

**Review and Evaluation of Characterization Data Provided
for Fansteel Corporation, Muskogee, Oklahoma**

Submitted to:

**Thomas Fredrichs
U.S. NRC**

Prepared by:

ICF Consulting

Under contract NRC-02-00-001 and Task No. 006

November 15, 2002

This page left blank intentionally.

Table of Contents

1.0	Introduction	1
2.0	Background	3
2.1	Site History	3
2.1.1	Site Location and Setting	3
2.1.2	History of Site Operations	4
2.1.3	Process Details and Locations	5
2.2	Overview of Site Characterization	8
2.3	Decontamination and Remediation Activities	8
3.0	Site Characterization Review Methodology	9
3.1	Review of Applicable Sampling Guidance	9
3.2	Regulatory Levels of Interest	12
3.3	Integrated Review Methodology	14
3.4	Steps to Determine if Additional Characterization is Needed	17
3.5	Cost of Additional Sampling	18
4.0	Buildings	19
4.1	Summary of Existing Characterization	19
4.1.1	Characterization Methodology	19
4.1.2	Characterization Techniques	20
4.1.3	Characterization Results	21
4.2	Identification of Potential Gaps in Characterization	31
4.3	Assumptions about Extent of Contamination and Recommendations for Additional Characterization	33
4.4	Costs Associated with Additional Characterization	34
5.0	Groundwater	42
5.1	Summary of Existing Characterization	42
5.1.1	Unconsolidated Aquifer	43
5.1.2	Bedrock Aquifer	53
5.2	Identification of Potential Gaps in Characterization	55
5.3	Assumptions about Extent of Contamination and Recommendations for Additional Characterization	58
5.4	Costs Associated with Additional Characterization	59
6.0	Ponds	60
6.1	Summary of Existing Characterization	61
6.1.1	Pond 2	62
6.1.2	Pond 3	64
6.1.3	Pond 5	67
6.1.4	Ponds 6 and 7	70
6.1.5	Pond 8	72

6.1.6	Pond 9	74
6.2	Identification of Potential Gaps in Characterization	77
6.3	Assumptions about Extent of Contamination and Recommendations for Additional Characterization	80
6.4	Costs Associated with Additional Characterization	81
7.0	Soils	82
7.1	Summary of Existing Characterization	82
7.2	Identification of Potential Gaps in Characterization	89
7.3	Assumptions about Extent of Contamination and Recommendations for Additional Characterization	92
7.4	Costs Associated with Additional Characterization	93
8.0	Surface Water and Sediments	95
8.1	Summary of Existing Characterization	95
	8.1.1 Surface Water	95
	8.1.2 Surface Sediment	99
8.2	Identification of Potential Gaps in Characterization	100
8.3	Assumptions about Extent of Contamination and Recommendations for Additional Characterization	101
8.4	Costs Associated with Additional Characterization	101
9.0	Conclusions	102
10.0	Bibliography	104

Attachment 1: Aerial Photographs of the Fansteel Site from 1973, 1984, and 2001

List of Figures

	<u>Located After Page</u>
Figure 1. Fansteel Facility Layout	4
Figure 2. Fansteel Building Locations	23
Figure 3. Monitoring Well Locations and Groundwater Contours	42
Figure 4. February 1993 Shallow Groundwater Sampling Results	45
Figure 5. 1996 Shallow Groundwater Sampling Results	49
Figure 6. Pond Sampling Locations	61
Figure 7. Soil Sampling locations	82
Figure 8. Surface Contamination Found Through Survey	84
Figure 9. Soil Contamination Found Through Sampling	90
Figure 10. Soil Contamination Below 4 Feet Deep	90
Figure 11. Surface Water and Sediment Sampling Locations	95

List of Tables

Table 1. Radiological Limits for Soil, Surface Water and Sediment, Pond Residue, and Groundwater at the Fansteel Site	13
Table 2. Radiological Limits for Equipment and Structures at the Fansteel Site	13
Table 3. Unit Costs of Additional Sampling by Media	18
Table 4. Characterization Measurements for Buildings	20
Table 5. Fansteel Remediation Limits for Buildings - Thorium	21
Table 6. Fansteel Radiation Limits for Uranium	22
Table 7. Fansteel Surface Release Limits	22
Table 8. Release Limits Established in NRC License	23
Table 9. Building Characteristics and Survey Results	35
Table 10. Monitoring Well Installation Data	44
Table 11. February 1993 Sampling Results for Gross Alpha and Gross Beta	46
Table 12. February 1993 Sampling Results for Individual Isotopes	47
Table 13. Summary of 1994 Monthly Groundwater Monitoring	48
Table 14. Summary of 1996 Quarterly Groundwater Monitoring	50
Table 15. February 1993 Sampling Results for Total Metals	51
Table 16. February 1993 Sampling Results for Dissolved Metals	52
Table 17. Volatile Organic Results in Groundwater	52
Table 18. Monitoring Well Installation Data	53
Table 19. Spring 1993 Sampling Results for Gross Alpha and Beta	54
Table 20. Spring 1993 Sampling Results for Individual Isotopes	54
Table 21. Summary of 1994 Monthly Groundwater Monitoring	55
Table 22. Summary of 1995 Quarterly Groundwater Monitoring	55
Table 23. February 1993 Sampling Results for Total Metals	55
Table 24. Estimated Costs Associated with Additional Groundwater Monitoring	59
Table 25. Radionuclide Concentrations in Pond 2	63
Table 26. Non-radioactive contaminants in Pond 2	64
Table 27. Radionuclide Concentrations in Pond 3	66
Table 28. Non-radioactive Contaminant Concentrations in Pond 3	67
Table 29. Radionuclide Concentrations in Pond 5	69
Table 30. Non-radioactive Contaminant Concentrations in Pond 5	69
Table 31. Radionuclide Concentrations in Pond 6	70
Table 32. Non-radioactive Contaminant Concentrations in Pond 6	71
Table 33. Radionuclide Concentrations in Pond 7	71
Table 34. Non-radioactive Contaminant Concentration in Pond 7	72
Table 35. Radionuclide Concentrations in Pond 8	73
Table 36. Non-radioactive Contaminant Concentrations in Pond 8	74
Table 37. Radionuclide Concentrations in Pond 9	76
Table 38. Non-Radioactive Contaminant Concentrations in Pond 9	77
Table 39. Results of Isotopic Analysis for Soils	86
Table 40. Results of TCLP Metals Analysis for Soils	88
Table 41. Estimated Costs Associated with Additional Surface Soil Sampling	94

Table 42. Estimated Costs Associated with Additional Subsurface Soil Sampling 94
Table 43. Radionuclide Concentrations in Surface Water 96
Table 44. Radiological Effluent Monitoring Results at Outfall 001 97
Table 45. Radiological Effluent Monitoring Results at Outfall 001 During 1991 to 1996 98
Table 46. Radionuclide Concentrations in Surface Sediments 100
Table 47. Summary of Costs of Recommended Additional Characterization 103

This page left blank intentionally.

1.0 Introduction

The Fansteel, Inc. facility is one of approximately 40 sites the U.S. Nuclear Regulatory Commission (NRC) has identified in its Site Decommissioning Management Plan (SDMP) as exceeding NRC criteria for unrestricted use that require special attention to ensure timely decommissioning.^{1,2}

From 1956 to 1989, Fansteel produced tantalum and columbium metal products. The operations included processing raw materials that exhibit low-level radioactivity from naturally occurring radioactive species, specifically uranium and thorium. Fansteel began reprocessing residues sometime after submitting an application for a license amendment in January 1995, but operations ceased in November 2001. On January 15, 2002 when Fansteel, Inc. filed a petition for bankruptcy.

The Fansteel site, located in Muskogee, Oklahoma, is approximately 110 acres in size and contains numerous structures and contaminated areas, including ponds, buildings, and a waste pile. A 1993 site survey conducted by Earth Sciences found radioactive contamination in buildings, soil, and groundwater. A groundwater treatment system has been in place since January 2000. According to NRC's 2001 decommissioning program status report, Fansteel has decontaminated approximately 35 acres of the facility designated as the Northwest Property Area (NWP). The NRC has released the NWP, where processing of licensed materials did not occur, for unrestricted use (Materials License SMB-911, Condition 9) and therefore will not require any further remediation. All processing activities took place on the remaining 75 acres in the eastern portion of the site, where buildings and soil that will require remediation are located. In 1997, NRC submitted questions to Earth Sciences concerning specific details about Fansteel that were undetermined or unclear in the 1993 Remediation Assessment. Following the response from Earth Sciences, NRC conducted an environmental assessment of the Fansteel site. In June and August of 1999, Earth Sciences completed two parts of a Decommissioning Plan for Fansteel, which has since been withdrawn.

The 1999 Decommissioning Plan included a cost estimate for decommissioning the site of \$4.5 million, based on (1) the assumption that materials in the ponds would be reprocessed to recover metal values and residue radioactive contamination and (2) the assumption that the license would be terminated under restricted release criteria that allows for the contaminated soils at the site to be placed in an onsite containment cell. This plan assumes a restricted release scenario for 6 to 12 acres around the containment cell, with the remaining portion of the approximately 110 acre

¹ Material in Sections 1 and 2 is taken from Remediation Assessment, Fansteel Inc., Muskogee, Oklahoma, Volume 1, Earth Science, December 1993; Environmental Assessment, License Amendment for Material License No. SMB-911, Docket 40-7580, U.S. Nuclear Regulatory Commission, December 1997; Decommissioning Plan for Fansteel, Earth Sciences, June and August 1999; Response to the NRC Environmental Assessment Comment Request, Earth Sciences, February 20, 1997; Facility Background and Operating Data, Fansteel, Inc., 1995; and information gathered during the site visit conducted on June 18, 2002.

² NUREG-1444, Site Decommissioning Management Plan, U.S. Nuclear Regulatory Commission, October 1993.

site being cleaned up for unrestricted release (e.g., potential radiological dose to the average member of the critical group will not exceed 25 mrem/yr).

As noted above, the 1999 Decommissioning Plan has been withdrawn. Fansteel submitted a revised cost estimate for decommissioning under unrestricted release criteria of approximately \$57 million on June 19, 2002.

As a result of the uncertainties surrounding the magnitude of the liability for cleanup and its potential effect on the bankruptcy proceedings, the NRC has requested that ICF Consulting (ICF) develop an independent decommissioning cost analysis and unrestricted and restricted release cost estimates.

This report presents ICF's review of the prior characterization data, including a summary of the available data, an evaluation of the completeness of these data, and suggestions regarding additional data that could increase the current understanding of the site and refine future cost estimates. ICF made its suggestions for additional data primarily to identify information that would be needed to increase the accuracy and precision of the decommissioning cost estimate. In areas where data is not available, the conservative approach must assume levels of contamination that may be higher than actual, in order to assure that the decommissioning cost estimate does not fall short. As a result of this approach, ICF's suggestions to obtain additional data represent engineering judgement rather than regulatory requirements. ICF also notes that the identified data gaps will aid in the formulation of assumptions used to estimate decommissioning costs under Tasks 3 and 4 of ICF's Task Order. Lastly, ICF neither validated nor reevaluated the quality assurance/quality control data associated with the analytical data provided by NRC and Fansteel, Inc. ICF used these data at "face value" to gain an understanding of the Fansteel site.

This introduction constitutes Section 1 of this report. Section 2 of this report provides an overview of the site history, and Section 3 discusses the characterization review methodology. Sections 4 through 8 discuss the various investigations of buildings, groundwater, ponds, soils, and surface water and sediments, respectively. Section 9 presents ICF's conclusions regarding the adequacy of site characterization, the need for additional characterization activities, and information related to the costs of such additional sampling and analysis by media. Section 10 provides a list of documents used in the preparation of this report.

2.0 Background

This section presents an overview of the site, a short summary of the site's history, an overview of characterization studies to date, and a description of known decontamination and remediation events conducted at the site.

2.1 Site History

2.1.1 Site Location and Setting

The Fansteel, Inc. facility occupies approximately 110 acres of land at a location approximately 2.5 miles northeast of the town of Muskogee, Oklahoma. The Arkansas River (Webber Falls Reservoir) forms the eastern edge of the site, which is bounded on the north by land owned by Muskogee Port Authority, on the south by U.S. Highway 62, and on the west by State Highway 165 and a service road. The nominal river elevation adjacent to the site is about 490 feet above mean sea level. The site is located in a generally rural area with rolling hills and agricultural land. Various sources indicate that the closest residential areas are located anywhere from 0.25 mile to 1.5 miles to the north, west, and south. The site is located on the U.S. Geological Survey Northeast Muskogee 7.5 minute quadrangle topographical map at North 35°46'28" latitude and West 95°18'12" longitude.

The site lies in the Central Lowlands physiographic province. The regional structure of the area consists of a broad fold that is part of the Ozark Uplift to the northeast. The facility was constructed on alluvial soils and unconsolidated alluvium that range from approximately 8 to 35 feet thick and are underlain by shale bedrock that consists of sandstone, shale siltstone and limestone. The natural soils consist of silty and sandy clay, fine sand, and coarse sand. The soils are deep and occur on high terraces. According to the U.S. Bureau of Mines, the residues at this facility represent the largest deposit of scandium, a rare earth element, in the world outside the former Soviet Union.

The facility is located in a region classified as an area with low to moderate seismic risk. Furthermore, the Unified Building Code has classified the area as being in seismic hazard zone 1, which indicates only minimal damage would occur during an earthquake. No flooding has been recorded at the Fansteel site since 1969, which is when the Floodplain Administrator for Muskogee County began maintaining flood records. Additionally, Federal Emergency Management Administration (FEMA) documentation indicates that Fansteel is outside the 500-year floodplain.

As expected in an area adjacent to a major river, the water table at the site is shallow. Groundwater flows largely toward the river with minor variations due to the topographic influences and possibly also due to site structures. The depth of water ranges from about 5.8 to 29.5 feet and averages about 16 feet. The groundwater is suitable for irrigation and for domestic, stock, and limited industrial purposes. The Muskogee Municipal Authority is not aware of any shallow aquifer use for drinking water in the local area.

2.1.2 History of Site Operations

The Fansteel site was undeveloped until the facility was constructed in 1956. Fansteel produced tantalum metal and columbium oxide extracted from ore and slag feedstock for approximately 33 years until operations ceased in December 1989.³ Fansteel continues to occupy the site, although its operations have been limited to environmental monitoring; maintenance of buildings, grounds and equipment remaining at the site; and the cleanup of operating areas. Figure 1 shows the layout of the Fansteel facility.

Historical processing operations included grinding raw materials and digesting them in hydrofluoric acid, then treating them with a variety of solvents and other materials to extract tantalum and niobium, and finally purifying them to produce tantalum and niobium powders. Approximately 9,000 dry tons of sludges resulting from operations are contained in Ponds 2, 3, and 5. Another estimated 78,500 dry tons of sludges resulting from wastewater treatment activities are currently stored in Ponds 6, 7, 8, and 9. In addition, operations contaminated buildings, soils, and groundwater on site.

The facility was built for the purpose of producing tantalum and columbium metal products. Tantalum is used in the electrical/electronics industry in the production of tantalum capacitors, as well as in aerospace and transportation applications. Columbium is used as an alloying element in steels and in superalloys. The raw materials that the facility processed, tantalum and columbium ores and tin slag, exhibit low-level radioactivity from naturally occurring radioactive species, specifically uranium and thorium. Because the radionuclides uranium oxide and thorium oxide are sometimes present at concentrations greater than 0.05 percent, the materials are subject to NRC regulation under 10 CFR 40, Domestic Licensing of Source Material. The Fansteel facility operated under NRC License No. SMB-911, which controls the handling and processing of the ores and slags and the handling and storage of the process materials that contain the source material.

In January 1995, the facility applied for an NRC license in order to permit the processing of ore residues, calcium fluoride residues, and wastewater treatment residues contained in various site impoundments (collectively referred to as "work in progress" (WIP) residues hereafter). The original work schedule indicated that Fansteel would terminate its license (SMB-911) after another 10 to 12 years of additional waste residue reprocessing. However, on January 15, 2002, Fansteel, Inc. filed a petition for bankruptcy, indefinitely discontinuing its reprocessing operation. This metals recovery process was a commercial venture, not a decommissioning activity; however, the processing of the WIP residue facilitated decommissioning. During processing, certain metals and rare earths, such as scandium, columbium, and tantalum, were removed from the WIP residues while simultaneously achieving a significant reduction in the volume of radioactive materials which would have been relocated to the containment cell described in Fansteel's 1999 decommissioning plan.

³ Columbium is the commonly used synonym for the element niobium.

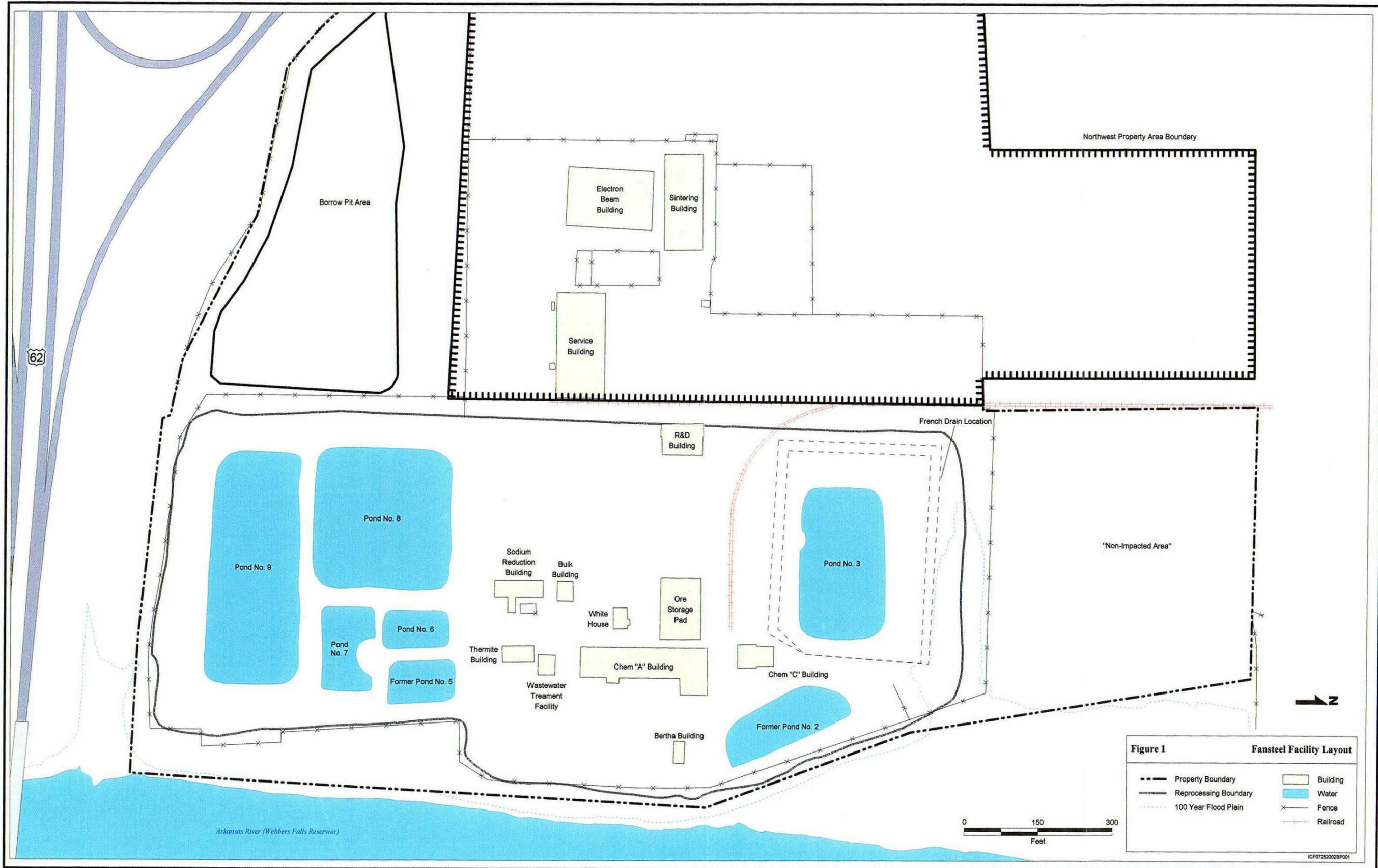


Figure 1 Fansteel Facility Layout

--- Property Boundary	□ Building
--- Reprocessing Boundary	■ Water
--- 100 Year Flood Plain	× Fence
	— Railroad

0 150 300
Feet



ICF07252002BP001

The facility also indicated a desire to reprocess wastewater from its ponds to extract calcium fluoride for re-sale. The reprocessing activities are very similar to the original process of extracting metals and rare earths. The principle difference between Process 1 (extraction) and Process 2 (reprocessing) was how the different types of feed material were addressed in the front end of the processes.

Currently, about eight personnel maintain the plant in a standby mode. The only aspects of the site in operational mode include security, safety, the wastewater treatment plant, groundwater treatment, environmental monitoring, the plant boilers and air compressors, security, and routine maintenance.

2.1.3 Process Details and Locations

Processing Ores and Slags

Fansteel procured tantalum and columbium ores from several international locations. Slag was acquired from tin-smelting operations in Thailand. Drummed and bagged ores and slags arrived at the facility via truck and train and were placed on the drum storage pad until they were required for production. Ore also was stored in the area west of the Sodium Reduction Building and north of Pond 8. The following summary provides a generic description of the processing of ores and tin slag into refined tantalum metal and columbium oxide. Because Fansteel's process is patented and proprietary, this report does not discuss Fansteel's specific process in detail.⁴

- Step 1:** Ore and tin slag are broken down to form tantalum and columbium salts or oxides. The raw materials, tin slag and ore, are ground and digested with aqueous hydrofluoric acid and/or sulfuric acid, forming fluoride salts of the metals. The ore are pulverized then transferred to the ore or slag feeder for dissolution. This material is fed into a vessel containing hydrofluoric acid. The digestion of the ore and slag with hydrofluoric acid usually takes place in a batch process. The solvent 4-methyl-2-pentanone, also known as methyl isobutyl ketone (MIBK), is used to extract and decant the hydrofluoric acid. The solid by-product residues from the ore digestion process are typically stored in impoundments. (The trace uranium and thorium contained in the ore and tin slag remained in these residues, thereby classifying it as source material licensed by the NRC).
- Step 2:** A liquid-liquid extraction procedure separates the dissolved tantalum and columbium salts from one another. First, MIBK is used to extract the tantalum salt. Next, hydrofluoric acid is added to change the solubility so that the MIBK can extract the columbium salt. This process generates wastewater containing spent hydrofluoric acid, which is discharged to wastewater treatment for

⁴ The description of the processing steps was obtained in whole or in part from the description of tantalum, columbium, and ferrocolumbium processing in "Technical Background Document, Identification and Description of Mineral Processing Sectors and Waste Streams," U.S. Environmental Protection Agency, April 1998, pp. 633-647.

neutralization and removal of fluoride. Fugitive air fumes are typically controlled by wet scrubbers, which generated wastewater.

- Step 3: Using de-ionized water, the salts are recovered from each MIBK solution. Barren MIBK is leftover from this process and is recycled.
- Step 4: Potassium fluoride and anhydrous ammonia are added in order to precipitate tantalum pentoxide and columbium pentoxide, respectively. The resulting crystals are washed and dried then calcined in a kiln. A wet scrubber may be used to control the fluoride fumes generated. Condensing, capturing, and discharging control the wastewater generated during this process.
- Step 5: The salts are reduced to metal using a process known as sodium reduction, which produced both columbium and tantalum metal from their salts. In the process, layers of either columbium or tantalum salt are alternated with layers of sodium in a reaction vessel, then capped with sodium chloride to prevent oxidation of the reduced metal. The reaction mixture is often ignited electrically, but once ignited, the exothermic reaction is self-sustaining. After cooling, the columbium or tantalum metal-containing material is crushed into a powder. These powders are further purified by magnetically extracting iron and leaching with water, followed by washing with nitric or hydrofluoric acid to eliminate free iron and nickel and to lower the oxygen which accumulated during milling.

At Fansteel, the process steps likely occurred in the Chemical A Building, the Chemical C Building, and the Sodium Reduction Building. Additional reagents that may have been used, but were not specified above, include sodium hydroxide and sodium chloride.

Wastewater Process Flow

The following describes the flow of wastes that occurred between ponds, buildings, and the wastewater treatment plant (WWTP) during operations:

- The WWTP received the following:
 - Process water from Chemical A Building #1
 - Process water from Chemical A Building #2
 - Process water from Pond 1S
 - Process water from Sodium Reduction Building
 - Calcium Fluoride from the Ammonia Stripper, which was installed in 1977
- The Ammonia Stripper received process water from Chemical A Building #2.
- Treated process water was sent to Ponds 8 and 9, which sent decanted water to Pond 7, which sent process water to Pond 6, which released the supernatant through permitted Outfall 001 while the precipitant remained in the ponds.

- Processing residues were placed in Ponds 1S, 1N, 2, 3, and 5.
- Permitted Outfall 003 discharged surface water from the northern area of the site, where the Chemical C Building, Pond 2, and Pond 3 are located. It also discharged storm water from the southeast area, where Pond 3 and the Chemical A Building are located.
- On June 18, 1989, a large supernatant discharge from Pond 3 occurred from the wet well and french drain system adjacent to the pond and several seeps near the southwestern corner of the pond, causing portions of the french drain system to collapse. An estimated 90,000 gallons of fluid was released into the Arkansas River before the discharge was arrested. Fansteel notified the National Response Center, the State Response Commission, the Muskogee Local Emergency Committee, and NRC immediately after the release was brought under control and again in writing on June 22, 1989. The fluids from Pond 3 and temporary ponds subsequently were removed and routed to the plant's wastewater treatment system as directed by the NRC. The release resulted in contamination of adjacent soils with some source material. As part of the remediation strategy, the site was required to perform a remediation assessment of the entire property. The assessment was completed in 1993 by Earth Sciences. Environmental assessment documents associated with amendment of the NRC license were prepared in 1994 and 1997. Cleanup activities were immediately undertaken and subsequent characterization revealed no radiological impact as supported by the 1993 Remediation Assessment. After the incident, Pond 3 did not receive liquid residues from ore/slag processing. Filter presses were put into operation to remove solid material from the acidic process water stream before further processing. Filtered solid materials were placed in 55-gallon drums and stored on the barrel storage pad near the Chemical A Building. Consequently, neither Pond 3 nor any other pond was required for further process use.

Work in Progress Residue Operations

The WIP processing operations consisted of an initial sulfate roast followed by a series of hydrometallurgical unit operations designed to recover and purify tantalum, columbium, scandium, uranium, and thorium components. Zirconium and the rare earths were also extracted and further purified to produce materials acceptable for commercial sale. Fluoride recovered from the WIP was precipitated in the WWTP and discharged to the existing calcium fluoride ponds. As mentioned in Section 2.1.2, these processes ceased in 2002 when Fansteel filed for bankruptcy.

2.2 Overview of Site Characterization

In 1993, a remediation assessment was performed at the Fansteel Muskogee facility by Earth Sciences, Inc. Radiological and chemical survey activities were conducted on the buildings, grounds, and equipment and dealt with air, water, soils and WIP residues. In the analysis of the Fansteel property, Earth Sciences utilized a number of facility studies conducted by other engineering firms. In 1997, NRC submitted questions to Earth Sciences concerning specific details about Fansteel that were undetermined or unclear in the 1993 remediation assessment. In that same year, NRC conducted an environmental assessment of the Fansteel facility. Earth Sciences completed two parts of a Decommissioning Plan for Fansteel in June and August of 1999, although the plan has been withdrawn.

ICF obtained additional facility-specific information from the Mineral Processing Survey that Fansteel submitted to the U.S. Environmental Protection Agency (EPA) in 1989, as well as the Facility Background and Operating Data document that Fansteel published in 1995.

2.3 Decontamination and Remediation Activities

In 1990, 1991, and 1992, chemical processing equipment used to extract tantalum and columbium from ores and slags were sold and removed from the site. At an unknown date, the residue present in Pond 5 was dried and placed in 1,200 one-ton bulker bags (about 3 feet by 3 feet by 3 feet), which are currently stored in the Sodium Reduction Building. As mentioned in the site history, the WIP operations to reprocess and recover valuable materials ceased in 2002. In January 2000, Fansteel began operating a french drain groundwater collection and remediation system. A contaminated pile of soil resulted from the construction of the french drain system, which was installed at the base of the shallow alluvial groundwater aquifer to intercept and collect groundwater which is then routed by gravity flow to a series of four sumps where it is then pumped to the wastewater treatment system. Treated effluent is released through National Pollutant Discharge Elimination System (NPDES) permitted Outfall 001. When ICF conducted its site visit in June, 2002, all sumps and other visible portions of this system appeared to be well maintained, and Fansteel employees stated that system performance was meeting expectations.

Fansteel's 1999 decommissioning plan proposed decontaminating various facilities as well as consolidating and stabilizing radiologically elevated soils and other materials in an on-site engineered cell. If these activities were conducted, title to the cell would be transferred to the U.S. Department of Energy (DOE), along with sufficient funds for monitoring and maintenance. An Environmental Impact Statement (EIS) would likely be required for on-site disposal. The facility is in the process of developing a new decommissioning plan; however, ICF is unaware of the details to be contained in the plan.

3.0 Site Characterization Review Methodology

In this section we describe the guidance documents used to develop our methodology for assessing the adequacy of prior characterization efforts, the regulatory levels of interest, and our methodology for determining whether Fansteel adequately characterized the building/structures, groundwater, pond residue, soil, and surface water and sediment.

3.1 Review of Applicable Sampling Guidance

We reviewed several characterization methodologies to develop our methodology for evaluating the adequacy of the characterization data. Specifically, to evaluate the adequacy (i.e., degree of characterization and representativeness) of the collected sampling and monitoring data, we used sampling guidance for characterizing hazardous wastes managed in land-based management units, Envirocare's waste acceptance criteria, NRC guidance documents, and best professional judgment. We describe these sampling guidances and their application below.

NRC Guidance Documents

Two NRC guidance documents were consulted, the *Draft Branch Technical Position on Site Characterization for Decommissioning*, (Branch Technical Position), Division of Waste Management, NMSS, November 1994; and the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), NUREG-1575, EPA 02-R-97-016, December 1997.

The Branch Technical Position provides a generic approach to site characterization and to preparation of a site characterization report (SCR). It describes NRC's expectations of how an SCR should describe the history and general physical setting of a site, the nature and extent of contamination, the physical characteristics of the site, and the dose assessment. The Branch Technical Position also provides references to more specialized documents addressing data collection, radiological surveys, testing methods, modeling, and quality assurance/quality control. In this task, the Branch Technical Position provided a framework for evaluation of data from previous characterization.

ICF also consulted MARSSIM for guidance on site characterization. Broadly speaking, MARSSIM provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological studies to demonstrate compliance with a dose-based or risk-based regulation. However, MARSSIM focuses on demonstrating compliance through a final status survey following scoping, characterization, and any necessary remedial action. Thus, MARSSIM's usefulness is limited in its application to the Fansteel site, because the focus of this investigation is characterization and because the MARSSIM methodology assumes that the results of a characterization or scoping study are available. Specifically, a characterization study has different data needs than a final status survey. For example, one of the objectives of a characterization survey is to determine if sampling areas are homogeneous or heterogeneous. That is, is the radioactive contamination consistent over a sampling area, or is it prone to hot spots? If the contamination is heterogeneous, more samples will be required to adequately characterize the site for the final survey. In addition, one of the variables needed to determine the

number of samples for the final status survey is a measure of the homogeneity or heterogeneity of the sampling area. Thus, the MARSSIM methodology cannot be used to determine the number of samples needed in a characterization survey, because it assumes the availability of the results of the characterization survey as inputs to the final status survey. We did not use MARSSIM to determine the adequacy of the available characterization data provided to ICF.

