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REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES

For The :
Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

Prepared By MK-Ferguson Company & Jacobs Engineering Group

DECEMBER 1989 REV. 1

U.S. Department Of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

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Revision 1

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Prepared for

U.S DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract DE-AC05-86OR21548

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) proposes to remove the bulk wastes from the Weldon Spring quarry (WSQ or quarry) as a separate operable unit of the total remedial action of the Weldon Spring Site Remedial Action Project (WSSRAP). The quarry, part of the Weldon Spring Site, is situated 5 miles south-southwest of the town of Weldon Spring, Missouri, and is contaminated with radioactive and chemical materials deposited during Department of the Army and Atomic Energy Commission (AEC) activities between 1942 and 1969. The Weldon Spring Site also includes the raffinate pits and chemical plant, an area which is not contiguous to the quarry.

The Remedial Investigation/Feasibility Study (RI/FS) process will be used to support the proposed removal, which is scheduled to be conducted prior to the record of decision (ROD) for the overall remedial action. This RI report is designed to meet one component of the documentation requirements for the proposed action. This report summarizes and evaluates information contained within pertinent studies completed over the years by Army, AEC, and DOE contractors and other agencies. An Engineering Evaluation/Cost Analysis (EE/CA) for removal and treatment of contaminated water from a pond situated within the quarry, an activity which must precede bulk waste removal, has been submitted. Additional separate operable units related to the quarry can only be addressed after the bulk wastes have been excavated and removed from the quarry.

It is estimated that approximately 95,000 cubic yards of contaminated waste materials, consisting of structural debris, drummed and unconfined wastes, process equipment, sludges, and other solid materials, have been deposited in the quarry. Uranium, thorium, radium, and radon are the radioactive constituents of concern. Chemical contaminants are known to

include nitroaromatic compounds, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals. Representative sampling of the in-place material is complicated by the hetergoeneity of the waste. The quarry pond, containing approximately three million gallons of contaminated water, shows elevated levels of uranium, manganese, arsenic, and 2,4-dinitrotoluene. Groundwater in the limestone bedrock of the quarry contains elevated concentrations of uranium, thorium, nitroaromatic compounds, nitrate, sulfate and chlorides.

The quarry was excavated into a limestone ridge bordering the Missouri River alluvial floodplain. The upper layers of limestone at the quarry include a complex system of solution channels, joints and fractures, through which groundwater movement probably occurs. Groundwater in the vicinity of the quarry is present within the alluvium, the limestone bedrock, and the deeper formations of dolomite and sandstone. A hydraulic connection apparently exists between the quarry groundwater and the nearby Femme Osage Slough, but there appears to be at least a partial hydrogeologic barrier to contaminant migration further south. The groundwater regime, however, has not yet been fully characterized. The groundwater regime will be futher characterized in subsequent investigations.

Wastes within the quarry, therefore, may pose a risk of future contamination to St. Charles County drinking water supply wells south of the quarry. To mitigate this potential risk, and to allow further characterization necessary to support any additional remedial activities, DOE proposes to remove the bulk wastes and place them in temporary, secure storage at the raffinate pits and chemical plant area. This action will permit appropriate classification and inventory of the contaminated materials for final disposal planning. Bulk waste removal will accomplish one critical task in the overall remediation of the Weldon Spring Site.

In addition to this RI report, a baseline risk evaluation has been performed and documented in a separate companion report. A feasibility study for the proposed bulk waste removal has been initiated. Additional characterization will be carried out as a separate environmental compliance component after the bulk wastes are removed.

1 INTRODUCTION

1.1 PURPOSE OF REPORT

1.1.1 Proposed Action

The U. S. Department of Energy (DOE) proposes, as a separate operable unit of the Weldon Spring Site Remedial Action Project (WSSRAP), to remove contaminated bulk wastes from the Weldon Spring quarry (referred to in this report as quarry or WSQ) and transport them approximately four miles to the chemical plant portion of the raffinate pits and chemical plant area (Figure 1.1). The wastes will be held in temporary storage prior to the record of decision (ROD) for the overall remedial action. The decision on the ultimate disposal of these bulk wastes will be included as part of the decision for management of the waste materials resulting from remedial action activities at the raffinate pits and chemical plant area.

Although the extent, pathways and mechanisms of contaminant transport at the quarry are not fully understood at this time, it can reasonably be concluded that the quarry wastes are the major source of contamination that has been detected in the surface water and groundwater in the quarry area. Expedited removal of the bulk wastes will mitigate the potential risks to public health and the environment by eliminating the primary source of contamination and reducing the potential for migration.

In addition, the proposed removal of quarry wastes will permit adequate definition of residual contamination in and around the quarry site. The need for removal of any residual materials (e.g., sludges or sediments present within bedrock fractures) and for groundwater remediation cannot be determined

until the removal has been accomplished and the remaining conditions evaluated.

The removal will also permit consolidation of all wastes associated with the Weldon Spring Site at one secure location, which will accomplish one necessary step in the overall remediation of the site. An investigation of the proposed temporary storage area is now underway, and study results will be presented in a separate stand-alone report.

1.1.2 Documentation Requirements

The work plan for the overall Weldon Spring Site RI/FS-EIS outlines the decisions made by DOE regarding the Weldon Spring quarry operable unit (Peterson et al, 1988). Four distinct response actions may be required at the quarry: 1) bulk waste removal; 2) removal of any residual materials following bulk waste removal; 3) groundwater restoration; and 4) cleanup of contaminated vicinity properties. In addition before the bulk wastes can be removed, contaminated water contained within the pond at the quarry must be removed. Those environmental compliance components associated with the quarry are shown in Figure 1.2.

This RI report has been prepared to support the proposed bulk waste removal from the quarry. Thus, the focus of this report is on compilation of existing data pertinent to the removal of the bulk wastes. Therefore, the scope of this report addresses contamination aspects only within the quarry fence limits. Areas outside the fence are discussed in terms of general site description and monitoring. A more comprehensive characterization will be developed after the bulk wastes are removed.

The purpose of this report is to satisfy the documentation requirements for operable unit remedial investigations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The information presented will serve as input into the selection of remedial action alternatives for the proposed waste removal.

An Engineering Evaluation/Cost Analysis (EE/CA) for removal and treatment of contaminated water from a pond situated within the quarry, an activity which must precede bulk waste removal has already been submitted (MacDonell et al, 1989). In addition a limited baseline risk evaluation has been prepared separately for the WSQ as it now exists using information presently available (Haroun et al, 1989). This evaluation was conducted for the baseline case to determine potential impacts of the quarry wastes to human health and the environment if no action is taken. Current data are considered to be sufficient to evaluate and justify the need for bulk waste removal. After removal of the bulk wastes, a comprehensive baseline risk assessment will be conducted to evaluate potential impacts to the environment and human health from the residual conditions.

Several additional areas in the vicinity of the quarry, but outside of the currently fenced boundaries, are contaminated with radioactivity. DOE proposes to clean up those vicinity properties which present an unacceptable risk to the general public. Vicinity properties to be remediated prior to issuance of the ROD will be addressed in separate environmental compliance documents.

1.2 SITE BACKGROUND

1.2.1 Site Description

The Weldon Spring Site is located near the community of Weldon Spring, St. Charles County, Missouri, about 30 miles west of St. Louis (Figures 1.1 and 1.3). The site consists of two noncontiguous areas: 1) the raffinate pits and chemical plant area and 2) the quarry. The raffinate pits and chemical plant are about 2 miles southwest of the junction of Missouri Route 94 and U.S. Route 40/61. The quarry is located about 4 miles south-southwest of the raffinate pits and chemical plant area and about 5 miles southwest of the community. Both areas are accessible from State Route 94, and are fenced and closed to the public.

The 9-acre quarry was excavated into a bluff which forms a valley wall at the edge of the Missouri River floodplain. A small pond, 0.5 acre in size, occupies the lowest point of the quarry. The surrounding topography is rugged, heavily wooded, and characterized by deeply dissected hills. To the south lies the broad, flat Missouri River floodplain. The Femme Osage Slough and the St. Charles County well field are located on the floodplain.

An estimated 95,000 cubic yards of bulk waste are present within the quarry. The heterogeneous material includes rubble, drummed waste, sludge, and soil contaminated with both radionuclides and chemical species. The areas of highest radioactivity are to the east and northeast of the pond. Chemically contaminated materials are present to the east and south of the pond. In addition, both pond water and groundwater within the saturated portions of the waste materials are contaminated.

1.2.2 Site History

The Army and the AEC used the Weldon Spring quarry for waste disposal during their operations from 1942 to 1969. Before 1942, limestone aggregate was mined from the quarry and used in construction of the Weldon Spring Ordnance Works, located about 4 miles to the northeast.

Between 1942 and 1945, the Army used the quarry for disposal of wastes generated from manufacturing at the ordnance works. After 1945, rubble contaminated with TNT and other nitroaromatic compounds was dumped into the quarry until 1957. The ordnance works, which produced DNT in addition to TNT, were operated until 1944, and the property was declared as surplus 2 years later. By the end of 1949, most of the land around the ordnance works and the quarry had been transferred to the state of Missouri and the University of Missouri.

In 1956, portions of the ordnance works area were transferred to the AEC. This agency then constructed and operated a feed materials plant, now known as the chemical plant, which processed uranium and thorium ore concentrates. Two years later, in 1958, the AEC assumed custody of the quarry for use as a disposal site for radioactively contaminated wastes. The feed materials plant was operated until 1966. Radioactive waste materials disposed in the quarry during this period included drummed wastes, uncontained wastes, building rubble, and contaminated process equipment.

In 1975, AEC contracted with National Lead Company of Ohio (NLO) to perform environmental monitoring and maintenance at the quarry. This responsibility was transferred to Bechtel National Inc. (BNI) in 1981, under contract to the DOE, AEC's successor. MK-Ferguson Company (MK-F), DOE's project management contractor (PMC), has been active at the site since 1986. In 1987 the

Weldon Spring quarry was placed on the National Priorities List under CERCLA.

1.2.3 Overview of Investigations

Since the 1950s, government agencies and contractors have conducted intermittent investigations at the Weldon Spring Site to assess the hydrogeologic and environmental setting, and to determine the nature and extent of contaminant sources and environmental contamination within and in the vicinity of the quarry.

Several types of site-specific studies have been conducted in the quarry area to achieve these objectives. Geological and hydrogeological investigations have included field reconnaissance and mapping, borehole logging, and sampling programs, monitor well installation, groundwater level measurements, pumping tests, and other aquifer tests. Water quality sampling and analyses for radiological and chemical parameters have been conducted in bedrock and alluvial groundwater, and bulk wastes have been characterized. Activities have included borehole and surface sampling of soils and wastes with analyses for radiological and chemical parameters. Sediment and water samples obtained from surface water bodies in and around the quarry have also been analyzed for radiological and chemical parameters. Environmental monitoring of air quality has also been conducted. These studies have confirmed the presence of both chemical and radiological contamination at the quarry.

1.3 REPORT ORGANIZATION

This report is generally organized in accordance with the March 1988 draft guidance document for conducting remedial investigations/feasibility studies (RI/FS) under CERCLA (EPA,

1988). Because the scope of this report is related to the proposed bulk waste removal, discussion focuses on the characterization of the waste materials now present in the quarry. The study area relevant to this report is generally confined to the area within the quarry fence. However, limited areas outside the fence are discussed in terms of monitoring and general site description. Topics such as groundwater, surface water, geology, meteorology, and ecology are discussed only as they pertain to the bulk waste removal. A thorough characterization of the area surrounding the quarry will be addressed in subsequent documents.

Study area investigations are summarized in Section 2; physical characteristics are presented in Section 3; and the nature and extent of contamination are discussed in Section 4. Contaminant fate and transport (Section 5) are discussed in terms of persistence and potential migration of contaminants from the quarry. Summary and conclusions are provided in Section 6. In addition, data relevant to the characterization of the quarry bulk wastes, sediments, surface water and groundwater are included in Appendices A through D.

2 PREVIOUS STUDY AREA INVESTIGATIONS

2.1 QUARRY INVESTIGATIONS

The Weldon Spring quarry has been studied since the 1950s. The objectives of these studies were, during the early years, to identify changes in the radioactive contaminant levels at the quarry, and, later, to permit suitable definition of levels of both radioactive and chemical contaminants through an ongoing monitoring and exploratory program.

This section briefly outlines the studies, presented by discipline and in chronological order, which have been done at the site under contract to the Department of the Army, AEC, and DOE. Because the focus of this report is the proposed removal of bulk wastes from the quarry to provide secure temporary storage and to permit further assessment of additional remediation required, the contaminant source investigations (Section 2.3) are the most pertinent to this effort. The results of all investigations, however, and their relevance to the bulk waste removal, are presented in Sections 3 and 4.

2.2 SURFACE FEATURES

Topographic mapping of the quarry, at 1"=100' with 2-foot contour intervals and at 1"=50' with 1-foot contour intervals, was completed in the mid-1980s (Surdex Corporation, 1983, 1987). Disposal areas, vegetation, roads, fences, and other surface features are described in Section 3.1.

2.3 CONTAMINANT SOURCE INVESTIGATIONS

Numerous investigations have been conducted to determine the sources of contamination at the quarry. The conclusions of these studies have been compiled and the resulting waste

characterization is presented in Section 4.1. These investigations are briefly summarized below:

1967 A task force formed by the Oak Ridge Operations Office of the AEC evaluated existing data to define management options for the quarry as a disposal facility. Disposal history at the quarry was summarized (Lenhard et al., 1967).

1975 National Lead Company of Ohio, Inc. (NLO) evaluated the quarry in terms of either decommissioning the quarry or using it for radioactive waste disposal, and generated descriptions of radioactive and chemical wastes within the quarry. The potential for migration of contaminants from the quarry wastes was also assessed (Pennak, 1975; Huey, 1978).

1979-81 Lawrence Berkeley Laboratory (LBL) completed a characterization and history of the quarry to determine potential environmental hazards posed by the quarry wastes. The investigation, which was reported by Berkeley Geoscience Associates (BGA), included extensive waste sampling and analysis for radiological parameters (BGA, 1984).

1984-85 Bechtel National, Inc. (BNI) conducted a radiological survey, which included a drilling program within the quarry perimeter and extensive sample analysis. Selected samples were also analyzed for chemical parameters (BNI, 1985c).

1986 BNI, in cooperation with TMA/Eberline, performed an extensive chemical sampling, analysis, and characterization program, focusing on volatiles,

semi-volatiles, PCBs, and nitroaromatics (Kaye and Davis 1987).

1987 PMC collected and analyzed surface soil samples from the exposed slope at the east end of the quarry for nitroaromatics (Meyer, 1988).

2.4 METEOROLOGICAL INVESTIGATIONS

No specific meteorological data has been collected at the quarry. Precipitation, evaporation, and wind speed and direction have been monitored at the chemical plant site. Air quality sampling for radon has been conducted at points along the quarry perimeter and at several off-site locations since 1981 (Weidner and Boback, 1982; BNI, 1983b, 1984b, 1985b, 1986; MKF and JEG, 1987, 1988a).

Section 3.2 includes data on local meteorology, based on records from the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA, 1984; 1981-1986). Annual wind rose diagrams for the Weldon Spring Site are available in previous annual Weldon Spring Environmental Monitoring Reports (BNI, 1986, 1985b).

2.5 SURFACE WATER AND SEDIMENT INVESTIGATIONS

Investigations of surface water and sediments present in the quarry are highlighted on Table 2.1, and briefly described below. Study results are presented in Sections 3.3, 4.2, and 4.3.

2.5.1 Surface Water Investigations

Surface water investigations have focused on defining the extent and nature of contamination due to the quarry wastes.

TABLE 2.1 Summary of Surface Water and Sediment Contaminant Studies Related to the Weldon Spring Quarry

Contractor	Year	Reference	Quarry Water	Pond Sediment
MCW	1960-1965	MCW, 1960-1965	R	
Task Force	1967	Lenhard et al, 1967	R	
NLO	1974-1975	Pennak, 1975	R/C	
NLO	1976	BGA, 1984	R	
NLO	1977	Huey, 1978	R/C	
NLO	1979-1980	Weidner & Boback, 1982	R/C	
LBL	1979-1981	BGA, 1984	R/C	R
USGS	1984	Kleeschulte and Emmett, 1986	R/C	
BNI	1984-1985	BNI, 1985c	R/C	R
BNI	1986	Kaye and Davis, 1987		C
BNI	1986	Glenn, 1986	C	
MKF	1987	MKF, 1987	R/C	
MKF	1987	MKF and JEG 1988a	R/C	

Notes:
MCW - Mallinckrodt Chemical Works
USGS - United States Geological Survey
R - Radiological Testing
C - Chemical Testing

Samples have been collected from the quarry pond as part of ongoing environmental monitoring (MCW, 1960-1965; Weidner and Boback, 1982; and MK-F and JEG, 1988a) and more extensive investigations. Analyses have included radiological and chemical parameters.

Early studies conducted for AEC by a task force (Lenhard et al, 1967) and NLO (Pennak, 1975 and Huey, 1978) focused on determining the potential hazards created by the quarry. These investigations included sampling from the quarry pond. Water samples were analyzed primarily for radiological parameters, with limited analysis for chemical parameters.

From 1979 through 1981, LBL performed the first comprehensive investigation of the quarry. These studies were

performed to investigate the extent of possible radionuclide migration from the quarry and to provide information on the geochemical environment of the migrating nuclides. As part of this assessment, water samples were collected from the quarry pond and analyzed for radiological and chemical parameters (BGA 1984).

The U.S. Geological Survey (USGS) began a 3-year study during October 1983, to determine the extent and magnitude of surface water and groundwater contamination caused by waste disposal at the quarry. A preliminary report was published, which presented the results of the first year of the study. This study summarized data already collected and outlined the need for additional data collection and analysis. In 1984, the USGS cc llected surface water samples from the quarry pond and analyzed them for radionuclides and various chemical constituents (Kleeschulte and Emmett, 1986).

BNI conducted characterization studies of the quarry which included sampling and analysis of pond water. The 1984-85 investigation focused on radiological parameters, priority pollutants, asbestos, PCBs, and pesticides (BNI, 1985c). A more extensive chemical analysis performed in 1986 included nitroaromatics, semi-volatile and volatile organic compounds, pesticides, and metals. (Glenn, 1986)

In March 1987, a Phase I Water Quality Assessment was performed by MK-F, for all water bodies associated with the Weldon Spring Site. The purpose of this study was to assess the overall water quality as well as provide baseline water quality information. A surface water sample was collected from the quarry pond and analyzed for radionuclides, certain inorganic anions, water quality indicators, and EPA Contract Laboratory Program (CLP) metals (MK-F, 1987a).

2.5.2 Sediment Investigations

Several of the surface water investigations also incorporated collection and analysis of sediment samples from the bottom or perimeter of the pond. The studies which included sediment characterization are shown on Table 2.1 and are briefly described below.

1979-81 LBL sampled pond sediments for uranium and radium content (BGA, 1984).

1984-85 BNI collected samples from the pond bottom for radiological analysis (BNI, 1985c).

1986 BNI analyzed sediment samples from the pond for chemical constituents (Kaye and Davis, 1987).

2.6 GEOLOGICAL INVESTIGATIONS

Subsurface investigations in the quarry area have been conducted by various contractors since 1951. Although many of the studies were not specifically conducted to characterize the geology at the quarry, they do provide data which can be used to define geologic conditions. This section briefly describes these programs, which are also highlighted on Table 2.2. Figures 2.1 and 2.2 show the locations of boreholes drilled during these investigations. A thorough discussion of the current understanding of the geology of the quarry and the monitoring well network area can be found in Section 3.4.

The first published report on the geology of the entire Weldon Spring Site was compiled by Roberts and Theis (1951). This investigation was conducted to determine subsurface conditions as a prerequisite to the location and design of special structures contemplated by the AEC. Data were gathered

TABLE 2.2 Summary of Geological Studies

Date	Contractor	Lead Agency	Driller	No. of Holes	Hole Series (alternate designation)	Comments	Reference
1951	USGS	AEC				Regional Geology	Roberts and Theis, 1951
1960	USGS	AEC		2	TWN/TWS	Monitoring wells installed	Richardson, 1960a and 1960b
1976-1977	NLO	AEC	Test Drilling Service Co.	12	TW1-TW12	Monitoring wells installed	Huey, 1978
1979-1981	LBL	DOE		22	0-,1,2-,3-,4-,B-,B1-, C-,C1-,D1-,t-	Auger holes drilled into quarry waste	BGA, 1984
1980-1981	LBL	DOE		42	OB, O, OBS	Drilled into alluvium	BGA, 1984
1982-1985	BNI	DOE			TW7-TW10 (M1002-MW1005) TWN/TWS (MW1012/MW1001)	Holes rejuvenated Core for TW7-TW10 relogged	BNI, 1985d
1984	BNI	DOE		76	QB1-QB74, S1/S2	Holes drilled into quarry wastes	BNI, 1985c
1983-1986	USGS					Geological summary of previous investigations	Kleeschulte and Emmett, 1986
1986		County	Layne Western	4	RMW1-RMW4	Monitoring wells installed	Soil Consultants Inc., 1988
1986	BNI	DOE		6	TW7-TW10 TWN/TWS	Holes redrilled; old holes grouted up	MK-F and JEG, 1987
1986	BNI	DOE	Brotcke Eng.	6	OB6,OB10,OB16 (MW1006-MW1011)	Monitoring wells drilled near previous LBL OB wells	MK-F and JEG, 1988a
1986	BNI	DOE	Bob Henson	17	001C-017C	Holes drilled in quarry wastes	Kaye and Davis, 1987
1987	PMC	DOE	UNC/Brotcke	15	MS	Holes drilled between quarry and Femme Osage Slough	Marutzky et al, 1986
1987	PMC	DOE	Brotcke Eng.	7	MW1013-MW1019	Monitoring wells installed	MK-F and JEG, 1988a

on types of rock and soil, their characteristic features, and hydrologic properties of each. Structural features of the rock were observed and recorded.

The earliest available geological study which specifically pertained to characterization of the quarry area was completed by the USGS for the AEC in 1960 (Richardson, 1960a and 1960b). A limited hydrogeological drilling program was conducted to assess the suitability of the quarry as a radioactive waste disposal site.

In 1976 and 1977, about eight years after the last period of waste disposal, National Lead Co. of Ohio drilled several test wells (TW-1 through TW-12) around the perimeter of the quarry (Huey, 1978). The borehole logs, which were the primary information on geologic conditions at the quarry, described typical lithologies of the Decorah and Kimmswick Formations.

LBL (BGA, 1984) performed an extensive geological, geophysical and hydrogeologic survey of the quarry area between 1979 and 1981. The investigation included:

1. Discussion of general geology of the quarry including bedrock stratigraphy. Geological cross-sections through the quarry were also prepared.

2. Mapping and characterization of joints and fractures observed in rock cores on the quarry walls and the bluff facing Femme Osage Slough. These features together with lineaments observed on aerial photographs were studied and compiled.

3. Geophysical logging to determine the extent of fracturing and define lithologic features. Types of logs that were run included caliper, gamma-gamma,

neutron, and natural gamma. Borehole television logging was also performed.

4. Drilling and sampling of hollow-stem auger alluvial borings in the vicinity of Femme Osage Slough. Borings comprised three series: OB-1 through OB-17; OBS-1 through OBS-15; and O-1 through O-10. Borings OB-11 through OB-17 were cored 15 to 20 feet into bedrock.

5. Drilling of auger holes within the quarry which provided data on depth to bedrock.

The next major program of assessment and characterization of the quarry site was undertaken by BNI under the direction of DOE during the period 1982 to 1985 (BNI, 1985c and 1985d). Geological elements of this program included: relogging existing rock cores (TW-7 through TW-10); refurbishing several existing monitoring wells (TW-7 through TW-10, TW-N and TW-S); and drilling within the quarry.

Since 1986, programs have included the drilling of new monitoring wells (Soil Consultants, Inc., 1988; MK-F and JEG, 1988a), boreholes through the quarry wastes (Kaye and Davis, 1987), and characterization holes in the quarry vicinity (Marutzky et al, 1988). Many of the holes were drilled into bedrock.

2.7 GROUNDWATER INVESTIGATIONS

Groundwater investigations conducted to date in the area of the quarry are highlighted on Table 2.3, and results and conclusions are described in detail in Sections 3.6 and 4.4. The most pertinent of these studies are briefly summarized below.

Regional groundwater studies for the entire Weldon Spring Site area have been conducted by the USGS since the 1940s. Fishel and Williams (1944) generated a preliminary potentiometric surface map of the regional water table aquifer. A second groundwater investigation conducted by Roberts and Theis in 1951 at the request of the AEC confirmed the location of the regional groundwater divide proposed by the 1944 study and determined the direction of groundwater movement (Roberts and Theis, 1951).

The first investigation to focus specifically on groundwater at the quarry was performed in 1959-60 by R.M. Richardson of the USGS. Two coreholes were drilled and pressure tested to determine the hydrogeologic conditions at the quarry. A subsequent study included periodic pumping of water from the quarry pond into little Femme Osage Creek from 1960 to 1963. Pumping was stopped as groundwater was apparently leaching uranium from the bulk wastes (Richardson, 1960a; 1960b).

In 1979-81, as part of the overall characterization of the quarry area, LBL performed a detailed study of groundwater occurrence, migration and quality. Investigations included characterization of the fracture patterns in the limestone bedrock, groundwater level measurements, aquifer testing in the bedrock and alluvium in the vicinity of Femme Osage Slough, and hydrochemical analyses of borehole water (BGA, 1984).

In 1983, USGS initiated a groundwater contamination survey in the vicinity of the Weldon Spring Site and quarry. Investigations include an assessment of regional and local groundwater occurrence, groundwater quality, and surface water/groundwater relations (Kleeschulte and Emmett, 1986; Kleeschulte et al, 1986; and Kleeschulte and Emmett, 1987).

TABLE 2.3 Summary of Groundwater Studies

Date	Contractor/Agency	Report(s)	Regional	Study Location: Bedrock At Quarry	Study Location: Alluvium MK+T RR/Slough	Study Location: Alluvium South of Slough	Description
1944	USGS	Fishel & Williams, 1944	X				Water Table Contour Map
1951	USGS	Roberts and Theis, 1951	X				Water Table Contour Map
1960-63	USGS	Richardson, 1960a and 1960b		X			Pressure Test, Pump Test
1960-64	MCW	MCW, 1960-1965		R			Environmental Monitoring
1967	Task Force	Lenhard et al., 1967		R			Groundwater Quality
1976-77	NLO	Huey, 1978		R, C			Groundwater Quality
1979-81	LBL	BGA, 1984		X, R, C	X, R, C	X, R, C	Pump Test, Tracer Tests, Point Dilution Tests, Fracture Map.
1982-85	BNI	BNI 1983-86		R, C[a]	R, C[b]	R, C[b]	Environmental Monitoring
1983-86	USGS	Kleeschulte and Emmett, 1986	R, C	R	R	R, C	Water Table Contour Maps and Groundwater Quality
1986-87	MK-F	MK-F and JEG, 1987, 1988a		R, C	R, C	R, C	Environmental Monitoring
1987	MK-F	MK-F, 1987a		X, R, C	X, R, C	X, R, C	Water Table Contour Map and Groundwater Quality

Notes:
- C - Chemical Testing of Groundwater Samples
- R - Radiological Testing of Groundwater Samples
- X - Measurement of Aquifer Properties (explained in "Description" Column)
- (a) - 1982 - 1984 only
- (b) - 1985 only

Field investigations during the water quality assessment conducted in 1987 by MK-F included groundwater level measurement and sampling. Groundwater was analyzed for the complete Hazardous Substance List, nitroaromatics, certain inorganic anions, water quality indicators, and radionuclides (MK-F, 1987a).

Early monitoring of groundwater by MCW (1960-1965) and AEC's task force (Lenhard, 1967) was limited to radiological parameters. Environmental monitoring, performed at the quarry since 1976, has included groundwater level measurements and water quality analyses. Prior to 1987, water quality testing was performed primarily for radionuclides, nitrate and chloride. In 1987, new monitoring wells were installed which conform with current EPA standards. In addition, water quality testing parameters were expanded and presently include radionuclides, nitroaromatics and inorganic anions (Huey, 1978; BNI, 1983a, 1983b, 1984b, 1985b, 1986; MK-F and JEG, 1987, 1988a).

2.8 ECOLOGICAL INVESTIGATIONS

Available information concerning the ecology of the quarry and its environs is based on information from the Missouri Department of Conservation and research reported in the Weldon Spring Draft Environmental Impact Statement (DOE, 1987a). This information is summarized in Section 3.8 of this report.

Beginning in 1987, MK-F and JEG conducted an ecological field investigation at the quarry. The overall purpose of this survey was to determine possible exposure pathways of chemical and radiological contamination to humans by ingestion of potentially contaminated fish and game. Results of this study are summarized in Section 3.8 (MK-F and JEG, 1988b, 1988d).

3 PHYSICAL CHARACTERISTICS OF STUDY AREA

3.1 SURFACE FEATURES

3.1.1 Natural Features

The 9-acre Weldon Spring quarry was excavated into a limestone outcrop. The upper elevations at the quarry are well above the Missouri River floodplain; the elevation of the rim ranges from about 540 to 560 feet MSL (see Figure 3.1). The quarry was originally excavated to a bottom elevation of approximately 446 feet. The present quarry floor covers an area of about 2 acres and is at an elevation of approximately 482 feet. A pond, covering about 0.5 acre, occupies the deepest portion of the floor (BNI, 1983a). A pyramid-shaped hill of limestone remains near the center of the quarry, northeast of the pond. The maximum elevation of the hill is 518 feet.

The Weldon Spring quarry is situated on the northern flank of the Salem Plateau Physiographic province. This region, with exception of the Missouri River floodplain, is characterized by rugged topography and narrow irregular drainage divides. The area surrounding the quarry is drained by many short, steep-gradient streams (Kleeschulte and Emmett, 1986). A topographic map of the area immediately surrounding the WSQ is shown in Figure 3.1.

The Missouri River is located about 1 mile to the southeast. Nearby streams include Little Femme Osage Creek to the west, an unnamed tributary to the north, and Femme Osage Creek to the southwest. Femme Osage Slough is located approximately 700 feet south of the quarry.

Vegetation at the site consists primarily of grasses, shrubs, and trees. Eastern cottonwood is the predominant tree

species (DOE, 1987a). Agricultural crops are grown on much of the land south of the quarry. The Weldon Spring Wildlife Area, which surrounds the WSQ, is largely undisturbed, heavily wooded, and contains regions of heavy underbrush (Boerner, 1986).

3.1.2 Man-made Features

The quarry is adjacent to both Missouri State Route 94 and the abandoned Missouri, Kansas and Texas (MK&T) railroad line (see Figure 3.2). The upper and lower quarry levels are accessible from State Route 94 by maintained gravel roads. A railroad spur enters the lower level of the quarry from the west and extends approximately one-third of the quarry length. This railroad spur is overgrown with vegetation and has deteriorated. The MK&T line itself was recently dismantled, and only a path remains.

Access to the quarry is restricted by a 7-foot high chainlink fence, which is topped by three strands of barbed wire. This fence completely surrounds the site. Gates at both the upper and lower entrances are locked.

The quarry property line generally coincides with the fence line shown on Figure 3.2. Slight differences between the fence line and the property line occur along the north and west. Total area within the surveyed property line is 8.66 acres (West County Surveying and Engineering, Inc., 1988).

With the exception of a telephone line into the quarry, utility easements in the quarry vicinity do not cross through the quarry. Easements for Southwest Bell Telephone Company and Union Electric Company generally run along Highway 94 north of the quarry. Exploration Pipeline Company has an easement along the southern edge of Femme Osage Slough.

The only structures within the quarry site are a sampling platform and a small storage shack, which are shown on Figure 3.2. The wooden pier, which extends into the quarry pond, was probably built in the early 1960s when water from the pond was pumped into Little Femme Osage Creek. The small, prefabricated shack is located on the 480-foot level.

3.1.3 Data Adequacy

No further investigations of surface features are necessary prior to removal of bulk wastes from the quarry.

3.2 METEOROLOGY

This subsection presents meteorological data to assist in characterizing the atmospheric transport of contaminants for risk assessment, and to determine the effect of weather patterns on remedial action. Since meteorological data are not recorded at the WSQ, data recorded at St. Charles and St. Louis, Missouri are provided. The meteorological station at St. Charles (station number 23027397) is located approximately 19 miles from the quarry at an elevation of 467 feet MSL. Data are available for the period 1951 to 1986 (NOAA, 1984; NOAA, 1981-1986). In those cases where long-term data are not available for St. Charles, data recorded at St. Louis-Lambert Field from 1941 to 1970 (Ruffner, 1978) are presented.

3.2.1 Local Climate

The climate in the Weldon Spring area is continental in nature with warm to hot summers and moderately cold winters. Alternating warm/cold, wet/dry air masses converging and passing through the area cause frequent changes in the weather. Table 3.1 summarizes pertinent meteorological data.

TABLE 3.1 Summary of Climatological Data

Average Annual Precipitation[a]	36.51 inches
Average Days of Precipitation .10 Inch or Greatera	64 days
Average Wind Speed[c]	9.5 mph from South
Average Monthly Temperature[a]	55.1F
Average Daily Maximum Temperature[a]	66.2F
Average Daily Minimum Temperature[a]	43.8F
Record Maximum Temperature[a]	115F
Record Minimum Temperature[a]	-19F
Average Annual Number of Days With Minimum Temperature Below Freezing[b]	111 days

a Based on data recorded at St. Charles for the period 1951 to 1986 (NOAA, 1984; NOAA, 1981-1986).

b Based on data recorded at St. Charles for the period 1951 to 1980 (NOAA, 1984).

c Based on data recorded at St. Louis for the period 1941 to 1970 (Ruffner, 1978).

3.2.1.1 Precipitation

Precipitation data relevant to the WSQ area, based primarily on climatological data for St. Charles, are presented in Tables 3.2 and 3.3. Mean annual precipitation in the area is approximately 36.5 inches. Between 1951 and 1986, the maximum monthly precipitation was 12.32 inches (June 1957) and the minimum monthly precipitation was 0.04 inches (January 1970). The maximum daily precipitation of 4.50 inches occurred on June 15, 1957 (NOAA, 1984).

On the average, more than half of the precipitation falls between March and July. The three winter months, December through February, are generally the driest. The heaviest rains generally occur in spring and summer, although intense storms can occur during any month. Summer rains are frequently in the form of thunderstorms, accompanied occasionally by hail and high winds (DOE, 1987). Based on St. Louis records from 1941 to 1970, measurable precipitation (0.01 inch or more) occurs on an average of 109 days a year with thunderstorms occurring on about 40 percent of these days (Ruffner, 1978).

Snow has fallen as early as October, and as late as May. However, most snowfall occurs from December through March. It is unusual for snow to remain on the ground for more than a week or two. Conditions sometimes fluctuate between rain and snow, and in these situations freezing drizzle or freezing rain occurs (Ruffner, 1978). Based on data recorded at St. Charles from 1951 to 1986, the mean annual snowfall is about 17.2 inches. The maximum monthly snowfall is 27.2 inches and occurred in January 1977 (NOAA, 1984).

TABLE 3.2 Precipitation

	Total Precipitation (inches)[a]				Snow, Sleet (inches)		
	Mean[b]	Max Monthly[b]	Min Monthly[b]	Max 24 hrs[b]	Mean[b]	Max Monthly[b]	Max 24 hrs[c]
Jan	1.74	5.47	0.04	1.89	5.0	27.2	11.2
Feb	2.26	6.33	0.23	2.81	4.3	12.2	8.3
Mar	3.07	6.15	0.75	2.95	3.8	20.0	10.0
Apr	3.72	8.29	1.26	2.40	0.2	4.0	6.1
May	3.98	8.47	1.30	2.70	0	0	T
Jun	3.93	12.32	0.45	4.50	0	0	0
Jul	4.27	10.57	0.39	3.86	0	0	0
Aug	2.66	6.62	0.10	2.54	0	0	0
Sep	2.97	8.19	0.10	2.88	0	0	0
Oct	2.70	7.46	0.30	3.39	0	0	T
Nov	2.69	7.13	0.33	2.75	1.5	11.0	10.3
Dec	2.52	8.20	0.07	3.40	2.4	26.5	12.0
Year	36.51	12.32	0.04	4.50	17.2	27.2	12.0

T: Trace

a Total precipitation includes water equivalent of snow/sleet.

b Based on data recorded at St. Charles for the period 1951 to 1986 (NOAA, 1984 and 1981-1986).

c Based on data recorded at St. Louis for the period 1941 to 1970 (Ruffner, 1978).

TABLE 3.3 Frequency of Extreme Precipitation

	Mean number of Days[a] Precipitation Equals or Exceeds		
	0.10 inch	0.50 inch	1.00 inch
Jan	4	1	0
Feb	4	1	0
Mar	6	2	1
Apr	7	2	1
May	7	3	1
Jun	6	2	1
Jul	6	3	1
Aug	5	2	1
Sep	5	2	1
Oct	5	2	1
Nov	5	1	1
Dec	4	1	1
Annual Total	64	22	10

a Based on data recorded at St. Charles for the period 1951 to 1980 (NOAA, 1984)

3.2.1.2 Temperature

Missouri is subject to frequent changes in temperature. Although winters are generally cold and summers hot, prolonged periods of very cold or very warm to hot weather are unusual. Occasionally mild periods with temperatures above freezing occur almost every winter. Conversely, during summer, occasional periods of dry, cool weather interrupt periods of heat and humidity (Ruffner, 1978).

Temperatures are not recorded at the quarry, however, data available for St. Charles for the period 1951 through 1986 are generally characteristic of the site. Table 3.4 summarizes mean, maximum, and minimum temperatures recorded at St. Charles.

TABLE 3.4 Temperatures

	Mean Temperatures (F)[a]			Extreme Temperatures (F)[a]	
	Daily Maximum	Daily Minimum	Monthly	Record Maximum	Record Minimum
Jan	38.4	18.8	28.6	75 +	-19
Feb	44.0	23.5	33.8	82	-13
Mar	54.1	32.6	43.4	88 +	-7
Apr	68.2	44.7	56.5	91 +	24
May	77.0	53.2	65.2	100 +	30 +
Jun	85.6	62.7	74.2	105 +	41 +
July	89.7	66.8	78.3	115 +	47 +
Aug	87.9	64.1	76.1	107	46 +
Sep	81.4	56.2	68.9	106 +	31
Oct	70.0	44.8	57.5	97	21 +
Nov	55.2	34.1	44.6	87 +	0 +
Dec	43.2	24.3	33.8	75 +	-13
Year	66.2	43.8	55.1	115	-19

a Based on data recorded at St. Charles for the period 1951 through 1986 (NOAA, 1984; NOAA 1981-1986).

\+ Occurred on two or more dates.

The frequency of temperature extremes is presented in Table 3.5. Recorded temperatures have ranged from -19F on January 11, 1982 to 115F on July 14, 1954 The average annual temperature is 55.1F. Average daily maximum and minimum are 66.2F and 43.8F, respectively. On the average, there are about 49 days a year when maximum temperatures are above 90F. Minimum temperatures below 32F occur about 111 days of the year, although temperatures below zero are infrequent (only about 5 days per year).

3.2.1.3 Wind Speed and Direction

Wind data recorded at St. Louis for the period 1941 to 1970 can be examined for long-term wind trends. Wind speeds and

TABLE 3.5 Frequency of Temperature Extremes[a]

	Mean Number of Days			
	Maximum is 90F and above	Maximum is 32F and below	Minimum is 32F and below	Minimum is 0F and below
Jan	0	11	27	3
Feb	0	6	23	1
Mar	0	1	16	0
Apr	0	0	3	0
May	2	0	0	0
Jun	10	0	0	0
July	16	0	0	0
Aug	14	0	0	0
Sep	6	0	0	0
Oct	1	0	3	0
Nov	0	1	14	0
Dec	0	6	25	1
Year	49	25	111	5

a Based on data recorded at St. Charles for the period 1951 through 1980 (NOAA, 1984)

prevailing directions are presented in Table 3.6. Prevailing winds are from the south during the summer and fall and from the northwest and west-northwest during the winter and early spring. The average annual wind speed is about 9.5 mph from the south. Average wind speeds are about 8.5 mph for May through November and about 10.9 mph for December through April.

Wind speed and direction were recorded at the Weldon Spring chemical plant meteorological station, which is located approximately 4 miles northeast of the WSQ. Limited data are available for 1984 and 1985. The annual wind rose diagram based on data collected during 1985 is presented on Figure 3.3. The prevailing winds during 1985 were generally from the south during the summer and early fall and from the northwest and west-northwest during the winter and early spring. Average wind speeds during the summer/fall months were about 8.7 mph and

TABLE 3.6 Wind Speed and Direction[a]

	Mean Wind Speed (MPH)	Prevailing Direction	Maximum Wind Speed (MPH)	Direction
Jan	10.2	NW	39	W
Feb	10.8	NW	46	NW
Mar	11.7	WNW	45	NE
Apr	11.4	WNW	45	W
May	9.5	S	42	SE
Jun	8.6	S	60	SE
July	7.7	S	40	NW
Aug	7.4	S	38	NW
Sep	8.0	S	39	SW
Oct	8.5	S	48	SW
Nov	9.9	S	41	S
Dec	10.2	WNW	44	W
Year	9.5	S	60	SE

a Based on data recorded at St. Louis for the period 1941 to 1970 (Ruffner, 1978).

about 11 mph during the winter months which corresponds well with St. Louis long-term trends (BNI, 1986).

3.2.1.4 Relative Humidity

Relative humidity data for St. Louis (1941 to 1970) are presented in Table 3.7. The table also lists a heat stress factor which indicates those months in which heat stress can be expected as a result of temperature and humidity. In general,

TABLE 3.7 Relative Humidity and Heat Stress Factors

	Relative Humidity (%)a				
	Midnight	6:00 am	Noon	6:00 pm	Heat Stress Factor[b]
Jan	76	81	64	68	-
Feb	75	79	60	63	-
Mar	73	80	57	58	-
Apr	70	77	54	53	-
May	75	82	56	55	0
Jun	78	84	57	56	f
July	78	86	57	56	f
Aug	80	89	57	58	f
Sep	83	91	60	63	0
Oct	76	84	55	60	-
Nov	78	84	62	68	-
Dec	81	85	69	74	-

a Relative humidity based on data recorded at St. Louis for the period 1941 to 1970 (Ruffner, 1978).

b Heat Stress Factors for St. Louis (Rudloff, 1981):
0 stands for occasionally: stress occurs only for a short period during the day-time generally in the afternoon.
f stands for frequently; stress occurs frequently; often for several hours in the daytime.

May through September are the months when heat stress can be expected.

3.2.1.5 Fog

Fog data for St. Louis are available from 1940 to 1971. Foggy conditions occur an average of 11 days a year, causing visibility to decrease to 0.25 mile or less. Fog generally does not occur between May and August (Ruffner, 1978).

3.2.1.6 Extreme Storm Conditions

Between 1916 and 1958, 446 tornados were reported in Missouri, an average of about 10 each year. About 70 percent of

these storms occurred from March through June, and about 82 percent occurred between noon and midnight, with the greatest activity between 4 and 6 pm (Ruffner, 1978). Tornados may occur in the St. Louis area once or twice a year, but they usually follow a narrow path and often dissipate after a mile or so. From 1939 through 1979 only four tornados caused extensive damage to the St. Louis area (DOE, 1987).

3.2.1.7 Temperature Inversions

Data on inversions in the quarry area are not available. Temperature inversions (increase of temperature with height) are caused by subsiding air at high levels in the atmosphere. Topography and atmospheric circulation are important factors. For example, at night when the air is calm and the sky is clear, rapid cooling of the ground surface typically produces a low-level (under 500 ft.) temperature inversion. Fall tends to be the season most favorable for this type of inversion to develop. Localized inversions can be caused by topographic depressions, such as the quarry, which prevent the free mixing of air with the surrounding area. Temperature inversions are important since they inhibit the vertical mixing of the air which causes entrapment of pollutants near the ground surface (Miller and Thompson, 1975; Strahler and Strahler, 1974).

3.2.2 Climatological Effects

Atmospheric transport of contaminants, such as radon, is an important consideration for risk assessment. Temperature inversions can cause increased radon concentrations within the quarry. Factors which affect temperature inversions are wind, temperature, and topography.

Climate can also affect personnel productivity and construction activities during the proposed remedial action. Heat stress is an important consideration for personnel wearing personal protective equipment, and can significantly reduce productivity and affect the health of the individual. Heat stress is caused by the interaction of various factors, including ambient temperature, humidity, and sunlight.

Wind speed and direction, precipitation, fog, weather extremes, and other meteorological phenomena can all affect remedial action. Certain weather conditions may necessitate restrictions of activities. For example, ice or fog along the transportation route may preclude or restrict transport of contaminated materials. As shown in this section, these phenomena are not completely random but can be generally related to certain seasons, months, or times of day.

3.2.3 Data Adequacy

Meteorological data available from St. Charles, St. Louis, and the chemical plant meteorological station are considered to be adequate for definition of the general meteorological conditions in the quarry vicinity. However, site-specific data to define the microclimatological conditions, such as inversions, at the quarry are not available.

3.3 SURFACE WATER

3.3.1 Surface Water Features and Drainage Patterns

The quarry lies about 1 mile northwest of the Missouri River and about 18 miles south of the Mississippi River. The drainage divide between the Missouri and Mississippi Rivers transects the chemical plant area north-northeast of the quarry. Streams in the immediate vicinity of the quarry include

Femme Osage Creek, Little Femme Osage Creek, and an unnamed tributary to Little Femme Osage Creek (Figure 3.4). All of these streams ultimately flow into the Missouri River. No streams flow through the quarry. Femme Osage Slough, which is also shown on Figure 3.4, is a stagnant body of water which was formed between 1960 and 1963 when the University of Missouri constructed a levee system for flood control (MK-F and JEG, 1987). The original downstream reaches of Femme Osage Creek and Little Femme Osage Creek, which were cut off by the levee, now form the slough. The water surface elevation of the slough averages about 450 feet (MK-F and JEG, 1988c).

