas. Subsequent downcutting of the Whitewood Creek channel routed the creek around this area leaving the youngest deposit of tailings currently existing within the Site.

#### 1.3.2 Whitewood Creek

From the 1870's until the cessation of tailings discharges in 1977, Whitewood Creek carried a heavy suspended solids load and exhibited a grayish, aesthetically displeasing color. As a

result, the waters of the creek were sparingly used for irrigation or stock watering purposes and did not provide a habitat for a permanent fishery. Since the cessation of tailings discharges, the physical appearance and quality of the waters of the creek have improved dramatically. Except during flooding conditions, the creek carries clear, aesthetically pleasing water with no visible suspended solids. As a result, it is occasionally used for irrigation and stock water supply, although the principal sources of stock water supplies continues to be groundwater wells and the principal source of irrigation water supply is the irrigation system that serves the irrigation lands in the lower portion of the Site from a diversion on the Belle Fourche River upstream from the confluence of Whitewood Creek. In the upper portion of the Site, there is some pumping or diversion of irrigation water from Whitewood Creek.

Whitewood Creek within the Site is designated by the State of South Dakota for the beneficial uses of warmwater, semipermanent fish propagation and limited contact recreation. A semipermanent warmwater fishery does exist in the creek within the Site. In addition, the State of South Dakota has occasionally stocked trout in the upper reaches of the creek within the Site and in reaches of the creek upstream from the site. This cold water fishery has not been and cannot be established on a permanent basis because of physical habitat restrictions, principally high water temperatures and low flows.

In the upper reaches of the Site, the Whitewood Creek

Corn, hay, alfalfa and milo are the principal crops grown on the irrigated crop lands (Fox 1984a at p 275). Hay is the principal crop grown on non-irrigated cropland. These crops are grown for livestock feed. The rangeland is used for grazing livestock, principally cattle but a few sheep and goats (Geochemical 1988c at pp 5-6). Some of the ranches maintain small vegetable gardens and a few fruit trees (mostly apple) to produce food for their own use (Geochemical 1988c at pp 3, 5-6).

#### 1.3.6 Population

The population of the Site is rural. Fox estimated that 80 households (exclusive of households within the Town of Whitewood) and a population of 1,104 existed within one mile on either side of the 18-mile reach of Whitewood Creek within the Site, and that 168 households (exclusive of those within the Town of Whitewood) and a population of 1,468 existed within three miles on either side of the creek (Fox 1984a at p 260). These 1- and 3-mile areas cover more land than the 100-year floodplain which defines the Site and include the Town of Whitewood (population 821) which is located outside of the Site near its upper end. Thus, these estimates overstate the number of households and population that exist on the Site per se. Geochemical Engineering inventoried the population living on or near the Site itself and found 22 active households and 5 vacant household properties<sup>4</sup> (Geochemical

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<sup>4</sup> Does not include Rock or Keiry. The vacant households are Dillinger, Nelson, Sheeler, Sheeler (two houses) and Uda.

practices or water quality conditions in the Whitewood Creek basin were conducted between 1960 and 1982. A review of these studies is provided by Fox (1984b in Appendix A). All but one of these studies were fairly narrowly focussed and most contained limited data.

The first comprehensive study of tailings deposits and groundwater quality on the Site was conducted by the South Dakota Geological Survey in the mid 1970s (Fox 1984b at p 29 in Appendix A). Although this study was complicated by monitoring well construction and analytical problems, it provides some evidence of elevated levels of arsenic in the alluvial groundwaters underlying tailings deposits and increasing concentrations of arsenic in Whitewood Creek as it passes through the Site.

#### **1.5 Nature and Extent of Contamination**

The investigations conducted by Fox (reported in 1984a, 1984b, 1984c, 1984d and 1984e) found elevated concentrations (i.e., greater than background concentrations) of arsenic, cadmium and other metals in three zones of material situated with the Site (i.e., within the 100-year floodplain of Whitewood Creek: (1) the tailings deposits, (2) the alluvial materials underlying these tailing deposits, and (3) the surface soils in some of the irrigated lands within the floodplain adjoining the tailings deposits. These studies also found the release or potential release of arsenic, cadmium and other metals into (1) the groundwaters contained in the alluvium underlying tailings

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deposits, (2) the surface waters of Whitewood Creek, (3) the native vegetation growing on the tailings deposits, and (4) the cultivated vegetation grown on irrigated lands within the floodplain adjoining the tailings deposits.

Subsequent investigations conducted by Geochemical Engineering, Inc. (Geochemical 1989a and 1989b) found elevated arsenic concentrations in the soils of two existing residential properties (on the Alan and Richter ranches) located on the fringe lands outside of the tailings deposit areas but within the Site.

#### 1.5.1 Tailings Deposits

The tailings deposits range in thickness from less than one foot to 15 feet and cover an area from 50 to 300 feet wide on either side of Whitewood Creek over most of its 18-mile length within the Site (Fox 1984a at p 61; also see Table 1-1 in this section for data on the thickness of the deposits). It is estimated that the total volume of these deposits within the Site is 25 to 37 million tons (M&K 1989a at p 13 and M&K 1989b at p 13). These tailings are readily identified by their color, texture and position relative to the stream (Fox 1984a at p 13). As explained in Section 1.4, they are the crushed ores remaining from the extraction of gold in ore milling operations. As such, they contain varying amounts of the unoxidized or partially oxidized minerals (arsenopyrites, pyrrhotites and pyrites) that were contained in the parent ores. They also contained varying amounts of the oxidized mineral products (e.g., arsenates and

concentration of 0.4 mg/l in the pore waters of the deposits, it is estimated that 40 kg/yr of arsenic are transported out of the tailings deposits and into the alluvial groundwater underlying the deposits (Cherry, et.al 1986c at p 11). This is an extremely small amount when compared to the estimated 45 million kilograms of arsenic contained in the tailings deposits and the estimated 640,000 kilograms of arsenic contained in the underlying alluvium.<sup>35</sup>

The foregoing conclusions indicate that the arsenic in the tailings deposit areas is very immobile and is being released and transported very slowly and in very low amounts into the underlying downgradient alluvial groundwaters. An analysis of the distribution of constituents in the tailings deposits verifies this by providing prima facie evidence that little vertical transport of arsenic is now occurring or has occurred over the past 80 years (Cherry, et.al 1986c at p 1). The small amount of arsenic that is transported into the underlying alluvium very slightly augments the large amount of arsenic already containing in this alluvium, the fate and transport of which will be discussed in the next section.

There undoubtedly is loss of tailings and their entrained arsenic to the surface waters of Whitewood Creek through scouring

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<sup>35</sup> It is estimated that 21.6 million tons ( $19.6 \times 10^9$  kg) of tailings exist within the Site. If these tailings have an average arsenic concentration of 2,320 mg/kg (derived from Table 1-1), then the total quantity of arsenic in the tailings is 45 million kilograms.

It is estimated that at least 10 million tons ( $9 \times 10^9$  kg) of alluvium underlie the tailings deposits within the Site. If this alluvium has an average arsenic concentration of 71 mg/kg (derived from Table 1-1), then the total quantity of arsenic in this alluvium is 640,000 kilograms.

absence of migration of arsenic into underlying groundwaters.

There may be some minor transport of arsenic from the irrigated (and non-irrigated) cropland soils to the surface waters of Whitewood Creek through soil erosion processes. This contribution cannot be distinguished from that from the tailings deposits (through scouring and erosion) discussed in Section 1.6.1, and it is included, to the extent that it occurs, in the estimates given for tailings deposits in that section.

#### **1.6.4 Arsenic in Residential Property Soils**

The above-background levels of arsenic in the soils of some of the residential properties within the Site are available for crop uptake from the gardens on these properties and human intake through incidental ingestion of soils by the residents of these properties. The human health impacts of arsenic intake through the consumption of fruits and vegetables grown in the gardens on these properties are assessed by USEPA (1989) and (ICF 1989). The human health impact of arsenic intake through the incidental ingestion of the surface soils on these properties is assessed in EPA's Final Endangerment Assessment (Jacobs 1989).

For the same reasons stated in Subsection 1.6.3, there is no indication that the arsenic contained in the soils of the residential properties within the Site are migrating into the upgradient alluvial groundwaters that underlie these properties or are migrating to the surface waters of Whitewood Creek.

person who lives in a home located within the tailings deposit areas and, thus, is exposed to the average concentrations of the soils of the tailings deposit areas 65% of the time, and who uses the downgradient alluvial groundwaters for drink water supply. Put in simpler terms, the representative Site resident is one who encounters the highest probable exposures under current residency and living patterns, whereas the maximum exposed Site resident is one who, in the future, may locate and live in a household situated in the tailings deposit areas, a possible but unlikely scenario.

#### 1.7.1 Potential Carcinogenic Risks

The assessment estimates (Jacobs 1989 at Table 6-1) that the potential lifetime excess carcinogenic risks from exposures to arsenic through the ingestion of within-Site soils and groundwater are as follows:

	<u>Groundwater</u>	<u>Soil</u>	<u>Total</u>
Representative Site Resident	$1.9 \times 10^{-4}$	$2.4 \times 10^{-4}$	$4.3 \times 10^{-4}$
Maximum Exposed Site Resident	$4.4 \times 10^{-3}$	$2.6 \times 10^{-3}$	$7.0 \times 10^{-3}$
Recreational Visitor	---	$8.2 \times 10^{-5}$	$8.2 \times 10^{-5}$
Reference Site Resident	$4.2 \times 10^{-5}$	$1.6 \times 10^{-5}$	$5.8 \times 10^{-5}$



The CERCLA program considers potential risks that are greater than  $1 \times 10^{-4}$  to be unacceptable. Against this criterion, the potential risks to recreational visitors and to the hypothetical resident of the reference site are acceptable, and the potential risks to both representative and maximum exposed Site residents are unacceptable. However, with respect to groundwater, the potential risk from consuming drinking water that has an arsenic concentration at the National Primary Drinking Water Standard would be  $1 \times 10^{-3}$ . Therefore, the potential risk to the representative Site resident from the consumption of groundwater would be acceptable<sup>41</sup>.

From these estimates, it is concluded that the arsenic concentrations in the surface soils within the Site present an unacceptable potential risk to residents of the Site. An examination of the derivation of this potential risk from these soils to the representative Site resident reveals that it derives from three sources: (1) the surface soils of those residential soils within the Site that exhibit elevated concentrations of arsenic, (2) the surface soils of the tailings deposit areas, and (3) the surface soils of the irrigated croplands within the Site. The contributions of these sources to this estimated potential risk are as follows:

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<sup>41</sup> It should be noted that the potential risk for groundwaters is associated with the consumption of drinking water drawn from the upgradient alluvial groundwaters which are not impacted by tailings. Hence this estimated potential risk is associated with arsenic concentrations in drinking water supplies that derive from natural causes.

Residential property soils	$2.03 \times 10^{-4}$
Tailings deposit area soils	$0.36 \times 10^{-4}$
Irrigated cropland soil	$0.06 \times 10^{-4}$
Combined	$2.40 \times 10^{-4}$

This partitioning clearly shows that the dominant contributor to the unacceptable potential risk to the representative Site resident from the incidental ingestion of within-Site soils is the surface soils on those residential properties that possess elevated arsenic concentrations as a result of past deposition or placement (as road gravel) of tailings on this properties.