We were cognizant of the principles in the Branch Technical Position and MARSSIM while conducting our assessment, including the following:

- Use of historical site assessment information to divide the site into classification areas (i.e., non-impacted areas and impacted areas). Areas that have no reasonable potential for residual contamination are classified as non-impacted areas. These areas have no radiological impact from site operations. Examples of non-impacted areas usually include administrative buildings that have or had nothing more than smoke detectors or exit signs with sealed radioactive sources. Impacted areas can be divided into three classes:⁵
 - ▶ Class 1 areas are areas that have, or had prior to remediation, a potential for radioactive contamination (based on operating history) or known contamination (based on previous radiation studies) *above the DCGL*.⁶
 - ▶ Class 2 areas are areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are *not expected to exceed the DCGL*.
 - ▶ Class 3 areas are any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of radioactive activity at a small fraction of the DCGL based on site operation history and previous radiation studies.
- Division of the site into sample grids.⁷
- Review of analytical data to the detection sensitivity of the instrumentation and comparison to the applicable DCGL.

⁵ Multi-Agency Radiation Survey and Site Investigation Manual, NUREG-1575, EPA 02-R-97-016, December 1997, pp 2-4 - 2-5.

⁶ In this review, we accept the DCGLs presented in the Earth Sciences Remediation Assessment report and the June 1999 Decommissioning Plan.

⁷ The Branch Technical Position references NRC's Manual for Conducting Radiological Surveys in Support of License Termination, NUREG/CR-5849, ORAU-92/C57, for additional guidance on classification of areas by contamination potential and on establishing reference grid systems. Our assessment is consistent with this approach.

- ▶ For direct measurements and sample analyses, MARSSIM states that minimum detectable concentrations (MDCs) less than 10 percent of the DCGLs are preferable, while MDCs up to 50 percent of the DCGLs are acceptable.

Waste Acceptance Criteria

Envirocare of Utah, Inc., as a condition of its acceptance of waste, requires facilities both to complete a detailed characterization of the waste stream and prepare a waste stream profile. Specifically, Envirocare requires that the history of the waste and the process by which the waste was generated be fully understood and documented. Hazardous waste determinations, radiological testing and evaluation, and related information must be made before the waste stream profile can be prepared. The generator is responsible for accurately and fully characterizing the waste and completing the waste stream profile. Although Envirocare does not specify a minimum number of samples on which the characterization and profile are to be based, it does require the generator to know the chemical and radiological composition of the waste and specifies:

“Please obtain sufficient samples to adequately determine a range and weighted average of activity in the waste. Analyze all waste streams by gamma spectroscopy. Obtain sufficient samples to ensure that results represent the waste. If Uranium, Plutonium, Thorium, or other non-gamma emitting nuclides are present in the material, the waste must be analyzed using radiochemistry to determine the concentrations of these additional contaminants in the material...”

We weighed Envirocare’s requirements in our decision-making process to determine whether a sufficient number of samples and analytes were characterized.

Characterizing Wastes in Land-Based Management Units

In evaluating sampling data provided by disposal facility operators attempting to demonstrate that their wastes are not hazardous, we attempt to review their sampling plans to see if they meet our minimum threshold for total number of samples, which is typically derived by:

- dividing the land-based management unit (impoundment or landfill) into equal-sized sections or grids (a minimum of four) of no greater than 10,000 ft² each;
- selecting four sampling points at random from each section;
- collecting full-depth core samples (to the base of unit or to groundwater); and

- compositing the four, full-depth core samples collected from each section in the laboratory to produce a four-point composite sample (and repeat for each section).

For subsurface sampling, when there is significant depth and a reasonable possibility of variability, we follow the same methodology, only we would require that the full-depth core samples be divided to represent specific depth intervals. For example, several full-depth core samples could be collected and composited within a section by specific depth intervals (e.g., 0-5 feet, 5-10 feet, 10-15 feet) until groundwater is encountered (or lower, if contamination is known or shown to have migrated below the water table).

We used this approach, which is based on EPA's publication SW-846, entitled "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,"⁸ to further develop our methodology for determining whether a sufficient number of samples were collected to characterize the surface soils, subsurface soils, sediments, and pond residues at the Fansteel site.⁹

For groundwater, we generally like to see a minimum of three monitoring wells installed at intervals of no more than 250 feet apart along the entire downgradient boundary of the unit, and at least one upgradient well (which must be unaffected by the disposal unit). We typically review groundwater monitoring data collected from all the wells over four quarters, spanning an entire year for all analytes potentially present, so as to characterize seasonal variations in the underlying groundwater regime and contaminant levels. We used this methodology, which is based on SW-846 and is used by EPA, to determine whether a sufficient number of samples were collected to characterize the underlying groundwater.¹⁰

3.2 Regulatory Levels of Interest

As noted earlier, one of the main objectives of this characterization study is to determine whether Fansteel has adequately characterized the nature and extent of the contamination at the site. Although one typically compares the observed characterization data to the regulatory levels to determine if decontamination or remediation is necessary, one can also use the regulatory levels of interest (or concern) as a tool for assessing the degree of sampling accuracy (i.e., how representative are the samples of the average "waste" being characterized) and precision (i.e., how representative are the samples of the expected variation in contaminant levels) that is required. For example, a higher degree of accuracy and precision would be required if one or more contaminants are present at a level (activity or concentration) that is close to the applicable regulatory threshold. Alternatively, relatively low precision can be tolerated if the contaminants of concern occur at levels far below or far above their applicable thresholds. However, one

⁸ SW-846 is EPA's official compendium of analytical and sampling methods that have been evaluated and approved for use in complying with the RCRA regulations. SW-846 sets forth acceptable, although not required, methods for the regulated communities to use in responding to RCRA-related sampling and analysis requirements.

⁹ See "Petitions to Delist Hazardous Waste - A Guidance Manual," U.S. EPA, Office of Solid Waste, (EPA/530-SE-85-003), April 1985.

¹⁰ See 40 CFR Part 264 Subpart F.

should ensure that a sufficient number of samples are collected to be representative of the entire population, and care should be used when designing a sampling plan to ensure that the entire area of interest is adequately characterized.

As instructed by the NRC, we used the unrestricted release criteria that are contained in Fansteel's license. Table 1 lists the criteria to be used for soil, surface water and sediments, pond residue, and groundwater at the Fansteel site. Table 2 lists the total, removable, and maximum radioactivity limits for equipment and structures as contained in Fansteel's NRC license for thorium and uranium. The license indicates that for surfaces of equipment and structures contaminated with natural thorium, the thorium release limits should be used, and that for surfaces contaminated with natural uranium and thorium that cannot be cleaned to the thorium release limit, the sum of uranium and thorium activity fractions may not exceed one. In evaluating the data in the Remedial Assessment, the use of a *removable* release limit would be more conservative, however no samples were collected to identify areas with *removable* surface contamination. In the absence of radioactivity data for *removable* contamination, ICF evaluated the survey data of the buildings against the *total* alpha and beta-gamma radiation release limits established in Fansteel's NRC license for thorium. These limits are indicated in shaded cells in Table 2. The release limits for stormwater and process water discharges are contained in Fansteel's National Pollutant Discharge Elimination System (NPDES) permit and are not presented below.

Table 1. Radiological Limits for Soil, Surface Water and Sediment, Pond Residue, and Groundwater at the Fansteel Site

Nuclide	Soil, Sediment, and Pond Residue Activity (pCi/g)	Groundwater and Surface Water Limit (pCi/L)
Gross Alpha (Excluding Ra-226, and U)	NA	15
Gross Beta	NA	50
Uranium (U-238, U-235, U-234)	NA	30
Uranium and Thorium	10	NA

NA = Not applicable

Table 2. Radiological Limits for Equipment and Structures at the Fansteel Site

Nuclide	Total Radioactivity (dpm/100 cm ²)	Removable Radioactivity (dpm/100 cm ²)	Maximum Radioactivity Over 100 cm ² (dpm/100 cm ²)
Thorium			
Alpha	1,000	200	3,000
Beta-gamma	5,000	1,000	15,000
Uranium			
Alpha	5,000	1,000	15,000
Beta-gamma	5,000	1,000	15,000

3.3 Integrated Review Methodology

The methodology for evaluating the adequacy of Fansteel's sampling data is based on the approach described for assessing hazardous wastes disposed in land-based management units, Envirocare's waste acceptance criteria, and best professional judgement (which included factors such as sampling accuracy and precision, site history, and relative comparisons of observed contaminant levels to regulatory levels of concern), and the insights gained from NRC guidance documents. Our methodology employs a series of questions and answers to form the basis for determining if a particular media was adequately characterized. Based on the number of "No" answers received and the relative importance of each question, best professional judgment was used to determine if each building/structure or media type is sufficiently characterized. The application of this methodology to each media type is further described in the following sections.

Buildings

1. Have historical records on the use of radioactive materials been kept for all rooms in a building?
2. Has each building been classified as impacted or non-impacted?
3. Has each room in an impacted building been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?
4. Has a sampling plan been prepared based on the Class ranking for that room/building?
5. Does the sampling plan address QA/QC requirements?
6. Has sampling been conducted in each room according to the sampling plan?
7. Are the number of samples taken known for each room?
8. Are the detection limits for each analytical instrument known for each room?
9. Has sampling been conducted for each room using appropriate instrumentation with appropriate sensitivity?
10. Are all sample results below the DCGL?
11. Were samples collected from beneath the building or areas of known releases?

Groundwater

1. Have historical records been kept for prior groundwater sampling events and spills impacting groundwater on the site?
2. Are the depth, direction, and flow of groundwater at the site known?
3. Are the uses of all aquifers known?
4. Has each distinct aquifer been classified as likely-impacted or non-impacted?
5. Have a sufficient number of wells been located downgradient of each known source, or on the downgradient portion of the facility?
6. Has a sampling plan been prepared for each likely-impacted aquifer based on historical knowledge, known surface and sub-surface contamination, and seasonal changes in groundwater flow and depth?
7. Does the sampling plan address all analytes of concern?

8. Does the sampling plan address QA/QC requirements?
9. Has sampling been conducted in each aquifer according to the sampling plan?
10. Are the number and depths of samples taken known for each well?
11. Are the detection limits for each analytical instrument known for all samples?
12. Has sampling been conducted for each well using appropriate instrumentation with appropriate sensitivity?
13. Are all sample results below the NRC or State regulatory levels?

Pond Residue

1. Have historical records been kept for all materials placed into the ponds?
2. Has each pond been classified as impacted or non-impacted?
3. Has each pond been appropriately divided into surface and depth sampling grids?
4. Has a sampling plan been prepared for each pond based on the historical knowledge of materials placed in the pond?
5. Does the sampling plan address all analytes of concern?
6. Does the sampling plan address QA/QC requirements?
7. Has sampling been conducted in each pond according to the sampling plan?
8. Are the number and depths of samples taken known for each pond?
9. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?
10. Are the detection limits for each analytical instrument known for each pond?
11. Has sampling been conducted for each pond using appropriate instrumentation with appropriate sensitivity?
12. Has clean soil or bedrock been found below each pond?
13. Has clean soil been found outside the perimeter of each pond?
14. Are all sample results below the action levels?

Soils

1. Have historical records been kept for all surface areas on the site?
2. Has each distinct surface and subsurface area been classified as impacted or non-impacted?
3. Has each distinct surface area been appropriately divided into sampling grids?
4. Has each distinct sub-surface area been assigned a depth of concern and appropriately divided into surface sampling grids?
5. Has a sampling plan been prepared for each impacted subsurface area based on the historical knowledge and surface contamination?
6. Does the sampling plan address all analytes of concern?
7. Does the sampling plan address QA/QC requirements?
8. Has sampling been conducted in each surface and subsurface grid according to the sampling plan?
9. Is the number of samples taken known for each surface grid or subsurface area?
10. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?

11. Are the detection limits for each analytical instrument known for each surface grid or subsurface area?
12. Has sampling been conducted for each surface grid and subsurface area using appropriate instrumentation with appropriate sensitivity?
13. Are all sample results below the appropriate action levels?
14. Has clean soil been found below the deepest level of contamination?

Surface Water and Sediments

1. Has outfall sampling, as required by Fansteel's NRC license conditions, been conducted in accordance with those conditions?
2. Has outfall sampling been conducted in accordance with permits held with the state of Oklahoma?
3. Are all sample results below the relevant action levels?

These questions were applied to buildings/structures, groundwater, pond residues, soil, and surface water and sediments, and the answers were used as a tool for identifying gaps in the site characterization.

At this point it is appropriate to emphasize the reason for this report's evaluation of whether or not additional characterization is needed for this site. As the overall focus of this Task Order is to develop independent cost estimates for site decommissioning, one obvious reason for understanding the magnitude (and cost) of additional characterization, is to allow for any additional costs to be incorporated into site decommissioning cost estimates. Fansteel's current cost estimate assumes that no additional characterization work is required at the site prior to the commencement of whole site remediation; this report will attempt to answer if that assumption is reasonable. An additional reason for investigating whether additional characterization is required, is to allow the government as regulators or as site owners (if the site ever became a Federal liability) to make informed decisions about the site. One example is that this report recommends additional subsurface soil characterization, to fully characterize contaminants found in the subsurface soils at the site. The report presents this information for NRC's evaluation as the current regulator. Additionally, if the site were to ever become a Federal liability, this report could serve to assist an agency in developing financial plans to deal with the site (e.g., based on this report an agency could choose to seek an appropriation of \$130K to finish site characterization, then refine the cost estimate to \$"X" M with the new characterization data, then seek an appropriation of \$"X" M for remediation).

Recommendation of areas for additional characterization: (1) does not indicate immediate health and safety issues; (2) is not meant to direct NRC to take any specific actions as regulators; (3) is not meant to be a criticism or indication that previous studies of the site were inadequate for their intended purposes; and (4) in no way is meant to be a request of Fansteel to perform additional characterization.

3.4 Steps to Determine if Additional Characterization is Needed

To determine whether additional characterization is necessary, and if so, how much additional characterization should be conducted, the questions described above were answered and considered in conjunction with the following: (1) the approach described for assessing hazardous wastes disposed in land-based management units; (2) Envirocare's waste acceptance criteria; (3) relative comparisons of observed concentrations to levels of regulatory concern; (4) best professional judgement; and (5) insights gained from NRC guidance documents. Absent "hard" guidelines for calculating exact numbers of samples, the methodology described in Sections 3.1 through 3.3 was invoked and operated between two extremes. One of these extremes is if, based on the sampling-to-date, the surrounding areas (e.g., grids) are sufficiently contaminated that additional characterization will not change the ultimate management of these areas, we assumed that the non-characterized area would exhibit the same characteristics exhibited by the characterized (and contaminated) areas. For example, if the methodology shows that a specific grid is inadequately characterized, but data show that surrounding grids have contaminants with levels or concentrations above the DCGL, the inadequately characterized grid was assumed to also be contaminated above the DCGL and would need to be remediated in the same manner as the surrounding grids. Thus, little benefit would be gained by further characterizing such under-characterized grids and a recommendation was made that no additional pre-remediation characterization be conducted in these grids.

The other extreme is a situation in which so little information is known about a contaminant of interest or area or media type that NRC would be forced to make worst-case assumptions absent further sampling, even though these assumptions might be overly conservative relative to the contamination actually present. For example, if a particular surface soil grid had a contaminant above the DCGL, yet the underlying subsurface grid had not been sampled for this contaminant, the assumption was made that the underlying soil also is contaminated. In addition, absent any information on the possible vertical extent of contamination, the depth of contamination was assumed to extend to the top of the underlying groundwater table. This assumption is conservative and could result in several meters of subsurface soil being remediated.

A third consideration in recommending additional characterization is the relative cost of additional sampling versus worst-case cost assumptions regarding treatment and/or disposal. For example, it may be more cost effective to require Fansteel to demolish a structure, super compact (or otherwise process) the debris, survey the debris, and ship the debris off-site for disposal, than it would be to require Fansteel to survey the structure, remediate the structure, process the debris, survey the debris, ship the debris off-site, and then resurvey the structure.

The specific application of the methodology described in this Section and the determination of whether additional samples need to be collected for each specific media is further described in Sections 4 through 8.

3.5 Cost of Additional Sampling

Unit costs for sample collection and analysis by media have been developed and are presented in Table 3. These unit costs are based upon costs presented in the 2001 R.S. Means *Cost Assemblies* and 2001 RS Means *Environmental Remediation Cost Data - Unit Price*, the 1997 *Mineral Processing Regulatory Impact Analysis*, and the 1999 *Decommissioning Cost Estimate for Fansteel* for License SMB-911. These unit costs have been used to calculate the costs of additional sample collection and analysis.

Table 3. Unit Costs of Additional Sampling by Media

Item	Unit cost	Unit	Source	Page
Water Analysis				
TAL Metals	\$ 302.42	per sample	RS Means Cost Assemblies	p. 3-258
VOCs	\$ 191.40	per sample	RS Means Cost Assemblies	p. 3-258
Gross alpha	\$ 50.46	per sample	RS Means Cost Assemblies	p. 3-270
Gross beta	\$ 64.38	per sample	RS Means Cost Assemblies	p. 3-269
Alpha spectroscopy	\$ 128.77	per sample	RS Means Cost Assemblies	p. 3-269
Soil and Sediment Analysis				
TAL Metals	\$ 302.42	per sample	RS Means Cost Assemblies	p. 3-261
VOCs	\$ 191.40	per sample	RS Means Cost Assemblies	p. 3-261
Gross alpha	\$ 78.30	per sample	RS Means Cost Assemblies	p. 3-272
Gross beta	\$ 64.38	per sample	RS Means Cost Assemblies	p. 3-272
Alpha spectroscopy	\$ 128.77	per sample	RS Means Cost Assemblies	p. 3-270
Soil Borings				
Drilling 4" dia. 0-10 ft	\$ 25.90	per ft	RS Means Unit Price	p. 9-24
Drilling 4" dia. 11-20 ft	\$ 16.58	per ft	RS Means Unit Price	p. 9-24
Drilling 4" dia. 21-30 ft	\$ 14.13	per ft	RS Means Unit Price	p. 9-24
Split Spoon Sampling	\$ 38.19	per sample	RS Means Unit Price	p.9-242
Monitoring Wells				
Installation	\$ 6050.00	per well	1997 Mineral Processing RIA	p. D-57

These costs have been updated to 2002 dollars (from 2001 dollars for costs from RS Means or 1997 dollars from 1997 Mineral Processing RIA) using data on the implicit price deflators from economic indicators found at: <http://www.access.gpo.gov/congress/eibrowse/broecind.html>.

4.0 Buildings

This Section provides an overview of the characterization activities performed on 15 facility buildings or structures located outside of the 35 acres of the facility designated as the Northwest Property during the 1993 Remediation Assessment performed by Earth Sciences Consultants, Inc. Waste-residue reprocessing operations approved by an NRC license dated May 20, 1999 were terminated following the filing of a petition for bankruptcy on January 15, 2002. These operations were limited to six buildings: Chemical A Building; R&D Building; Chemical C Building; White House; Thermite Building; and Sodium Reduction Building. The remaining buildings are used strictly for storage and facility maintenance. In Section 4.1, survey methodologies from the Remediation Assessment are described and a detailed description and history for each of the facility buildings is provided. Characterization findings are summarized in Table 9 at the end of this Section. Section 4.2 identifies potential gaps in characterization. Section 4.3 provides recommendations for further characterization and Section 4.4 identifies potential costs of additional characterization.

4.1 Summary of Existing Characterization

Available building characterization data is limited to the 1993 Earth Sciences Remediation Assessment. Facility personnel have no knowledge of any spills in or around any of the buildings and are not aware of any additional characterization conducted. Although one building (Chemical C building) was remediated for asbestos in the mid-1980's there have been no remediation or decontamination events for the buildings.¹¹ Process equipment in the buildings still holds 13 tons of WIP material. All drains in and around the buildings flow to the wastewater treatment plant on site.

4.1.1 Characterization Methodology

Buildings

A detailed description of the characterization methodology used in the Remediation Assessment was not available, however a limited description was provided.¹² A preliminary scoping survey was performed to identify buildings, portions of buildings, and equipment requiring decontamination. Buildings selected for characterization were numbered seven through 20 with an additional structure labeled S1. A one-meter square gridding system was used to identify survey points on each building exterior and interior surface. A selected portion of these grids were then surveyed for radioactivity. Approximately four percent of the available grids or one grid in 25 was surveyed for building exterior and roof surfaces. Eleven percent of the available grids or one grid in nine was surveyed for interior surfaces. The Remediation Assessment does

¹¹ The 1993 Earth Science's Remediation Assessment Report Appendix D with building survey data notes "asbestos" in the comments section for Building C, which would imply that all the asbestos was not remediated.

¹² The Earth Sciences Consultants, Inc.'s work plan, "Work Plan - Remedial Assessment, Fansteel Metals, Muskogee, Oklahoma" (revised July 1992) was not available, but is expected to contain detailed characterization methodology.

not provide any information on whether grids were randomly selected for survey or selected with bias based on process knowledge and building operations.

Equipment and Facilities

Survey points for equipment and facilities were arbitrarily assigned for each identified item of equipment or facility component. One set of measurements was obtained for every four square meters of surface area. The survey of equipment and facilities utilized the same survey instruments and methods as for building surfaces.

4.1.2 Characterization Techniques

Table 4 contains the measurements that were collected for a one minute count from each of the building grids selected for survey.

Table 4. Characterization Measurements for Buildings

Radioactivity	Number of measurements	Location of measurements
Beta and/or gamma	3	at the surface of the upper right-hand quadrant, the center, and the lower left-hand quadrant of the grid
Alpha	1	at the surface of the center of the grid
Gamma	1	at the surface for the center of the grid
Gamma	1	at a distance of one meter normal to the center of the grid

The following radiation survey instruments were used in the radiological survey of Fansteel facility buildings:

- Ludlum Model 43-68 gas proportional probe attached to a Ludlum Model 2221 or Model 2200 single channel analyzer for alpha beta activity measurements.
- Ludlum Model 43-10 or 43-5 alpha scintillation probe attached to a Ludlum Model 2221 or 2200 single channel analyzer for alpha activity measurements.
- Ludlum Model 44-10 gamma scintillation probe attached to a Ludlum Model 2221 or Model 2200 single channel analyzer for gamma radiation measurements.
- Ludlum Model 44-9 pancake type Geiger-Muller probe attached to a Ludlum Model 2221 or 2200 single channel analyzer or Ludlum Model 3 ratemeter for measurement of beta and/or gamma radioactivity.

4.1.3 Characterization Results

The Remediation Assessment states that the Chemical C, R&D, and Chemical A buildings (Buildings 13, 15, and 16) are contaminated as well as portions of the paved ore storage and transportation areas west of the Chemical A building.¹³ The report also states that roof surfaces for all buildings appear to have elevated radioactivity due to fugitive dust emissions and/or windblown material. The Remediation Assessment does not include any further discussion of the building survey data and does not clearly identify the action level used to establish the presence of contamination.

Fansteel operates under NRC license No. SMB-911 which specifies surface release limits for radioactivity on equipment and structure surfaces. For natural thorium, surfaces are to be cleaned to the release limits shown in Table 5 below.

Table 5. Fansteel Remediation Limits for Buildings - Thorium

Release Limit (dpm/100 cm ²)	Radioactivity	Contamination
200	alpha	removable
1,000	alpha	total
3,000	alpha	maximum (over 100 cm ²)
1,000	beta-gamma	removable
5,000	beta-gamma	total
15,000	beta-gamma	maximum (over 100 cm ²)

For surfaces contaminated with natural uranium and thorium that cannot be cleaned to the thorium release limit, the sum of uranium and thorium activity fractions may not exceed one. Table 6 contains the uranium release limits.

¹³ Fansteel's Eastern Property Area Decommissioning Plan for License No. SMB-911 dated June 16, 1999 states that in addition to the Chemical C, Chemical A, and R&D Buildings, the Thermite and Sodium Reduction Buildings were determined to be affected.

Table 6. Fansteel Radiation Limits for Uranium

Release Limit (dpm/100 cm ²)	Radioactivity	Contamination
1,000	alpha	removable
5,000	alpha	total
15,000	alpha	maximum (over 100 cm ²)
1,000	beta-gamma	removable
5,000	beta-gamma	total
15,000	beta-gamma	maximum (over 100 cm ²)

The exposure rate from building surfaces is not to exceed 5 μ R/hr at one meter from the surface averaged over an area not to exceed 10 m².

Surface release limits in the license, as presented in Table 7, correspond to guideline values previously established by NRC.

Table 7. Fansteel Surface Release Limits

Survey Type	Removable	Average ¹	Maximum ¹
NRC guideline for beta/gamma emitters (except Sr-90)	1,000 dpm/100cm ²	5,000 dpm/100cm ²	15,000 dpm/100cm ²

Reference: *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material*, U.S. NRC, April 1993.

¹ Average and maximum contamination levels apply to areas not exceeding 1 m² and 100 cm² respectively.

Appendix D of the Remediation Assessment provides a table of survey results for the interior and exterior surfaces of the buildings as well as equipment and facilities. The footnote on this table indicates that alpha results >200 dpm/100cm² and beta results >1,000 dpm/100cm² have been shaded (to denote contamination). These levels correspond to the release limits for natural thorium established in Fansteel's NRC license for *removable* alpha and *removable* beta-gamma radiation. However, alpha results >200 dpm/100cm² and beta-gamma results >5,000 dpm/100 cm² have actually been shaded in the table. This latter limit corresponds to the *total* beta-gamma radiation release limit established in Fansteel's NRC license for surfaces contaminated with thorium or with both natural uranium and thorium. It is unclear why a *removable* release limit was used for alpha radiation and a *total* release limit for beta-gamma radiation. Use of a *removable* release limit would be more conservative, however no samples were collected to identify areas with *removable* surface contamination.

In the absence of radioactivity data for *removable* contamination, ICF evaluated the survey data of the buildings against the *total* alpha and beta-gamma radiation release limits established in Fansteel's NRC license for thorium as indicated in Table 8.

Table 8. Release Limits Established in NRC License

Release Limit	Radioactivity
>1,000 dpm/100cm ²	total alpha radioactivity
>5,000 dpm/100cm ²	total beta-gamma activity

Based on these release limits, the following buildings had exterior grids with contamination above the action levels: (1) Chemical C Building, (2) R&D Building, (3) Chemical A Building, (4) Building 18, and (5) Building 19.¹⁴

Based on these release limits, the following buildings had interior grids with contamination above the action levels: (1) Little Bertha Building, (2) Chemical C Building, (3) R&D Building, (4) Chemical A Building, (5) Building 18, and (6) Building 19.¹⁵

Appendix D of the Remediation Assessment includes gamma survey results taken at the center of the grid and at one meter from the center of the grid. These data are provided in counts per minute (cpm) and have not been converted into a surface radioactive contamination measurement (i.e., dpm/100 cm²).

The following building descriptions are based on building floor plans prepared by Earth Sciences Consultants, Inc. in 1993 and observations from a site visit conducted by ICF on June 18, 2002. Process descriptions were obtained from a document prepared by Fansteel and submitted to NRC as background information for the preparation of an environmental assessment in support of a license amendment.¹⁶

Buildings Characterized

Survey data for the following buildings have been included in Earth Science's Remediation Assessment. Characterization data for contaminated buildings is summarized in Table 9 at the end of this section. The building locations are shown in Figure 2.

Building 7 (White House)¹⁷

The White House was used primarily as a break room, and includes a locker room, showers, and two restrooms. The building is located approximately 25 feet west of the Chemical A Building and is constructed on a concrete pad with cinder block and corrugated metal exterior walls and a

¹⁴ Buildings 18 and 19 are not believed to currently exist at the site.

¹⁵ Ibid.

¹⁶ Fansteel, Inc., Facility Background and Operating Data, 1995. Muskogee, OK.

¹⁷ This building is also referred to as the Personnel Change House in Fansteel's Eastern Property Area Decommissioning Plan for License No. SMB-911 dated June 16, 1999.

corrugated metal roof. The building measures approximately 45 feet by 30 feet by 12 feet high. A three-walled open-air corrugated metal structure is attached on the south side and measures approximately 8 feet by 8 feet by 10 feet high. A 1993 floor plan also depicts an enclosed room on the north side of the building measuring approximately 8 feet by 8 feet.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Building 8 (Bulk Building)

The Bulk Building is believed to have handled quantities of scrap including residues from ore and slag dissolutions, sodium reduction residues, off-specification tantalum powder lots, and columbium press cake. Hydrofluoric acid (HF) and nitric acid (HNO₃) were used in the processing of this scrap, which was subsequently processed by liquid-liquid extraction. The Bulk Building is depicted in some historical site drawings, but was removed in 1999. According to a 1993 floor plan, the building measured approximately 50 feet by 40 feet.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Building 9 (Thermite Building)

The Thermite Building was used to reprocess high-purity scrap materials such as bar ends, ingot ends and filings, beam melt furnace cleanings, tantalum wire, capacitors, sheet, foil, and other off-specification materials. HF and HNO₃ were used in the scrap dissolving process. The building, currently used as a maintenance shop, is located on the south end of the paved concrete drive east of the Sodium Reduction Building and is constructed of corrugated metal with a concrete slab floor. It is a one-level, two-story building with one room and measures approximately 80 feet by 40 feet by 25 feet high. Approximately twenty 55-gallon drums wrapped in blue plastic were being stored on pallets east of the building at the time of the ICF site visit.¹⁸

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Building 10 (Weir Building)

The Weir Building is not depicted on some historical site drawings, but is located just south of the Thermite Building and north of Ponds 5 and 6. It is constructed of corrugated metal with a concrete slab floor. The Weir Building is used to monitor Outfall 001 and measures approximately 20 feet by 20 feet by 14 feet high. This one-room building houses a monitoring system that includes a pump, pH and temperature instruments, and a sump.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

¹⁸ According to a December 18, 2001 NRC Inspection Report 040-07580/01-03, recovery product was in temporary storage at an outdoor location behind the plant.

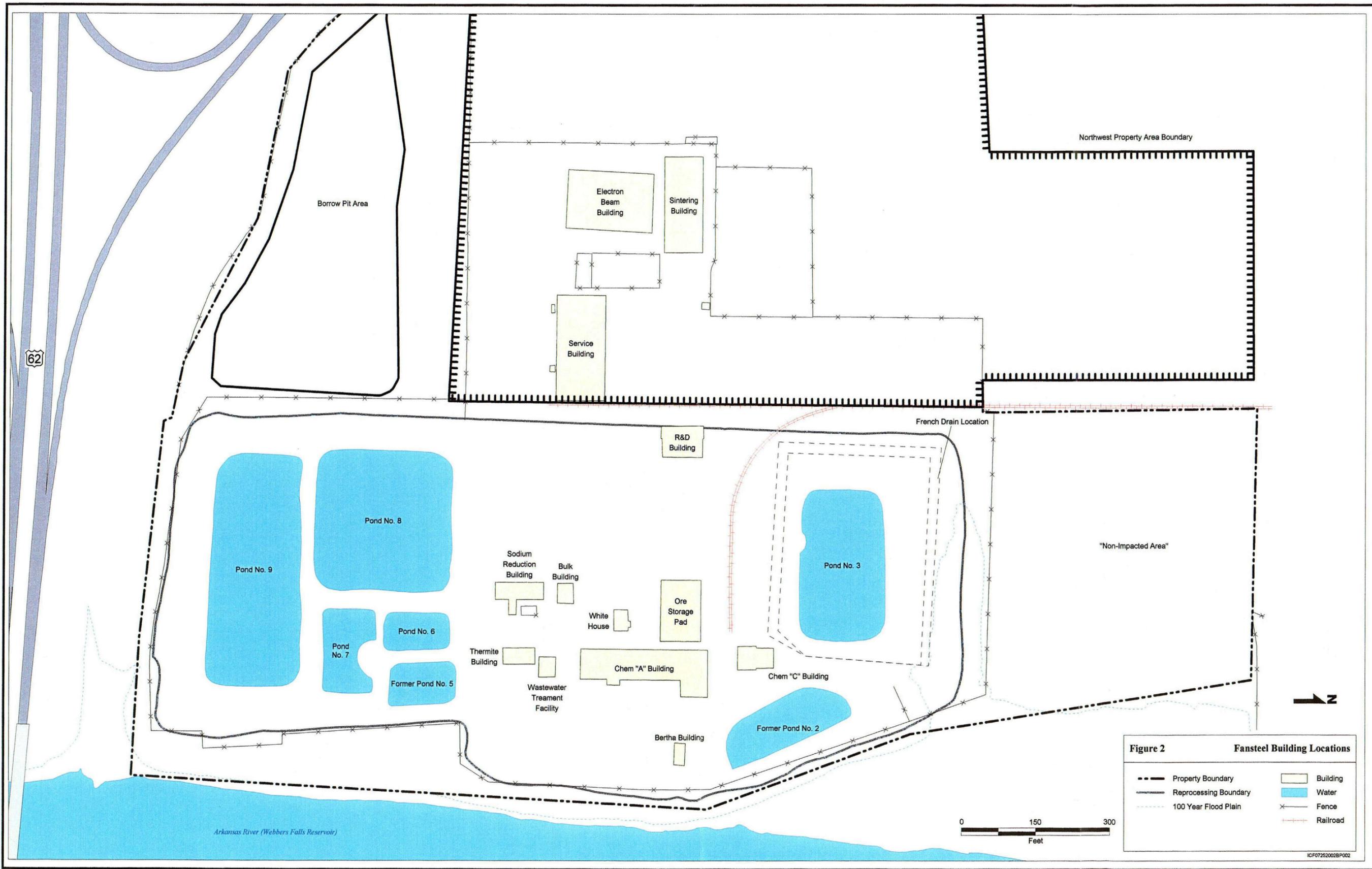


Figure 2 Fansteel Building Locations

--- Property Boundary	□ Building
— Reprocessing Boundary	■ Water
⋯ 100 Year Flood Plain	× Fence
	—+— Railroad

ICF07252002BP002

Building 11 (Sodium Reduction Building)

Controlled sodium reduction of tantalum powder began in the late 1950's in the Sodium Reduction Building. The tantalum powder was reduced using an exothermic-type reduction with the addition of sodium to potassium tanafluoride (K_2TaF_7) at a controlled rate and temperature. Three types of reductions were conducted. The first, a high-temperature reduction using K_2TaF_7 with tantalum fines, sodium chloride (NaCl), and molten sodium with an argon blanket, produced a metal powder cake that was subsequently crushed, milled, and water washed. The powder was produced for use in wire and sheet bar applications. The second reduction process was similar, but involved the addition of sodium sulfate (Na_2SO_4) to produce a metal powder used for high-charge capacitor applications. The third reduction process used potassium compounds with the feed stock. After drying, the material was reduced, crushed, and placed into a large wash tank. In each reduction process, the powder was milled, screened and acid washed.