The only surface water feature within the quarry is a 0.5 acre pond, which contains approximately 3 million gallons of water. The maximum pond depth is about 20 feet (BNI, 1986). The floor of the quarry pond was originally at about 446 feet MSL (BNI, 1983a). The average water surface elevation of the pond during non-pumping periods is approximately 465 feet. Even during the 1988 drought conditions the pond's water level only dropped to elevation 464 feet (MK-F and JEG, 1988c). During the 1960-63 USGS pumping tests, the pond was drawn down to a minimum elevation of 452 feet (Richardson, 1960b). Inflow into the quarry is limited to direct rainfall, and subsurface inflows, since its high rim prevents the entry of surface runoff from the surrounding area. Drainage from the quarry is primarily through the subsurface, with limited surface drainage from the southern and western rims.

3.3.2 Flooding

Although R.M. Richardson observed a quarry pond high-water mark of 467 feet MSL (Kleeschulte and Emmett, 1986); the frequency at which this elevation has been attained or exceeded is unknown. Due to its topographic setting, flooding within the

quarry would result only from extreme precipitation events or high groundwater.

In general, flooding of the WSQ by the Missouri River is not likely because of the steep limestone bluffs immediately to the south (see Figure 3.2). The southern rim of the quarry is at an elevation of about 540 to 560 feet, which is approximately 100 feet above the Missouri River floodplain. Flooding is more likely along the western edge of the quarry where the elevation of the rim is considerably lower, at about 485 feet. Based on flood profile maps for the Missouri River prepared by the U. S. Army Corps of Engineers, the 500-year water surface elevation is estimated to be 474 feet near the quarry (U. S. Corps of Engineers, 1980). Although flood data for the nearby streams are not available, flooding caused by these streams is unlikely. Major floods on both the Missouri River and small tributaries generally occur between April and July, caused by prolonged periods of heavy rains. Flash flooding along minor streams following heavy thunderstorm rains also occurs most frequently in the spring and early summer, but may occur during any month (Ruffner, 1987).

3.3.3 Data Adequacy

Information currently available on surface water is considered adequate with respect to removal of bulk wastes from the quarry.

3.4 GEOLOGY

3.4.1 Regional Setting

The surface of the Weldon Spring region is almost entirely covered by unconsolidated materials consisting of alluvium, glacial drift, and weathered rock. In the rugged hilly

portions of the region located marginal to the Missouri River Valley, bedrock is overlain by a variable thickness of weathered rock, loess, and glacial drift. Numerous bedrock outcrops occur along natural drainage channels which transect the region, including steep massive exposures along the flanks of the Missouri and Mississippi Rivers. Within the floodplains of the Missouri and Mississippi Rivers, the upper weathered bedrock surface is covered by alluvium up to 100 feet in thickness. The bedrock underlying the soil cover consists of limestone, shale, sandstone, and dolomite.

The bedrock in the Weldon Spring Area has a regional strike of N 60 W with a regional dip of approximately 0.5 to the northeast. The strata of the region have been broadly uplifted by the Ozark doming that resulted in a northeast sloping monoclinal structure (BNI, 1987). Roberts and Theis (1951) identified two major joint sets in the Weldon Spring area: one set trending between N 30° E and N 72° E and a second set trending between N 30° W and N 65° W. The joint planes are nearly vertical.

Table 3.8 presents a generalized description of the regional geologic formations. Kleeschulte and Emmett (1986) and the Missouri Geological Survey (1977) are the primary sources for the rock descriptions.

3.4.2 Geologic Units at the WSQ

The bedrock in the quarry area is predominantly limestone and dolomite overlying sandstone and shale. Bedrock exposures exist on the quarry walls and on the steep bluffs along the Missouri River. The bedrock is overlain in upland areas by 10 to 40 feet of silty clay, derived primarily from wind-deposited glacial debris and glacial fill (BGA, 1984). In the monitoring well network area outside the WSQ on the Missouri River

TABLE 3.8 Generalized Stratigraphic Column for the Weldon Spring Quarry Area

System	Formation	Thickness (feet)	Description
Quaternary	Alluvium and Residual Soils	15-100	Predominantly silty clay grading to sands and gravels near the Missouri River.
Mississippian	Chouteau Limestone	25	Fine grained, thin to medium bedded, gray dolomitic limestone.
Devonian	Bushberg Sandstone	5-8	Fine- to medium-grained, friable, reddish-brown quartz sandstone.
Ordovician	Kimmswick Limestone	70	Medium- to coarsely crystalline, massive bedded, white to light gray limestone; contains large voids due to fossiliferous, solution effects along vertical fractures.
	Decorah Formation	20-40	Green to brown shales with numerous, thin, interbedded limestone layers layers in lower part that grade upward into a medium to thinly bedded limestone containing thin shale partings.
	Plattin Limestone	100-120	Gray to dark gray, fine- to medium-grained, thin-bedded fossiliferous limestone.
	Joachim Dolomite	100	Yellowish-brown, thin to massively bedded dolomite. Contains many thin shale layers. Grades into siltstone and sand near the base.
	St. Peter Sandstone	100-120	Yellowish white to white, fine- to medium-grained, friable, massive to cross-bedded quartz sandstone. This formation is a regional aquifer that yields moderate water flows (10-140 gpm).
	Powell Dolomite	50-60	Medium to finely crystalline dolomite, often sandy, occasionally cherty or shaley.
	Cotter Dolomite	200-250	Light gray to light brown, medium to finely crystalline, cherty, argillaceous dolomite interbedded with green shale.

Sources: Missouri Geological Survey (1977), Kleeschulte and Emmett (1986) and BGA (1984).

floodplain, the bedrock is overlain by as much as 100 feet of alluvium deposited by the Missouri River (LWC, 1986).

The primary surface rock unit in the vicinity of the quarry is the Kimmswick Limestone of Ordovician age. The Kimmswick is underlain by other Ordovician strata which include, in descending order, the Decorah Formation (shale and limestone), the Plattin Limestone, the Joachim Dolomite, and the St. Peter Sandstone. The original floor of the quarry was excavated about 15 feet into the Decorah. The strata overlying the Kimmswick are generally eroded in the vicinity of the quarry, but remnants of the Devonian Bushberg Sandstone and Mississippian Chouteau Limestone may cap the Ordovician rock at higher elevations (Missouri Geological Survey, 1977).

Figures 3.6 through 3.9 are cross sections drawn through the quarry area or parallel to Femme Osage Slough. The locations of these cross sections are shown on Figure 3.5. Figure 3.10 is a bedrock surface contour map and Figure 3.11 is an elevation map of the top of Decorah Formation. These figures illustrate current geological knowledge of the site. Of particular interest are the sloping bedrock surface at the alluvium-bedrock contact and the nature of the soils adjacent to Little Femme Osage Slough. The base of the Kimmswick and most of the Decorah Formation, which contain the primary pathways for contaminant migration from the quarry, are in contact with fine-grained soils, silty clay, and organic silt and clay, in the slough area. An underlying soil layer consisting of silty sand is present below a depth of about 20 feet at the slough and farther to the southeast. Data for the cross-sections were obtained from drill logs of the boreholes noted on the cross-sections.

3.4.3 Discontinuities at the WSQ

The results of fracture and lineament mapping investigations performed by LBL are shown in Figure 3.12. Fracture and joint orientations are summarized in the rosette diagram, which shows that the predominant set is oriented about N 70° W. Joints in this set are vertical and have an average spacing of about 30 feet along the limestone bluffs facing the slough (BGA, 1984). Two secondary vertical joint sets are also present; their orientations are N 60° E and north-south.

As part of the fracture mapping program, LBL also identified potential conduits for fluid flow in the quarry limestone. Most of the joints are open with apertures that vary from 1 inch to several feet. Clay fillings are present in many of the joints. Three zones of closely spaced fractures south and east of the quarry are indicated on Figure 3.12. These zones coincide with gullies in the bluffs and probably represent areas of more intense weathering and solution activity. The joint surfaces along the bluff and on the quarry walls are typically etched with patterns which indicate that most of the joints have been in contact with groundwater at some time (BGA, 1984). Field observations and borehole infiltration tests indicate that the joints become increasingly tighter as the Kimmswick/Decorah contact is approached from the surface.

3.4.4 Data Adequacy

In general, bedrock geologic conditions at the WSQ are sufficiently characterized for the initial task of bulk waste removal. Therefore, no further investigations are planned prior to the proposed remedial action.

Further geologic characterization will be necessary, however, before final site remediation can commence.

Conventional investigative techniques, such as drilling or geophysical surveys are not feasible because of the nature of the bulk wastes in the quarry. In addition, such investigations could pose environmental risk in and of themselves. For example, even if boring through the wastes could be conducted successfully, it is possible that contaminants could migrate from the quarry via this new pathway. For these reasons, prior removal of the bulk wastes is essential in order to completely characterize the geologic conditions at the quarry in a safe and effective manner.

3.5 SOILS

3.5.1 Soil Characteristics

Two distinct soil types are present in the quarry area. Loess deposits and residual soils cover the upland regions, while river alluvium is found along the Missouri River and its tributaries.

As described by BGA (1984), the principal surficial deposit on the tops of bluffs and on the upland surfaces is a silty clay soil developed from loess and deposited during and following the Wisconsin glaciation. This soil is a brown to yellow-brown silty clay loam of the Winfield and Menfro soils. A residual soil from weathering of the limestone is present in some areas between the silty clay and bedrock. The upland soils near the quarry are generally not saturated. Boreholes drilled under the direction of National Lead Co. of Ohio intersected up to 30 feet of silty clay on the ridge bordering the quarry to the southeast (Huey, 1978). Soil is not present where the weathered surface of the limestone is exposed on the steep quarry walls and on the steep slopes of bluffs along the abandoned MK&T right of way. Small talus fans of slope debris (weathered limestone and clay)

are found at the foot of these slopes and within reentrants in the bluffs (BGA, 1984).

The principal surficial deposit along the Missouri River floodplain to the south of the quarry is river alluvium, with a maximum depth near the quarry of approximately 100 feet. The alluvium extends from the base of the bedrock bluffs along the abandoned railroad right of way to the Missouri River. Along the first 1,000 feet south of the cliffs, the alluvium thickness increases dramatically until it levels off at a maximum thickness of about 100 feet in the St. Charles County well field area. The primary sediments between the bluff and the Femme Osage Slough are silts and clays with minor amounts of sand.

3.5.2 Data Adequacy

Additional information concerning soils in the quarry vicinity is not necessary to assess the feasibility of removing the bulk waste. Soils or soil-like materials present within the quarry are considered part of the bulk waste to be removed. The characteristics of these soils are discussed in Section 4.0.

3.6 HYDROGEOLOGY

3.6.1 Geologic Aspects

Two lithologically distinct aquifers comprise the near-surface groundwater regime in the quarry area. A predominantly limestone bedrock aquifer carries groundwater at the quarry. Groundwater also occurs in an alluvial aquifer between the quarry bluff and the Missouri River. Details of the geology at the quarry are discussed in Section 3.4.

3.6.1.1 Bedrock Aquifer

Near-surface groundwater occurs at the site in the Kimmswick Limestone, Decorah Formation, and Plattin Limestone. This groundwater is potentially affected by contamination from the quarry (Kleeschulte and Emmett, 1986). Kleeschulte and Emmet concluded in their 1986 report that water in the quarry has a large uranium concentration. Movement of water in the quarry area is southward toward the Missouri River.

A typical limestone possesses three types of porosity (Mifflin and Hess, 1979): intergranular porosity; fractures, joints, and bedding planes; and solution-enlarged cavities. Studies conducted to date on the nature of the limestone at the quarry agree that the major pathways for groundwater movement are joints and fractures (Richardson, 1960a; Huey, 1978; BGA, 1984). In the formations where groundwater occurs at the site (the lower 10 feet of the Kimmswick and below), porosity from fractures, joints and bedding planes seems to predominate. Solution-enlarged cavities do occur in the near-surface weathered portions of the Kimmswick Formation (BGA, 1984), but these are generally above the current groundwater table.

LBL conducted a fracture mapping program, geophysical borehole logging, and core logging of fractures and joints between 1979 and 1981. The details of the study are summarized in Section 3.4.3. The fracture patterns observed on the surface were found to extend through the Decorah Formation and probably into the Plattin Formation. It was concluded that the Kimmswick, Decorah, and probably the Plattin, can be considered as one continuous hydrologic system in the quarry area (BGA, 1984).

The Decorah Formation, which contains shale beds, is considered to be a leaky confining layer on a regional scale

(Kleeschulte and Emmett, 1986). However, there are two factors which may reduce the confining effect of the Decorah, locally at the quarry. First, the presence of pervasive vertical joints and fractures constitute pathways that hydraulically connect the formations. Second, since the quarry was excavated about 15 feet into the Decorah, the horizontal permeability of the Decorah may be more significant in regard to hydraulic connection to the quarry wastes and surrounding area than the vertical permeability.

The vadose zone at the quarry rim generally consists of a few feet of silty clay loess deposits and the underlying upper weathered portion of the limestone (Kleeschulte and Emmett, 1986). The solution-enlarged features of the weathered upper portion of the bedrock create pathways through which recharge from precipitation can readily flow.

3.6.1.2 Alluvial Aquifer

The geology of the alluvial aquifer consists of Missouri River deposits overlying the limestone bedrock. The thickness of the alluvium is about 40 to 60 feet at the Femme Osage Slough, and typically consists of silt and clay with variable thickness of fine sand at its base. The concentration of finer grained material increases in the northerly and westerly direction at the slough and along the edge of the rock bluff to the south of the quarry. Effective porosity in the alluvium is intergranular and increases where the alluvial materials become coarser. LBL's sampling of alluvial materials south of the slough indicated a grain size coarsening with depth (BGA, 1984).

The vadose zone in the alluvium occurs generally in the upper 10 feet of silt, since the water table elevation lies within approximately 10 feet of the surface. Depth to water varies with the season. Pumping and river stage significantly affect

groundwater levels. The aquifer is readily recharged by precipitation through the vadose zone and by flood water.

3.6.2 Hydraulic Aspects

3.6.2.1 Bedrock Aquifer

Aquifer tests have been conducted within the bedrock and alluvial materials in the WSQ vicinity. Aquifer test locations are shown on Figure 3.13.

Pumping tests were performed at the quarry by R.M. Richardson (1960b) of the USGS. In July 1960, the quarry pond was pumped for 41-3/4 hours. The initial water surface elevation of the pond was at 455.25 feet. At the end of the test, the water surface elevation had dropped to 452.50 feet for a total drawdown of 2.75 feet. The total volume of water pumped during the test was 551,000 gallons. Rate of recovery was about 8 gpm for the first 24 hours, decreasing to about 3 gpm. Richardson reports the higher rate was due to water draining into the pond from the silt covering the quarry floor, while the lower rate represents groundwater inflow. Additional pumping tests were performed on August 4 and August 11, 1960. Total discharges for those tests were 86,200 gallons (after 12 hours) and 82,800 gallons (after 8 hours), respectively. Richardson also concluded that the pond is hydraulically connected to the bedrock; that the natural groundwater gradient at the quarry slopes toward the alluvium of the Missouri River floodplain; and that the potential exists for migration of contaminants from the quarry toward the alluvium.

Richardson also conducted two pressure tests on the 3-inch diameter boreholes used as observation holes during the pumping tests. At an injection pressure of 50 pounds per square inch, the upper interval above 470 feet elevation accepted 35 to

50 gpm while the bedrock between 470 feet and 430 feet accepted 0.5 to 1.5 gpm at the same pressure. According to geologic logs, the interval from 470 to 430 feet elevation encompasses the lower 10 feet of the Kimmswick and the upper 30 feet of the Decorah. This and results from the pressure testing indicate that the permeability in the bedrock decreases with depth (Richardson, 1960b).

LBL conducted pumping tests in wells OB-11 through OB-15, a point dilution test at well OBS-13, and a tracer test at wells OBS-13 and OBS-14 (see Figure 3.13) in order to ascertain the hydraulic properties of the limestone aquifer around the WSQ. The values obtained for various aquifer parameters are presented in Table 3.9. The formation in which the tests were performed was not identified. However, based on current knowledge of local lithology and with an understanding of the depth at which the tests were performed, it can be concluded that the pumping tests were conducted in the upper portion of the Plattin Formation and possibly a few feet of the lower Decorah Formation. The point dilution test was most likely conducted in the Plattin Formation.

The aquifer tests performed by LBL characterize the bedrock below the alluvium as a fracture flow system with predominantly horizontal flow paths. This conclusion, though, may not specifically characterize the flow at the quarry itself, where the groundwater flow influencing contaminant transport is predominantly in the lower Kimmswick and Decorah Formations. Also, the test locations may not necessarily be representative of the fracture flow system as a whole. The hydraulic properties indicated in Table 3.9 are highly influenced by fracture interconnection and frequency, which can vary widely with location. Additional tests will be conducted, as necessary, to further characterize site conditions during subsequent RI activities.

TABLE 3.9 Hydraulic Properties of Bedrock Aquifer

Aquifer Parameter	Value
Transmissivity[a]	139 gpd/ft
Effective Porosity[b]	0.001 to 0.002 (dimensionless)
Storativity[a]	1×10^{-4} (dimensionless)
Natural Groundwater Velocity[c]	0.2 ft/day

a Based on pump tests in wells OB-11 through OB-15.

b Based on tracer test at wells OBS-13 and OBS-14.

c Based on point dilution test at well OBS-13.

Source: BGA, 1984

3.6.2.2 Alluvial Aquifer

The hydraulic properties of the alluvial aquifer are extremely variable, depending on the thickness and grain size distribution of the material at a given location. The area from Femme Osage Slough north to the limestone bluffs is considered separately from the coarser and thicker portion of the aquifer, which occurs in the monitoring area south of the slough.

A qualitative characterization of the hydraulic properties of the alluvium between the quarry and Femme Osage Slough was based on observations made during the drilling of the OB-1 to OB-17 series wells. The alluvium in that area consists of very fine-grained clays and silts which extend to the limestone bedrock. When wells were pumped in this area, the well bores emptied with very long projected recovery times. It was

concluded that detailed hydrologic testing was not necessary because of the limited areal extent and apparent low hydraulic conductivity of this portion of the alluvium (BGA, 1984). However, additional tests will be conducted, as necessary, to further characterize conditions during subsequent investigations.

Pumping tests (wells 0-2, 0-3, OBS-14 and OBS-15), tracer test (well 0-2) and point dilution tests (wells OBS-11, OBS-16, and OBS-19) were conducted in the alluvium south of Femme Osage Slough to characterize the alluvial aquifer. Except for OBS-19, all the wells where testing was performed are located in the monitoring network area (see Figure 3.13). The aquifer characteristics determined by the tests are presented in Table 3.10. In general, it was found that the aquifer becomes thicker and more permeable with higher groundwater velocities further south of the slough. The groundwater velocity at the slough was

TABLE 3.10 Hydraulic Properties of Alluvial Aquifer South of Femme Osage Slough

Aquifer Parameter	Value
Transmissivity[a]	6957 gpd/ft
Permeability[a]	174 gpd/ft^2
Effective Porosity[b]	0.25 to 0.29 (dimensionless)
Storativity[a,c]	5×10^{-3} (dimensionless)
Natural Groundwater Velocity[d]	0 ft day

a Based on pumping tests at well 0-2 with 0-3, OBS-14 and OBS-15 used as observation wells.
b Based on tracer test at well 0-2.
c The storativity value is probably low because steady state conditions were reached in a short time and thus did not allow enough time for complete drainage of stored water.
d Based on point dilution tests at wells OBS-11 and OBS-16. Velocity was less than the resolution of the test. Test in well OBS-19 indicated a velocity of 0.8 ft/day.

Source: BGA, 1984

lower than the resolution of the point dilution tests. This negligible groundwater velocity and generally lower permeability of fine-grained material suggests that the clay and silt alluvium at the slough may act as a groundwater barrier. However, there may be groundwater flow underneath this clayey and silty material through the fractured bedrock. The point dilution tests in the alluvium were performed within 40 feet of the surface, while the depth to bedrock at the slough is about 60.5 feet (BGA, 1984).

3.6.2.3 Groundwater Levels and Flow Characteristics

In the immediate vicinity of the quarry, details of groundwater flow direction in the bedrock have not been completely defined. Richardson (1960a) concluded, on the basis of information from wells TW-N and TW-S, that groundwater flow in the bedrock through the quarry was from north to south. Groundwater levels obtained in 1980 by Lawrence Berkeley Laboratory also show a southerly flow of groundwater through the quarry. However, measurements taken in 1987 (see Appendix D for water level data) during the MK-F and JEG environmental monitoring of the site indicate flow from the quarry toward both the north and south (Figures 3.14, 3.15 and 3.18). This indicates a possible mounding of groundwater caused by recharge through the quarry pond and vicinity. Since only one well is available for measurement north of the quarry, such conclusions must be considered tentative. In general, the groundwater levels at the quarry are above 460 feet. To the west of the quarry, the bed of Little Femme Osage Creek is at about 450 feet. This implies a westward gradient toward Little Femme Osage Creek from the quarry. The vertical extent of groundwater flow in the bedrock has not been defined at this time.

The groundwater flow direction from the south rim toward Femme Osage Slough has been well established. Groundwater

levels in the bedrock at the south rim consistently measure about 10 feet higher in elevation than in the alluvium near the slough. The abrupt change in groundwater elevation at the interface of the two groundwater regimes indicates poor hydraulic connection between the bedrock aquifer and the alluvium and creates a relatively steep gradient toward the south of about 0.05. Suspected pathways for the groundwater flow within the bedrock are the fractures in the Kimmswick and Decorah Formations. Details of the groundwater pathways from the bedrock to the alluvium are unknown at this time.

Groundwater flow in the alluvium near the slough is not well defined. Between the abandoned MK&T right of way and the slough, the gradient is southward toward the slough (Figures 3.14 and 3.15), although south of the slough, the groundwater flow direction may vary. The water level contour map presented by Kleeschulte and Emmett in 1986 (Figure 3.16) shows a groundwater high southwest of the slough generating a flow northward toward the western end of the slough. Recent groundwater level data obtained by MK-F and JEG indicates a southeast gradient across the slough (Figures 3.14 and 3.15). Groundwater flow direction at the western end of the slough seems to vary depending on the stage of the Missouri River. At low river stages, the slough may act as a drain for groundwater while at other times, groundwater in the slough vicinity may be virtually stagnant or may flow southeast across the slough. A recent study performed by PMC on drought conditions and the groundwater regimes around the WSQ demonstrates further evidence of isolation of the slough from the alluvial aquifer. Figures 3.17 and 3.18 are water level contour maps drawn from data obtained under drought conditions in June 1988. The groundwater slough indicating poor hydraulic connection between levels in the alluvium immediately south of the slough are about 5 to 8 feet lower than the elevation of the water within the the slough and the alluvial aquifer (MK-F and JEG, 1988c).

In any case, the amount of water passing through the alluvium in the vicinity of the slough is minimal. The negligible groundwater velocity, mentioned in Section 3.6.2.2, indicates that flow conditions are virtually stagnant in the fine-grained materials. These low velocities, coupled with the tightness of the material and resultant low transmissivity, severely retard flow of alluvial groundwater in any direction at the slough.

3.6.2.4 Mechanisms of Recharge/Discharge

At the quarry, surface recharge to the bedrock is limited to precipitation or storm runoff contributions. Discharge may occur as springs, seeps, evapotranspiration, underflow, flow to pumping wells, flow to gaining streams, and flow to the alluvium of the Missouri River floodplain.

A hydraulic connection apparently exists between the quarry groundwater and the Femme Osage Slough (Marutzky et al, 1988). Current levels of contamination in the slough are believed to be due primarily to discharge of contaminated groundwater originating at the quarry; but low permeability sediments at the slough appear to impede further migration.

Pumping and river stage significantly affect discharge/recharge relationships in the alluvial aquifer. Recharge to the alluvial aquifer occurs from precipitation and possibly as flow from the underlying and adjacent bedrock. Discharge also occurs as evapotranspiration.

3.6.2.5 Interaction Between Groundwater Bearing Units

Within the bedrock aquifer, the Kimmswick and Decorah are interconnected by vertical joints and fractures. However, the interconnection between the Decorah and Plattin is uncertain.

At the base of the bluff south of the quarry, the alluvium abuts the truncated beds of the bedrock aquifer, and groundwater tends to migrate from the bedrock into the alluvium. It is assumed that there is a degree of connection between the bedrock below the alluvium (primarily the Plattin Formation) and the alluvium. The magnitude and direction of flow at this interface is unknown at this time.

Some evidence of interconnection is found in the water level measurements in the paired bedrock/alluvial wells between the quarry and the slough. In this area, two sets of paired wells (MW-1013/MW-1014 and MW-1015/MW-1016) were constructed: one well of each pair is completed in the alluvium, the other monitors the bedrock. Water levels (see Appendix D) in the paired wells, as measured by MK-F (1987a), are within a few inches of each other. This suggests a high degree of interconnection between the bedrock and alluvium in this area. The hydrologic complexity of the bedrock/alluvium interface is further illustrated by the uranium concentrations detected in the paired wells. At the MW-1013 and MW-1014 locations (see Figure 2.1), uranium concentrations in the limestone and alluvium were 650 pCi/l and 600 pCi/l, respectively. Further east at the MW-1015 and MW-1016 locations, the concentrations were 292.5 pCi/l in the bedrock and 21 pCi/l in the alluvium. This implies a locally varying interconnection between the alluvium and the bedrock (MK-F, 1987a), which may be a result of bedrock aquifer heterogeneity due to fracture flow.

3.6.2.6 Seasonal Variation in Groundwater

A comparison of seasonal variations in groundwater conditions (Figures 3.14 and 3.15) shows that water levels in the bedrock differed by about 5 feet between fall 1987 and spring 1988. It is reasonable to expect higher water levels in spring and early summer when heavy rains generally occur. Water

elevations in the alluvium also vary seasonally with changes in the stage of the Missouri River. The highest stages of the river generally occur in spring and early summer. During rain and floods the alluvial aquifer is recharged. When the river is low and there is no precipitation, water is lost to evapotranspiration and discharge to the river. Pumping is also a significant form of discharge affecting water levels in the alluvial aquifer.

Surface water and groundwater levels obtained during summer 1988 drought conditions are depicted on Figures 3.17 and 3.18. Comparison with Figures 3.14 and 3.15 demonstrate that groundwater levels in the bedrock and alluvium around the slough dropped a few feet in drought conditions. Water levels in the alluvial aquifer further south of the slough (in the County Well field) exhibited much greater reductions due to pumping and greater evapotranspiration. These results further indicate the limited interaction between the aquifers north and south of the slough. (MK-F and JEG, 1988c).

3.6.3 Data Adequacy

The current geohydrological information generated by various studies is considered to be adequate with respect to bulk waste removal from the quarry. No further investigations are necessary prior to the proposed action.

Detailed characterization of the groundwater transport mechanisms and pathways will be necessary prior to final quarry remediation. However, good understanding of the nature and extent of fractures and joints can be developed only after the bulk wastes have been removed and the limestone walls and floors exposed for study. The residual wastes (i.e., within bedrock fractures) and the groundwater will be managed as additional

separate operable units. These operable units will be investigated in a subsequent RI.

3.7 DEMOGRAPHY AND LAND USE

3.7.1 Population

The Weldon Spring quarry is situated within the metropolitan St. Louis area, in St. Charles County (see Figure 1.2). Numerous municipalities are located within a 30-mile radius of the quarry, and range in size from small towns to the City of St. Louis. The nearest community, Defiance, is located about 3 miles from the quarry and has a population of about 100. The closest residence is 0.5 miles west of the quarry.

Table 3.11 indicates population trends over a 26-year period for local populations in the vicinity. With the exceptions of the City of St. Louis and portions of the St. Louis Metropolitan Area, all of these population centers are in St. Charles County.

Population groups near the quarry include persons who spend a significant amount of time in the vicinity of the site and those who are in the vicinity for only a short time. The first group consists of residents in the immediate vicinity of the quarry. The second category includes visitors to the neighboring wildlife areas and people driving near the quarry.

3.7.1.1 Institutions

Francis Howell High School is located about 4.5 miles northeast of the quarry on State Route 94. Student enrollment has increased from 500 in 1955 to more than 2,000 in the 1980s. In addition to regular classes, a preschool program (150-200 students) and a parenting class (80 parents) are also held at

Table 3-11 Local Populations in the Vicinity of the Quarry

City	Distance from Quarry (miles)	1960	1970	% Change 1960-1970	1980	% Change 1970-1980	1986	% Change 1980-1986
Cottleville	8	N/A	230	- - -	184	-20.0	180	-2.2
New Melle	8	N/A	N/A	- - -	168	- - -	210	+25.0
O'Fallon	11	3,770	7,018	+86.2	8,677	+23.6	12,090	+39.3
St. Charles	19	21,189	31,834	+50.2	37,379	+17.4	41,990	+12.3
St. Louis	30	750,026	622,236	-17.0	453,085	-27.2	426,300	-5.9
St. Peters	13	404	486	+20.3	15,700	+3,130.0	27,280	+73.8
Weldon Spring	5	N/A	N/A	- - -	700	- - -	760	+8.6
Weldon Spring Heights	5	N/A	135	- - -	144	+6.7	170	+18.1
Wentzville	12	2,742	3,223	+17.5	3,193	-1.0	4,540	+42.2
St. Louis Metropolitan Area	28	2,104,699	2,410,844	+14.6	2,356,460	-2.3	2,438,000	+3.5

Notes: N/A not available

Sources: 1960-1980 data from DOE, 1987a; 1986 data from Serrioz, 1989

the school. It is estimated that 2,300 people are on campus on a daily basis (Meshkov et al, 1986). The St. Charles County Extension Center is located adjacent to the high school.

Other institutional facilities in the area include a State of Missouri highway maintenance facility, located on Highway 94 just west of the school and immediately northeast of the chemical plant, and the Army Reserve and National Guard Training area approximately 2 miles north of the quarry. An active water treatment plant is located about 1 mile northeast of the quarry, adjacent to State Route 94.

3.7.1.2 Neighboring Wildlife Areas

The Missouri Department of Conservation operates three wildlife areas in the quarry vicinity; the August A. Busch Memorial Wildlife Area, the Weldon Spring Wildlife Area, and the Howell Island Wildlife Area. These wildlife parks are dedicated to a range of recreational uses. The Weldon Spring Wildlife Area is immediately adjacent to the quarry (see Figure 1.1).

Most of the visitors to the wildlife centers are from the St. Louis metropolitan area. Annual attendance at the Busch Area is approximately 700,000 people (Meshkov et al, 1986), but no data are available for the other areas. The average duration of each visit to the Busch Area is 4 hours, and use is heaviest in the spring and summer, ranging from 102,000 to 130,000 visitors per month (Meshkov et al, 1986).

3.7.2 Land Use

The quarry is in a relatively remote location. The rugged topography precludes extensive agricultural or industrial use, except along the Missouri River floodplain. Currently, most of the land surrounding the quarry is wildlife habitat, under the

jurisdiction of the Missouri Department of Conservation. Much of the land to the south, along the Missouri River floodplain, is devoted to agricultural use. The University of Missouri, which operates the St. Charles County Extension Center adjacent to the high school, owns 740 acres of land 5 miles east of the WSQ. The majority of this land is used for pasture (BNI, 1984), but a portion (about 250 acres) is being developed as a high-technology research park and remains under University ownership.

3.7.3 Use of Surface Waters

The only surface water feature at the quarry is the pond. The pond is not used for drinking water supply, recreation, or fishing, and access is restricted by a fence surrounding the quarry.

3.7.4 Use of Groundwater

The St. Charles County well field, approximately 3,000 feet downgradient and south of the quarry, is a source of water for county residents. The larger communities of St. Charles, O'Fallon, and St. Peters rely primarily on their own water sources. Public Water District #2, Missouri Cities Water Company, Francis Howell High School, the Army, and many of the outlying county residents rely on this well field for all or part of their water supply. These wells service many of the communities, institutions, and facilities surrounding the Weldon Spring Site.

As shown on Figure 3.17, there are thirteen wells in the County well field which extend approximately 100 feet to bedrock, although not all are in use. The wells draw water from the Missouri River alluvium. Several private wells in the site

area draw water from the Burlington-Keokuk aquifer and lower aquifers.

3.7.5 Data Adequacy

The available demographic and land use data are adequate with respect to the proposed action of bulk waste removal from the quarry. No further investigations are necessary prior to the proposed action.

3.8 ECOLOGY

3.8.1 Fauna and Flora

Much of the area surrounding the quarry is state-owned wildlife areas. The Weldon Spring Wildlife Area, located immediately adjacent to the quarry, is actively managed for wildlife. A variety of habitat types (forest, agricultural fields and old fields and pasture) occur in the area which support a wide diversity of plant and animal species (Haroun et al, 1989).

The quarry area is primarily forest, with some old-field habitat. The quarry rim and surrounding area consist primarily of slope forest and bottomland forest, and the predominant tree species are eastern cottonwood and sycamore. Much of the quarry floor is old-field habitat characterized by a variety of grasses, herbs, and shrubs. The Missouri Department of Conservation (Dickneite, 1988) reports 25 amphibian, 47 reptile, 29 mammal species, and 299 bird species may inhabit or utilize the quarry area. The terrestrial habitat present at the quarry may be used by a variety of small mammals such as squirrels, raccoons, and mice. The quarry pond, the only aquatic habitat within the quarry site, may provide suitable habitat for some waterfowl and amphibians.

In addition to the quarry pond, aquatic habitats in the vicinity of the quarry include the Missouri River, Little Femme Osage Creek, Femme Osage Slough, and numerous small, unnamed creeks, drainages, and ponds throughout the Weldon Spring Wildlife Area. The Missouri Department of Conservation (Dickneite, 1988) lists more than 105 species of fish as having been recorded for St. Charles County and many of these may be found in the various aquatic habitats in the Weldon Spring area. Common fish in these habitats include carp, channel catfish, buffalo, suckers, bass, sunfishes, crappie, shad, freshwater drum, white bass, and a variety of minnows, shiners, and darters.

3.8.2 Critical Habitats

Several species classified as rare or endangered are known to occur in the area (i.e., St. Charles County, Weldon Spring Wildlife Area, August A. Busch Memorial Wildlife Area, and Howell Island Wildlife Area). These species are listed in Table 3.12. No designated critical habitat for any of these species is known to exist at the quarry. The nearby Howell Island Wildlife Area south of the quarry provides an important night roost for overwintering bald eagles (a federally endangered species), and two Category 2 fish species are known to occur in the Missouri River south of the quarry (Category 2 means candidate for federal listing as endangered or threatened). The Missouri Department of Conservation (Gaines, 1988) reports 17 state endangered, 17 state rare, and 8 state "special concern" species in the vicinity of the quarry (Table 3.12). Of these species, the Cooper's hawk (Accipiter cooperii, state endangered) and the wood frog (Rana sylvatica, state rare) have been reported to occur at the Weldon Spring Wildlife Area, and these species could make use of the habitats present at and around the quarry. Several natural communities of high quality have also been identified in the area of the Weldon Spring site

(Gaines, 1988); however, none of these communities occur at or near the quarry (Haroun et al, 1989).

3.8.3 Biocontamination

The quarry is presently fenced, and direct human exposure to contaminants could only occur if an individual deliberately trespassed on the site. It is possible that small animals that have migrated from the quarry may be ingested by humans, but the probability of this is considered to be low.

In 1987, MK-F and JEG conducted a special study on bio-uptake of contaminants for the entire Weldon Spring Site, including the quarry area. Collection of fish specimens from the quarry pond and trapping of small mammals in the quarry area were unsuccessful (MK-F and JEG, 1988d). The extent of or potential for biocontamination is currently not known, but will be determined in subsequent investigations.

3.8.4 Data Adequacy

The available ecological information appears adequate to aid in assessing the feasibility of bulk waste removal from the quarry.

TABLE 3.12 Threatened, Endangered, or Special Concern Species Reported from St. Charles County, Missouri, and Potentially Occurring at the Weldon Spring Quarry Area

Species	Status	
	Federal[a]	State[b]
Plants		
Starwort (variety)	C2	
Forbes saxifrage	C3	Watch list
Rose turtlehead	C3	Endangered
Arrow arum	--	Rare
Star duckweed	--	Rare
Bugseed (variety)	--	Watch list
Adder's tongue fern (variety)	--	Undetermined
Salt meadow grass (variety)	--	Undetermined
Fish		
Pallid sturgeon	C2	Endangered
Pugnose minnow	--	Endangered
Sturgeon chub	C2	Rare
Sicklefin chub	C2	Rare
Alligator gar	--	Rare
Brown bullhead	--	Rare
Alabama shad	--	Rare
Starhead topminnow	--	Watch list
Western sand darter	--	Watch list
Reptiles and Amphibians		
Western fox snake	--	Endangered
Rattlesnake	--	Endangered
Western smooth green snake	--	Endangered
Wood frog	--	Rare
Northern crawfish frog	--	Watch list
Birds		
Bald eagle	Endangered	Endangered
Peregrine falcon	Endangered	Endangered
Least tern	C2	Endangered
Cooper's hawk	--	Endangered
Northern Harrier	--	Endangered
Sharp-skinned hawk	--	Endangered
Osprey	--	Endangered
Barn owl	--	Endangered
Double-crested cormorant	--	Endangered
Snowy egret	--	Endangered
Bachman's sparrow	--	Endangered

TABLE 3.12 (Continued)

Species	Status	
	Federal[a]	State[b]
American bittern	--	Rare
Yellow-headed blackbird	--	Rare
Red-shouldered hawk	--	Rare
Black-crowned night heron	--	Rare
Little blue heron	--	Rare
Mississippi kite	--	Rare
Upland sandpiper	--	Rare
Henslow's sparrow	--	Rare
Sedge wren	--	Watch list
Mammals		
Long-tailed weasel	--	Rare

[a] C2 = federal candidate for listing as a threatened or endangered species.
C3 = former federal candidate species.

[b] Watch list = species of possible concern for which the Missouri Department of Conservation is seeking further information; this listing does not imply that these species are imperiled.
Undetermined = possibly rare or endangered but insufficient information is available to determine the proper status.

Sources: Dickneite, 1988; Gaines, 1988; as cited by Haroun et al, 1989.

4 NATURE AND EXTENT OF CONTAMINATION

4.1 QUARRY WASTE CHARACTERIZATION

The chemical and radiological contamination within the Weldon Spring quarry, caused by early disposal activities at the site, has been documented to varying degrees. Portions of the disposal history for the quarry are well documented; while other portions are not. In addition, radiological contamination has been documented much more extensively and defined in greater detail than chemical contamination. Because of this and the relative importance of the radiological contamination compared to the chemical contamination, much more detail is provided on the radiological characteristics of the quarry bulk wastes.

A number of hazardous contaminants, both drummed and uncontained, are present within the quarry. Excavation and temporary storage of these wastes is critical to restoration of the site and further characterization and possible remediation of groundwater which is known to be contaminated. For this reason, this subsection focuses primarily on the nature and extent of the contaminated wastes which are the target of the proposed bulk waste removal. The status of surface water, groundwater, and air presented in other subsections is described only insofar as it relates to the proposed removal.

4.1.1 Disposal History

The waste materials deposited in the quarry are the main source of contamination in the vicinity of the WSQ. The quarry was originally mined for limestone aggregate used in construction of the Weldon Spring Ordnance Works (WSOW), and was used for intermittent disposal of chemically and radiologically contaminated materials from 1942 to 1969. Table 4.1 summarizes

the known disposal history. Figure 4.1 is a generalized cross-section through the quarry, showing the presumed locations of the wastes.

From 1942 to 1945, the Army used the quarry for disposal of TNT and DNT wastes generated during explosives production (MK-F and JEG, 1988a). It is believed that the greatest amount of TNT and DNT waste was disposed in the vicinity of the pond. The total volume of waste disposed of during this period is unknown.

At the end of World War II, the ordnance works was closed and an extensive decommissioning effort was begun. In 1946, approximately 90 tons of explosives were disposed of in the quarry (MK-F, 1987a). The exact location is not documented.

Between 1946 and 1957, the Army also disposed of TNT-contaminated process residues and building rubble from the ordnance works decommissioning. It is reported that more than 200 buildings were destroyed (MK-F, 1987a), and a portion of the wastes is believed to have been dumped in the deepest part of the quarry and over the high rim at the northeast corner (BGA,1984). Photos taken about 1960 indicate that the rubble in the northeast corner underlies the 500-foot elevation level, and consists primarily of large-diameter pipe and corrugated steel roofing material (PNL Photography, undated).

In 1959, the AEC dumped drummed thorium residues, containing about 3.8 percent Th-232, near the hill in the middle of the quarry (Lenhard et al, 1967). Some drums were dumped at the 510-foot level. These thorium wastes totalled approximately 185 cubic yards of material (MK-F and JEG, 1988a). The Th-232 radioactive decay series is the principal source of radiation in this material; the Ra-228 content of the waste is approximately 0.25 curie. This waste is currently below the water level in the pond and is presumed to be water-saturated (Figure 4.1).

TABLE 4.1 Waste Disposal at the Weldon Spring Quarry

Date	Material	Quantity
1942-1945	NITROAROMATICS AND RESIDUES[7] Quarry used for TNT/DNT waste disposal.	unknown
1946	NITROAROMATICS AND RESIDUES[6] Quarry used for TNT/DNT waste disposal.	90 tons
1946-1957	TNT RESIDUES[4,5,6] Residues and rubble dumped in deepest part of Quarry and in northeast corner.	unknown
1959	THORIUM RESIDUES[1,2,3,5,7] Disposal of drums containing 3.8% thorium residues. Estimated Ra-228 content of 0.25 Ci.	185 yd^3
Early 60's	BUILDING RUBBLE, EQUIPMENT, SOILS[1,2,3,4,5,6,7] Demolition rubble from Destrehan Street Plant. Covers approximately one-acre to 30-ft deep in the deepest part of the Quarry. Contains uranium and radium contamination with less than 1 Ci Ra-226.	50,000 yd^3
1963-1965	THORIUM AND URANIUM RESIDUES[4,5,6,7] Several thousand drums containing thorium and rare earths from Granite City Arsenal. Initially intended for disposal. Much of waste later removed for reprocessing.	unknown
1966	THORIUM RESIDUES[5] Drums and residues from shutdown and cleanup of Weldon Spring Chemical Plant process equipment.	unknown
1966	THORIUM RESIDUES[1,2,3,4,5,7] Hundreds of drums brought from Cincinnati by rail. Contain 3% thorium with estimated 1 Ci Ra-228. Placed above water level.	555 yd^3
1966	TNT/DNT RESIDUES[1,5,7] Contaminated stone and earth dumped in northeast corner of Quarry covering the Cincinnati thorium residues.	unknown
1968-1969	URANIUM AND THORIUM RESIDUES[2,3,4,5,6,7] Contaminated building rubble and process equipment from Weldon Spring Chemical Plant. Principal sources of radioactivity are Ra-226 and Ra-228.	5,560 yd^3

Sources:
1. Lenhard et al, 1967
2. Pennak, 1975
3. BNI, 1983a
4. BGA, 1984
5. Kleeschulte and Emmett, 1986
6. MK-F, 1987a
7. MK-F and JEG, 1988a

Photographs taken of the dumped drums indicate that between one-fourth and one-half of the drums ruptured during disposal (PNL Photography, undated).

In the early 1960s, approximately 50,000 cubic yards of building rubble, process equipment, and soils from the demolition of the Mallinckrodt Chemical Works Destrehan Street feed plant were deposited in the quarry (Lenhard et al, 1967). Available documentation is unclear about the date of disposal. The Task Force Report states that it was done in 1963 and 1964 (Lenhard et al, 1967), while LBL states that disposal took place between 1960 and 1962 (BGA, 1984). The waste is contaminated with uranium and radium, containing less than 1 curie Ra-226, and covers approximately 1 acre of the quarry floor to a depth of about 30 feet. Waste was initially dumped in the eastern portion and moved into the pond area by bulldozer, and waste now covers TNT-contaminated rubble and Th-232 wastes. It is estimated that about one-third of the waste is below the average water level in the pond.

Between 1963 and 1965, the AEC granted permission for disposal of several thousand barrels of low-level radioactive wastes from the Army's Granite City Arsenal. These materials, containing up to a few percent thorium and up to a few tenths percent uranium, were the residues from the processing of euxinite ore for the recovery of niobium and tantalum. Continued storage of these wastes at the arsenal was judged inadvisable because of storage drum corrosion. The upper east end gate in the quarry's security fence was installed at this time to allow trucks to enter and dump the barrels over the high rim at the northeast end. After disposal began, a local company purchased the entire quantity of material for recovery of rare earths. Dumping was suspended and the purchaser removed as much of the dumped material as was practical. It is not known how

much of this material is left in the quarry (Kleeschulte and Emmett, 1986; BGA, 1984).

In 1966, drums and contained thorium residues from shutdown and cleanup of the Weldon Spring feed materials plant were disposed of in the quarry. No records regarding waste volume or disposal location are available (Kleeschulte and Emmett, 1986).

Also in 1966, several hundred drums, or approximately 555 cubic yards, of thorium residues from Cincinnati, Ohio were dumped into the quarry. Dumping began in the northeast corner of the quarry at the 480-foot elevation level and proceeded to the west. Although the wastes were originally placed above the water table, investigations by LBL (BGA, 1984) indicate that the drums may be below the present quarry pond water level. The source of radiation is the Th-232 radioactive decay series, and this 3-percent thorium waste contains an estimated 1 curie of Ra-228. Stone and earth contaminated with TNT and DNT were later dumped over these thorium residues (Lenhard et al, 1967; MK-F and JEG, 1988a).

In 1968 and 1969, several buildings at the chemical plant were decontaminated and approximately 5,560 cubic yards of waste materials were dumped in the quarry. These materials included process equipment and building rubble from a thorium nitrate processing plant. The wastes, contaminated with thorium and uranium, were placed on the main quarry floor and also dumped over the rim at the northeast corner of the quarry. The extent of radioactive and chemical contamination of this material is not known (BGA, 1984; MK-F and JEG, 1988a).