An examination of the derivation of the potential risk from within-Site soils to the maximum exposed Site resident reveals that it derives wholly from potential residential exposure to the surface soils of the tailings deposit areas. Although such exposure does not currently exist, it is theoretically possible that it could occur as a result of a person or family building and living in a home in the tailings deposit areas. In summary, the assessment shows that, with respect to the incidental ingestion of within-Site soils by Site residents, the soils of existing and potential residential properties located on the fringe of the tailings deposit areas that exhibited elevated arsenic concentrations present the dominant potential carcinogenic risk for current living and exposure patterns, and the soils of the tailings deposit areas present the dominant risk for possible future living and exposure patterns.

From the above estimates, it also is concluded that arsenic

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concentrations in the downgradient alluvial groundwaters present a possible future unacceptable potential risk (the risk estimated for the maximum exposed site resident for groundwater). These groundwaters do not present a current potential risk because they are not being currently used for water supply, and because a State regulation prohibits the installation of water supply wells within the 100-year floodplain of Whitewood Creek within which these groundwaters are situated.

#### 1.7.2 Potential Non-Carcinogenic Health Impacts

The assessment estimates (Jacobs 1989 at Tables 6-2 through 6-6) that the potential hazard indices associated with the combined exposures to arsenic, cadmium, chromium, copper, lead, manganese, mercury and nickel through the ingestion of within-site soils and groundwater are as follows:

	<u>Groundwater</u>	<u>Soil</u>	<u>Total</u>
Representative Site Resident	0.54	0.14	0.7
Maximum Exposed Site Resident	3.8	1.1	4.9
Recreational Visitor	- --	---	0.05
Reference Site Resident	0.4	0.0	0.4
Representative Child Site Resident	---	---	1.0

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The CERCLA program considers a hazard index greater than one to be potentially unacceptable. Under this criterion, the potential non-carcinogenic health impacts from the ingestion of within-Site soil and the consumption of within-Site groundwaters are acceptable except for the maximum exposed Site resident. The potential health impacts for such an individual are unacceptable. The cause of these unacceptable impacts is the assumed residency of the maximum exposed Site resident on the tailings deposit areas and the concomitant high rates of incidental ingestion of the soils in these areas and the consumption of downgradient alluvial groundwaters, exposure not currently encountered by Site residents but exposures that could be encountered in the future if the tailings deposit areas were to be used for residential properties and the downgradient alluvial groundwaters were to be used for drinking water supply.

**Reference 3**

**Excerpts From Whitewood Creek Study,  
South Dakota Department of Water and Natural Resources;  
EPA and Homestake Mining Company; November 1984**

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**WHITEWOOD CREEK STUDY**  
**PHASE II**

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A FOX COMPANY

## 1.0 INTRODUCTION

The Whitewood Creek Study focused on an eighteen mile segment of the floodplain of Whitewood Creek above its confluence with the Belle Fourche River and a five mile section of the Belle Fourche River (see Plates 1 and 2) which had been impacted by the historical release of tailings from the mining activities near Lead, South Dakota.

Whitewood Creek is a tributary of the Belle Fourche River, flowing northeast from its source in the Black Hills of South Dakota past the Homestake Mine and the towns of Lead, Deadwood, and Whitewood before emerging onto the floodplain of the Belle Fourche River on the Missouri Plateau. It is fed by several small headwater streams that enter upstream of the 18 mile segment under study. From there Whitewood Creek flows into the Belle Fourche River at the downstream end of the 18 mile segment (it should be noted that this 18 mile stream segment is linear rather than stream miles). The Belle Fourche River joins the Cheyenne River approximately 130 miles farther downstream.

The Homestake Mining Company, located in Lead, South Dakota, began gold mining operations in the Whitewood Creek watershed in the late 1870's following development of the gold deposits which was initiated prior to 1850. The first milling utilized crude methods to crush the ore and recovered gold by gravity means or by amalgamation with mercury. By 1880, the very primitive nonmechanized methods of milling were replaced by more than 1000 stamp mills (large blocks of cast iron or steel dropped onto replaceable anvils), crushing the ore to a coarse sand size. The tailings were then discharged to Whitewood Creek or its tributaries. Prior to the turn of the century much of the ore consisted of oxide or hydroxide minerals which were residual oxidation products of the arsenopyrite, pyrrhotite and pyrite mineralization of the original unoxidized ore bodies.

After the turn of the century the deeper, reduced ores from below the zone of oxidation were the focus of mining activity. These ores contained large percentages of reduced oxidation-state minerals, including arsenopyrite and pyrrhotite. The use of cyanide in the milling process also began about this time. As the mining went deeper, maintenance of the structural integrity of the mine walls necessitated backfilling with the coarse fraction (i.e., sand size portion of the tailings). The finer fraction, referred to as the slimes, continued to be discharged to the Whitewood Creek Basin. Discharge from a number of sources ceased in approximately 1920, when Homestake Mining Company became the only remaining source of tailings discharge.

Mill tailings were discharged directly into Whitewood Creek throughout the hundred year history of the mining operations until 1977, with exception of a brief period (about 5 years) during World War II when the mine was closed. In 1977 Homestake Mining Company, the only large commercial mining company remaining in the area, constructed a tailings impoundment in the upper reaches of the watershed. Mining operations over the the last century have

produced about 1,000,000,000 tons of ore and currently extend to a depth exceeding 8,000 feet below the surface. The processing of the ores has changed over the years, as have the extractive metallurgy and the characteristics of the waste stream. Methods for the comminution and beneficiation of the ores have become progressively more efficient, as discussed above, so that earlier tailings were more coarse and contained higher metal values (F. Fox, personal communication, 1983).

Mercury amalgamation of the ores was used over the greater portion of the operation and was continued until January 1971. There are various figures quoted in available literature for the volumes of mercury used and lost to the waste stream in this process. Quotes vary from an eighth of an ounce to almost half an ounce per ton of ore crushed, with up to 50 percent of this volume being lost to the waste stream. Levels of mercury in the receiving stream have been reported to be as high as 9.1 mg/l (South Dakota Dept. of Health, 1960) in 1953 although average levels were considerably lower. Cyanide has also been utilized in the gold recovery process since the early 1900's, and has been used increasingly to process the lower grades of ore and increase gold and silver recoveries. Since the cessation of mercury use in 1971, cyanide has been used exclusively for gold recovery. The tailings also contained considerable quantities of arsenic which was derived from minerals in the ore.

Tailings, consisting of finely ground rock, residual metallic and non-metallic compounds not extracted by the beneficiation processes, and trace compounds used in the extractive processes, have been transported and deposited by fluvial processes acting in the portion of Whitewood Creek downstream from the mine. In places the tailings remain in abandoned channel meanders, bars, and other depositional features and may be continuing to leach metals to surface and subsurface waters. Reports indicate that in 1963 as much as 3,000 tons per day of tailings, together with 12,500 tons per day of water, were being discharged to Whitewood Creek, though this process was ceased in late 1977. Thus, although direct discharge of the tailings has ceased, the tailings currently in place along Whitewood Creek provide a potential to cause degradation of ground water quality in the alluvial deposits and of surface water quality in the Whitewood Creek valley and downstream area. The potential for the release of deleterious chemical constituents from the tailings to ground water and surface water is aggravated by the fact that the sulfide minerals in the tailings (arsenopyrite and pyrrhotite) can oxidize when in contact with water and oxygen. Acid formation accompanies the oxidation process (Cherry, et al., 1984).

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) (PL-96-510) required the President to identify the 400 facilities in the Nation warranting the highest priority for remedial action. In order to set the priorities, CERCLA requires that criteria be established based on relative risk or danger.

On October 23, 1981, Environmental Protection Agency (USEPA) published an interim list of 115 priority sites under CERCLA. One of the interim sites so designated was an 18 mile segment of Whitewood Creek. The Whitewood Creek site was listed principally upon information provided to USEPA by the State

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**Mining Waste NPL Site Summary Report**  
**Wayne Interim Storage Facility/W.R. Grace**  
**Wayne, New Jersey**

**U.S. Environmental Protection Agency**  
**Office of Solid Waste**

**June 21, 1991**

**FINAL DRAFT**

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## **DISCLAIMER AND ACKNOWLEDGEMENTS**

The mention of company or product names is not to be considered an endorsement by the U.S. Government or by the U.S. Environmental Protection Agency (EPA). This document was prepared by Science Applications International Corporation (SAIC) in partial fulfillment of EPA Contract Number 68-WO-0025, Work Assignment Number 20. A previous draft of this report was reviewed by Bob Wing of EPA Region II [(212) 264-8670], the Remedial Project Manager for the site, whose comments have been incorporated into the report.

**WAYNE INTERIM STORAGE FACILITY/W.R. GRACE**

**WAYNE, NEW JERSEY**

**INTRODUCTION**

This Site Summary Report for the Wayne Interim Storage Facility/W.R. Grace site is one of a series of reports on mining sites on the National Priorities List (NPL). The reports have been prepared to support EPA's mining program activities. In general, these reports summarize types of environmental damages and associated mining waste management practices at sites on (or proposed for) the NPL as of February 11, 1991 (56 Federal Register 5598). This summary report is based on information obtained from EPA files and reports and a review by the EPA Region II Remedial Project Manager for the site, Bob Wing.

**SITE OVERVIEW**

The Wayne Interim Storage Facility/W.R. Grace NPL site consists of 6.5 acres located in Wayne Township, Passaic County, New Jersey. At this site, thorium and rare earth elements were extracted from monazite sands between 1948 and 1971 (Reference 1, pages 7 and 8). The facility is located in a primarily residential area; however, land within .25 mile of the site is also used for commercial, industrial, and agricultural purposes (Reference 2, page 7). The site is included in the Department of Energy's (DOE's) Formerly Utilized Sites Remedial Action Program (FUSRAP) (Reference 1, page 9).

Constituents of concern are thorium and decay products, radium-226, uranium and decay products, and radon (Reference 2, page 2). DOE is the Potentially Responsible Party (PRP). The site has been on the NPL since 1984 (Reference 1, page 9). Preliminary chemical and radioactive characterization and the removal of wastes from vicinity properties to an onsite storage pile has been conducted (Reference 1, page 10). DOE is currently conducting the Remedial Investigation (Reference 4).

**OPERATING HISTORY**

Beginning in 1948, Rare Earths, Incorporated, extracted thorium and rare earths from monazite ore on the site. W.R. Grace acquired Rare Earths, Incorporated, in 1957 and continued operations until 1971 (Reference 1, pages 7 and 8). After 1971, the site was licensed for storage only (Reference 1, page 8). Electronucleonics, Incorporated, operated the property from 1975 to 1983, using it for

office and storage space (Reference 1, page 8; Reference 2, page 10). W.R. Grace retained ownership until 1984, when DOE acquired the site (Reference 1, page 9). The site is intended to be an interim storage site until a permanent waste disposal site is established (Reference 1, page 9).

From 1985 to 1987, DOE excavated contaminated material from area property to an onsite storage area. Areas excavated included a bus maintenance facility, a township park, and property along Sheffield Brook and Pompton River. Approximately 38,500 cubic yards of waste is stored currently in an onsite pile, while an estimated 70,000 cubic yards of material is buried onsite (Reference 1, page 10). The buried wastes contain approximately 76 tons of thorium (Reference 5). Information concerning the buried wastes are incomplete due to an onsite fire in 1977 which destroyed burial records (Reference 1, page 8).