The building is located on the south end of the concrete paved area west of the Thermite Building and is constructed of corrugated metal with a concrete slab floor. It is a one-level, three-story building measuring 120 feet by 40 feet by 30 feet high with a one story attachment on the east side measuring 20 feet by 39 feet by 10 feet high. Currently, the building holds 1,200 one-ton bags of WIP residue collected from former Pond 5. However, since the introduction of the WIP residue it is not known if the building would exceed contamination limits at this time. It is assumed that the building would be contaminated for purposes of the development of the decommissioning cost estimate.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Building 12 (Little Bertha Building)

The Little Bertha Building was used for bench tests and other research and development laboratory work. The building is located on the concrete pad that extends within six feet of the french drain sump house on the eastern edge and up to the Chemical A Building on the western edge. The one-room building measures 44 feet by 15 feet and is approximately 18 feet high. The building is constructed of corrugated metal and has two circular vents about 4 feet in diameter protruding from the roof. At the time of the site visit several junk piles sat on the concrete pad just north and east of the building. The junk piles included dirt, wooden pallets, corrugated metal, tanks, drums, and cinder blocks.

Alpha contamination above the total radiation release limit was found on two interior walls of this building. Beta/gamma contamination was found on the floor and two interior walls of this building.

Building 13 (Chemical C Building)

Raw materials including tin-smelting slag, natural ores, and chemically or physically upgraded ores and concentrates were ground and digested in hydrofluoric acid in the Chemical C Building to extract tantalum and columbium. Ores were fed into a ball-type conveyor belt and pulverized

before being discharged from the mill. Ground material was transferred to a feeder hopper and fed into a vessel containing HF. Once the ore or slag came into contact with 70 percent HF, the dissolution process began. Residues were tested for tantalum content and either transferred to a disposal pond (e.g., Pond 3) or recycled. Tantalum and columbium separated from the residues and contained in aqueous solution became feed material for a mixer settler box operation, which separated and purified the two metals. MIBK and sulfuric acid (H_2SO_4) were used to remove tantalum and columbium from the aqueous solution, which was subsequently discharged to the wastewater treatment plant for neutralization and removal of fluoride. The tantalum/columbium solution was then sent through a series of mixing and settling chambers to separate the metals. The subsequent solutions were then stored for further processing.

Equipment used in the ore digestion process was decontaminated and sold to a company named Titantalum in 1999. Equipment currently housed in the building was used briefly for initial processing of WIP residue, and includes a cement truck used for the transfer of calcium fluoride and several empty tanks.

The Chemical C Building is located just north of the Chemical A building and consists of two connected rooms. The north room measures approximately 42 feet by 70 feet by 34 feet high. The south room measures approximately 48 feet by 78 feet by 28 feet high. The building is constructed of corrugated metal with a jointed concrete floor. An empty Na_2SO_4 silo sits west of the Chemical C Building on the south side. The Na_2SO_4 was transferred from rail cars to the concrete staging platform located on the north end of the building. A cooling tower sits east of the building on the south side.

Beta/gamma contamination above the total radiation release limit was found on two exterior walls of this building. Alpha contamination above the total radiation release limit was found on three interior walls, the floor, and the sump. Beta/gamma contamination above the total radiation release limit was found on six interior walls, the floor, the ceiling, and the sump. Contamination above the maximum NRC guideline for beta/gamma emitters was found on two walls, the floor, the ceiling, and the sump.

Building 14

A building numbered 14, located on the east side of the Chemical A building to the east of the boiler room and west of Little Bertha Building, is depicted in a 1993 Earth Sciences site drawing. No building existed in this location at the time of the ICF site visit.¹⁹

There are no alpha or beta/gamma results above the total radiation release limits for this building.

¹⁹ A corrugated metal shack was observed adjacent to the Chemical A building during the ICF site visit, but was located to the south of the boiler room.

Building 15 (R&D Building)

The eastern portion of the R&D Building is now used as a workshop. The R&D Building is located on the western edge of the primary processing portion of the property. The east half of the building is a single-level, three-story structure constructed of corrugated metal with a concrete floor. A floor drain runs through the center of the building. The integrity of the floor drain has not been tested. The two-level office building makes up the west half of the building and has a brick exterior. A 1993 floor plan depicts offices, storage rooms, a laboratory, and bathrooms in this half of the building. The building measures approximately 70 feet by 100 feet by 31 feet high.

Alpha contamination above the radiation release limit was found on the roof of this building. Beta/gamma contamination above the total radiation release limit was found on the floor in this building.

Building 16 (Chemical A Building)

High-purity columbium solutions and high-purity tantalum solutions from the Chemical C Building were further processed in the Chemical A Building. The columbium solution was sparged with anhydrous ammonia (NH_3) to precipitate the columbium. The slurry was pumped through a plate and frame press to remove columbium oxide (Nb_2O_5). The liquor from the precipitation was stored in a separate holding tank for settling of remaining columbium. Following settling, the liquor was routed to a stripping tower to remove NH_3 . The remaining slurry was pumped through a separate plate filter and remaining liquids were transferred to wastewater treatment. The columbium filter press cake was dried in a gas-fired calciner, blended, and then packaged.

A potassium fluoride solution was added to the tantalum solution to precipitate the tantalum and form K_2TaF_7 crystals. The crystals were centrifuged to remove any remaining liquids and washed with a solution of potassium chloride (KCl). The crystals were then placed in a rotary vacuum dryer before being transferred to the Sodium Reduction Building.

Original process units still in place include a belt press, steam heated dryer, mixer, calciner, heater, and 20-30 metal tanks. Organics were stored at the south end of the building inside metal tanks. The tanks are empty with the exception of residual water. All process materials and solvents have been de-inventoried.

This building is the largest on the site and measures approximately 300 feet long by 70 feet wide by 60 feet high. The building is one level on the south end with the exception of a metal platform one level above. The north end of the building has a third and fourth floor and partial fifth floor. The building is constructed of cinder blocks with steel girder supports and a brick exterior. A floor drain is located in the center of the concrete slab floor, which is cracked, jointed, and uneven. The building houses a significant amount of piping and vents. The building also includes several small control room/offices at the north end on the west wall on the first floor. These rooms have wood paneling and a linoleum tile floor.

Two 1993 floor plans of this building depict a small maintenance shop and ball mill room on the east wall toward the north end of the building on the first floor. A pump room is also depicted extending beyond the east wall toward the south end of the building on the first floor. The floor plans show a screening room, several drying rooms, several storage rooms, a furnace room, and bathrooms on the third floor. The fourth floor is shown with one large room and a smaller "AO Smith" room. The floor plans also note the existence of a heater on the fifth level.

The Chemical A Building has a boiler room extending beyond the east wall at the north end of the building. The boiler room measures approximately 45 feet by 65 feet by 21 feet high. The floor plans depict several tanks, boilers, and air compressors in this room, which also has a small basin pump house extending beyond the south wall. The pump house measures approximately 12 feet by 12 feet by 10 feet high. The floor plans also show two trenches located in the room, with one extending into the main portion of the Chemical A Building.

An Ion Exchange Building is connected to the south end of the Chemical A Building. It is a one-level, two-story building and has corrugated metal walls and roof with a concrete floor. The building measures approximately 28 feet by 65 feet by 21 feet high. This building was originally designed to purify scandium recovered from the reprocessing of WIP residues, but was never used. The construction date of the building is unknown.

Three tanks are located just outside the Chemical A Building on the east wall (south of the boiler room), two marked sodium hydroxide (NaOH) and one marked HF.²⁰

Beta/gamma contamination above the total radiation release limit was found on the roof and three exterior platforms of the Chemical A Building. Alpha contamination above the total radiation release limit was found in room 101 and the trench, as well as on one wall in room 104 and one elevator shaft wall. Beta/gamma contamination above the total radiation release limit was found on heating units, a scrubber, a platform, seven walls in room 101, three walls in room 103, three walls in room 104, one wall in room 402, three walls in the elevator shaft, the trenches in rooms 101 and 102, and the floors in rooms 103, 104, 311, and 401. Multiple grids with beta/gamma contamination above the total radiation release limit were found inside room 101. Contamination above the maximum NRC guideline for beta/gamma emitters was found on two walls in room 101, one wall in room 104, the powder wash floor in room 311, and multiple floor grids in room 101.

Building 17

A building numbered 17, located approximately 100 feet west of the Chemical A building at the north end in the paved ore storage area, is depicted in a 1993 Earth Sciences site drawing. No building existed in this location at the time of the ICF site visit.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

²⁰ According to a December 18, 2001 NRC Inspection Report, 40,000 pounds of hydrofluoric acid and 31,000 pounds of ammonium hydroxide remained at the site at the time of the inspection.

Buildings 18 and 19

Buildings numbered 18 and 19, located approximately 75 feet south of the midpoint of the south side of Pond 3, are depicted in a 1993 Earth Sciences site drawing. No buildings existed in this location at the time of the ICF site visit.

Beta/gamma contamination above the total radiation release limit was found on two exterior walls of Building 18 and the roofs of both Buildings 18 and 19. Beta/gamma contamination above the total radiation release limit was found on two interior walls of Building 18, one interior wall in Building 19, and the ceiling of Building 19.

Building 20

A building numbered 20, located adjacent to the east wall of Chemical C Building on the south end, is depicted in a 1993 Earth Science's site drawing. A small corrugated-metal shack located on the east wall of the Chemical C building towards the south end was observed during the ICF site visit and *may* be Building 20. The shack measures approximately 10 feet by 20 feet by 15 feet high.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Building S1

A building labeled BS No. 1, located just off the southeast corner of the Chemical C Building, is depicted in a 1993 Earth Science's site drawing. A cooling tower located off the southeast corner of the Chemical C Building was observed during the ICF site visit and *may* be the structure depicted. The cooling tower is constructed of corrugated metal and measures approximately 15 feet by 40 feet by 25 feet high.

There are no alpha or beta/gamma results above the total radiation release limits for this building.

Buildings Not Characterized

The following buildings are not included in the Earth Science's Remediation Assessment and are believed to have been constructed after 1993.

Control Station

A small control station is located approximately 10 feet north of Pond 9 at the southeast corner of Pond 8. The control station measures approximately 8 feet by 8 feet by 8 feet high. It was used in creating a slurry for the reprocessing of CaF_2 .

Maintenance Shop

The Maintenance Shop, constructed in 1999, is located north of the Sodium Reduction Building and slightly west of the location where the Bulk Building once stood. The Maintenance Shop is a one-level, two-story building constructed of corrugated metal and a concrete slab floor. The building measures approximately 60 feet by 20 feet by 20 feet high. Four large stacks of pallets were stored on the concrete pad just east of this building at the time of the site visit.

Evaporator Building

This building is labeled as a wastewater treatment plant on some historical site drawings, however Fansteel personnel referred to it as the Evaporator Building during the ICF visit. Most recently, the building was intended for use in the reprocessing of CaF_2 , but was not used prior to Fansteel filing for bankruptcy. No previous operations in this building are known.

The Evaporator Building is located south of the Ion Exchange Building and just north of the Thermite Building. It is a one-level, two-story building constructed of corrugated metal and a jointed concrete floor. The building measures approximately 40 feet by 60 feet by 20 feet high. The interior walls are insulated and the building currently contains four evaporation units and two tanks.

French Drain Sump Houses

Four french drain sump houses on the site collect groundwater from the french drain system. These one-room, single-story structures are constructed of corrugated metal with a concrete slab floor. The sump houses are located on the north, east, southeast, and southwestern edges of the property. The french drain sump houses measure approximately 10 feet by 10 feet by 10 feet high.

Additional Facility Structures or Surfaces

Paved Ore Storage and Transportation Areas

This area is believed to have been used for the storage of bags and drums of ore. Following the failure of Pond No. 3, liquid residues from ore/slag processing were sent to filter presses producing filtered solid wastes. These wastes were placed in 55-gallon drums and also stored in the paved ore storage area. The area extends from the Chemical C Building on the north side, to the White House on the south side and approximately 200 feet west of the Chemical A Building. The area of the pad is approximately 10,000 ft². Paved concrete transportation areas are adjacent to all buildings. At the time of the site visit, the pad was being used to store piles of rusting pipes, I-beams, and wooden pallets. An acid tank farm also sits approximately 50 feet west of the Chemical A Building and has a concrete berm for secondary containment. The tanks still

contained sulfuric acid (H₂SO₄) and NaOH at the time of the site visit.²¹ A discussion of radiological sampling of soils below the storage pad is provided in Section 7.

Wastewater Treatment Plant (WWTP)

The WWTP was first operational in 1973. Starting in 1988, wastewater from the scrubber overflow, ammonia stripper, two Chemical A Building processes, and the sodium reduction process entered the WWTP. Acidic and ammonia waters were held in temporary holding ponds prior to treatment. Supernatant pumped from these ponds was then neutralized to remove fluoride by CaF₂ precipitation. Treated water from this facility was routed to Ponds 8 and 9. Today, all waters from building floor drains and the french drain are routed to the WWTP.

The treatment facility is located in a paved concrete area east of the Chemical A Building and west of the Little Bertha Building. The treatment facility consists of a series of below ground-level concrete tanks and includes a couple of above-ground holding tanks and two large lime silos. The lime silos measure approximately 10 feet in diameter by 30 feet high.

Gunch Building

The Gunch Building is referenced in some historical site descriptions. Facility personnel described the Gunch house was a "wooden lean-to" used to store gunch. The building no longer existed on the site at the time of the ICF site visit.

4.2 Identification of Potential Gaps in Characterization

To assess whether there are gaps in the characterization of the buildings, we answered the questions in the checklist presented in Section 3.3.

1. Have Historical records in the use of radioactive materials been kept for all rooms in a building?
No.
2. Has each building been classified as impacted or non-impacted?
No.
3. Has each room in an impacted building been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?
No.

²¹ According to a December 18, 2001 NRC Inspection Report, 46,000 pounds of sulfuric acid and 38,000 pounds of sodium hydroxide remained at the site at the time of the inspection.

4. Has a sampling grid been prepared based on the Class ranking for that room/building?

The sampling plan was not available for review.

5. Does the sampling plan address QA/QC requirements?

The sampling plan was not available for review.

6. Has sampling been conducted in each room according to the sampling plan?

The sampling plan was not available for review.

7. Are the number of samples taken known for each room?

Yes.

8. Are the detection limits for each analytical instrument known for each room?

They can be inferred from the results.

9. Has sampling been conducted for each room using the appropriate instrumentation with appropriate sensitivity?

Appropriate instrumentation with adequate sensitivity appears to have been used. However, this question can only be definitively answered with more specific and complete historical information about the operations that tools place in each building.

10. Are all sample results below the DCGL?

No.

11. Were samples collected from beneath the building or areas of know releases?

No.

In the absence of detailed information regarding the characterization methodology, a full assessment of the completeness of building characterization is not feasible. Assuming the 1993 Earth Science's Remediation Assessment was adequate and complete in survey of the buildings existing at that time, the following gaps remain:

- Waste-in-process reprocessing operations conducted after the 1993 Earth Science's Remediation Assessment in the Chemical A Building, R&D Building, Chemical C Building, White House, Thermite Building, and Sodium Reduction Building make them potential candidates for additional contamination.

- The buildings not characterized, which are believed to have been constructed following the 1993 Remediation Assessment, need to be characterized. These buildings may have potentially been subject to contamination from the more recent WIP reprocessing operations.
- The ore storage pad and transportation areas should be evaluated for fixed contamination that may require disposal of the concrete as radioactive material.
- Areas in and around the wastewater treatment plant have not been characterized.
- The Remediation Assessment did not include the collection of wipe samples to identify loose or removable contamination.

4.3 Assumptions about Extent of Contamination and Recommendations for Additional Characterization

Several assumptions can be drawn from the characterization described above. The Chemical A and Chemical C buildings were contaminated throughout prior to the initiation of WIP reprocessing, would not likely benefit from additional characterization, and will require extensive decontamination. The extent of contamination from the WIP reprocessing operations is unknown. The extent of contamination for the paved ore storage pad, transportation areas, and wastewater treatment plant are unknown.

Additional characterization that may be required to delineate the extent of contamination, includes:

- Additional survey of buildings involved in reprocessing operations including: R&D Building, White House, Thermite Building, and Sodium Reduction Building.
- Collection of wipe samples on moderately contaminated surfaces to assess removable contamination.
- Survey of the ore storage pad and transportation areas.
- Survey of the areas in and around the wastewater treatment plant.
- Initial survey of the Control Station, Maintenance Shop, Evaporator Building, and French Drain Sump Houses.

Absent additional characterization, the following assumptions are recommended to be used in developing a cost estimate:

- Areas of contamination identified during the survey have fixed contamination and will require disposal of building materials as radioactive waste.

- Paved areas of the ore storage pad, transportation areas, and wastewater treatment plant are contaminated.

4.4 Costs Associated with Additional Characterization

Although gaps in building and structural characterization have been identified, further characterization at this time is unnecessary. Specifically, these gaps in building characterization can be addressed at the time of building decontamination and decommissioning, when materials are remediated, packaged, and surveyed.

Table 9. Building Characteristics and Survey Results

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/ Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	$\beta\gamma$			α	$\beta\gamma$
Exterior										
Bldg. 13 <i>Chemical C Building</i>	Corrugated metal, concrete slab floor	north room 42x70x34	93	Wall 1	12	12	--	1	267	6,750
		south room 48x78x28		Wall 4	15	15	--	2	317	6,238
		one level								
Bldg. 15 <i>R&D Building</i>	Corrugated metal, concrete slab floor for workshop/ brick exterior, wood paneling, concrete slab floor with linoleum tiling for office building	70x100x31 Workshop is one level Office building is two levels	100	Roof	35	35	2	--	2,133	1,667

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/ Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	$\beta\gamma$			α	$\beta\gamma$
Bldg. 16 <i>Chemical A Building</i>	Cinderblock, steel girders, brick exterior, concrete slab floor/ Corrugated metal for attached ion exchange building	300x70x60 (main building) south end is one level north end is five levels	435	Platform 101, Office Area Roof	12	12	--	1	324	5,600
		45x65x21 (boiler room) one level		Platform 102, Big Berth A Platform	12	12	--	1	<200	5,721
		12x12x10 (pump house) one level		Platform 201	5	5	--	3	<200	7,742
				Platform 301, Little Berth A Platform	19	19	--	3	595	14,785
Bldg. 18	NA	NA	NA	North Wall	1	1	--	1	224	6,570
				West Wall	1	1	--	1	<200	5,745
				Roof	1	1	--	1	576	6,265
Bldg. 19	NA	NA	NA	Roof	1	1	--	1	341	7,145
Interior										
Bldg. 12 <i>Little Bertha Building</i>	Corrugated metal with concrete slab floor	44x15x18	34	Room 101, Floor	6	6	--	4	650	9,609

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	$\beta\gamma$			α	$\beta\gamma$
				Room 101, Wall 2	2	2	1	1	1,814	11,826
				Room 101, Wall 3	3	3	1	1	2,135	10,043
Bldg. 13 Chemical C Building	Corrugated metal, concrete slab floor	north room 42x70x34 south room 48x78x28 one level	203	Room 101, Floor	30	30	29	29	9,490	208,548
				Room 101, Sump	14	14	14	14	4,942	70,179
				Room 101, Wall 1	24	24	2	3	1,239	11,028
				Room 101, Wall 2	16	16	1	2	1,004	22,632
				Room 101, Wall 4	15	15	1	1	1,744	6,650
				Room 102, Ceiling	34	34	--	2	519	33,172
				Room 102, Wall 5	7	7	--	5	<200	30,161
				Room 102, Wall 6	15	15	--	2	<200	6,505
				Room 102, Wall 7	19	19	--	3	859	9,301

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/ Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	$\beta\gamma$			α	$\beta\gamma$
Bldg. 15 <i>R&D Building</i>	Corrugated metal, concrete slab floor for workshop/ brick exterior, wood paneling, concrete slab floor with linoleum tiling for office building	70x100x31 Workshop is one level Office building is two levels	634	Room 101, Floor	28	28	--	1	311	6,538

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/ Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	βγ			α	βγ
Bldg. 16 <i>Chemical A Building</i>	Cinderblock, steel girders, brick exterior, concrete slab floor/ Corrugated metal for attached ion exchange building	300x70x60 (main building) south end is one level north end is five levels	2521	Room 101, DRAVO	12	12	--	1	483	6,336
				Room 101, DRAVO	12	12	--	1	394	7,680
				Room 101, Big Berth A	10	10	--	1	593	5,548
		Room 101		215	215	10	21	1,924	29,282	
		Room 101, Trench		6	6	--	1	731	5,195	
		Room 101, Wall 122		18	18	--	1	242	7,151	
		Room 101, Wall 123		117	117	--	14	331	18,129	
		Room 101, Wall 125		128	128	--	8	874	22,097	
		Room 101, Wall 126		19	19	--	1	380	5,645	
		Room 101, Wall 127		6	6	--	1	<200	6,065	
		Room 101, Wall 134		3	3	--	2	<200	7,548	
Room 101, Wall 135	6	6	--	3	430	8,839				

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	βγ			α	βγ
				Room 102, Trench	2	2	1	1	1,169	5,635
				Room 103, Floor	6	6	--	1	227	5,982
				Room 103, Wall 91	6	6	--	2	232	6,276
				Room 103, Wall 92	6	6	--	1	232	5,215
				Room 103, Wall 93	9	9	--	1	277	5,269
				Room 104, Floor	12	12	--	5	462	13,118
				Room 104, Wall 86	6	6	--	2	281	8,763
				Room 104, Wall 187	12	12	--	6	652	31,290
				Room 104, Wall 89	18	18	1	4	1,005	8,871
				Room 311, Powder Wash Floor	51	51	--	7	210	30,860
				Room 401, Floor	133	133	--	9	244	9,677

Building	Building Construction Materials	Building Dimensions (ft)	Total Number of Grids ¹	Contaminated Building Area/Component	Number of grids sampled		Number of grids above action level for alpha	Number of grids above action level for beta/gamma	Highest level of contamination (dpm/100cm ²) ²	
					α	βγ			α	βγ
				Room 402, Wall 11	7	7	--	1	200	5,538
				Elevator Shaft, Wall 1	2	2	--	2	331	6,781
				Elevator Shaft, Wall 3	2	2	--	2	769	11,238
				Elevator Shaft, Wall 5	2	2	1	2	1,188	8,848
Bldg. 18	NA	NA	NA	Room 101, Wall 1	1	1	--	1	<200	6,395
				Room 101, Wall 2	1	1	--	1	<200	5,145
Bldg. 19	NA	NA	NA	Ceiling	1	1	--	1	<200	5,510
				Room 101, Wall 1	1	1	--	1	<200	5,680
Equipment/Facility Components										
Bldg. 16 <i>Chemical A Building</i>		300x70x60		Room 101, Scrubber	4	4	--	2	380	6,452
				Room 401, Heater Unit	6	6	--	1	248	13,065

¹ Total interior grid counts include equipment and facility components.

² Results in excess of the NRC guideline value for maximum beta/gamma contamination (i.e., 15,000 dpm/100 cm²) have been shaded.

5.0 Groundwater

Due to contamination of surface and subsurface soils at the Fansteel site, Earth Science's investigated the existence and extent of groundwater contamination and presented the results in their Remediation Assessment report dated December 1993. The results of this assessment indicate that the shallow aquifer is contaminated with a number of different isotopes as well as metals and an organic compound. The primary radioactive isotopes of concern are U-233, U-234, U-235, U-238, Th-228, Th-230, and Th-232. The primary metals contaminating the shallow groundwater are arsenic, barium, chromium, and nickel. The organic compound detected in the shallow groundwater is 4-methyl-2-pentanone (also known as methyl isobutyl ketone or MIBK). Based on Earth Science's investigation the deeper bedrock aquifer does not appear to have been affected by Fansteel's operations.

Earth Sciences installed 25 shallow monitoring wells and four bedrock monitoring wells in 1993 to evaluate the underlying groundwater resources. In addition, approximately 20 monitoring wells are known to have been installed sometime prior to 1989. To assess the adequacy of the groundwater characterization ICF Consulting reviewed the groundwater assessment conducted by Earth Sciences in February and March of 1993, monthly sampling data collected between March 1993 and December 1994, and quarterly sampling data collected between January 1995 and December 1996. The results of sampling from the 20 wells installed prior to 1989 were not reviewed because the data was not available. Figure 3 contains a map of the monitoring well locations at the site and the groundwater contours and flow direction.

The Remediation Assessment established that groundwater flow on the site is more complex than the topography and proximity of the river might suggest. Generally groundwater flows from west to east toward the Arkansas River. However, in the northeast portion of the site, groundwater flows north and east toward a depression and apparent intermittent stream. In the southern portion of the site the groundwater appears to flow to the south off the site to another depression. In the southwest portion of the site, groundwater appears to flow in a southwesterly direction. The groundwater flow map appears to be based on data from only one set of water level measurements, and as such the accuracy of the groundwater flow maps generated by Earth Sciences is suspect.

The remainder of this section discusses our assessment of Earth Sciences characterization of groundwater at the Fansteel site. In Section 5.1, we present the results of the Earth Sciences study. Section 5.2 presents our assessment of the adequacy of the groundwater characterization to date, while Section 5.3 presents our assessment of whether additional sampling is needed. Finally, Section 5.4 presents the costs associated with the recommended additional sampling.

5.1 Summary of Existing Characterization

The existing groundwater characterization consists of sampling conducted in February and March 1993, which is summarized in Earth Science's Remediation Assessment, the collection of monthly groundwater samples from March 1993 to December 1994, and the collection of quarterly groundwater samples from January 1995 to December 1996. The Remediation

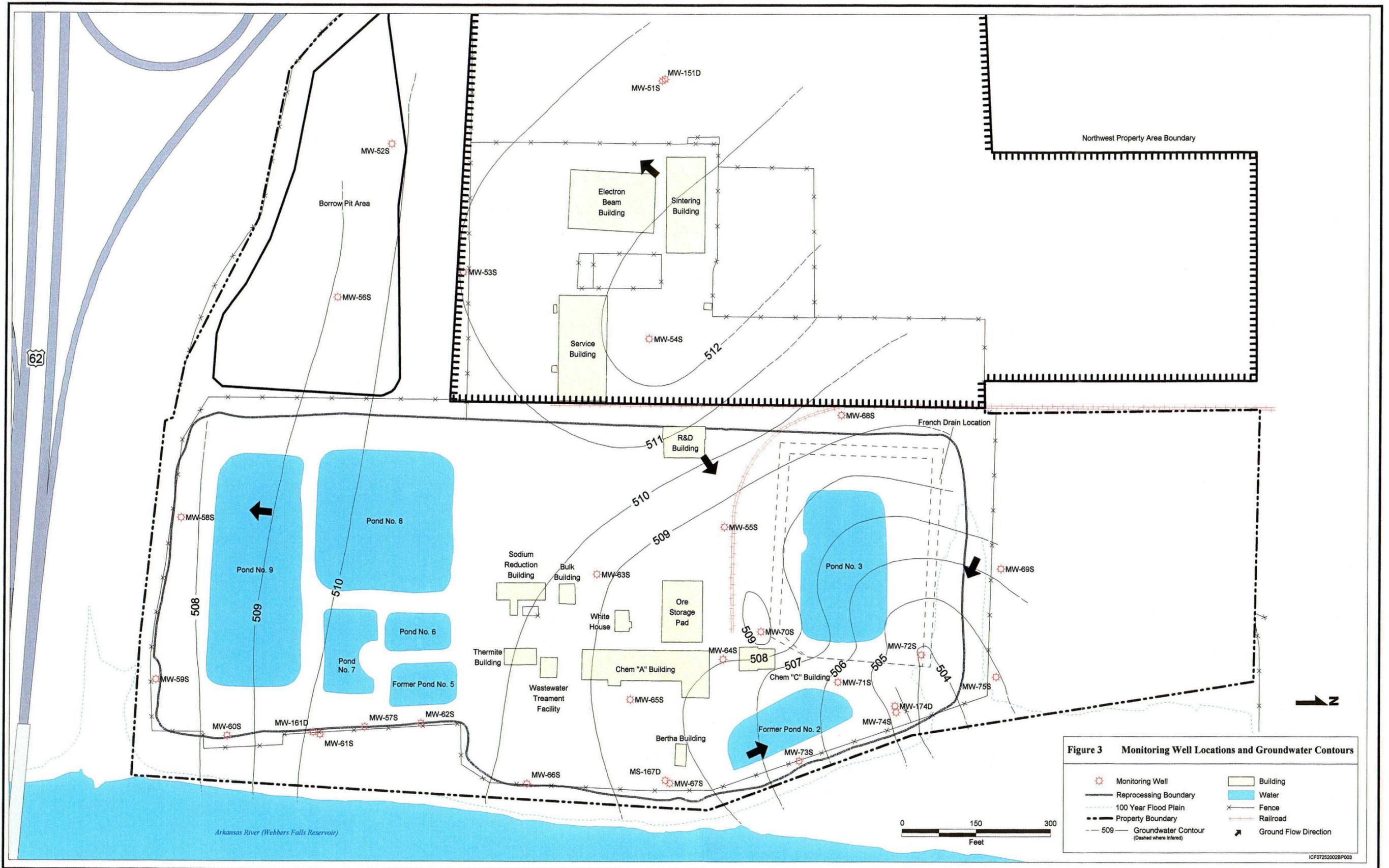
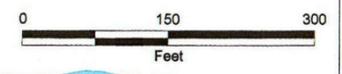


Figure 3 Monitoring Well Locations and Groundwater Contours

	Monitoring Well		Building
	Reprocessing Boundary		Water
	100 Year Flood Plain		Fence
	Property Boundary		Railroad
	Groundwater Contour (Dashed where Intersected)		Ground Flow Direction



Assessment includes discussion on Earth Science's methodology for collecting groundwater samples. Since Earth Science's *Response to the NRC Environmental Assessment Comment Request* report, which contains the monthly and quarterly sampling data, does not specify the sampling methodology, ICF assumes that Earth Sciences used the same methodology for the monthly and quarterly sampling events as was described in the Remediation Assessment.