At about this time, barium sulfate residues stored at the St. Louis-Lambert Airport Storage Site were scheduled for disposal at the quarry as a part of the storage site decontamination. Approximately 8,700 tons of leached and 1,500

tons of unleached barium sulfate cake had been stored at the airport site. These wastes were once believed to have been deposited at the WSQ in 1969 (ORNL, 1979), although, investigations by NRC concluded that they were disposed of at the West Lake Landfill (Booth et al, 1982; NRC, 1988).

4.1.2 Waste Characteristics

The quarry wastes can be described in terms of physical, radiological, and chemical characteristics. Cleanup criteria for the quarry have not yet been established. Thus, guidelines and background levels developed for soils, which are discussed in subsection 4.2, are used here for comparison purposes.

4.1.2.1 Physical Characteristics

The wastes deposited in the quarry consist of a heterogeneous mixture of rubble, soils, sediments or sludges, and interstitial water. Rubble consists of concrete and steel building materials, drums, and process equipment. Many of the drums are ruptured and corroded. Water in the quarry pond is also contaminated, but is not considered to be part of the bulk wastes. An estimated 40,200 cubic yards of contaminated rubble, 50,700 cubic yards of contaminated soil and clay, and 4,100 cubic yards of contaminated pond sediment are thought to be present within the quarry. The total volume of waste within the WSQ is estimated to be about 95,000 cubic yards (DOE, 1987a).

Most of the rubble is believed to be on the quarry floor in the 40-foot region, as shown on Figure 4.2 (DOE, 1987a). The density of the wastes in this area, which include cement and steel rubble, was estimated to be 4,400 pounds per cubic yard (BNI, 1984a). Waste density in the other areas was estimated to be 3,100 pounds per cubic yard, which is the assumed value for soil, clay, and sludge in the quarry (BNI, 1984a). The physical

characteristics of these waste components are summarized in Table 4.2.

Data describing the physical characteristics of the sediment are unavailable, but it is assumed that sediment will also weigh approximately 3,100 pounds per cubic yard (BNI, 1984a).

Before the contaminated materials at the quarry can be excavated, the water within the pond must be removed. It is estimated that the quarry pond contains approximately 3,000,000 gallons of water (BNI, 1984a) and contamination in the pond is clearly a result of the wastes stored in the quarry as discussed in Section 4.3.3. An additional increment of water from groundwater inflow and precipitation will also require removal during pond dewatering operations.

4.1.2.2 Radiological Characteristics

The greatest quantity of contamination in the quarry bulk waste is radiological. A majority of the quarry bulk waste is known to contain above-background concentrations of U-238, Th-232, and daughter radionuclides of the uranium and thorium decay series (see Figures 4.3 and 4.4), often exceeding DOE guidelines for residual radioactive material in soils (BNI, 1985c; BGA, 1984). Gamma exposure rates above background levels have been recorded at the quarry and are a direct result of these radiologically-contaminated wastes (BNI, 1985c; BGA, 1984; MK-F and JEG, 1987, 1988a). Radon and airborne radionuclide-containing particulates are expected to be the most important occupational and potential off-site exposure hazards during bulk waste removal. For these reasons and to provide radiological data necessary for subsequent environmental documents, this section discusses in detail the known radiological characteristics of the quarry bulk wastes.

TABLE 4.2 Weldon Spring Quarry Physical Characteristics of Quarry Wastes[a]

Region[b]	Volume[f] (yd^3)	Density (lb/yd^3)	Weight[f] (tons)
40-ft	64,200[c]	4,400	141,000
Pond[d]	742	4,400	1,650
25-ft	4,060	3,100	6,290
14-ft	17,240	3,100	26,700
7-ft	7,320	3,100	11,400
0.5-ft	1,240	3,100	1,930
Total/Average	95,000	4,000e	189,000

a Source: modified from DOE, 1987a.

b Regions of waste with corresponding depth are indicated on Figure 4.2.

c Increased by 9,000 yd^3 of material to give a total waste volume of 95,000 yd^3 (BNI, 1985c). It is believed by staff of BNI that 95,000 yd^3 is a better estimate than the sum of volumes, 86,000 yd^3, because the amounts of material under the pond and in the 40-ft region are uncertain (Hickey, 1986).

d Depth of contaminated waste below the pond is assumed to be one foot (DOE, 1987a).

e Average density of quarry wastes.

f Volumes and weights are rounded.

The basic data utilized to describe the nature and extent of radiological contamination in the bulk wastes are surface and subsurface soil radionuclide concentrations, borehole gamma logging data obtained by BNI (1985c) and LBL (BGA, 1984), and depth to quarry bedrock data determined during a chemical characterization performed by BNI (Kaye and Davis, 1987). The purpose, scope, procedures and analytical methods employed in the BNI and LBL radiological surveys as well as soil radionuclide concentrations and borehole logging data are discussed in this section. An interpretation of the distribution of radiological contamination in the bulk waste is also presented.

LBL Radiological Survey

LBL performed a radiological survey of the quarry intermittently during the years 1979 through 1981. The purpose of this study was to investigate the radiological hazards posed by the site, develop capabilities to predict the potential for migration of radionuclides in groundwater, perform a preliminary investigation of the effects of proposed engineering options for the site, and to provide preliminary information on the waste inventory. The scope of the LBL study, as it relates to the bulk waste characteristics, was as follows: drill 22 boreholes (19 of which reached bedrock), perform 81 gamma exposure rate measurements, gamma log 20 boreholes, collect 57 surface and 93 subsurface soil samples, and collect 4 sediment and 1 core sample from the quarry pond (BGA, 1984). Gamma logging and soil radionuclide concentration data necessary to determine the nature and extent of the radiological contamination are discussed below.

Borehole gamma logging was used by LBL as a quick method of identifying areas and volumes containing above-background concentrations of gamma-emitting radionuclides. The type of

gamma logging employed by LBL provided qualitative information of Ra-226 and Ra-228 subsurface soil concentrations in the area around the borehole. LBL gamma logged 20 of the 22 boreholes shown as open circles in Figure 4.5. Gamma logging results in 16 of these 20 boreholes indicate above-background concentrations of Ra-226 and/or Ra-228.

Fifty-seven surface soil samples (zero-to-6-inch depth) were collected within the quarry by LBL at the locations shown as open circles in Figure 4.6. Ninety-three subsurface soil samples were collected from 20 of the 22 boreholes (Figure 4.5) using split spoon samplers driven on 5 foot depth intervals. The amount of soil recovered in split spoon samples varied from 0 to 18 inches and averaged 8 to 9 inches. The surface and subsurface soil samples were analyzed with sodium iodide (NaI) and high-purity germanium (HpGe) detection systems. Ra-226 and Ra-228 concentration results for surface and subsurface soil samples are detailed in the BGA report and summarized in Table 4.3.

LBL analyzed borehole gamma logs and laboratory surface and subsurface soil samples for the radionuclides Ra-226 and Ra-228. LBL did not directly analyze for U-238 and Th-232, two important components of the radiological quarry waste, because these parent radionuclide concentrations were inferred by assuming secular equilibrium with daughters Ra-226 and Ra-228, respectively. The secular equilibrium assumption, however, is not valid with respect to the quarry waste. If parent radionuclides are not chemically removed from a substance and sufficient time is allowed to permit the ingrowth of daughter radionuclides with half-lives much shorter than the parent half-life, then the assumption of secular equilibrium is valid. If such a condition existed, Ra-226 activity concentrations could be determined analytically and the result assigned to both Ra-226 and U-238 activity concentrations with very small

TABLE 4.3 Range of Ra-226 and Ra-228 Concentrations Detected in the Quarry Wastes

Radionuclides	Soil Sample Type	Concentration Range (pCi/g)
Ra-226	Surface	0.4 - 2780
Ra-228	Surface	0.1 - 813
Ra-226	Subsurface	1.0 - 701
Ra-228	Subsurface	<1.0 - 2200

Source: BGA, 1984.

resulting error. This same scenario is valid for determining Th-232 activity concentration from Ra-228 analytical results if the two assumptions above are true.

This is not the case for the quarry wastes however. As stated in the BGA report, much of the radioactive waste in the quarry contains chemically separated uranium, as well as uranium and thorium series radioactive decay products which are not in equilibrium with the parent (U-238 and Th-232) radionuclides. Since uranium and Th-232 were chemically separated from the ore and subsequent waste handled at the Weldon Spring and Destrehan Street plants, the locations where most of the quarry waste originated, testing for Ra-226 and Ra-228 and assigning the activity concentrations to U-238 and Th-232 respectively is incorrect. Because of this inconsistency the U-238 and Th-232 activity concentrations reported by BGA are not quoted in this report. However, the Ra-226 and Ra-228 activity concentrations obtained by laboratory NaI and HpGe detection are valid and are helpful in determining the extent of radiological contamination within the quarry.

An interesting aspect of the BGA report involves a limited gamma ray spectrum from one quarry surface soil sample suggesting the presence of Th-227 in concentrations above that

found in natural uranium ore (BGA, 1984). According to the physics of secular equilibrium, the existence of Th-227 in this sample would require the presence of similar activity concentrations of Ac-227 and possibly Pa-231, the long-lived parent radionuclides of Th-227, though neither the BGA or BNI reports provide evidence of this. BGA states that the higher concentration of Th-227 in these wastes could be indicative of an abundance of U-235 relative to natural equilibrium conditions (enriched uranium). However, they further state that the Th-227 concentrations are not sufficiently high to indicate the presence of enriched uranium in these waste piles. BGA also states that Ra-226 and its daughters, chemically separated uranium, and Th-230 in concentrations far exceeding that associated with the equilibrium U-238 decay series are found in this and other surface soil sample analyses.

To investigate this occurrence the PMC obtained one surface (zero-to-6-inch depth) and two subsurface (6-inch depth intervals) soil samples from the waste pile material where LBL previously collected their sample. These samples, collected on November 14, 1988, were analyzed by gamma spectroscopy. The gamma spectrums revealed high concentrations of Th-230, lower concentrations of Ra-226 and daughters, U-238 out of equilibrium with its long-lived daughters and higher concentrations of Th-227 than parent U-235. These data correspond well with the LBL qualitative information discussed above (Fleming, 1989a).

Based on the limited information in the BGA report and the PMC sample data this surface material probably results from disposal of raffinate, the waste product of the uranium and thorium purification processes. Raffinate from the Weldon Spring Site raffinate pits has been sampled extensively and is known to contain concentrations of Th-230 far exceeding those of accompanying U-238 decay series isotopes. Th-227 concentrations in excess of parent U-235 concentrations are also found in

raffinate, along with Ra-226 and daughters. Both the LBL and PMC data support this hypothesis (Fleming, 1989a).

BNI Radiological Survey

BNI conducted an extensive radiological characterization in 1984 through 1985. The purpose of the BNI survey was to acquire data necessary to perform an engineering evaluation assessing the alternatives for decontaminating and decommissioning the Weldon Spring Site. The quarry radiological survey provides information regarding the vertical and areal extent of contamination. The scope involved surveying the entire area within the quarry fence and identifying areas and volumes exceeding DOE guidelines for residual radioactive material in soil (BNI, 1985c).

During this study BNI established a 50-foot-by-50-foot survey grid system within the quarry; performed 1,686 beta-gamma dose rate measurements, 55 gamma exposure rate measurements, and 29 radon flux measurements; gamma logged 75 boreholes; and collected 184 systematic and 73 biased surface soil samples, 90 subsurface soil samples and 3 sediment samples from the quarry pond.

BNI gamma logged 75 6-inch boreholes using a 2 inch-by-2 inch NaI gamma scintillometer. Gamma count rate measurements were typically made at 1-foot depth intervals. BNI discovered 25 contaminated boreholes on the basis of both gamma loging and subsurface soil sample analysis, and 19 contaminated boreholes on the basis of gamma logging alone.

BNI collected 257 surface soil samples (zero-to-6-inch depth) at the borehole locations shown on Figure 4.6. Biased surface soil samples, those not falling on intersecting grid points, were collected in areas of suspect contamination to

better define areal contamination limits. The 257 samples were analyzed for Ra-226, U-238, and Ra-228 using a HpGe gamma spectroscopy detection system. Eighty-five of these samples were also analyzed for Th-230 by radiochemical analysis.

A total of 90 subsurface soil samples excluding borehole spoil samples, which are samples collected from borehole soil at undetermined depths, were collected from the 28 boreholes shown on Figure 4.7. Fifty-five of the subsurface soil samples were radiochemically analyzed for Th-230; 39 of these samples were also radiochemically analyzed for U-234, U-235, U-238, Ra-226, Ra-228, Th-232 and Pb-210. Fifty-one subsurface soil samples were analyzed by HpGe gamma spectroscopy for U-238, Ra-226 and Ra-228. Radionuclide concentration results for surface and subsurface soil samples are summarized in Table 4.4.

Analysis of BNI's radiological soil sample data shows low concentrations of uranium contamination slightly enriched in the U-235 isotope. Fifteen of the 42 samples radiochemically analyzed for U-238, U-234, and U-235 showed U-235 concentrations greater than the 0.72 weight percent (Connolly, 1978) found in natural uranium. These U-235 concentrations range from 0.77 to 2.3 weight percent of the total uranium present in the sample. Twelve of the fifteen samples showing slightly elevated levels of U-235 were found in 3 boreholes as shown in Figure 4.7.

Slightly enriched uranium may also be present in the quarry pond sediment based on BNI results discussed in Section 4.2.3.1 of this report. The existence of slightly enriched uranium in a small portion of the quarry wastes is possible since the Weldon Spring Uranium Feed Materials Plant received 842 metric tons of slightly enriched (typically 1 weight percent) uranium, of which 8.6 metric tons have not been accounted for (DOE, 1986b).

TABLE 4.4 Range of Radionuclide Concentrations in Soil Samples at the WSQ

Radionuclide	Surface Sample Concentration Range (pCi/g)	Subsurface Sample Concentration Range (pCi/g)
U-238	<1.0 - 1,600	1.4 - 2,400
Ra-226	<1.0 - 1,200	0.5 - 1,100
Ra-228	<1.0 - 250	1.0 - 806
Th-230	<1.0 - 1,300	<1.0 - 6,800

Source: BNI, 1985c.

The risk associated with exposure to natural uranium comes mainly from the U-238 and U-234 isotopes. Uranium enriched to the levels described above does not contain sufficient concentrations of U-235 to outweigh the risks from the U-238 and U-234 also present (DOE, 1985d). Waste containing enriched uranium will be included in the bulk waste removal.

BNI analyzed a total of 301 surface and subsurface soil samples for Th-232 by HpGe gamma spectroscopy. Because of the nature of the quarry waste, this form of analysis will not always be valid for Th-232 activity concentration results. The Th-232 decay series radionuclides contained in the quarry wastes may be found as either the entire decay series in its natural secular equilibrium state, or as Th-232 chemically separated from Ra-228 and subsequent daughters. Since Th-232 is a pure alpha emitter, it cannot be directly detected by gamma spectroscopy. However, the activity concentration of its gamma-emitting daughters can be determined by HpGe gamma spectroscopy and this value accurately assigned to the Th-232 activity concentration, providing Th-232 is in secular equilibrium with its daughters.

Chemically separated Th-232 found in the quarry wastes can be detected by HpGe gamma spectroscopy accurately because sufficient time has elapsed following disposal to allow at least 87 percent of secular equilibrium to have occurred between Th-232 and its daughters, based on the last disposal date of 1969. However, quarry wastes containing chemically separated Ra-228 and subsequent daughters, (with no parent Th-232) will not yield accurate Th-232 concentrations when analyzed by HpGe gamma spectroscopy.

Th-232 was chemically separated from its daughters at the Weldon Spring Uranium Feed Materials Plant. Residue and debris containing chemically separated Th-232 and/or chemically separated Ra-228 and subsequent daughters are present in the quarry. Therefore the assumption of secular equilibrium between Th-232 and its daughters with respect to quarry waste is not valid. Ra-228 concentrations can be determined accurately with HpGe gamma spectroscopy, but only radiochemical analysis will yield reliable Th-232 concentrations from quarry waste samples. Therefore, this report regards all BNI HpGe gamma spectroscopy Th-232 concentrations as Ra-228 concentrations; Th-232 concentration obtained by radiochemical analysis will be the only Th-232 concentration data quoted in this section.

Distribution of Radiological Contamination

The depth-specific areal extent of radiological contamination is shown on Figures 4.8 through 4.16. These figures were developed by combining the radionuclide concentration data at each sampling location for the representative contaminants: U-238, Th-232, Th-230, Ra-228 and Ra-226. Although other radioactive daughter products are present in the waste in varying degrees of secular equilibrium, cleanup of material containing the representative radionuclides will assure removal of all radioactive daughter products. This

is because one or more of the representative contaminants will always be present at any given location within the quarry at concentrations comparable to the concentrations of any radioactive daughter products which were not specifically measured (Fleming, 1989b; BNI, 1985c).

Figure 4.8 shows the areal extent of radiological contamination for the zero-to-0.5 foot depth interval. Figures 4.9 through 4.16 show the areal extent of radiological contamination for successive depth intervals in five foot increments to a maximum depth of 40 feet. The zero to 0.5 foot interval was chosen to be representative of surface soil. The subsequent five foot intervals characterize radionuclide distributions with depth and indicate anticipated waste conditions during excavation.

The figures were generated by averaging radionuclide-specific concentrations at each sampling location over the specific depth interval. These average values were then used to define the extent of contamination for each depth interval. Depth-specific minimum and maximum radionuclide concentrations are provided in Table 4.5. The boundaries on each figure reflect surface concentrations greater than 5 pCi/g and subsurface radionuclide concentrations greater than 15 pCi/g for Th-232, Th-230, Ra-228, and Ra-226. For U-238, both surface and subsurface boundaries were drawn based on a minimum concentration of 15 pCi/g. Department of Energy residual radioactive material in soil guidelines have been set at 5 pCi/g and 15 pCi/g for radium and thorium (DOE, 1987b). Since no such guideline has been established for uranium the value of 15 pCi/g was chosen for comparative purposes.

The extent of surficial contamination shown in Figure 4.8 is very accurate because of the extensive surface (zero to 6-inch) sampling and analysis performed. The figures showing

TABLE 4.5 Minimum and Maximum Radionculide Concentrations by Depth at the Weldon Spring Quarry

	Radionuclide Concentration (pCi/g)									
	Ra -226		Th-230		U-238		Ra-228		Th-232	
Depth[a]	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
0.0 - 0.5	0.4	2780.0	0.7	1300.0	3.0	1600.0	0.1	813.0	1.4	8.0
0.5 - 5.0	0.2	340.0	3.2	6800.0	1.4	394.0	0.5	86.6	0.9	36.0
5.0 - 10.0	0.9	1100.0	1.3	1300.0	5.0	2400.0	0.5	1413.0	0.9	7.0
10.0 - 15.0	0.9	701.0	0.2	540.0	33.0	1500.0	0.4	2200.0	0.7	6.0
15.0 - 20.0	0.9	144.0	1.2	110.0	16.0	55.0	0.8	123.0	7.0	7.0
20.0 - 25.0	0.9	52.2	1.1	41.0	3.0	12.0	0.2	149.0	0.7	1.0
25.0 - 30.0	0.5	22.7	- -	- -	- -	- -	0.1	85.0	- -	- -
30.0 - 35.0	0.9	3.8	- -	- -	- -	- -	0.7	18.6	- -	- -
35.0 - 40.0	0.7	20.0	- -	- -	- -	- -	0.5	12.4	- -	- -

-- No data available for this radionuclide at this depth interval.

a See Figures 4.8 through 4.16 for corresponding areas of radiological contamination.

SOURCES: BGA, 1984 and BNI, 1985c

the subsurface extent of contamination become less accurate with increasing depth due to progressively fewer samples, the heterogeneity of the waste material, and auger refusal which limited sample collection with increasing depth.

A summary of radionuclide-specific and depth-specific average concentrations is provided in Table 4.6. These averages relate only to quarry areas where sufficient data were available to estimate these parameters.

TABLE 4.6 Average Concentration by Depth at the WSQ

Depth (ft)	Average Radionuclide Concentrationa (pCi/g) Ra-226	Th-230	U-238	Ra-228	Th-232
0.0 - 0.5	105.0	150.1	174.1	19.7	- -
0.5 - 5.0	54.2	1457.3	123.3	35.9	25.7
5.0 - 10.0	195.9	502.8	422.8	259.5	- -
10.0 - 15.0	189.6	318.6	342.2	598.7	- -
15.0 - 20.0	67.3	94.2	46.0	51.0	- -
20.0 - 25.0	36.3	16.0	- -	61.2	- -
25.0 - 30.0	20.7	- -	- -	44.2	- -
30.0 - 35.0	- -	- -	- -	18.6	- -
35.0 - 40.0	18.3	- -	- -	- -	- -
TOTAL WGT AV	108.8	327.9	198.0	96.4	25.7

a Individual and total averages weighted by area
- - no data available for this radionuclide at this depth interval

Sources: BGA, 1984 and BNI, 1985c

Areal average radionuclide concentrations shown in Table 4.6 for an entire depth interval were calculated using a computer-generated grid model whereby a grid was constructed in each area containing above-guideline radionuclide concentrations. Each grid quadrant was assigned a radionuclide concentration extrapolated from known sample concentrations within the gridded area. The average concentrations therefore

represent a weighted average over the entire area of above-guideline radionuclide concentration, at the given depth.

Depth of contamination is based on radiological analysis results and depth to bedrock data. Boreholes were drilled by LBL and BNI to determine the radiologic characteristics of the bulk wastes (BGA, 1984 and BNI, 1985c). Depth to bedrock data are also available from boreholes drilled by BNI (Kaye and Davis, 1987) as part of a chemical characterization survey.

By combining the information in Table 4.6 with historical records of waste disposal and the quarry topography, the quarry can be divided into four zones to facilitate analysis and comparison of the data. These are: (1) the haulway; (2) the sump; (3) the northeast corner; and (4) the rim. The four zones are identified in Figure 4.17. The haulway zone includes the area surrounding the gravel road and adjacent railroad spur which enter the quarry at the lower gate. The sump zone includes the pond and the area directly east. The northeast corner zone includes the bench area near the upper quarry gate and the northeast section of the present quarry floor. The rim zone includes the upper gate plateau area encompassing a section of the upper haul road in the extreme northeast corner of the quarry rim, and five small areas of contamination; three on the southeast rim and two on the north rim. Estimated areas for each zone are provided in Table 4.7.

The volume of radiologically contaminated material in each zone is summarized in Table 4.7. The total volume of 83,200 cubic yards compares favorably with a previous estimate of 95,000 cubic yards (see Table 4.2, Section 4.1.2.1) which included a 9,000 cubic yards contingency (DOE, 1987a). Details on how the volume estimates for each zone were made are provided in the following subsections.

Haulway Zone - The haulway zone generally contains the lowest radiological contaminant concentrations. Contamination is likely due to accidental spills from dump trucks and railroad cars, or from tires spreading contamination during hauling operations. Maximum representative contaminant concentrations in this zone are: 312 pCi/g for U-238, 2,305 pCi/g for Ra-226, 15 pCi/g for Ra-228 and 150 pCi/g for Th-230 (BGA, 1984 and BNI, 1985c). Th-232 concentrations in this zone were not obtained.

TABLE 4.7 Summary of Estimated Areas and Volumes of Radiological Contamination at the Weldon Spring Quarry

Zone[a]	Area (ft^2)	Volume (yd^3)
Haulway	48,300	6,600
Sump[b]	58,900	55,100
Northeast Corner	52,800	21,300
Rim	11,000	200
TOTAL	171,000	83,200

[a] See Figure 4.17 for zones.
[b] Includes 4,100 yd^3 of sediment in pond.

The depth of contamination in this zone was characterized by seven subsurface boreholes as summarized in Table 4.8. Bedrock was reached at six locations at an average depth of 3.7 feet. Radionuclide analyses were performed on samples from only three boreholes. At two of these boreholes the maximum depth of contamination was 0.5 foot. At the other location the contamination extended deeper than 1 foot, the depth where auger refusal occurred.

Because of the limited amount of data on contamination depth, it is assumed that contamination extends to bedrock at the average depth of 3.7 ft. This yields an estimated volume of 6,600 cubic yards for this 48,300 ft^2 area.

Sump Zone - The sump zone comprises the deepest mined area of the quarry and includes the existing pond. It was probably the first area within the quarry where disposal of wastes occurred. Maximum representative contaminant concentrations in this zone are: 2,400 pCi/g for U-238, 486 pCi/g for Ra-226, 2,200 pCi/g for Ra-228, 1,300 pCi/g for Th-230 and 8.0 pCi/g for Th-232 (BGA, 1984 and BNI, 1985c).

TABLE 4.8 Summary of Contaminant Depths for the Haulway Zone

Location Identification*	Depth To Bedrock (ft)	Depth Of Contamination (ft)
S1	3.5	0.5
CV	AR	1.0+
S2	4.0	0.5
B1	2.0	NR
B2	6.0	NR
B9	3.5	NR
B10	3.0	NR

AR - Auger refusal.
NR - No radiological analyses (these boreholes were drilled to determine chemical characteristics of the bulk wastes).
\+ - Contamination extends beyond this depth.

* See Figure 4.5 for borehole locations.

Sources: BGA, 1984; BNI, 1985c; and Kaye and Davis, 1987.

This zone contains the greatest volume of radioactively contaminated rubble. This area was the main dump area for the Destrehan Street Plant rubble. Ra-226, U-238, and Th-230 contamination located in the southern half of this zone extends to depths of 40 feet.

There is also a significant volume of Ra-228 contamination near the limestone hill in the northern section of the sump zone. The origin of this contamination is believed to be from

drummed thorium residue dumping in 1959. Undated photographs taken before the Destrehan Street dumping period show drums resting on a slope next to the east edge of the limestone hill (PNL Photography, undated). This slope extended to the deepest section of the sump zone, where the Destrehan Street rubble was placed.

The depth of contamination in the sump zone is inferred from sample results from 20 boreholes. Fourteen of the 20 boreholes reached bedrock. At 5 borehole locations contamination did not extend to bedrock. However, the only radionuclides analyzed for at these 5 locations were Ra-226 and Ra-228. Contamination from other radionuclides may extend to bedrock. Six boreholes were not completed to bedrock due to auger refusal which occurred at an average depth of 13.4 feet. This information is summarized in Table 4.9 for the locations shown on Figure 4.5.

A reasonable estimate of the volume of radiological contamination in the sump zone can be made from the information presented in Table 4.9. For all boreholes where no radiological data was collected or where analysis was not performed for all representative radionuclides, the contamination was assumed to extend to bedrock. For boreholes where auger refusal occurred before the maximum depth of contamination was reached, the average measured depth to bedrock was assigned. This resulted in an average contaminant depth of 36.7 feet. Using the disposal area of 37,500 ft^2 the volume of contamination is estimated to be 51,000 cubic yards.

Both BNI and LBL data indicate that the sediments in the quarry pond are contaminated, but no definitive depth of contamination is available. BNI sampling data indicate contamination deeper than one foot (BNI, 1985c). LBL data indicate contamination deeper than 1.5 feet (BGA, 1984). A

TABLE 4.9 Summary of Contaminant Depths for the Sump Zone

Location Identification **	Depth To Bedrock	Depth Of Contamination
B3	36.8	NR
B4	39.5	NR
B5	34.0	NR
B6	37.5	NR
B7	40.5	NR
B8	31.0	NR
S3	AR	12 +
S4	AR	12 +
S5	AR	22.5 +
S6	AR	7.5 +
S7	AR	1.5 +
S8	AR	25 +
0-0	39.5	39.5
1-1	21.5	21.5
1-3	39.3	20.5 *
1-5	37.0	30.5 *
2-2	38.8	25.0 *
2-4	39.5	39.5
3-1	38.5	10.0 *
4-1	40.0	0.0 *

AR Auger refusal.
NR No radiological analysis (these boreholes were drilled to determine chemical characteristics of the bulk wastes).
* Not used in computing average depth of contamination because analysis was not performed for all representative radionuclides.
+ Contamination extends beyond this depth.
** See Figure 4.5 for sample locations.

prior estimate made by BNI indicated that 4,100 cubic yards of radiologically contaminated material is in the pond (BNI, 1985c). This volume would result from an average contaminant depth of approximately 5 feet for the 21,400 ft^2 pond. A volume of 4,100 cubic yards will be assumed for the purposes of this report.

Northeast Corner - Waste in the northeast corner zone was deposited on an existing rock bench. Waste materials presently resting on the bench may have been dumped from the quarry upper gate on the northeast quarry rim and/or hauled up an incline extending from the present floor of the quarry to the top of the bench. Other wastes in this zone were either dumped from or pushed up against the bench and rest on the present quarry floor. This zone is therefore comprised of 3 man-made waste piles; the upper pile which extends 40 feet from the upper gate plateau of the rim zone to the top of the waste pile on the bench, the pile on the bench, and the lower pile extending 20 feet from the bench to the quarry floor.

Maximum contaminant concentrations in the northeast corner zone are: 420 pCi/g for U-238, 2,780 pCi/g for Ra-226, 806 pCi/g for Ra-228, 6,800 pCi/g for Th-230, and 56.0 pCi/g for Th-232 (BGA, 1984 and BNI, 1985c) . The U-238, Ra-226, and Th-230 concentration data in this zone indicate levels similar to those found in the sump zone.

The origin of the radiological contamination in this zone is likely due to dumping during the period 1963 through 1969. Debris consisted of uranium and thorium contaminated residues as well as rubble and equipment from cleanup and shutdown of the Weldon Spring Chemical Plant. This would account for the similar concentrations of Ra-226, U-238, and Th-230 in the sump and northeast corner zones.

Evidence locating the 1966 dumping of drummed thorium residues could not be inferred from either the BNI or LBL data. These drums, containing 3% thorium residues, were reported to have been dumped in this zone and covered with TNT-contaminated earth. High Ra-228 concentrations similar to those found in the sump zone near the limestone hill would identify this debris because the Ra-228 would have attained approximate secular equilibrium with the parent Th-232. Such levels of Ra-228 were not found by BNI or LBL.

The depth of radiological contamination in the northeast corner is inferred from the results of 3 boreholes drilled in the lower waste pile, 27 boreholes drilled in the bench pile, and 6 boreholes drilled in the upper pile. A summary of these boreholes is presented in Table 4.10.

One of the three holes drilled in the lower pile reached bedrock at a depth of 6.0 feet. No radionuclide analyses were performed on samples from this location. Auger refusal occurred at the two other borehole locations where radioactive contamination extended to greater than 3 feet and greater than 10 feet.

Twelve of the boreholes on the bench pile reached bedrock at the average depth of 9.7 feet. For 4 of these 12 boreholes no radionuclide analyses were performed. For the remaining 8 boreholes, contamination extended to bedrock. Auger refusal occurred at the remaining 15 boreholes on the bench at an average depth of 6.4 feet.

Each of the 6 boreholes drilled in the upper pile reached bedrock at an average depth of 26 feet. At two of these locations no radionuclide analyses were performed. At one

TABLE 4.10 Summary of Contaminant Depths for the Northeast Corner Zone

Waste Pile	Location Identification**	Depth To Bedrock (ft)	Depth Of Contamination (ft)
Lower	B11	6.0	NR
	S9	AR	3.0 +
	S10	AR	10.0 +
Bench	B12	6.5	NR
	B13	10.2	NR
	B14	12.1	NR
	B15	10.8	NR
	S11	AR	0.0
	S12	AR	6.0 +
	S13	AR	3.0 +
	S14	AR	6.0 +
	S15	AR	3.0 +
	S16	AR	3.0 +
	S17	AR	2.0 +
	S18	AR	8.0 +
	S19	AR	6.0 +
	S20	AR	7.0 +
	S21	AR	9.0 +
	S22	AR	8.0 +
	S23	AR	6.0 +
	S24	AR	12.5 +
	S25	AR	6.0 +
	B-0	14	14.0
	B1-1	9.5	9.5
	B1-2	11.1	11.1
	B1-3	10.7	10.7
	B1-4	11.4	11.4
	C-MID	8.7	8.7
	C1-3	5.2	5.2
	D1-1	5.7	5.7
Upper	T-1	29.0	29.0
	T-2	26.0	26.0
	T-3	24.0	24.0
	T-5	21.0	12.0 *
	B16	30.5	NR
	B17	25.5	NR

AR - Auger refusal.
NR- No radiological analyses (these boreholes were drilled to determine chemical characteristics of the bulk wastes).
+ - Contamination extends beyond this depth
* - Analysis was performed for only Ra-226 and Ra-228.
**- See Figure 4.5 for sample locations.
Sources: BGA, 1984; BNI, 1985c; and Kaye and Davis, 1987.

location the maximum depth of contaminated material, occurred at 12.0 feet. At this location, however, samples were analyzed for only Ra-228 and Ra-226. Contamination from other radionuclides may extend to bedrock.

A volume of 11,000 cubic yards on the 30,400 ft^2 bench is estimated by assuming that radiological contamination extends to bedrock (average depth 9.7 feet). An average depth of contamination of 10 feet for the lower pile is estimated by assuming a constant pile slope from the present quarry floor (elevation 480 ft) to the top of the bench pile (elevation 500 ft). Applying this depth over the entire lower pile area of 16,800 ft^2 yields a volume of 6,200 cubic yards. By assuming a constant pile slope from an elevation of 515 feet to the upper gate plateau elevation of 555 feet (average contaminant depth of 20 feet) over an area of 5,550 ft^2, the volume of the upper pile is estimated to be 4,100 cubic yards. The total estimated volume contained in the northeast corner zone is the sum of the three piles described above, which is 21,300 cubic yards.

Rim Zone - The rim zone is divided into 6 areas of contamination not included in the major zones; i.e., the upper gate plateau and 5 small areas along the southeast and north quarry rim, shown on Figure 4.17.

The upper gate plateau area includes approximately 11,000 ft^2 and extends from the upper gate to the edge of the upper hill of the northeast corner zone, and about 150 feet down the roadway running along the northeast fence. The existence of contamination in this area is most likely due to accidental spills from trucks dumping waste over the northeast rim during the 1963 through 1969 dumping period. Maximum representative contaminant concentrations of surface soil samples (zero-to-6-inch depth) in this area are: 109 pCi/g for Ra-226, 250 pCi/g for Ra-228, 14 pCi/g for U-238, and 180 pCi/g for

Th-230 (BGA, 1984 and BNI, 1985c). Th-232 concentrations are not available for this zone. No subsurface soil samples were taken in this area. Since the assumed mode of contamination was truck spills, the depth of radiological contamination was assumed to be 0.5 foot. This gives an estimated volume in this area of 200 cubic yards.

The five remaining areas of the rim zone, identified as R1 through R5 on Figure 4.17, each include a single BNI surface soil sample exceeding DOE soil cleanup guidelines. Each area contains only 1 contaminated surface sample with all neighboring surface samples being below guidelines, and each area is also near a road (State Route 94 or the haul road along the quarry rim). A possible explanation of the origin of this contamination would again be accidental spills from trucks during hauling operations. No subsurface soil samples were taken at these locations. The volume of radiologically contaminated material at these locations is considered negligible.

4.1.2.3 Chemical Characteristics

In 1984, as a part of the radiological characterization, BNI collected six subsurface and one surface sample for chemical analysis. The samples were analyzed for Resource Conservation and Recovery Act (RCRA) characteristics, extraction procedure (EP) toxicity, priority pollutants, pesticides, polychlorinated biphenyls (PCBs), and asbestos. Subsurface sampling was accomplished with split-spoons driven in advance of an auger. Analyses were performed on a composite of the entire soil column at each location shown on Figure 4.7. The samples were reportedly collected, packaged, preserved and analyzed in accordance with EPA procedures identified in the July 1984 edition of 40 CFR 136 (BNI, 1985c).

Detected concentrations of metals, cyanide, organic priority pollutants, and other organic pollutants are summarized in Table 4.11. Complete data are provided in Appendix A. All extraction procedure (EP) toxicity results for the samples were below regulatory guidelines, which suggests that metals found within the quarry wastes are not readily leachable (Kaye and Davis, 1987). Most organic pollutants analyzed were below detection levels. Positive results were obtained for benzene hexachlorides; PCBs (Aroclor 1254), up to 46 mg/kg; polynuclear aromatic hydrocarbons (PAHs), up to 75 mg/kg; and diacetone alcohol, up to 14 mg/kg (BNI, 1985c).

It was reported that the presence of PCBs prevented the detection of certain pesticides and that a dilution factor was applied to radiologically contaminated samples to avoid contaminating the analytical equipment; however, no specific information regarding data quality or QA/QC procedures was reported. The results of this study indicate, in general terms, which of the analyzed constituents are present. However, due to the limited number of samples, the degree of compositing and the variability of the waste material, it was decided that additional information regarding the chemical composition of the material was needed to characterize the waste and to aid in preparing remedial action plans.

Based on the results of the 1984 study, BNI conducted a more extensive chemical characterization survey in 1986 (Kaye and Davis, 1987) in order to determine the presence and areal extent of selected chemical compounds including volatile organics, base-neutral and acid extractable organics (semi-volatiles), PCBs, trinitrotoluene (TNT), dinitrotoluene (DNT), and TNT breakdown products. A total of 88 samples were analyzed from 17 borings (see Figure 4.18) including 26 for volatiles, 68 for semi-volatiles, 67 for nitroaromatics, and 65 for PCBs. Borehole locations were selected based on historical

TABLE 4.11 Chemical Constituents Detected in Quarry Wastes During 1984-1985 Chemical Analysis

Parameter	Concentrations (mg/kg)[a] Subsurface Samples[b] Range	Average	Surface Sample
Priority Pollutant Metals and Cyanide			
Antimony	<20[c]	<20[c]	71
Arsenic	73 - 120	100	100
Beryllium	0.45 - 0.83	0.62	0.61
Cadmium	1.8 - 98	19	2.0
Chromium	19 - 49	30	24
Copper	38 - 160	100	140
Lead	130 - 410	280	950
Mercury	0.18 - 6.3	2.0	0.7
Nickel	19 - 120	43	300
Selenium	17 - 28	23	22
Silver	5.8 - 8.3	7.0	7.5
Thallium	3.0 - 6.2	4.7	5.1
Zinc	68 - 870	340	39
Cyanide	0.2 - 0.6	0.38	0.2
Organic Priority Pollutantsd,e			
Alpha-benzene hexachloride	0.0051 - 0.0053	0.0052	ND
Delta-benzene hexachloride	0.019 - 0.095	0.045	0.0035
Gamma-benzene hexachloride (lindane)	0.0013	0.0013	ND
PCB Aroclor 1254	0.56 - 46	12	1
PCB Aroclor 1260	9	9	ND
Other Organic Pollutants			
2-Pentanone-4-hydroxy-4-methyl (diacetone alcohol)	2 - 6[f]	4.6	14
2-Methylnaphthalene	0.67	0.67	<0.06[c]

a All compounds that gave one or more positive results (above detection limits) are listed in this table. Concentrations are generally rounded to two significant figures. Samples were taken in the last quarter of 1984 from six boreholes in the quarry wastes and one surface sample. (see Figure 4.7)

b Constituents were detected in all 6 samples except for; PCB Aroclor 1254, 2-pentanone-4-hydroxy-4-methyl, and cyanide in 5 samples; delta-benzene hexachloride and silver in 3 samples; alpha-benzene hexachloride in 2 samples; and gamma-benzene hexachloride in 1 sample.

c Lower limit of detection.

d The 29 volatile priority pollutants measured for were not detected at a sensitivity level of 1 ppb. The presence of PCBs increased the detection limit of most pesticides.

e Thirteen semi-volatile organic compounds were also detected at one borehole. These compounds are indicated with an asterisk on Table 4.12. Concentrations detected were within the range indicated on the table.

f Concentrations for diacetone alcohol are estimated concentrations.

ND not detected.

Source: BNI (1985c) and DOE (1987a).

data, including types of materials disposed, disposal locations, past characterization data, and topography. Samples were collected as the boreholes were advanced using split-spoons, or double tube core barrels if rubble was encountered. According to Kaye and Davis, water introduced into the boreholes to cool and lubricate the bit may have resulted in some leaching of chemicals from the solid soil matrix. Only those portions of the samples that were soil or soil-like materials were analyzed, and each borehole sample was divided into incremental (3 feet or less) samples.

As determined by Kaye and Davis (1987), 7 volatile compounds, 20 semi-volatiles, 5 nitroaromatic compounds, and 2 PCBs were detected. Table 4.12 summarizes the constituents detected in the survey (see Appendix A for additional data). The averages shown represent the average of detected values and do not necessarily represent the average concentration for the entire waste material. The concentrations of volatiles are somewhat questionable, since volatiles were also present in method and field blanks, suggesting the inadvertent introduction of some of these chemicals during field collection or laboratory extraction. Also, holding times were exceeded for essentially all of the samples. However, trichloroethene was not detected in the blanks and the detected concentrations of acetone, 2-butanone and toluene in the blanks were sufficiently low that these compounds may be present in the quarry. The detected semi-volatiles consisted primarily of PAHs, phthalates and a furan; phthalates are plasticizers commonly found in environmental samples. PAHs may be present in the quarry as a result of previous burning operations. Maximum observed concentrations of the PAHs were 150, 190, 110, and 170 mg/kg for phenanthrene, fluoranthene, benzo(b)fluoranthene, and pyrene respectively. Nitroaromatics detected included 2,4-DNT, 2,6-DNT, 2,6-diamino-4-nitrotoluene, 2,4,6-TNT, and 2,4-diamino-6-nitrotoluene.

Table 4-12 Organic Compounds, PCBs, and Nitroaromatics Detected in Quarry Wastes During 1986 Chemical Analysis

	Concentration (mg/kg) Range	Average[e]	Number of Boreholes Where Chemical was Detected	Borehole Where Maximum Value Was Detected[f]
Volatiles[b,c]				
Acetone	1.4 - 52	13	6	B6
2-Butanone	0.86 - 1.7	1.4	2	B6
Ethylbenzene	0.68 - 1.8	0.99	8	B5
Methylene Chloride	0.79 - 6.4	2.9	8	B16
Toluene	0.75	0.75	1	B3
Total Xylenes	0.66 - 1.4	0.95	2	B17
Trichloroethene	0.90	0.90	1	B7
Semi-Volatiles[c]				
Acenaphthene	1.7 - 18	7.6	4	B7
Dibenzofuran*	1.4 - 3.6	2.5	2	B8
Fluorene*	6.6 - 19	13	2	B7
Phenanthrene*	0.73 - 150	26	6	B6
Anthracene*	0.34 - 37	9.7	6	B6
Fluoranthene*	0.78 - 190	24	6	B6
Pyrene*	0.68 - 170	23	6	B6
Benzo(a)Anthracene*	0.53 - 86	15	6	B6
Chrysene*	0.46 - 89	13	6	B6
Benzo(b)Fluoranthene*	0.62 - 110	17.2	6	B6
Benzo(k)Fluoranthene*	0.78 - 0.98	0.88	2	B7
Benzo(a)Pyrene*	0.46 - 68	11	6	B6
Indeno(1,2,3-cd)Pyrene	0.45 - 49	9.3	6	B6
Dibenz(a,h)Anthracene	0.33 - 17	2.9	4	B7
Benzo(g,h,i)Perylene	0.41 - 50	10	6	B6
2,4-Dinitrotoluene[g]	1.7 - 10	6.3	1	B16
2,6-Dinitrotoluene[g]	0.53 - 3.7	1.6	1	B16
Di-n-butylphthalate*	0.47 - 0.58	0.53	2	B7
Bis(2-ethylhexl)Phthalates	0.66 - 1.6	1.0	3	B3
Naphthalene*	1.3	1.3	1	B4
PCBs[c]				
Aroclor 1254*	0.46 - 120	21	9	B8
Aroclor 1260*	9.1 - 12	11	1	B3

Table 4-12 Organic Compounds, PCBs, and Nitroaromatics Detected in Quarry Wastes During 1986 Chemical Analysis (Continued)

	Concentration (mg/kg) Range	Average[e]	Number of Boreholes Where Chemical was Detected	Borehole Where Maximum Value Was Detected[f]
Nitroaromatics[d]				
2,6-Diamino-4-Nitrotoluene	0.33 - 0.58	0.47	3	B7
2,4,6-Trinitrotoluene	0.38 - 1,600	260	6	B17
2,4-Dinitrotoluene	0.46 - 33	8.1	3	B16
2,6-Dinitrotoluene	0.36 - 68	9.5	3	B16
2,4-Diamino-6-Nitrotoluene	1.3 - 7.3	4.8	2	B17

a Chemical constituents that were detected above the detection limits are presented. Concentrations are rounded to two significant figures. Samples were collected in the last quarter of 1986 from 17 boreholes in the Quarry wastes (see Figure 4.18).

b Six of the seven volatile compounds detected in the samples were also found in method blanks. Only Trichloroethene was not detected in method blanks.

c Analyses for volatile organics, semi-volatile organics, and PCBs were performed in accordance with the EPA Contract Laboratory Program.

d Analyses for nitroaromatics were performed according to the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) Method 4B, using high pressure liquid chromatography.

e Averages are for detected values only and do not necessarily indicate the average concentration for the entire waste material.

f Detection of a chemical indicates that the species was detected in at least one incremental sample from a borehole. Each incremental sample was not necessarily tested for all chemical species.

g Also see concentrations under "Nitroaromatics" category for analyses by USATHAMA Method 4B.

* These compounds were also detected during 1984-1985 analysis by BNI (1985c).

Source: Kaye and Davis, 1987.

The highest concentrations of nitroaromatics were found in the eastern portion of the quarry (borings B16 and B17, shown on Figure 4.18). The maximum concentration of 2,4,6-TNT was 1,600 mg/kg, detected at boring B17. Two PCBs, Aroclors 1254 and 1260, were detected. The maximum PCB concentration was 120 mg/kg for Aroclor 1254 at boring B8 (see Figure 4.18). Aroclor 1254 was detected at nine boreholes, while Aroclor 1260 was detected only at boring B3, with a maximum concentration of 11.8 mg/kg (Kaye and Davis, 1987).