#### **SITE CHARACTERIZATION**

Due to limited investigation, incomplete information is available concerning the site. A series of radiation surveys were conducted from 1981 to 1983 by the New Jersey Department of Environmental Protection (NJDEP), EPA, and the Nuclear Regulatory Commission (NRC) (Reference 1, page 8). A report prepared by ERM in 1983 (Reference 6) characterized ground-water contamination at the site. Another report prepared in 1983 for the NRC (Reference 7) characterized surface and subsurface soil. Remedial Investigation field work has been initiated by DOE; however, results are not yet available (Reference 4).

#### **Ground Water**

The geology of the area consists of glacial deposits with a thickness of 20 to 50 feet overlying the Brunswick formation of sandstone and mudstone. Ground water is found in the unconsolidated glacial deposits as well as in the underlying bedrock aquifer (Reference 6). Both aquifers are sources of ground water for public water supply and industrial use, though the bedrock aquifer is the major source of ground water in the County (Reference 6).

Six onsite wells were installed in the uppermost aquifer in 1982, at depths ranging from 8.5 to 20 feet (Reference 6, page 3). At least four wells are downgradient of contaminated areas, while two are very close to contaminated areas. Sampling was conducted in December 1982 and January 1983 (Reference 6, page 3). Results of monitoring do not indicate that gross alpha levels in excess of the primary drinking water standard of 15 pico Curies per liter (pCi/l) are migrating beyond the facility boundary. Levels of gross alpha in downgradient ground-water wells ranged from Not Detected (ND) to 9 pCi/l, while levels of gross alpha in ground-water wells close to areas of contamination ranged

from 40 to 300 pCi/l. The pH of ground-water samples ranged from 4.6 to 11.5 (Reference 6, Table 2). Information concerning monitoring for other parameters and any additional conclusions on ground-water contamination were not presented in the available references.

### Soils

Levels of thorium-232, thorium-228, radium-226, and uranium-238 are summarized below (in Table 1) for surface and subsurface soil samples at 43 onsite locations (Reference 7, Table 3). Between one and six subsurface samples were collected from each location at depths of 0.5 to 6.3 meters.

**TABLE 1. TOTAL CONSTITUENT CONCENTRATION IN ONSITE SOIL (IN pCi/g)**

Location	Thorium-232	Thorium-228	Radium-226	Uranium-238
Surface	1.46-3970	1.20-4,000	0.59-930	ND-910
Subsurface	0.40-14,800	0.71-15,700	0.52-1,760	ND-653

No information on background soil levels for this area was presented (Reference 7, Table 3).

Available information from the 1983 Radiological Survey, from which these data were obtained, was incomplete (Reference 7). Therefore, sample dates, extent of contamination, and offsite contamination are not known.

### **ENVIRONMENTAL DAMAGES AND RISKS**

Aerial surveys conducted during 1981 and 1982 indicated elevated levels of radiation at the site and at an area west of the plant site (Reference 1, page 8). Radiological surveys conducted in 1982 and 1983 revealed offsite contamination of ground water, surface water, soil, and sediments with thorium, radium, and uranium (Reference 1, page 8). According to a separate 1982-1983 ground-water monitoring survey, data did not show gross alpha levels in the uppermost aquifer migrating beyond site boundaries at levels above the primary drinking water standard (Reference 6).

Characterization of the confluence of Sheffield Brook with the Pompton River in 1986 suggested that contamination was confined to the mouth of the Brook, and did not extend downstream into the river. In addition, following the excavation of portions of Sheffield Brook in 1987, no chemical contamination attributable to the site remained (Reference 1, page 10).

The area surrounding the site is primarily residential, with some commercial properties (Reference 2, page 7). The specific risks associated with the site were not provided in the available references.

#### **REMEDIAL ACTIONS AND COSTS**

Removal of waste from nearby properties to an onsite storage pile was conducted from 1985 to 1987 (Reference 1, page 10). According to EPA, the cost to remove, transport, and dispose of waste materials from three DOE FUSRAP sites in New Jersey is estimated by the NJDEP to be \$210,000,000. The volume of soil at the Grace site represents approximately 20 percent of the total volume of waste materials from the three sites.

#### **CURRENT STATUS**

An interagency agreement between EPA and DOE for site study and clean-up was signed on September 17, 1990. EPA is currently reviewing public comments received on the agreement. Field work is presently being conducted by DOE, although a work plan for the Remedial Investigation Feasibility Study has not been approved by EPA (Reference 4). Additional Remedial Investigation field work is expected to be initiated in the fall of 1991, while DOE expects a Record of Decision to be signed in 1994 (Reference 4; Reference 3).

## REFERENCES

1. Federal Facility Agreement; EPA and DOE; September 17, 1990.
2. Potential Hazardous Waste Site Inspection Report; EPA; undated (ca. 1984).
3. Letter Concerning Planning Documents for Remedial Investigation; From William M. Seay, DOE, to Bob Wing, EPA; February 26, 1991.
4. Telephone Communication Concerning Current Site Status; From Sue McCarter, SAIC, to Bob Wing, EPA; January 23, 1991.
5. Letter Concerning Transfer of Property; From B.L. Molbey, W.R. Grace, to Bernard Singer, Atomic Energy Commission; October 30, 1974.
6. Preliminary Investigation of Shallow Ground-water Contamination at the W.R. Grace Facility, Pompton Plains, New Jersey; Prepared for W.R. Grace by ERM Southeast, Inc.; March 1983.
7. Radiological Survey of the W.R. Grace Property, Wayne, New Jersey; Prepared for the U.S. Regulatory Commission by Radiological Site Assessment Program, Oak Ridge Associated Universities; January 1983.

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EPA. Potential Hazardous Waste Site Inspection Report. Undated (ca. 1984).

EPA and DOE. Federal Facility Agreement. September 17, 1990.

McCarter, Sue (SAIC). Telephone Communication Concerning Current Site Status to Bob Wing, EPA. January 23, 1991.

Molbey, B.L. (W.R. Grace). Letter Concerning Transfer of Property to Bernard Singer, Atomic Energy Commission. October 30, 1974.

Prepared for the U.S. Regulatory Commission by Radiological Site Assessment Program, Oak Ridge Associated Universities. Radiological Survey of the W.R. Grace Property, Wayne, New Jersey. January 1983.

Prepared for W.R. Grace by ERM Southeast, Inc. Preliminary Investigation of Shallow Ground-water Contamination at the W.R. Grace Facility, Pompton Plains, New Jersey. March 1983.

Seay, William M. (DOE). Letter Transmitting Planning Documents for Remedial Investigation to Bob Wing, EPA. February 26, 1991.

Stevens, Mary (SAIC). Telephone Communication Concerning Onsite Mining Activities to Bob Wing, EPA. Undated (ca. July 1990).



**Reference 1**

**Excerpts From Federal Facility Agreement; EPA and DOE;  
September 17, 1990**

525

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245

Based on the information available to the Parties on the effective date of this FEDERAL FACILITY AGREEMENT (Agreement), and without trial or adjudication of any issues of fact or law, the Parties agree as follows:

including the Site Remedial Investigation performed by DOE as described in Part XI (Remedial Investigation) below and Attachment 2.

## VI. FINDINGS OF FACT

For the purpose of this Agreement only, the following constitutes a summary of facts upon which this Agreement is based. None of the facts related herein shall be considered admissions by any Party with respect to any unrelated claims by a Party or by persons not a Party to this Agreement.

(1) During the 1940s and 1950s, the Manhattan Engineering District (MED) and its immediate successor, the Atomic Energy Commission (AEC), conducted several programs involving research, development, processing, and production of uranium and thorium, and the storing of their processing residues. Nearly all of this work involved some participation by private contractors and/or institutions. Generally, privately-owned and institutionally-owned sites that became contaminated during this early period of the nuclear program, and have since been converted to other use, were decontaminated or stabilized in accordance with the guidelines and survey methods then in existence.

(2) However, radiological guidelines have since become more stringent. As a result, the Department of Energy (DOE) initiated the Formerly Utilized Sites Remedial Action Program (FUSRAP) in 1974 with the singular mission of identifying, decontaminating, or otherwise controlling sites where low activity radioactive contamination (exceeding current guidelines) remains from the early years of the nation's atomic energy program or commercial operations causing conditions that Congress has authorized DOE to remedy.

(3) DOE has authority under the Atomic Energy Act to conduct Remedial Actions at a number of sites around the country. In addition to its authority under the Atomic Energy Act, Congressional Committee Reports accompanying the FY 1984 and FY 1985 Energy and Water Development Appropriations Acts, Public Laws 98-50 and 98-360, respectively, authorized DOE to conduct a decontamination research and development project at various New Jersey locations where radioactive contamination is present.

(4) In 1948, Rare Earths, Inc., began to extract thorium and rare earths from monazite sands at a six and a half acre site in Wayne Township, Passaic County, New Jersey. Upon passage of the Atomic Energy Act in 1954, Rare Earths, Inc., received an Atomic Energy Commission (AEC) license for this processing.

(5) In 1957, the Davison Chemical Division of W.R. Grace acquired Rare Earths, Inc.

(6) W.R. Grace continued operations at the site until July, 1971. After 1971, the site was licensed for storage only. During part of this time Electro-Nucleonics, Inc., rented the site for office and storage space.

(7) A railroad siding in Pequannock Township, New Jersey, was used for transfer of radioactive ores from railroad cars to trucks used to haul the ore the remaining distance (1-2 miles) to the site. During the transfer, some radioactive ore was spilled, resulting in contamination of about 400 cubic yards of soil near the area.

(8) From 1948 through 1971, radioactive processing wastes were buried on site. Some radioactive processing wastes were released to storm drains as liquid effluent. The storm drain empties into Sheffield Brook, which overflows its banks during periods of heavy rainfall, causing contamination from the processing operations to spread to nearby low-lying properties.

(9) In 1974, the Nuclear Regulatory Commission (NRC) assumed licensing responsibilities formerly held by the AEC.

(10) In 1974 and 1975, the site was partially decontaminated, then decommissioned and the storage license terminated. Some buildings and equipment were buried on site. The rest were decontaminated to then-current criteria. The site was released for unrestricted use, provided the land deed indicated radioactive material was buried on site.

(11) A fire in May, 1977, destroyed most of the early records that could have identified wastes and burial locations.

(12) EG&G performed aerial surveys of the W.R. Grace facility and areas west of the site in 1981 and 1982 for U.S. EPA at the request of the New Jersey Department of Environmental Protection (NJDEP). Results indicated radiation levels elevated above background in these areas.

(13) Further radiological surveys by NJDEP and by Oak Ridge Associated Universities for the U.S. Nuclear Regulatory Commission in 1982 and 1983 detailed areas of radiological contamination in the Sheffield Brook area, the township park, the right-of-way property, the school bus maintenance facility, the railroad siding and several other Vicinity Properties, as well as the W.R. Grace processing facility itself. Thorium, its daughter isotopes and related radionuclides, including thorium-232, radium-228, radium-226 and uranium-238, were identified in contaminated soil, surface water, sediments and groundwater to above background levels and in many cases above the applicable guidelines and standards. Borehole sampling indicated buried radioactive material to a depth of at least 16 feet.

(14) In December, 1982, W.R. Grace installed one deep and six shallow groundwater monitoring wells.