Earth Sciences used common well purging and sampling procedures to ensure quality sample results. Well purging was performed using a 3.5 inch diameter PVC bailer, which is a commonly used, but not the best, method. This purging method requires the field technician to slowly lower the bailer into the water to minimize introducing oxygen into the groundwater and to minimize disturbance of fines in the sand pack around the well. Also PVC tends to adsorb contaminants from the groundwater at a higher rate than less sorptive materials such as Teflon or stainless steel. The Remediation Assessment did not discuss the purging methodology beyond the type of bailer used and the volume of water extracted. Earth Sciences purged three well volumes from each well or until the well was bailed dry. Three to four well volumes is generally considered adequate to ensure that fresh formation water is collected.

Earth Sciences used a 3.5 inch diameter PVC bailer to collect the samples. For sample collection, Teflon bailers are typically recommended as superior sample collection devices to PVC bailers.²² As mentioned above, PVC bailers tend to adsorb contaminants to a greater extent than Teflon or stainless steel bailers. The direction and extent to which the use of PVC bailers might bias the sample results is not known. The Remediation Assessment does not indicate whether the bailers were laboratory decontaminated or field decontaminated. Laboratory decontaminated bailers wrapped in aluminum foil are preferred to field decontaminated bailers.

According to the Remediation Assessment, the groundwater samples were analyzed using appropriate analytical techniques and with adequate detection limits. Earth Sciences indicates that the samples collected between October 1993 and May 1994 might be higher than they should have been due to a calibration error. A review of the results from this period shows that the sample results tend to be higher than samples collected after May 1994.

The remainder of this section discusses Earth Sciences efforts to characterize the shallow unconsolidated aquifer (Section 5.1.1) and the deeper bedrock aquifer (Section 5.1.2).

5.1.1 Unconsolidated Aquifer

Earth Sciences installed 25 monitoring wells in February 1993 in the unconsolidated material underlying the Fansteel site.²³ These monitoring wells were installed to determine the impact of Fansteel's operations on the shallowest aquifer beneath the site. Monitoring wells were installed

²² New Jersey Department of Environmental Protection and Energy, *Field Sampling Procedures Manual*, May 1992, page 169.

²³ Well installation details are not included in the Remediation Assessment for ten of the monitoring wells and four of the monitoring wells have sample results that date back to April 1991. Thus, all 25 of the wells may not have been installed in February 1993.

along the eastern, northern, and southern boundaries of the process area and at various locations within the site.

The number and location of monitoring wells were apparently selected to monitor the potential sources of groundwater and to provide coverage along the eastern, northern, and southern boundaries to determine if contaminated groundwater was migrating off site. The monitoring wells for the shallow aquifer were installed to depths of between 9 and 33.5 feet. Table 10 provides information on the screened interval, the total depth, and depth to groundwater for each of the wells as obtained from Table 1 and the boring logs in Appendix A of Earth Science's Remediation Assessment. The screened interval for ten of the wells could not be confirmed because the well construction details for these wells are not included in Appendix A of the Remediation Assessment.

Table 10. Monitoring Well Installation Data

Monitoring Well Number	Ground Surface Elevation (ft amsl) ¹	Groundwater Elevation (ft amsl) ¹	Depth to Groundwater (ft bgs) ²	Total Depth of Monitoring Well (ft bgs) ²	Screened Interval (ft bgs) ²
MW-51S	540.90	511.45	29.45	31.8	13.0 - 35.0 ³
MW-52S	524.28	509.94	14.34	18.0	8.0 - 18.0
MW-53S	537.70	511.69	26.01	33.5	18.5 - 33.5
MW-54S	531.80	512.27	19.53	30.0	15.0 - 30.0
MW-55S	524.60	508.49	16.11	22.5	7.5 - 22.5
MW-56S	521.89	509.22	12.67	18.0	8.0 - 18.0
MW-57S	522.42	510.80	11.62	19.0	4.0 - 19.0
MW-58S	524.47	507.93	16.54	23.0	8.0 - 23.0
MW-59S	515.66	507.21	8.45	15.5	4.0 - 15.5 ³
MW-60S	519.88	508.45	11.43	17.0	7.0 - 17.0
MW-61S	522.48	510.36	12.12	21.5	4.0 - 21.5 ³
MW-62S	522.66	510.89	11.77	20.2	4.0 - 20.2 ³
MW-63S	534.32	509.15	25.17	33.5	14.5 - 33.5 ³
MW-64S	532.50	508.01	24.49	31.0	16.0 - 31.0
MW-65S	533.55	508.74	24.81	31.5	16.5 - 31.5
MW-66S	520.83	509.57	11.26	22.0	5.0 - 22.0 ³
MW-67S	526.93	508.60	18.33	26.0	7.5 - 26.0 ³
MW-68S	527.78	509.33	18.45	26.8	12.0 - 26.8
MW-69S	515.51	506.22	9.29	13.4	3.5 - 13.5
MW-70S	533.45	509.33	24.12	32.0	12.0 - 32.0 ³
MW-71S	526.91	505.57	21.34	24.0	9.0 - 24.0

Monitoring Well Number	Ground Surface Elevation (ft amsl) ¹	Groundwater Elevation (ft amsl) ¹	Depth to Groundwater (ft bgs) ²	Total Depth of Monitoring Well (ft bgs) ²	Screened Interval (ft bgs) ²
MW-72S	512.12	503.83	8.29	19.5	3.5 - 19.5 ³
MW-73S	519.82	506.38	13.44	14.0	3.5 - 14.0 ³
MW-74S	518.62	504.85	13.77	17.0	7.0 - 17.0
MW-75S	510.81	504.99	5.82	9.0	4.0 - 9.0

¹ amsl = above mean sea level

² bgs = below ground surface

³ These wells do not have well construction details in Appendix A of Earth Science's Remediation Assessment.

In February 1993, groundwater samples were collected from the 25 shallow monitoring wells and analyzed for:

- gross alpha
- gross beta
- uranium (233 and 234, 235, 238)
- radium (226, 228)
- potassium (40)
- thorium (228, 230, 232)
- total and dissolved metals
- fluoride, ammonia, nitrate/nitrite, sulfate
- volatile organic compounds
- semi-volatile organic compounds.

All of the groundwater samples were analyzed for gross alpha and gross beta. Samples that had either gross alpha greater than 15 pCi/l or gross beta greater than 50 pCi/l were analyzed for individual isotopes. A total of eighteen groundwater samples were analyzed for the individual isotopes. Only one well, MW-59S, had gross alpha or gross beta levels above these levels and was not analyzed for individual isotopes. All of the samples were analyzed for total metals, and eight samples were analyzed for dissolved metals. According to Earth Sciences, a minimum of 20 percent of the samples were to be analyzed for dissolved metals. Samples with the highest total metals concentrations were selected for dissolved metals analysis. The groundwater samples collected during the monthly and quarterly sampling conducted from March 1993 through December 1996 were analyzed for gross alpha, gross beta, pH, conductivity, fluoride, ammonia, and total dissolved solids. The results of these sampling events are summarized in Tables 11 to 17. However, results for fluoride, ammonia, nitrate/nitrite, and sulfate are not summarized in the tables. Sample results that are above the action levels are in shaded boxes in the results tables.

Table 11 shows that in February 1993 four of the seven upgradient wells had elevated levels of gross alpha, and that 10 of the 18 downgradient wells had elevated levels of gross alpha. Figure 4 shows gross alpha, gross beta, and uranium contamination in the shallow wells. Five of the downgradient wells that did not have elevated gross alpha levels had elevated gross beta levels.

For wells with groundwater sample results that have elevated gross beta but not elevated gross alpha concentrations, Earth Sciences has hypothesized that the gross beta levels are due to naturally occurring deposits of K-40 and that the groundwater is not necessarily impacted by Fansteel's operations in these areas. Based on the sampling data, there does appear to be a correlation between elevated gross beta and elevated levels of K-40. However, Earth Sciences did not analyze the five samples with only elevated gross beta for K-40. Thus the hypothesis lacks the necessary data to fully support it.

For most of the wells the source of groundwater contamination can be inferred by the proximity to process areas. However, for MW-56S, which is located in the borrow pit area, the source of contamination is not clear because, according to Fansteel personnel, no processing or storage of radioactive materials is known to have occurred upgradient or within 300 feet of this well.

Table 11. February 1993 Sampling Results for Gross Alpha and Gross Beta

Monitoring Well Number	Upgradient or Downgradient well	Gross Alpha (15 pCi/l)	Gross Beta (50 pCi/l)
MW-51S	Upgradient	8	8
MW-52S	Upgradient	79	160
MW-53S	Upgradient	6	10
MW-54S	Upgradient	15	25
MW-55S	Upgradient	40	36
MW-56S	Downgradient	76	34
MW-57S	Downgradient	23	120
MW-58S	Downgradient	5	45
MW-59S	Downgradient	19	110
MW-60S	Downgradient	24	240
MW-61S	Downgradient	0	150
MW-62S	Downgradient	2	200
MW-63S	Downgradient	0	210
MW-64S	Downgradient	12	130
MW-65S	Downgradient	19	100
MW-66S	Downgradient	140	120
MW-67S	Downgradient	1,300	440
MW-68S	Upgradient	52	59
MW-69S	Upgradient	30	24
MW-70S	Downgradient	1	370
MW-71S	Downgradient	29	140
MW-72S	Downgradient	7	10
MW-73S	Downgradient	830	1,300
MW-74S	Downgradient	2,600	930
MW-75S	Upgradient	14	18

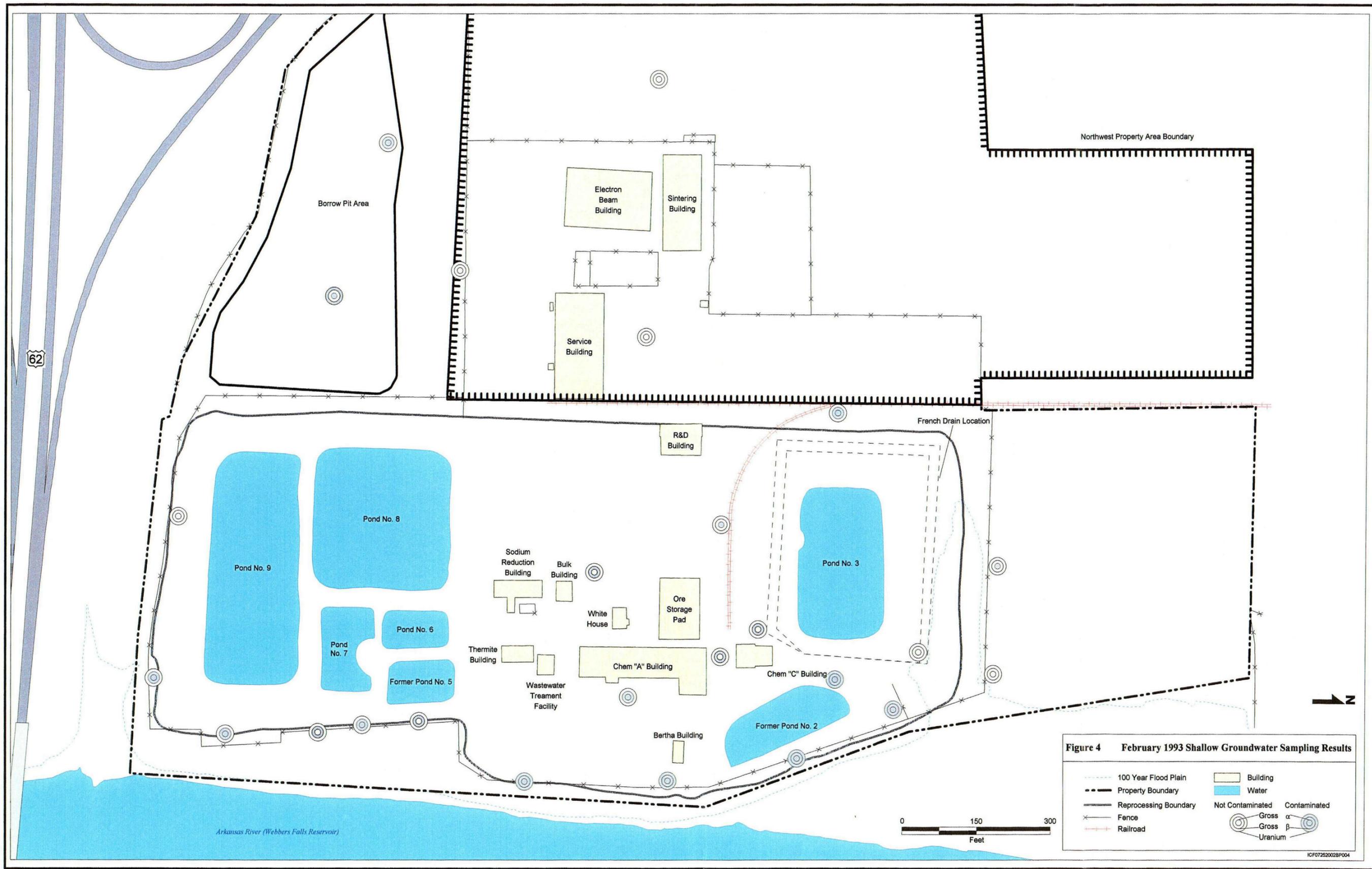


Figure 4 February 1993 Shallow Groundwater Sampling Results

	100 Year Flood Plain		Building
	Property Boundary		Water
	Reprocessing Boundary		Not Contaminated
	Fence		Gross α
	Railroad		Gross β
			Uranium

ICF072520028P004

Table 12 shows that the following six wells have elevated concentrations of uranium: MW-56S, MW-66S, MW-67S, MW-71S, MW-73S, and MW-74S. Well MW-56S is located in the borrow pit area. Well MW-71S is located east of Pond 3 and may be downgradient of a small portion of Pond 3. The remaining monitoring wells are located east of the processing area along the eastern property boundary. The natural uranium concentrations in these wells ranges from slightly over the action level to 1,600 times the action level. No other isotopes had results above the action levels.

Table 12. February 1993 Sampling Results for Individual Isotopes

Monitoring Well Number ¹	Individual Isotopes (pCi/l)								
	Uranium 233 & 234	Uranium 235	Uranium 238	Radium 226	Radium 228	Potassium 40	Thorium 228	Thorium 230	Thorium 232
Action Level ²	30 (total)			60	60	4000	15 (total)		
MW-52S	0.7	0.0	0.9	4.1	5.9	2.0	6.4	4.0	5.6
MW-55S	1.4	0.0	1.3	2.0	3.0	4.8	1.9	1.0	1.6
MW-56S	37.0	2.2	29.0	0.5	1.4	1.9	0.7	0.6	0.4
MW-57S	1.9	0.0	0.8	1.4	2.0	80.0	1.5	0.9	1.2
MW-60S	0.4	0.0	0.0	3.2	2.2	210.0	1.7	0.4	1.1
MW-61S	0.7	0.0	0.4	1.0	1.4	130.0	0.3	0.2	0.2
MW-62S	4.3	0.2	3.6	0.6	NA	NA	0.5	0.3	0.1
MW-63S	0.2	0.0	0.2	0.2	NA	NA	0.1	0.4	0.0
MW-64S	6.2	0.4	7.0	1.3	NA	NA	1.1	0.8	0.9
MW-65S	3.0	0.0	3.1	1.7	NA	NA	0.9	0.7	0.6
MW-66S	970.0	40.0	980.0	1.5	NA	NA	0.4	0.5	0.6
MW-67S	900.0	42.0	900.0	0.1	NA	NA	0.5	2.4	0.0
MW-68S	1.5	0.0	1.3	2.0	NA	NA	3.0	1.5	2.3
MW-69S	0.7	0.0	0.4	2.0	2.3	1.0	2.1	1.4	1.5
MW-70S	2.6	0.0	2.1	1.1	NA	NA	0.0	0.0	0.1
MW-71S	19.0	1.1	21.0	1.5	NA	NA	1.4	1.7	1.1
MW-73S	42.0	8.9	35.0	5.8	11.0	26.5	3.5	1.2	1.4
MW-74S	21,000.0	2,100.0	25,000.0	1.4	NA	NA	0.8	0.0	0.5

NA = Not analyzed

¹ Groundwater samples from the wells not included in this table were not analyzed for individual isotopes.

² The action levels for uranium and thorium were obtained from Fansteel's NRC license. The action levels for radium and potassium were obtained from 10 CFR Part 20 Appendix B, Table 2.

Table 13 shows that in 1994, which is five years after Fansteel ceased operations, there is still significant groundwater contamination. This table presents the annual average gross alpha and gross beta concentrations for each well and the number of samples during 1994 that were over the action levels. The data in Table 13 shows that only one of the seven upgradient wells has an average gross alpha concentration above the action level of 15 pCi/l. However, all seven of the upgradient wells had one or more samples above the action level. This table also shows that five

of the 18 downgradient wells have average gross alpha concentrations above the action level, and that all of the downgradient wells had one or more samples above the action level. All but two wells (one upgradient and one downgradient) had average gross beta concentrations above the action level of 50 pCi/l. As Earth Sciences has hypothesized, the samples with elevated gross beta but not elevated gross alpha are due to naturally occurring deposits of K-40 and thus the groundwater is not necessarily impacted by Fansteel's operations. All of the wells with elevated gross alpha also had elevated levels of gross beta.

Table 13. Summary of 1994 Monthly Groundwater Monitoring

Monitoring Well Number	Total Number of Samples	Gross Alpha		Gross Beta	
		Annual Average (pCi/l)	Number of Samples above 15 pCi/l	Annual Average (pCi/l)	Number of Samples above 50 pCi/l
MW-51S	11	15	3	94	4
MW-52S	11	17	5	82	4
MW-53S	11	8	1	66	4
MW-54S	11	14	2	49	4
MW-55S	11	10	2	66	4
MW-56S	11	38	7	78	3
MW-57S	11	12	2	158	9
MW-58S	11	13	5	104	8
MW-59S	11	1	2	165	8
MW-60S	10	11	3	237	9
MW-61S	10	4	2	122	7
MW-62S	11	3	2	140	7
MW-63S	11	4	1	162	7
MW-64S	10	8	2	102	7
MW-65S	11	14	3	84	7
MW-66S	10	93	5	131	7
MW-67S	10	836	10	416	9
MW-68S	10	7	1	85	3
MW-69S	11	18	3	67	4
MW-70S	10	18	3	190	7
MW-71S	10	18	4	105	6
MW-72S	10	13	2	49	3
MW-73S	2	594	2	576	2
MW-74S	11	3,906	10 ¹	1,763	11
MW-75S	11	16	2	89	3

¹ Only sample results for ten gross alpha samples were available for MW-74S.

Table 14 shows that in 1996, which is seven years after Fansteel ceased operations, there is still significant groundwater contamination. Figure 5 shows gross alpha and gross beta contamination in the shallow wells for samples collected in 1996. The data in Table 14 shows that none of the seven upgradient wells have an average gross alpha or gross beta concentration above the action levels. This table also shows that four of the 18 downgradient wells have average gross alpha concentrations above the action level, and that only two other downgradient wells had one sample above the action level. Eleven wells had average gross beta concentrations above the action level of 50 pCi/l that did not have elevated gross alpha concentrations. As Earth Sciences has hypothesized, the samples with elevated gross beta but not elevated gross alpha are due to naturally occurring deposits of K-40 and thus the groundwater is not necessarily impacted by Fansteel's operations. Three of the four wells with elevated gross alpha also had elevated levels of gross beta. The monitoring well located in the borrow pit area, MW-56S, did not have elevated gross beta levels.

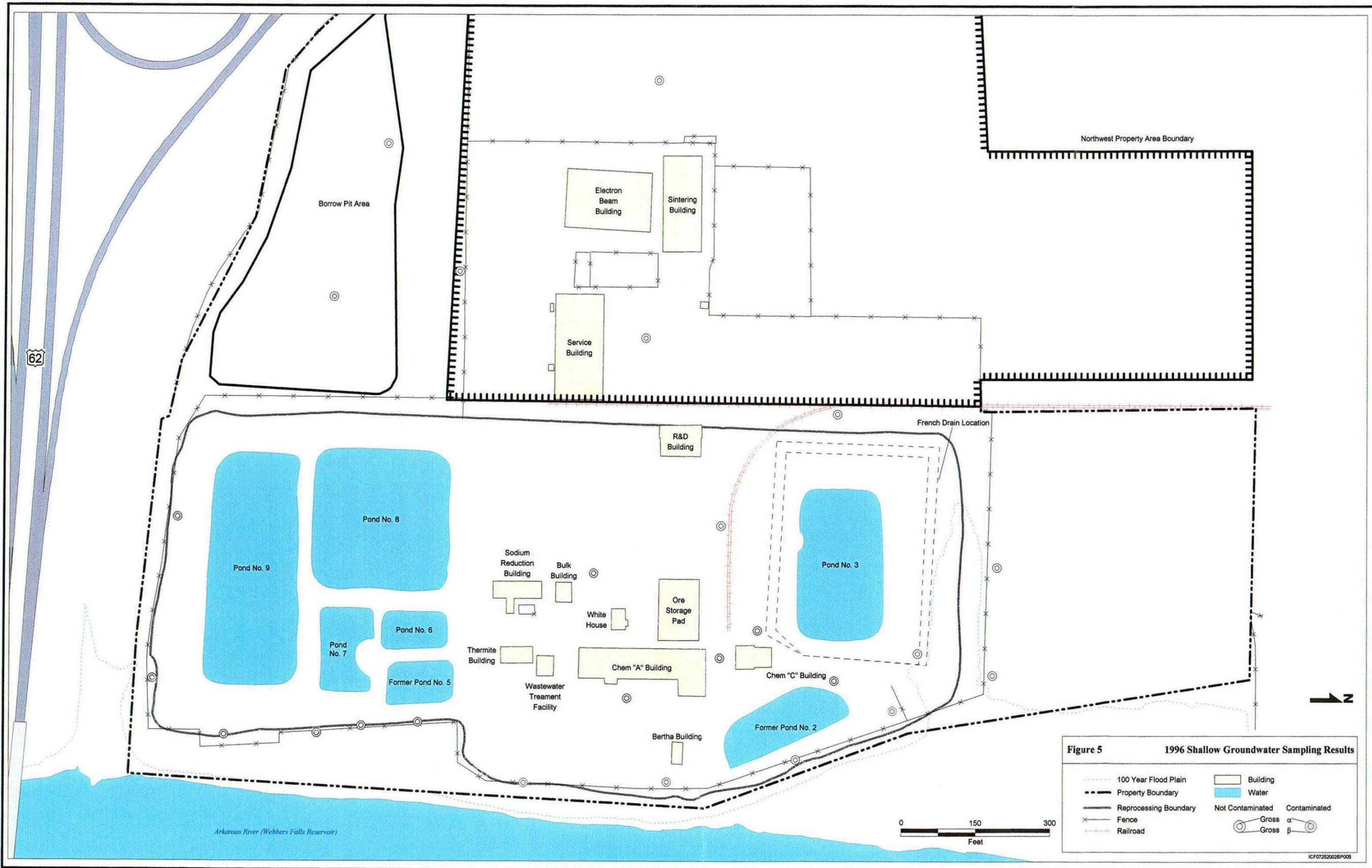
During the monthly and quarterly sampling conducted from March 1993 to December 1996, the groundwater samples were also analyzed for conductivity and pH. Conductivity is a measure of electrical conductivity in the groundwater and is useful for determining which wells are upgradient and which wells have been impacted by site operations. For example, the upgradient wells generally have conductivities in the 300 to 800 micromhos per centimeter (mhos/cm) range, while the downgradient wells generally have conductivities in the 2,000 to 10,000 mhos/cm range, with a maximum of 41,000. The pH in all the wells tends to be between 5 and 8, except for three downgradient wells, MW-67S, MW-73S and MW-74S. MW-67S has an average pH of 8.9 and the other two wells have pH readings in the 3 to 4 range. The higher pH in MW-67S is an indicator that this well may have been affected by the waste water treatment plant operations. The lower pH in MW-73S and MW-74S is an indicator that these well may have been affected by the residue in Pond 2, which has a pH between 2 and 3.

Table 14. Summary of 1996 Quarterly Groundwater Monitoring

Monitoring Well Number	Total Number of Samples	Gross Alpha		Gross Beta	
		Annual Average (pCi/l)	Number of Samples above 15 pCi/l	Annual Average (pCi/l)	Number of Samples above 50 pCi/l
MW-51S	4	4	0	4	0
MW-52S	4	6	0	7	0
MW-53S	4	3	0	3	0
MW-54S	4	3	0	5	0
MW-55S	4	2	0	8	0
MW-56S	4	40	4	17	0
MW-57S	4	6	0	140	4
MW-58S	4	9	1	93	4
MW-59S	4	0	0	112	4
MW-60S	4	8	1	228	4
MW-61S	4	9	0	157	4
MW-62S	4	4	0	113	4
MW-63S	4	4	0	81	3
MW-64S	4	7	0	89	4
MW-65S	4	3	0	97	4
MW-66S	4	63	4	117	4
MW-67S	4	1,373	4	539	4
MW-68S	4	3	0	2	0
MW-69S	4	2	0	2	0
MW-70S	4	4	0	102	2
MW-71S	4	5	0	61	4
MW-72S	4	6	0	23	0
MW-73S ¹	0	NA	0	NA	0
MW-74S	4	3,185	4	1,748	4
MW-75S	4	4	0	4	0

¹ Monitoring well 73 was not sampled because the well was dry.

Tables 15, 16, and 17 show that the groundwater is also contaminated with four heavy metals, arsenic, cadmium, chromium, and lead, and the volatile organic compound MIBK. As Table 16 shows, the groundwater contains elevated concentrations of dissolved arsenic, cadmium, and chromium as well. Table 17 shows that MIBK is mainly found in the wells just east of Pond 2 (MW-73S and MW-74S) and is also found at lower concentrations in the wells east of the waste water treatment plant (MW-67S) and north of the Chemical A building (MW-64S).



62

Borrow Pit Area

Electron Beam Building

Sintering Building

Service Building

Northwest Property Area Boundary

French Drain Location

Pond No. 9

Pond No. 8

Pond No. 7

Pond No. 6

Former Pond No. 5

Sodium Reduction Building

Bulk Building

White House

Ore Storage Pad

Thermite Building

Wastewater Treatment Facility

Chem "A" Building

Chem "C" Building

Bertha Building

Former Pond No. 2

Pond No. 3

Arkansas River (Webbers Falls Reservoir)



Table 15. February 1993 Sampling Results for Total Metals

Monitoring Well Number	Total Metals (µg/l)								
	Arsenic	Barium	Cadmium	Chromium	Nickel	Lead	Antimony	Columbium	Tantalum
Action Level	50		5	100		15		NA	NA
MW-51S	<1	80	18	<10	<11	7	<1	<10	40
MW-52S	<1	173	10	<10	<11	12	<1	<10	60
MW-53S	4	100	7	13	<11	6	<30	<100	<100
MW-54S	<1	327	4	<10	27	35	<30	20	40
MW-55S	21	295	29	64	101	17	35	50	60
MW-56S	11	91	<4	17	133	55	46	50	160
MW-57S	70	164	8	<10	34	16	78	20	70
MW-58S	330	80	5	<10	41	5	<30	10	70
MW-59S	126	74	6	20	157	5	<30	<100	100
MW-60S	391	177	7	<10	74	12	<1	20	110
MW-61S	405	85	6	<10	17	7	<1	<10	60
MW-62S	538	57	5	<10	<11	3	<1	<100	100
MW-63S	1,100	43	6	19	56	2	56	<100	<100
MW-64S	177	204	6	38	72	9	<30	<100	<100
MW-65S	403	201	10	67	82	10	38	<100	<100
MW-66S	205	100	6	<10	110	8	<1	<100	<100
MW-67S	2,830	24	7	23	33	2	3	<100	<100
MW-68S	7	184	11	24	31	12	<30	<100	<100
MW-69S	9	277	10	16	38	140	36	20	50
MW-70S	126	239	5	<10	<11	1	<30	<100	<100
MW-71S	494	257	13	71	107	14	<1	300	<100
MW-72S	18	62	9	31	836	<1	44	100	200
MW-73S	116	173	79	126	935	110	284	600	400
MW-74S	149	152	119	1,580	2,380	4	<1	1,900	600
MW-75S	8	149	6	<10	12	11	<30	<10	40

Values are rounded to the nearest whole number.

Table 16. February 1993 Sampling Results for Dissolved Metals

Monitoring Well Number	Dissolved Metals (µg/l)								
	Arsenic	Barium	Cadmium	Chromium	Nickel	Lead	Antimony	Columbium	Tantalum
Action Level	50	NA	5	100	NA	15	NA	NA	NA
MW-55S	12	98	6	<10	68	2	6	<100	<100
MW-62S	550	26	<5	<10	<40	<1	<3	<100	100
MW-63S	650	26	5	<10	53	<1	4	<100	200
MW-65S	300	73	<5	<10	54	<1	7	<100	<100
MW-66S	430	63	10	<10	120	<1	4	<100	<100
MW-67S	4,000	93	<5	<10	<40	4	12	<100	100
MW-73S	180	230	190	1,400	2,300	2	<3	1,400	900
MW-74S	910	96	110	1,500	2,300	5	4	1,500	800

Values are rounded to the nearest whole number.

Table 17. Volatile Organic Results in Groundwater (µg/l)

Monitoring Well Number ¹	4-methyl 2-pentanone (µg/l)
MW-51S	<10
MW-52S	<10
MW-56S	<10
MW-57S	<10
MW-58S	<10
MW-59S	<10
MW-60S	<10
MW-61S	<10
MW-62S	<10
MW-63S	<10
MW-64S	430
MW-65S	<10
MW-66S	<10
MW-67S	820
MW-68S	<10
MW-69S	<10
MW-70S	<10
MW-71S	37
MW-72S	<10
MW-73S	80,500 ²
MW-74S	83,000
MW-75S	<10

¹ Monitoring wells MW-53S, MW-54S, and MW-55S were not analyzed for volatile organic compounds.

² Average of two samples.

5.1.2 Bedrock Aquifer

Four monitoring wells were installed in February 1993 in the bedrock underlying the site to determine the impact of Fansteel's operations on the deeper bedrock aquifer. One of the bedrock monitoring wells was installed upgradient of the site operation buildings on the west side of the property. The other three bedrock monitoring wells were installed along the eastern boundary of the property. These three wells are downgradient of Fansteel's operations. The monitoring wells for the deep bedrock aquifer were installed to depths of between 38 and 70 feet. Table 18 provides information on the screened interval, the total depth, and depth to groundwater for each of the wells as obtained from Table 1 and the boring logs in Appendix A of Earth Science's Remediation Assessment.

Table 18. Monitoring Well Installation Data

Monitoring Well Number	Ground Surface Elevation (ft amsl) ¹	Groundwater Elevation (ft amsl) ¹	Depth to Groundwater (ft bgs) ²	Total Depth of Monitoring Well (ft bgs) ²	Screened Interval (ft bgs) ²
MW-151D	540.65	491.58	49.07	70.0	60.0 - 70.0
MW-161D	522.16	503.3	18.86	46.0	36.0 - 46.0
MW-167D	527.50	488.80	38.7	53.0	43.0 - 53.0
MW-174D	518.51	499.31	19.2	38.0	28.0 - 38.0

¹ amsl = above mean sea level

² bgs = below ground surface

In March and April 1993, groundwater samples were collected from the four deep monitoring wells and analyzed for:

- gross alpha
- gross beta
- uranium (233 and 234, 235, 238)
- radium (226, 228)
- potassium (40)
- thorium (228, 230, 232)
- total metals
- fluoride, ammonia, nitrate/nitrite, sulfate
- volatile organic compounds
- semi-volatile organic compounds.

All of the groundwater samples were analyzed for gross alpha and gross beta. Samples that had either gross alpha greater than 15 pCi/l or gross beta greater than 50 pCi/l were analyzed for individual isotopes. Only the groundwater sample from the upgradient well (MW-151D) was analyzed for the individual isotopes. All of the samples were analyzed for total metals. The groundwater samples collected during the monthly and quarterly sampling conducted from March 1993 through December 1996 were analyzed for gross alpha, gross beta, pH, conductivity,

fluoride, ammonia, and total dissolved solids. The results of these sampling events are summarized in Tables 19 to 23. However, results for fluoride, ammonia, nitrate/nitrite, and sulfate are not summarized in the tables. Sample results that are above the action levels are in bold text in the results tables.

Table 19 shows that in the Spring of 1993 the one upgradient well had elevated levels of gross alpha. Since further sampling of this well did not show elevated gross alpha and gross beta contamination, the high initial sampling results may have been due to cross contamination that occurred during well installation. The remaining tables (20 to 23) show that the bedrock aquifer has not been affected by Fansteel's operations.