Quality control measures instituted include chain-of-custody documentation, generation of QC samples for blanks and duplicates, and matrix spiking. Field blanks were analyzed a minimum of once every six samples. The results indicate the presence of volatiles and nitroaromatics. Method blanks were analyzed a minimum of once every ten samples and detected the same volatile organics observed in the field blanks. Table 4.13

TABLE 4.13 Contamination of Blanks

Contaminant	Method Blanks (mg/kg)		Field Blanks (mg/kg)	
	Range	Average[a]	Range	Average[a]
Methylene Chloride	0.005-7.4	2.1	0.50 -12	3.8
Acetone	0.01 -3.2	3.4	0.99 -25	10
2-Butanone	0.01 -1.2	1.1	0.99 - 1.0	1.0
Toluene	0.005-1.1	0.82	ND[b]	NA[c]
Ethylbenzene	0.005-1.1	0.83	0.50 -1.0	0.77
Styrene	0.005-0.5	50.55	ND	NA
Total Xylenes	0.005-1.4	0.92	0.49 -1.4	0.92
2,6-Dinitrotoluene	ND	NA	0.046-4.30[d]	3.1[d]

a Average of those above detection limit.
b None above detection limit.
c Not applicable.
d Units = ug/l.
Source: Kaye and Davis, 1987

shows the range and average concentrations present in the blanks. Matrix spikes and matrix spike duplicates were analyzed, with matrix spikes analyzed once in every ten samples.

Table 4.14 summarizes the results for matrix spikes. Recovery values for volatiles and semi-volatiles were within or near the range of values generally accepted as part of the EPA Contract Laboratory Program (CLP). No generally accepted recovery range is provided by CLP for nitroaromatics; however, the values are believed to be reasonable. PCB recovery values were poor. The unusually low values shown in Table 4.14 were

TABLE 4.14 Matrix Spike Results

Parameter	Number of Analyses	Range of Recoveries (%)	Mean of Recoveries (%)	Range of Accepted Recovery (%)
Volatiles	6	26 - 133	96	59 - 172
Semi-volatiles	7	9 - 128	68	17 - 142
Nitroaromatics	8	20.9 - 127.2	88.8	b
PCBs		0 - 3 [c]	1 [c]	b

a Reference (EPA, 1985).

b None currently established.

c This value was calculated using 5 samples since 3 were out of control due to the low concentration of the spike compared to the concentration in the sample.

Source: Kaye and Davis, 1987

reported as matrix interference. Holding times were exceeded for 83 percent of the volatiles, 93 percent of the semi-volatiles, and 100 percent of both nitroaromatics and PCBs (Kaye and Davis, 1987).

Both BNI surveys involved analysis for volatiles, semi-volatiles, and PCBs. No volatiles were detected in the first study, which suggests that the volatiles detected in the second analysis are probably laboratory artifacts; however, differences could also be due to sampling method variations between studies. The PAHs were found in the same general location by both studies. PCB Aroclors 1254 and 1260 were also detected in both analyses.

In May 1987, PMC collected three surface samples from the northeastern corner of the quarry, where surficial discoloration suggested the presence of nitroaromatics. The sampled materials consisted of a soil and limestone aggregate mixture with an "oily" brown staining. Analytical results confirmed the presence of high nitroaromatic levels in this area. Maximum concentrations detected were 20,000 mg/kg for 2,4,6-TNT; 29 mg/kg for 2,4 DNT; 8.6 mg/kg for 2,6 DNT; 130 mg/kg for nitrobenzene; 280 mg/kg for 1,3,5-trinitrobenzene; and less than 0.8 mg/kg for 1,3-dinitrobenzene (Meyer, 1988).

The areal distribution of the chemicals found within the WSQ is shown on Figure 4.18. Results indicate that chemical contamination is present throughout the quarry, and that the distribution of the various contaminants is very heterogeneous. In general, however, the combustion products are found near the pond, while the nitroaromatics are more in the eastern end of the WSQ. This distribution is consistent with the disposal history, specifically the burning of waste near the pond and the disposal of nitroaromatic waste in the eastern portion of the site. Although the PCBs and phthalates did not show a defined

distribution, the highest concentrations were detected in the area near the pond, which is also the region where the majority of the wastes are deposited (Kaye and Davis, 1987).

The vertical distribution of chemicals is controlled by previous disposal practices, geologic conditions, and physical-chemical factors of the individual compounds which determine transport and deposition. PCBs were generally limited to near-surface depths (0-6 feet) while nitroaromatics and semi-volatiles were detected at greater depths. The bulk of the chemical contamination is found at depths of less than 12 feet, which is in general agreement with the vertical distribution of radiological parameters (Kaye and Davis, 1987). Table 4.15 summarizes the cumulative vertical distribution of chemicals found, and bar charts in Figure 4.19 show the vertical distribution at select locations. Additional bar charts for all borings are provided in Appendix A. Borings from the eastern end of the quarry (B16) and from the area near the pond (B7)

TABLE 4.15 Vertical Distribution of Chemicals at the Weldon Spring Quarry

Depth (ft)	Percent of Total Detected Mass			
	PCBs	Volatiles	Semi-Volatiles	Nitroaromatics
0-6	93	38	8	57
0-12	100	61	64	98
0-18	100	64	94	99
0-36	100	100	100	100

Source: Kaye and Davis, 1987

show the extreme variability in concentrations with depth. The charts also indicate the shift in chemical predominance in soil from nitroaromatics at the eastern end of the quarry to semi-volatiles in the area near the pond.

Although the analytical data from the two chemical characterization studies can not be validated in entirety, the general types of compounds identified are consistent with the past disposal practices. Given the extreme variability of the waste material and the relatively few samples taken, completely correlatable analytical data would not be anticipated. However, these chemical characterization data are considered sufficient for purposes of the planned bulk waste removal.

4.1.3 Additional Characterization

Current data provide an understanding of the contaminants present and their general location. However, because of sampling difficulties caused by the types and placement of the wastes, an accurate assessment of the total quantities and exact distributions of the contaminants is not possible.

Investigations confirm the presence of radiological and chemical constituents in general agreement with past disposal practices at the quarry. Collection of additional characterization data prior to the proposed bulk waste removal will not substantially increase current knowledge concerning the quarry wastes. In addition to the difficulty of drilling through the types of materials present and obtaining representative samples, the lubricating fluid required for drilling tends to wash and dilute the resultant samples. Trenching studies also would not permit complete characterization of the wastes. For the proposed bulk waste removal, the existing data are considered sufficient. Only as wastes are removed can a more definitive account of the material

be accomplished. Once the wastes have been excavated and transported to temporary storage, they can be more fully characterized prior to final disposition.

Saturated material such as soils, pond sediment, and uranium and thorium residues below the water table will also be removed from the quarry. It will be important to minimize the free water present in these materials to preclude spills of the liquids during transport and to minimize leachate at the temporary storage area. The characterization of wastes has not determined the moisture content and physical properties of the pond sediment or saturated residues. This type of information will be necessary to design a system to remove free water from sludge and saturated soil, as appropriate.

4.2 SOILS AND SEDIMENTS

4.2.1 Background Measurements

Background radionuclide concentrations and radiation levels measured in soils near the quarry are summarized in Table 4.16. These values are based on measurements taken by BNI (BNI, 1985c), ORAU (Boerner, 1986), UNC-Geotech (Marutzky, 1988), and WSSRAP (MK-F and JEG, 1988b). BNI collected soil samples from five locations within 1 to 7 miles of the quarry. Figure 4.20 shows the eight UNC-Geotech sampling locations. ORAU also made background measurements at six locations within 25 miles of the quarry, as shown in Figure 4.21.

A soil sample collected and analyzed near monitoring well TW-N, north of the WSQ (see Figure A.1) was assumed to represent background conditions. BNI measured volatile organics, semi-volatile organics, PCBs, and nitroaromatics in 1986. Two volatile organics were detected (ethylbenzene at 0.88 mg/kg and methylene chloride at 2.4 mg/kg), but these may be laboratory

TABLE 4.16 Background Radiation Levels and Radionuclide Concentrations in Soil in the Vicinity of the WSQ

	Level or Concentration[c]	
	Range	Average
Gamma Exposure Rate at 3 ft. (uRoentgens/h)[a]	5-11	8.7
Surface Beta-Gamma Dose Rate (mrad/h)[b]	0.03-0.05	0.04
Radionuclide Concentrations (pCi/g)		
Uranium as U-238[a]	0.6-2.0	1.3
Ra-226[a]	0.3-1.5	0.9
Th-230[b]	0.1-0.3	0.2
Th-232[a]	0.3-1.5	1.0
Lead-210[a]	0.5-2.0	1.3

a Based on values reported in: BNI, 1985c; Boerner, 1986; Marutzky et al, 1988; and MK-F and JEG, 1988b.

b Based on values reported in BNI, 1985c.

c Sample locations are shown on Figures 4.20 and 4.21.

artifacts. Bis(2-ethylhexl)phthalate was detected at a concentration of 1.8 mg/kg. No other constituents were detected.

To assess radiological contamination in sediments, ORAU (Boerner, 1986) measured background radionuclide concentrations in sediments in the quarry vicinity. U-238 concentrations ranged from less than 0.60 to 1.44 pCi/g, with an average concentration of about 0.95 pCi/g. Concentrations of Ra-226 and

Th-232 ranged from 0.35 to 0.92 pCi/g and from 0.24 to 1.02 pCi/g, respectively. These values were based on sediment samples collected from five locations within 25 miles of the quarry. Sample locations are shown on Figure 4.21.

4.2.2 Guidelines and Criteria

DOE has established guidelines for radionuclide contamination in soil and sediment for Surplus Facilities Management Program (SFMP) and Formerly Utilized Sites Remedial Action Program (FUSRAP) sites. The guidelines for residual concentrations of Th-232, Th-230, Ra-228, and Ra-226 are 5.0 pCi/g, averaged over the first 15 centimeters of soil below the surface; and 15 pCi/g, averaged over 15-centimeter-thick layers of soil more than 15 centimeters below the surface (DOE, 1987b). These values represent the level of residual radioactivity that is acceptable for unrestricted use of a site. Concentrations of radionuclides are to be specified as above background concentrations averaged over an area of 100 square meters. Uranium and chemical contamination guidelines for this site are currently not available. Site specific guidelines will be established prior to the final remediation of the quarry.

4.2.3 Sediment Characteristics

4.2.3.1 Radiological Contamination

As part of BNI's radiological survey (BNI, 1985c), three sediment or sludge samples were taken at different locations from the quarry pond. Sediment samples were analyzed by basic radiochemical techniques for U-234, -235, and -238; Ra-226; Th-230 and -232; and Ac-228. The radionuclide concentrations detected in the three sediment samples are shown in Table 4.17. Results indicate elevated concentrations of U-234, -235, -238,

TABLE 4.17 Radionuclide Concentrations in Sediment from the Quarry Pond

Radionuclide	Concentration (pCi/g)[a] Sample 1	Sample 2	Sample 3	Average
U-234	765	770	1180	905
U-235	31	227	62	107
U-238	762	735	1170	889
Ra-226	11	6.9	3	7
Th-230	405	220	323	316
Th-232	3.9	2.7	0.2	2.3
Ac-228	2.3	2.6	2.7	2.5

[a] per BNI, 1985c

Ra-226, and Th-230. Sample 2 in Table 4.17 also indicates enriched uranium, the implications of which were discussed earlier in Section 4.1.2.2.

LBL also analyzed pond sediment samples for U-238 content. Four samples were collected from mud and organic sediments, and showed U-238 concentrations of 129 pCi/g and 198 pCi/g in the organic sediments, and 25 pCi/g and 63 pCi/g in the mud sediments (see Table B.2 in Appendix B). The particularly high U-238 concentrations in the organic sediments suggests precipitation of the transported uranium in the reducing environment provided by decaying organic matter at the bottom of the quarry pond (BGA, 1984).

Actual depths of sediment contamination have not been established. However, LBL concluded that uranium concentrations generally decreased with depth, based on their analysis of an 18-inch continuous core sample taken from the south edge of the quarry pond. Concentrations ranged from 20.7 pCi/g near the top to about 0.9 pCi/g at depth (BGA, 1984).

4.2.3.2 Chemical Contamination

As part of their chemical characterization study in 1986, BNI collected five sediment samples from the quarry pond using a Ponar Grab Sampler. Analyses for semi-volatiles, nitroaromatics, and PCBs were completed for all samples while analyses for volatiles were completed for two samples. All results are provided in Appendix B. Three volatiles, 13 semi-volatiles, one PCB, and one nitroaromatic were above the detection limit. It is important to note that all three volatiles were also found in the field and method blanks, and that two of the three volatiles were found at a background location. These observations strongly suggest that the presence of these volatile organics at concentrations above the detection limit is a laboratory artifact. The semi-volatile compounds in pond sediment are consistent with the distribution of these compounds in the bulk wastes. The maximum observed concentrations of the PAHs in sediment included 18, 18, and 13 mg/kg for phenanthrene, fluoranthene, and benzo(b)fluoranthene, respectively. These PAHs are the same compounds for which maximum concentrations were observed in soils from the quarry. TNT was the only nitroaromatic observed in sediment from the pond, and was detected at a concentration of 0.33 mg/kg in the southernmost portion of the pond. Only one sediment sample, taken along the eastern portion of the quarry pond, indicated the presence of PCBs. Aroclor 1254 was detected at a concentration of 4.8 mg/kg. (Kaye and Davis, 1987)

4.2.4 Additional Characterization

The radiological and chemical characteristics of the sediment at the quarry have been sufficiently defined for the bulk waste removal. Once these materials have been excavated and transported to temporary storage, they can be more fully characterized prior to final disposition.

4.3 SURFACE WATER

4.3.1 Background Measurements

Water in the Missouri River near St. Charles is moderately mineralized (Missouri Geological Survey, 1977). Calcium, magnesium, sodium bicarbonate, and sulfate are the predominant chemical constituents, and the content of dissolved solids varies depending on the amounts of these constituents. Turbidity is relatively high, although upstream regulation has resulted in decreases over recent years.

BNI has measured background radionuclide concentrations in surface water (1985c). Surface water samples were collected from three locations within 1 to 7 miles of the quarry, and were analyzed for total uranium; U-234,- 235, and -238; Ra-226; Th-230; and Ac-228. Resultant radionuclide concentrations (range and average) are presented in Table 4.18. Gross alpha and gross beta concentrations were measured by ORAU (Boerner, 1986) and are also provided in Table 4.18. ORAU collected water samples from six locations near the quarry, as shown in Figure 4.21.

TABLE 4.18 Background Radiological Measurements in Surface Water[a,b]

	Concentration (pCi/l) Range	Average
Gross Alpha	0.48 - 4.09	1.78
Gross Beta	3.50 - 7.39	4.94
Total Uranium	<1.5	<1.5
U-234	0.3 - 1.4	0.9
U-235	<0.1	<0.1
U-238	0.3 - 1.4	0.9
Ra-226	0.1 - 0.2	0.1
Th-230	<0.2	<0.2
Ac-228	<5.0	<5.0

a Gross alpha and gross beta concentrations are based on six water samples (Boerner, 1986). Sample locations are shown on Figure 4.21

b Radionuclide concentrations are based on three water samples (BNI, 1985c).

4.3.2 Guidelines and Criteria

Water quality standards and criteria can be used to assess the extent of water contamination and potential hazard due to radiological and non-radiological contaminants from the WSQ. Since water at the quarry is not a source of drinking water, standards and criteria presented here are for comparison purposes only.

Radiation protection standards and associated Derived Concentration Guides (DCGs) for drinking water have been established by DOE (DOE 1986a). Based on radiological toxicity, the maximum permissible concentrations for radionuclides are presented in Table 4.19. These concentrations are based on an annual radiation protection standard of 100 mrem/yr (MK-F and JEG, 1988a).

Water quality standards for various chemical species have been established for drinking water supply and irrigation water by the state of Missouri (Missouri Water Quality Standards: 10 CSR Part 20-7 as revised on December 12, 1987). The criteria for drinking water in Missouri are presented in Table 4.20, and are as stringent as the EPA Primary Drinking Water Standards (40 CFR Part 141.11). Criteria for irrigation water in Missouri are 0.1 mg/l for arsenic, beryllium, and chromium, and 2 mg/l for boron (10 CSR Part 20-7, December 12, 1987). The EPA Secondary Drinking Water Standards (40 CFR 143.3, February 1988) also limit total dissolved solids (TDS) to 500 mg/l and the pH range from 6.5 to 8.5.

TABLE 4.19 DOE Derived Concentration Guide For Radionuclides in Drinking Water[a]

Radionuclide	DOE Derived Concentration Guide (pCi/l)[b]
U - 238	600
U - 235	600
U - 234	500
U - Natural	550[c]
Th - 232	50
Th - 230	300
Ra - 228	100[d]
Ra - 226	100[d]

a MK-F and JEG, 1988a

b Based on a radiation protection standard of 100 mrem/yr.

c MK-F and JEG, 1987

d The DOE DCGs for Ra-228 and Ra-226 exceed the EPA Primary Drinking Water Standard for combined Ra-228 and Ra-226 of 5 pCi/l and for gross alpha particle activity (including Ra-226 but excluding radon and uranium) of 15pCi/l (40 CFR 141.15).

TABLE 4.20 State of Missouri Regulatory Limits on Concentrations of Chemical Species in Drinking Water

Chemical Species	Concentration[a] (mg/l)
Antimony	0.146
Arsenic	0.05
Barium	1
Cadmium	0.01
Chromium	0.05
Copper	1.0
Iron	0.3
Lead	0.05
Manganese	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Thallium	0.013
Zinc	5
Chloride	250
Fluoride	2.2
Nitrate (as N)	10
Sulfate	250

a These values are based on the Missouri Water Quality Standards (10 CSR, Part 20-7 as revised on December 12, 1987) and are at least as stringent as the EPA Primary and Secondary Drinking Water Standards (40 CFR Parts 141.11 and 143.3) with the exception of fluoride for which the Secondary Standard is 2.0 mg/l. The Primary Standard for fluoride is 4.0 mg/l.

EPA has established water quality criteria for certain toxic pollutants, which were published in the Federal Register on November 28, 1980 (v. 45, F.R. 79318). Criteria for selected pollutants are 14.3 mg/l for toluene, 15 mg/l for bis(2-ethylhexl)phthalate, 34 mg/l for di-n-butyl phthalate, and 350 mg/l for diethyl phthalate. These criteria were established for the protection of human health from the toxic properties of the pollutant ingested through water and contaminated aquatic organisms. Because of potential carcinogenic effects, the ambient water quality criteria for 2,4-dinitrotoluene (0.11 ug/l) is based on an increased lifetime cancer risk of 10^{-6}. The proposed maximum contaminant level guideline (MCLG) for asbestos is 7.1 X 10^{6} fibers/liter (MacDonell et al, 1989).

4.3.3 Surface Water Characteristics

4.3.3.1 Radiological Contamination

The pond is the only surface water feature within the quarry, and contamination in the pond is clearly a result of the wastes stored in the quarry. Studies have shown that uranium concentrations in the pond water are above DCG limits. Historical values of uranium are presented in Table 4.21. Very little uranium was present in the quarry pond before water was pumped out between 1960 and 1963 (Kleeschulte and Emmett, 1986). When water was removed, the pond responded as a large-diameter well, and uranium values increased significantly as water moved through the wastes toward the pond (Richardson, 1960b). The high concentration in 1967 (16,000 pCi/l) was detected in a sample collected from the bottom of the pond and suggests that stratification may occur. The much lower 1974 value (1500 pCi/l) was observed in a sample collected 3 inches below the water surface (Pennak, 1975). Depths associated with other data are not available. Since 1974, uranium activity has remained relatively stable. Changes of several hundred pCi/l

TABLE 4.21 Historical Uranium Activities for WSQ Pond Water[a]

Year	Number of Samples	Total Uranium Concentration (pCi/l)[b] Range	Average
1960	1	2	2
1961	8	60 - 4500	1680
1962	12	290 - 8000	3670
1963	6	2100 - 12500	8350
1964	6	30 - 4100	2200
1967[c]	1	16000	16000
1974[d]	1	1500	1500
1976	1	3200	3200
1977	6	2800 - 4300	3600
1979	3	3100 - 3200	3170
1980	2	2200 - 2500	2350
1981	1	2000	2000
1984	1	1400	1400
1985	1	1240	1240
1987	1	2100	2100

a Sources: 1960 - 1964 data, Mallinckrodt Chemical Works (1960-1964); 1967 data, Lenhard et al (1967); 1974 data, Pennak (1975); 1977 data, Huey (1978); 1976, 1979-1981 data, BGA (1984); 1984 data, Kleeschulte and Emmett (1986); 1985 data, BNI (1985c); and 1987 data, MK-F (1987a).

b Uranium data in the references are given in units of uCi/cc (1960-1964 data and 1967 data), ppm (1976-1981 data), pCi/l (1974, 1985, and 1987 data), and ug/l (1984 data). The data given in units of mg/l or ppm were converted to pCi/l total uranium using the conversion factor of 1 mg/l = 1 ppm = 668 pCi/l.

c Sample collected from the bottom of the Quarry pond.

d Sample collected 3 in. from surface.

TABLE 4.22 Radionuclide Concentrations Observed in Quarry Pond Water

Radionuclide	Concentration[a] Range (pCi/l)
Ra-226	0.2 - 3.9
Ra-228	0.45 - 3
Th-230	0.3 - 2
Th-232	0.5 - 2
Pb-210	4 - 5

a Based on data presented in Table H.4 of the Draft EIS (DOE, 1987a), March 1987 sampling and analysis by WSSRAP (MK-F, 1987a) and composite sampling and analysis by BNI (1985c). Concentrations observed in a sample collected from the bottom of the Quarry pond are not included (see text).

may represent seasonal variations or differences between sampling methods or locations.

In 1985, BNI took composites from the quarry pond and had them analyzed for isotopic uranium. Those analyses indicated average concentrations for U-234, -235, and -238 of 600, 30, and 610 pCi/l, respectively (BNI, 1985c).

Water samples from the quarry pond have also been analyzed for other radionuclides. Table 4.22 summarizes the observed concentrations of Ra-226, Ra-228, Th-230, Th-232, and Pb-210. Compared to background levels, slightly elevated concentrations have been detected. A sample collected from the bottom of the pond in 1967 showed considerably higher concentrations of Ra-226

(30 pCi/l), Ra-228 (140 pCi/l), and Th-232 (less than 100 pCi/l) which further provides evidence of stratification (Lenhard et al, 1967). However, all concentrations have been below the established DOE DCGs for the ingestion of drinking water.

4.3.3.2 Chemical Contamination

As part of the preliminary chemical characterization survey in 1984, BNI collected grab samples from the quarry pond at two locations. The samples from each location were combined to make composites that were analyzed for the presence of priority pollutants, pesticides and PCBs, and asbestos. Results are provided in Appendix C. Organic priority pollutants, pesticides, and PCBs were not detected. Low levels of chromium, mercury and zinc were detected at 0.02, 0.0006, and 0.02 mg/l, respectively; but did not exceed drinking water standards (BNI, 1985c). These data plus other data described below are included in Table 4.23. Asbestos fibers were measured at a concentration of 1.9×10^6 fibers/liter (BNI, 1985c). This concentration is less than the proposed MCLG of 7.1×10^6 fibers/liter.

In 1986, BNI contracted Envirodyne Engineers, Inc. and TMA/NORCAL to perform more detailed chemical analysis on two additional pond water samples. Organic compounds detected in the samples are presented in Table 4.24. Results of this analysis indicated that, of the organics analyzed, only 2,4-dinitrotoluene exceeds the EPA water quality criteria for 10^{-6} risk of 0.11 µg/l (Glenn, 1986).

A single grab sample was collected in March, 1987 from the pond surface and analyzed for radiological parameters, metals, inorganic anions and water quality parameters (MK-F, 1987a). All constituents analyzed, with the exception of nitrate, were within the range of previous measurements as presented in Table 4.23. The suspect nitrate value of 546 mg/l (as N) exceeds the

drinking water standard of 10 mg/l (as N) and is outside of the historical concentration ranges presented in Table 4.14. Subsequent sampling support the earlier nitrate values in Table 4.23.

A comparison of measured concentrations in Table 4.23 with the Missouri drinking water limits indicate that only the average concentrations for arsenic and manganese have exceeded the drinking water standards for the inorganic constituents shown.

An Interim Response Action (IRA) has been proposed for the construction and operation of a water treatment system for the quarry. Water will be collected, treated, and then discharged to the Missouri River to reduce the risk of contaminant migration and to facilitate future remedial action at the quarry. A feasibility report for the water treatment plant was completed in May 1987 (MKE, 1987), and an Engineering Evaluation/Cost Analysis (MacDonell et al, 1989) has been prepared.

4.3.4 Surface Water Monitoring

An Environmental Monitoring Program Plan (EMPP) is being developed for 1989 which will describe the location, frequency, and chemical and radiological analytical parameters to be analyzed. To monitor potential migration of contaminants from the quarry, surface water sampling at the locations shown on Figure 4.22 will continue. Samples will be analyzed for radionuclides, inorganic anions, and metals. Currently, surface water samples are collected on a quarterly basis and results are published in the Annual Environmental Monitoring Reports for the Weldon Spring Site (e.g., MK-F and JEG, 1988a).

TABLE 4.23 Chemical Constituents in the Quarry Pond and Drinking Water Limits

	Concentration (mg/l)[a] Range	Average	Concentration[b] (mg/l)	Missouri Drinking[c] Water Limit Concentrations (mg/l)
Aluminum	<0.1 - 0.08	.045	0.17	
Antimony	-	-	<0.06	0.146
Arsenic	<0.001 - 0.15	0.075	<0.01	0.05
Barium	0.04 - 0.36	0.11	0.05	1
Beryllium	<0.001	<0.001	<0.005	
Boron	0.52 - 0.60	0.56	-	
Cadmium	<0.001 - 0.01	<0.006	<0.005	0.01
Calcium	70 - 100	86	83	
Chromium	<0.001 - 0.02	0.013	0.051	0.05
Cobalt	<0.01	<0.01	<0.05	
Copper	<0.001, 0.02	<0.01	0.013	1
Cyanide	<0.02	<0.02	-	
Iron	0.003 - 0.33	0.068	0.071	0.3
Lead	0.002, 0.05	<0.05	<0.005	0.05
Lithium	<0.01 - 0.036	0.025	-	
Magnesium	16 - 26	22	17	
Manganese	0.003 - 0.26	0.07	0.038	0.05
Mercury	0.0001- 0.0006	0.0004	<0.0002	0.002
Molybdenum	<0.01 - 0.07	0.035-		
Nickel	<0.001 - 0.02	<0.01	<0.04	
Phosphorus (as P_2O_5)	<0.5	<0.5	-	
Potassium	11 - 18	15	10	
Selenium	<0.05	<0.05	<0.005	0.01
Silicon (as SiO_2)	13 - 21	16	-	

TABLE 4.23 Chemical Constituents in the Quarry Pond and Drinking Water Limits (Continued)

	Concentration (mg/l)[a] Range	Average	Concentration[b] (mg/l)	Missouri Drinking[c] Water Limit Concentrations (mg/l)
Silver	-	-	0.015	0.05
Sodium	14 - 29	22	15	
Strontium	0.37 - 0.54	0.47	-	
Thallium	-	-	<0.010	0.013
Tin	<0.05	<0.05	-	
Titanium	-	-	<0.01	
Vanadium	-	-	<0.05	
Zinc	0.005 - 0.31	0.068	0.007	5
Chloride	14 - 200	44	8	250
Fluoride	0.9 - 1.1	1.0	0.43	2.2
Nitrate (as N)	<1 - 9	3.7	e	10
Sulfate	150 - 240	200	202	250
Bicarbonate	190 - 220	210	-	
pH (in units)	7.3 - 8.2	7.7	-	6.5 - 8.5[d]

a Per DOE, 1987a; samples were collected in 1979-1981, 1984 and 1985.

b Per MK-F, 1987a; sample was collected 3/11/87.

c These values are based on Missouri Water Quality Standards (10CSR, Part 20-7 as revised on December 12, 1987) and are at least as stringent as the EPA Primary and Secondary Drinking Water Standards (40 CFR Parts 141.11 and 143.3), with the exception of fluoride where the Secondary Standard is 2.0 mg/l. The Primary Standard for fluoride is 4.0 mg/l.

d From EPA Secondary Drinking Water Standards (40 CFR Part 143.3)

e Detected concentration of 546 mg/l (as N) has been disregarded; see text.

TABLE 4.24 Cyanide and Organic Compounds Present in the Quarry Pond

Compound	Concentration[a] (µg/l)
Cyanide	3
Toluene	5
Bis (2-ethylhexl) phthalate	2
Di-n-butyl phthalate	3
Diethyl phthalate	2
2-amino-4, 6-dinitrotoluene	26
2, 4, 6-trinitrotoluene	9
4-amino-2, 6-dinitrotoluene	15
2, 4-dinitrotoluene	10
2, 4-diamino-6-nitrotoluene	6
2, 6-diamino-4-nitrotoluene	3
6-amino-hexanoic acid	254

a per MKE, 1987 (after Glen, 1986)

4.3.5 Additional Characterization

Additional surface water characterization to initiate the bulk waste removal is not needed. The surface water monitoring program described in subsection 4.3.4 will be sufficient to monitor potential surface water problems associated with the bulk waste removal.

4.4 GROUNDWATER

4.4.1 Background Measurements

A comprehensive aquifer-wide characterization of background groundwater quality has not been performed, although LBL performed a specific ion analysis at the quarry which provides some localized information. Their analyses indicate that bedrock groundwater at the quarry is enriched in calcium, magnesium, carbonate, and sulfate, and displays low levels of

iron. The presence of the first three constituents is likely a reflection of the chemistry of the limestone bedrock. It is not clear whether the elevated sulfate levels are due to leaching from the contaminants in the quarry, natural conditions, or inflow of groundwater containing elevated sulfate levels from offsite (BGA, 1984; MK-F and JEG, 1987).

Between 1960 and 1964, Mallinckrodt Chemical Works tested groundwater samples from Test Well 1 (TW-N) for uranium concentrations. The range of average yearly values was 5 to 22 pCi/l, which, at the time, were believed to be background levels. However, because TW-N may be affected by contaminant migration from the WSQ, these values are no longer considered background. Although levels have not been established for the bedrock aquifer at the quarry, the USGS has determined that background uranium concentrations in the shallow bedrock aquifer to the north range from less than 0.3 to 2.5 pCi/l (Kleeschulte and Emmett, 1987). This range is fairly typical of areas which are not influenced by uranium mines.

4.4.2 Guidelines and Criteria

To assess potential hazards due to radiological and chemical contaminants, the water quality standards and criteria discussed in subsection 4.3.2 can be used. It is not intended to address groundwater contamination in the area of the quarry in this report since complete characterization will be accomplished in subsequent compliance documents.

4.4.3 Groundwater Characteristics

4.4.3.1 Radiological Contamination

Groundwater in the quarry bedrock has been tested for radiological parameters since 1960. Tables D.1 and D.2 in

Appendix D show the results of monitoring for total uranium, Ra-226, and Th-230 between 1960 and 1986. None of the wells were sampled on a consistent basis over the entire 26-year period. Well locations are shown on Figure D.1.

Table 4.25 summarizes the range of concentrations detected in the groundwater. Results show that bedrock groundwater is contaminated with uranium; highest concentrations have generally been found in the southeast region of the WSQ. A high uranium concentration of 18,700 pCi/l was detected in well TW-8 in 1977. Uranium concentrations detected in 1987 are shown on Figure 4.23. Although elevated levels of Ra-226 and Th-230 have been detected, concentrations have all been below the DCG established by DOE (see Table 4.19).

In 1986, wells MW-1001, MW-1002, and MW-1003 were constructed to replace TW-S, TW-7, and TW-8. After installation, uranium concentrations detected in the new wells

TABLE 4.25 Radionuclide Concentrations Detected in Groundwater at the WSQ

Radionuclide	Concentration Range (pCi/l
Total Uranium[a,b]	3 - 18,700
Ra-226[a]	0.1 - 31.6
Th-230[c]	<0.1 - 43

a based on data provided in Table D.1 in Appendix D.
b detection limits varied throughout the sampling period
c based on data provided in Table D.2 in Appendix D.

were significantly lower than values previously detected at the same locations (Table D.1 in Appendix D). It is believed that the new wells were sealed off from the groundwater regime during grouting of the old wells and that concentrations detected at these new replacement wells are not representative (MK-F and JEG, 1988a).

Neither the vertical flow of groundwater in the bedrock nor the extent of vertical contamination in the bedrock has been defined. It is known that the contamination in the bedrock around the quarry extends from the lower portions of the Kimmswick to the Decorah Formation. The upper Plattin below the alluvium north of the Femme Osage Slough may also be contaminated. The existence or extent of groundwater contamination below these strata have not been evaluated to date. A more detailed assessment of groundwater contamination will be addressed as a subsequent compliance component.

4.4.3.2 Chemical Contamination

Prior to 1987, annual monitoring of groundwater was restricted to radiological parameters and selected inorganic ions (chloride and nitrate). Special investigations, however, did include more rigorous testing of groundwater chemistry. Chemical characterization was greatly expanded during the 1987 monitoring program. Tables D.3 through D.6 in Appendix D present the concentrations of chemical species detected in bedrock groundwater at the quarry.

From 1979 to 1980, LBL and the University of Missouri conducted specific ion analyses on samples from the TW series and OB series wells for the presence of Ca, Mg, Na, K, bicarbonate, sulfate, Cl, nitrate, B, Ba, F, Fe, Li, Mn, P, silica, Sn, Sr, and Zn. The purpose of the analyses was to use ions as potential tracers of groundwater movement and to

determine soil sorption properties. In general, it was found that water samples high in uranium also tended to be high in total dissolved solids (TDS) except bicarbonate, suggesting that other ions in addition to uranium are being leached from the quarry materials and transported via groundwater. However, only sulfate has been conclusively correlated with the presence of high uranium levels (BGA, 1984).

The Phase I Water Quality Assessment (MK-F, 1987a), performed from sampling in March 1987, provided the first comprehensive chemical groundwater evaluation. Ten monitoring wells in the quarry area, four of which were completed in bedrock, were sampled and analyzed for radiological parameters (discussed in previous subsection), priority pollutants, pesticides, PCBs, nitroaromatics, CLP metals and inorganic anions. Pesticides, PCBs and semi-volatiles were not detected in any groundwater samples. No elevated concentrations of CLP metals were observed. Elevated concentrations of nitroaromatics and inorganic anions were detected in several wells. Nitrate levels in excess of drinking water standards were observed in wells MW-1004 and MW-1005. Elevated sulfate concentrations were observed in numerous wells at the WSQ. Elevated levels of chloride were also found, but their concentrations were well below state drinking water limits. Low concentrations of nitroaromatic compounds were observed in Quarry rim wells. This contamination originated as waste material deposited in the WSQ (MK-F, 1987a).

Additional sampling and analyses at the quarry continued as part of the WSSRAP annual environmental monitoring program. Quarterly groundwater samples were analyzed for nitroaromatics and inorganic anions, as well as for radionuclides discussed previously. Results are provided in Appendix D. These analyses confirmed the presence of low levels of nitroaromatics plus nitrate and sulfate levels above drinking water standards.

Chloride levels were elevated but still below drinking water standards. Figures 4.24 and 4.25 illustrate the average concentrations of nitrates and sulfates detected in bedrock groundwater at the quarry during 1987. Nitrate levels in excess of drinking water standards (10 mg/l as N) were detected along the south quarry rim. Elevated sulfate levels (greater than 50 mg/l) were observed in all wells at the WSQ (see Figure 4.25). Average chloride concentrations were below 50 mg/l at all wells except at MW-1012, where the average chloride concentration was 125 mg/l. Nitroaromatic compounds were detected in wells MW-1002, MW-1004 and MW-1012 (see Table A.4). The highest average concentration noted at the quarry for 1987 was 3.45 ug/l for 2,4,6 TNT at MW-1002. (MK-F and JEG, 1988a)

4.4.4 Groundwater Monitoring

Twenty-eight DOE monitoring wells currently exist at the WSQ and vicinity. Eleven of these wells monitor bedrock groundwater quality at and very near the quarry. The remaining seventeen wells are completed in the alluvial aquifer. Completion information for all DOE WSQ monitoring wells is presented in Table 4.26. Monitoring well locations are shown in Figure 4.26. As mentioned previously, MW-1001, MW-1002, and MW-1003 may be isolated from the groundwater regime by grout from the abandonment of the corresponding TW-series wells at each site. Wells MW-1020 through MW-1028 were installed recently and monitoring at them began in late 1988. The four St. Charles County monitoring wells (RMW-1, -2, -3, and -4) are also monitored by DOE.

This monitoring network will be routinely sampled before, during and after bulk waste removal to establish baseline conditions and evaluate the effects of bulk waste removal on groundwater quality. The Environmental Monitoring Program Plan describes the location, frequency and analytical parameters to

TABLE 4.26 Weldon Spring Quarry Monitoring Well Construction Details

Well Number	Old Well Number	Elevation Top of Casing (ft. msl)	Total Depth (ft.)	Screen Interval Elevation (ft. msl)	Screen Length (ft.)
+*MW-1001	TW-S	548.29	114.0+	443.5+ - 438.5+ D	5.0
+*MW-1002	TW-7	558.12	121.6+	447.5+ - 442.5+ D	5.0
+*MW-1003	TW-8	543.82	108.0+	455.9+ - 450.9+ D	5.0
+*MW-1004	TW-9	538.21	100.5+	451.9+ - 446.9+ D	5.0
+*MW-1005	TW-10	540.96	105.0+	445.4+ - 440.4+ D	5.0
MW-1006	OB-6A	456.37	11.0	450.3 - 445.3 A	5.0
MW-1007	OB-6B	456.86	11.5	445.6 - 442.6 A	3.0
MW-1008	OB-10A	456.09	10.0	448.5 - 445.5 A	3.0
MW-1009	OB-10B	456.99	15.0	446.1 - 441.1 A	5.0
MW-1010	OBS-16A	457.42	27.5	437.4 - 432.4 A	5.0
MW-1011	OBS-16B	457.97	17.5	445.7 - 440.7 A	5.0
* MW-1012	TW-N	532.25	91.3	452.8 - 442.8 D	10.0
* MW-1013	NEW	460.39	35.0	432.9 - 422.9 D,P	10.0
MW-1014	NEW	460.30	21.2	442.1 - 437.1 A	5.0
* MW-1015	NEW	462.17	30.5	444.0 - 429.0 D	15.0
MW-1016	NEW	461.55	15.5	449.2 - 444.2 A	5.0
MW-1017	NEW	460.16	55.5	422.1 - 402.1 A	20.0
MW-1018	NEW	462.10	49.0	431.5 - 411.5 A	20.0
MW-1019	NEW	464.11	68.0	413.5 - 393.5 A	20.0
MW-1020	NEW	462.93	37.9	443.3 - 423.3 A	20.0
MW-1021	NEW	461.26	78.3	401.5 - 381.5 A	20.0
MW-1022	NEW	460.62	42.5	440.8 - 420.8 A	20.0
MW-1023	NEW	460.42	37.5	440.7 - 420.7 A	20.0
MW-1024	NEW	406.29	38.8	386.2 - 366.2 A	20.0
* MW-1025	NEW	528.82	80.2	465.7 - 445.7 K,D	20.0
MW-1026	NEW	483.73	80.5	422.0 - 402.0 A	20.0
* MW-1027	NEW	488.21	45.0	460.1 - 440.1 D	20.0
* MW-1028	NEW	467.77	47.0	437.5 - 417.5 P	20.0

* Wells completed in bedrock

\+ Construction data for wells MW-1001 through MW-1005 are from 1984 completion records; those wells were rebuilt in 1986. Completion records for the rebuilt wells are not available.

A Screened in Alluvium/Soils above bedrock

K Screened in Kimmswick Formation

D Screened in Decorah Formation

P Screened in Plattin Limestone

See Figure 4.26 for well locations.

Source: Maher, 1989 and unpublished PMC files.

be analyzed in groundwater. This plan will be revised annually. Current groundwater monitoring parameters include: uranium, Ra-226, Th-230 and -232, nitrate, sulfate, chloride, fluoride, and nitroaromatic compounds. Groundwater monitoring results are presented in the Annual Environmental Monitoring Reports of the Weldon Spring Site (e.g., MK-F and JEG, 1988a). Data from bedrock monitor wells at the quarry are included in Appendix D of this report.

4.4.5 Additional Characterization

Additional groundwater characterization beyond that described above will not be needed to design the bulk waste removal. There may, however, be the need for the installation and monitoring of one or two bedrock wells west of the quarry and one southeast of the quarry and south of the slough (between MW-1020 and MW-1023) to detect potential excursions of contaminants in bedrock during the bulk waste removal.

4.5 AIR

4.5.1 Background Measurements

Both Rn-222 and Rn-220 are present at the quarry, although Rn-222 predominates. Rn-220 is produced by the decay of Ra-224, while Rn-222 is produced by the decay of Ra-226. The term radon as used in this report refers to all isotopes of radon. U-238 and Th-232, the long-lived parent radionuclides of Ra-226 and Ra-224, respectively, are naturally present in soil. The background concentration of radon fluctuates with both soil conditions and meteorological dispersion conditions. Background levels of average annual radon concentrations have ranged from about 0.2 to 0.5 pCi/l, based on data collected between 1983 and 1987. From 1983 to 1985, radon measurements taken at Florissant, Missouri were considered by BNI to be background

levels and ranged from 0.2 to 0.5 pCi/l (BNI 1984b, 1985b, 1986). Since 1986, background levels (0.47 pCi/l in 1986 and 0.3 pCi/l in 1987) have been measured at the Busch Wildlife Area.

Background levels of gamma radiation are due to radioactive materials in the earth and cosmic radiation throughout the atmosphere. Based on a radiological characterization survey performed in 1987, WSSRAP and UNC personnel determined that the average background gamma radiation exposure rates for the Weldon Spring area range from 78 to 96 mR/year with an average of 85 mR/year and a statistical error (two sigma) of 12 mR/year. There is good agreement between these measurements and previous studies which indicated the background exposure rates ranged from 60 to 105 mR/year (MK-F and JEG, 1988a).

4.5.2 Guidelines and Criteria

Radiation protection guidelines for radon have been established for DOE installations. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed (1) 100 pCi/l at any given point, (2) an annual average concentration of 30 pCi/l over the facility site, and (3) an annual average concentration of 3 pCi/l at or above any location outside the facility site (Gilbert et al, 1989). The air immersion derived concentration guideline for Rn-220 is 3 pCi/l (DOE Order 5400.XX).

4.5.3 Air Contaminants

4.5.3.1 Radon Gas

LBL made borehole and soil gas radon concentration measurements using Terradex track etch detectors enclosed in plastic cups. The cups were placed in PVC borehole casings about 8 inches below the ground surface and in shallow holes

about 8 inches deep. The PVC casings were covered with polyethylene sheeting and the shallow holes covered with 2 foot diameter garbage can lids to minimize atmospheric gas exchange. The cups were left in the boreholes and shallow holes for 2 to 3 weeks and then sent to Terradex, Inc. for analysis. (BGA, 1984)

Track etch detector cups must be fitted with a special membrane seal provided by Terradex prior to field use. This membrane allows the passage of radon gas to the track etch detector, but stops particulate-borne radon daughters and radioactively-contaminated dust particles from entering the cup, interacting with the detector and invalidating the radon concentration measurements. The BGA report does not clearly state that the membrane was correctly fitted to all track etch detector cups used.

To perform accurate radon concentration measurements in soil gas, special care must be taken to refill the shallow holes containing the track etch detector cups completely with the excavated soil. If care is not taken to refill the holes completely, the point of measurement (the shallow hole) may no longer accurately represent the media in which the measurement is taken (soil). This situation would result in radon concentration data that is not representative of the actual radon concentrations in soil gas. The BGA report does not clearly state whether the shallow holes were completely refilled once the track etch detector cups were in place. Because of the uncertainties in LBL's data collection methods discussed above, borehole and soil gas radon concentration data provided by BGA are not quoted in this report.

LBL also performed atmospheric radon concentration measurements. Results of these measurements ranged from 0.8 to 18 pCi/l, with an average of 14 pCi/l (BGA, 1984).

BNI measured surface radon flux during their 1984-85 survey at 29 locations. Charcoal canisters were placed in direct contact with the ground surface at these locations and exposed for 2 days before undergoing gamma spectrometry analysis. Results ranged from 0.06-42.9 $pCi/m^2/s$ (BNI, 1985c).

Six measurements of Rn-222 and Rn-220 working levels were taken by the PMC in February 1987. These measurements were made in the northeast corner zone between 7:30 and 10:30 a.m., when atmospheric inversion conditions would most likely produce the highest radon concentrations on the quarry floor. Results of these measurements ranged from 0.003 to 0.13 Working Levels for Rn-222 and from 0.002 to 0.039 Working Levels for Rn-220.

A radon gas monitoring program has been in place at the quarry since 1980. Terradex Type-F Track-Etch detectors, which sum the contributions of all radon isotopes, are housed in protective plastic cups and mounted (inverted) on posts, and are collected on a quarterly exchange basis and returned to Terradex for analysis (MK-F and JEG, 1988a). Six detectors are installed along the perimeter of the quarry fence, as shown on Figure 4.27. Monitoring has also been performed offsite (see Figure 4.28) to establish background levels. Currently background concentrations are measured at the Busch Wildlife Area (location RN-4001).

Average radon concentrations measured around the quarry are summarized in Table 4.27. Monitoring results show that radon levels above background, but still within the DOE concentration guideline for uncontrolled areas, have been detected.