(15) Groundwater in the vicinity of the WISS is found in both the unconsolidated glacial deposits and the underlying bedrock. Groundwater in the unconsolidated material in the stratified glacial deposits is an important source of water for public supply and industrial use in Wanaque, Pompton Lakes and along the western side of Wayne Township. However, for the most part, these unconsolidated deposits have not been extensively explored and represent a potentially important source of groundwater for future development. Currently, the Brunswick formation is the major source of groundwater for public supply and industrial use in Passaic County.

(16) The W.R. Grace site was proposed to the National Priorities List (NPL) on September 8, 1983. The site was included on the NPL on September 21, 1984.

(17) Through Congressional action (PL98-50) in 1984, the site was included in DOE's FUSRAP program whereby DOE was authorized to conduct a decontamination research and development project related to the radioactive contaminants. Neither DOE nor its predecessor agencies had a role in the generation of this contamination.

(18) On September 18, 1984, DOE accepted the site from W.R. Grace in compliance with Congressional direction for use as an interim storage site, pending establishment of a permanent disposal site. DOE renamed the site the Wayne Interim Storage Site (WISS). Preparation for on-site interim waste storage involved demolishing two on-site buildings in 1985 to increase room for the storage pile, then building a cell complete with berm, liner, leachate collection system and impermeable covering. The drainage pattern on the WISS was improved to inhibit migration of radiological contamination from material buried on site.

(19) The agreement for DOE to accept the donation of real property and funds from W.R. Grace provides that it shall not affect the rights and liabilities of W.R. Grace under other existing applicable laws.

(20) From November, 1984, to January, 1985, DOE installed six bedrock (deep) and five overburden (shallow) groundwater monitoring wells in pairs, making a total of six groundwater monitoring locations around the perimeter of the site. These wells were installed as part of requirements for the NJDEP Emergency Groundwater Permit and New Jersey Pollutant Discharge Elimination System (NJPDES) permit.

(21) In 1984, DOE established a quarterly environmental monitoring program for air, surface water, groundwater, sediments and external gamma radiation. To meet NJPDES requirements, groundwater is sampled for radionuclides and selected chemicals each quarter. Annual environmental reports from DOE summarize the results of the monitoring.

(22) In January and February, 1985, DOE performed a limited chemical characterization of the site and found organic and inorganic compounds and metals. Previous characterizations indicated that hazardous substances included sulfuric acid, oxalic acid, hydrochloric acid, ammonium chloride, sodium metabisulfate, ammonium hydroxide and hexamine solutions.

(23) In 1985, DOE remediated the bus maintenance facility by removing contaminated soils to the WISS. A small section of the bus maintenance facility still above DOE guidelines was remediated in 1986 and the property was verified as clean.

(24) In 1985, the township park was excavated. A small remaining area still above DOE guidelines was excavated in 1986 and the property has been verified as clean.

(25) In 1986, two small areas from the front yard of the WISS and from the right-of-way property were excavated.

(26) Characterization of the confluence of Sheffield Brook with the Pompton River in 1986 by DOE suggested contamination was confined to the mouth of the brook and did not extend into the river or downstream.

(27) Also in 1986, an area along Sheffield Brook was excavated. In 1987, DOE completed excavation along Sheffield Brook and into the mouth of the brook where it entered the Pompton River. All excavated soils were placed in a storage pile on the WISS. Post-excavation radiological surveys of these areas were performed to ensure that no radionuclide concentrations above DOE guidelines remained. These excavated properties conform to all applicable radiological guidelines for their release with no radiological restrictions on its use.

(28) U.S. EPA performed oversight chemical analyses on the Sheffield Brook excavation during the summers of 1986 and 1987 to determine if chemical contamination remained. The results verified that no chemical contamination was present that was attributable to the WISS.

(29) The storage pile at the WISS contains about 38,500 cubic yards of contaminated material. In addition, about 70,000 cubic yards of FUSRAP Waste are buried on the site.

**Reference 2**

**Excerpts From Potential Hazardous Waste Site Inspection Report; EPA;  
Undated (ca. 1984)**







POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT  
PART 3 - DESCRIPTION OF HAZARDOUS CONDITIONS AND INCIDENTS

IDENTIFICATION  
STATE SITE NUMBER

II. HAZARDOUS CONDITIONS AND INCIDENTS

01 ☒ A GROUNDWATER CONTAMINATION  
03 POPULATION POTENTIALLY AFFECTED

02 ☐ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☒ POTENTIAL ☐ ALLEGED

no known contamination  
no potential contamination

01 ☒ B SURFACE WATER CONTAMINATION  
03 POPULATION POTENTIALLY AFFECTED

02 ☒ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☐ POTENTIAL ☐ ALLEGED

Stationary accumulation on waste pile - green material  
Drainage leads to Shippensburg Creek - then to Potomac River  
no known contamination  
no potential contamination

01 ☒ C CONTAMINATION OF AIR  
03 POPULATION POTENTIALLY AFFECTED

02 ☒ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☐ POTENTIAL ☐ ALLEGED

Odors in warehouse building adjacent to waste pile  
Drainage leads to waste pile - all known

01 ☐ D FIRE EXPLOSIVE CONDITIONS  
03 POPULATION POTENTIALLY AFFECTED

02 ☐ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☐ POTENTIAL ☐ ALLEGED

01 ☒ E DIRECT CONTACT  
03 POPULATION POTENTIALLY AFFECTED

02 ☒ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☒ POTENTIAL ☐ ALLEGED

10/82 p. 14  
Some contamination areas are visible in the area  
mainly in residential areas. Road is visible  
to the south of area. Future development  
will be in the area - constant

01 ☒ F CONTAMINATION OF SOIL  
03 AREA POTENTIALLY AFFECTED

02 ☒ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☐ POTENTIAL ☐ ALLEGED

buried material and grounds of process is contaminated  
brook sediment is contaminated as a result of discharge. Brook  
banks and immediate area contaminated  
potential contamination

01 ☒ G DRINKING WATER CONTAMINATION  
03 POPULATION POTENTIALLY AFFECTED

02 ☐ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☐ POTENTIAL ☐ ALLEGED

known via water

01 ☒ H WORKER EXPOSURE/INJURY  
03 WORKERS POTENTIALLY AFFECTED

02 ☐ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☒ POTENTIAL ☐ ALLEGED

no known exposure  
no known injury

01 ☒ I POPULATION EXPOSURE/INJURY  
03 POPULATION POTENTIALLY AFFECTED

02 ☐ OBSERVED (DATE) \_\_\_\_\_  
04 NARRATIVE DESCRIPTION

☒ POTENTIAL ☐ ALLEGED

contamination in the area of the site  
no known exposure  
no known injury



POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION  
PART 4 - PERMIT AND DESCRIPTIVE INFORMATION

IDENTIFICATION  
1. STATE 2. SITE NUMBER

II. PERMIT INFORMATION

01 TYPE OF PERMIT ISSUED (Circle all that apply)	02 PERMIT NUMBER	03 DATE ISSUED	04 EXPIRATION DATE	05 COMMENTS
<input type="checkbox"/> A NPDES				
<input type="checkbox"/> B UIC				
<input type="checkbox"/> C AIR				
<input type="checkbox"/> D RCRA				
<input type="checkbox"/> E RCRA INTERIM STATUS				
<input type="checkbox"/> F SPCC PLAN				
<input checked="" type="checkbox"/> G STATE (Specify)	1. WATER POLLUTION - INDUSTRIAL DISCHARGE - E			
<input type="checkbox"/> H LOCAL (Specify)				
<input checked="" type="checkbox"/> I OTHER (Specify) 1122	STA-422	11-21	1-2-81	1. 11-21-81
<input type="checkbox"/> J NONE				

III. SITE DESCRIPTION

01 STORAGE/ DISPOSAL (Circle all that apply)	02 AMOUNT	03 UNIT OF MEASURE	04 TREATMENT (Circle all that apply)	05 OTHER
<input checked="" type="checkbox"/> A SURFACE IMPOUNDMENT			<input checked="" type="checkbox"/> A INCINERATION	<input checked="" type="checkbox"/> A BUILDINGS ON SITE
<input checked="" type="checkbox"/> B PILES			<input type="checkbox"/> B UNDERGROUND INJECTION	
<input type="checkbox"/> C DRUMS, ABOVE GROUND			<input checked="" type="checkbox"/> C CHEMICAL/PHYSICAL	
<input type="checkbox"/> D TANK, ABOVE GROUND			<input type="checkbox"/> D BIOLOGICAL	
<input type="checkbox"/> E TANK, BELOW GROUND			<input type="checkbox"/> E WASTE OIL PROCESSING	
<input checked="" type="checkbox"/> F LANDFILL			<input type="checkbox"/> F SOLVENT RECOVERY	
<input type="checkbox"/> G LANDFARM			<input type="checkbox"/> G OTHER RECYCLING/RECOVERY	
<input checked="" type="checkbox"/> H OPEN DUMP			<input type="checkbox"/> H OTHER (Specify)	
<input type="checkbox"/> I OTHER (Specify)				

07 COMMENTS

IV. CONTAINMENT

01 CONTAINMENT OF WASTES (Circle all that apply)	<input type="checkbox"/> A. ADEQUATE, SECURE	<input type="checkbox"/> B. MODERATE	<input checked="" type="checkbox"/> C. INADEQUATE, POOR	<input type="checkbox"/> D. INSECURE, UNSOUND, DANGEROUS
02 DESCRIPTION OF DRUMS, DRUMS, LINERS, BARRIERS, ETC.				

V. ACCESSIBILITY

01 WASTE EASILY ACCESSIBLE	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
02 COMMENTS	INSUFFICIENT COVER

VI. SOURCES OF INFORMATION (Circle all that apply) (If other than owner, specify name, address, phone number)

STATE FILES



POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT  
PART 5 - WATER DEMOGRAPHIC AND ENVIRONMENTAL DATA

11 IDENTIFICATION  
C STATE/DC SITE NUMBER

VI ENVIRONMENTAL INFORMATION

01 PERMEABILITY OF UNSATURATED ZONE (check one)

☐ A  $10^{-6} - 10^{-8}$  cm/sec ☐ B  $10^{-4} - 10^{-6}$  cm/sec ☐ C  $10^{-2} - 10^{-3}$  cm/sec ☐ D GREATER THAN  $10^{-2}$  cm/sec

02 PERMEABILITY OF BEDROCK (check one)

☐ A IMPERMEABLE (less than  $10^{-6}$  cm/sec) ☐ B RELATIVELY IMPERMEABLE ( $10^{-6} - 10^{-8}$  cm/sec) ☐ C RELATIVELY PERMEABLE ( $10^{-4} - 10^{-5}$  cm/sec) ☐ D VERY PERMEABLE (greater than  $10^{-2}$  cm/sec)

03 DEPTH TO BEDROCK

~ 70 ft

04 DEPTH OF CONTAMINATED SOIL ZONE

~ 15 ft

05 SOIL pH

06 NET PRECIPITATION

(in)

07 ONE YEAR 24 HOUR RAINFALL

(in)

08 SLOPE

SITE SLOPE

DIRECTION OF SITE SLOPE

WEST

TERRAIN AVERAGE SLOPE

09 FLOOD POTENTIAL

SITE IS IN \_\_\_\_\_ YEAR FLOODPLAIN

10

☐ SITE IS ON BARRIER ISLAND COASTAL HIGH HAZARD AREA RIVERINE FLOODWAY

11 DISTANCE TO WETLANDS (in feet)

ESTUARINE

OTHER

A. \_\_\_\_\_ (ft)

B. \_\_\_\_\_ (ft)

12 DISTANCE TO CRITICAL HABITAT for endangered species

\_\_\_\_\_ (ft)