Table 19. Spring 1993 Sampling Results for Gross Alpha and Beta

Monitoring Well Number	Gross Alpha (pCi/l)	Gross Beta (pCi/l)
Action Level	15	50
MW-151D	26	52
MW-161D	4	8
MW-167D	0	16
MW-174D	10	10

Table 20. Spring 1993 Sampling Results for Individual Isotopes

Monitoring Well Number	Individual Isotopes (pCi/l)								
	Uranium 233 & 234	Uranium 235	Uranium 238	Radium 226	Radium 228	Potassium 40	Thorium 228	Thorium 230	Thorium 232
Action Level ¹	30			60	60	4000	15		
MW-151	9.1	0.4	5.0	1.2	0.4	11.7	2.1	0.7	1.3

Groundwater samples from the wells not included in this table were not analyzed for individual isotopes.

¹ The action levels for uranium and thorium were obtained from Fansteel's NRC license. The action levels for radium and potassium were obtained from 10 CFR Part 20 Appendix B, Table 2.

Table 21. Summary of 1994 Monthly Groundwater Monitoring

Monitoring Well Number	Total Number of Samples	Gross Alpha		Gross Beta	
		Annual Average (pCi/l)	Number of Samples above 15 pCi/l	Annual Average (pCi/l)	Number of Samples above 50 pCi/l
MW-151	10	3	0	5	0
MW-161	10	5	1	2	0
MW-167	10	4	0	4	0
MW-174	10	6	1	5	0

Table 22. Summary of 1995 Quarterly Groundwater Monitoring¹

Monitoring Well Number	Total Number of Samples	Gross Alpha		Gross Beta	
		Annual Average (pCi/l)	Number of Samples above 15 pCi/l	Annual Average (pCi/l)	Number of Samples above 50 pCi/l
MW-151	2	2	0	3	0
MW-161	2	2	0	2	0
MW-167	2	2	0	2	0
MW-174	2	1	0	4	0

¹ The deeper bedrock monitoring wells were not sampled after the second quarter of 1995.

Table 23. February 1993 Sampling Results for Total Metals

Monitoring Well Number	Total Metals (µg/l)								
	Arsenic	Barium	Cadmium	Chromium	Nickel	Lead	Antimony	Columbium	Tantalum
Action Level	50		5	100		15		NA	NA
MW-151	120	76	6	15	<11	39	<1	<100	<100
MW-161	5	81	<4	<10	<11	122	<1	<100	<100
MW-167	4	350	<4	<10	<11	9	<1	<100	<100
MW-174	11	85	<4	11	<11	9	<1	<100	<100

Values are rounded to the nearest whole number.
NA = Not applicable.

5.2 Identification of Potential Gaps in Characterization

Radiological contamination was found above the levels contained in Fansteel's NRC license in 23 of the 25 shallow wells and one of the four deep wells. However, only five of the shallow wells and none of the deep wells appear to have significant contamination detected on an

ongoing basis. The wells where significant, lasting contamination was found are located in the borrow pit area (MW-56S) and along the eastern property line (MW-66S, MW-67S, MW-73S, and MW-74S).

Non-radiological contamination of underlying groundwater at the site has been found in many of the wells. Elevated concentrations of metals were found primarily in the wells along the southern and eastern property boundary. A volatile organic compound, MIBK, was found in the wells surrounding the former Pond 2. No semi-volatile organic compounds were detected at elevated concentrations.

Given these results, we now answer the questions from Section 3.3 to identify whether gaps exist in the groundwater characterization.

1. Have historical records been kept for prior groundwater sampling events on the site?

Partial yes. Yes for the Earth Sciences sampling events in 1993 through 1996. Unknown, for any earlier or later sampling events.

2. Is the depth, direction, and flow of groundwater at the site known?

The aquifer directly beneath the site has been well documented as well as the bedrock aquifer beneath the site. However, the direction of groundwater flow is suspect on some areas of the site due to radial flow originating near the center of the site. The radial flow is suspect because this type of flow is likely to be representative of a snapshot of groundwater flow and not a steady state flow pattern.

3. Are the uses of all aquifers known?

Yes. Groundwater is used as a source of drinking water by local residents near the facility.

4. Has each distinct aquifer been classified as likely-impacted or non-impacted?

Yes. The uppermost aquifer is clearly contaminated. The bedrock aquifer does not appear to be contaminated.

5. Have a sufficient number of wells been located downgradient of each known source, or on the downgradient portion of the facility?

No. Twelve monitoring wells were placed an average of every 300 feet (minimum distance is about 110 feet and the maximum is about 410 feet), along the eastern portion of the property and curving around to the west to cover the area downgradient of the main processing areas. These wells can be used to establish whether contamination has migrated to the property boundary. Additional wells were placed downgradient of most

of the processing facilities on the site, except for the Chemical C building. The Chemical C building was used for digesting the virgin ore and tin slag with hydrofluoric acid and sulfuric acid. Since this building was used for approximately 30 years, has a sectioned concrete floor, and was "modernized" only once in 1964, ICF suspects that this building may be a significant source of soil and groundwater contamination. The closest well is about 75 feet away and may not be downgradient, thus ICF can not conclusively determine if this building is a source of groundwater contamination. Also the groundwater contamination in the borrow pit area has not been sufficiently defined, especially since the source of this contamination is unknown.

6. Has a sampling plan been prepared for each likely-impacted aquifer based on historical knowledge, known surface and sub-surface contamination, and seasonal changes in groundwater flow and depth?

Earth Sciences prepared a sampling plan that included both the shallow aquifer in the unconsolidated materials and the deeper bedrock aquifer. Since ICF has not received the sampling plan for review, the extent to which it addresses these issues is not known.

7. Does the sampling plan address QA/QC requirements?

The sampling plan was not available for review. Although ICF has not reviewed the sampling plan, it appears to have addressed QA/QC requirements.

8. Has sampling been conducted in each aquifer according to the sampling plan?

The sampling plan was not available for review.

9. Are the number and depths of samples taken known for each well?

Yes.

10. Are the detection limits for each analytical instrument known for all samples?

They can be inferred from the sampling results.

11. Has sampling been conducted for each well using appropriate instrumentation with appropriate sensitivity?

Yes. The detection limits for the radionuclides are well below the action levels for these materials.

12. Are all sample results below NRC or State regulatory levels?

No.

Based on these answers, we find the following three gaps in the groundwater characterization at the site. First, given the likelihood that the Chemical C Building is a source of groundwater contamination, this source has not been adequately characterized. Obtaining a greater understanding of the magnitude of the Chemical C building as a source of groundwater contamination is important to developing an effective remediation strategy. Second, the groundwater flow direction has not adequately been analyzed to fully establish the groundwater flow direction throughout the site. The groundwater flow map shows an area of radial flow near the center of the site. Radial flow means that groundwater is flowing from one area and flowing in all directions. In this case the radial flow is in three directions. Radial flow is not a sustainable flow pattern unless there is a source of groundwater entering the site from the north northwest that then radiates out on the site. Such a flow pattern does not seem plausible given the site geology and hydrogeology. Thus the groundwater map presented in the Earth Science's report most likely captures a transient condition of the groundwater flow on the site.

Third, one well that was expected to be upgradient shows that the groundwater has elevated concentrations of gross alpha and uranium. The well in question is MW-56S in the borrow pit in the southwest corner of the site. The site activities that affect the groundwater in the borrow pit area are not known. The groundwater in the borrow pit area should be further investigated to determine the extent of contamination.

5.3 Assumptions about Extent of Contamination and Recommendations for Additional Characterization

Given the three gaps in characterization and the need to understand groundwater contamination to design appropriate soil and groundwater remedial measures, we recommend the following actions. First, the installation and sampling of a monitoring well immediately down gradient of the Chemical C Building. The well should be sampled for gross alpha, gross beta, and individual isotopes. Second, the monthly and quarterly groundwater level measurements collected during 1993 through 1996 or other groundwater level measurements should be analyzed to firmly establish groundwater flow patterns on the site. Third, two monitoring wells should be installed in the borrow pit to further delineate the extent of groundwater contamination in this area. One well should be placed upgradient of MW-56S and one well should be placed downgradient of MW-56S. These wells should be analyzed for gross alpha, gross beta, and individual isotopes.

Fansteel has already installed a groundwater collection and treatment system that covers the area downgradient of the processing area. Thus the installation of a monitoring well downgradient of the Chemical C Building is not critical to the design of a remediation system. However, a well in this location would be useful for monitoring changes in groundwater upgradient of the collection trenches. The contaminated groundwater in the borrow pit area may not be captured by the collection system. Thus without further groundwater investigation, ICF might recommend extending the groundwater collection system trench another 200 to 300 feet west along the southern property boundary.

5.4 Costs Associated with Additional Characterization

To calculate the cost associated with additional ground water monitoring, we first identified the number of new wells to be installed (three). Given one sampling event, we then calculated that three samples would need to be analyzed. Next, we calculated the total unit cost of analysis, resulting in a total unit cost of \$574. As shown in Table 24, we then multiplied the unit cost to install additional wells by the number of additional wells needed, and multiplied the unit cost of sampling by the number of samples requiring analysis. We summed the costs to arrive at a subtotal of \$21,594. To account for sample collection and associated costs of sampling, we added 15 percent of this subtotal cost on to this estimate, which results in a total cost of \$24,833.

Table 24. Estimated Costs Associated with Additional Groundwater Monitoring

Number of new wells needed	3
Number of samples needed per event	3
Number of sampling events	2
Number of samples analyzed	6
Unit cost to install each well	\$6,050
Unit cost to analyze each sample	\$ 574
Total cost to install 3 wells	\$ 18,150
Total cost of analysis	\$ 3,444
Subtotal cost	\$ 21,594
Associated sampling costs (15 percent)	\$ 3,239
Total cost	\$ 24,833

6.0 Ponds

Over the course of Fansteel's operations from 1956 to 1989 (and between 2000 and 2001), ten holding ponds have been used at the site. During site operations, the ponds held acid slurries, process water, and wastewater treatment slurries. The holding ponds now contain sludges or residues contaminated with organic, inorganic, and radioactive waste. The primary contaminants of concern are: chromium; methyl isobutyl ketone (MIBK, also known as 4-Methyl-2-pentanone); radioactive source material such as U-233, U-234, U-235, U-238, Th-230, Th-234, and their decay products. The presence of hazardous and radioactive contaminants increases the probability that some of the material in the ponds will have to be disposed as mixed waste.

There are two types of ponds at the Fansteel site. The first type includes those that were used to store process residues. The second type are those that were and are currently used for wastewater treatment. Ponds 1N and 1S, 2, 3 and 5 were principally used to hold processing residues (Ponds 2 and 5 also received wastewater at some point). All of these ponds, with the exception of Pond 3, have been filled in.

Ponds 5, 6, 7, 8, and 9 are wastewater treatment settling ponds and contain principally calcium carbonate and calcium fluoride. Ponds 6 through 9 are connected in series and water and calcium fluoride sludge and water can pass between them. Before Ponds 8 and 9 were built in 1984, Ponds 2, 5, 6, and 7 were connected in series. Water from the wastewater treatment plant is still pumped into Ponds 8 and 9. As the calcium fluoride settles out, the water is pumped to Ponds 6 and 7 for further clarification where it is eventually released to the Arkansas River through NPDES outfall 001. The ponds are open to the atmosphere. A high berm surrounds the block of ponds. Precipitation events soak the berms and form puddles between some of the ponds.

Ponds 2, 3, and 5 through 9 were sampled explicitly to characterize the material in the ponds. These seven ponds are discussed in this section. Ponds 1S and 1N were partially characterized through soil borings. Pond 4 has been filled in for approximately 23 years and the area has not been characterized. No soil testing has been done within the pond berms or between or under the ponds. This section addresses only the contents of the ponds themselves. Soils surrounding or underlying the ponds is addressed in the Section 7.

The most recent characterization of the holding ponds was performed by Earth Sciences Consultants, Inc. in 1993. Their Remediation Assessment serves as the primary source of characterization and pond information used in this review. In addition, site details were taken from The National Survey of Solid Wastes from Mineral Processing Facilities, (EPA, 1989), from NRC officials familiar with the facility, and from a site visit performed by ICF in June, 2002.

In Section 6.1, we present the results of these investigations. Section 6.2 discusses our assessment of the adequacy of the pond characterization to date, while Section 6.3 presents our assessment of whether additional sampling is needed. Finally, Section 6.4 presents the costs associated with the additional sampling.

6.1 Summary of Existing Characterization

Pond residues were sampled by Earth Sciences at 25 different locations within Ponds 2, 3, 5, 6, 7, 8, and 9. Pond sampling locations are identified in Figure 6. Ponds 1N and 1S are covered with soil and were partially characterized through soil borings (see Section 7 of this document for a discussion of borehole analyses).

According to the Remediation Assessment, the residues contained within the seven ponds could not support a drill rig and standard split-spoon sampling techniques. Thus, traditional sampling techniques could not effectively sample the residues and an alternative method was used. Residue samples were collected at each location using a hollow steel sampling barrel connected to an air compressor. The sampling barrel and air compressor were mounted on a pontoon barge. Once at a sampling location, the sample barrel was inserted into the pond residues while a slight vacuum was created on the inside of the sample barrel. The barrel was manually advanced through the pond residues until the bottom of the pond was encountered. The vacuum was maintained as the sample barrel was slowly extracted from the residues. The residue samples were then extracted from the sample barrel by reversing the vacuum and exerting a small amount of pressure to the inside of the barrel.

Once extracted, the residue sample was divided into equal thirds, placed into three separate stainless steel buckets, and homogenized. The homogenized samples were placed into appropriate sample containers resulting in three samples per location. The sample barrel and stainless steel buckets were decontaminated between sampling locations by swabbing the interior of the barrel and scrubbing the buckets with deionized water and soap followed by rinses of deionized water, a five percent nitric acid solution, methanol, and a final deionized water rinse. The barge and all sampling equipment were steam cleaned between ponds and surveyed with beta/gamma meters to ensure that all residual radioactivity had been removed.

The three residue samples collected from each sample location corresponded to the top third, middle third, and bottom third of residue present in each pond. The thirds were identified as A, B, and C from top to bottom. The average depths of each sample in feet are indicated in the tables below. Accu-Labs Research, Inc. and Antech Ltd. laboratories analyzed the samples for the following radiological and chemical parameters:

- Total metals (antimony, arsenic, barium, beryllium, cadmium, chromium, columbium, lead, mercury, molybdenum, nickel, selenium, silver, tantalum, and tin) utilizing inductively coupled argon plasma procedures;
- Toxicity Characteristic Leaching Procedure (TCLP) metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver and nickel);
- Ammonia, chloride, fluoride, nitrate, sulfate, and cyanide;

Number of Pond Residue Samples	
Pond 2	3 locations, 9 samples
Pond 3	5 locations, 15 samples
Pond 5	3 locations, 9 samples
Pond 6	2 locations, 2 samples
Pond 7	2 locations, 2 samples
Pond 8	5 locations, 15 samples
Pond 9	5 locations, 12 samples

- Aluminum, calcium, iron, potassium, magnesium, manganese, and sodium;
- Alkalinity, pH, and specific conductance;
- Volatile Organic Compounds (VOCs);
- Semivolatile organic compounds; and
- Gross alpha and gross beta radioactivity, uranium isotopes, thorium 230, radium 226, radium 228, and other isotopes.

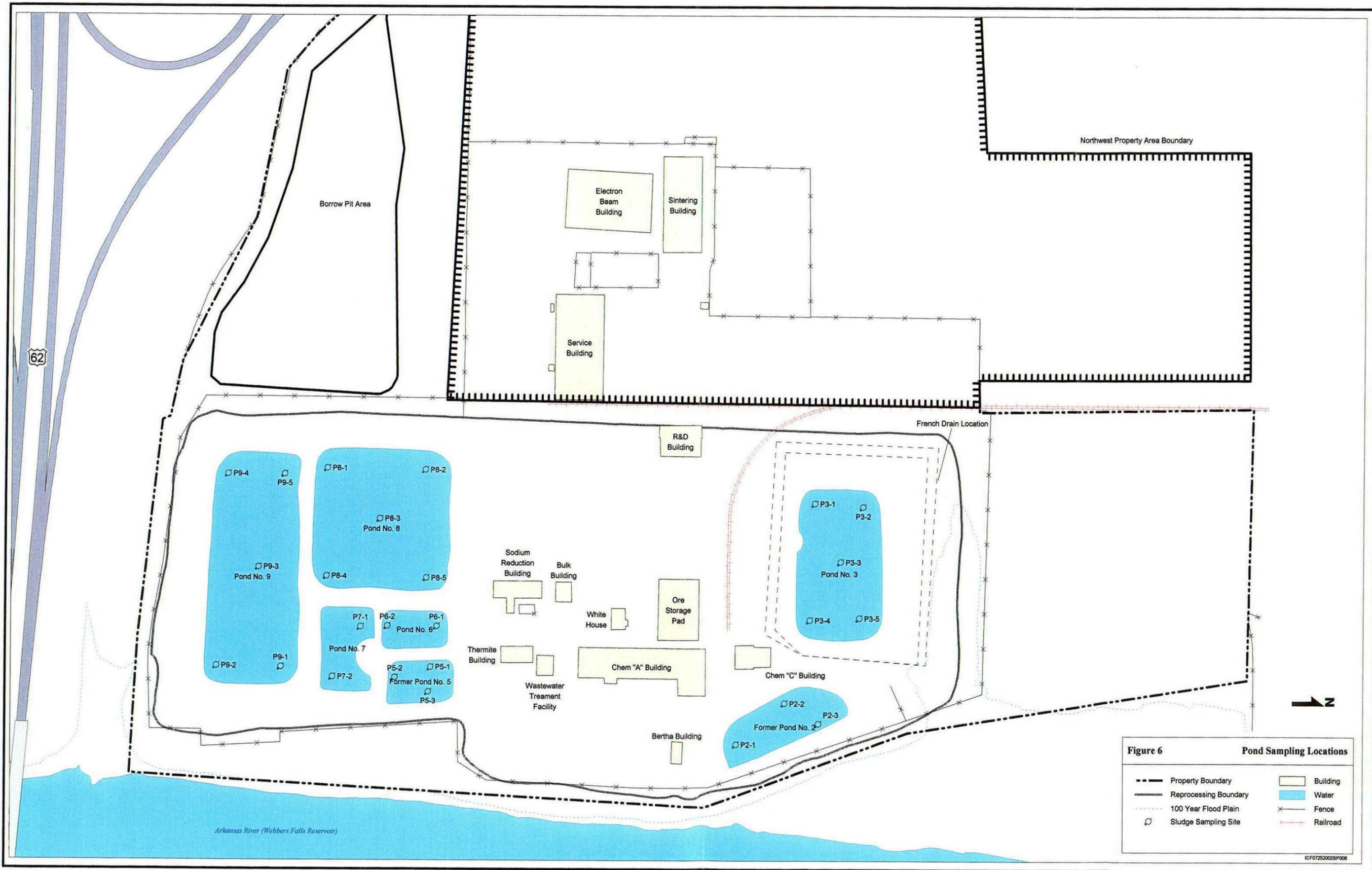
All but eight samples were analyzed for all of these parameters.²⁴ Elevated levels of radioactivity and metals were found in all of the ponds analyzed. All samples exhibited significant radioactivity, with gross alpha values in several ponds in the thousands of picocuries per gram (pCi/g) range. Uranium and thorium were present in all samples, in some ponds at hundreds of pCi/g. However, site personnel believe that the 60,000 tons of calcium fluoride residue contains less than one percent radiological constituents. The following sections describe the results of sampling conducted in the ponds.

6.1.1 Pond 2

Pond 2 was used to store acidic ore processing residue from the ore digestion process, including digested ores and slags and fluids comprised of hydrofluoric and sulfuric acids and containing MIBK, heavy metals, and radioactive waste. A total of nine residue samples were collected from three sampling locations in Pond 2. Its original dimensions were 351 feet by 151 feet or approximately 1.2 acres. Site personnel indicated that the pond is 10 feet deep with the sides sloping in an approximate ratio of 3 to 1. The pond was constructed in 1960 and included a clay liner. It was used to hold process residue until Pond 3 was built in 1979. A very small portion of the residue has been removed and reprocessed (about 34.1 tons of WIP out of the 10,500 tons estimated to be left in Ponds 2 and 3). Most of the process residue remains in the pond which is capped with a PVC sheet and one polyethylene sheet. Site personnel indicate that there are 24 inches of fill soil on top of the polyethylene while some documents indicate between 6 and 12 inches. The area is now covered with grass.

Analysis of the nine samples from Pond 2 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and thorium. Gross alpha and gross beta radioactivity were found at levels above the Earth Sciences background measurements of the site of 20 and 25 pCi/g. The average gross alpha and gross beta levels for Pond 2 were 4,478 and 2,091 pCi/g respectively. The maximum levels of gross alpha and gross beta were 6,700 and 3,100 pCi/g respectively. For specific radioactive isotopes analyzed in Pond 2, the NRC limit is 10 pCi/g. The average level of uranium isotopes was found to be 238 pCi/g although U-235 had the lowest levels with an average of 14 pCi/g and U-238 the highest average at 357 pCi/g. Thorium isotopes 230 and 234 had averages of 697 and 180 pCi/g, respectively, with maximums of 860 and 280 pCi/g,

²⁴ Sample P5-2 was analyzed for all parameters except radioactive constituents. P5-2A, B, and C were divided into separate depths and analyzed only for radioactive constituents. P8-1B was not analyzed for total metals or TCLP metals. P9-2B, C and P9-5A were not analyzed for radioactive constituents. It is not clear why these analyses were not done.



respectively. Analytical results for Pond 2 radionuclide concentrations are summarized in Table 25.

Analysis of the samples from Pond 2 for TCLP metals indicated that all residue samples exhibited leachable concentrations of chromium. Five of the nine residue samples contained leachable concentrations of chromium in excess of 5.0 milligrams per liter (mg/l). Wastes that contain leachable chromium above this level are hazardous waste. The concentrations of leachable chromium in the five samples had an average measurement of 7.4 mg/l and a maximum of 20 mg/l. The only VOC detected in Pond 2 was MIBK, identified in each of the nine residue samples with an average concentration of 210 mg/kg (maximum at 730 mg/kg). The treatment level for MIBK found in mixed waste is 33 mg/kg.²⁵ Elevated levels of fluoride were found in Pond 2, the average being 466 mg/l with a maximum of 650 mg/l. Also, Pond 2 was found to be acidic with an average pH at 2.77 (minimum at 2.33 standard units). Table 26 presents the concentrations of non-radioactive constituents in Pond 2 that were above action or treatment levels.

Table 25. Radionuclide Concentrations in Pond 2 (pCi/g)

Sample ID	Gross Alpha Action level = 20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U-238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th-234 Action Level = 10 ^b
Top Third of Pond Residue (~0 - 4 ft)							
P2-1A	2,300 ±100	920 ±20	180 ±10	5.8 ±1.7	180 ±10	640 ±40	91 ±8
P2-2A	6,200 ±100	2,700 ±100	440 ±10	19 ±3	440 ±10	650 ±30	130 ±40
P2-3A	4,900 ±100	2,200 ±100	320 ±20	1 ±3	350 ±20	710 ±30	220 ±40
<i>Average</i>	<i>4467</i>	<i>1,940</i>	<i>313</i>	<i>8.6</i>	<i>323</i>	<i>667</i>	<i>147</i>
Middle Third of Pond Residue (~4 - 8 ft)							
P2-1B	4,800 ±100	2,400 ±100	510 ±10	19 ±3	530 ±20	780 ±40	260 ±40
P2-2B	3,200 ±100	1,500 ±100	170 ±10	5.3 ±1.7	170 ±10	420 ±30	140 ±30
P2-3B	6,700 ±100	3,100 ±100	550 ±25	29 ±6	580 ±30	690 ±40	280 ±30
<i>Average</i>	<i>4,900</i>	<i>2,333</i>	<i>410</i>	<i>17.8</i>	<i>427</i>	<i>630</i>	<i>227</i>
Bottom Third of Pond Residue (~8 - 12 ft)							
P2-1C	3,200 ±100	2,000 ±100	410 ±10	22 ±3	430 ±10	850 ±40	160 ±30
P2-2C	5,200 ±100	2,200 ±100	290 ±10	13 ±2	280 ±10	670 ±30	210 ±60
P2-3C	3,800 ±100	1,800 ±100	230 ±10	13 ±3	250 ±10	860 ±40	130 ±10
<i>Average</i>	<i>4,067</i>	<i>2,000</i>	<i>310</i>	<i>16</i>	<i>320</i>	<i>793</i>	<i>167</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

²⁵ Mixed waste containing MIBK must be treated to reduce the MIBK to 33 mg/kg as per 40 CFR 268.48.

Table 26. Non-radioactive contaminants in Pond 2

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Top Third of Pond Residue (~0 - 4 ft)			
P2-1A	7.2	130	2.89
P2-2A	15	43	2.42
P2-3A	20	61	2.33
<i>Average</i>	<i>14</i>	<i>78</i>	<i>2.55</i>
Middle Third of Pond Residue (~4 - 8 ft)			
P2-1B	-	160	3.34
P2-2B	4.4	70	2.7
P2-3B	5	490	2.65
<i>Average</i>	<i>4.13</i>	<i>240</i>	<i>2.9</i>
Bottom Third of Pond Residue (~8 - 12 ft)			
P2-1C	0.5	140	3.38
P2-2C	4.9	68	2.7
P2-3C	6.8	730	2.51
<i>Average</i>	<i>4.1</i>	<i>312.67</i>	<i>2.86</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: - indicates that no analysis was done. Shaded cells indicates volumes exceeded action or treatment levels.

6.1.2 Pond 3

Pond 3 also was used to store acidic processing residue from the ore digestion process, including digested ores and slags and fluids comprised of hydrofluoric and sulfuric acids and containing MIBK, heavy metals, and radioactive waste. A total of 15 residue samples in Pond 3 were collected at five locations, four near the corners of the pond, and one in the center. Pond 3 is approximately 400 feet by 250 feet or 2.3 acres. The pond is 25 feet deep with a side slope of 3:1. Pond 3 has a synthetic liner. The pond used to hold approximate 2.6 million cubic feet of residue from the Chemical C Building but currently, it is estimated that the remaining “blue mud” process residue is approximately 12 feet deep at the east end and 8 feet deep at the west end of the pond, for an estimated volume of 1.2 million cubic feet.

The original Pond 3 was smaller and occupied approximately the eastern half of its current location. No information was available about whether this pond was lined. The current Pond 3 was expanded in 1979, encompassing most of Pond 4, and a synthetic liner was laid down. The

areas of Pond 4 that were not incorporated into the new Pond 3 were filled in with soil. It is not clear whether Pond 4 was lined, or what was done with the waste contained in it. However, during the construction of Pond 3, the crews hit the watertable in the alluvial soils. As a result, a french drain and sump were set up around the pond.

The analysis of the 15 residue samples from Pond 3 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and thorium. The average gross alpha and gross beta levels for Pond 3 were 5,263 and 2,674 pCi/g respectively. The maximum levels of gross alpha and gross beta were 6,500 and 3,700 pCi/g respectively. The average level of uranium isotopes was found to be 399 pCi/g although U-235 had the lowest levels with an average of 30 pCi/g. Thorium isotopes 230 and 234 had averages of 766 and 253 pCi/g, respectively, with maximums of 1,100 and 320 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 27.

Thirteen of the 15 residue samples collected from Pond 3 exhibited leachable concentrations of chromium with an average of 12.7 mg/l and a maximum of 36 mg/l. The only VOC detected in Pond 3 residues was MIBK. MIBK was identified in each of the 15 residue samples with an average concentration of 575 mg/kg and a maximum of 1,300 mg/kg. Elevated levels of fluoride were found at an average of 526 mg/l with a maximum of 670 mg/l. Pond 3 was found to have an average pH of 2.8 with a minimum of 2.1 standard units. Table 28 presents the concentrations of non-radioactive constituents in Pond 3 that were above action levels.

Table 27. Radionuclide Concentrations in Pond 3 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U- 238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th- 234 Action Level = 10 ^b
Top Third of Pond Residue (~0 - 4 ft)							
P3-1A	5800 ±100	2700 ±100	570 ±20	20 ±4	580 ±20	770 ±30	230 ±10
P3-2A	3400 ±100	1800 ±100	290 ±20	14 ±5	290 ±20	790 ±30	180 ±10
P3-3A	5400 ±100	2900 ±100	510 ±20	30 ±5	560 ±20	950 ±40	290 ±20
P3-4A	5900 ±100	2700 ±100	420 ±40	22 ±10	430 ±40	700 ±30	280 ±20
P3-5A	6500 ±100	3100 ±100	820 ±30	39 ±6	870 ±30	430 ±20	320 ±20
<i>Average</i>	<i>5400</i>	<i>2640</i>	<i>522</i>	<i>25</i>	<i>546</i>	<i>728</i>	<i>260</i>
Middle Third of Pond Residue (~4 - 8 ft)							
P3-1B	5200 ±100	2900 ±100	860 ±30	46 ±8	910 ±30	780 ±30	210 ±30
P3-2B	5500 ±100	2500 ±100	650 ±50	33 ±12	710 ±60	1100 ±100	240 ±40
P3-3B	3300 ±100	1700 ±100	420 ±20	42 ±6	460 ±20	690 ±30	250 ±30
P3-4B	6400 ±100	3700 ±100	820 ±30	32 ±6	850 ±30	850 ±40	240 ±30
P3-5B	840 ±40	610 ±20	170 ±20	12 ±5	180 ±20	210 ±20	110 ±20
<i>Average</i>	<i>4248</i>	<i>2282</i>	<i>584</i>	<i>33</i>	<i>622</i>	<i>726</i>	<i>210</i>
Bottom Third of Pond Residue (~8 - 12 ft)							
P3-1C	7600 ±100	3800 ±100	950 ±30	43 ±7	1000 ±100	800 ±40	340 ±30
P3-2C	6300 ±100	3100 ±100	800 ±30	45 ±7	870 ±30	1200 ±100	310 ±20
P3-3C	5500 ±100	2700 ±100	340 ±20	14 ±3	340 ±20	920 ±40	220 ±40
P3-4C	6900 ±100	3800 ±100	1000 ±100	41 ±6	110 ±100	810 ±30	340 ±20
P3-5C	4400 ±100	2100 ±100	350 ±20	20 ±5	370 ±20	490 ±30	240 ±30
<i>Average</i>	<i>6140</i>	<i>3100</i>	<i>688</i>	<i>32.6</i>	<i>538</i>	<i>844</i>	<i>290</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 28. Non-radioactive Contaminant Concentrations in Pond 3

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Top Third of Pond Residue (~0 - 4 ft)			
P3-1A	6.7	150	2.99
P3-2A	3.6	34	3.06
P3-3A	10	330	2.67
P3-4A	13	660	2.42
P3-5A	9.2	200	2.72
<i>Average</i>	8.5	275	2.8
Middle Third of Pond Residue (~4 - 8 ft)			
P3-1B	8.5	780	2.34
P3-2B	7.5	330	2.65
P3-3B	13	850	2.63
P3-4B	15	880	2.47
P3-5B	<0.1	750	5.56
<i>Average</i>	8.8	718	3.13
Bottom Third of Pond Residue (~8 - 12 ft)			
P3-1C	15	2.47	610
P3-2C	36	1300	2.1
P3-3C	13	830	2.66
P3-4C	18	800	2.37
P3-5C	10	600	2.94
<i>Average</i>	18	566	2.8

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: Shaded cells indicate values that exceeded action or treatment levels.

6.1.3 Pond 5

Pond 5 is a filled-in basin that was used both for storage of ore processing residues and for wastewater treatment, although the exact time frame for these usages is unknown. A total of five residue samples were collected from Pond 5 at three sampling locations. The pond is approximately 200 feet by 100 feet or about 0.5 acres. Pond 5 is approximately 10 feet deep. The pond was constructed in 1973 with a clay liner. At an unknown date, the residue present in

Pond 5 was dried and placed in 1,200 one-ton bulker bags (about one cubic yard). This material was intended to be used as feed material for reprocessing. The bags are currently stored in the Sodium Reduction Building. It appears that the sampling was done after the process material had already been removed but some wastewater treatment residues remained as there was only three feet of residue to sample. Eventually, Pond 5 was closed by filling in with topsoil.