The highest concentration was detected at the quarry fence near the upper gate (location RN-1002) in 1987. This concentration was 2.6 pCi/l, which is 2.3 pCi/l above background

TABLE 4.27 Radon Concentrations in the Vicinity of the WSQ

Year	Average Annual Radon Concentration (pCi/l)[a]							
	1980	1981	1982	1983	1984	1985	1986	1987
Quarry [b]								
RN-1001	0.90	0.49	0.76	0.83	1.24	1.0	0.85	1.5
RN-1002	----	----	----	----	----	----	----	2.6
RN-1003	0.81	1.15	1.31	0.68	0.68	0.7	0.60	1.5
RN-1004	0.78	0.56	0.41	0.36	0.28	0.2	0.46	0.6
RN-1005	0.50	0.54	0.49	0.44	0.79	0.4	0.43	0.6
RN-1006	----	----	----	----	----	----	----	0.5
6	0.23	0.49	0.36	0.39	0.22	0.4	0.24	----
8	0.87	1.00	0.89	1.22	0.90	1.3	1.30	----
Offsite [c]								
RN-4001	0.23	0.29	0.21	0.25	0.22	.2	0.36	0.3[e]
15	----	0.38	0.28	0.44	0.57	.3	0.47[e]	----
16[d]	----	----	----	0.29[e]	0.20[e]	.5[e]	----	----

a All measurements include background. Sources: 1980 data (Weidner and Boback, 1982); 1981-1985 data (BNI, 1983a, 1983b, 1984b, 1985b, 1986); 1986-1987 data (MK-F and JEG, 1987, 1988a).

b For locations see Figure 4.27. Monitoring at locations 6 and 8 was discontinued in 1987.

c For locations see Figure 4.28

d Located in Florissant, Missouri.

e These concentrations were assumed to represent background concentrations.

---- Not measured

and equals 77 percent of the DOE Rn-222 average annual guideline for concentration uncontrolled areas (3 pCi/l).

Radon values around the WSQ are measurably above background levels. Much of the contaminated quarry wastes contains significant quantities of radium with its associated decay products. Radon produced from the waste can diffuse to the surface, thus raising the ambient air concentration in the surrounding area. During meteorological inversion conditions, usually nocturnally in the summer and fall, there is a tendency for radon to be trapped within the quarry perimeter. Radon concentrations also vary seasonally. Winter concentrations generally are only 30 percent of the annual average, while the fall concentrations are about 30 percent higher than the annual average (MK-Ferguson, 1988a). There is little year-to-year variability, since meteorological conditions are similar from year to year and since potential underground areas of significant radium contamination have not been disturbed.

4.5.3.2 External Gamma Exposure Rates

LBL performed 81 gamma exposure rate measurements within the quarry using a 3-inch by 3-inch NaI gamma scintillometer. Exposure rates ranged from 1.5 to 625 uR/hr. No beta-gamma dose rate measurements were made by LBL (BGA, 1984).

BNI performed 1,686 beta-gamma dose rate and 55 gamma exposure rate measurements during their 1984-1985 radiological survey. Beta-gamma dose rate measurements were made at 12.5-foot intervals along the ground surface using a thin-window Geiger-Mueller probe. The detector was calibrated with a Sr-90/Y-90 beta source and an uranium slab source. Beta-gamma dose rate measurements ranged from 0.02-38.5 mrad/hr (BNl, 1985c).

Gamma exposure rate measurements were taken at 55 locations within the quarry using a pressurized ionization chamber (PIC) and a 2-inch by 2-inch NaI gamma scintillometer placed 3 feet above the quarry floor. Gamma scintillometer count rates were correlated to PIC exposure rates at 11 of the 55 measurement locations and the correlation was used to estimate gamma exposure rates at the 44 locations where only the NaI scintillometer was used. PIC gamma exposure rates 3 feet above the quarry floor ranged from 8 to 286 uR/hr (BNI, 1985c).

External gamma exposure rates have also been monitored since 1982, using Eberline spherical environmental thermoluminescent dosimeters (TLDs). The TLDs are exchanged quarterly and returned to Eberline for processing (MK-F and JEG, 1988a). The monitoring locations are the same as for the ambient radon monitoring locations shown on Figures 4.27 and 4.28.

Average external gamma exposure rates recorded during 1982-1985 by BNI and 1986-1987 by PMC are shown in Table 4.28. As discussed in subsection 4.5.1, the normal average background exposure rate is 85 mR/year. Annual average exposure rates measured at the quarry have ranged from 62 mR/year to 158 mR/year. This maximum exposure rate is 73 mR/year above normal background and assuming full time occupancy, the subsequent dose rate would be about 73 percent of the DOE radiation protection standard of 100 mrem/year.

The results of previous years' area TLD monitoring have shown consistent values. Two detectors consistently measure higher exposure rates (TD-1001 and 8). The interpretation is that these two detectors are located fairly close to deposits of Ra-226 or Th-232, both of which have significant gamma-emitting daughters. It is not coincidental that these two locations also show elevated Rn-222 levels significantly above background (MK-F, 1987b).

TABLE 4.28 External Gamma Exposure Rates in the Vicinity of the WSQ

	Average External Gamma Exposure Rate (mR/yr)[a,f]					
Year	1982	1983	1984	1985	1986	1987
Quarry [b]						
TD-1001	105	117	158	149	105	110
TD-1002	---	---	---	---	---	110
TD-1003	73	92	127	115	98	102
TD-1004	89	74	106	112	94	106
TD-1005	72	88	114	115	81	62
TD-1006	---	---	---	---	---	77
6	78	78	98	107	93	---
8	95	123	144	142	102	---
Offsite [c]						
TD-4001	65	66	103	107	87	73[e]
15	72	80	109	105	80[e]	---
16[d]	---	---	107[e]	99[e]	---	---

a All measurements include background. Sources: 1982-1985 data (BNI, 1983a, 1983b, 1984b, 1985b, 1986); 1986-1987 data (MK-F and JEG, 1987, 1988a)

b For locations see Figure 4.27. Monitoring at locations 6 and 8 was discontinued in 1987.

c For locations see Figure 4.28.

d Located in Florissant, Missouri.

e These values were assumed to represent background exposure rates.

f For gamma radiation, 1 mR = 1 mrad = 1 mrem. Also, 1 year is assumed to have 8,760 hours.

--- Not measured.

4.5.3.3 Particulates

From 1961 through 1965, when disposal activity was highest, Mallinckrodt Chemical Works monitored uranium concentrations in air at the south edge of the quarry. Measured uranium concentrations are summarized in Table 4.29. Values are quite variable, ranging from a low of 0.3 X 10^{-14} µCi/cc to a high of 40.0 X 10^{-14} µCi/cc. All concentrations were less than the maximum permissible concentration (MPC) of 200 X 10^{-14} µCi/cc in effect at that time (MCW, 1959-1965; 1960-1964). However,

TABLE 4.29 Air Concentrations of Uranium at the Weldon Spring Quarry

	Number of Samples	Uranium Concentration (uCi/cc x 10^{+14} a,c) Minimum	Maximum	Average	Percent of MPC[b]
1961					
Jan-Mar	1	--	--	5.5	2.8
Apr-Jun	3	0.3	6.0	3.4	1.7
Jul-Sept	2	1.2	2.7	1.9	0.9
Oct-Dec	2	3.3	13.0	8.2	4.1
1962					
Jan-Jun	5	0.9	4.6	2.4	1.2
Jul-Dec	6	0.4	2.7	1.3	0.6
1963					
Jan-Jun	6	0.7	7.0	2.6	1.3
1964					
Jan-Jun	5	4.0	14.0	8.0	4.0
Jul-Dec	2	0.3	8.0	4.2	2.1
1965					
Jan-Dec	2	30.0	40.0	35.0	17.5

a Source: Mallinckrodt Chemical Works, 1959-1965 and 1960-1964

b Based on average uranium concentration and a maximum permissible concentration (MPC) for uranium in air of 200 x 10^{-14} -Ci/cc in effect at that time. (MCW, 1959-1965 and 1960-1964). The current MPC is 0.95 x 10^{-13} -Ci/cc (Haroun, 1989).

c Detected uranium concentrations are multiplied by 10^{+14} to give the magnitudes presented in the table; e.g., a magnitude of 5.5 in the table represents a uranium concentration of 5.5 x 10^{-14} -Ci/cc.

the current MPC for natural uranium is 0.95 X 10^{-13} µCi/cc (Haroun, 1989). No data are available after 1965, since subsequent monitoring programs have not included measurements for uranium in air.

4.5.4 Air Quality Monitoring

An ongoing monitoring program for radon and external gamma dose rates is in place at the WSQ, using the monitoring locations shown on Figure 4.27. Currently, air monitoring is conducted by the PMC on a quarterly basis. Results are provided in the Annual Environmental Monitoring Reports for the Weldon Spring Site (e.g. MK-F and JEG, 1988a). In early 1989, the PMC plans to initiate gross alpha air particulate monitoring at two locations along the quarry perimeter and at one background station. Routine air monitoring is addressed in the annual EMPP.

4.5.5. Additional Characterization

Additional characterization of air contaminants at the quarry are not required prior to bulk waste removal. The potential for air particulate transport may increase during the proposed removal action. The air quality monitoring network described above will be able to record any potential contaminant excursion to the atmosphere.

5 CONTAMINANT FATE AND TRANSPORT

5.1 CONTAMINANT FATE AND TRANSPORT

Investigations and studies completed to date by numerous DOE, Army, and AEC contractors strongly suggest that the nature of the hydrogeological system in the vicinity of the quarry may allow migration of chemical and radiological contaminants to surface water bodies and drinking water aquifers beyond the quarry boundaries. Migration by other pathways appears to be less likely. The contaminants known to be present within the quarry as a result of earlier disposal practices are persistent, and their removal will eliminate a major source of contamination in the area, and permit further characterization of the nature and extent of transport through evaluation of the hydrogeologic regime. During the proposed bulk waste removal, extensive monitoring of personnel and equipment, surface water and groundwater, and air quality will be used to minimize potential worker health and environmental problems. Monitoring of surface water, groundwater, and air quality will indicate whether migration of contaminants from the quarry is being aggravated so that necessary mitigating measures can be implemented in a timely fashion.

5.2 CONTAMINANT PERSISTENCE

Persistence, the measure of the length of time over which a compound or substance will continue to exist in a given medium, is affected by numerous processes. The materials deposited in the quarry are accessible to these processes. Key transformation processes influencing persistence include chemical hydrolysis, biological transformation, photolysis, oxidation-reduction, and radiological decay. Volatilization and plant processes can also affect persistence. Therefore, accurate definition of a particular substance's persistence is

inherently difficult. Given the heterogeneous nature of the bulk waste, it is not possible to quantify the persistence of individual chemical species.

Persistence of a radionuclide can be described in terms of its half-life in a given medium due to decay processes. Half-lives can vary from less than a second to billions of years. The half-lives of the U-238 and Th-232 decay series radionuclides can be found in Figures 4.3 and 4.4.

5.3 POTENTIAL ROUTES OF MIGRATION

Potential pathways for contaminant migration at the quarry, especially as they relate to the proposed bulk waste removal, have been discussed. These pathways include air, surface water, groundwater, and transport by man and fauna. The most probable routes of migration are through the subsurface and by air transport, although transport by the surface pathway cannot be ruled out.

The security system in place at the quarry should preclude human transport of contaminants. The quarry is fenced at this time to prevent unauthorized entry, and personnel and vehicles leaving the site are monitored for radioactive contamination. Migration via fauna is expected to be insignificant (Haroun et al, 1989).

Although air transport of contaminants, which includes wind movement of contaminated particles and movement of airborne contaminants of near-molecular size is possible, it is expected to be minimal for several reasons. No materials are currently being processed on site, vegetation is extensive, and the more highly contaminated materials are located well below the quarry

rim. However, radon concentrations are already elevated at the east end of the quarry. In addition, during the remediation or under extreme weather conditions, there is potential for air transport.

Radon monitoring through 1987 (MK-F and JEG, 1987, 1988a) along the perimeter of the quarry (see Figure 4.12) has detected levels above background but within DOE guidelines for radon levels in uncontrolled areas. Levels for 1987 were less than 3 pCi/l above background. Rn-222 and Rn-220 produced by decay of Ra-226 and Ra-224 in the wastes can diffuse to the surface, raising ambient concentrations at the quarry boundaries. Comparison of measured levels with background measurements do indicate elevated levels at the quarry edge, particularly at the eastern edges. Table 4.27 includes a summary of radon measurements over a period of several years.

Contaminant migration over the surface, promoted by storm runoff, is possible. However, most runoff from precipitation within the quarry fenceline will flow to the pond, and it is only runoff along the western and southwestern boundaries of the quarry area which could drain away from the quarry. These particular locations represent only about 10 percent of the overall area. The quarry's surface outlet to the west is at approximately 484 feet MSL, a vertical distance of about 19 feet above the normal pond level. Therefore, essentially all runoff from precipitation falling on the rest of the quarry would stay within the quarry confines. This runoff, however, could be available for infiltration and migration along the subsurface pathways. The area along the western and southwestern edges of the quarry is reported to be uncontaminated, with the exception of shallow contamination within the upper 6 inches of surface along the access road and the abandoned railroad right of way (BNI, 1985c). Intense rainfall of significant duration in this particular area could lead to some migration from the quarry to

the west, but typical precipitation would probably not pose a risk of migration.

The most likely migration route is via the subsurface. Contaminants from the surface could move downward through the vadose zone to the saturated zone and then flow laterally or continue downward through permeable geologic strata. Data presented in Section 4.4 show that groundwater in the bedrock of the quarry is contaminated. The potential for further lateral migration will be defined after the bulk waste removal is completed and the site has been fully characterized. The DOE monitoring well network, described in Section 4.4.4, will be used to detect possible movement of contaminants from the quarry as a result of the removal.

5.4 CONTAMINANT MIGRATION

Migration of contaminants from the quarry is likely, given the nature of the hydrogeologic system and the presence of persistent contaminants in the wastes. These points are addressed in more detail in Sections 3 and 4. Until the bulk wastes have been removed from the quarry, however, detailed characterization of the site, which will include an evaluation of the extent of migration, cannot be conducted.

6 SUMMARY AND CONCLUSIONS

6.1 SUMMARY

The information presented in this report is focused on the proposed bulk waste removal from the Weldon Spring quarry. The extent of residual and groundwater contamination cannot be completely investigated until after the bulk wastes have been removed. For this reason, the information contained within this report is limited to contaminant characteristics, discussion of the physical characteristics of the quarry area, the general types and nature of the wastes, and potential migration pathways. The environmental setting at the quarry is described in terms of its surface features, meteorology, hydrology, hydrogeology, and ecology. To assist in assessment of potential exposure risk, demographic and land use information is also supplied. The data represented within the report are based on investigations conducted by various agencies or firms contracted to the DOE, its predecessors, or to the Department of the Army.

6.1.1 Nature and Extent of Contamination

From 1942 through 1969, the AEC and the Army disposed of chemical and radiological wastes in the quarry, which is now the main source of contamination in the vicinity. The quarry is estimated to contain 95,000 cubic yards of contaminated waste materials (DOE, 1987), the bulk of which is situated on the quarry floor, east of the pond. The heterogeneous mixture contains building rubble, process equipment, drummed and unconfined residues, sediments, and soils. Uranium, radium, and thorium are the primary radiologic contaminants of concern. The principal chemical contaminants include nitroaromatic compounds, polynuclear aromatic hydrocarbons, PCBs, and metals.

The quarry pond, containing an estimated 3 million gallons of water, is also contaminated. Uranium is the principle radiological contaminant, and arsenic and manganese are the only chemical contaminants detected which exceed current drinking water standards. However, elevated concentrations of 2,4-dinitrotoluene have also been confirmed. Removal and treatment of the pond water will be conducted as an IRA and documented in an EE/CA.

Groundwater in bedrock at the quarry has been shown to contain elevated concentrations of uranium, thorium, nitroaromatics, nitrate, and sulfate, all of which can be linked to quarry wastes. Elevated chloride levels have also been found. Based on groundwater studies, it is possible that this contaminated groundwater may be migrating southward from the bedrock to the alluvium. Movement of contaminants in other directions is uncertain at this time. Removal of residual material, remediation of groundwater, and any other necessary quarry remedial efforts will be managed as subsequent compliance components of the WSSRAP.

6.1.2 Contaminant Fate and Transport

Groundwater appears to be the primary pathway for contaminant transport from the quarry. Contaminated leachate from the wastes, including those wastes which are in contact with groundwater, provide the sources for contaminant migration. Although it is likely that contaminated groundwater moves from the quarry through fractures and discontinuities within the limestone bedrock, a detailed characterization cannot be conducted prior to the bulk waste removal. Results of previous investigations indicated that migration is generally southward, although it may also occur in other directions. Some surface transport westward from the western edge of the quarry may also take place.

A monitoring network has been installed at the site to detect migration of contaminants, if it occurs, especially during the bulk waste removal. The current monitoring program encompasses groundwater, surface water, and air quality monitoring. Baseline water and air quality data are available in published Annual Environmental Monitoring Reports prepared for the Weldon Spring Site.

6.2 CONCLUSIONS

Removal of the bulk wastes with transport to a temporary storage area prior to final disposal will accomplish one step in the overall remediation of the Weldon Spring Site, and will expedite the planning, design, and implementation of long-term remedial action of the quarry. The environmental documentation process for the quarry bulk wastes can be completed on the basis of the information currently available.

6.2.1 Remedial Action Objectives

The bulk wastes present in the quarry pose a potential risk to the health of the local population and to the environment. Removal of these wastes will reduce that potential risk by eliminating the primary source of contamination in the area, thereby reducing the potential for further contaminant migration. Once the wastes have been removed and consolidated in a secure location, additional characterization of the quarry can be conducted safely and effectively.

The wastes will be consolidated in the chemical plant portion of the raffinate pits and chemical plant area. This will enable DOE to better control access, prevent accidental releases, and fully characterize and inventory the wastes prior to their final disposition, and will also allow continuous environmental monitoring.

6.2.2 Data Limitations and Recommendations for Future Work

The information and data currently available, which have been summarized in this report, are considered to be sufficient to properly assess the feasibility of the proposed bulk waste remedial action and to develop a limited baseline risk evaluation. Data limitations which impact final site remediation can be resolved following completion of the proposed removal operation.

Considerable historical documentation of waste disposal practices, including analytical data regarding the heterogeneity of the wastes, has been reviewed. Characterization studies of the quarry confirm the presence of radiological and chemical contaminants, which is generally consistent with the types of materials disposed of in the quarry. It is likely that additional in-situ characterization will not significantly increase the understanding of the wastes, and it is therefore proposed to assess the feasibility of removal and develop the baseline risk evaluation on the basis of the existing data.

Data concerning the actual site characteristics of the quarry, such as bedrock geologic conditions, are adequate for evaluating the feasibility of bulk waste removal. Information on the nature and extent of contamination will be considerably expanded as the quarry is studied after the completion of the removal program.

Groundwater flow and quality in the bedrock to the north, east and west of the quarry have not yet been adequately characterized. Details of groundwater flow in the alluvium and bedrock at Femme Osage Slough, and the mechanics whereby contamination is apparently limited to the vicinity of the slough, are also undetermined. However, this information is not necessary for the proposed remedial action, and further

characterization of local groundwater will be addressed in detail after the wastes have been removed. Recent additions to the monitoring network will augment the understanding of bedrock water quality and the mechanics of groundwater flow in the vicinity of the quarry. However, additional bedrock monitor wells to the west and southeast of the quarry should be installed before initiation of waste removal to monitor contaminant migration in bedrock, should it occur.

7 REFERENCES

Bechtel National, Inc. 1983a. Weldon Spring Site Environmental Monitoring Report, Calendar Year 1981. Prepared for U.S Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. May 27, 1983.

Bechtel National, Inc. 1983b. Weldon Spring Site Environmental Monitoring Report, Calendar Year 1982. Prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. May 1983.

Bechtel National, Inc. 1984a. Engineering Evaluation Alternatives for the Disposition of the Weldon Spring Raffinate Pits Site. DOE/OR/20722-5. Prepared for U.S. Department of Energy, Oak Ridge Operations Office. Oak Ridge, Tenn. April 1984.

Bechtel National, Inc. 1984b. Weldon Spring Site Environmental Monitoring Report, Calendar Year 1983. Prepared for U.S. Department of Energy. Oak Ridge Operations Office, Oak Ridge, Tenn. June 1984.

Bechtel National, Inc. 1985a. Addendum to the Engineering Evaluation of Alternatives for the Disposition of the Weldon Spring Raffinate Pits Site, Weldon Spring, Missouri. DOE/OR/20722-5, Add. 1. April 1985.

Bechtel National, Inc. 1985b. Weldon Spring Site Environmental Monitoring Report, Calendar Year 1984. Prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. July 1985.

Bechtel National, Inc. 1985c. Radiological Survey Report for the Weldon Spring Quarry. DOE/OR/20722-70. Prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. September 1985.

Bechtel National, Inc. 1985d. Report on Ground-water Monitoring Well Rehabilitation and Radiological Characterization Drilling, Weldon Spring Quarry, St. Charles County, Missouri. DOE/OR/20722-63. Prepared for U.S. Department of Energy, Oak Ridge Operations Office. Oak Ridge, Tenn. December 1985.

Bechtel National, Inc. 1986. Weldon Spring Site Annual Site Environmental Monitoring Report, Weldon Spring, Missouri, Calendar Year 1985. DOE/OR/20722-101. Prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn. September 1986.

Bechtel National, Inc. 1987. Hydrogeological Characterization Report for Weldon Spring Chemical Plant, Weldon Spring, Missouri. Prepared for U.S. Department of Energy, Oak Ridge Operations Office. Oak Ridge, Tenn. February 1987 (Draft).

Berkeley Geosciences Associates. 1984. Characterization and Assessment for the Weldon Spring Quarry Low Level Radioactive Waste Storage Site. DOE/OR-853. Prepared for Oak Ridge National Laboratory. September 1984.

Boerner, A.J. 1986. Radiological Survey of the August A. Busch and Weldon Spring Wildlife Areas, Weldon Spring Site, St. Charles County, Missouri. Prepared by Oak Ridge Associated Universities, Oak Ridge, Tenn. for U.S. Department of Energy. April 1986.

Booth, L.F., D.W. Groff, G.S. McDowell, J.J. Adler, S.I. Peck, P.L. Nyerges, and F.L. Bronson. 1982. Radiological Survey of the West Lake Landfill St. Louis County, Missouri. Prepared by Radiation Management Corporation, Northbrook, Ill. for U.S. Nuclear Regulatory Commission. May, 1982.

Connolly, Thomas J. 1978. Foundations of Nuclear Engineering. John Wiley and Sons, New York, New York.

Dickneite, D.F. 1988. Letter from D.F. Dickneite (Environmental Administrator, Missouri Department of Conservation, Jefferson City) to I. Hlohowsky (Argonne National Laboratory, Argonne, Ill.) Aug. 24, 1988.

Fishel, V.C. and C.C. Williams. 1944. The Contamination of Ground and Surface Waters by Liquid Wastes from the Weldon Springs Ordinance Works, Missouri. U.S. Geological Survey, Lawrence, Kansas.

Fleming, Dave. 1989a. Inter-Office Correspondence: Summary of November 14, 1988 WSQ Samples and Raffinate Pit Sludge Sampling Results. January 30, 1989.

Fleming, Dave. 1989b. Inter-Office Correspondence: Comparison of Radionuclide Data in the Bechtel Radiological Survey Report for the WSQ. January 30, 1989.

Gaines, E. P. 1988. Letter from E.P. Gaines (Data Manager, Missouri Department of Conservation, Jefferson City) to I. Hlohowsky (Argonne National Laboratory, Argonne, Ill.). Sept. 8, 1988.

Gilbert, T.L., C. Yu, Y.C. Yuan, A.J. Zielen, M.J. Jusko, and A. Wallo III, 1989. A Manual for Implementing Residual Radioactivity Guidelines: A Supplement to U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Surplus Facilities Management Program Sites. ANL/ES-160; DOE/CH/8901. Prepared for the U.S. Department of Energy, Assistant Secretary for Nuclear Energy, Office of Remedial Action and Waste Technology, by Argonne National Laboratory, Argonne IL. June 1989.

Glenn, R.D. 1986. Letter Report from R.D. Glenn (Bechtel National, Inc., Oak Ridge, Tenn.) to R. Nelson (U.S. Dept. of Energy, St. Charles, MO), November 17, 1986.

Haroun, Lynne. 1989. Letter from Lynne Haroun (Argonne National Laboratory, Argonne, Ill.) to Anne C. Connell (Morrison-Knudsen Engineers, Inc., San Francisco, Calif.). Jan. 4, 1989.

Haroun, L.A., J.M. Peterson, M.M. MacDonell, and I. Hlohowskyj. 1989. Baseline Risk Evaluation for Exposure to Bulk Wastes at the Weldon Spring Quarry, Weldon Spring, Missouri. DOE/OR/21548-065. Prepared by Argonne National Laboratory, Argonne, Illinois for U.S. Department of Energy. June 1989.

Hickey, C. 1986. Personal communication from C. Hickey (Bechtel National, Inc., Oak Ridge, Tenn.) to P. Benioff (Argonne National Laboratory, Argonne, Ill.), March 5 and March 14, 1986. Cited in U.S. Department of Energy, 1987.

Huey, E.A. 1978. Report on Preliminary Geological, Hydrological, and Radiological Survey at Weldon Spring Quarry during 1976 and 1977. National Lead Company of Ohio, Inc., Cincinnati, Ohio. December 1978.

Kaye, M.E., and J.L. Davis. 1987. Chemical Characterization Report for the Weldon Spring Quarry, St. Charles County, Missouri. DOE/OR/20722-176. Prepared by Bechtel National, Inc., Oak Ridge, Tenn., for U.S. Department of Energy, Oak Ridge Operations Office. August 1987.

Kleeschulte, M.J. and L.F. Emmett. 1986. Compilation and Preliminary Interpretation of Hydrologic Data for the Weldon Spring Radioactive Waste Disposal Sites, St. Charles County, Missouri. A Progress Report. U.S. Geological Survey Water Resources Investigation Report 85-4272.

Kleeschulte, M.J., L.F. Emmett and J.H. Barks. 1986. Hydrologic Data for the Weldon Spring Radioactive Waste-Disposal Sites, St. Charles County, Missouri 1984-1986. U.S. Geological Survey Open File Report 86-488. Rolla, Mo.

Kleeschulte, M.J. and L.F. Emmett. 1987. Hydrology and Water Quality at the Weldon Spring Radioactive Waste Disposal Sites, St. Charles County, Missouri. U.S. Geological Survey Water Resources Investigations Report 87-4169.

Layne-Western Company, Inc. 1986. Groundwater Hydrology Investigation, Weldon Spring, Missouri. Kansas City, Kansas. 3 Vol. January 1986.

Lenhard, L.A., F.J. Belcher and S.N. Holt. 1967. Weldon Spring Raffinate Pits and Quarry Task Force Report. Oak Ridge Operations Office, U.S. Atomic Energy Commission. June 1, 1967.

MacDonell, M.M., J. Peterson and I.E. Joya. 1989. Engineering Evaluation/Cost Analysis, Proposed Removal Action at the Weldon Spring Quarry,DOE/OR/21548-039. Prepared by Argonne National Laboratory, Argonne, Illinois, for U.S. Department of Energy, Oak Ridge Operations Office. January, 1989.

Maher, Shawna. 1989. Inter-Office Correspondence: Table 4.26 of the WSSRAP Quarry Remedial Investigation for Quarry Bulk Waste - Monitoring Well Construction Details. June 21, 1989.

Mallinckrodt Chemical Works. 1960-1964. AEC Quarry Environmental Monitoring Reports. Weldon Spring, Missouri.

Mallinckrodt Chemical Works. 1959-1965. Off-Site Environmental Monitoring Reports. Weldon Spring, Missouri.

Marutzky, S.J., R. Colby, and L.S. Cahn. 1988. Radiologic Characterization of the Weldon Spring, Missouri, Remedial Action Site. UNC/GJ-HMWP-4; DOE/ID/12584-22. Prepared by UNC Geotech, Inc., Grand Junction, Colo., for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, Mo. February 1988.

Meshkov, N., P. Bennioff, J. Wang, and Y. Yuan. 1986. Weldon Spring Historical Dose Estimates. ANL/EES-TM-308. Prepared by Argonne National Laboratory, Argonne, Illinois for U.S. Department of Energy.

Meyer, Ken. 1988. Inter-Office Correspondence: Previous WSQ Soil Sampling. October 24, 1988.

Mifflen, M.D. and J.W. Hess. 1979. "Regional Carbonate Flow Systems in Nevada." Journal of Hydrology 43, 217-237, 1979. Cited in BGA, 1984.

Miller, Albert and Jack C. Thompson, 1975. Elements of Meteorology. Charles E. Merrill Publishing Company, Columbus, Ohio.

Missouri Geological Survey. 1977. The Resources of St. Charles County, Missouri, Land, Water, and Minerals. Rolla, Mo. April 1977.

MK Engineers, Inc. 1987. WSSRAP Contaminated Water Treatment, Quarry and Raffinate Pits, Final Feasibility Report. San Francisco, Ca. May 1987.

MK-Ferguson Company. 1987a. Phase I Water Quality Assessment. DOE/OR/21548-003. Prepared for U.S. Department of Energy, Oak Ridge Operations. St. Charles, Mo. December 1987.

MK-Ferguson Company, 1987b. Environmental Monitoring Program Plan, Weldon Spring Site. Prepared for U.S. Department of Energy, February 1987.

MK-Ferguson Company and Jacobs Engineering Group, Inc. 1987. Weldon Spring Annual Environmental Monitoring Report, Calendar Year 1986. Prepared for U.S. Department of Energy, St. Charles, Mo. May 1987.

MK-Ferguson Company and Jacobs Engineering Group, Inc. 1988a. Weldon Spring Site Annual Environmental Monitoring Report, Calendar Year 1987. Prepared for U.S. Department of Energy. St. Charles, Mo.

MK-Ferguson Company and Jacobs Engineering Group, Inc. 1988b. WSSRAP Report on WSS Contaminants, Findings and Recommendations Regarding August A. Busch and Weldon Spring Wildlife Area Locations 3, 4, 5, and 8. Prepared for U.S. Department of Energy. St. Charles, Mo. April 1988.

MK-Ferguson Company and Jacobs Engineering Group, Inc. 1988c. Initial Assessment of the Effect of Drought Conditions on Contaminant Migration from the Weldon Spring Quarry. Prepared for U.S. Department of Energy, Oak Ridge Operations Office. August 1988.

MK-Ferguson Company and Jacobs Engineering Group, Inc. 1988d. Radiological and Chemical Uptake by Selected Biota at the Weldon Spring Site. October 1988 (Draft).

MK-Ferguson and Jacobs Engineering Group, Inc. 1988e. WSSRAP Groundwater Sampling Field Data Forms. March 1987 - March 1988.

National Oceanic and Atmospheric Administration. 1981-1986. Annual Climatological Summaries lle, North . National Climatic Data Center. Ashevi Carolina.

National Oceanic and Atmospheric Administration. 1984. Climatography of the United States, No. 20, Saint Charles, MO. National Climatic Data Center. Asheville, North Carolina.

Oak Ridge National Laboratory (ORNL). 1979. Radiological Survey of the St. Louis Airport Storage Site, St. Louis, Missouri. Prepared for the U.S. Department of Energy, Final Report, DOE/EV/-0005/16, September 1979.

Pennak, A.F. 1975. Weldon Spring Decommissioning Study, Quarry Supplement. NLCO-1121. Sup. 1. Prepared by National Lead Company of Ohio, Cincinnati, Ohio, for U.S. Energy Research and Development Administration, Oak Ridge Operations Office. September 10, 1975.

PNL Photography. Undated. Miscellaneous Photographs of Weldon Spring Quarry. Photo No. 096773: 2, 3, 5, 7, 16, 17, 19, 20, 23, 24, 27, 28, 30-35 and 38. Richland, Washington.

Richardson, R.M. 1960a. Possible Use of Quarry at Mallinckrodt Chemical Works, Weldon Spring, Missouri, for the Disposal of Uranium Contaminated Building Debris and Rubble and Residues Containing Thorium and Uranium. U.S. Geological Survey. Oak Ridge, Tenn. June 1960.

Richardson, R.M. 1960b. Untitled letter report from R. M. Richardson of U.S. Geological Survey to Mr. Arthur Schoon of Oak Ridge Operations Office, U.S. Atomic Energy Commission. November 1960.

Roberts, C.M. and C.V. Theis. 1951. Preliminary Investigations of Groundwater Occurrences in the Weldon Spring Area, St. Charles County, Missouri. U.S. Geological Survey. Indianapolis, Ind. Reprinted in 1982 as U.S. Geological Survey Open File Report 82-1008.

Rudloff, W. 1981. World Climates with Table of Climatic Data and Practical Suggestions. Wissenchaftliche Verlagsgelsellschaft, mbH, Stuttgart.

Ruffner, J.A. 1978. Climates of the States. Gale Research Company, Detroit, Michigan.

Serrioz, Shannon. 1989. Phone call from S. Serrioz (Morrison Knudson-Ferguson, St. Charles, Missouri) to Glenn Griffin (Research and Statistics, St. Louis Planning Department, Missouri). January 10, 1989.

Soil Consultants, Inc. 1988. Groundwater Monitoring Program, St. Charles County, Weldon Spring Well Field. Saint Peters, Mo. March 1988.

Strahler, Arthur N. and Alan H. Strahler. 1974. Introduction to Environmental Science. Hamilton Publishing Company, Santa Barbara, California.

Surdex Corporation. 1983. Untitled 1"=50' scale topographic map of WSQ.

Surdex Corporation. 1987. Topographic Map - Weldon Spring Quarry Site 1"=100'.

U.S. Army Corps of Engineers. 1980. Missouri River Profiles. Missouri River Basin, River Miles 45.45 to 68.56. File No. R-1-5402. U.S. Army Engineer District, Kansas City, Mo. December 1980.

U.S. Department of Energy. 1986a. DOE-Derived Concentration Guides for Drinking Water and Breathing Air Contaminated with Radionuclides by Members of the Public. Attachment to Memorandum from R.J. Stern (Director, Office of Environmental Guidance) to Distribution. February 1986.

U.S. Department of Energy. 1986b. Historical Nuclear Material Balance Report for the Former AEC-Owned Weldon Spring Chemical Plant, Weldon Spring, Missouri. DOE/OR-872. July 1986.

U.S. Department of Energy. 1987. Draft Environmental Impact Statement, Remedial Action at the Weldon Spring Site. DOE/EIS-0117D, Office of Remedial Action and Waste Technology. February 1987.

U.S. Environmental Protection Agency. 1985. Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses. Technical Directive Document No. HQ-8410-01. May 1985. Cited in Kaye and Davis, 1987.

U.S. Environmental Protection Agency. 1988. Draft Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. March 1988.

U.S. Geological Survey. 1954. Weldon Spring Quadrangle, Missouri, 7.5 Minute Series (Topographic).

U.S. Geological Survey. 1972. Defiance Quadrange, Missouri - St. Charles County, 7.5 Minute Series (Topographic).

U.S. Geological Survey. 1987. Water Resources Data, Missouri, Water Year 1986. Rolla, Mo. July 1987.

U.S. Nuclear Regulatory Commission (NRC). 1988. Radioactive Material in the West Lake Landfill. NUREG-1308. Washington, D.C. April 1988.

Weidner, R.B. and M.W. Boback. 1982. Weldon Spring Storage Site Environmental Monitoring Report for 1979 and 1980. Prepared by National Lead Company of Ohio, Cincinnati, Ohio for U.S. Department of Energy. April 1982.

West County Surveying and Engineering, Inc. 1988. Weldon Spring Quarry - Easement Survey. August 29, 1988.

APPENDIX A
WASTE CHARACTERIZATION DATA

A.1

RADIOLOGICAL CHARACTERIZATION DATA FROM BERKELEY GEOSCIENCES ASSOCIATES, 1984 AND BECHTEL NATIONAL, INC., 1985c

TABLE A.1 (Sheet 1 of 5)

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
A	7500.000	13200.000
AA	7450.000	13550.000
AB	7500.000	13550.000
AC	7675.000	13550.000
AD	7700.000	13550.000
AE	7439.000	13600.000
AF	7450.000	13600.000
AG	7500.000	13600.000
AH	7550.000	13600.000
AI	7575.000	13600.000
AJ	7700.000	13600.000
AK	7725.000	13600.000
AL	7550.000	13625.000
AM	7437.000	13650.000
AN	7450.000	13650.000
AP	7500.000	13650.000
AQ	7550.000	13650.000
AR	7675.000	13650.000
AS	7700.000	13650.000
AT	7725.000	13650.000
AU	7450.000	13700.000
AV	7500.000	13700.000
AW	7550.000	13700.000
AX	7600.000	13700.000
AY	7700.000	13700.000
AZ	7739.000	13700.000
B	7525.000	13200.000
BA	7500.000	13750.000
BB	7600.000	13750.000
BC	7650.000	13750.000
BD	7700.000	13750.000
BE	7475.000	13800.000
BF	7550.000	13800.000
BG	7600.000	13800.000
BH	7650.000	13800.000
BI	7700.000	13800.000
BJ	7732.000	13800.000
BK	7525.000	13825.000
BL	7600.000	13825.000
BM	7625.000	13825.000
BN	7650.000	13825.000
BP	7675.000	13825.000
BQ	7700.000	13825.000
BR	7475.000	13850.000
BS	7550.000	13850.000
BT	7650.000	13850.000
BU	7700.000	13850.000
BV	7745.000	13850.000
BW	7525.000	13875.000
BX	7650.000	13878.000
BY	7525.000	13900.000
BZ	7550.000	13900.000

TABLE A.1

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
C	7525.000	13225.000
CA	7650.000	13900.000
CB	7700.000	13900.000
CC	7525.000	13925.000
CD	7575.000	13950.000
CE	7700.000	13950.000
CF	7525.000	13975.000
CG	7600.000	13975.000
CH	7650.000	13975.000
CI	7725.000	13975.000
CJ	7625.000	14000.000
CK	7600.000	14022.900
CL	7625.000	14050.000
CM	7650.000	14050.000
CN	7675.000	14050.000
CP	7650.000	14070.000
CQ	7675.000	14075.000
CR	7750.000	14075.000
CS	7725.000	14100.000
CT	7700.000	14113.000
CU	7725.000	14125.000
CV	7600.000	13354.000
CW	7488.000	13565.000
CX	7700.000	13650.000
CY	7550.000	13667.000
CZ	7525.000	13700.000
D	7475.000	13250.000
DA	7550.000	13748.000
E	7500.000	13250.000
F	7525.000	13250.000
G	7525.000	13300.000
H	7550.000	13300.000
I	7550.000	13325.000
J	7600.000	13325.000
K	7525.000	13350.000
L	7600.000	13350.000
M	7650.000	13350.000
N	7650.000	13375.000
P	7700.000	13375.000
Q	7625.000	13400.000
R	7675.000	13400.000
S	7700.000	13400.000
S1	7800.000	13054.000
S10	7550.000	13153.000
S100	7400.000	13750.000
S101	7419.300	13750.000
S102	7450.000	13750.000
S103	7550.000	13750.000
S104	7737.000	13750.000
S105	7770.000	13750.000
S106	7450.000	13775.000
S107	7475.000	13775.000
S108	7500.000	13775.000
S109	7525.000	13775.000
S11	7550.000	13175.000
S110	7401.000	13800.000

TABLE A.1

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
S111	7427.000	13800.000
S112	7500.000	13800.000
S113	7769.000	13800.000
S114	7475.000	13825.000
S115	7500.000	13825.000
S116	7550.000	13825.000
S117	7575.000	13825.000
S118	7450.000	13836.000
S119	7417.600	13850.000
S12	7550.000	13200.000
S120	7450.000	13850.000
S121	7456.000	13850.000
S122	7500.000	13850.000
S123	7525.000	13850.000
S124	7600.000	13850.000
S125	7768.000	13850.000
S126	7475.000	13875.000
S127	7500.000	13875.000
S128	7450.000	13900.000
S129	7454.000	13900.000
S13	7600.000	13200.000
S130	7500.000	13900.000
S131	7600.000	13900.000
S132	7745.000	13900.000
S133	7766.000	13900.000
S134	7450.000	13919.900
S135	7500.000	13925.000
S136	7550.000	13925.000
S137	7513.000	13950.000
S138	7550.000	13950.000
S139	7600.000	13950.000
S14	7650.000	13200.000
S140	7737.000	13950.000
S141	7764.000	13950.000
S142	7500.000	13962.000
S143	7500.000	13975.000
S144	7575.000	13975.000
S145	7625.000	13975.000
S146	7750.000	13975.000
S147	7550.000	13988.400
S148	7650.000	14000.000
S149	7863.000	14000.000
S15	7700.000	13200.000
S150	7700.000	14000.000
S151	7763.000	14000.000
S152	7550.000	14001.500
S153	7700.000	14050.000
S154	7725.000	14050.000
S155	7750.000	14050.000
S156	7763.000	14050.000
S157	7750.000	14100.000
S158	7761.700	14100.000
S159	7700.000	14125.000
S16	7750.000	13200.000
S160	7750.000	14125.000
S161	7750.000	14137.000

TABLE A.1

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
S17	7800.000	13200.000
S18	7450.000	13204.000
S19	7500.000	13225.000
S2	7700.000	13100.000
S20	7400.000	13250.000
S21	7450.000	13250.000
S22	7550.000	13250.000
S23	7600.000	13250.000
S24	7650.000	13250.000
S25	7700.000	13250.000
S26	7798.000	13250.000
S27	7350.000	13257.000
S28	7500.000	13275.000
S29	7300.000	13300.000
S3	7750.000	13100.000
S30	7350.000	13300.000
S31	7400.000	13300.000
S32	7450.000	13300.000
S33	7500.000	13300.000
S34	7600.000	13300.000
S35	7650.000	13300.000
S36	7700.000	13300.000
S37	7750.000	13300.000
S38	7787.000	13300.000
S39	7250.000	13314.000
S4	7800.000	13100.000
S40	7650.000	13325.000
S41	7252.000	13350.000
S42	7300.000	13350.000
S43	7350.000	13350.000
S44	7400.000	13350.000
S45	7450.000	13350.000
S46	7500.000	13350.000
S47	7550.000	13350.000
S48	7625.000	13350.000
S49	7675.000	13350.000
S5	7650.000	13103.000
S50	7700.000	13350.000
S51	7750.000	13350.000
S52	7781.000	13350.000
S53	7269.000	13400.000
S54	7300.000	13400.000
S55	7350.000	13400.000
S56	7400.000	13400.000
S57	7500.000	13400.000
S58	7600.000	13400.000
S59	7650.000	13400.000
S6	7600.000	13150.000
S60	7750.000	13400.000
S61	7779.000	13400.000
S62	7300.000	13450.000
S63	7350.000	13450.000
S64	7383.000	13450.000
S65	7650.000	13450.000
S66	7725.000	13450.000
S67	7778.000	13450.000

TABLE A.1 (Sheet 5 of 5)

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
S68	7305.000	13500.000
S69	7355.000	13500.000
S7	7650.000	13150.000
S70	7381.600	13500.000
S71	7675.000	13500.000
S72	7746.000	13500.000
S73	7777.000	13500.000
S74	7350.000	13550.000
S75	7383.300	13550.000
S76	7550.000	13550.000
S77	7650.000	13550.000
S78	7725.000	13550.000
S79	7777.000	13550.000
S8	7750.000	13150.000
S80	7350.000	13600.000
S81	7390.000	13600.000
S82	7395.000	13600.000
S83	7600.000	13600.000
S84	7625.000	13600.000
S85	7650.000	13600.000
S86	7743.000	13600.000
S87	7776.000	13600.000
S88	7354.000	13650.000
S89	7390.000	13650.000
S9	7800.000	13150.000
S90	7600.000	13650.000
S91	7650.000	13650.000
S92	7747.000	13650.000
S93	7774.000	13650.000
S94	7370.200	13700.000
S95	7400.000	13700.000
S96	7434.000	13700.000
S97	7650.000	13700.000
S98	7772.000	13700.000
S99	7386.000	13750.000
T	7725.000	13400.000
U	7675.000	13450.000
V	7700.000	13450.000
W	7750.000	13450.000
X	7700.000	13500.000
Y	7725.000	13500.000
Z	7429.000	13550.000

TABLE A.2

WELDON SPRINGS QUARY SITE
SUBSURFACE SAMPLES - BECHTEL NATIONAL, INC. (BNI)

SAMPLES	NORTHING	EASTING
D	7475.000	13250.000
D1	7659.000	13341.000
D10	7689.000	13847.000
D11	7550.000	13850.000
D12	7595.000	13854.000
D13	7650.000	13878.000
D14	7550.000	13900.000
D15	7650.000	13900.000
D16	7700.000	13900.000
D17	7724.000	13903.000
D18	7715.000	13928.000
D19	7563.000	13938.000
D2	7721.000	13483.000
D20	7600.000	13950.000
D21	7650.000	13950.000
D22	7700.000	13950.000
D23	7727.000	13950.000
D24	7683.000	13963.000
D25	7641.000	13984.000
D3	7494.000	13550.000
D4	7488.000	13565.000
D5	7453.000	13700.000
D6	7525.000	13700.000
D7	7594.000	13724.000
D8	7550.000	13748.000
D9	7656.000	13800.000
DA	7550.000	13748.000

TABLE A.3

WELDON SPRINGS QUARRY SITE
SURFACE SAMPLES - BERKELEY GEOSCIENCES ASSOCIATES (BGA)

SAMPLES	NORTHING	EASTING
WSQ-10	7525.000	13185.000
WSQ-11	7525.000	13170.000
WSQ-2	7485.000	13220.000
WSQ-20	7710.000	13950.000
WSQ-21	7685.000	13960.000
WSQ-22	7720.000	13930.000
WSQ-23	7650.000	13900.000
WSQ-24	7665.000	13890.000
WSQ-3	7560.000	13315.000
WSQ-40	7600.000	13715.000
WSQ-41	7515.000	13650.000
WSQ-42	7565.000	13530.000
WSQ-43	7640.000	13760.000
WSQ-44	7710.000	14060.000
WSQ-45	7720.000	14065.000
WSQ-46	7580.000	13420.000
WSQ-47	7620.000	13530.000
WSQ-48	7500.000	13225.000
WSQ-52	7675.000	13930.000
WSQ-53	7440.000	13880.000
WSQ-54	7610.000	14015.000
WSQ-55	7460.000	13710.000
WSQ-57	7640.000	13760.000
WSQ-64	7730.000	14075.000
WSQ-7	7680.000	13710.000
WSQ-70	7485.000	13700.000
WSQ-74	7720.000	13635.000
WSQ-8	7615.000	13440.000
WSQ-87	7445.000	13475.000
WSQ-88	7510.000	13435.000
WSQ27-39	7640.000	13760.000
WSQ58-63	7720.000	14050.000

TABLE A.4

WELDON SPRINGS QUARRY SITE

SUBSURFACE SAMPLES - BERKELEY GEOSCIENCES ASSOCIATES (BGA)

SAMPLES	NORTHING	EASTING
0-0	7619.000	13700.000
1-1	7611.000	13720.000
1-3	7542.000	13655.000
1-5	7483.000	13580.000
2-2	7500.000	13650.000
2-4	7483.000	13700.000
3-1	7590.000	13690.000
4-1	7572.000	13740.000
B-0	7715.000	13940.000
B1-1	7692.000	13930.000
B1-2	7689.000	13960.000
B1-3	7666.000	13935.000
B1-4	7648.000	13960.000
C-MIDDLE	7653.000	13890.000
C1-3	7583.000	13875.000
D1-1	7683.000	13880.000
T-1	7695.000	14030.000
T-2	7714.000	14015.000
T-3	7715.000	14025.000
T-4	7716.000	14040.000
T-5	7716.000	14080.000

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION* BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
0-0	0.00	5.20	5.60	0.00	0.00	0.00	2.10	1.00	0.00
1-1	0.00	22.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-3	0.00	10.80	4.30	7.60	25.70	9.30	2.65	3.83	2.73
1-5	0.00	97.00	231.00	485.50	144.00	52.20	22.70	2.22	0.00
2-2	0.00	60.00	22.00	11.00	20.00	52.00	1.70	2.50	0.00
2-4	0.00	23.00	490.00	60.00	5.70	6.00	1.30	1.30	20.00
3-1	0.00	30.00	31.00	4.70	4.00	1.90	0.00	1.80	2.90
4-1	0.00	6.90	3.70	2.60	1.30	0.90	1.10	0.90	0.70
A	40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	140.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB	140.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AD	4.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AE	54.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AF	220.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG	200.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AH	410.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AI	74.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AJ	16.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AK	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AM	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AN	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP	200.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AQ	190.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AT	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AU	110.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV	81.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AW	69.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AX	320.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AY	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AZ	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-0	0.00	40.00	58.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-1	0.00	18.00	83.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-2	0.00	18.00	160.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-3	0.00	3.30	22.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-4	0.00	13.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00
BA	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB	240.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BC	625.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BD	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BF	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BH	1200.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BI	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Concentration in pCi/g.