ENDANGERED SPECIES

13 LAND USE IN VICINITY

DISTANCE TO

COMMERCIAL/INDUSTRIAL

RESIDENTIAL AREAS NATIONAL/STATE PARKS,  
FORESTS, OR WILDLIFE RESERVES

AGRICULTURAL LANDS  
PRIME AG LAND

AG LAND

A.  $< 1/4$  (mi)

B.  $< 1/4$  (mi)

C. \_\_\_\_\_ (mi)

D.  $< 1/4$  (mi)

14 DESCRIPTION OF SITE IN RELATION TO SURROUNDING TOPOGRAPHY

PRIMARYLY RESIDENTIAL WITH A  
FEW COMMERCIAL PROPERTIES

VII SOURCES OF INFORMATION (check appropriate reference: F, S, M, R, P, A, L, N, O, U, V, W, X, Y, Z)

STATE FILES



POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT  
PART 7 - OWNER INFORMATION

IDENTIFICATION  
10 STATE SITE NUMBER

II. CURRENT OWNER(S)				PARENT COMPANY (if applicable)			
01 NAME		02 D-B NUMBER		03 NAME		04 D-B NUMBER	
WR GRACE & COMPANY							
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		05 STREET ADDRESS (P.O. Box, RFD, etc.)		06 SIC CODE	
P.O. Box 8117							
03 CITY	04 STATE	07 ZIP CODE		13 CITY		13 STATE	14 ZIP CODE
BALTIMORE	MD	21203					
01 NAME		02 D-B NUMBER		03 NAME		04 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		05 STREET ADDRESS (P.O. Box, RFD, etc.)		06 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		13 CITY		13 STATE	14 ZIP CODE
01 NAME		02 D-B NUMBER		03 NAME		04 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		05 STREET ADDRESS (P.O. Box, RFD, etc.)		06 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		13 CITY		13 STATE	14 ZIP CODE
01 NAME		02 D-B NUMBER		03 NAME		04 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		05 STREET ADDRESS (P.O. Box, RFD, etc.)		06 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		13 CITY		13 STATE	14 ZIP CODE
01 NAME		02 D-B NUMBER		03 NAME		04 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		05 STREET ADDRESS (P.O. Box, RFD, etc.)		06 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		13 CITY		13 STATE	14 ZIP CODE
III. PREVIOUS OWNER(S) (List most recent first)				IV. REALTY OWNER(S) (if applicable, list most recent first)			
01 NAME		02 D-B NUMBER		01 NAME		02 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		03 CITY		04 STATE	07 ZIP CODE
01 NAME		02 D-B NUMBER		01 NAME		02 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		03 CITY		04 STATE	07 ZIP CODE
01 NAME		02 D-B NUMBER		01 NAME		02 D-B NUMBER	
03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE		03 STREET ADDRESS (P.O. Box, RFD, etc.)		04 SIC CODE	
03 CITY	04 STATE	07 ZIP CODE		03 CITY		04 STATE	07 ZIP CODE
V. SOURCES OF INFORMATION (List sources referenced, e.g., EPA file, report number, etc.)							

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POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT  
PART 8 - OPERATOR INFORMATION

IDENTIFICATION

10 SITE NUMBER

II CURRENT OPERATOR <small>(If not a registered firm, name)</small>				OPERATOR'S PARENT COMPANY <small>(If applicable)</small>			
01 NAME <b>ELECTRONUCLEONICS INC</b>		02 D-B NUMBER		10 NAME		11 D-B NUMBER	
03 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small> <b>868 BLACK OAK RIDGE RD</b>		04 SIC CODE		12 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		13 SIC CODE	
05 CITY <b>WAYNE</b>		06 STATE 07 ZIP CODE <b>NY 07470</b>		14 CITY		15 STATE 16 ZIP CODE	
08 YEARS OF OPERATION <b>1975-PRES</b>		09 NAME OF OWNER <b>ENI</b>					
III PREVIOUS OPERATOR(S) <small>(List most recent first; provide only if operator firm changes)</small>				PREVIOUS OPERATORS' PARENT COMPANIES <small>(If applicable)</small>			
01 NAME <b>WR GRAZE</b>		02 D-B NUMBER		10 NAME		11 D-B NUMBER	
03 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small> <b>BLACK OAK RIDGE RD</b>		04 SIC CODE		12 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		13 SIC CODE	
05 CITY <b>WAYNE</b>		06 STATE 07 ZIP CODE <b>NY 07470</b>		14 CITY		15 STATE 16 ZIP CODE	
08 YEARS OF OPERATION <b>194-1975</b>		09 NAME OF OWNER DURING THIS PERIOD <b>WR GRAZE</b>					
01 NAME		02 D-B NUMBER		10 NAME		11 D-B NUMBER	
03 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		04 SIC CODE		12 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		13 SIC CODE	
05 CITY		06 STATE 07 ZIP CODE		14 CITY		15 STATE 16 ZIP CODE	
08 YEARS OF OPERATION		09 NAME OF OWNER DURING THIS PERIOD					
01 NAME		02 D-B NUMBER		10 NAME		11 D-B NUMBER	
03 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		04 SIC CODE		12 STREET ADDRESS <small>(P.O. Box, RFD, etc.)</small>		13 SIC CODE	
05 CITY		06 STATE 07 ZIP CODE		14 CITY		15 STATE 16 ZIP CODE	
08 YEARS OF OPERATION		09 NAME OF OWNER DURING THIS PERIOD					

IV. SOURCES OF INFORMATION (List sources referenced, e.g., local files, agency records, etc.)

STATE FILES



POTENTIAL HAZARDOUS WASTE SITE  
SITE INSPECTION REPORT  
PART 10 - PAST RESPONSE ACTIVITIES

IDENTIFICATION

STATE SITE NUMBER

II. PAST RESPONSE ACTIVITIES

01 ☐ A WATER SUPPLY CLOSED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ B TEMPORARY WATER SUPPLY PROVIDED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ C PERMANENT WATER SUPPLY PROVIDED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ D SPILLED MATERIAL REMOVED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ E CONTAMINATED SOIL REMOVED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ F WASTE REPACKAGED  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ G WASTE DISPOSED ELSEWHERE  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☒ H ON SITE BURIAL  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☒ I IN SITU CHEMICAL TREATMENT  
04 DESCRIPTION

02 DATE

03 AGENCY

PART OF NORMAL NRC L. JENSEN, NOT

01 ☐ J IN SITU BIOLOGICAL TREATMENT  
04 DESCRIPTION

02 DATE

03 AGENCY

PART OF NRC REFERENCE

01 ☒ K IN SITU PHYSICAL TREATMENT  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ L ENCAPSULATION  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ M EMERGENCY WASTE TREATMENT  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ N CUTOFF WALLS  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ O EMERGENCY DIKING/SURFACE WATER DIVERSION  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ P CUTOFF TRENCHES/SUMP  
04 DESCRIPTION

02 DATE

03 AGENCY

01 ☐ Q SUBSURFACE CUTOFF WALL  
04 DESCRIPTION

02 DATE

03 AGENCY

**Reference 3**

**Letter Concerning Planning Documents for Remedial Investigation,  
From William M. Seay, DOE, to Bob Wing, EPA;  
February 26, 1991**



# Department of Energy

Oak Ridge Operations  
P O. Box 2001  
Oak Ridge, Tennessee 37831 - 8723

91-113

*Project file:*  
*WAYNE*

February 26, 1991

Mr. Robert Wing  
Federal Facilities Section  
EPA Region II  
Jack K. Javits Federal Building  
New York, New York 10278

Dear Mr. Wing:

## DRAFT WAYNE SCOPING/PLANNING DOCUMENTS FOR EPA REVIEW

Enclosed are ten copies each of the scoping/planning documents for the remedial investigation/feasibility study-environmental impact study (RI/FS-EIS) for the Wayne site in Wayne, New Jersey. Each set of documents consists of a work plan, a field sampling plan which will direct the radiological/chemical/geological investigations, a quality assurance project plan, a health and safety plan, and a community relations plan. The geological investigation was completed in the fall of 1989 and chemical sampling of the storage pile was completed in the fall of 1990.

As specified in the Wayne site Federal Facilities Agreement (FFA), these documents are being submitted to the Environmental Protection Agency (EPA) for review and comment. The FFA also states that a 60-day comment period is allowed for EPA's review; therefore, we hope to receive your comments by April 30, 1991. EPA and subsequent public review of these documents is on the critical path for initiating the remedial investigation field work this fall. Any acceleration or delay in the review cycle will directly affect the start date for the field work.

To expedite and simplify your review, please don't hesitate to contact me at any time at FTS 626-1830. You may also feel free to contact Rick Robertson at Bechtel with technical comments. Rick can be reached at FTS 626-4718. We look forward to working with you on finalizing the remedial investigation approach for the Department of Energy's responsibilities related to the overall Wayne site.

Sincerely,

William M. Seay, Deputy Director  
Former Sites Restoration Division

## Enclosures

cc: Rick Robertson, BNI  
Larry Jensen, ANL  
Jim Wagoner, DOE-HQ  
Peter J. Gross, DOE



**Reference 4**

**Telephone Communication Concerning Current Site Status;  
From Sue McCarter, SAIC, to Bob Wing, EPA;  
January 23, 1991**

**TELECOMMUNICATIONS  
SUMMARY REPORT**

SAIC Contact: Sue McCarter

Date: 1/23/91

Time: 10:30 a.m.

Made Call  X  Received Call    

Person(s) Contacted (Organization): Bob Wing, EPA, (212) 264-8670

Subject: Current status of W.R. Grace

Summary: DOE signed the Interagency Agreement on July 23, 1990, and EPA signed the agreement on September 17, 1990. Even though the agreement had been signed, it went through a public comment period that ended on November 19, 1990. EPA is now in the process of reviewing these comments and anticipates completing the review by late February. Once the agreement becomes effective, EPA can request a schedule from DOE on completing the Remedial Investigation. DOE has provided EPA with a draft work plan, not submitted for review since it had not received full clearance from DOE. However, DOE began field work in the absence of a work plan and Interagency Agreement. Most field work has been done, although no schedule was negotiated. Bob feels a Remedial Investigation may be available by the fall of 1991. DOE said it expects a ROD in 1994, but EPA has responded unofficially that it does not accept that date. (Also, since the work plan will most likely be submitted after field work has been completed, EPA has reserved the right to request additional field work if it does not approve DOE's work plan.)

Regarding NJDEP's proposal to ship waste to a disposal facility in Utah, Bob says the Remedial Investigation/Feasibility Study must be completed and an in-depth characterization of the waste must be performed before shipments can be considered. The facility may or may not accept the waste since DOE characterizes it as by- product materials. The Utah disposal permit does not allow acceptance of this type of waste yet; and, the disposal facility is not equipped with a cell to accept this type of waste. It must first obtain an amendment to its license and then construct an appropriate cell to accept W.R. Grace's waste.