The analysis of the 9 samples from Pond 5 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and thorium. The average gross alpha and gross beta levels for Pond 5 were 120 and 64 pCi/g, respectively. The maximum levels of gross alpha and gross beta were 390 and 170 pCi/g, respectively. The average level of uranium isotopes was found to be 14 pCi/g, although U-235 had the lowest levels with an average of 1 pCi/g. Thorium isotopes 230 and 234 had averages of 9 and 15 pCi/g, respectively, with maximums of 38 and 69 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 29.

TCLP chromium concentrations were found well below the EPA action level, and MIBK was detected at an average of 2,340 mg/kg with a maximum of 3,000 mg/kg. The average pH for Pond 5 is 8.8 with a maximum of 10.3 standard units. Mercury was found at a concentration of 1.3 mg/l in one Pond 5 sample (P5-1B), which is above the level of 0.2 mg/l for hazardous waste. Table 30 presents the concentrations of non-radioactive constituents in Pond 5 that were above action or treatment levels.

Table 29. Radionuclide Concentrations in Pond 5 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U- 238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th- 234 Action Level = 10 ^b
Top Third of Pond Residue (~0 - 1.5 ft)							
P5-1A	190 ±20	88 ±8	28 ±2	1.4±0.4	28 ±1	12 ±1	21 ±2
P5-2A	44 ±11	34 ±6	4.1±0.5	0.1±0.1	4.1 ±0.5	2.8 ±0.5	4.3 ±1.3
P5-3A	84 ±14	31 ±6	6.8±0.7	0.1±0.2	7.0 ±0.8	7.3 ±0.9	4.9 ±0.8
<i>Average</i>	<i>106</i>	<i>51</i>	<i>13</i>	<i>0.5</i>	<i>13</i>	<i>7.4</i>	<i>10</i>
Middle Third of Pond Residue (~1.5 - 3 ft)							
P5-1B	170 ±20	170 ±20	97 ±2	5.0 ±0.6	97 ±2	8.8 ±0.7	69 ±4
P5-2B	130 ±20	52 ±7	10 ±1	0.6 ±0.2	10 ±1	11 ±1	6.8 ±1.2
P5-3B	40 ±10	21 ±6	2.3 ±0.4	0.1 ±0.1	2.6 ±0.5	1.2 ±0.4	2.5 ±1.0
<i>Average</i>	<i>113.3</i>	<i>81</i>	<i>36.4</i>	<i>1.9</i>	<i>36.5</i>	<i>7.0</i>	<i>26.1</i>
Bottom Third of Pond Residue (~3 - 4.7 ft)							
P5-1C	19 ±8	17 ±5	3.9 ±0.6	0.0 ±0.1	2.7 ±0.5	1.2 ±0.3	2.8 ±0.6
P5-2C	390 ±30	140 ±10	36 ±2	1.5 ±0.3	39 ±2	38 ±2	21 ±3
P5-3C	16 ±8	22 ±6	0.6 ±0.3	0.0 ±0.1	0.4 ±0.3	0.4 ±0.3	1.1 ±0.5
<i>Average</i>	<i>141.7</i>	<i>59.7</i>	<i>13.5</i>	<i>0.5</i>	<i>14.0</i>	<i>13.2</i>	<i>8.3</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 30. Non-radioactive Contaminant Concentrations in Pond 5

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
P5-1A	<0.1	1600	7.93
P5-1B	<0.1	2500	6.48
P5-1C	<0.1	3000	9.16
P5-2	0.11	2400	9.2
P5-3	0.1	2200	10.31
<i>Average</i>	<i>0.1</i>	<i>2340</i>	<i>8.6</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: Shaded numbers exceeded action or treatment levels.

6.1.4 Ponds 6 and 7

Ponds 6 and 7, along with Ponds 8 and 9, were used to treat process wastewater and principally contain calcium carbonate and calcium fluoride. Ponds 6 and 7 were the final polishing basins where treated wastewater was retained prior to discharge via NPDES outfall 001 to the Webber Falls Reservoir. Only a small amount of residue (3 feet) was present in each of these ponds during the initial characterization. Consequently, only one sample increment was obtained from each of the two samples in these ponds. Pond 6 is approximately 200 feet by 100 feet (0.5 acres) and is 10 feet deep. Pond 7 is approximately 250 feet by 150 feet or about 0.85 acres and is estimated to be less than 10 feet deep. Both ponds have clay liners.

The analysis of the two samples from Pond 6 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and thorium. The average gross alpha and gross beta levels for Pond 6 were 130 and 61 pCi/g, respectively. The average level of uranium isotopes was found to be 9 pCi/g, although U-235 had the lowest levels with an average of 1.4 pCi/g. Thorium isotopes 230 and 234 had averages of 8 and 11 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 31.

Neither chromium nor VOCs were detected in Pond 6. The pH of the two Pond 6 residue samples was 7.93 and 8.08 standard units. Table 32 presents the concentrations of non-radioactive constituents that were above action or treatment levels in Pond 6.

Table 31. Radionuclide Concentrations in Pond 6 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level =25 ^a	U-233 & U-234 Action Level =10 ^b	U-235 Action Level =10 ^b	U- 238 Action Level =10 ^b	Th-230 Action Level =10 ^b	Th- 234 Action Level =10 ^b
Pond Residue (0 - 3 ft)							
P6-1	110 ±20	55 ±7	8.4 ±0.7	0.3 ±0.1	8.6 ±0.7	8.2 ±0.9	7.9 ±0.8
P6-2	150 ±20	67 ±7	17 ±1	2.4 ±0.5	19 ±1	8 ±0.7	14 ±2
<i>Average</i>	<i>130</i>	<i>61</i>	<i>12.7</i>	<i>1.4</i>	<i>13.8</i>	<i>8.1</i>	<i>11</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 32. Non-radioactive Contaminant Concentrations in Pond 6

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Pond Residue (0 - 3 ft)			
P6-1	<0.1	3,300	7.93
P6-2	<0.1	3,700	8.08
<i>Average</i>	<i>0.1</i>	<i>3,500</i>	<i>8.0</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: Shaded cells indicate values that exceeded action or treatment levels.

The analysis of the 2 samples from Pond 7 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and thorium. The average gross alpha and gross beta levels for Pond 7 were 495 and 200 pCi/g, respectively. The average level of uranium isotopes was found to be 35 pCi/g, although U-235 had the lowest levels with an average of 2.6 pCi/g. Thorium isotopes 230 and 234 had averages of 39 and 42 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 33.

In Pond 7, TCLP chromium levels were negligible. No VOCs were detected in Pond 7. The pH of the residues in Pond 7 were 8.02 and 9.57 standard units. Table 34 presents the concentrations of any non-radioactive constituents that were above action or treatment levels in Pond 7.

Table 33. Radionuclide Concentrations in Pond 7 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U- 238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th- 234 Action Level = 10 ^b
Pond Residue (0 - 3 ft)							
P7-1	310 ±30	130 ±10	26 ±2	1.3 ±0.5	25 ±2	24 ±1	26 ±4
P7-2	680 ±40	270 ±10	74 ±4	3.9 ±1	81 ±5	54 ±3	57 ±4
<i>Average</i>	<i>495</i>	<i>200</i>	<i>50</i>	<i>2.6</i>	<i>53</i>	<i>39</i>	<i>42</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 34. Non-radioactive Contaminant Concentration in Pond 7

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Pond Residue (0 - 3 ft)			
P7-1	<0.1	<4.2	8.0
P7-2	<0.1	<4.8	9.6
<i>Average</i>	<i>0.1</i>	<i>4.5</i>	<i>8.8</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

6.1.5 Pond 8

Pond 8 was used as the one of the first settling ponds for wastewater treatment slurry. A total of 15 residue samples were collected from five locations within Pond 8, which is about 350 feet by 350 feet, or 2.8 acres, and is approximately 25 feet deep. This pond was constructed in 1978 with a synthetic liner that some Fansteel documents indicate may be leaking. The wastewater treatment slurry can also be pumped out of the pond and be loaded into cement trucks to the west of the pond. Fansteel personnel estimate that there is approximately 60,000 tons of calcium fluoride in Ponds 8 and 9.

The analysis of the 15 samples from Pond 8 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and radium, although levels were lower than for Ponds 2 and 3. The average gross alpha and gross beta levels for Pond 8 were 209 and 100 pCi/g, respectively. The maximum levels of gross alpha and gross beta were 310 and 190 pCi/g, respectively. The average level of uranium isotopes was found to be 20 pCi/g, although U-235 had the lowest levels with an average of 1 pCi/g. Thorium isotopes 230 and 234 had averages of 15 and 23 pCi/g, respectively, with maximums of 29 and 60 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 35.

TCLP testing revealed most chromium concentrations at 0.1 mg/l with the highest concentration at 0.18 mg/l. However, MIBK was detected at concentrations ranging from 4.8 to 190 mg/kg, well above the 33 mg/kg action limit. The pH of Pond 8 averaged at 9.97 standard units. Fourteen of the 15 samples had a pH less than 11.0, only one sample (P8-2C) exhibited a pH of 12.67, which does not appear to be representative of other Pond 8 residues. Table 36 presents the concentrations of non-radioactive constituents in Pond 8 that were above action or treatment levels.

Table 35. Radionuclide Concentrations in Pond 8 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U- 238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th- 234 Action Level = 10 ^b
Top Third of Pond Residue (~0 - 8 ft)							
P8-1A	300 ±20	190 ±10	74 ±5	2.7 ±0.9	73 ±5	14 ±1	60 ±5
P8-2A	120 ±20	63 ±7	16 ±1	1.1 ±0.3	17 ±1	10 ±1	12 ±1
P8-3A	210 ±20	100 ±10	39 ±2	1.5 ±0.4	42 ±2	12 ±1	32 ±4
P8-4A	170 ±20	88 ±8	33 ±2	1.9 ±0.5	33 ±2	9.9 ±0.9	28 ±4
P8-5A	160 ±20	76 ±8	30 ±2	1.6 ±0.4	30 ±2	7.4 ±0.7	27 ±2
<i>Average</i>	<i>192</i>	<i>103.4</i>	<i>38.6</i>	<i>1.76</i>	<i>39</i>	<i>10.66</i>	<i>31.8</i>
Middle Third of Pond Residue (~8 - 18 ft)							
P8-1B	150 ±20	82 ±8	28 ±2	1.1 ±0.4	31 ±2	12 ±1	21 ±2
P8-2B	160 ±20	59 ±7	9.6 ±0.9	0.7 ±0.2	9.9 ±0.9	13 ±1	6.6 ±2.1
P8-3B	120 ±20	76 ±8	25 ±2	0.8 ±0.3	27 ±2	6.8 ±0.7	24 ±2
P8-4B	120 ±20	81 ±8	31 ±2	1 ±0.4	31 ±2	7.7±0.7	26 ±2
P8-5B	140 ±20	72 ±8	19 ±1	1.5 ±0.4	21 ±1	7.8 ±0.9	14 ±2
<i>Average</i>	<i>138</i>	<i>74</i>	<i>23</i>	<i>1</i>	<i>24</i>	<i>9.5</i>	<i>18</i>
Bottom Third of Pond Residue (~18 - 27 ft)							
P8-1C	240 ±20	110 ±10	32 ±2	1.4 ±0.5	34 ±2	24 ±1	26 ±4
P8-2C	360 ±30	150 ±10	25 ±2	1.6 ±0.5	25 ±2	29 ±2	19 ±2
P8-3C	290 ±30	110 ±10	20 ±2	1.2 ±0.3	20 ±1	21 ±1	16 ±1
P8-4C	300 ±20	120 ±10	20 ±1	0.7 ±0.2	21 ±1	20 ±1	17 ±2
P8-5C	310 ±30	130 ±10	23 ±2	1.2 ±0.4	24 ±2	14 ±1	19 ±2
<i>Average</i>	<i>297.5</i>	<i>122.5</i>	<i>24.3</i>	<i>1.2</i>	<i>25.0</i>	<i>23.5</i>	<i>19.5</i>

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 36. Non-radioactive Contaminant Concentrations in Pond 8

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Top Third of Pond Residue (~0 - 8 ft)			
P8-1A	0.1	120	9.95
P8-2A	0.1	120	10.99
P8-3A	0.1	86	8.93
P8-4A	0.1	100	9.12
P8-5A	0.18	240	9.78
<i>Average</i>	<i>0.12</i>	<i>133</i>	<i>9.8</i>
Middle Third of Pond Residue (~8 - 18 ft)			
P8-1B	-	190	-
P8-2B	0.1	120	10.97
P8-3B	0.1	110	9.45
P8-4B	0.1	94	9.56
P8-5B	0.1	540	11.02
<i>Average</i>	<i>0.1</i>	<i>168.47</i>	<i>10.25</i>
Bottom Third of Pond Residue (~18 - 27 ft)			
P8-1C	0.1	37	9.01
P8-2C	0.1	100	12.67
P8-2C	0.1	57	10.53
P8-4C	0.1	4.8	7.84
P8-5C	0.1	50	9.69
<i>Average</i>	<i>0.11</i>	<i>158.36</i>	<i>9.97</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: Shaded cells indicate values that exceeded action or treatment levels.

6.1.6 Pond 9

Pond 9 was also used as one of the first settling ponds for wastewater treatment slurry. The pond is full of water and slurry and the calcium fluoride can be seen breaking the surface. A total of 15 residue samples were collected from five locations within Pond 9, which is approximately 600 feet by 250 feet and 25 feet deep. Pond 9 was constructed in 1985 with a clay and synthetic liner

that some Fansteel documents indicate may be leaking. Fansteel personnel estimate that there is approximately 60,000 tons of calcium fluoride in Ponds 8 and 9.

The analysis of the 12 samples from Pond 9 revealed elevated gross alpha and gross beta as well as elevated levels of uranium and radium. The average gross alpha and gross beta levels for Pond 9 were 52 and 50 pCi/g respectively. Both gross alpha and gross beta had maximums of 100 pCi/g. The average level of uranium isotopes was found to be 14 pCi/g, although U-235 had the lowest levels with an average of 1 pCi/g. Thorium isotopes 230 and 234 averaged at 6 and 15 pCi/g, respectively. Analytical results for radionuclide concentrations are summarized in Table 37.

The average amount of chromium found was 0.2 mg/kg, well below the action level of 5 mg/l. MIBK was present with an average concentration of 88 mg/kg although fourteen of the 15 samples had levels under 160 mg/kg. The average pH of Pond 9 was 9.5 standard units with a maximum at 10.8 standard units. Table 38 presents the concentrations of non-radioactive constituents in Pond 9 that were above action or treatment levels.

Table 37. Radionuclide Concentrations in Pond 9 (pCi/g)

Sample ID	Gross Alpha Action level =20 ^a	Gross Beta Action Level = 25 ^a	U-233 & U-234 Action Level = 10 ^b	U-235 Action Level = 10 ^b	U- 238 Action Level = 10 ^b	Th-230 Action Level = 10 ^b	Th- 234 Action Level = 10 ^b
Top Third of Pond Residue (~0 - 8 ft)							
P9-1A	77 ±11	49 ±7	12 ±1	1.6 ±0.3	15 ±1	13 ±2	6.9 ±1.8
P9-2A	82 ±11	91 ±8	42 ±2	1.9 ±0.3	43 ±2	14 ±1	31 ±3
P9-3A	44 ±9	54 ±6	21 ±1	1.2 ±0.3	25 ±1	0.9 ±3.8	16 ±1
P9-4A	100 ±10	100 ±10	53 ±2	2.8 ±0.4	57 ±2	10 ±2	47 ±3
P9-5A	-	-	-	-	-	-	-
<i>Average</i>	76	74	32	1.9	35	9.5	25
Middle Third of Pond Residue (~8 - 15 ft)							
P9-1B	50 ±9	50 ±6	24 ±1	1.1 ±0.2	24 ±1	4.1 ±0.8	20 ±2
P9-2B	-	-	-	-	-	-	-
P9-3B	30 ±8	24 ±5	7.1 ±0.8	0.6 ±0.2	7.6 ±0.8	2.4 ±0.9	4.3 ±0.6
P9-4B	37 ±8	32 ±6	11 ±1	0.8 ±0.2	13 ±1	1.6 ±1	6.9 ±1.9
P9-5B	34 ±8	38 ±6	11 ±1	1.2 ±0.3	14 ±1	1 ±0.7	8.7 ±0.8
<i>Average</i>	38	36	13	0.9	15	2.3	10
Bottom Third of Pond Residue (~18 - 23 ft)							
P9-1C	21 ±6	33 ±6	11 ±1	0.4 ±0.2	11 ±1	3.3 ±1	6.9 ±1.8
P9-2C	-	-	-	-	-	-	-
P9-3C	30 ±7	32 ±6	10 ±1	0.5 ±0.2	11 ±1	9 ±5	8.6 ±0.7
P9-4C	51 ±9	48 ±6	16 ±1	0.5 ±0.2	17 ±1	4.3 ±1.4	11 ±2
P9-5C	60 ±10	50 ±6	21 ±1	4 ±1	26 ±1	4.9 ±0.7	14 ±1
<i>Average</i>	40.5	41	15	1.4	16	5.4	10

^a Earth Sciences Consultants background measurements of the site.

^b Branch Technical Position, October 23, 1981, 46 FR 52061.

Table 38. Non-Radioactive Contaminant Concentrations in Pond 9

Sample ID	Chromium (5 mg/l) ^a	MIBK (33 mg/kg) ^b	pH (Standard Units)
Top Third of Pond Residue (~0 - 8 ft)			
P9-1A	0.1	3.4	10.14
P9-2A	0.3	190	9.78
P9-3A	0.34	6	8.44
P9-4A	0.11	110	9.14
P9-5A	0.25	130	10
<i>Average</i>	<i>0.22</i>	<i>88</i>	<i>9.5</i>
Middle Third of Pond Residue (~8 - 15 ft)			
P9-1B	0.34	16	9.4
P9-2B	0.28	80	10.2
P9-3B	<0.1	36	9.2
P9-4B	0.34	150	10.8
P9-5B	0.12	160	9.9
<i>Average</i>	<i>0.24</i>	<i>88</i>	<i>9.9</i>
Bottom Third of Pond Residue (~15 - 23 ft)			
P9-1C	0.23	25	10
P9-2C	0.1	35	9.2
P9-3C	0.25	120	9.7
P9-4C	0.1	110	9.5
P9-5C	0.1	74	9.4
<i>Average</i>	<i>0.16</i>	<i>73</i>	<i>9.5</i>

^a 40 CFR 261

^b Where mixed waste is found, MIBK must be treated to 33 mg/kg (40 CFR 268.48).

Note: Shaded numbers exceeded action or treatment levels.

6.2 Identification of Potential Gaps in Characterization

In reviewing the adequacy of the pond residue sampling data, we relied on the Earth Sciences' Remediation Assessment from 1993. Their analyses indicate that all ponds contain radioactive isotopes and some contain elevated levels of metals and volatile organic compounds. In addition, Ponds 2 and 3 exhibit acidic pH while Ponds 5 through 9 exhibit slightly basic pH. The two

process residue ponds sampled, Ponds 2 and 3, were found to have radioactivity above NRC regulatory limits. Leachable chromium at levels considered characteristically hazardous indicates that residue from Ponds 2 and 3 will classify as mixed waste (both hazardous and radioactive). The presence of mixed waste can complicate the disposal of the wastes from these two ponds. Ponds 5 through 9 also contain radioactive constituents above levels of concern. Leachable chromium levels were below the action level. However, the presence of MIBK in the wastewater treatment ponds raises the possibility that this contaminant may qualify as a listed waste. Should that be the case, the residue in Ponds 5 through 9 may also need to be disposed as a mixed waste.

Given these results, we now answer the questions from section 3.3 to identify whether gaps exist in the pond characterization.

1. Have historical records been kept for all materials placed into the ponds?

In general, the type of waste deposited in the ponds over the last 30 years is known. However, it is not clear whether Fansteel kept historical records for all materials placed in the ponds since the beginning of site activity. For example, the history of Ponds 1N, 1S, and 4 is unclear. Another outstanding question is what was done with residues removed from these ponds.

2. Has each pond been classified as impacted or non-impacted?

Although the 1993 Remediation Assessment does not specifically state whether areas are impacted or non-impacted, it appears that the ponds were impacted based on their history of use and the results of analyses performed on the pond residue.

3. Has each pond been appropriately divided into surface and depth sampling grids?

The Earth Sciences Remediation Assessment characterization does not discuss the methodology of horizontal sampling of the ponds. There was no obvious grid system used to determine how many samples per pond should have been taken. However, all but one of the pond samples were divided and analyzed by depth (Pond 5 samples were not divided into depths for non-radioactive analysis).

4. Has a sampling plan been prepared for each pond based on the historical knowledge of materials placed in the pond?

The sampling plan was not available for review. However, the methodology used to collect the pond residue is discussed in the Earth Sciences' Remediation Assessment. There is some concern that use of a vacuum barrel, although innovative, may not have been sufficient to preserve any horizontal layers found in the pond residue. Nevertheless, assuming that the slurries or wastewater were relatively homogeneous while they were stored in the ponds, we would not expect to see horizontal layers or hot spots of contaminated residue. Rather, the residues present in each of the ponds located on site

appear to be fairly well homogenized. No significant trends could be identified in any of the ponds which would indicate the presence of particularly contaminated or relatively clean "layers" or locations that would necessitate a diverse remediation strategy for the ponds. Thus, it is assumed that all waste present in the ponds must be treated and disposed in the same manner.

5. Does the sampling plan address all analytes of concern?

It appears that the analysis included all analytes of concern. However, the analysis for eight of the 67 samples (12 percent) are incomplete.

6. Does the sampling plan address QA/QC requirements?

Unknown.

7. Has sampling been conducted in each pond according to the sampling plan?

Unknown.

8. Are the number and depths of samples taken known for each pond?

Yes. Each sample has a specific number and can be located on the site map. Sample depths were known for all except samples P5-2 and P5-3. It seems that radionuclide analyses for Pond 5 samples were not divided into three levels for these two samples, and the depth of these samples are unknown.

9. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?

Yes, the land based management unit characterization methodology suggests four samples per acre. According to this source, the number of pond samples taken in each pond is roughly sufficient. For example, Pond 9 is approximately 3.5 acres, which indicates that 14 samples are needed to accurately characterize it, and 12 were taken. Rough calculations of the dimensions of the ponds suggest that a minimum of 45 samples should have been taken, while 74 samples were actually collected.

10. Are the detection limits for each analytical instrument known for each pond?

Detection limits for radiological components are known and are below the action levels for gross alpha, gross beta, uranium, and thorium. The detection limits for non-radiological parameters can be inferred from the sampling results.

11. Has sampling been conducted for each pond using appropriate instrumentation with appropriate sensitivity?

For radioactive constituents, the levels are high enough above the detection level as to not be of concern. For non-radioactive contaminants, it is unknown.

12. Has clean soil or bedrock been found below each pond?

No. We are not aware of any sampling beneath the ponds. The integrity of existing pond liners is also unknown. It is assumed that additional contamination exists under the ponds. See Section 7 for a discussion of sampling of soils underneath the ponds.

13. Has clean soil been found outside the perimeter of each pond?

No. Some soil borings have been taken around the perimeter of the wastewater treatment ponds (5 through 9). No samples have been taken or analyzed outside the perimeter of each pond. See Section 7 for a complete discussion of the soils surrounding the ponds.

14. Are all sample results below the appropriate action level?

No. For gross alpha and gross beta, 97 and 94 percent of the samples were found to have concentrations above site background levels. For uranium, U-233, U-234 and U-238, 87 percent of the samples were above the NRC limit. Only 33 percent of pond residue samples were above the NRC limits for uranium 235. For thorium 230 and thorium 234, 66 and 78 percent of the samples were above NRC limits. Eighteen samples or 72 percent exhibited levels of chromium above action levels. For MIBK, 84 percent of the samples were found to be above treatment levels.

6.3 Assumptions about Extent of Contamination and Recommendations for Additional Characterization

Based on the above discussion, we have identified the following gaps in the pond characterization. First, eight of the 67 samples (12 percent) were not analyzed for all contaminants of concern. Specifically, sample P5-2 was not divided into separate depths but was analyzed in bulk for all parameters except radioactive constituents. Samples P5-2A, B, and C were divided into separate depths and analyzed only for radioactive constituents. P8-1B was not analyzed for total metals or TCLP metals. P9-2B, C and P9-5A were not analyzed for radioactive constituents. It is not clear why these analyses were not done.

Second, it is assumed that when Pond 4 was removed and combined with the newer Pond 3, that the residue and any liner were also removed. However, there is little information about the history of Pond 4 and the soil where it was located has not been sampled. Please see Section 7 for a complete discussion of recommended further soil sampling.

Third, based on EPA's land-based management unit characterization methodology, more samples should have been taken from some of the ponds. However, due to the relative homogeneity of the samples taken from the ponds (all the ponds contain radioactive waste and at least two

contain mixed waste), further sampling is not recommended. Note that waste disposal facilities may require additional characterization in order to accept the waste.

6.4 Costs Associated with Additional Characterization

No further sampling is recommended for the ponds, therefore no costs are discussed. However, additional characterization may be required to meet certain waste disposal facility requirements. A rough estimate can be made of the volume of waste taken from or still present within the seven ponds analyzed in the Remediation Assessment. The volume of process waste buried in Pond 2 (based on a full volume and 3:1 sloping sides) would be 757,000 cubic feet. It was assumed that the average depth of process waste in Pond 3 is 10 feet (8 feet at one end and 12 at the other), but with a significant stretch of the pond nearly empty, a conservative estimate is that there is 1.2 million cubic feet of residue. The volume of dried process waste removed from Pond 5 is approximately 1,200 tons, or an estimated 32,400 cubic feet. The volume of wastewater treatment residue (CaF₂) in Ponds 5 through 9 is estimated to be 7.26 million cubic feet, although taking into account the water, which could be removed, the dry volume is probably smaller. Site personnel indicated that these ponds hold approximately 60,000 tons of CaF₂. Sampling of soil surrounding and underneath the ponds maybe recommended and are discussed in Section 7.

7.0 Soils

Surface and subsurface soils at the Fansteel site have been contaminated with a number of different isotopes over the years, as well as chemicals. The primary radioactive isotopes of concern are U-238, U-235, U-234, Th-232, Th-230, and Th-228. Examination of background soils for Radium-226 (a U-238 decay product) and Radium-228 (a U-232 decay product) indicates that the parent radionuclides are in a condition of approximate equilibrium with their decay products. The most pervasive chemical contaminants of concern in the site soils include MIBK, ammonia, barium, fluoride, and tin. Columbium, a radioactive contaminant, is also found throughout the site soils. The presence of chemical and radiological contaminants in the surface soil at the site raises the possibility that the soil might be considered mixed waste and would require disposal currently available at a single facility (Envirocare in Clive, Utah).

7.1 Summary of Existing Characterization

Earth Sciences conducted a soil analysis as part of their 1993 Remediation Assessment, using surface scans, soil borings, test pits, and monitoring wells. Figure 7 shows the soil sampling locations throughout the site.

Available Site History

Limited historical information was available in the Earth Sciences report for the surface areas of the site. The following paragraphs describe what is known about the different areas of the site.

Borrow Pit Area

The borrow pit is in the southwest corner of the property. The original surface soil and some subsurface soil in the borrow pit have been removed for use in constructing berms, impoundments, improving drainage, and other uses at the site.

"Non-Impacted Area"

The northeastern portion of the site, north of the active processing boundary is known as the "non-impacted area."

Ore Storage Pad

This is a poured concrete pad that is about 10,000 ft² and was used for storage of drums and bags of ore and drummed process residue. The pad is in generally good condition. Its installation date is unknown due to lack of information provided in the existing documents. Prior to installation, ore and slag was stored on the ground in the same area. According to the June 1999 Decommissioning Plan, the removal of the concrete pad and examination of underlying soil is not planned unless additional processing operations impact the pad surface.

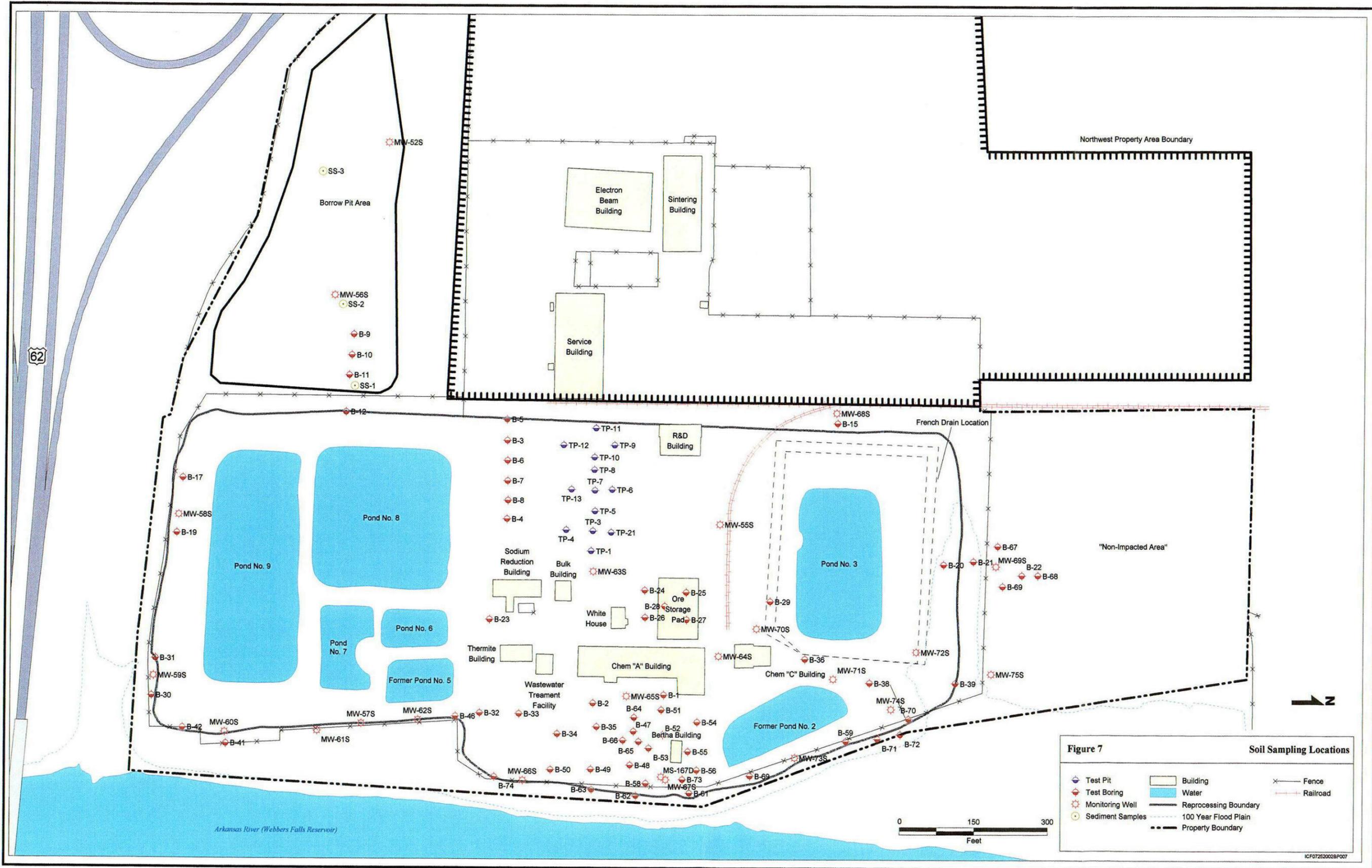


Figure 7 Soil Sampling Locations

Former Ponds 1N and 1S

These two ponds were located between the Chemical A Building and the Webber Falls Reservoir (Arkansas River). They were approximately 80 feet by 60 feet each and about 15 feet deep. Information about their construction date was unavailable. According to site personnel, Pond 1S has a clay liner and Pond 1N was constructed with a synthetic liner. Pond 1N was used to hold process water laden with lime before the wastewater treatment plant was built (in 1973). Pond 1S was used to hold process residue. Some of the process residue was removed from 1S, dried, bagged, and placed in the Sodium Reduction Building. Both ponds were filled in with clean topsoil in 1991 or 1992 and they are now covered with grass.