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
BK	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BL	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BQ	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BR	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BT	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BU	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BV	57.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BX	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BY	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-MIDDLE	0.00	3.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00
C1-3	0.00	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CB	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CG	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CI	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CJ	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CK	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CL	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CN	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	33.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CR	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CT	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CU	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CV	68.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CW	240.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CX	40.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CY	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CZ	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1-1	0.00	9.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D10	0.00	19.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00
D11	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D12	0.00	12.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D13	0.00	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D14	0.00	11.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
D15	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D16	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D17	0.00	74.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D18	0.00	31.00	1100.00	0.00	0.00	0.00	0.00	0.00	0.00
D19	0.00	13.50	3.20	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D20	0.00	7.50	3.30	0.00	0.00	0.00	0.00	0.00	0.00
D21	0.00	4.80	15.20	0.00	0.00	0.00	0.00	0.00	0.00
D22	0.00	1.80	45.50	0.00	0.00	0.00	0.00	0.00	0.00
D23	0.00	40.80	250.00	0.00	0.00	0.00	0.00	0.00	0.00
D24	0.00	278.50	72.90	278.50	0.00	0.00	0.00	0.00	0.00
D25	0.00	32.70	186.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.00	250.00	117.70	170.00	0.00	0.00	0.00	0.00	0.00
D4	0.00	122.00	85.80	31.00	0.00	0.00	0.00	0.00	0.00
D5	0.00	118.00	370.00	130.00	22.00	1.40	0.00	0.00	0.00
D6	0.00	5.90	34.50	0.00	0.00	0.00	0.00	0.00	0.00
D7	0.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D8	0.00	10.70	3.80	1.20	1.20	1.20	0.00	0.00	0.00
D9	0.00	36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DA	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L	5.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	9.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S10	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S100	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S101	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S102	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S103	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S104	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S105	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S106	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S107	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S108	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S109	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S11	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S110	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S111	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S112	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S113	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S114	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S115	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S116	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S117	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S118	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S119	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S12	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S120	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S121	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S122	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S123	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S124	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S125	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S126	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S127	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S128	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S129	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S13	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S130	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S131	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S132	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S133	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S134	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S135	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S136	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S137	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S138	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S139	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S14	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S140	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S141	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S142	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S144	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S145	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S146	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S147	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S148	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S149	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S15	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S150	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S151	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S152	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S153	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S154	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S155	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S156	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S157	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S158	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S159	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S16	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S161	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S17	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S18	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S19	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S20	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S21	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S22	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S23	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S24	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S25	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S26	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S27	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S28	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S29	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S3	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S31	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S33	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S34	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S35	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S36	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S37	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S38	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S39	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S4	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S40	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S41	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S42	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S43	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S44	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S45	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S46	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S47	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S48	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S49	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S5	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S50	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S51	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S52	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S53	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S54	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S55	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S56	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S57	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S58	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S59	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S60	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S61	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S62	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S63	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S64	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S65	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S66	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S67	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S68	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S69	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S7	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S70	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S71	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S72	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S73	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S74	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S75	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S76	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S77	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S78	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S79	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S8	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S80	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S81	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S82	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S83	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S84	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S85	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S86	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S87	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S88	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S89	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S9	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S90	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S91	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S92	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S93	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S94	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S95	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S96	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S97	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S98	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S99	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T-1	0.00	0.00	0.90	1.20	0.90	1.00	0.50	0.00	0.00
T-2	0.00	0.00	200.00	7.40	4.70	0.00	0.00	0.00	0.00
T-3	0.00	40.00	0.00	6.00	5.00	5.50	0.00	0.00	0.00
T-4	0.00	1.60	1.10	1.60	1.10	0.00	0.00	0.00	0.00
T-5	0.00	0.00	0.00	1.20	1.70	1.00	0.00	0.00	0.00
U	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.5

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
V	6.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-10	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-11	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-2	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-20	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-21	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-22	4.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-23	1.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-24	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-3	1770.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-40	353.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-41	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-42	122.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-43	58.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-44	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-45	23.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-46	3.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-47	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-48	2305.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-52	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-53	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-54	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-55	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-57	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-64	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-7	16.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-70	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-74	3.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-8	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-87	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-88	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ27-39	1087.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ58-63	108.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X	4.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION* BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
0-0	0.00	1.00	1.20	613.00	123.00	149.00	85.00	18.60	12.40
1-1	0.00	0.90	1413.00	2050.00	0.00	0.00	0.00	0.00	0.00
1-3	0.00	1.06	0.68	0.55	0.84	0.52	0.84	0.92	5.44
1-5	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.78	0.00
2-2	0.00	0.90	0.50	0.40	0.00	0.20	0.90	0.90	0.00
2-4	0.00	0.50	0.00	0.00	0.90	0.90	1.00	1.00	0.50
3-1	0.00	2.90	2.80	0.70	1.90	1.80	0.00	0.80	0.90
4-1	0.00	1.50	1.50	0.60	0.80	0.10	0.80	0.70	0.60
A	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AD	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AE	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AF	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AH	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AI	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AJ	15.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AK	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AM	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AN	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AQ	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS	5.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AT	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AU	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AW	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AX	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AY	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AZ	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-0	0.00	22.00	38.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-1	0.00	10.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-2	0.00	9.10	19.00	4.70	0.00	0.00	0.00	0.00	0.00
B1-3	0.00	5.60	10.00	0.00	0.00	0.00	0.00	0.00	0.00
B1-4	0.00	10.00	4.40	0.00	0.00	0.00	0.00	0.00	0.00
BA	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BC	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BD	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BF	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BH	38.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BI	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Concentration in pCi/g.

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
BK	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BL	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BQ	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BT	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BU	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BV	250.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BX	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BY	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C-MIDDLE	0.00	6.00	31.00	0.00	0.00	0.00	0.00	0.00	0.00
C1-3	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CB	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CG	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CI	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CJ	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CK	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CL	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CN	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	8.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CR	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CT	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CU	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CX	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CY	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1-1	0.00	3.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D10	0.00	38.00	54.00	0.00	0.00	0.00	0.00	0.00	0.00
D11	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D12	0.00	32.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D13	0.00	22.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D14	0.00	9.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D15	0.00	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D16	0.00	8.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D18	0.00	13.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
D19	0.00	36.80	10.10	0.00	0.00	0.00	0.00	0.00	0.00
D20	0.00	3.60	4.20	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
D21	0.00	12.30	10.10	0.00	0.00	0.00	0.00	0.00	0.00
D22	0.00	22.00	48.50	0.00	0.00	0.00	0.00	0.00	0.00
D23	0.00	23.10	806.00	0.00	0.00	0.00	0.00	0.00	0.00
D24	0.00	182.50	23.30	0.00	0.00	0.00	0.00	0.00	0.00
D25	0.00	26.80	75.60	0.00	0.00	0.00	0.00	0.00	0.00
D8	0.00	3.10	1.80	1.10	1.40	1.10	0.00	0.00	0.00
DA	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	7.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S10	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S100	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S101	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S102	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S103	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S104	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S105	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S106	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S107	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S108	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S109	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S11	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S110	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S111	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S112	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S113	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S114	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S115	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S116	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S117	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S118	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S119	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S12	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S120	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S121	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S122	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S123	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S124	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S125	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S126	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S127	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S128	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S129	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S13	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S130	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S131	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S132	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S133	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S134	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S135	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S136	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S137	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S138	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S139	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S14	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S140	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S141	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S142	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S144	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S145	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S146	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S147	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S148	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S149	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S15	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S150	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S151	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S152	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S153	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S154	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S156	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S157	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S158	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S159	38.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S16	1.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S161	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S17	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S18	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S19	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S20	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S21	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S22	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S24	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S25	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S26	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S27	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

(Sheet 5 of 7)

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S28	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S29	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S3	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S31	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S33	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S34	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S35	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S36	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S37	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S38	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S39	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S4	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S40	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S41	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S42	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S43	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S44	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S45	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S46	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S47	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S48	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S49	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S5	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S51	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S52	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S53	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S54	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S55	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S56	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S57	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S58	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S59	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S60	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S61	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S62	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S63	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S64	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S65	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S66	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S67	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S68	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S69	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S7	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S70	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S71	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S72	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA228
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S73	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S74	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S75	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S76	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S77	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S78	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S79	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S8	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S80	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S81	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S82	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S83	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S84	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S85	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S86	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S87	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S88	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S89	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S9	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S90	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S91	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S92	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S93	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S94	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S95	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S96	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S97	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S98	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S99	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T-1	0.00	2.10	3.00	1.70	1.20	1.10	0.10	0.00	0.00
T-2	0.00	0.00	320.00	11.00	7.10	5.10	0.00	0.00	0.00
T-3	0.00	75.00	3.50	10.20	9.30	10.30	0.00	0.00	0.00
T-4	0.00	1.60	1.20	2.30	1.20	0.00	0.00	0.00	0.00
T-5	0.00	0.80	0.90	1.10	1.10	1.40	0.00	0.00	0.00
U	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-10	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-11	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-2	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-20	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-21	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-22	34.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-23	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-24	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-41	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-42	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-44	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-45	30.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.6

WELDON SPRINGS QUARRY SITE
RA226
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
WSQ-46	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-47	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-52	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-53	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-54	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-55	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-57	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-64	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-7	8.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-70	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-74	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-8	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-87	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ-88	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ27-39	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WSQ58-63	249.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X	8.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.7

(Sheet 1 of 2)

WELDON SPRINGS QUARRY SITE
TH230
CONCENTRATION* BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
AA	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AI	350.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AK	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL	210.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP	1300.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AT	84.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AX	320.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BF	4.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BK	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BL	72.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN	480.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	51.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BQ	140.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BR	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BX	86.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	39.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CB	36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CC	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE	110.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CG	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CI	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CJ	35.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CL	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CN	18.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ	180.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CR	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CW	170.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CZ	1300.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.00	3.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D10	0.00	180.00	620.00	0.00	0.00	0.00	0.00	0.00	0.00
D18	0.00	85.00	61.00	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.00	4.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.00	135.50	370.00	300.00	0.00	0.00	0.00	0.00	0.00
D4	0.00	438.00	120.30	240.00	0.00	0.00	0.00	0.00	0.00
D5	0.00	1080.00	1300.00	540.00	110.00	16.00	0.00	0.00	0.00
D6	0.00	201.00	190.00	0.00	0.00	0.00	0.00	0.00	0.00

* Concentration in pCi/g.

TABLE A.7

(Sheet 2 of 2)

WELDON SPRINGS QUARRY SITE
TH230
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
D7	0.00	1300.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D8	0.00	92.30	1.50	1.10	1.40	15.20	0.00	0.00	0.00
D9	0.00	5500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	31.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	3.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	42.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	130.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S100	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S106	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S107	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S111	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S120	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S122	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S126	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S13	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S130	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S135	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S139	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S14	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S141	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S142	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S143	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S146	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S15	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S152	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S160	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S20	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S31	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S36	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S40	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S46	5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S51	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S55	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S57	4.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S71	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S72	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S74	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S8	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S83	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S84	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S91	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	4.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.8

WELDON SPRINGS QUARRY SITE
TN232
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
CW	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CZ	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D18	0.00	4.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.00	1.70	2.70	0.70	0.00	0.00	0.00	0.00	0.00
D4	0.00	1.90	1.30	1.50	0.00	0.00	0.00	0.00	0.00
D5	0.00	3.50	5.00	6.00	7.00	0.90	0.00	0.00	0.00
D6	0.00	5.30	5.50	0.00	0.00	0.00	0.00	0.00	0.00
D7	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D9	0.00	29.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Concentration in pCi/g.

TABLE A.9

(Sheet 1 of 4)

WELDON SPRINGS QUARRY SITE
U-238
CONCENTRATION* BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
A	57.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	490.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB	1600.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AD	16.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AE	47.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AF	82.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG	220.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AH	970.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AI	110.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AJ	119.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AK	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AL	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AM	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AN	120.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP	63.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AQ	210.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AS	22.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AT	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AU	73.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AV	110.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AW	135.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AX	230.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AY	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AZ	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB	110.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BC	311.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BD	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BF	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BG	170.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BH	98.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BI	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BJ	62.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BK	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BL	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BN	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BP	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BQ	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BR	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BS	61.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BT	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BU	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BV	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BW	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BX	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Concentration in pCi/g.

TABLE A.9

(Sheet 2 of 4)

WELDON SPRINGS QUARRY SITE
U-238
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
BY	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BZ	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CA	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CB	66.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD	90.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE	55.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CG	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CI	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CJ	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CK	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CL	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CN	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP	6.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CQ	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CR	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CT	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CU	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CW	71.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CY	93.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CZ	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.00	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D10	0.00	34.00	49.00	0.00	0.00	0.00	0.00	0.00	0.00
D12	0.00	64.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D13	0.00	71.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D14	0.00	73.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D15	0.00	394.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D16	0.00	116.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D17	0.00	189.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D18	0.00	82.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
D19	0.00	70.50	81.10	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D20	0.00	161.00	132.00	0.00	0.00	0.00	0.00	0.00	0.00
D21	0.00	270.00	126.00	0.00	0.00	0.00	0.00	0.00	0.00
D22	0.00	164.00	25.90	0.00	0.00	0.00	0.00	0.00	0.00
D23	0.00	98.20	420.00	0.00	0.00	0.00	0.00	0.00	0.00
D25	0.00	0.00	81.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.00	172.50	133.30	110.00	0.00	0.00	0.00	0.00	0.00
D4	0.00	95.40	212.50	1500.00	0.00	0.00	0.00	0.00	0.00
D5	0.00	76.50	120.00	56.00	55.00	10.50	0.00	0.00	0.00
D6	0.00	95.80	1330.00	0.00	0.00	0.00	0.00	0.00	0.00
D7	0.00	270.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D8	0.00	54.40	164.80	43.70	34.80	5.70	0.00	0.00	0.00
D9	0.00	71.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DA	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.9

(Sheet 3 of 4)

WELDON SPRINGS QUARRY SITE
U-238
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
F	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
J	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M	28.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S10	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S100	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S101	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S102	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S103	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S104	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S105	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S106	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S107	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S108	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S109	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S11	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S110	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S111	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S112	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S113	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S114	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S115	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S116	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S117	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S119	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S120	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S121	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S122	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S123	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S124	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S125	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S126	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S127	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S128	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S129	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S13	5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S130	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S131	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S132	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S133	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S134	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S135	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S136	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE A.9

(Sheet 4 of 4)

WELDON SPRINGS QUARRY SITE
U-238
CONCENTRATION BY DEPTH IN FEET

SAMPLES	0-0.5	.5-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
S137	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S138	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S139	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S14	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S140	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S141	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S144	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S145	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S146	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S147	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S148	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S150	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S151	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S152	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S154	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S156	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S158	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S159	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S16	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S161	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S17	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S18	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S19	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S21	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S22	21.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S26	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S27	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S28	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S29	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S30	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S31	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S32	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S33	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S34	22.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S38	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S39	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S40	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S41	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S42	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S43	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S44	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S45	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S47	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S48	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S49	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S50	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S51	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S52	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S53	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S54	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A.2

CHEMICAL CHARACTERIZATION DATA FROM BECHTEL NATIONAL, INC., 1985c

(Sample locations for this portion of the Appendix are shown in Figure A.1; numbered locations on Figure A.1 correspond to Customer or Client I.D. number in Appendix A.2)

TABLE A.10
EP TOXICITY RESULTS ON SOIL SAMPLES FRON THE WSQ

EP TOXICITY RESULTS

EAL	Customer	Arsenic mg/L	Barium mg/L	Cadmium mg/L	Chromium mg/L
1777-59-19	QB-57	<0.1	1.0	<0.01	0.02
1777-59-20	QB-58 Composite	<0.1	0.7	<0.01	0.04
1777-59-21	QB-59 Composite	<0.1	2.4	<0.01	0.02
1777-59-22	QB-60 Composite	<0.1	0.2	<0.01	<0.01
1777-59-23	E13782 N7633	<0.1	0.4	<0.01	0.05
1777-59-24	QB-64 Composite	<0.1	0.8	0.01	0.02
1777-59-25	QB-68 Composite	<0.1	0.5	0.25	0.06

EAL	Customer	Lead mg/L	Mercury mg/L	Selenium mg/L	Silver mg/L
1777-59-19	QB-57	<0.05	<0.004	<0.1	<0.01
1777-59-20	QB-58 Composite	<0.05	<0.004	<0.1	<0.01
1777-59-21	QB-59 Composite	0.16	<0.004	0.14	<0.01
1777-59-22	QB-60 Composite	<0.05	<0.004	<0.1	<0.01
1777-59-23	E13782 N7633	<0.05	<0.004	0.15	<0.01
1777-59-24	QB-64 Composite	<0.05	0.009	<0.1	<0.01
1777-59-25	QB-68 Composite	<0.05	0.01	<0.1	<0.01

TABLE A.10 (continued)
EP TOXICITY RESULTS ON SOIL SAMPLES FRON THE WSQ

EP TOXICITY RESULTS

EAL	Customer	Endrin mg/L	Lindane mg/L	Methoxychlor mg/L
1777-59-19	QB-57	<0.001	<0.001	<0.02
1777-59-20	QB-58 Composite	<0.001	<0.001	<0.02
1777-59-21	QB-59 Composite	<0.001	<0.001	<0.02
1777-59-22	QB-60 Composite	<0.001	<0.001	<0.02
1777-59-23	E13782 N7633	<0.001	<0.001	<0.02
1777-59-24	QB-64 Composite	<0.001	<0.001	<0.02
1777-59-25	QB-68 Composite	<0.001	<0.001	<0.02

EAL	Customer	Toxaphene mg/L	2,4-D mg/L	2,4,5-TP Silvex mg/L
1777-59-19	QB-57	<0.1	<0.001	<0.001
1777-59-20	QB-58 Composite	<0.1	<0.001	<0.001
1777-59-21	QB-59 Composite	<0.1	<0.001	<0.001
1777-59-22	QB-60 Composite	<0.1	<0.001	<0.001
1777-59-23	E13782 N7633	<0.1	<0.001	<0.001
1777-59-24	QB-64 Composite	<0.1	<0.001	<0.001
1777-59-25	QB-68 Composite	<0.1	<0.001	<0.001

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Aberline

Date: April 16, 1985

EAL Lab No.: 1777-59-26

Client I.D.: Qb-57

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC	5.1	pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
b-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<260
D-BHC	19	Toxaphene	<1,500
Aldrin		PCB's	
heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<28	PCB-1248	
p,p-DDD (4,4')		PCB-1254	560
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 16, 1985
LAL Lab No.: 1777-59-27
Client I.D.: QB-58 Composite

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC	5.3	pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
b-BHC		Endosulfan Sulfate	
heptachlor		Chlordane	<1,200
D-BHC	95	Toxaphene	<5,200
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<130	PCB-1248	
p,p-DDD (4,4')		PCB-1254	9,200
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 16, 1985
EAL Lab No.: 1777-59-28
Client I.D.: QB-59 Composite

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC		pp-DDT (4,4')	
g-BHC	1.3	Endrin Aldehyde	
B-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<100
D-BHC		Toxaphene	<590
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<11	PCB-1248	
p,p-DDD (4,4')		PCB-1254	1,000
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 16, 1985
EAL Lab No.: 1777-59-29
Client I.D.: QB-60 Composite

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC		pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
b-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<200
D-BHC		Toxaphene	<1,200
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<22	PCB-1248	
p,p-DDD (4,4')		PCB-1254	1,000
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Liberline

Date: April 16, 1985

EAL Lab No.: 1777-59-31

Client I.D.: QB-64 Composite

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC		pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
b-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<10,000
D-BHC		Toxaphene	<60,000
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<1,100	PCB-1248	
p,p-DDD (4,4')		PCB-1254	46,000
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Lberline

Date: April 16, 1985

EAL Lab No.: 1777-59-32

Client I.D.: QB-68 Composite

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC		pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
B-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<1,100
D-BHC	22	Toxaphene	<6,400
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<120	PCB-1248	
p,p-DDD (4,4')		PCB-1254	
b-Endosulfan		PCB-1260	9,000
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.11
PESTICIDES AND PCBs CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 16, 1985
EAL Lab No.: 1777-59-30
Client I.D.: E13782 N7633

Compound	ug/kg(ppb)	Compound	ug/kg(ppb)
a-BHC		pp-DDT (4,4')	
g-BHC		Endrin Aldehyde	
B-BHC		Endosulfan Sulfate	
Heptachlor		Chlordane	<190
D-BHC	3.5	Toxaphene	<1,100
Aldrin		PCB's	
Heptachlor Epoxide		PCB-1016	
a-Endosulfan		PCB-1221	
p,p-DDE (4,4')		PCB-1232	
Dieldrin		PCB-1242	
Endrin	<20	PCB-1248	
p,p-DDD (4,4')		PCB-1254	1,000
B-Endosulfan		PCB-1260	
1,2,3,4-TCDD		PCB-1262	

Note: The presence of PCB prevents the detection of the remaining pesticides.

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-33
Client I.D.: QB - 57

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-34
Client I.D.: QB 58, Composite

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-35
Client I.D.: GB-59 Composite

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-36
Client I.D.: QB-60 Composite

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Liberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-37
Client I.D.: QB-64 Composite

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-39
Client I.D.: QB-68 Composite

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.12
PRIORITY AND NON-PRIORITY POLLUTANT
CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline Instrument Corp.

Date: April 18, 1985
EAL Lab No.: 1777-59-38
Client I.D.: E13782 N7633

(REVISED)

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ng/g(ppb)	VOLATILE	ng/g(ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 15, 1985

EAL Lab No.: 1777-59-26

Client I.D.: QB-57

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<900	hexachlorobutadiene	<900
p-chloro-m-cresol	<900	hexachlorocyclopentadiene	<900
2-chlorophenol	<900	isophorone	<900
2,4-dichlorophenol	<900	naphthalene	<900
2,4-dimethylphenol	<900	nitrobenzene	<900
2-nitrophenol	<900	N-nitrosodiphenylamine	<900
4-nitrophenol	<4,500	N-nitrosodipropylamine	<900
2,4-dinitrophenol	<4,500	bis(2-ethylhexyl)phthalate	<900
4,6-dinitro-2-methylphenol	<4,500	benzyl butyl phthalate	<900
pentachlorophenol	<4,500	di-n-butyl phthalate	<900
phenol	<900	di-n-octyl phthalate	<900
acenaphthene	<900	diethyl phthalate	<900
benzidine	<4,500	dimethyl phthalate	<900
1,2,4-trichlorobenzene	<900	benzo(a)anthracene	40,000
hexachlorobenzene	<900	benzo(a)pyrene	68,000
hexachloroethane	<900	benzo(b)fluoranthene } benzo(k)fluoranthene }	75,000
bis(2-chloroethyl)ether	<900		
2-chloronaphthalene	<900	chrysene	36,000
1-2-dichlorobenzene	<900	acenaphthylene	<900
1,3-dichlorobenzene	<900	anthracene	11,000
1,4-dichlorobenzene	<900	benzo(ghi)perylene	<900
3,3'-dichlorobenzidine	<1,800	fluorene	<900
2,4-dinitrotoluene	<900	phenanthrene	41,000
1,2-diphenylhydrazine	<900	dibenzo(a,h)anthracene	<900
4-chlorophenyl phenyl ether	<900	indeno(1,2,3-cd)pyrene	<900
bis(2-chloroisopropyl)ether	<900	pyrene	63,000
fluoranthene	72,000	2,6-dinitrotoluene	<900
bis(2-chloroethoxy)methane	<900	4-bromophenyl phenyl ether	<900

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<4,500	aniline	<900
2-methylphenol	<900	benzyl alcohol	<900
4-methylphenol	<900	4-chloroaniline	<900
2,4,5-trichlorophenol	<900	dibenzofuran	<900
2-methylnapthalene	<900	2-nitroaniline	<4,500
3-nitroaniline	<4,500	4-nitroaniline	<4,500
2-pentanone-4-hydroxy-4-methyl	*6,000	sulfur	*720

Dilution factor of 900.
*estimated concentrations

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 15, 1985

EAL Lab No.: 1777-59-27

Client I.D.: QB-58 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	mg/kg(ppm)	COMPOUNDS	mg/kg(ppm)
2,4,6-trichlorophenol	<3	hexachlorobutadiene	<3
p-chloro-m-cresol	<3	hexachlorocyclopentadiene	<3
2-chlorophenol	<3	isophorone	<3
2,4-dichlorophenol	<3	naphthalene	<3
2,4-dimethylphenol	<3	nitrobenzene	<3
2-nitrophenol	<3	N-nitrosodiphenylamine	<3
4-nitrophenol	<15	N-nitrosodipropylamine	<3
2,4-dinitrophenol	<15	bis(2-ethylhexyl)phthalate	<3
4,6-dinitro-2-methylphenol	<15	benzyl butyl phthalate	<3
pentachlorophenol	<15	di-n-butyl phthalate	<3
phenol	<3	di-n-octyl phthalate	<3
acenaphthene	<3	diethyl phthalate	<3
benzidine	<15	dimethyl phthalate	<3
1,2,4-trichlorobenzene	<3	benzo(a)anthracene	<3
hexachlorobenzene	<3	benzo(a)pyrene	<3
hexachloroethane	<3	benzo(b)fluoranthene	<3
bis(2-chloroethyl)ether	<3	benzo(k)fluoranthene	<3
2-chloronaphthalene	<3	chrysene	31
1-2-dichlorobenzene	<3	acenaphthylene	<3
1,3-dichlorobenzene	<3	anthracene	<3
1,4-dichlorobenzene	<3	benzo(ghi)perylene	<3
3,3'-dichlorobenzidine	<6	fluorene	<3
2,4-dinitrotoluene	<3	phenanthrene	60
1,2-diphenylhydrazine	<3	dibenzo(a,h)anthracene	<3
4-chlorophenyl phenyl ether	<3	indeno(1,2,3-cd)pyrene	<3
bis(2-chloroisopropyl)ether	<3	pyrene	55
fluoranthene	68	2,6-dinitrotoluene	<3
bis(2-chloroethoxy)methane	<3	4-bromophenyl phenyl ether	<3

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<15	aniline	<3
2-methylphenol	<3	benzyl alcohol	<3
4-methylphenol	<3	4-chloroaniline	<3
2,4,5-trichlorophenol	<3	dibenzofuran	<3
2-methylnapthalene	<3	2-nitroaniline	<15
3-nitroaniline	<15	4-nitroaniline	<15

ution factor of 3.

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 15, 1985

EAL Lab No.: 1777-59-28

Client I.D.: GL-59 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<60	hexachlorobutadiene	<60
p-chloro-m-cresol	<60	hexachlorocyclopentadiene	<60
2-chlorophenol	<60	isophorone	<60
2,4-dichlorophenol	<60	naphthalene	<60
2,4-dimethylphenol	<60	nitrobenzene	<60
2-nitrophenol	<60	N-nitrosodiphenylamine	<60
4-nitrophenol	<300	N-nitrosodipropylamine	<60
2,4-dinitrophenol	<300	bis(2-ethylhexyl)phthalate	<60
4,6-dinitro-2-methylphenol	<300	benzyl butyl phthalate	<60
pentachlorophenol	<300	di-n-butyl phthalate	<60
phenol	<60	di-n-octyl phthalate	<60
acenaphthene	<60	diethyl phthalate	<60
benzidine	<300	dimethyl phthalate	<60
1,2,4-trichlorobenzene	<60	benzo(a)anthracene	<60
hexachlorobenzene	<60	benzo(a)pyrene	<60
hexachloroethane	<60	benzo(b)fluoranthene	<60
bis(2-chloroethyl)ether	<60	benzo(k)fluoranthene	<60
2-chloronaphthalene	<60	chrysene	<60
1-2-dichlorobenzene	<60	acenaphthylene	<60
1,3-dichlorobenzene	<60	anthracene	<60
1,4-dichlorobenzene	<60	benzo(ghi)perylene	<60
3,3'-dichlorobenzidine	<120	fluorene	<60
2,4-dinitrotoluene	<60	phenanthrene	<60
1,2-diphenylhydrazine	<60	dibenzo(a,h)anthracene	<60
4-chlorophenyl phenyl ether	<60	indeno(1,2,3-cd)pyrene	<60
bis(2-chloroisopropyl)ether	<60	pyrene	<60
fluoranthene	<60	2,6-dinitrotoluene	<60
bis(2-chloroethoxy)methane	<60	4-bromophenyl phenyl ether	<60

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<300	aniline	<60
2-methylphenol	<60	benzyl alcohol	<60
4-metnylphenol	<60	4-chloroaniline	<60
2,4,5-trichlorophenol	<60	dibenzofuran	<60
2-methylnapthalene	<60	2-nitroaniline	<300
3-nitroaniline	<300	4-nitroaniline	<300
2-pentanone-4-hydroxy-4-methyl	*2,000		

Dilution factor of 60.
*estimated concentration

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Eberline

Date: April 15, 1985

EAL Lab No.: 1777-59-29

Client I.D.: LB-60 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<60	hexachlorobutadiene	<60
p-chloro-m-cresol	<60	hexachlorocyclopentadiene	<60
2-chlorophenol	<60	isophorone	<60
2,4-dichlorophenol	<60	naphthalene	<60
2,4-dimethylphenol	<60	nitrobenzene	<60
2-nitrophenol	<60	N-nitrosodiphenylamine	<60
4-nitrophenol	<300	N-nitrosodipropylamine	<60
2,4-dinitrophenol	<300	bis(2-ethylhexyl)phthalate	<60
4,6-dinitro-2-methylphenol	<300	benzyl butyl phthalate	<60
pentachlorophenol	<300	di-n-butyl phthalate	<60
phenol	<60	di-n-octyl phthalate	<60
acenaphthene	<60	diethyl phthalate	<60
benzidine	<300	dimethyl phthalate	<60
1,2,4-trichlorobenzene	<60	benzo(a)anthracene	<60
hexachlorobenzene	<60	benzo(a)pyrene	<60
hexachloroethane	<60	benzo(b)fluoranthene	<60
bis(2-chloroethyl)ether	<60	benzo(k)fluoranthene	<60
2-chloronaphthalene	<60	chrysene	<60
1-2-dichlorobenzene	<60	acenaphthylene	<60
1,3-dichlorobenzene	<60	anthracene	<60
1,4-dichlorobenzene	<60	benzo(ghi)perylene	<60
3,3'-dichlorobenzidine	<120	fluorene	<60
2,4-dinitrotoluene	<60	phenanthrene	<60
1,2-diphenylhydrazine	<60	dibenzo(a,h)anthracene	<60
4-chlorophenyl phenyl ether	<60	indeno(1,2,3-cd)pyrene	<60
bis(2-chloroisopropyl)ether	<60	pyrene	<60
fluoranthene	<60	2,6-dinitrotoluene	<60
bis(2-chloroethoxy)methane	<60	4-bromophenyl phenyl ether	<60

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<300	aniline	<60
2-methylphenol	<60	benzyl alcohol	<60
4-methylphenol	<60	4-chloroaniline	<60
2,4,5-trichlorophenol	<60	dibenzofuran	<60
2-methylnapthalene	<60	2-nitroaniline	<300
3-nitroaniline	<300	4-nitroaniline	<300
2-pentanone-4-hydroxy-4-methyl	*4,000		

Dilution factor of 60.
*estimated concentration

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Lberline

Date: April 15, 1985

EAL Lab No.: 1777-59-31

Client I.D.: CL-64 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<300	hexachlorobutadiene	<300
p-chloro-m-cresol	<300	hexachlorocyclopentadiene	<300
2-chlorophenol	<300	isophorone	<300
2,4-dichlorophenol	<300	naphthalene	<300
2,4-dimethylphenol	<300	nitrobenzene	<300
2-nitrophenol	<300	N-nitrosodiphenylamine	<300
4-nitrophenol	<1,500	N-nitrosodipropylamine	<300
2,4-dinitrophenol	<1,500	bis(2-ethylhexyl)phthalate	<300
4,6-dinitro-2-methylphenol	<1,500	benzyl butyl phthalate	<300
pentachlorophenol	<1,500	di-n-butyl phthalate	<300
phenol	<300	di-n-octyl phthalate	<300
acenaphthene	<300	diethyl phthalate	<300
benzidine	<1,500	dimethyl phthalate	<300
1,2,4-trichlorobenzene	<300	benzo(a)anthracene	<300
hexachlorobenzene	<300	benzo(a)pyrene	<300
hexachloroethane	<300	benzo(b)fluoranthene	<300
bis(2-chloroethyl)ether	<300	benzo(k)fluoranthene	<300
2-chloronaphthalene	<300	chrysene	<300
1-2-dichlorobenzene	<300	acenaphthylene	<300
1,3-dichlorobenzene	<300	anthracene	<300
1,4-dichlorobenzene	<300	benzo(ghi)perylene	<300
3,3'-dichlorobenzidine	<600	fluorene	<300
2,4-dinitrotoluene	<300	phenanthrene	16,000
1,2-diphenylhydrazine	<300	dibenzo(a,h)anthracene	<300
4-chlorophenyl phenyl ether	<300	indeno(1,2,3-cd)pyrene	<300
bis(2-chloroisopropyl)ether	<300	pyrene	30,000
fluoranthene	15,000	2,6-dinitrotoluene	<300
bis(2-chloroethoxy)methane	<300	4-bromophenyl phenyl ether	<300

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<1,500	aniline	<300
2-methylphenol	<300	benzyl alcohol	<300
4-methylphenol	<300	4-chloroaniline	<300
2,4,5-trichlorophenol	<300	dibenzofuran	<300
2-methylnapthalene	<300	2-nitroaniline	<1,500
3-nitroaniline	<1,500	4-nitroaniline	<1,500
2-pentanone-4-hydroxy-4-methyl	*4,900	sulfur	*4,200

Dilution factor of 300.
*estimated concentration

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Liberline

Date: April 15, 1985

EAL Lab No.: 1777-59-32

Client I.D.: GB-68 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<60	hexachlorobutadiene	<60
p-chloro-m-cresol	<60	hexachlorocyclopentadiene	<60
2-chlorophenol	<60	isophorone	<60
2,4-dichlorophenol	<60	naphthalene	740
2,4-dimethylphenol	<60	nitrobenzene	<60
2-nitrophenol	<60	N-nitrosodiphenylamine	<60
4-nitrophenol	<300	N-nitrosodipropylamine	<60
2,4-dinitrophenol	<300	bis(2-ethylhexyl)phthalate	<60
4,6-dinitro-2-methylphenol	<300	benzyl butyl phthalate	<60
pentachlorophenol	<300	di-n-butyl phthalate	1,200
phenol	<60	di-n-octyl phthalate	<60
acenaphthene	<60	diethyl phthalate	<60
benzidine	<300	dimethyl phthalate	<60
1,2,4-trichlorobenzene	<60	benzo(a)anthracene	<60
hexachlorobenzene	<60	benzo(a)pyrene	<60
hexachloroethane	<60	benzo(b)fluoranthene } benzo(k)fluoranthene }	5,300
bis(2-chloroethyl)ether	<60		
2-chloronaphthalene	<60	chrysene	<60
1-2-dichlorobenzene	<60	acenaphthylene	<60
1,3-dichlorobenzene	<60	anthracene	3,200
1,4-dichlorobenzene	<60	benzo(ghi)perylene	<60
3,3'-dichlorobenzidine	<120	fluorene	2,600
2,4-dinitrotoluene	<60	phenanthrene	13,000
1,2-diphenylhydrazine	<60	dibenzo(a,h)anthracene	<60
4-chlorophenyl phenyl ether	<60	indeno(1,2,3-cd)pyrene	<60
bis(2-chloroisopropyl)ether	<60	pyrene	14,000
fluoranthene	15,000	2,6-dinitrotoluene	<60
bis(2-chloroethoxy)methane	<60	4-bromophenyl phenyl ether	<60

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<300	aniline	<60
2-methylphenol	<60	benzyl alcohol	<60
4-methylphenol	<60	4-chloroaniline	<60
2,4,5-trichlorophenol	<60	dibenzofuran	1,200
2-methylnapthalene	670	2-nitroaniline	<300
3-nitroaniline	<300	4-nitroaniline	<300
2-pentanone-4-hydroxy-4-methyl	*6,000	sulfur	*31,000

Dilution factor of 60.

*estimated concentrations

TABLE A.13
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN SOIL SAMPLES FROM THE WSQ

Liberline

Date: April 15, 1985

EAL Lab No.: 1777-59-30

Client I.D.: E13782 N7633

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/kg	COMPOUNDS	ug/kg
2,4,6-trichlorophenol	<60	hexachlorobutadiene	<60
p-chloro-m-cresol	<60	hexachlorocyclopentadiene	<60
2-chlorophenol	<60	isophorone	<60
2,4-dichlorophenol	<60	naphthalene	<60
2,4-dimethylphenol	<60	nitrobenzene	<60
2-nitrophenol	<60	N-nitrosodiphenylamine	<60
4-nitrophenol	<300	N-nitrosodipropylamine	<60
2,4-dinitrophenol	<300	bis(2-ethylhexyl)phthalate	<60
4,6-dinitro-2-methylphenol	<300	benzyl butyl phthalate	<60
pentachlorophenol	<300	di-n-butyl phthalate	<60
phenol	<60	di-n-octyl phthalate	<60
acenaphthene	<60	diethyl phthalate	<60
benzidine	<300	dimethyl phthalate	<60
1,2,4-trichlorobenzene	<60	benzo(a)anthracene	<60
hexachlorobenzene	<60	benzo(a)pyrene	<60
hexachloroethane	<60	benzo(b)fluoranthene	<60
bis(2-chloroethyl)ether	<60	benzo(k)fluoranthene	<60
2-chloronaphthalene	<60	chrysene	<60
1-2-dichlorobenzene	<60	acenaphthylene	<60
1,3-dichlorobenzene	<60	anthracene	<60
1,4-dichlorobenzene	<60	benzo(ghi)perylene	<60
3,3'-dichlorobenzidine	<120	fluorene	<60
2,4-dinitrotoluene	<60	phenanthrene	<60
1,2-diphenylhydrazine	<60	dibenzo(a,h)anthracene	<60
4-chlorophenyl phenyl ether	<60	indeno(1,2,3-cd)pyrene	<60
bis(2-chloroisopropyl)ether	<60	pyrene	<60
fluoranthene	<60	2,6-dinitrotoluene	<60
bis(2-chloroethoxy)methane	<60	4-bromophenyl phenyl ether	<60

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<300	aniline	<60
2-methylphenol	<60	benzyl alcohol	<60
4-methylphenol	<60	4-chloroaniline	<60
2,4,5-trichlorophenol	<60	dibenzofuran	<60
2-methylnapthalene	<60	2-nitroaniline	<300
3-nitroaniline	<300	4-nitroaniline	<300
2-pentanone-4-hydroxy-4-methyl	*14,000	sulfur	*15,000

Dilution factor of 60.
*estimated concentration

TABLE A.14
PRIORITY POLLUTANT METALS IN SOIL SAMPLES FROM THE WSQ

EAL	Customer	Silver mg/kg	Beryllium mg/kg	Cadmium mg/kg
1777-59-26	QB-57	<0.2	0.45	2.5
1777-59-27	QB-58 Composite	5.8	0.65	6.4
1777-59-28	QB-59 Composite	<0.2	0.54	1.8
1777-59-29	QB-60 Composite	6.9	0.63	2.3
1777-59-30	E 13782 N7633	7.5	0.61	2.0
1777-59-31	QB-64 Composite	<0.2	0.56	3.2
1777-59-32	QB-68 Composite	8.3	0.69	98

EAL	Customer	Chromium mg/kg	Copper mg/kg	Nickel mg/kg
1777-59-26	QB-57	19	38	19
1777-59-27	QB-58 Composite	49	160	24
1777-59-28	QB-59 Composite	19	110	120
1777-59-29	QB-60 Composite	33	58	23
1777-59-30	E 13782 N7633	24	140	300
1777-59-31	QB-64 Composite	29	92	45
1777-59-32	QB-68 Composite	30	150	29

EAL	Customer	Lead mg/kg	Antimony mg/kg	Zinc mg/kg	Arsenic mg/kg
1777-59-26	QB-57	130	<20	170	100
1777-59-27	QB-58 Composite	290	<20	490	90
1777-59-28	QB-59 Composite	390	<20	68	100
1777-59-29	QB-60 Composite	180	<20	200	120
1777-59-30	E 13782 N7633	950	71	39	100
1777-59-31	QB-64 Composite	280	<20	270	73
1777-59-32	QB-68 Composite	410	<20	870	120

TABLE A.14 (continued)
PRIORITY POLLUTANT METALS IN SOIL SAMPLES FROM THE WSQ

ZAL	Customer	Selenium mg/kg	Mercury mg/kg	Thallium mg/kg
1777-59-26	QB-57	17	0.18	3.0
1777-59-27	QB-58 Composite	28	2.9	4.9
1777-59-28	QB-59 Composite	20	0.41	6.2
1777-59-29	QB-60 Composite	28	0.28	4.0
1777-59-30	E 13782 N7633	22	0.7	5.1
1777-59-31	QB-64 Composite	26	2.1	5.1
1777-59-32	QB-68 Composite	21	6.3	5.1

ZAL	Customer	Cyanide mg/kg	pH (Corrosivity)	Asbestos %
1777-59-26	QB-57	0.2	8.2	<1
1777-59-27	QB-58 Composite	0.4	9.5	<1
1777-59-28	QB-59 Composite	<0.2	8.3	<1
1777-59-29	QB-60 Composite	0.2	7.5	<1
1777-59-30	E 13782 N7633	0.2	8.2	<1
1777-59-31	QB-64	0.6	6.0	<1
1777-59-32	QB-68 Composite	0.5	7.5	<1

		Reactivity	Ignitability
1777-59-26	QB-57	(1)	(2)
1777-59-27	QB-58 Composite	(1)	(2)
1777-59-28	QB-59 Composite	(1)	(2)
1777-59-29	QB-60 Composite	(1)	(2)
1777-59-30	E 13782 N7633	(1)	(2)
1777-59-31	QB-64	(1)	(2)
1777-59-32	QB-68 Composite	(1)	(2)

(1) These soil samples do not react with water or with alkali. The samples emit carbon dioxide when treated with acid, but do not emit any hydrogen sulfide or hydrogen cyanide. As such, these samples are not classified as reactive.

(2) These soil samples are not ignitable when subjected to friction, moisture or open flame, and as such are not classified as ignitable.