2-1-91

**Reference 5**

**Letter Concerning Transfer of Property;  
From B.L. Molbey, W.R. Grace, to Bernard Singer, Atomic Energy Commission;  
October 30, 1974**

REGULATORY OPERATIONS

40-56



W.R. GRACE & CO., DAWSON CHEMICAL DIVISION  
CHARLES & BALTIMORE STREETS, BALTIMORE, MD. 21203 ■ 301 727 3900

October 30, 1974

Mr. Bernard Singer  
Chief, Materials Licensing  
United States Atomic Energy Commission  
Washington, D. C. 20545

Attention: Mr. Buchanan

Re: License STA-422



Gentlemen:

We have applied for a Release of our property at 868 Black Oak Ridge Road, Wayne Township, New Jersey, from AEC Storage License STA-422. This property was inspected on September 20, 1974, by Mr. Epstein, of the AEC Compliance Section at King of Prussia, Pennsylvania. I understand that he recommended approval of our application on the basis of his inspection.

On Tuesday, October 29, I called Mr. McClintock to ask him to trace our application, which seems to be lost somewhere between his office and yours. Mr. McClintock informed me that when he forwarded Mr. Epstein's report, he recommended that certain items of information, not included in Applied Health Physics' decontamination report, be developed; namely:

- (1) The total amount of radioactive materials buried on the site,
- (2) An evaluation to show that the buried material will not be washed into local streams by erosion of the surface of the burial area, and
- (3) An assurance that future owners of the property will not excavate or in any way disturb the buried material.

I submit the following in answer to these questions:

- (1) Our records show total burials of 7.7 curies of thorium or 152,350 pounds buried in accordance with 10CFR20.

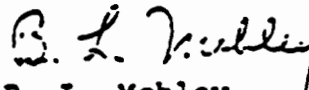
W.R.GRACE & CO.  
DAVISON CHEMICAL DIVISION

Mr. Bernard Singer  
October 30, 1974  
Page 2

- (2) The burial area was graded, dressed with over 600 yards of fill dirt, and seeded. Numerous measurements of the drainage from the area failed to disclose any radio-activity of the runoff water. The area is already generating its own crop of grass and weeds. Judging by past experience, it will be further stabilized with fast-growing tree seedlings from the adjacent woods within a season or two. The grading was done so as to enhance proper drainage and minimize erosion. Retainer walls were erected where deemed necessary to further reduce any chance of erosion. Several hard rains have been experienced since completion of the job, and no significant erosion has been observed.
- (3) We expect to sell the property to Electro-Nucleonics, Inc., presently tenants renting office and storage space, as soon as the facilities are released as per our application. The conditions of sale will include a deed restriction against disturbing in any way the buried material. This restriction will be made binding on any future resale of the property.

I trust this will satisfy the questions raised by Mr. McClintock's transmittal of Mr. Epstein's compliance inspection report. If there are any further questions, please don't hesitate to call me at (301) 727-3900.

Very truly yours,



B. L. Mobley  
Supervisor  
Environmental Control

BLM:nbs

cc: Mr. R. McClintock  
U. S. Atomic Energy Commission  
Directorate of Regulatory Operations  
Region I  
631 Park Avenue  
King of Prussia, Pennsylvania 19406

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**Reference 6**

**Excerpts from Preliminary Investigation of Shallow Ground-water Contamination  
at the W.R. Grace Facility, Pompton Plains, New Jersey;  
Prepared for W.R. Grace by ERM Southeast, Inc.;  
March 1983**

PRELIMINARY INVESTIGATION OF SHALLOW GROUND-WATER  
CONTAMINATION AT THE W.R. GRACE FACILITY  
POMPTON PLAINS, NEW JERSEY

March, 1983

Prepared For:

W.R. Grace & Company

Prepared by:

ERM-Southeast, Inc.  
P.O. Box 881  
Brentwood, Tennessee 37027

information as well as the available well logs in the Area indicate that the thickness of the unconsolidated glacial deposits beneath the W.R. Grace facility are expected to range from 20-30 feet. The drilling log of the on-site artesian well reports a total of 37 feet of unconsolidated deposits at the site.

The Brunswick Formation of the Triassic age underlies the unconsolidated glacial deposits at the W.R. Grace facility (Figure 4). This bedrock formation typically consists of alternating beds of reddish-brown sandstone and mudstone. The texture of the bedrock is generally coarser in the northern part of the area than in the southern part. In the general area of the site, the Brunswick Formation typically forms broad valleys between the Watchung Mountains and the gently rolling lowlands east of the First Watchung Mountains. The underlying bedrock generally has a monoclinial dip of 10-15 degrees west, however, locally, steeper dips can be found throughout the area. Minor north trending normal faults cut the Triassic rocks in several areas. The Brunswick Formation contains vertical joints with the major joint sets being parallel and transverse to the strike of the beds.

Ground-Water Hydrology - Ground-water in the vicinity of the W.R. Grace facility is found in both the unconsolidated glacial deposits as well as the underlying Brunswick Formation. The occurrence and movement of ground-water in the unconsolidated deposits are controlled by intergranular openings in the deposits, whereas ground-water in the consolidated bedrock occurs in and moves through cleavage planes, joints, fractures, and faults. These secondary openings in the consolidated bedrock form a comparatively small volume in comparison to the total volume of rock. These openings also become fewer and tighter with increased depth below the land surface.

548 The total ground-water flow system in Passaic County is a few hundred feet thick and is comprised of several small basins separated by divides which approx-



systems in Passaic County are reported to be generally small with the largest system underlying an area of only a few square miles. No regional ground-water flow system underlies the entire county.

The stratified glacial deposits of Quaternary age are an important source of ground-water for public supply and industrial use in Wanaque and Pompton Lakes and along the western side of Wayne township. However, for the most part, these unconsolidated deposits have not been extensively explored and represent a potentially important source of ground-water for future development according to the USGS. These stratified glacial deposits generally yield larger quantities of water to individual wells than do the other major geologic units in Passaic County. Recorded yields of wells in these unconsolidated deposits range from 4 to 920 gallons per minute with the median yields of domestic wells being approximately 16 gallons per minute and those of public and industrial wells being approximately 130 gallons per minute. Most wells tapping the unconsolidated glacial deposits are between 50 and 125 feet deep.

The Brunswick Formation which underlies the unconsolidated deposits in the vicinity of the W.R. Grace facility is the most important aquifer in Passaic County. This formation is the major source of ground-water for public supply and industrial use in the county. Yields of public and industrial wells in the vicinity are reported to range from 20 to 510 gallons per minute with a median yield of approximately 130 gallons per minute. Most of the high yielding wells tapping the Brunswick Formation are located in the valleys in the more industrial areas in Hawthorne, Patterson, Clifton, and Passaic and are located in or on the flank of pre-glacial valleys containing comparatively thicker unconsolidated deposits. These locations are conducive to higher recharge rates to the bedrock aquifer. Domestic wells tapping the Brunswick Formation typically have much smaller yields with a median reported yield of approximately 16 gallons per minute. Most domes

industrial wells range between 200 and 400 feet deep.

#### Field Investigations

The field investigations implemented as part of this project were conducted to determine gross alpha radiation levels in the shallow ground-water system underlying the W.R. Grace facility. A total of six shallow ground-water monitoring wells were installed at the W.R. Grace site during the weeks of December 13, and December 20, 1982. Two of these new on-site monitoring wells (EN-5 and EN-6) were located in close proximity to known waste disposal sites. The four remaining wells were located west of the known areas of waste disposal to provide more representative data of ground-water quality downgradient of the facility. The locations of the six on-site monitoring wells are depicted in Figure 6.

The six ground-water monitoring wells were drilled and installed by the Warren-George Drilling Company under the direct supervision of a staff geologist from ERM, Inc. Each of the ground-water monitoring wells was constructed of 2-inch pipe equipped with a 5-foot section of 0.02 inch slotted PVC pipe. An outer protective steel casing was installed at monitoring wells EN-1, EN-4, EN-5, and EN-6, and equipped with locable steel caps. Monitoring wells EN-2 and EN-3 were required to be completed flush with the ground surface with screw-on caps being installed. The total depths for each of the ground-water monitoring wells installed at the site are as follows: EN-1, 10 feet; EN-2, 10 feet; EN-3, 3.5 feet; EN-4, 20 feet; EN-5, 14 feet; and EN-6, 20 feet. Individual drilling logs depicting construction details of each monitoring well are provided in Appendix II.

The materials encountered during the installation of the on-site monitoring wells indicated primarily a heterogeneous mixture of sands, silts, and clays. At monitoring well EN-1, a brown, silty fine sand was encountered from approxi-

ately 3 to 10 feet. At monitoring wells EN-2, EN-3, and EN-4, the underlying materials consisted of a mixture of sand, silty, and clay. At monitoring wells EN-5 and EN-6, a light gray sandy muck material, believed to possibly be waste materials, was encountered in each of these borings. Due to the drilling method utilized to install these monitoring wells, it was impossible to identify any stratification in the underlying deposits. In order to aid in the future classification of the unconsolidated deposits encountered during the installation of these monitoring wells, as well as for possible determination of gross alpha radiation concentrations, shelly tube samples were collected at varying intervals at each of the on-site monitoring wells. The depth of each shelly tube sample in the on-site borings is provided in the drilling logs contained in Appendix II.

Following the completion of installation of the on-site ground-water monitoring wells, the first set of ground-water samples was collected on December 20 and 21, 1982 by ERM personnel. The initial ground-water sample from each well was collected without purging any water from the well. Samples from the wells were collected utilizing a one-inch PVC bottom-filling bailer with individual samples being collected in 500 milliliter unpreserved polyethylene sample containers. Prior to sampling each well, the depth to water level from the top of casing was measured utilizing an electric water level indicator. Following the collection of the initial sample at each well, each well was bailed until the well was essentially dry.

Following collection of the initial ground-water samples, two subsequent samples were collected from each well with the exception of monitoring well EN-6 from which only one subsequent sample was collected. The ground-water samples collected subsequent to the initial sample were collected following extensive bailing of each well between collection of water samples. The third sample from monitoring well EN-6 was not collected due to the time delays incurred in

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plastic container. Water levels were also obtained from each well immediately prior to sampling. Water level measurements obtained prior to sampling on January 13, 1983, as well as the water level and pH measurements obtained on January 12, are summarized in Table 1.

Monitoring wells EN-1, EN-3, EN-5, and EN-6 were sampled without any recharge problems. However, monitoring wells EN-2 and EN-4 required recovery periods of approximately 1 hour and 3 hours, respectively, before a complete one-gallon sample could be collected. The on-site artesian well was also sampled during this survey with one-gallon samples being collected at depths of 5 feet and 190 feet using a Kemmerer sampler. A more detailed discussion of the second sampling survey is provided in Appendix III along with the ground-water sampling data sheets which summarize the sampling of each monitoring well.

Although further investigation is necessary to determine the actual levels of gross alpha in the ground-water beneath the W.R. Grace site, the results available to date do not show a concentration distribution which would indicate that gross alpha levels in excess of the primary drinking water standard (5 pCi/liter) were migrating beyond the boundaries of the facility. The higher levels of gross alpha have been detected at locations where they would be expected with decreasing levels being found with increased distance from the waste disposal sites. The low gross alpha levels detected in monitoring wells EN-1, EN-3, and EN-4 located near the site boundaries reveal gross alpha levels below 15 pCi/liter at these locations. However, it should be noted that the heterogeneous nature of the underlying geologic materials as well as the uncertainties associated with the exact locations of waste materials can result in a highly variable area and vertical waste migration pattern.