Former Ponds 3 and 4

A 1973 aerial photo of the Fansteel site shows the original footprints of Ponds 3 and 4, which were almost triangular in shape and were located in the approximate location of current Pond 3. From the photo, it appears that the eastern pond abutted the Chemical C building and the southern tip of the western pond almost reaches the midpoint of the curve in the railroad spur. These ponds appear to straddle the footprint of the french drain that was installed in 1979. Attachment 1 contains copies of the aerial photographs reviewed for this analysis.

According to site personnel, the original Pond 3 was smaller than current Pond 3 and occupied approximately the eastern half of its current location. No information was available about whether original Pond 3 was lined. Information about Pond 4 is scarce. It was probably constructed in the early 1960's just north of the original Pond 3. Information about whether or not the pond was lined is unavailable. Pond 4 and Pond 3 were combined to make the current Pond 3. Remaining areas of Pond 4 not incorporated in the new Pond 3 were filled-in between 1975 and 1985. These areas are currently covered by grass.

Waste Pile

A large pile of soils recovered from the construction of the french drain along the eastern edge of the property is located between the Bulk Sodium Storage building and the R&D building. The rectangular pile is approximately 5 feet high and measures approximately 90 feet on the east-west side and 30 feet on the north-south side. It is covered by a synthetic liner held in place by sand bags. Site personnel believe this soil is contaminated.

Ore Storage West of Sodium Reduction Building

The Fansteel report "Facility Background and Operating Data" indicates that there was an ore and slag storage area west of the sodium reduction building.²⁶ From a map provided in the report it appears that this area is approximately the width of the sodium reduction building, and extends from this building to the northwest property boundary. No further information about the types of materials stored here or when the area was used was available.

²⁶ *Facility Background and Operating Data*, Fansteel Inc., 1995.

Catchment Basin P10

Catchment basin P10 collected storm water runoff from the area east of the Chemical A building. The supernatant contents of this basin were pumped to the treatment plant for processing and eventually discharged to Ponds 8 and 9. This area has since been paved with concrete and Basin P10 no longer exists.

Survey for Buried Objects

Using test pits and electromagnetic metal detectors, the site was investigated to determine if objects such as drums, tanks, or other containers were buried onsite. The details about these methods of surveying are described in more detail below.

Surface Soil Scan

Earth Sciences conducted an instrumental survey at the Fansteel site in 1993 to determine the presence of surficial contamination by radioactive materials and indicate the possible presence of subsurface accumulations of radioactivity. At designated points at the ground surface, alpha, beta, and gamma radioactivity measurements were obtained; additionally, at an elevation of one meter above each of the designated points, gamma radioactivity measurements were obtained. The following instruments were used to perform these surveys:

- Alpha and Beta: Ludlum Model 43-68 gas proportional probe attached to a Ludlum Model 2221 or Model 2200 single channel analyzer.
- Alpha: Ludlum Model 43-10 or 43-5 alpha scintillation probe attached to a Ludlum Model 2221 or 2200 single channel analyzer.
- Gamma: Ludlum Model 44-10 gamma scintillation probe attached to a Ludlum Model 2221 or 2200 single channel analyzer.
- Beta and/or Gamma: Ludlum Model 44-9 pancake type Geiger-Muller probe attached to a Ludlum Model 2221 or 2200 single channel analyzer or Ludlum Model 3 ratemeter.

The survey locations were determined by imposing one of two grids over the south and east plant areas of the property. A grid point spacing at 10 meter intervals was used to survey the areas of the property where manufacturing, process, storage, and waste management occurred. Outside the designated remediation assessment study areas, a grid point spacing at 25 meter intervals was used. The electromagnetic detectors were used on the 25 meter grid but not the 10 meter grid.

According to Earth Sciences, the instrumental survey was able to yield little additional information about the concentration of radionuclides in the soil for two reasons. First, surveys of surface alpha and beta activity are only marginally useful because soil has a shielding effect on alpha and beta particles. Second, while gamma radiation surveys are generally capable of

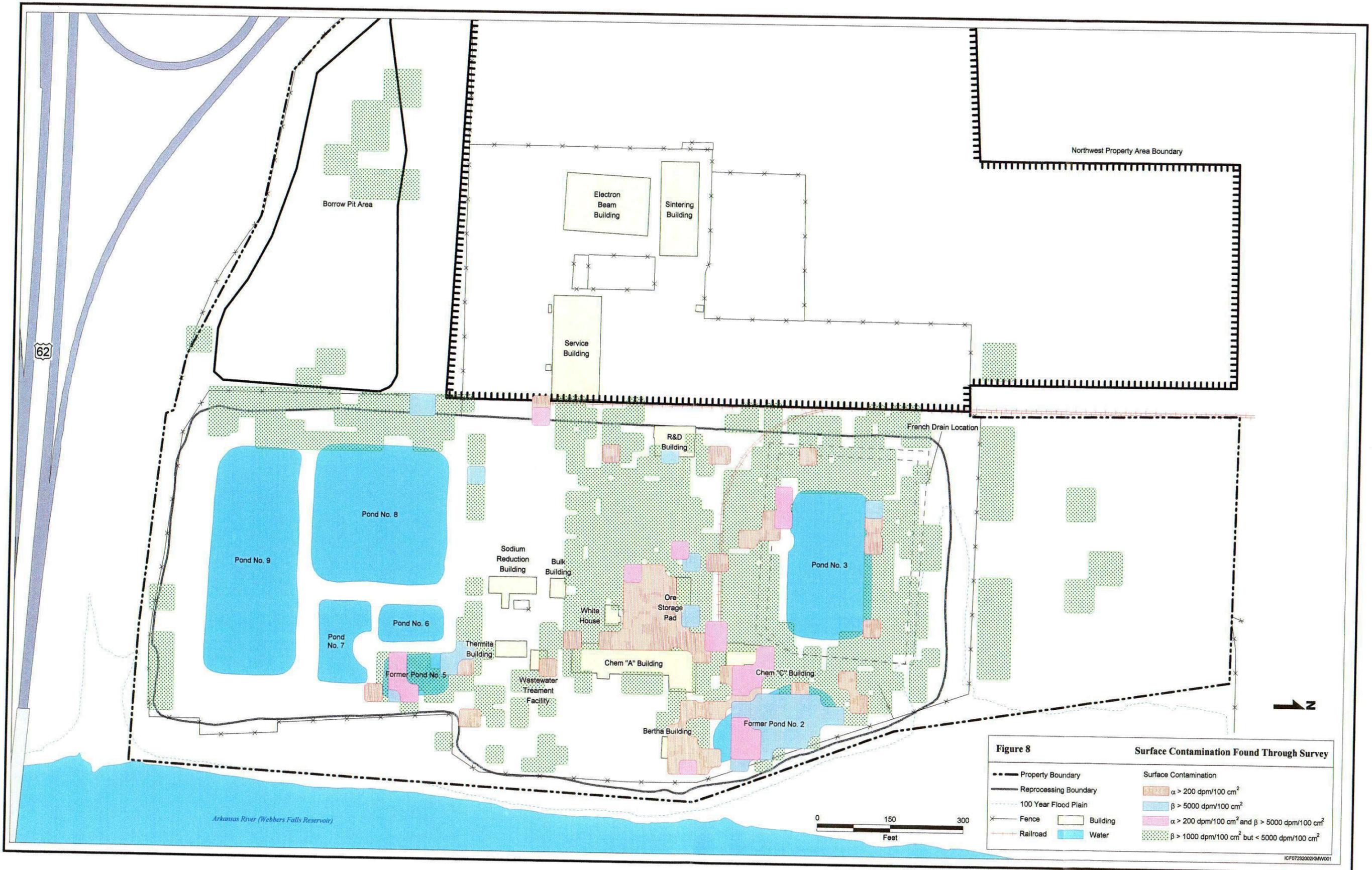


Figure 8 Surface Contamination Found Through Survey

--- Property Boundary	Surface Contamination
--- Reprocessing Boundary	Orange: $\alpha > 200$ dpm/100 cm ²
--- 100 Year Flood Plain	Blue: $\beta > 5000$ dpm/100 cm ²
× Fence	Pink: $\alpha > 200$ dpm/100 cm ² and $\beta > 5000$ dpm/100 cm ²
--- Railroad	Green Stippling: $\beta > 1000$ dpm/100 cm ² but < 5000 dpm/100 cm ²
Yellow: Building	Light Blue: Water

detecting the presence of concentrations of radionuclides in soils, the large quantities of radioactive materials in Ponds 2, 3, and 5 generated a high and variable background that precluded a meaningful interpretation of the results.

Figure 8 presents the results of the surface scan, by showing where either alpha radioactivity was greater than 200 dpm/100cm² or where beta radioactivity was greater than 1,000 dpm/100cm². While these levels do not automatically trigger cleanup requirements, the presence of radioactivity above these levels does indicate that an area has been impacted. The most obvious concentration of hot spots lies in the east and northeast portion of the property, particularly in the area in and around former Pond 2, west of the Chemical A Building, and all around the Chemical C Building. The area in and around former Pond 5, just south of the Chemical A Building, also has elevated levels of radioactivity. A few other survey points surrounding Pond 3 also have high levels of radioactivity. In addition, much of the rest of the site has beta contamination in excess of 1,000 dpm/100 cm². The source of this contamination is unclear, but may be from windblown contamination.

Subsurface Soil Samples

In addition to the surface scans, Earth Sciences took surface and subsurface soil samples from 67 soil borings, 29 monitoring wells, and 13 test pits. Split spoon samples were collected continuously throughout the depth of the boreholes and monitoring wells. Most of the boreholes and wells were at least 20 feet deep. The test pits were about 5 feet deep. No buried objects were found in any of the test pits. Three samples from each of the boreholes and monitoring wells and one sample from each test pit were sent for chemical, radiological, or chemical and radiological analyses. All test borings were located according to a surveyed site grid system, although the details of this system are unclear.

Radiological samples were collected and transported for laboratory analysis for gross alpha and beta. If gross alpha or gross beta was detected at levels significantly above background concentration, individual radionuclide analyses were performed to determine contributing species. In the Remediation Assessment, Earth Sciences did not define the specific levels of gross alpha and beta that were significantly above background concentration. However, in its *Response to the NRC Environmental Assessment Comment Request*, Fansteel indicated that "samples with a gross alpha particle activity greater than or equal to the background mean alpha particle activity plus one standard deviation were submitted for radiochemical analysis."²⁷ Thus, the indicator level for isotopic analysis appears to be 20 pCi/g gross alpha (15.6 pCi/g background + 4.5 pCi/g standard deviation). However, this protocol was not consistently followed, as seven samples with gross alpha concentrations of 21 pCi/g or higher were not analyzed for individual isotopes.

A total of 55 samples from 32 borehole locations, 4 monitoring wells, and 1 test pit were analyzed for isotope-specific contamination. Table 39 presents a summary of the isotopic

²⁷ *Response to the NRC Environmental Assessment Comment Request*, Fansteel, February 20, 1997, Response to Soil question 9.

contamination found on the site, and indicates when the combined uranium and thorium levels were above the unrestricted release limit of 10 pCi/g (as stipulated in License Number SMB-911 Amendment 7). Figure 9 presents a map showing locations where the combined uranium and thorium concentrations exceeded the 10 pCi/g unrestricted release level in gray. This figure assumes the area of inference around a sampling point has a 50 foot radius. Sampling locations where only gross alpha and gross beta concentrations were measured are shown as a circle. Samples where the isotopic concentrations were below the 10 pCi/g unrestricted release level are shown in hatching. Finally, samples with gross alpha concentrations equal to or greater than 21 pCi/g but did not have isotopic analysis performed are shown as green circles.

The greatest area of soil contamination is located between the Chemical A Building, former Pond 2, the Webbers Falls Reservoir, and former pond 5. This area of contamination includes the location of former ponds 1N and 1S and areas of significant facility activity. A second area of contamination is located between Pond 3 and the Eastern property boundary. This second area of contamination is near and downgradient of the location of former Ponds 3 and 4. The sources of contamination for boreholes B-8 (west of the sodium reduction building), B-17 (south of pond 9), and B-22 (in the “non-impacted area”) are unclear.

Figure 10 presents a map showing locations where the combined uranium and thorium concentrations exceeded the 10 pCi/g unrestricted release at depths equal to or greater than 4 feet below ground surface. This figure shows the same two areas of contamination as Figure 9. The highest concentrations of uranium and thorium are located between Pond 3 and the eastern property boundary, and just northeast of the Bertha building. Boreholes B-38, B-72, B-73, and MW-71S have concentrations of uranium and thorium ranging from 84 pCi/g to 117 pCi/g.

Table 39. Results of Isotopic Analysis for Soils

Sample Location	Depth (ft)	Total Uranium (U-233/234, U-235, U238) (pCi/g)	Total Thorium (Th-228, Th 230, Th-232) (pCi/g)	Total U+Th (pCi/g) Unrestricted Release Level = 10 pCi/g
B8	0-0.5	6.2	13	19.2
B10	2.0-4.5	4.7	5.2	9.9
B15	0-0.5	1.6	5.1	6.7
B17	0.5-2.5	0.8	16.3	17.1
B22	0-0.5	7.2	10.3	17.5
B28	0-0.5	0.7	5.2	5.9
B29	0-0.5	7.4	6.4	13.8
B29	0.5-2.5	12.3	3.3	15.6
B32	0-0.5	3.1	11.1	14.2
B33	4.0-7.5	6.5	10.4	16.9
B36	0-0.5	1.9	3.2	5.1
B36	9-11	36.9	71	107.9
B38	0-0.5	2.3	4.6	6.9
B47	0.5-2.5	11.3	26.1	37.4
B47	24.5-26	1.4	5.4	6.8

Sample Location	Depth (ft)	Total Uranium (U-233/234, U-235, U238) (pCi/g)	Total Thorium (Th-228, Th 230, Th-232) (pCi/g)	Total U+Th (pCi/g) Unrestricted Release Level = 10 pCi/g
B48	12.5-15	3.3	6.1	9.4
B49	0-0.5	6.8	9.7	16.5
B49	0.5-2.0	7.9	9.9	17.8
B50	0-0.5	9.2	6.9	16.1
B50	0.5-2.0	3.9	4.3	8.2
B51	0.5-2.5	4.6	14.2	18.8
B52	0.5-2.5	6.1	14.6	20.7
B54	0-0.5	13.3	17.1	30.4
B54	0.5-2.0	9.5	14.7	24.2
B55	1-2	39.6	41	80.6
B55	7-9.5	1	4.4	5.4
B56	0-0.5	20.2	35	55.2
B58	0-0.5	2.8	4.8	7.6
B58	2-4.5	5.5	8.5	14
B59	12.5-15	44	5	49
B60	0-0.5	1.7	4.5	6.2
B61	0-0.5	16.3	23.2	39.5
B61	15-17	3.5	3.3	6.8
B61	5-7.5	1.4	3.4	4.8
B62	0.0.5	1.9	5.2	7.1
B62	15-17	7.4	5.1	12.5
B63	12.5-15	1.4	3.2	4.6
B63	15-17.5	2	5.2	7.2
B64	9.5-12.5	8.5	9	17.5
B64	18-20	3.7	5.1	8.8
B65	15-17.5	1	7.7	8.7
B65	20-22.5	10	8.3	18.3
B66	5-7.5	3.8	6	9.8
B72	12.5-15	10.5	3.5	14
B72	15-16	93.3	2.5	95.8
B73	4.5-7	35.9	48	83.9
B74	0-0.5	35.8	22.3	58.1
MW-56S	0-0.5	0.8	3.2	4
MW-65S	0-0.5	3.8	3.3	7.1
MW-65S	10-12	8.8	4.2	13
MW-71S	17-19.5	115.3	2	117.3
MW-71S	19.5-22	4.2	3.2	7.4
MW-75S	0-0.5	6.3	10.2	16.5
TP-10	1.6	1.4	3.3	4.7

B = boring, MW = Monitoring well, TP = test pit

Shading indicated locations at which the combined uranium and thorium total exceeds the unrestricted release limit of 10 pCi/g.

A total of 287 samples from 67 borehole locations, 25 monitoring wells, and 13 test pits were analyzed for total chemical contaminants. Samples were analyzed for total metals (tantalum, columbium, tin lead, nickel, antimony, arsenic, barium, cadmium, calcium, chromium, mercury, selenium, and silver), total fluoride, total ammonia, total sulfate, and MIBK. A total of 43 samples from 25 boreholes, 7 monitoring wells and 5 test pits were analyzed in the laboratory for the USEPA Toxicity Characteristics Leaching Procedure (TCLP) metals to determine the mobility of any contaminant detected. Samples were chosen based on the highest total metals concentrations detected. Table 40 presents the results of the TCLP metals analysis. Only one sample (from borehole B-56) has a leachable metals concentration in excess of the TCLP limits. Because this sampling location also had levels of uranium and thorium in excess of the unrestricted release limits, this one location appears to be mixed waste.

Table 40. Results of TCLP Metals Analysis for Soils

Sample Location	depth (ft)	Ag	As	Ba	Cd	Cr	Pb	Hg	Se
(TC Limit)		5	5	100	1	5	5	0.2	1
B6	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B12	17.5-19	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B15	9.2-10	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B29	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B29	0.5-2.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B34	22-22	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B35	10-11	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B35	11-12	<0.1	<0.1	<10	<0.1	0.21	<0.1	<0.01	<0.1
B36	11-13	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B39	8-10	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B39	12-13	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B42	9-11	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B47	15-17.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B49	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B50	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B54	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B54	0.5-2	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B55	1-2	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B56	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B56	4.5-7	<0.1	<0.1	220	<0.1	<0.1	<0.1	<0.01	<0.1
B58	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B59	12.5-15	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B60	15-17	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B61	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B62	15-17	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B63	15-17.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1

Sample Location	depth (ft)	Ag	As	Ba	Cd	Cr	Pb	Hg	Se
(TC Limit)		5	5	100	1	5	5	0.2	1
B64	18-20	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B65	15-17.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B66	17.5-20	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B72	15-16	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
B73	0.8-2	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-52S	3.5-7	<0.1	<0.1	<10	<0.1	<0.1	0.11	<0.01	<0.1
MW-54S	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-54S	2.0-4.5	<0.1	<0.1	<10	<0.1	<0.1	0.13	<0.01	<0.1
MW-55S	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-56S	3.5-5.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-60S	9.5-12	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-64S	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-71S	2-4.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
MW-75S	0-0.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
TP-3	1.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
TP-4	3	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
TP-9	1.7	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
TP-10	1.6	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1
TP-13	2.5	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<0.01	<0.1

Shading indicates locations at which the leachable metal concentration exceeded EPA TCLP level.

7.2 Identification of Potential Gaps in Characterization

To assess whether there are gaps in the characterization of surface and subsurface soils, we used the checklist presented in Section 3.3.

1. Have historical records been kept for all surface areas on the site?

No.

2. Has each distinct surface and subsurface area been classified as impacted or non-impacted?

Yes. An area on the northeast portion of the site has been classified as non-impacted and the rest of the site has been classified as impacted. The basis for this classification is unknown.

3. Has each distinct surface area been appropriately divided into sampling grids?

Only for surface scans.

4. Has each distinct sub-surface area been assigned a depth of concern and appropriately divided into surface sampling grids?

No.

5. Has a sampling plan been prepared for each impacted subsurface area based on the historical knowledge and surface contamination?

The sampling plan was not available for review.

6. Does the sampling plan address all analytes of concern?

The sampling plan was not available for review.

7. Does the sampling plan address QA/QC requirements?

The sampling plan was not available for review.

8. Has sampling been conducted in each surface and subsurface grid according to the sampling plan?

The sampling plan was not available for review.

9. Is the number of samples taken known for each surface grid or subsurface area?

Yes. Although a sampling plan was not available for review, the number and locations of all surface and subsurface samples is known.

10. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?

No. Approximately 250 - 300 sample locations would be needed. Each location would need to be evaluated at different depths. However, only 105 sampling locations were utilized, and isotopic analyses were only performed at 37 of these locations.

11. Are the detection limits for each analytical instrument known for each surface grid or subsurface area?

They can be inferred from the sampling results.

12. Has sampling been conducted for each surface grid and subsurface area using appropriate instrumentation with appropriate sensitivity?

No. The number of samples sent for laboratory analysis appears to be insufficient to characterize the site both with respect to ground area and depth. First, samples sent for

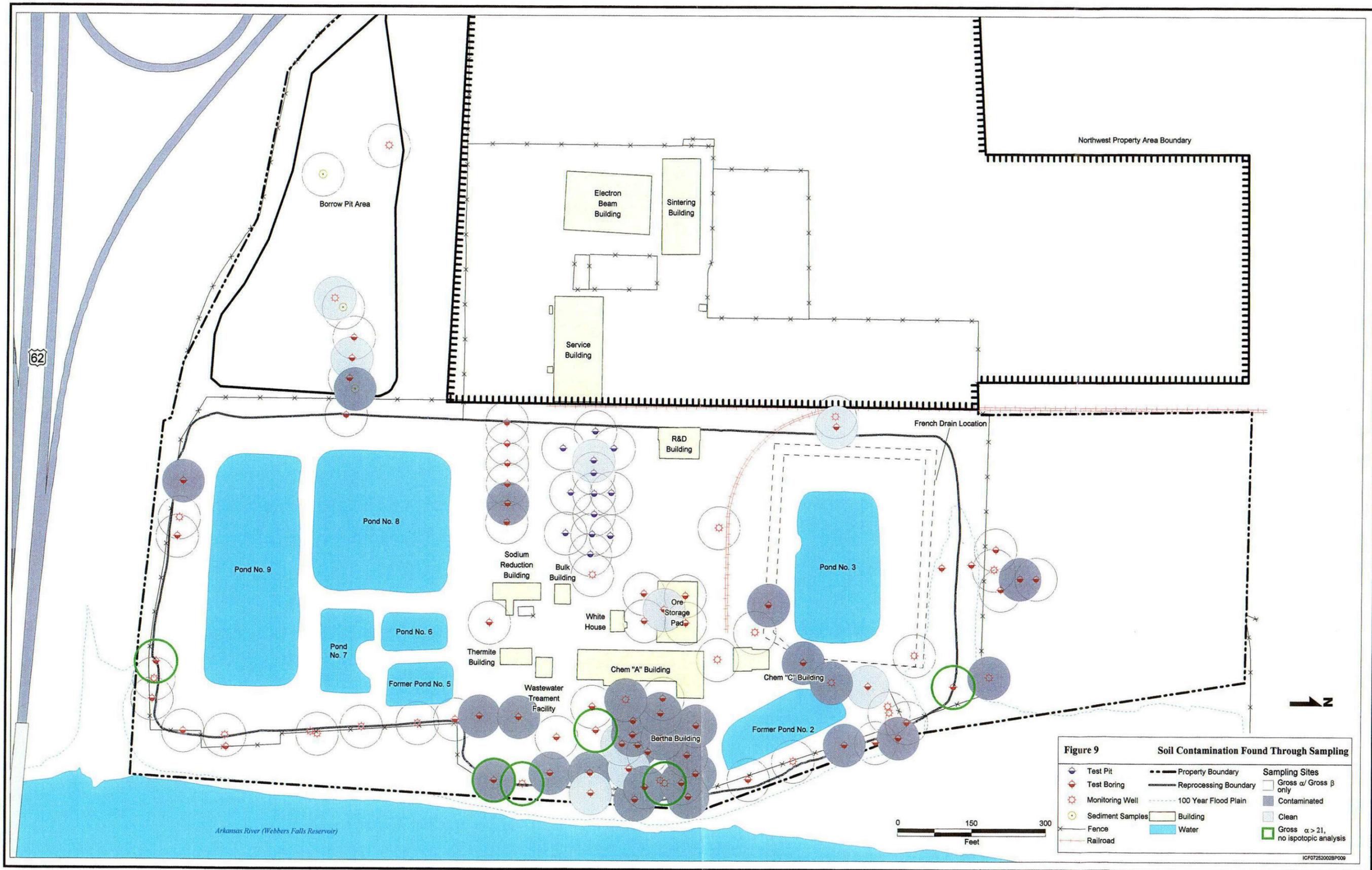


Figure 9 Soil Contamination Found Through Sampling

<ul style="list-style-type: none"> Test Pit Test Boring Monitoring Well Sediment Samples Fence Railroad 	<ul style="list-style-type: none"> Property Boundary Reprocessing Boundary 100 Year Flood Plain Building Water 	<p>Sampling Sites</p> <ul style="list-style-type: none"> Gross α / Gross β only Contaminated Clean Gross $\alpha > 21$, no isotopic analysis
---	--	--



Figure 10 Soil Contamination Below 4 Feet Deep

	Test Boring		Building
	Monitoring Well		Water
	Fence		Property Boundary
	Railroad		Reprocessing Boundary
	100 Year Flood Plain		Contamination Below 4 Feet

0 150 300
Feet

laboratory analysis were only analyzed for isotopes when gross alpha exceeded one standard deviation above background (which is about 20 pCi/g gross alpha). This assumes a direct relationship between the quantity of gross alpha and the total quantity of thorium and uranium. However, at least one sample (B-29) exceeded the 10 pCi/g total uranium and thorium limit even though the gross alpha level was below 20 pCi/g, suggesting that using gross alpha as a screen to identify contamination above the unrestricted release levels might be unsuitable.

Second, at least six samples had gross alpha readings above 20 pCi/g but were not analyzed for individual isotopes. Third, some sampling locations only had only one gross alpha reading, instead of three (B-30, B-39, B-42, and B-46) and some sampling locations were not analyzed for gross alpha or gross beta at all (B-20, B-21, and B-41).

In addition, the fact that a maximum of three samples from a soil boring or monitoring well were sent for laboratory analysis does not allow the volume of subsurface contamination to be established. For example, for a soil boring of 20 feet, samples were taken at intervals of 2 to 3 feet. So, between 7 and 10 samples were taken. However, only three samples were sent for laboratory analysis - the uppermost, the deepest, and one of the intermediate depths. Using this method, if the sample from an intermediate depth of 10 feet showed contamination, it would be impossible to determine at what depth the contamination began and ended because samples immediately above and below the sample were not sent for laboratory analysis.

13. Are all sample results below the appropriate action levels?

No. 31 samples at 27 locations exceed the action level for combined uranium and thorium.

14. Has clean soil been found below the deepest level of contamination?

No. At least three sampling locations had their highest concentrations in the deepest sample (B-62, B-65, and B-72).

Summary of Remaining Gaps

Overall, there was poor coverage of the site with respect to subsurface soil samples. Large areas of the site remain unsampled and there was a seemingly arbitrary selection of sampling points. In addition, the areas under the ponds could not be sampled without puncturing the liners. These areas, as well as the berms around and between the ponds have not been characterized. Furthermore, there was no sampling beneath buildings, but there were 3 boreholes installed through the ore storage pad during the survey. Finally, because the pile of dirt from french drain construction was amassed after the sampling was conducted, this pile has not been sampled.

7.3 Assumptions about Extent of Contamination and Recommendations for Additional Characterization

Two assumptions can be drawn from the characterization described above. First, all soil East of the Thermite building, Evaporator Building, Chemical A Building, bounded by former ponds 2 and 5 is contaminated. Approximately 10 percent of this soil is potentially mixed waste. Second, the area bounded by the Chemical A Building to the south, the midpoint of Pond 3 to the west, the "non-impacted area to the north, and the river to the east (excluding the area within the Pond 3 french drain area) is contaminated at depths up to 20 feet.

The following areas will require additional characterization to delineate the extent of contamination:

- Beneath and immediately adjacent to ponds. However, these areas cannot be sampled until remediation of the ponds takes place, to prevent puncturing liners and further affecting subsurface soils and groundwater.
- Between the Sodium Reduction Building, the Thermite Building, and the Ore Storage Pad. Approximately three soil borings are needed.
- Between the R&D building and the Ore Storage Pad (once the waste pile has been removed). Approximately six soil borings are needed.
- Between the rail spur and the Pond 3 french drain. Approximately five soil borings are needed.
- Within the Pond 3 french drain area (to the extent possible without puncturing the liner). Approximately six soil borings are needed.
- Between the Chemical C Building and former Pond 2. Approximately two soil borings are needed.
- Outside the property boundary northeast of former Pond 2. Approximately six soil borings are needed.
- In the borrow pit (because of groundwater and sediment contamination found in that area). Approximately six soil borings are needed.
- In the "non-impacted area" north of Pond 3 to ensure this area is really not impacted. Approximately 25 surface soil samples are needed.

For these locations both surface sampling (in the first 6 inches) and subsurface sampling (below the first six inches) should be conducted, except in the "non impacted area" where only surface sampling is recommended.

Absent additional sampling, the following assumptions would need to be made in developing a cost estimate.

- Any soil below the ponds is contaminated from the base of the pond to bedrock.
- Any soil in the berms between and within 10 feet of ponds is contaminated to the base of the ponds.
- Surface soils between the Sodium Reduction Building, the Thermite Building, the Ore Storage Pad and Pond 6 are contaminated.
- The soil stored between the Ore Storage Pad the R&D building is contaminated as well as the surface soil in this area.
- All soil in the Pond 3 french drain area is contaminated down to bedrock.
- Ten percent of the surface soils in the "non-impacted area" is contaminated.

7.4 Costs Associated with Additional Characterization

To calculate the cost associated with additional characterization of soils, we calculated that 25 surface samples and 34 boreholes are needed. To calculate the cost associated with additional surface soil characterization, the number of samples was multiplied by the unit cost per sample for soil analysis of alpha spectroscopy. From Table 3 in Section 3.5, the unit cost associated with alpha spectroscopy is \$129 per sample. As shown in Table 41, a total of 25 samples will require analysis, at a total cost of \$3,225. To account for sample collection and associated costs of sampling, we added 10 percent of the total analytical cost on to this estimate, which results in a total cost of \$3,547.

To calculate the cost of the soil borings, we calculated the overall number of samples that needed to be taken assuming five samples are required per borehole. As shown in Table 42, 34 boreholes and 170 samples would be needed. Unit costs for installation of boreholes, sample collection, and sample analysis were multiplied by the numbers of boreholes needed and samples requiring analysis to calculate the cost of the additional characterization of subsurface soils. Unit costs were taken from Table 3 in Section 3.5. Required analysis included TAL metals and alpha spectroscopy, for a total unit cost for analysis of \$431 per sample. As shown in Table 42, unit costs for the installation of boreholes, sample collection, and sample analysis were multiplied by the numbers of boreholes needed and samples requiring analysis and were summed to calculate a cost of \$96,639. To account for sample collection and associated costs of sampling, we added 10 percent of the sub-total cost on to this estimate, which results in a total cost of \$106,303. This cost does not include sampling under pond liners, because we do not believe such sampling can be attempted until remediation is underway.

Table 41. Estimated Costs Associated with Additional Surface Soil Sampling

Total Number of Samples Needed	25
Unit Cost for Sample Analysis	\$ 167
Total Analysis Cost	\$ 3,225
Associated sampling costs (10 percent)	\$ 323
Total Cost	\$ 3,548

Table 42. Estimated Costs Associated with Additional Subsurface Soil Sampling

Number of boreholes needed	34
Number of samples per borehole	5
Number of samples analyzed	170
Unit cost to install each 25 ft borehole	\$ 495.45
Unit cost to take each sample	\$ 38.19
Unit cost to analyze each sample	\$ 431.19
Total cost to install boreholes	\$ 16,845
Total cost to take samples	\$ 6,492
Total cost of analysis	\$ 73,302
Subtotal Cost	\$ 96,639
Associated sampling costs (10 percent)	\$ 9,664
Total Cost	\$ 106,303

8.0 Surface Water and Sediments

The Fansteel site is bordered by the Arkansas River to the East. The rivers in this area of Oklahoma, just north of Muskogee, are generally well regulated by a series of locks and dams for flood control. The portion of the river adjacent to Fansteel is impounded by the Webber Falls Lock and Dam and the site is located above the level of maximum probable flood (500-year flood plain). The resulting Webber Falls Reservoir is used primarily for power generation and recreational purposes. It is not used for drinking water because it is highly mineralized. The nearest intake is about 16 miles upstream at the confluence of the Verdigris and Neosho Rivers. The nearest downstream intake is near the confluence of the Arkansas and Mississippi rivers.