A.3

CHEMICAL CHARACTERIZATION DATA FROM KAYE AND DAVIS, 1987

(Exception is Table A.21 which is from Meyer, 1988)

TABLE A.15
SAMPLE ANALYSIS SCHEDULE

Boring	Depth (ft)	Volatiles	Semi-volatiles	Nitro-aromatics	PCBs
B1	0-1		X	X	X
B2	0-3(1)		X	X	X
	2-3(1)	X			
	3-4(1)		X	X	X
B3	0-3		X	X	X
	3-6		X	X	X
	6-9		X	X	X
	8-9	X			
	9-12		X	X	X
	11-12	X			
	27-30(1)		X	X	X
	33-35(1)		X	X	X
B4	0-3		X	X	X
	2-3	X			
	3-6		X	X	X
	6-9(1)		X	X	X
B5	0-3(1)		X	X	X
	6-9(1)		X	X	X
	21-22,23-24(1)		X	X	X
	24-27	X	X	X	X
	27-30		X	X	X
	28-29	X			
	30-31	X			
	30-32		X	X	X
B6	0-1	X			
	1-2	X			
	2-3	X			
	0-3		X	X	X
	3-4	X			
	4-5	X			
	3-6		X	X	X
	6-9		X		X
	15-16	X	X	X	X
	25-26(1)	X			
	29-30(1)	X			
	27-30(1)		X	X	X
	32-33(1)		X	X	X
	33-34(1)	X			
	34-35	X			
	33-36	X	X	X	X

TABLE A.15
SAMPLE ANALYSIS SCHEDULE
(continued)

Boring	Depth (ft)	Volatiles	Semi-volatiles	Nitro-aromatics	PCBs
B7	0-3	X	X	X	X
	3-6(1)		X	X	X
	6-9(1)		X	X	X
	9-12(1)		X	X	X
	12-15(1)		X	X	X
	13-14(1)	X			
	15-18		X	X	X
	18-21(1)		X	X	X
	19-20	X			
	21-24(1)		X	X	X
	24-27(1)	X	X	X	X
	27-30(1)		X	X	X
	30-33		X	X	X
	33-36		X	X	X
	36-38		X	X	X
B8	0-3		X	X	X
	6-9		X		X
B9	0-2		X	X	X
B10	0-1(1)		X	X	X
B11	0-3(1)			X	
B12	0-3		X	X	X
	3-5		X	X	X
B13	7-8		X	X	X
B14	0-3(1)		X	X	X
	3-6(1)		X	X	
B15	0-3(1)		X	X	
	3-6(1)		X	X	
	6-9(1)		X	X	X
B16	0-3		X	X	X
	3-5		X	X	X
	9-12		X	X	X
	12-15		X	X	X
	15-18		X	X	X
	18-21		X	X	X
	21-24		X	X	X
	24-25(1)	X			
	24-25, 26-27(1)		X	X	X
	27-29(1)		X	X	X

TABLE A.15
SAMPLE ANALYSIS SCHEDULE

(continued)

Boring	Depth (ft)	Volatiles	Semi-volatiles	Nitro-aromatics	PCBs
B17	0-2		X	X	X
	3-6		X	X	X
	5-6	X			
	6-9		X	X	X
	9-12	X	X	X	X
	12-15		X	X	X
	15-18		X	X	X
	18-21		X	X	X
	21-24	X	X	X	X
	24-25		X	X	X
TW-N	0-3	X	X	X	X
Sediment					
S1	surface		X	X	X
S2	surface		X	X	X
S3	surface	X	X	X	X
S4	surface		X	X	X
S5	surface	X	X	X	X

(1) Part or all of the sample was cored.

TABLE A.16
PARAMETERS ABOVE AND BELOW THE DETECTION LIMIT (DL)
IN SOIL BORINGS AND AT SEDIMENT SAMPLING LOCATIONS
AT WHICH ANALYSIS WERE COMPLETED

Parameter	At or Above DL		Below DL		Locations at Which Analyses Were Completed	
	Soil	Sediment	Soil	Sediment	Soil	Sediment
Volatiles						
Acetone	6	0	2	2	8	2
2-Butanone	2	0	6	2	8	2
Ethylbenzene	8	2	0	0	8	2
Methylene Chloride	8	2	0	0	8	2
Toluene	1	0	7	2	8	2
Total Xylenes	2	2	6	0	8	2
Trichloroethene	1	0	7	2	8	2
Semi-Volatiles						
Acenaphthene	4	1	12	4	16	5
Dibenzofuran	2	1	14	4	16	5
Fluorene	3	0	13	5	16	5
Phenanthrene	6	1	10	4	16	5
Anthracene	6	1	10	4	16	5
Fluoranthene	6	2	10	3	16	5
Pyrene	6	1	10	4	16	5
Benzo(a)Anthracene	6	1	10	4	16	5
Chrysene	6	1	10	4	16	5
Benzo(b)Fluoranthene	6	2	10	3	16	5
Benzo(k)Fluoranthene	2	0	14	5	16	5
Benzo(a)Pyrene	6	1	10	4	16	5
Indeno(1,2,3-cd)Pyrene	6	1	10	4	16	5
Dibenz(a,h)Anthracene	4	0	12	5	16	5
Benzo(g,h,i)Perylene	6	1	10	4	16	5
2,4-Dinitrotoluene	2	0	14	5	16	5
2,6-Dinitrotoluene	1	0	15	5	16	5
Di-n-butylphthalate	2	0	14	5	16	5
Bis(2-ethyhexyl)Phthalates	3	0	13	5	16	5
Naphthalene	1	1	15	4	16	5
Nitroaromatics						
2,6-Diamino-4-Nitrotoluene	3	0	14	5	17	5
2,4,6-Trinitrotoluene (TNT)	6	1	11	4	17	5
2,4-Diamino-6-Nitrotoluene	2	0	15	5	17	5
2,4-Dinitrotoluene (2,4-DNT)	3	0	14	5	17	5
2,6-Dinitrotoluene (2,6-DNT)	3	0	14	5	17	5
PCBs						
Aroclor 1254	8	1	8	4	16	5
Aroclor 1260	2	0	14	5	16	5

TABLE A.17
SUMMARY OF ORGANIC VOLATILE CONCENTRATIONS

ORGANIC VOLATILES CONCENTRATIONS (ug/kg)[1]

Location	Depth (ft)	Chemical Constituent						
		Acetone	2-Butanone	Ethylbenzene	Methylene chloride	Toluene	Total Xylenes	Trichloroethene
B2	2-3	14,000[2]	ND[3]	800[2,4]	5,500[2,4]	ND	ND	ND
B3	8-9	46,000	ND	ND	2,600[2,4]	750	ND	ND
	11-12	2,800	ND	990[2,4]	1,700[2,4]	ND	ND	ND
B4	2-3	1,400	ND	940[2,4]	5,700[2,4]	ND	ND	ND
B5	24-27	ND	ND	1,800[4]	3,600[4]	ND	ND	ND
	28-29	ND	ND	1,100[4]	2,000[4]	ND	ND	ND
	30-31	ND	ND	890[4]	2,200[4]	ND	ND	ND
B6	0-1	ND	1,400	1,600[2,4]	2,400[4]	ND	660[4,5]	ND
	1-2	ND	ND	1,000[2,4]	3,000[4]	ND	ND	ND
	2-3	ND	ND	1,000[2,4]	880[4]	ND	ND	ND
	3-4	ND	ND	890[2,4]	1,000[4]	ND	ND	ND
	4-5	52,000	ND	1,000[2,4]	990[4]	ND	ND	ND
	15-16	5,900	ND	850[2,4]	790[4]	ND	ND	ND
	25-26	ND	1,600[4]	970[2,4]	3,200[2,4]	ND	ND	ND
	29-30	ND	1,700[4]	1,100[2,4]	2,200[2,4]	ND	ND	ND
	33-34	1,500[4]	1,600[4]	920[2,4]	2,800[2,4]	ND	680[2,4]	ND
	34-35	ND	ND	1,100[2,4]	2,300[2,4]	ND	ND	ND
	33-36	ND	860[4]	860[2,4]	2,700[2,4]	ND	ND	ND
B7	0-3	ND	ND	840[2,4]	5,900[2,4]	ND	ND	ND
	13-14	ND	ND	780[2,4]	2,100[2,4]	ND	ND	900
	19-20	ND	1,400[4]	910[4]	ND	ND	ND	ND
	24-27	ND	ND	980[4]	1,100[4]	ND	ND	ND
B16	24-25	4,000	ND	940[2,4]	6,400[2,4]	ND	ND	ND

TABLE A.17 (continued)
SUMMARY OF ORGANIC VOLATILE CONCENTRATIONS

Location	Depth (ft)	Chemical Constituent						
		Acetone	2-Butanone	Ethylbenzene	Methylene chloride	Toluene	Total Xylenes	Trichloroethene
B17	5-6	14,000[2]	ND	750[2,4]	4,100[2,4]	ND	1,100[2,4]	ND
	9-12	2,800[2]	ND	680[2,4]	3,400[2,4]	ND	930[2,4]	ND
	21-24	3,800[2]	ND	990[2,4]	3,600[2,4]	ND	1,400[2,4]	ND
TW-N[5]	0-3	ND	ND	880[2,4]	2,400[2,4]	ND	ND	ND

Notes:
(1) All volatile organics that were detected at levels above the detection limit are presented. Depths at which samples were analyzed but volatile organics were not detected are not presented. See Table 5-6 for a complete sample analysis schedule.
(2) Present in field blank above limit of detection.
(3) ND = Not detected at or above detection limit.
(4) Present in method blank above limit of detection.
(5) TW-N = Assumed background location for soil.

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS

SEMI-VOLATILE CONCENTRATIONS (ug/kg)[1]

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N[2]
Napthalene	0-3	ND[4]	1,300	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	ND	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	NA	ND	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA[5]	NA	NA	NA	ND	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Acenaphthene	0-3	ND	1,700	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	4,500	ND	18,000	6,000	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Dibenzofuran	0-3	ND	1,400	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	ND	ND	ND	3,600	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
(Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Phenanthrene	0-3	3,900	14,000	2,400	3,300	1,100	4,600	ND	ND	NA	ND
	3-6	2,600	1,200	NA	16,000	1,500	NA	ND	NA	ND	NA
	6-9	2,600	740	48,000	2,000	120,000	56,000	NA	NA	NA	NA
	9-12	730	NA	NA	NA	120,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	4,200	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	150,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	1,300	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	12,000	NA	NA	NA	NA	NA
Anthracene	0-3	550	2,100	ND	690	ND	ND	ND	ND	NA	ND
	3-6	390	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	490	ND	9,000	340	33,000	11,000	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	28,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	610	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	37,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	2,500	NA	NA	NA	NA	NA
Fluoranthene	0-3	3,500	12,000	2,700	3,300	1,400	6,000	ND	ND	NA	ND
	3-6	4,000	1,300	NA	15,000	1,300	NA	ND	NA	ND	NA
	6-9	3,100	780	53,000	2,200	8,600	58,000	NA	NA	NA	NA
	9-12	970	NA	NA	NA	140,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	4,600	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	190,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	1,100	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	18,000	NA	NA	NA	NA	NA
Pyrene	0-3	4,900	15,000	3,000	2,500	1,300	5,100	ND	ND	NA	ND
	3-6	3,500	1,100	NA	8,700	1,300	NA	ND	NA	ND	NA
	6-9	2,600	680	ND	1,900	76,000	57,000	NA	NA	NA	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
(Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Pyrene (Continued)	9-12	830	NA	NA	NA	110,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	4,800	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	170,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	870	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	15,000	NA	NA	NA	NA	NA
Benzo(a)Anthracene	0-3	3,000	6,600	1,600	2,000	650	ND	ND	ND	NA	ND
	3-6	1,900	660	NA	ND	550	NA	ND	NA	ND	NA
	6-9	ND	ND	17,000	1,200	38,000	32,000	NA	NA	NA	NA
	9-12	550	NA	NA	NA	63,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	2,100	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	86,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	530	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	6,600	NA	NA	NA	NA	NA
Chrysene	0-3	2,700	5,200	1,500	1,600	710	ND	ND	ND	NA	ND
	3-6	1,600	660	NA	ND	640	NA	ND	NA	ND	NA
	6-9	1,800	460	17,000	1,200	34,000	32,000	NA	NA	NA	NA
	9-12	630	NA	NA	NA	60,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	2,000	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	89,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	520	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	6,500	NA	NA	NA	NA	NA
Benzo(b)Fluoranthene	0-3	4,200	3,800	1,300	2,500	940	ND	ND	ND	NA	ND
	3-6	2,500	900	NA	9,900	810	NA	ND	NA	ND	NA
	6-9	2,600	620	26,000	1,500	46,000	47,000	NA	NA	NA	NA
	9-12	890	NA	NA	NA	89,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	1,500	NA	NA	NA	ND	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
TABLE 5-9 (Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Benzo(b)Fluoranthene (Continued)	15-16	NA	NA	NA	110,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	670	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	8,800	NA	NA	NA	NA	NA
Benzo(a)Pyrene	0-3	2,300	5,100	1,300	1,500	510	ND	ND	ND	NA	ND
	3-6	2,900	540	NA	7,000	460	NA	ND	NA	ND	NA
	6-9	2,900	650	15,000	990	31,000	26,000	NA	NA	NA	NA
	9-12	1,000	NA	NA	NA	47,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	1,700	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	68,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	4,300	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)Pyrene	0-3	2,100	3,000	1,000	1,200	ND	ND	ND	ND	NA	ND
	3-6	1,500	450	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	1,400	ND	8,400	770	18,000	25,000	NA	NA	NA	NA
	9-12	490	NA	NA	NA	33,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	1,600	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	49,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	2,400	NA	NA	NA	NA	NA
Dibenz(a,h)Anthracene	0-3	910	1,400	ND	630	ND	ND	ND	ND	NA	ND
	3-6	1,300	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	1,200	ND	ND	330	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	17,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	580	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
(Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Benzo(g,h,i)Perylene	0-3	1,800	3,800	880	1,600	ND	ND	ND	ND	NA	ND
	3-6	1,300	410	NA	4,600	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	12,000	840	23,000	22,000	NA	NA	NA	NA
	9-12	430	NA	NA	NA	40,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	1,500	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	50,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	3,000	NA	NA	NA	NA	NA
2,4-Dinitrotoluene	0-3	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	9,700	NA
	6-9	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	7,100	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	10,000	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	1,700	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	2,900	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
2,6-Dinitrotoluene	0-3	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	3,700	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	1,500	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	720	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	530	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Bis(2-ethylhexyl)Phthalate	0-3	ND	ND	ND	ND	ND	ND	790	660	NA	1,800
	3-6	1,600	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
(Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Bis(2-ethylhexyl)Phthalate (Continued)	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Benzo(k)Fluoranthene	0-3	ND	ND	780	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	980	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
Fluorene	0-3	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	ND	NA	ND	NA
	6-9	ND	ND	ND	ND	19,000	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	15,000	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	15-16	NA	NA	NA	13,000	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	6,600	NA	NA	NA	NA	NA
Di-n-butyl-pthalate	0-3	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND
	3-6	ND	ND	NA	ND	ND	NA	470	NA	ND	NA
	6-9	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
	9-12	ND	NA	NA	NA	ND	NA	NA	NA	ND	NA
	12-15	NA	NA	NA	NA	580	NA	NA	NA	ND	NA

TABLE A.18
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS
(Continued)

Semi-Volatile	Depth (ft)	Location									
		B3	B4	B5	B6	B7	B8	B14	B15	B16	TW-N(2)
Di-n-butyl-pthalate (Continued)	15-16	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA
	15-18	NA	NA	NA	NA	ND	NA	NA	NA	ND	NA
	18-21	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA
	21-24	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA

Notes:
(1) All semi-volatile organics that were detected at levels above the detection limit are presented. Depths at which samples were analyzed but volatile organics were not detected are not presented. See Table 5-6 for a complete sample analysis schedule.
(2) TW-N = Assumed background location for soil.
(3) Surface sample.
(4) ND = Not detected at or above detection limit.
(5) NA = Not analyzed at this depth (See Table 5-6 for complete analytical schedule).

TABLE A.19
SUMMARY OF NITROAROMATIC CONCENTRATIONS

NITROAROMATICS CONCENTRATIONS (ug/kg)[1]

Location	Depth (ft)	2,6-Diamino-4-Nitrotoluene	2,4,6-Trinitrotoluene	2,4-Dinitrotoluene	2,6-Dinitrotoluene	2,4-Diamino-6-Nitrotoluene
B1	0-1	ND[2]	3,160	ND	ND	ND
B5	27-30	540	ND	ND	ND	ND
	30-32	376	ND	ND	ND	
B7	9-12	540	ND	ND	ND	
	24-27	330	ND	ND	ND	ND
	30-30	580	ND	ND	ND	
B8	0-3	ND	1,230	ND	ND	ND
B10	0-1	ND	1,550	903	1,160	ND
B11	0-3	ND	42,200	ND	ND	ND
B16	0-3	ND	688,000	9,610	19,100	3,110
	3-5	332	690,000	22,900	68,000	4,580
	9-12	ND	1,478,000	12,800	12,000	1,280
	12-15	560	27,100	33,100	4,220	ND
	15-18	ND	8,250	15,400	3,650	ND
	18-21	ND	4,900	10,500	2,330	ND
	21-24	ND	2,390	620	ND	ND
	24-25	ND	850	ND	ND	ND
	26-27	ND	850	ND	ND	ND
	27-29	ND	940	ND	ND	ND
B17	0-2	ND	414,000	1,140	362	7,030
	3-6	ND	1,600,000	910	1,240	ND
	6-9	ND	681,000	459	557	5,280
	9-12	ND	370,000	600	465	7,270
	12-15	ND	1,440	ND	ND	ND
	15-18	ND	968	ND	ND	ND
	18-21	ND	375	ND	ND	ND
	21-24	ND	8,220	2,780	404	ND
	24-25	ND	2,380	1,330	ND	ND
TW-N[3]	0-3	ND	ND	ND	ND	ND

Notes: (1) All nitroaromatics that were detected at levels above the detection limit are presented. Depths at which samples were analyzed but nitroaromatics were not detected are not presented. See Table 5-6 for a complete sample analysis schedule.

(2) ND = Not Detected at or above detection limit.

(3) TW-N = Assumed background location for soil.

TABLE A.20
SUMMARY OF PCBs CONCENTRATIONS

PCBs CONCENTRATIONS (ug/kg)[1]

Location	Depth (ft)	Aroclor 1254	Aroclor 1260
B3	0-3	ND[2]	9,100
	3-6	ND	11,800
	6-9	4,200	ND
	27-30	460	ND
B4	6-9	7,400	ND
B5	0-3	19,000	ND
B6	0-3	18,000	ND
	3-6	34,000	ND
	6-9	6,500	ND
B7	0-3	22,000	ND
B8	0-3	120,000	ND
B9	0-2	5,000	ND
B12	0-3	8,400	ND
B14	0-3	4,400	ND
TW-N[3]	0-3	ND	ND

Note: (1) All PCBs that were detected at levels above the detection limit are presented. Depths at which samples were analyzed but PCBs were not detected are not presented. See Table 5-6 for a complete sample analysis schedule.

(2) ND = Not detected at or above detection limit.

(2) TW-N = Assumed background location for soil.

TABLE A.21
SUMMARY OF NITROAROMATICS CONCENTRATIONS DETECTED IN THE SURFACE SAMPLES COLLECTED FROM THE NORTHEASTERN CORNER OF THE WSQ

	Concentration [a] (ug/g)				
	Quarry Top	Quarry Middle	Quarry Bottom	Method Blank	Detection Limit (ug/g)
2, 4, 6-TNT	20055	15127	4907	--	1.0
2, 4-DNT	18.1	28.9	6.6	--	0.4
2, 6-DNT	--	8.59	5.9	--	1.2
Nitrobenzene	93.4	133	8.4	--	1.2
1, 3, 5 - Trinitrobenzene	110	277	18.0	--	0.06
1, 3 - Dinitrobenzene	--	--	--	--	0.8

-- Concentration less than detection limit.
a Three samples were collected from the northeast corner of the quarry on 5/20/87.

SOURCE: Meyer, 1988.

APPENDIX B
SEDIMENT DATA

TABLE B.1
RADIOCHEMICAL ANALYSIS OF SEDIMENTS FROM THE WSQ

Coordinates		Depth	Concentration (pCi/g +/- 2 sigma)						
E,W	N,S	(ft)	Uranium-234	Uranium-235	Uranium-238	Radium-226	Thorium-230	Thorium-232	Actinium-228
13400.0	7600.0	N/A	765.0 +/- 21.0	31.0 +/- 4.0	782.0 +/- 21.0	11.0 +/- 1.0	465.0 +/- 15.0	3.9 +/- 1.4	2.3 +/- 0.4
13475.0	7475.0	N/A	770.0 +/- 6.0	227.0 +/- 3.0	735.0 +/- 6.0	6.9 +/- 0.1	220.0 +/- 15.0	2.7 +/- 0.5	2.6 +/- 0.4
13500.0	7550.0	N/A	1180.0 +/- 17.0	62.0 +/- 4.0	1170.0 +/- 16.0	3.0 +/- 0.1	323.0 +/- 4.0	0.2 +/- 0.1	2.7 +/- 0.7

N/A Not applicable

SOURCE: BNI, 1985c

TABLE B.2
URANIUM CONCENTRATIONS IN SEDIMENT SAMPLES COLLECTED FROM THE QUARRY POND

Sample	Ge-Detector 63-Kev Uranium (ppm)	Ge-Detector 93-Kev Uranium (ppm)	NaI-Detector >1000 Kev Uranium (ppm)
Quarry Pond			
SED 8-1 (mud)	84	87	3.2
SED 8-2 (organics & mud)	430	430	7.6
SED 8-3 (mud, soil previously covered by water)	210	200	5.4
SED 8-4 (organics, gravel, mud)	660	630	9.3
Quarry Pond (Core)			
WSQ-87A	69	74	4.3
WSQ-87B	3.0	3.5	2.3
WSQ-87C	14	15	2.4
WSQ-87D	10	9.3	- -
WSQ-87E	4.3	5.1	- -
WSQ-87F	3.3	3.8	2.6

Note: Conversion to radiometric units may be made using 1 ppm Uranium = 0.3 pCi/g Uranium.

SOURCE: BGA, 1984

TABLE B.3
SUMMARY OF ORGANIC CONCENTRATIONS IN SEDIMENTS

	Concentration (mg/kg) at	
	S3	S5
Acetone	ND	ND
2-Butanone	ND	ND
Ethylbenzene	3.4[b]	2.7[b]
Methylene Chloride	12[b]	7.8[b]
Toluene	ND	ND
Total Xylenes	4.6[b]	3.6[b]
Trichloroethene	ND	ND

a. Only samples from S3 and S5 (see Figure B.1) were analyzed.

b. Constituent was also present in field and method blanks at or above limit of detection.

ND = Not detected at or above detection limit.

SOURCE: Kaye and Davis, 1987.

TABLE B.4
SUMMARY OF SEMI-VOLATILE CONCENTRATIONS IN SEDIMENTS

	Concentration (mg/kg) at	
	S1	S5
Napthalene	ND	5.5
Acenaphtene	ND	3.0
Dibenzofuran	ND	1.7
Phenanthrene	ND	18
Fluoranthene	9.0	18
Pyrene	ND	14
Benzo(a)Anthracene	ND	8.2
Chrysene	ND	7.2
Benzo(b)Fluoranthene	9.8	13
Benzo(a)Pyrene	ND	6.2
Indeno(1,2,3-cd) Pyrene	ND	4.8
Dibenz(a,h)Anthracene	ND	ND
Benzo(g,h,l)Perylene	ND	6.0
2,4-Dinitrotoluene	ND	ND
2,6-Dinitrotoluene	ND	ND
Bis(2-ethylhexyl)Phthalate	ND	ND
Benzo(k)Fluoranthene	ND	ND
Fluorene	ND	ND
Di-n-buthyl-Phthalate	ND	ND

ND = Not detected at or above detection limit.

SOURCE: Kaye and Davis, 1987.

TABLE B.5
SUMMART OF NITROAROMATICS CONCENTRATIONS IN SEDIMENTS

	Concentration (mg/kg) at S5
2,6-Diamino-4-Nitrotoluene	ND
2,4,6-Trinitrotoluene	0.33
2,4-Dinitrotoluene	ND
2,6-Dinitrotoluene	ND
2,4-Diamino-6-Nitrotoluene	ND

ND = Not detected at or above detection limit.

SOURCE: Kaye and Davis, 1987.

TABLE B.6
SUMMARY OF PCBs CONCENTRATIONS IN SEDIMENTS

	Concentration (mg/kg) at S3
Aroclor 1254	4.8
Aroclor 1260	ND

ND = Not detected.

SOURCE: Kaye and Davis, 1987.

APPENDIX C
SURFACE WATER DATA

TABLE C.1
PESTICIDES AND PCBs CONCENTRATIONS IN QUARRY POND WATER

Eberline

Date: April 16, 1985
EAL Lab No.: 1777-59-13
Client I.D.: Pond N7600 E13500 Composite

Compound	ug/L(ppb)	Compound	ug/L(ppb)
a-BHC	<0.2	pp-DDT (4,4')	<0.2
g-BHC	<0.2	Endrin Aldehyde	<0.2
B-BHC	<0.2	Endosulfan Sulfate	<0.2
Heptachlor	<0.2	Chlordane	<0.5
D-BHC	<0.2	Toxaphene	<7
Aldrin	<0.2	PCB's	
Heptachlor Epoxide	<0.2	PCB-1016	<2
a-Endosulfan	<0.2	PCB-1221	<2
p,p-DDE (4,4')	<0.2	PCB-1232	<2
Dieldrin	<0.2	PCB-1242	<2
Endrin	<0.2	PCB-1248	<2
p,p-DDD (4,4')	<0.2	PCB-1254	<2
B-Endosulfan	<0.2	PCB-1260	<2
1,2,3,4-TCDD	<0.2	PCB-1262	<2

SOURCE: BNI, 1985c

TABLE C.1
PESTICIDES AND PCBs CONCENTRATIONS IN QUARRY POND WATER
(CONTINUED)

Eberline

Date: April 16, 1985
EAL Lab No.: 1777-59-14
Client I.D.: Pond N7500 E13475
Composite

Compound	ug/L(ppb)	Compound	ug/L(ppb)
a-BHC	<0.2	pp-DDT (4,4')	<0.2
g-BHC	<0.2	Endrin Aldehyde	<0.2
B-BHC	<0.2	Endosulfan Sulfate	<0.2
Heptachlor	<0.2	Chlordane	<0.7
D-BHC	<0.2	Toxaphene	<9
Aldrin	<0.2	PCB's	
Heptachlor Epoxide	<0.2	PCB-1016	<3
a-Endosulfan	<0.2	PCB-1221	<3
p,p-DDE (4,4')	<0.2	PCB-1232	<3
Dieldrin	<0.2	PCB-1242	<3
Endrin	<0.2	PCB-1248	<3
p,p-DDD (4,4')	<0.2	PCB-1254	<3
B-Endosulfan	<0.2	PCB-1260	<3
1,2,3,4-TCDD	<0.2	PCB-1262	<3

TABLE C.2
PRIORITY AND NON-PRIORITY POLLUTANT CONCENTRATIONS IN QUARRY POND WATER

Eberline

Date: April 15, 1985
EAL Lab No.: 1777-59-10
Client I.D.: Pond N7600 E13500 Composite

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ug/L(ppb)	VOLATILE	ug/L (ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

SOURCE: BNI, 1985c

TABLE C.2
PRIORITY AND NON-PRIORITY POLLUTANT CONCENTRATIONS IN QUARRY POND WATER
(continued)

Eberline

Date: April 15, 1985
EAL Lab No.: 1777-59-11
Client I.D.: Pond N7500 E13475
Composite

PRIORITY POLLUTANT DATA SHEET

VOLATILES	ug/L (ppb)	VOLATILE	ug/L (ppb)
benzene	< 1	trans-1,3-dichloropropene	< 1
carbon tetrachloride	< 1	cis-1,3-dichloropropene	< 1
chlorobenzene	< 1	ethylbenzene	< 1
1,2-dichloroethane	< 1	methylene chloride	< 1
1,1,1-trichloroethane	< 1	chloromethane	< 1
1,1-dichloroethane	< 1	bromomethane	< 1
1,1,2-trichloroethane	< 1	bromoform	< 1
1,1,2,2-tetrachloroethane	< 1	bromodichloromethane	< 1
chloroethane	< 1	fluorotrichloromethane	< 1
2-chloroethylvinyl ether	< 1	dichlorodifluoromethane	< 1
chloroform	< 1	chlorodibromomethane	< 1
1,1-dichloroethene	< 1	tetrachloroethene	< 1
trans-1,2-dichloroethene	< 1	toluene	< 1
1,2-dichloropropane	< 1	trichloroethene	< 1
		vinyl chloride	< 1

NON-PRIORITY POLLUTANT

carbon disulfide	< 1	acetone	<10
4-methyl-2-pentanone	<10	2-butanone	<20
styrene	< 1	2-hexanone	<10
vinyl acetate	< 2	xylenes	< 1

TABLE C.3
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN QUARRY POND WATER

Eberline

Date: April 15, 1985

EML Lab No.: 1777-59-7

Client I.D.: Pond N7600 E1350 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/L	COMPOUNDS	ug/L
2,4,6-trichlorophenol	<1	hexachlorobutadiene	<1
p-chloro-m-cresol	<1	hexachlorocyclopentadiene	<1
2-chlorophenol	<1	isophorone	<1
2,4-dichlorophenol	<1	naphthalene	<1
2,4-dimethylphenol	<1	nitrobenzene	<1
2-nitrophenol	<1	N-nitrosodiphenylamine	<1
4-nitrophenol	<5	N-nitrosodipropylamine	<1
2,4-dinitrophenol	<5	bis(2-ethylhexyl)phthalate	<1
4,6-dinitro-2-methylphenol	<5	benzyl butyl phthalate	<1
pentachlorophenol	<5	di-n-butyl phthalate	<1
phenol	<1	di-n-octyl phthalate	<1
acenaphthene	<1	diethyl phthalate	<1
benzidine	<5	dimethyl phthalate	<1
1,2,4-trichlorobenzene	<1	benzo(a)anthracene	<1
hexachlorobenzene	<1	benzo(a)pyrene	<1
hexachloroethane	<1	benzo(b)fluoranthene	<1
bis(2-chloroethyl)ether	<1	benzo(k)fluoranthene	<1
2-chloronaphthalene	<1	chrysene	<1
1-2-dichlorobenzene	<1	acenaphthylene	<1
1,3-dichlorobenzene	<1	anthracene	<1
1,4-dichlorobenzene	<1	benzo(ghi)perylene	<1
3,3'-dichlorobenzidine	<2	fluorene	<1
2,4-dinitrotoluene	<1	phenanthrene	<1
1,2-diphenylhydrazine	<1	dibenzo(a,h)anthracene	<1
4-chlorophenyl phenyl ether	<1	indeno(1,2,3-cd)pyrene	<1
bis(2-chloroisopropyl)ether	<1	pyrene	<1
fluoranthene	<1	2,6-dinitrotoluene	<1
bis(2-chloroethoxy)methane	<1	4-bromophenyl phenyl ether	<1

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<5	aniline	<1
2-methylphenol	<1	benzyl alcohol	<1
4-methylphenol	<1	4-chloroaniline	<1
2,4,5-trichlorophenol	<1	dibenzofuran	<1
2-methylnapthalene	<1	2-nitroaniline	<5
3-nitroaniline	<5	4-nitroaniline	<5

SOURCE: BNI, 1985c

TABLE C.3
PRIORITY AND NON-PRIORITY POLLUTANT COMPOUND CONCENTRATIONS IN QUARRY POND WATER
(continued)

Eberline

Date: April 15, 1985

EAL Lab No.: 1777-59-8

Client I.D.: Pond N7500 E13475 Composite

PRIORITY POLLUTANT COMPOUNDS

COMPOUNDS	ug/L	COMPOUNDS	ug/L
2,4,6-trichlorophenol	<1	hexachlorobutadiene	<1
p-chloro-m-cresol	<1	hexachlorocyclopentadiene	<1
2-chlorophenol	<1	isophorone	<1
2,4-dichlorophenol	<1	naphthalene	<1
2,4-dimethylphenol	<1	nitrobenzene	<1
2-nitrophenol	<1	N-nitrosodiphenylamine	<1
4-nitrophenol	<5	N-nitrosodipropylamine	<1
2,4-dinitrophenol	<5	bis(2-ethylhexyl)phthalate	<1
4,6-dinitro-2-methylphenol	<5	benzyl butyl phthalate	<1
pentachlorophenol	<5	di-n-butyl phthalate	<1
phenol	<1	di-n-octyl phthalate	<1
acenaphthene	<1	diethyl phthalate	<1
benzidine	<5	dimethyl phthalate	<1
1,2,4-trichlorobenzene	<1	benzo(a)anthracene	<1
hexachlorobenzene	<1	benzo(a)pyrene	<1
hexachloroethane	<1	benzo(b)flucranthene	<1
bis(2-chloroethyl)ether	<1	benzo(k)fluoranthene	<1
2-chloronaphthalene	<1	chrysene	<1
1-2-dichlorobenzene	<1	acenaphthylene	<1
1,3-dichlorobenzene	<1	anthracene	<1
1,4-dichlorobenzene	<1	benzo(ghi)perylene	<1
3,3'-dichlorobenzidine	<2	fluorene	<1
2,4-dinitrotoluene	<1	phenanthrene	<1
1,2-diphenylhydrazine	<1	dibenzo(a,h)anthracene	<1
4-chlorophenyl phenyl ether	<1	indeno(1,2,3-cd)pyrene	<1
bis(2-chloroisopropyl)ether	<1	pyrene	<1
fluoranthene	<1	2,6-dinitrotoluene	<1
bis(2-chloroethoxy)methane	<1	4-bromophenyl phenyl ether	<1

NON-PRIORITY POLLUTANT COMPOUNDS

benzoic acid	<5	aniline	<1
2-methylphenol	<1	benzyl alcohol	<1
4-methylphenol	<1	4-chloroaniline	<1
2,4,5-trichlorophenol	<1	dibenzofuran	<1
2-methylnapthalene	<1	2-nitroaniline	<5
3-nitroaniline	<5	4-nitroaniline	<5

TABLE C.4
ASBESTOS CONCENTRATION IN QUARRY POND WATER

ASBESTOS BY TRANSMISSION ELECTRON MICROSCOPY								
EAL NO.	CUSTOMER NO.	LDL[a] f/b/L	ASBESTOS FIBERS Chrysotile	ASBESTOS FIBERS Amphibole	FIBER CONC. f/b/liter	MASS CONC. µg/liter	MEAN FIBER DIAMETER µm	MEAN FIBE LENGTH µm
1777-59-1	Pond N7600 E13500 Composite	1.5×10^5	13	0	1.9×10^6	3.2×10^{-2}	0.077	1.38

[a]Lower Detection Limit

SOURCE: BNI, 1985c

EAL Corporation

TABLE C.5
CHEMICAL CONSTITUENTS DETECTED IN SURFACE WATER SAMPLES FROM THE QUARRY POND

	Composite Sample 1a	Composite Sample 2b
Silver	< 0.003	< 0.003
Beryllium	< 0.001	< 0.001
Cadmium	< 0.007	< 0.007
Chromium	0.02	0.02
Copper	< 0.01	< 0.01
Nickel	< 0.04	< 0.04
Lead	< 0.05	< 0.05
Antimony	< 0.4	< 0.4
Zinc	0.02	0.02
Arsenic	< 0.004	< 0.004
Selenium	< 0.005	< 0.005
Mercury	0.0004	0.0006
Thallium	< 0.05	< 0.05
Cyanide	< 0.02	< 0.02

[a] Sample collected at N7600 E13500
[b] Sample collected at N7500 E13475

SOURCE: BNI, 1985c

APPENDIX D
GROUNDWATER DATA

Data from groundwater sampling and analyses performed by the following groups in and around the Weldon Spring Quarry were used to construct Table D.1. Well locations are shown on Figure D.1.

YEARS(s)	SAMPLED BY:	REFERENCE
1960 to 1964	Mallinckrodt Chemical Works	MCW, 1960-1964
1976, 1977	National Lead Company of Ohio	Huey, 1978
1979 to 1981	Lawrence Berkeley Laboratory	BGA, 1984
1982 to 1985	Bechtel National, Inc.	BNI, 1983a, 1983b, 1984b, 1985b, 1986
1986	U.S. Geological Survey	Kleeschulte et al., 1986
1986A, 1987	MK Ferguson and Jacobs Engineering Group	MK-F and JEG, 1987, 1988a

TABLE D.1

CHRONOLOGICAL SUMMARY OF MONITORING FOR URANIUM, RADIUM-226, CHLORIDE, AND NITRATE IN BEDROCK GROUNDWATER AT THE WSQ

HOLE	YEAR	NO. TESTS	URANIUM (PCi/L)			RA-226 (PCi/L)			CHLORIDE (MG/L)			NITRATE (MG/L)		
			MIN	MAX	AV	MIN	MAX	AV	MIN	MAX	AV	MIN	MAX	AV
(TWN)	1960	1			22									
	1961	8			5									
	1962	12			19									
	1963	6			6									
	1964	6			8									
TWN	1977	6	6.7	53.4	29	0.9	8.6	3	16	50	26	0.9	3.7	1.8
	1980	4	6.7	267	83				32	38	35	<1	3	2
	1984	1			3			0.9						
	1985	4	<3	7	5	0.3	0.8	0.6						
	1986A	2	<3	19	11			0.4						
MW1012	1986A	1			<2			0.3						
	1987	(4)			4.4			<1			124.6			0.4
(TWS)	1960	1			7									
	1961	8			4									
	1962	8			7									
	1963	2			9									
	1964	2			6									
TWS	1977	6	20	1470	394	0.5	31.6	7.1	18	27	20	0.7	1.3	0.9
	1979	1			51									
	1980	4	6.7	60	32				27	31	29	<1	26	9.3
	1982	2	3.3	13.3	8.7	1.5	2	1.8	0.5	25	12.8			<.1
	1983	1			16			1.3						
	1984	1			1467			0.5						
	1985	3	<3	17	9	<.1	0.7	0.5						
	1986A	1			5			0.6						
MW1001	1986A	1			11			0						
	1987	(4)			11.1						17.9			0.2

Note: (4) Indicates quarterly measurement schedule
MW1012 and TWN are replacement holes for Test Well No. 1 (TWN)
MW1001 and TWS are replacement holes for Test Well No.2 (TWS)
MW series holes are replacements for TW series holes as shown

(continued)

TABLE D.1 (continued)

HOLE	YEAR	NO. TESTS	URANIUM (PCi/L) MIN	MAX	AV	RA-226 (PCi/L) MIN	MAX	AV	CHLORIDE (MG/L) MIN	MAX	AV	NITRATE (MG/L) MIN	MAX	AV
TW1	1976	1			3073						22			
	1977	6	213	8684	5001	0.5	0.9	0.6	2	22	15	0.7	1.3	1
	1979	2	1870	1937	1904						11			7
	1980	4	333	453	382				3	11	5	<1	5	2.5
TW2	1976	1			59						13			
	1977	6	307	4542	2314	0.5	18	3.6	3	17	9	0.9	3	1.8
	1978	1			93									
	1980	4	100	200	130				3.5	5	4.2	2	4	2.5
	1981	1			17				2	4	2.5			
	1986	1			94									
TW3	1976	1			1336						23			
	1977	6	2405	5878	4542	0.5	3.6	1.4	13	24	21	0.7	1.3	0.9
	1980	4	733	1133	967				8.4	12	10	6	10	8.5
TW4	1976	1			381						14			
	1977	6	26	354	120	0.5	1.4	0.9	1	5	3	0.6	1.8	1
	1979	1			133									
	1980	4	33	133	71				3.4	6.3	4.6	<1	3	1.8
TW5	1976	1			114						11			
	1977	6	27	107	65	1.4	2.3	1.8	2	6	4.5	0.6	1	0.8
	1979	1			27						79			2
	1980	4	7	106	57				<1	53	14	<1	86	25
TW6	1976	1			434						108			
	1977	6	1467	5870	3068	0.5	1.4	0.98	33	106	63	6	54	28
	1979	2	200	4676	2438						90			17
	1980	3	2405	7872	5389				27	130	85	12	62	42
	1981	1			5424									
	1986	1			2538									
TW7	1977	6	67	654	271	0.5	1.8	1	50	174	86	18	120	44
	1979	1			180									
	1980	4	213	500	361				55	80	73	14	86	36
	1983	1			107			2						
	1984	2			29			0.5			1			0.6
	1985	4	120	180	142	0.7	1.8	1.3						
	1986	1			273									
	1986A	1			267			1.2						
MW1002	1986A	2	<2	4	<3	0	0.7	0.35						
	1987				2.2			<1			7.3			18.2

(continued)

TABLE D.1 (continued)

HOLE	YEAR	NO. TESTS	URANIUM (PCi/L)			RA-226 (PCi/L)			CHLORIDE (MG/L)			NITRATE (MG/L)		
			MIN	MAX	AV	MIN	MAX	AV	MIN	MAX	AV	MIN	MAX	AV
TW8	1976	1			3941									
	1977	5	10020	18704	13761	0.5	2.2	1.2	53	110	82	46	83	56
	1980	4	6947	8150	7532				108	115	111	28	89	47
	1984	1			5536			0.5						
	1985	4	6070	12673	6705	0.3	1.9	0.8						
	1986	1			9352									
	1986A	1			8160			0.2						
MW1003	1986A	1			<2			0.2						
	1987	(4)			0.6						10.8			0.2
TW9	1976	1			2806						15			
	1977	6	5478	8684	6680	0.5	1.4	0.7	21	29	24	0.6	4.2	1.7
	1979	2	3941	4209	4075									
	1982	1			6012			7			29			
	1980	4	4476	5344	4993				23	24	23.4	<1	13	4.8
	1984	1			3			0.5						
	1985	4	1467	3735	2685	<.1	0.7	0.4						
	1986				3140									
	1986A	1			3060			0.3						
MW1004	1986A	2	1564	2500	2032	0.1	1.5	0.8						
	1987	(4)			3050			<1			12.4			135
TW10	1976	1			6.7						12			
	1977	6	6.7	26.7	13.3	0.5	9	2.7	8	13	11	0.6	1	0.8
	1980	4	6.7	60	27				12	20	15	<1	2	1.8
MW1005	1987	(4)			610			<1			39			151

TABLE D.2
THORIUM 230 CONCENTRATIONS IN BEDROCK GROUNDWATER AT THE WSQ

Th-230 Concentrations in Bedrock at Quarry

Year	No. Wells Sampled	Samples Per Well	Concentration pCi/l Min.	Max.	Average	Reference
1984		1-2	0.2	2.0	0.62	(BNI, 1985b)
1985		3-4	0.1	43.0	3.04	(BNI, 1986)
1986	5	2	0.1	15.0	1.16	(MK-F and JEG, 1987)
1987(a)						

Notes:

(a) In 1987, Well MW-1012 showed an elevated level of 12 pCi/l Th-230 during one sampling event (2 March 1987). Subsequent sampling at this well produced results at background levels. (MKF and JEG, 1988a)

Table D-3: Concentrations of Chemical Species in Groundwater in Bedrock around WSQ (mg/l)[a]

Chemical Species	Bedrock Inside Quarry Fence and Along Access Road[b, d]		Bedrock Around Quarry[c] 1987	
	Range	Average	Range	Average
METALS				
Aluminum	No Test	-	0.13 - 0.37	0.21
Antimony	No Test		0.06 - 0.097	0.076
Berryllium	< 0.001	<0.001	< 0.005	< 0.005
Barium	0.028 - 0.57	0.11	0.074 - 0.17	0.12
Cadmium	< 0.01	< 0.01	< 0.005	< 0.005
Calcium	48 - 290	140	104 - 146	118
Chromium	< 0.01	< 0.01	.038 - 0.076	0.054
Cobalt	< 0.01	< 0.01	< 0.05	< 0.05
Copper	<0.01 - 0.08	0.018	0.007 - 0.02	0.014
Iron	< 0.02 - 6.8	0.49	0.023 - 0.22	0.091
Lead	0.05 - 0.26	0.057	< 0.005	< 0.005
Lithium	< 0.01 - 0.04	0.016	Undetected	
Magnesium	4.9 - 62	40	21 - 47	34
Manganese	< 0.01 - 3.6	0.48	0.064 - 0.84	0.48
Mercury	No Test	-	< 0.0002	< 0.0002
Molybdenum	0.14	0.14	No Test	
Nickel	< 0.01 - 0.04	< 0.01	.036 - .052	0.042
Potassium	2.3 - 18	6.7	6.4 - 8.7	7.8
Selenium	< 0.05	< 0.05	< 0.005	< 0.005
Silver	No Test		< 0.01 - 0.02	0.016
Sodium	1 - 100	26	26 - 188	67
Strontium	0.12 - 1.3	0.68	No Test	
Tin	< 0.05 - 0.25	0.074	No Test	
Titanium	No Test		< 0.01	< 0.01
Vanadium	No Test		< 0.05	<0.05
Zinc	< 0.01 - 4.5	0.26	0.007 - 0.029	0.017
INORGANIC ANIONS				
Chloride	1 - 130	60	7 - 125	38
Fluoride	<0.1 - 1.1	0.49	<0.25 - 0.97	0.65
Nitrate	< 1 - 89	15	0.4 - 579	279
Sulfate	11 - 700	190	63 - 479	312
OTHER SPECIES				
Arsenic	< 0.1	< 0.1	<0.01	< 0.01
Bicarbonate	130 - 640	380	No Test	
Boron	0.05 - 0.56	0.22	No Test	
Cyanide	< 0.02	< 0.02	< 0.01	
Phosphorus (as P_2O_5)	0.11 - 7.4	0.74	No Test	
Silicon (as SiO_2)	7.5 - 28	16	No Test	
pH	6.0 - 7.6	7.0	No Test	

NOTES:

a Concentrations are given to two significant figures. Samples were collected in 1979 - 1981 and 1985.

b Eleven boreholes were sampled at four or five dates to yield 47 samples. The boreholes were located along the southern (4) and eastern (1) perimeter fence and along the access road (6) to the Quarry rim.

c Samples collected 3/87 from DOE Monitoring Wells MW 1002, 1004, 1005, 1012.

d Modified from DEIS (DOE, 1987).

Sources: Berkeley Geosciences Associates (1984); Bechtel National (1985c); MK-Ferguson (1987).

TABLE D.4

NITROAROMATIC COMPOUNDS IN BEDROCK GROUNDWATER AT THE WSQ

Compound	Concentration (ug/l) detected at [a,b]			
	MW-1002	MW-1004	MW-1005	MW-1012
2, 4, 6-TNT	4.3	3.1	0.1	0.5
2, 4-DNT	0.5	0.5	0.2	0.2
2, 6-DNT	0.9	1.5	0.6	0.6
Nitrobenzene	0.6	0.6	0.6	0.6
1, 3, 5 - Trinitrobenzene	0.9	0.3	0.1	0.03
1, 3 - Dinitrobenzene	0.4	0.4	0.4	0.4

a Samples collected 3/87. Well locations shown on Figure D.1

b Nitroaromatics analysis performed following USATHAMA Method (HPLC).