The ground-water level measurements made to date from the on-site monitoring wells reveal a highly variable ground-water surface beneath the site (Figure 6). This is due to the <sup>h?</sup> heterogeneous nature of the underlying deposits as well as the presence of the waste disposal areas. As expected, the higher ground-water levels are present to the east in the area of actual waste disposal with the apparent hydraulic gradient being toward the west. The considerably higher ground-water levels measured in monitoring wells EN-5 and EN-6 are most likely due to the presence of waste materials and generally distributed nature of deposits in that area as a result of waste disposal activities. The considerably lower ground-water elevation observed in well EN-1 when compared to wells EN-2, EN-3, and EN-4 indicates the variability in the underlying geologic deposits and their hydraulic characteristics.

#### Recommendations

Based upon the limited available data base pertaining to geologic and grou

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### Results of Field Investigations

Information generated to date during the field investigations conducted as part of this preliminary assessment program is limited to the analytical results of the first series of samples collected during the initial December 1982 survey and water level measurements obtained during both the December 1982 and the January 1983 surveys. The analytical results for the December 1982 and January 1983 sampling surveys are provided in Tables 2 and 3, respectively, with the water level measurements from the on-site wells being summarized in Table 4. Analytical results for the January 1983 sampling survey are not available from the Environmental Science & Engineering Laboratory.

The distribution of gross alpha levels detected in the two ERM-Southeast surveys shows higher levels in the areas of known waste disposal sites (wells EN-5 and EN-6) with decreasing levels being detected with increased distance from these known disposal sites. Gross alpha levels at wells EN-1 and EN-4 located near the property boundaries showed much lower gross alpha levels than detected in the area of the waste disposal sites.

TABLE 1

WATER-LEVEL AND pH MEASUREMENTS  
W.R. GRACE - POMPTON PLAINS, N.J.

<u>Well</u>	<u>pH*</u>	<u>Water level from top of casing</u>	
		<u>1/12/83</u>	<u>1/13/83</u>
EN-1	5.5	5.58'	5.84'
EN-2	6.0	1.15'	3.30'
EN-3	5.3	0.80'	2.64'
EN-4	5.0	5.17'	14.00'
EN-5	5.5	4.57'	4.73'
EN-6	5.0	4.90'	8.69'
Artesian	5.0	4.13'	—

\*pH paper utilized to obtain field pH readings.

TABLE 2

GROSS ALPHA RESULTS FOR GROUND-WATER SAMPLES  
COLLECTED DURING DECEMBER 1961  
W.R. GRACE FACILITY, POMPTON PLAINS

<u>Sample Number</u>	<u>pH<sub>a</sub></u>	<u>Gross Alpha pCi/l</u>
EN 1-1	8.0	7 $\pm$ 2
EN 1-2	6.9	5 $\pm$ 2
EN 1-3	6.8	3 $\pm$ 2
EN 2-1	11.5	0 $\pm$ 2
EN 2-2	8.0	3 $\pm$ 2
EN 2-3	6.8	2 $\pm$ 2
EN 3-1	6.4	4 $\pm$ 2
EN 3-2	7.0	6 $\pm$ 3
EN 3-3	7.0	2 $\pm$ 2
EN 4-1	7.3	5 $\pm$ 2
EN 4-2	7.3	3 $\pm$ 2
EN 4-3	7.3	9 $\pm$ 2
EN 5-1	4.6	50 $\pm$ 10
EN 5-2	5.7	90 $\pm$ 20
EN 5-3	6.5	40 $\pm$ 10
EN 6-1		300 $\pm$ 30
EN 6-2		300 $\pm$ 30
Deep Well Surface		9 $\pm$ 2
Deep Well Bottom (190')		5 $\pm$ 2
Deep Well Bottom #2 (190')		11 $\pm$ 2

\*pH paper utilized to obtain field pH readings.



**Reference 7**

**Excerpts from Radiological Survey of the W.R. Grace Property, Wayne, New Jersey;  
Prepared for the U.S. Regulatory Commission by Radiological Site Assessment Program,  
Oak Ridge Associated Universities; January 1983**

RADIOLOGICAL SURVEY  
OF THE  
W.R. GRACE PROPERTY  
WAYNE, NEW JERSEY

Prepared for

Division of Fuel Cycle and Material Safety  
U.S. Nuclear Regulatory Commission

P. W. Frame

Project Staff

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Prepared by

Radiological Site Assessment Program  
Manpower Education, Research, and Training Division  
Oak Ridge Associated Universities  
Oak Ridge, Tennessee 37830

FINAL REPORT

January 1983

This report is based on work performed under Interagency Agreement: DOE No. 40-770-80, NRC Fin. No. A-9093 between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Associated Universities performs complementary work under contract number DE-AC05-76OR00033 with the U.S. Department of Energy.

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### Appendices

Appendix A: Glossary of Terms

Appendix B: Thorium and Uranium Decay Series

Appendix C: Ground-Penetrating Radar Survey of  
the W.R. Grace Site, Wayne, New Jersey

Appendix D: Major Analytical Equipment

Appendix E: Analytical Procedures

**TABLE 3**  
**RADIONUCLIDE CONCENTRATIONS IN ON-SITE**  
**BOREHOLE SOIL SAMPLES**

Sample Location <sup>a</sup>	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-232	Ra-226	U-238
B1	Surface	4.36 ± 0.59 <sup>b</sup>	4.22 ± 0.40	1.20 ± 0.25	<4.67
	0.5	1.12 ± 0.34	1.10 ± 0.24	0.62 ± 0.19	<2.62
	0.75	0.96 ± 0.25	1.09 ± 0.23	0.88 ± 0.18	<2.53
B2	Surface	5.41 ± 0.65	5.34 ± 0.51	1.34 ± 0.31	<4.51
	0.5	1.14 ± 0.36	0.96 ± 0.25	0.74 ± 0.16	<2.59
	1.0	0.96 ± 0.26	0.93 ± 0.26	0.70 ± 0.17	<1.86
B3	Surface	5.31 ± 0.73	6.17 ± 0.65	2.29 ± 0.40	<5.45
	0.5	1.44 ± 0.31	1.35 ± 0.29	1.01 ± 0.20	1.49 ± 0.52
	0.75	1.05 ± 0.29	1.05 ± 0.23	0.64 ± 0.17	<2.69
B4	Surface	3.45 ± 0.67	3.76 ± 0.57	1.30 ± 0.34	<4.73
	0.5	0.99 ± 0.24	1.10 ± 0.21	0.72 ± 0.17	<2.62
B5	Surface	4.19 ± 0.66	4.40 ± 0.53	1.39 ± 0.36	1.54 ± 0.57
	0.5	1.54 ± 0.42	2.07 ± 0.32	1.14 ± 0.24	<2.76
B6	Surface	1.67 ± 0.30	1.73 ± 0.26	0.88 ± 0.20	<2.81
	0.5	1.43 ± 0.37	1.45 ± 0.27	1.35 ± 0.22	<2.34
	1.0	1.32 ± 0.32	1.38 ± 0.31	1.03 ± 0.20	<3.56
B7	Surface	1.46 ± 0.49	1.20 ± 0.33	0.79 ± 0.23	<1.93
	0.5	0.89 ± 0.25	0.87 ± 0.27	0.69 ± 0.18	<2.93
	0.75	0.84 ± 0.27	0.91 ± 0.21	0.59 ± 0.16	<2.61
B8	Surface	1.47 ± 0.38	1.41 ± 0.29	1.12 ± 0.24	<3.17
	0.5	1.62 ± 0.43	1.60 ± 0.35	1.63 ± 0.28	<2.95
	1.0	1.53 ± 0.37	1.45 ± 0.35	1.12 ± 0.24	<3.38
B9	Surface	1.91 ± 0.33	1.59 ± 0.31	0.65 ± 0.21	<3.22
	0.5	2.38 ± 0.44	2.43 ± 0.35	0.93 ± 0.23	<3.33
	1.0	4.98 ± 0.51	4.92 ± 0.48	0.89 ± 0.26	5.54 ± 0.52
B10	Surface	39.7 ± 1.3	30.0 ± 1.0	2.17 ± 0.54	<6.95
	0.5	31.9 ± 1.2	25.3 ± 0.9	1.15 ± 0.38	16.6 ± 0.5
	2.4	1.90 ± 0.34	1.54 ± 0.30	0.79 ± 0.20	18.4 ± 0.6
B11 <sup>c</sup>	Surface	258 ± 3	227 ± 3	14.4 ± 1.4	29.5 ± 0.7
	0.5	196 ± 3	181 ± 3	8.35 ± 1.26	35.0 ± 0.9
	0.75	191 ± 3	182 ± 3	7.08 ± 1.19	53.0 ± 0.9

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE  
BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-232	Ra-226	U-238
B12	Surface	56.8 ± 1.6	45.5 ± 1.3	3.60 ± 0.61	11.1 ± 0.6
	0.5	16.6 ± 0.9	8.64 ± 0.60	2.29 ± 0.35	15.4 ± 0.6
B13	Surface	13.8 ± 0.9	12.8 ± 0.8	2.57 ± 0.49	8.8 ± 0.6
	0.5	4.41 ± 0.53	4.78 ± 0.44	1.24 ± 0.27	<4.16
	1.0	5.04 ± 0.55	4.84 ± 0.52	0.91 ± 0.24	<3.93
	2.0	1.20 ± 0.28	1.43 ± 0.27	0.80 ± 0.21	<2.62
B14	Surface	10.9 ± 1.0	11.2 ± 0.6	2.79 ± 0.41	9.19 ± 0.55
	0.5	6.45 ± 0.58	5.73 ± 0.48	2.32 ± 0.34	4.77 ± 0.51
	1.0	6.88 ± 0.58	5.86 ± 0.48	2.59 ± 0.34	<4.84
B15	Surface	3970 ± 30	4080 ± 30	296 ± 16	1910 ± 4
	0.5	702 ± 22	785 ± 15	477 ± 11	559 ± 3
	1.0	4630 ± 30	5150 ± 30	782 ± 19	653 ± 3
B16	Surface	1750 ± 10	1860 ± 10	1930 ± 9	205 ± 1
	0.5	565 ± 8	437 ± 9	370 ± 6	185 ± 1
	1.0	366 ± 7	392 ± 5	171 ± 4	123 ± 1
B17	Surface	6.21 ± 0.60	6.02 ± 0.57	1.41 ± 0.32	41.0 ± 0.8
	0.5	33.4 ± 1.6	30.5 ± 1.1	11.8 ± 0.7	30.2 ± 0.6
	1.0	88.6 ± 2.1	55.7 ± 1.5	5.02 ± 0.79	40.1 ± 0.8
B18	Surface	23.5 ± 1.1	18.0 ± 0.9	4.41 ± 0.55	40.4 ± 0.7
	0.5	17.8 ± 1.0	15.3 ± 0.8	4.32 ± 0.45	26.2 ± 0.6
	1.0	36.0 ± 1.3	23.8 ± 1.0	4.32 ± 0.56	16.4 ± 0.6
B19	Surface	13.1 ± 0.80	10.4 ± 0.6	1.53 ± 0.32	<4.71
	0.5	<2.59	<0.75	<1.17	<42.9
	1.0	9.37 ± 0.82	10.0 ± 0.7	1.69 ± 0.39	10.5 ± 0.5
	1.5	3.45 ± 0.41	3.21 ± 0.35	1.02 ± 0.22	3.46 ± 0.50
	2.0	1.23 ± 0.29	1.23 ± 0.23	0.83 ± 0.19	<2.60
	2.5	1.09 ± 0.28	1.06 ± 0.22	0.81 ± 0.21	<2.39
	4.8	17.9 ± 1.0	17.1 ± 0.9	1.51 ± 0.41	4.62 ± 0.50
B20	Surface	195 ± 3	135 ± 2	5.83 ± 0.97	<12.3
	0.5	990 ± 11	931 ± 9	27.4 ± 4.6	<68.7
	1.7	842 ± 8	617 ± 8	16.2 ± 3.1	248 ± 85
B21	Surface	206 ± 3	212 ± 4	14.0 ± 1.5	39.6 ± 0.8
	0.5	406 ± 7	376 ± 6	14.6 ± 2.5	<34.0
	1.7	616 ± 9	355 ± 5	<1.76	<39.3

TABLE 3, cont.