There are five outfalls at the site, all of which discharge liquid effluent to the Arkansas River. Outfall 004, located next to Outfall 001, is no longer active. It was used by a tenant on the property and was regulated by a separate NPDES permit. The remaining four outfalls are used by Fansteel and are regulated under NPDES permit OK0001643, and under waste disposal permit CW-69-020 managed by the Oklahoma Department of Environmental Quality (OKDEQ). Outfalls 001, 002, and 003 were part of the original permit, Outfall 005 was added in 1996.

Outfall 001 is the effluent monitoring point for the facility's wastewater treatment plant and is regularly monitored, with grab samples taken at least three times per week. Outfalls 002, 003, and 005 are intermittent and consist entirely of stormwater runoff and discharge. They are sampled after significant rain events.

8.1 Summary of Existing Characterization

The majority of the characterization data available for review was from the Remediation Assessment conducted by Earth Sciences Consultants, Inc. in 1993. Additional characterization data were provided by Fansteel in a Response to NRC Environmental Assessment Comment Request report. A small amount of data were also provided in NRC's Environmental Assessment prepared for License Amendment for material license SMB-911.

8.1.1 Surface Water

As part of the Remediation Assessment, a total of seven samples were taken at the permitted outfalls and from surface water in the borrow pit area. The location of the 7 surface water samples during the characterization study are identified in Figure 11. Surface water was collected directly into laboratory supplied sample containers. The samples were analyzed for:

- Gross alpha and gross beta
- Total metals (tantalum, columbium, tin, lead, nickel, antimony, arsenic, barium, cadmium, calcium, chromium, mercury, selenium, and silver)
- Total ammonia, total sulfate and pH
- MIBK (4-methyl-2-pentanone).

Background water quality samples of the Arkansas River were not taken by Fansteel as part of the characterization study as they relied on existing literature regarding water quality in this area.

For surface water radiological analyses, the Oklahoma Water Resources Board action levels (gross alpha >15 pCi/l and gross beta > 50 pCi/l) were used to evaluate the presence of radioactivity in surface water, and as criterion for whether the sample would be analyzed for specific radionuclides. Water containing radioactivity in excess of these results of these criterion were assumed to be impacted by plant operations. Using these criteria, only 2 of the 7 water samples were analyzed for specific radionuclides, Outfall 2 (SS-002) and borrow pit area sample 1 (SS-1). Table 43 presents the sampling results.

The sample from Outfall 2 exhibited elevated gross alpha and gross beta as well as elevated levels of uranium and radium. A borrow pit sample also showed elevated gross alpha and beta as well as elevated levels of uranium, thorium, and radium. Both areas appear to have been impacted by site operations. Outfall 2 results are expected given the results obtained from soil borings in this area and historic operations. The cause of the elevated levels on the eastern side of the borrow pit are not known. Elevated levels of columbium and tantalum were also identified in this area.

As stated previously, the site has an ongoing liquid effluent monitoring program. Flow rates are regularly monitored. Liquid discharge from Outfall 001 are sampled three times per week or once per 24 hours if discharge is sporadic. The other outfalls are monitored after significant rain activity as they only discharge stormwater. ICF reviewed seven years of historical monitoring data. Action levels for gross alpha and gross beta are 15 pCi/L and 50 pCi/L respectively. Specific isotopic analysis is conducted if these criterion are exceeded. If the results exceed 25 percent of the effluent limits in 10 CFR Part 20, trends would be analyzed.

Table 43. Radionuclide Concentrations in Surface Water

Sample ID	Gross Alpha (15 pCi/l)	Gross Beta (50 pCi/l)	Total Uranium (U-233/234, U-235, U-238) (pCi/l)	Total Thorium (Th-228, Th-230, Th-232) (pCi/l)
SS-001	4 ±8	8 ±9	-	-
SS-002	45 ±18	70 ±12	17.0	4.9
SS-003	2 ±1	4 ±1	-	-
SS-005	3 ±2	7 ±2	-	-
SS-1	110 ±70	150 ±40	14.2	22.6
SS-2	2 ±2	7 ±2	-	-
SS-3	3 ±2	8 ±2	-	-

Notes: - Dash denotes not analyzed. Results above the action level are in bold.

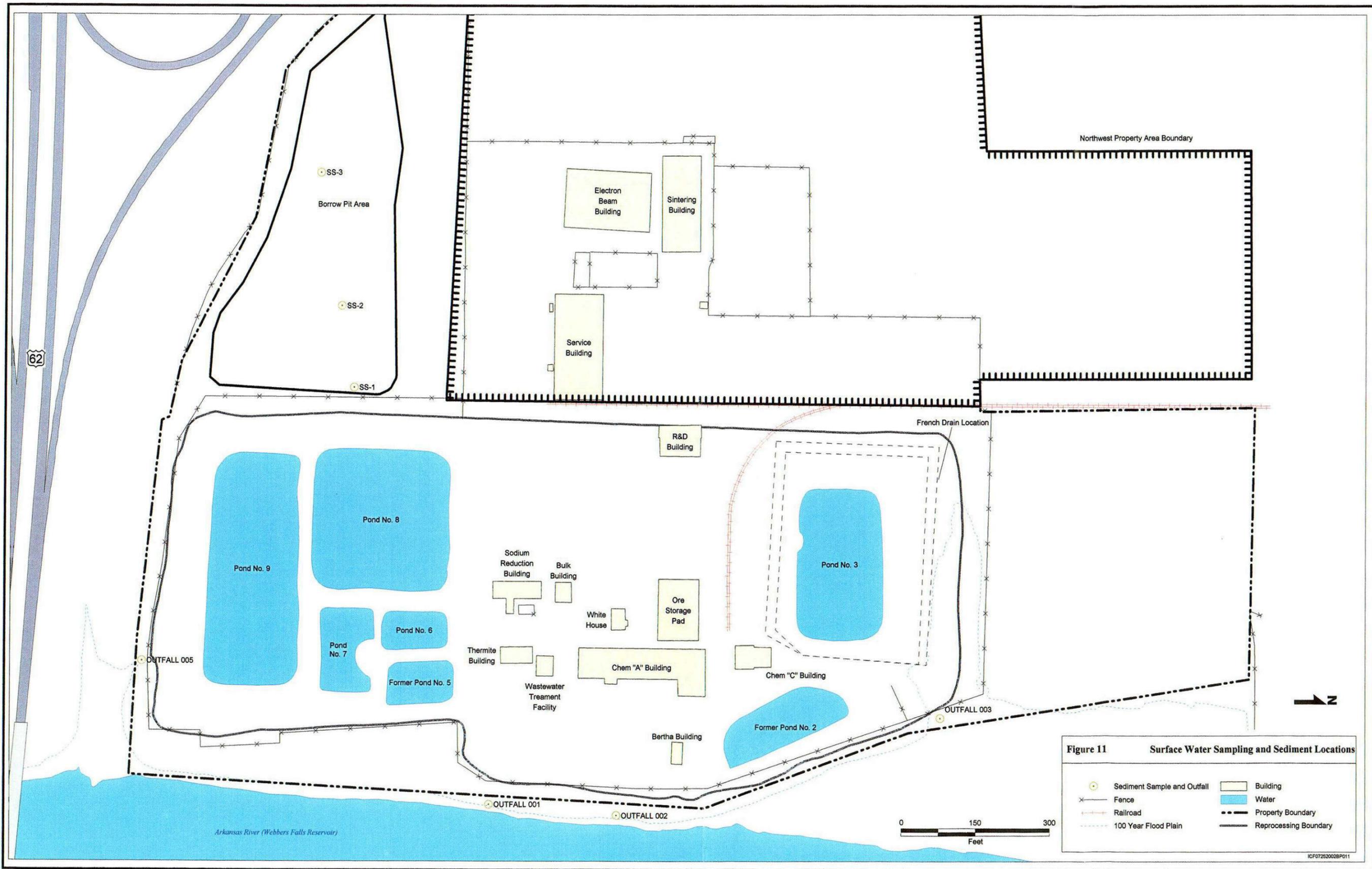


Figure 11 Surface Water Sampling and Sediment Locations

- | | | | |
|--|-----------------------------|--|-----------------------|
| | Sediment Sample and Outfall | | Building |
| | Fence | | Water |
| | Railroad | | Property Boundary |
| | 100 Year Flood Plain | | Reprocessing Boundary |

0 150 300
Feet

The data shows that there have been routine excursions above the 50 pCi/l action level for gross beta at Outfall 001. Supplemental data submitted by Fansteel in response to questions posed by NRC during the license amendment process indicate elevated levels of gross beta at Outfall 001 over several years. These data are summarized in Table 44.

Table 44. Radiological Effluent Monitoring Results at Outfall 001²⁸

Sample Date	Alpha (pCi/l) (State limit = 15 pCi/l)	Beta (pCi/l) (State limit = 50 pCi/l)
10-13-94	7 +/- 6	140 +/- 13
10-14-94	1 +/- 6	150 +/- 14
11-10-94	9 +/- 8	140 +/- 14
11-11-94	1 +/- 8	160 +/- 17
11-15-94	0 +/- 7	120 +/- 12
11-16-94	4 +/- 7	110 +/- 10
11-17-94	2 +/- 6	110 +/- 10
01-10-95	4 +/- 4	100 +/- 9
01-11-95	4 +/- 5	100 +/- 9
01-12-95	4 +/- 4	100 +/- 9
02-07-95	2 +/- 7	91 +/- 7
02-08-95	-5 +/- 5	87 +/- 10
02-09-95	-4 +/- 5	87 +/- 9
05-02-95	5 +/- 3	97 +/- 3
05-03-95	3 +/- 3	90 +/- 3
05-06-95	3 +/- 2	84 +/- 3
05-08-95	2 +/- 2	80 +/- 2
05-09-95	2 +/- 2	74 +/- 2
05-10-95	2 +/- 1	74 +/- 2
06-13-95	6 +/- 5	80 +/- 7
06-14-95	3 +/- 4	68 +/- 6
06-15-95	5 +/- 5	72 +/- 6

²⁸ Response to the NRC Environmental Assessment Comment Request, Fansteel, February 20, 1997, Response to Effluent and Environmental Monitoring question 8.

Quarterly effluent monitoring data for Outfall 001 during the period 1991 to 1996 indicates three instances above the 15 pCi/l action level for gross alpha. These data further illustrate the routine exceedence of the 50 pCi/l gross beta limit at this Outfall. The results of this monitoring are presented in Table 45.

Table 45. Radiological Effluent Monitoring Results at Outfall 001 During 1991 to 1996

Year-Quarter	Gross Alpha (pCi/l) (State limit = 15 pCi/l)	Gross Beta (pCi/l) (State limit = 50 pCi/l)
1991-1	18	170
1991-2	3	17
1991-3	5	19
1991-4	3	16
1991-Average	7	56
1992-1	2	27
1992-2	1	14
1992-3	4	11
1992-4	3	10
1992-Average	3	16
1993-1	3	8
1993-2	4	16
1993-3	10	350
1993-4	-	-
1993-Average	6	125
1994-1	-	-
1994-2	no discharge	no discharge
1994-3	no discharge	no discharge
1994-4	3	133
1994-Average	3	133
1995-1	2	94
1995-2	2	80
1995-3	no discharge	no discharge
1995-4	no discharge	no discharge
1995-Average	3	87

Year-Quarter	Gross Alpha (pCi/l) (State limit = 15 pCi/l)	Gross Beta (pCi/l) (State limit = 50 pCi/l)
1996-1	no discharge	no discharge
1996-2	no discharge	no discharge
1996-3	no discharge	no discharge
1996-4	11	112

Source: *Environmental Assessment - License Amendment for Material License No. SMB-911, U.S. Nuclear Regulatory Commission, December 1997.*

Outfalls are also monitored for nonradiological constituents including fluoride, lead, columbium, tantalum, zinc, total suspended solids, pH, and flow rate. All constituents were generally within the NPDES permit limits. When reprocessing was started at the facility in 1999, the concentration of toxics in the effluent from outfall 001 exceeded the parameters identified by the permit. Retooling of the process brought the site back into compliance. They have participated in a TRE program with the State and have been in compliance since the initial exceedance. The site is slated to complete the program this year.

Surface water samples in the northeast section of the borrow pit area exhibit elevated levels of barium, cadmium, chromium, lead, colombium, and tantalum. Ammonia was also detected in one surface water sample from the borrow pit area. The surface water quality of all of the outfalls exhibited relatively low levels of fluoride, ammonia, and cadmium. MIBK was found in elevated concentrations at Outfall 001. Elevated levels of lead and chromium were exhibited at Outfalls 002, 003, and 005. Arsenic was found in significant concentrations at Outfalls 001 and 002.

Site personnel indicated that the company that leased property on the Fansteel site and operated Outfall 004 had issues with exceeding the toxicity parameters of their permit when they were operating. Of the total of 8 exceedances registered at the site, 7 are attributable to the third party that leased a portion of the facility. However, details were not provided regarding the nature of the violations.

8.1.2 Surface Sediment

In general, a sediment sample was collected at each surface water sampling location for comparative purposes. However, no sediment was available for sampling at Outfall 001 (SS-001). A new disposable sampling trowel was used at each location to collect sediments. The sediments were analyzed for the same radiological and chemical parameters as surface water:

- Gross alpha and gross beta
- Total metals (tantalum, columbium, tin, lead, nickel, antimony, arsenic, barium, cadmium, calcium, chromium, mercury, selenium, and silver)
- Total ammonia, total sulfate and pH
- MIBK.

For sediment analyses in the Remediation Assessment, if either gross alpha or gross beta parameters were detected at levels one standard deviation above the mean background concentration in soil, individual radionuclide analyses were performed to determine the contributing species. The mean background radiological levels calculated for soils (see Section 7) were also used for sediments. The average gross alpha and gross beta activity measured in the background soils were 15.6 pCi/g and 20.5 pCi/g, respectively. The standard deviations for gross alpha and gross beta activity measured in the background soils were 4.2 pCi/g and 4.5 pCi/g, respectively. Thus, the levels at which isotopic analysis was triggered for sediments is 20 pCi/g for gross alpha and 25 pCi/g for gross beta.

Table 46 presents the results of the isotopic analysis for sediments. All three samples analyzed for individual isotopes exceeded the unrestricted release level for combined uranium and thorium in soil of 10 pCi/g. The Remediation Assessment indicated that sediment samples near Outfalls 002 and 003 (SS-002 and SS-003) exhibited slightly elevated gross alpha radioactivity of 28 pCi/g and 24 pCi/g, respectively, with Outfall 003 also showing elevated uranium. There is no explanation regarding the elevated level demonstrated in the borrow pit (SS-1).

Table 46. Radionuclide Concentrations in Surface Sediments

Sample ID	Total Uranium (U-233/234, U-235, U-238) (pCi/g)	Total Thorium (Th-228, Th-230, Th-232) (pCi/g)	Total U+Th (pCi/g) Unrestricted Release Limit = 10 pCi/g
SS-001	-	-	-
SS-002	5.6	4.6	10.2
SS-003	13.0	9.0	22.0
SS-005	-	-	-
SS-1	14.3	8.6	22.9
SS-2	-	-	-
SS-3	-	-	-

Notes - Dash denotes not analyzed. Results above action level are in shaded cells.

8.2 Identification of Potential Gaps in Characterization

To assess whether there are gaps in the characterization of surface water and sediment, we used the checklist presented in Section 3.3.

1. Has outfall monitoring required by the facilities NRC license been conducted?

Yes.

2. Has outfall monitoring required by the State of Oklahoma been conducted?

Yes.

3. Are all sample results below the appropriate action levels?

No. Radionuclide concentrations in Surface Water Samples SS-002 and SS-1 both exceeded the gross alpha and gross beta limits. Further, the gross beta limit of 50 pCi/l was consistently exceeded in Outfall 001 over a period of five years. In addition, sediment sampling at Outfall 002 and 003 and at one location in the borrow pit (SS-1) exceed the combined uranium/thorium non-restricted release limit of 10 pCi/g.

8.3 Assumptions about Extent of Contamination and Recommendations for Additional Characterization

The surface water data is augmented by almost ten years of effluent monitoring data provided by Fansteel. The State of Oklahoma and the Army Corps of Engineers have also published sufficient information to establish the background quality of the Arkansas River in this area. Therefore, no additional surface water sampling (in addition to the ongoing liquid effluent monitoring program) appears warranted.

Due to the elevated radioactivity levels found in sediment samples in the area of the Borrow Pit, we believe that additional sampling in this area is warranted. All documentation seems to indicate that no industrial activity took place in this area, however because of the limited sampling conducted here, there may be a need to further investigate this area to determine the source of the elevated readings. As there is no creek or standing body of water in this area, the additional soil sampling recommended in Section 7 should be adequate in delineating the source of contamination in this area. Further discussion of the sampling recommended for the Borrow Pit area is contained in Section 7.3.

8.4 Costs Associated with Additional Characterization

The costs associated with the recommended additional surface sediment sampling are included in Section 7.4.

9.0 Conclusions

For the most part Earth Sciences has characterized the nature and extent of the radiological and chemical contamination at the Fansteel site. The Remediation Assessment shows that site operations spanning nearly 50 years have generated significant quantities of radioactive and mixed wastes, contaminated many of the buildings, and affected the soils and groundwater at the site. On the basis of our review of the characterization data, we make the following conclusions.

- Operations have resulted in the radiological contamination of most building surfaces at the site. Many of the buildings on the site likely can be decontaminated as opposed to requiring demolition and off site disposal.
- Groundwater monitoring indicates that the underlying groundwater is contaminated with radionuclides, metals, and to a lesser extent, organics.
- Large quantities of mixed waste in the form of pond residue are presently located at the site. Approximately two million cubic feet of radioactively contaminated pond residue will require disposal as mixed waste. Removing liquids from this waste could significantly reduce the volume.
- Large quantities of radioactively contaminated waste in the form of pond residue are presently located at the site. Approximately 7.5 million cubic feet of slightly radioactively contaminated pond residue will require disposal. None of this waste is expected to be mixed waste. Removing liquids from this waste could significantly reduce the volume.
- The majority of the surface soils at the site are contaminated. The primary radioactive isotopes of concern are U-234, U-235, U-238, Th-230, and Th-232.
- Significant subsurface contamination of the site exists due to historical operations and disposal practices, including the use of the ponds with only natural clay liners.
- A large portion of the subsurface site remains uncharacterized, including areas beneath the buildings and ponds, and areas adjacent to underground process and drainage lines.

As a result of our evaluation of the site characterization information, we believe that additional characterization would be helpful, but is not necessary prior to initiating a remedial action. We present a summary of the costs associated with the additional characterization by medium in Table 47. Note that these costs do not include collecting samples underneath the buildings or from below the bottoms of the ponds, because sampling below the ponds while the ponds still have material in them would only increase the likelihood of spreading contamination.

Table 47. Summary of Costs of Recommended Additional Characterization

Medium	Cost of Additional Characterization
Buildings	NA
Groundwater	\$ 24,833
Ponds	NA
Soil	\$ 106,303
Surface Water and Sediments	NA
Total	\$ 131,136

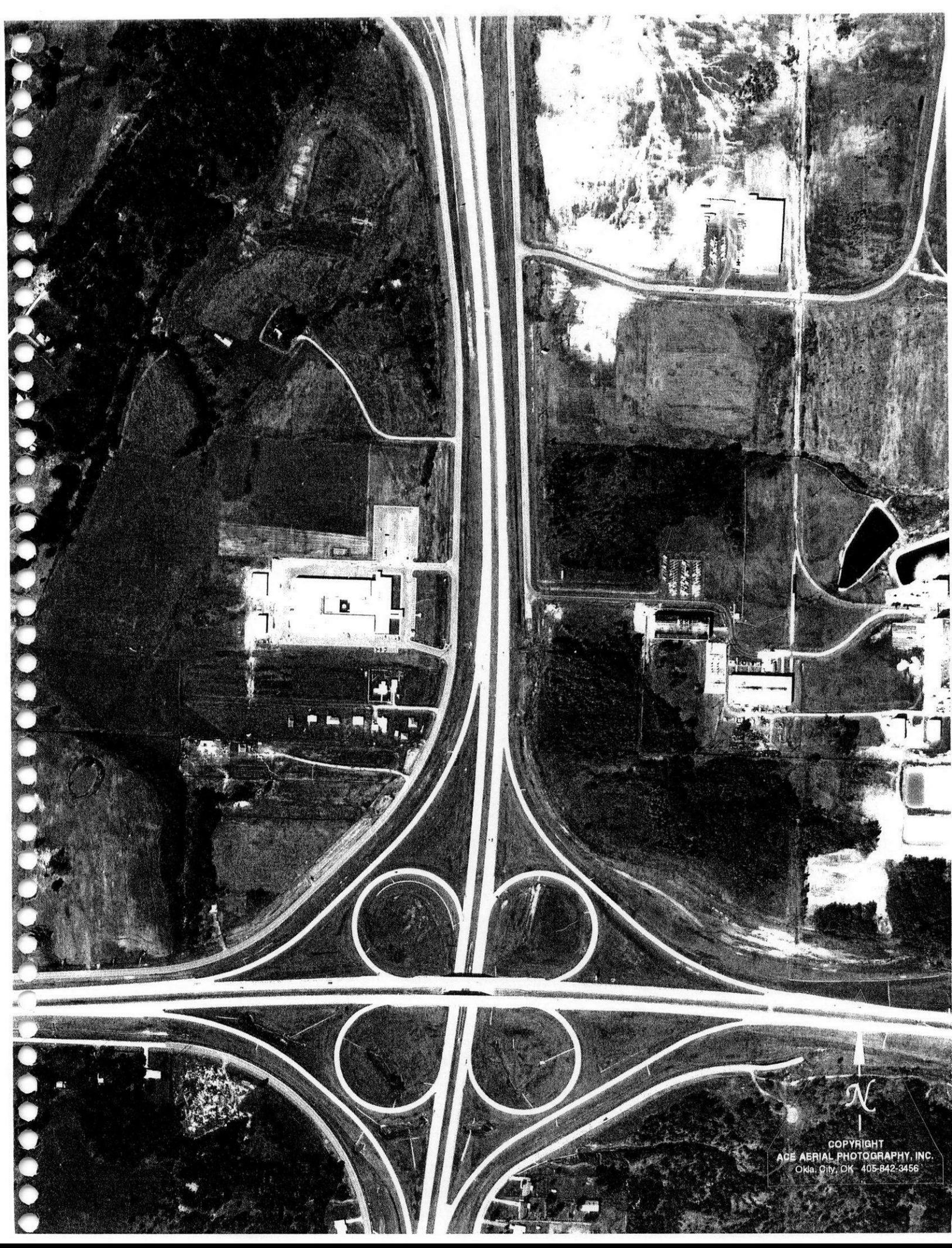
10.0 Bibliography

1. Earth Sciences, Inc. Decommissioning Plan, U.S. NRC License No. SMB-911, Fansteel, Inc. June 1999.
2. Earth Sciences, Inc. Decommissioning Plan, U.S. NRC License No. SMB-911, Fansteel, Inc., Containment Cell Portion. August 1999.
3. Earth Sciences, Inc. Environmental Assessment Report, Fansteel, Inc., Muskogee, Oklahoma. Project No. 111. June 1994.
4. Earth Sciences, Inc. Remediation Assessment, Fansteel Inc., Muskogee, Oklahoma. Volume I-IV. Project No. 111. December 1993.
5. Earth Sciences, Inc. Response to the NRC Environmental Assessment Comment Request. Project No. 3789C. February 20, 1997.
6. Environmental Cost Handling Options and Solutions. Environmental Remediation Cost Data-Assemblies. 7th annual edition. R.S. Means Company, Inc. and Talisman Partners, Ltd., publishers 2001.
7. Environmental Cost Handling Options and Solutions. Environmental Remediation Cost Data-Unit Price. 7th annual edition. R.S. Means Company, Inc. and Talisman Partners, Ltd., publishers. 2001.
8. Fansteel, Inc. Facility Background and Operating Data. 1995.
9. New Jersey Department of Environmental Protection and Energy. Field Sampling Procedures Manual. May 1992.
10. U.S. Environmental Protection Agency. National Survey of Solid Wastes from Mineral Processing Facilities Questionnaire completed by Fansteel, Inc. 1989.
11. U.S. Environmental Protection Agency. Technical Background Document, Identification and Description of Mineral Processing Sectors and Waste Streams. April 1998.
12. U.S. Nuclear Regulatory Commission. Environmental Assessment, License Amendment for Material License No. SMB-911, Docket 40-7580. December 1997.
13. U.S. Nuclear Regulatory Commission. Site Decommissioning Management Plan. NUREG-1444. October 1993.

ATTACHMENT 1

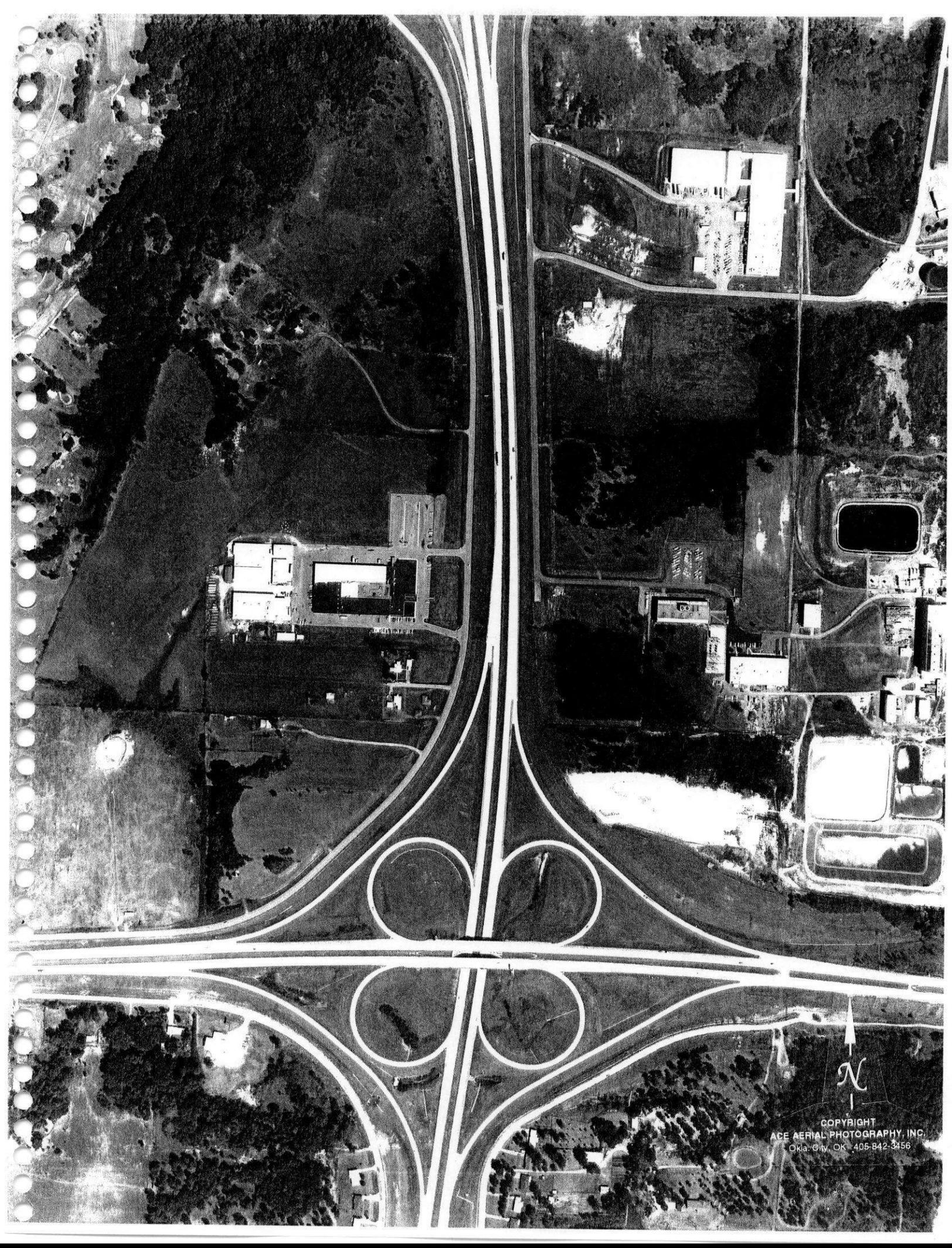
Aerial Photographs of the Fansteel Site

1973 Aerial Photograph



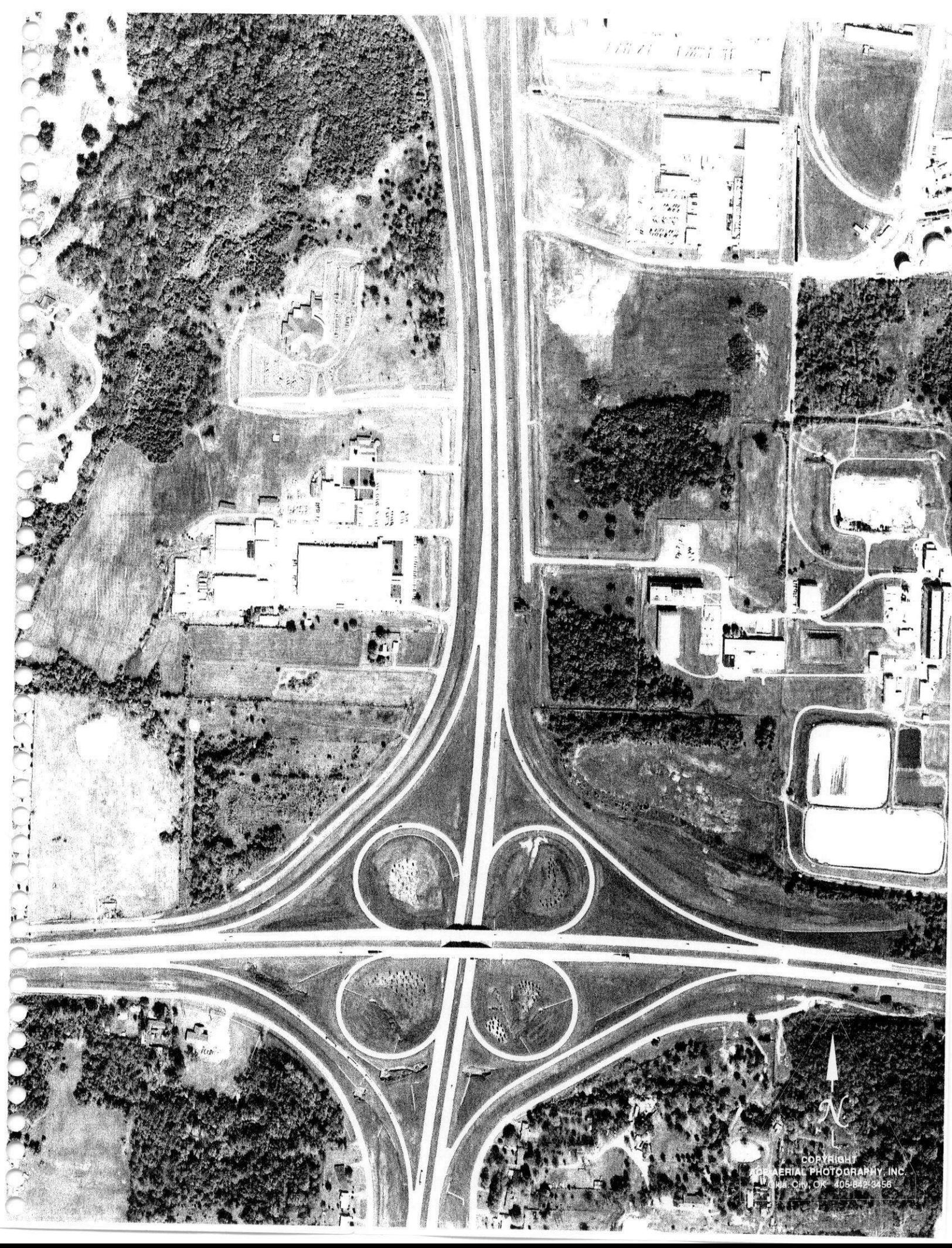
COPYRIGHT
ACE AERIAL PHOTOGRAPHY, INC.
Okla. City, OK 405-842-3456

1984 Aerial Photograph



COPYRIGHT
ACE AERIAL PHOTOGRAPHY, INC.
Okla. City, OK 405-842-3456

2001 Aerial Photograph



COPYRIGHT
AERIAL PHOTOGRAPHY, INC.
TULSA CITY, OK 406-842-3456