**RADIONUCLIDE CONCENTRATIONS IN ON-SITE  
BOREHOLE SOIL SAMPLES**

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-226)	Th-232	Ra-226	U-238
B22	Surface	595 ± 8	568 ± 9	59.4 ± 4.1	<51.9
	0.5	7570 ± 50	7040 ± 40	1760 ± 20	180 ± 1
B23	Surface	106 ± 4	118 ± 3	48.7 ± 2.0	<18.7
	0.5	69.6 ± 3.8	75.5 ± 3.2	38.9 ± 1.4	<15.2
	1.0	169 ± 5	189 ± 4	115 ± 3	<24.4
B24	Surface	643 ± 9	589 ± 6	253 ± 5	<49.7
	0.5	430 ± 4	458 ± 4	200 ± 3	18.9 ± 0.7
	1.0	293 ± 4	436 ± 4	79.8 ± 2.1	45.7 ± 0.8
B25	Surface	47.2 ± 1.6	41.6 ± 1.3	8.16 ± 0.73	<8.08
	0.5	31.8 ± 1.5	27.8 ± 1.0	5.99 ± 0.63	<6.56
	1.0	2.93 ± 0.42	3.04 ± 0.32	1.11 ± 0.22	<2.89
	2.0	1.32 ± 0.33	1.38 ± 0.26	0.89 ± 0.20	<3.13
B26	Surface	14.8 ± 0.8	15.0 ± 0.7	7.27 ± 0.53	0.74 ± 0.53
	0.5	18.2 ± 1.0	17.1 ± 0.8	9.74 ± 0.63	<5.84
	1.0	8200 ± 500	7660 ± 500	101 ± 146	106 ± 2
B27	Surface	34.2 ± 1.8	31.9 ± 1.7	3.49 ± 0.80	<9.73
	0.6	3190 ± 20	3160 ± 20	555 ± 14	44.4 ± 1.1
B28	Surface	21.4 ± 1.2	21.7 ± 1.0	4.13 ± 0.56	<6.52
	0.5	9.24 ± 0.72	10.3 ± 0.6	6.51 ± 0.43	2.68 ± 0.48
	1.0	0.91 ± 0.22	0.96 ± 0.19	0.59 ± 0.14	<2.34
	1.5	0.85 ± 0.25	0.96 ± 0.25	0.61 ± 0.18	<2.27
	3.2	4.34 ± 0.56	4.14 ± 0.50	1.23 ± 0.36	<4.18
B29	Surface	184 ± 3	150 ± 3	20.5 ± 1.3	<14.9
	0.5	390 ± 5	347 ± 4	41.6 ± 2.0	46.2 ± 0.8
	1.0	1150 ± 10	808 ± 7	84.5 ± 4.6	79.8 ± 1.0
	3.9	14800 ± 700	15700 ± 600	1450 ± 300	110 ± 1
B30	Surface	46.9 ± 1.5	44.4 ± 1.3	5.33 ± 0.67	<7.02
	1.0	3080 ± 30	2280 ± 20	343 ± 12	53.1 ± 1.0
B31	Surface	26.8 ± 1.1	30.0 ± 1.0	3.43 ± 0.53	<5.88
	0.5	10.7 ± 0.9	13.5 ± 0.6	1.67 ± 0.32	<4.13
	1.0	4.82 ± 0.49	5.95 ± 0.53	0.90 ± 0.28	<3.42
	4.8	35.7 ± 1.4	33.0 ± 1.2	3.76 ± 0.49	<6.67

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TABLE 3, cont.  
RADIONUCLIDE CONCENTRATIONS IN ON-SITE  
BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-232	Ra-226	U-238
B32	Surface	33.1 ± 1.0	26.4 ± 0.9	3.89 ± 0.40	<5.83
	0.5	309 ± 3	254 ± 3	23.9 ± 1.5	26.3 ± 0.7
B33	Surface	47.6 ± 1.6	49.3 ± 1.4	8.42 ± 0.76	<9.02
	0.5	26.7 ± 1.1	24.3 ± 0.9	3.02 ± 0.51	<5.83
	5.4	3.91 ± 0.43	3.60 ± 0.37	1.19 ± 0.27	<3.32
B34	Surface	171 ± 3	178 ± 3	26.5 ± 1.6	<17.9
	0.3	55.1 ± 2.0	57.1 ± 1.5	7.47 ± 0.79	<9.19
	0.5	62.0 ± 1.8	67.3 ± 1.6	11.2 ± 0.8	<9.57
B35	Surface	1.58 ± 0.34	1.48 ± 0.30	0.89 ± 0.22	<3.33
	0.5	2.02 ± 0.30	1.77 ± 0.31	0.81 ± 0.21	<3.32
	1.0	2.01 ± 0.41	2.13 ± 0.29	0.83 ± 0.22	<2.64
	2.0	1.04 ± 0.39	1.21 ± 0.23	0.70 ± 0.17	<2.86
	3.0	1.50 ± 0.30	1.30 ± 0.24	0.81 ± 0.18	<2.59
	6.3	1.27 ± 0.36	1.20 ± 0.28	0.96 ± 0.22	<3.55
B36	Surface	28.0 ± 1.5	29.5 ± 1.1	3.35 ± 0.53	<6.43
	0.5	1.04 ± 0.33	1.21 ± 0.31	0.70 ± 0.22	<2.79
	1.0	1.10 ± 0.29	1.15 ± 0.25	0.62 ± 0.17	<2.78
	2.0	1.35 ± 0.28	1.26 ± 0.24	0.60 ± 0.16	<3.10
	2.5	1.51 ± 0.31	1.21 ± 0.25	0.74 ± 0.18	<2.76
B37	Surface	114 ± 1	112 ± 2	17.3 ± 0.7	18.7 ± 0.6
	0.5	60.4 ± 1.3	51.6 ± 1.1	28.5 ± 0.7	15.9 ± 0.7
B38	Surface	1.98 ± 0.33	1.85 ± 0.34	1.14 ± 0.19	<2.60
	2.0	1.35 ± 0.29	1.41 ± 0.24	0.84 ± 0.19	<0.10
B39	Surface	2.05 ± 0.32	1.91 ± 0.27	0.81 ± 0.18	<2.76
	2.0	2.50 ± 0.38	2.22 ± 0.30	0.92 ± 0.21	<2.90
B40	Surface	2.75 ± 0.42	2.53 ± 0.32	1.79 ± 0.23	<2.60
	0.5	0.88 ± 0.36	1.01 ± 0.29	0.61 ± 0.20	<3.66
	1.8	0.40 ± 0.33	0.55 ± 0.24	0.53 ± 0.15	<2.57
B41	Surface	2.23 ± 0.40	2.24 ± 0.12	0.59 ± 0.20	<3.45
	0.5	1.03 ± 0.33	1.18 ± 0.25	0.61 ± 0.17	<3.09
	1.8	0.67 ± 0.22	0.71 ± 0.23	0.52 ± 0.18	<2.85

TABLE 3, cont.

**RADIONUCLIDE CONCENTRATIONS IN ON-SITE  
BOREHOLE SOIL SAMPLES**

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)						
		Th-232 (Ra-228)		Th-228		Ra-226		U-238
B42	Surface	2.34 ±	0.42	4.22 ±	0.37	0.66 ±	0.20	<3.07
	0.5	2.29 ±	0.35	3.91 ±	0.36	0.78 ±	0.20	<3.19
	1.0	0.66 ±	0.23	2.51 ±	0.30	0.58 ±	0.14	<2.93
	1.5	0.76 ±	0.25	2.37 ±	0.27	0.40 ±	0.14	<2.09
	3.3	2.26 ±	0.35	5.66 ±	0.40	0.60 ±	0.22	<2.63
B43	Surface	12.9 ±	0.8	17.5 ±	0.8	1.64 ±	0.36	<5.23
	0.5	0.82 ±	0.25	3.22 ±	0.32	0.58 ±	0.18	<2.42
	1.0	1.07 ±	0.30	2.55 ±	0.29	0.58 ±	0.20	<2.60
	3.6	7.04 ±	0.58	8.43 ±	0.55	0.79 ±	0.27	1.38 ± 0.47

<sup>a</sup> Refer to Figure 10.

<sup>b</sup> Error is 2σ based on counting statistics only.

<sup>c</sup> Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.



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TABLE 4  
RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES

Sample Location <sup>a</sup>	Description	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
D1	Drainage Stream	5.28 ± 0.72 <sup>b</sup>	5.04 ± 0.56	1.70 ± 0.35	<4.46
D2	Drainage Stream	2.29 ± 0.55	1.77 ± 0.43	0.51 ± 0.31	<4.05
D3	Drainage Stream	4.72 ± 0.64	2.75 ± 0.43	0.76 ± 0.39	<3.84
D4	Drainage Stream	2.03 ± 0.32	1.73 ± 0.31	0.63 ± 0.20	<2.61
D5	Drainage Tile	5.12 ± 0.46	4.70 ± 0.39	1.31 ± 0.24	<3.22
D6	Drainage Tile	9.17 ± 0.78	9.78 ± 0.59	1.77 ± 0.32	<4.14
D7	Drainage Tile	18.0 ± 1.0	19.1 ± 0.9	3.04 ± 0.47	<6.14
D8	Storm Sewer	16.8 ± 1.0	17.5 ± 0.8	3.65 ± 0.48	6.03 ± 0.51
D9	Storm Sewer	23.4 ± 1.0	25.2 ± 0.9	3.89 ± 0.47	13.6 ± 0.6
D10	Storm Sewer	43.2 ± 1.5	38.7 ± 1.2	4.12 ± 0.61	19.9 ± 0.7
D11	Storm Sewer	24.7 ± 1.3	24.4 ± 1.0	3.67 ± 0.51	<6.36
D12	Storm Sewer	383 ± 4	327 ± 3	30.2 ± 1.8	24.5 ± 0.8
D13	Storm Sewer	78.2 ± 1.9	70.0 ± 1.6	5.37 ± 0.77	12.7 ± 0.6
D14	Storm Sewer	951 ± 6	866 ± 5	101 ± 3	46.9 ± 1.0
D15	Storm Sewer	10.9 ± 0.8	9.57 ± 0.63	1.49 ± 0.33	<4.26

Refer to Figure 12.

Error is 2σ based on counting statistics only.

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