Source: MK-F, 1987

TABLE D.5

AVERAGE INORGANIC ANION CONCENTRATIONS IN BEDROCK GROUNDWATER AT THE WSQ FOR 1987

Well Number	Concentration (mg/l)			
	Nitrate (as N)	Sulfate	Chloride	Fluoride
MW1001	0.2	307.8	17.9	0.7
MW1002	18.2	63.5	7.3	0.4
MW1003	0.2	81.2	10.8	0.4
MW1004	134.7	157.5	12.4	0.8
MW1005	150.8	221.0	39.0	0.6
MW1012	0.4	482.3	124.6	0.7
MW1013	2.1	361.0	132.1	0.4
MW1015	0.1	464.8	102.6	0.4

SOURCE: MK-F and JEG, 1988a

TABLE D.6
AVERAGE NITROAROMATIC CONCENTRATIONS IN BEDROCK GROUNDWATER AT THE WSQ FOR 1987

	Concentration (ug/l)					
Well Number	1,4,6-TNT	2,4-DNT	2,6-DNT	Nitro-benzene	1,2,5-Trinitro-benzene	1,3-Dinitro-benzene
MW1001	0.00	0.00	0.00	0.00	0.00	0.00
MW1002	3.45	0.13	0.23	0.55	1.30	0.00
MW1003	0.00	0.00	0.00	0.00	0.00	0.00
MW1004	2.68	0.21	0.38	0.00	0.38	0.00
MW1005	0.03	0.25	0.45	0.43	0.16	0.00
MW1012	0.00	0.05	0.00	0.00	0.00	0.00
MW1013	0.00	0.22	0.00	0.24	0.16	0.00
MW1015	12.10	0.00	0.00	11.00	3.43	1.68

SOURCE: MK-F and JEG, 1988a

TABLE D.7
GROUNDWATER LEVELS AT THE WSQ

Well Number	Aquifer Monitored	Groundwater Elevation (ft. msl) 3/87	9/87	2-3/88	6/88
MW1001	bedrock	449.39	445.77	448.29	NA
MW1002	bedrock	466.62	465.34	467.71	466.27
MW1003	bedrock	438.42	437.92	NA	NA
MW1004	bedrock	464.41	463.41	465.21	463.88
MW1005	bedrock	465.08	463.40	465.88	464.25
MW1006	alluvial	451.77	449.85	451.77	449.31
MW1007	alluvial	452.16	449.80	451.36	449.31
MW1008	alluvial	452.29	449.42	451.71	449.03
MW1009	alluvial	451.69	449.21	451.22	447.43
MW1010	alluvial	446.82	444.58	445.87	440.47
MW1011	alluvial	447.84	444.70	445.82	440.32
MW1012	bedrock	451.85	459.38	461.90	458.71
MW1013	bedrock	NA	448.30	449.57	446.34
MW1014	alluvial	NA	448.03	450.02	446.54
MW1015	bedrock	NA	450.28	452.38	449.57
MW1016	alluvial	NA	450.39	452.13	449.18
MW1017	alluvial	NA	444.89	445.43	441.41
MW1018	alluvial	NA	445.97	446.90	442.85
MW1019	alluvial	NA	446.83	447.43	443.92

NA = Not available

Sources: 3/87 data from MK-F, 1987;
9/87 and 2-3/88 data from MK-F and JEG, 1988e; and
6/88 data from MK-F and JEG, 1988d.

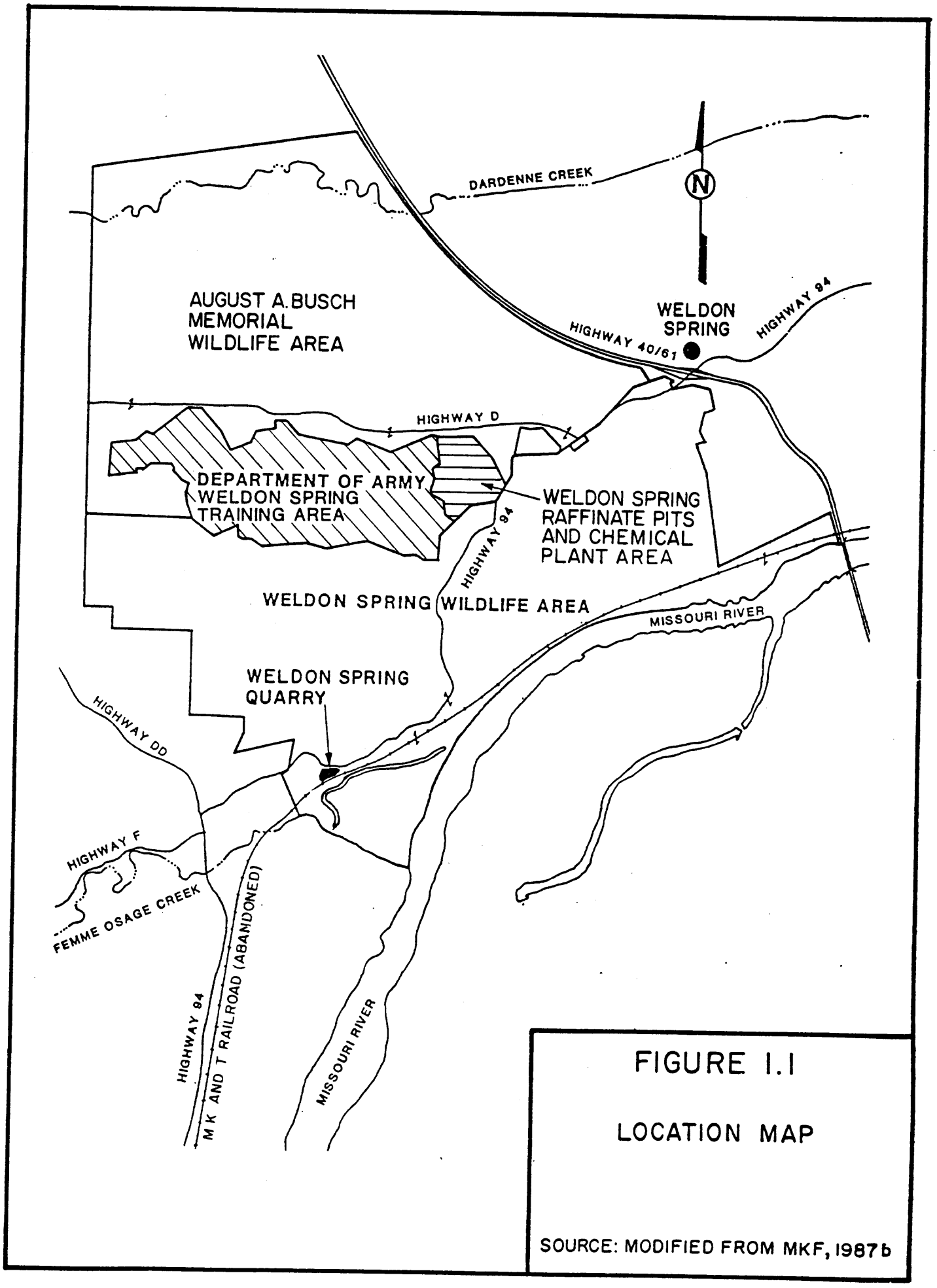


FIGURE 1.1

LOCATION MAP

SOURCE: MODIFIED FROM MKF, 1987b

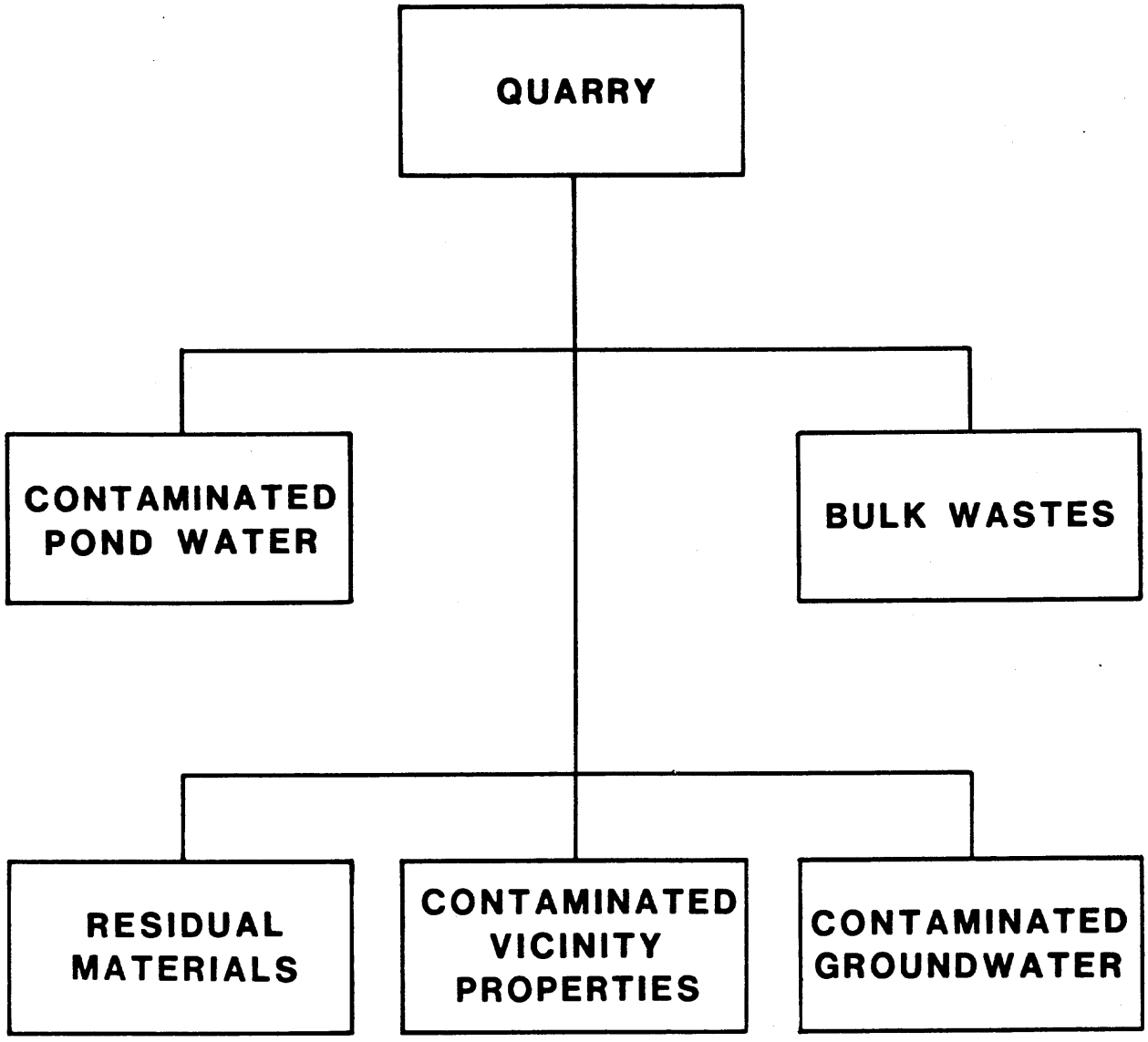


FIGURE 1.2

ENVIRONMENTAL COMPLIANCE COMPONENTS FOR THE WELDON SPRING QUARRY

SOURCE: MODIFIED FROM HAROUN ET AL, 1989

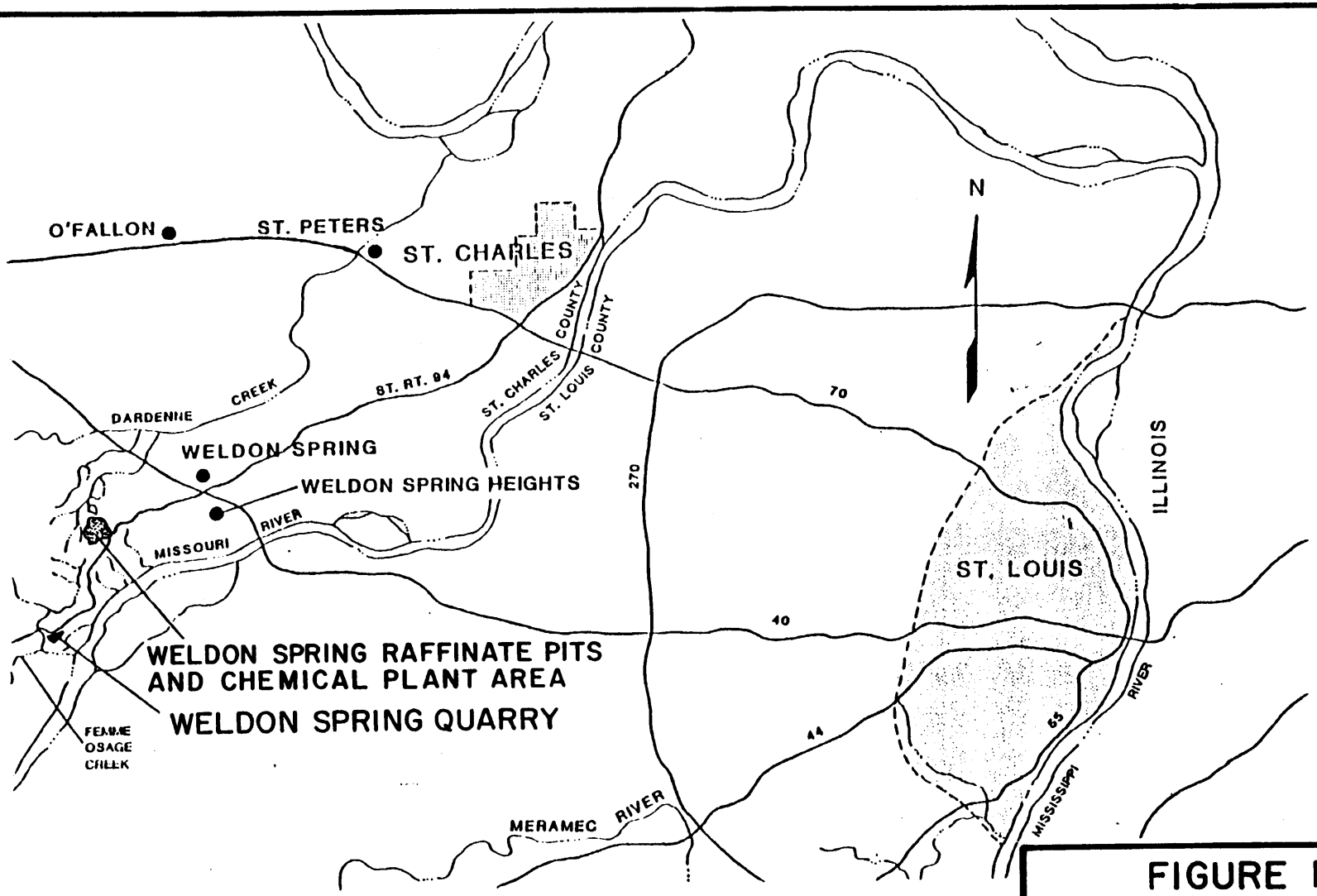


FIGURE 1.3

GENERAL LOCATION OF THE WELDON SPRING SITE AND QUARRY

SOURCE: MK-F AND JEG, 1988a

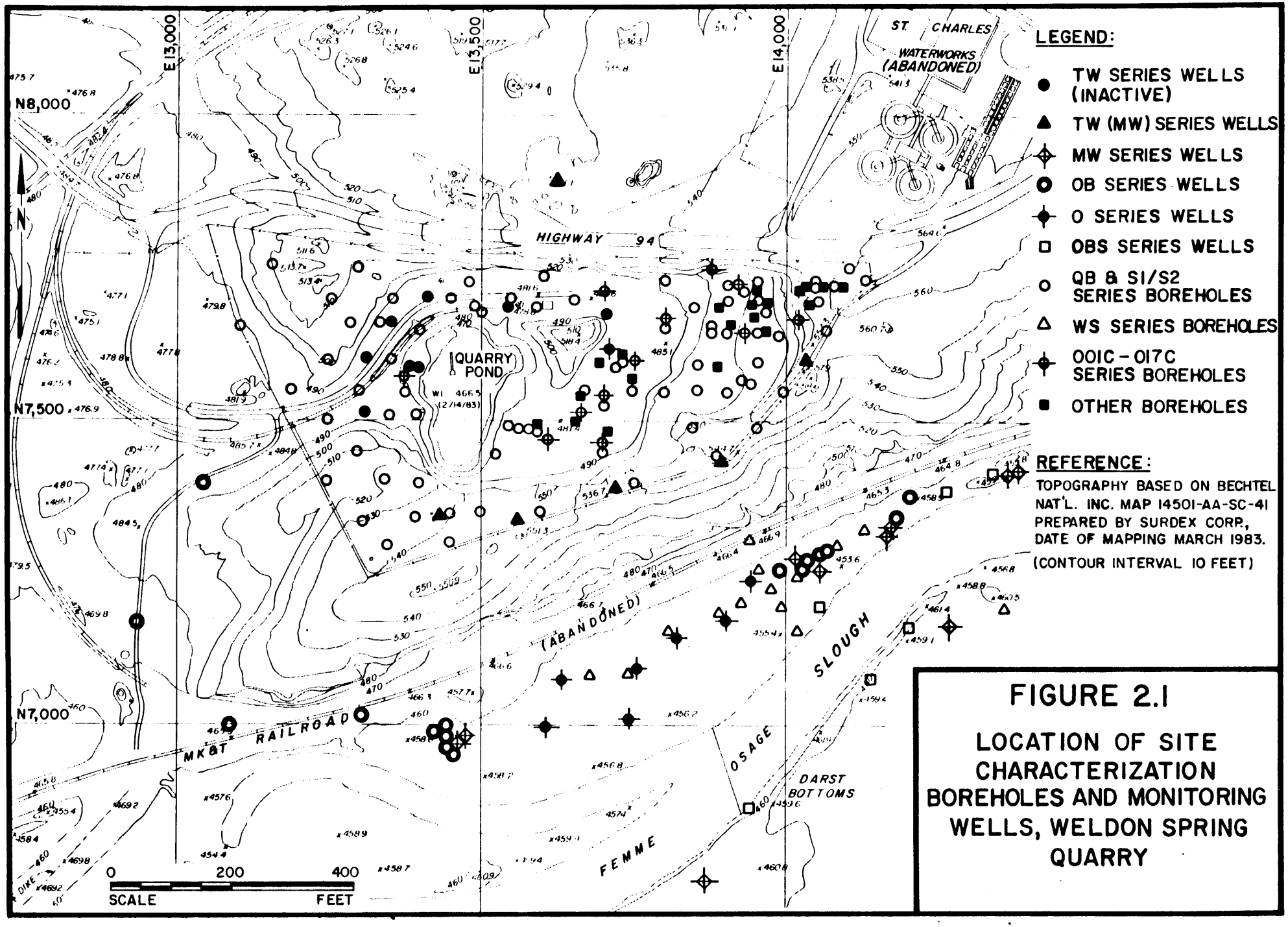


FIGURE 2.1

LOCATION OF SITE CHARACTERIZATION BOREHOLES AND MONITORING WELLS, WELDON SPRING QUARRY

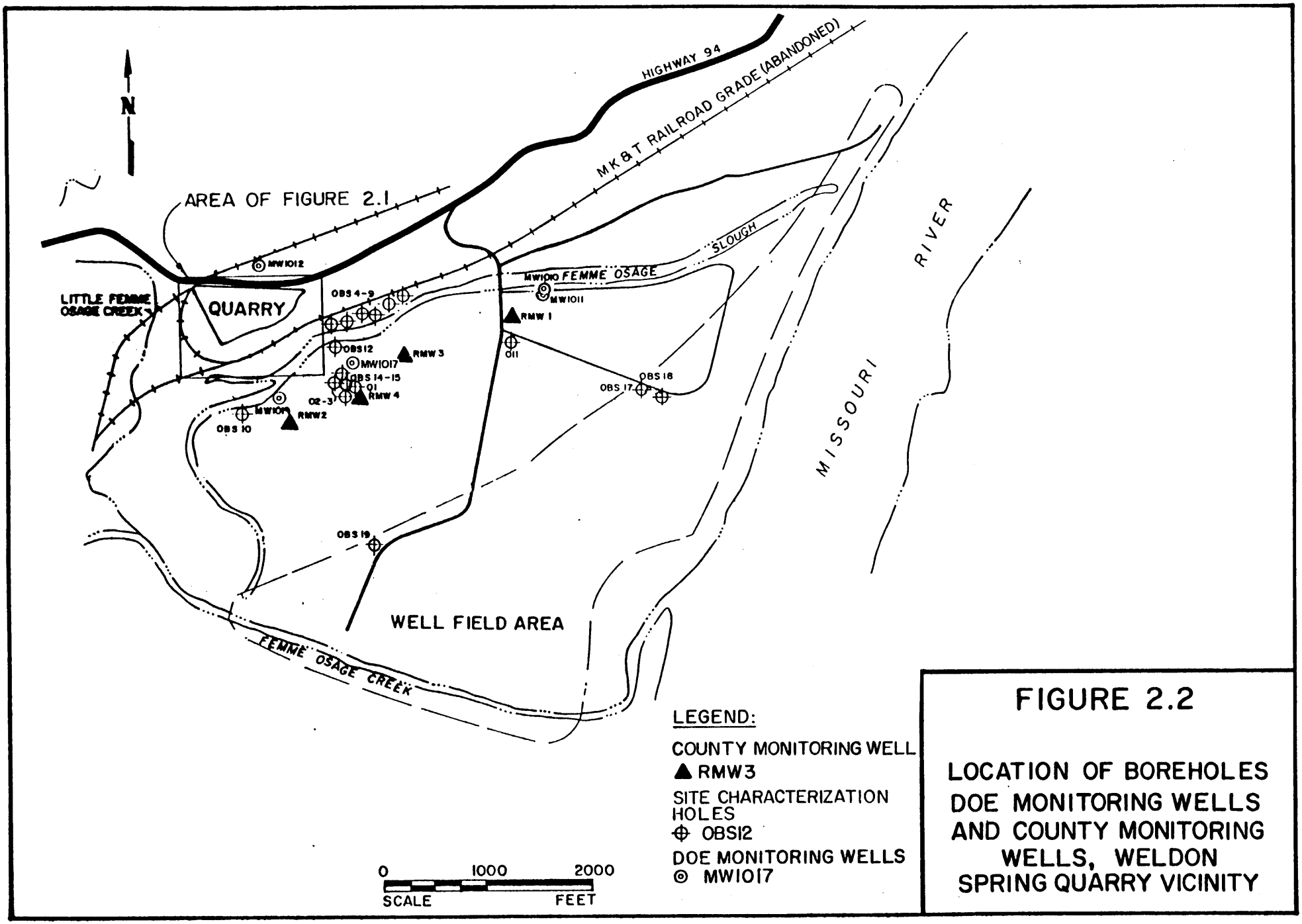
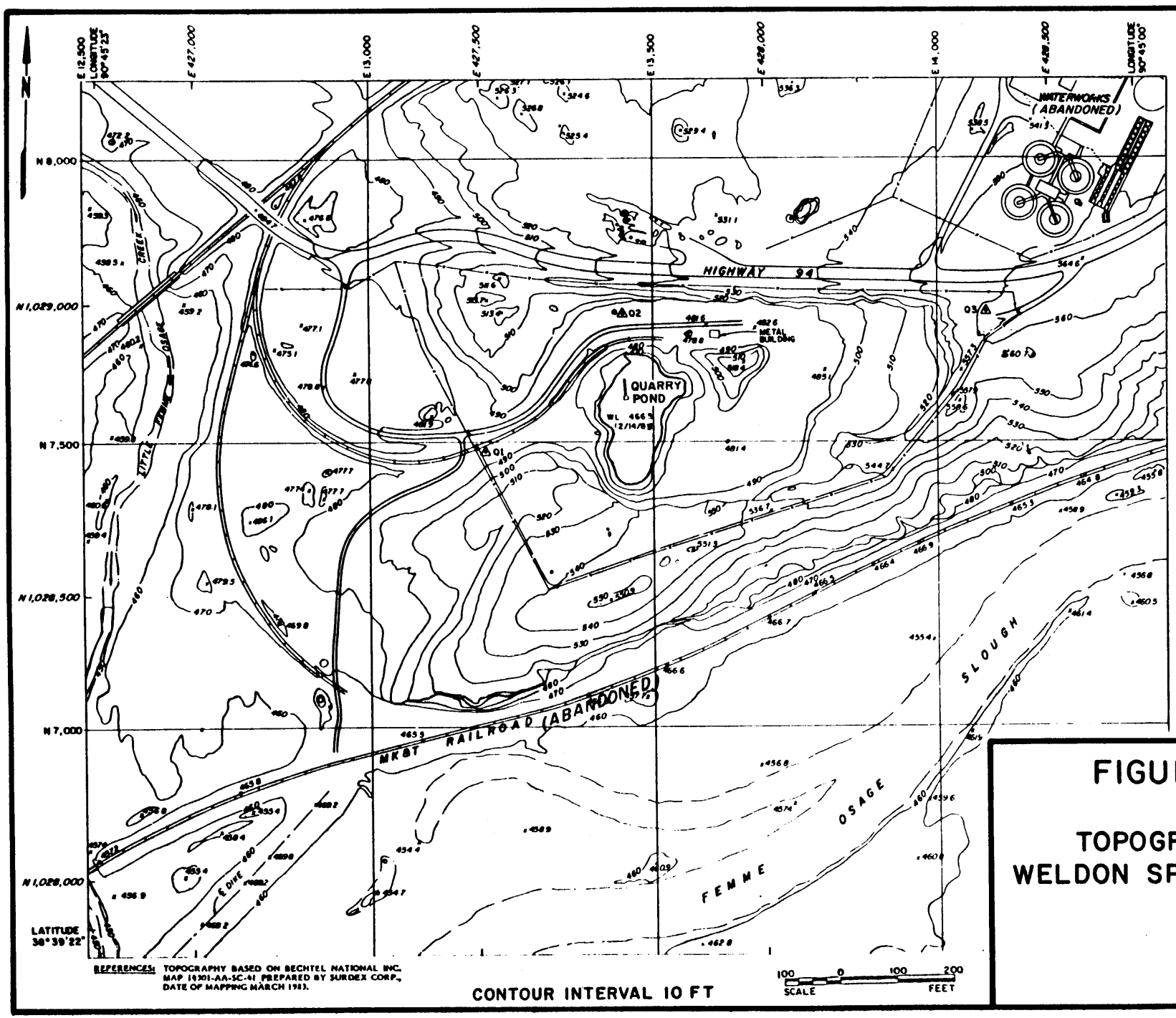


FIGURE 2.2

LOCATION OF BOREHOLES DOE MONITORING WELLS AND COUNTY MONITORING WELLS, WELDON SPRING QUARRY VICINITY



REFERENCES: TOPOGRAPHY BASED ON BECHTEL NATIONAL INC. MAP 14301-AA-SC-01 PREPARED BY SURDEX CORP., DATE OF MAPPING MARCH 1983.

CONTOUR INTERVAL 10 FT

100 0 100 200
SCALE FEET

FIGURE 3.1

TOPOGRAPHY AT WELDON SPRING QUARRY

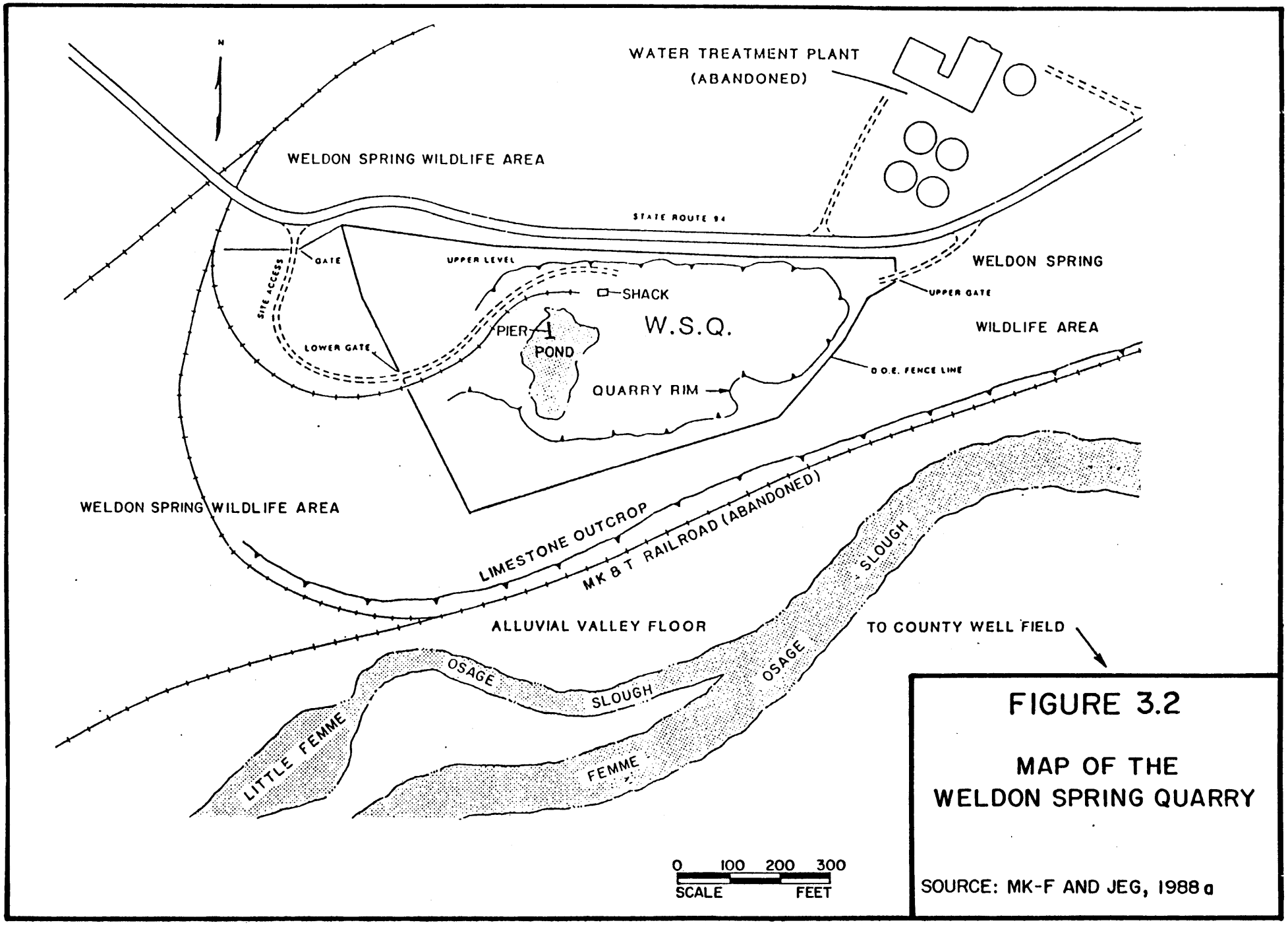
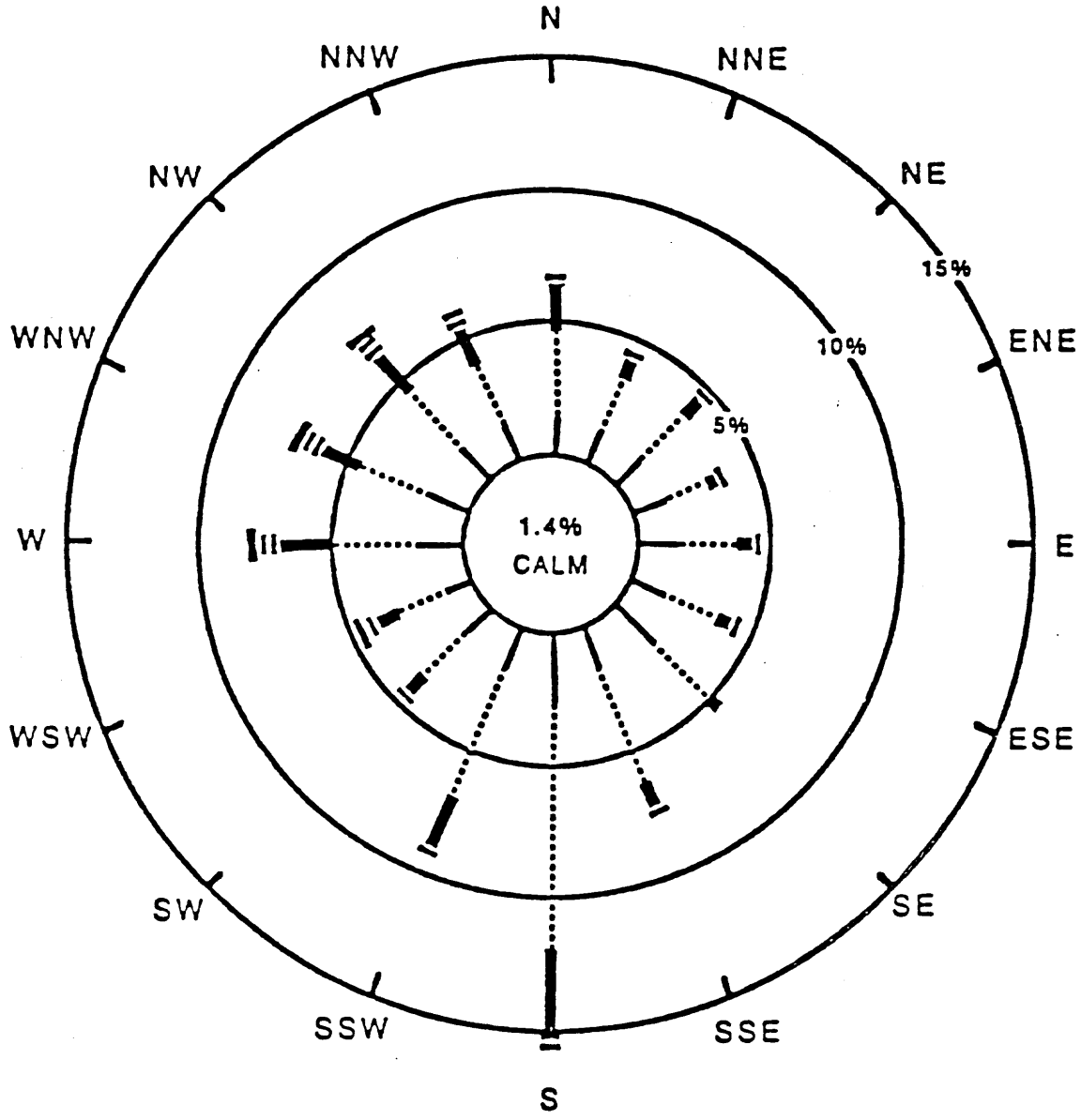


FIGURE 3.2

MAP OF THE WELDON SPRING QUARRY

SOURCE: MK-F AND JEG, 1988 a



NOTE:
BASED ON DATA FROM WELDON SPRING SITE METEOROLOGICAL STATION DURING 1985.

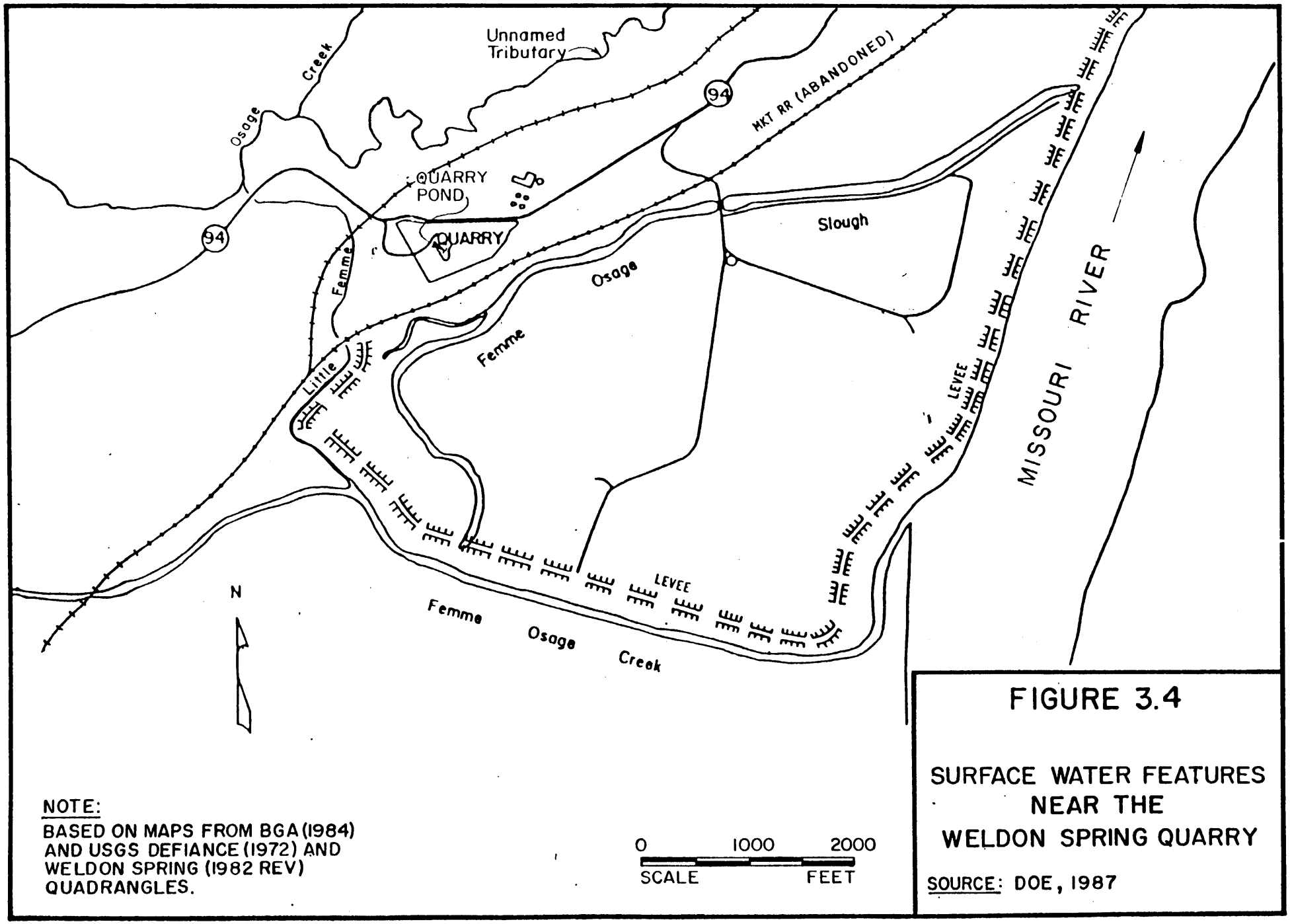
WIND SPEED

MPH 0 2.2 6.7 11 18 24.5

FIGURE 3.3

ANNUAL WIND ROSE FOR THE WELDON SPRING SITE

SOURCE: BNI, 1986



NOTE:
BASED ON MAPS FROM BGA (1984) AND USGS DEFIANCE (1972) AND WELDON SPRING (1982 REV) QUADRANGLES.

FIGURE 3.4

SURFACE WATER FEATURES NEAR THE WELDON SPRING QUARRY

SOURCE: DOE, 1987

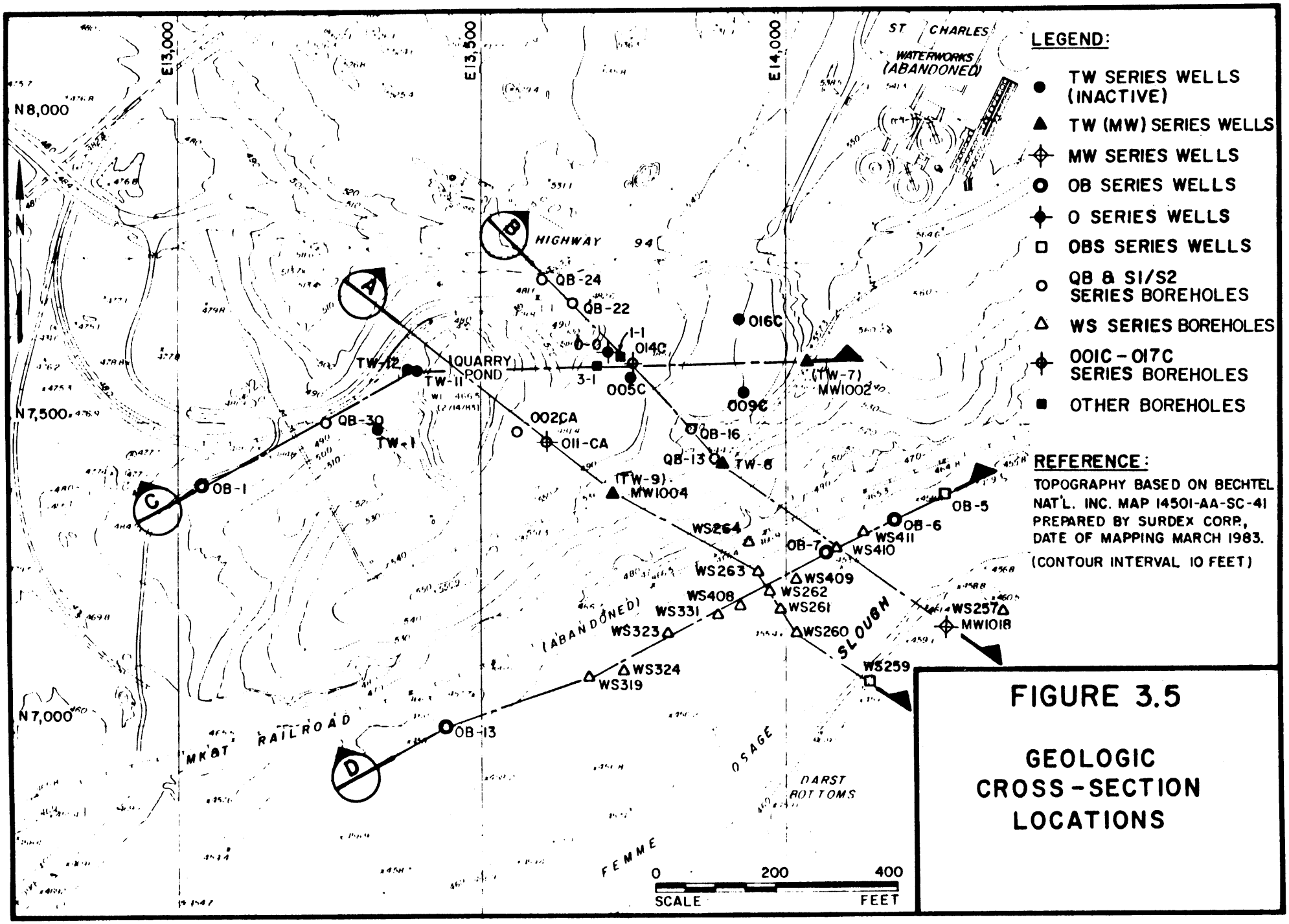
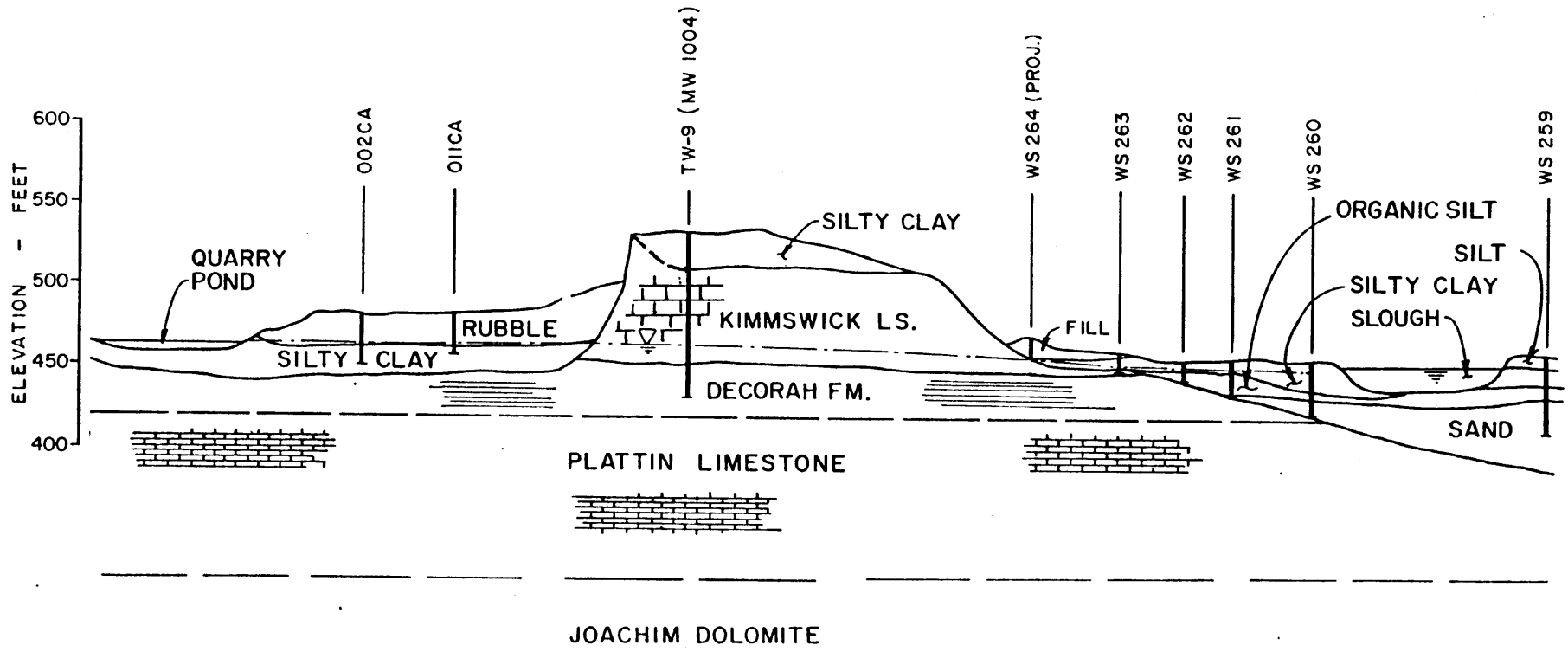


FIGURE 3.5

GEOLOGIC CROSS-SECTION LOCATIONS

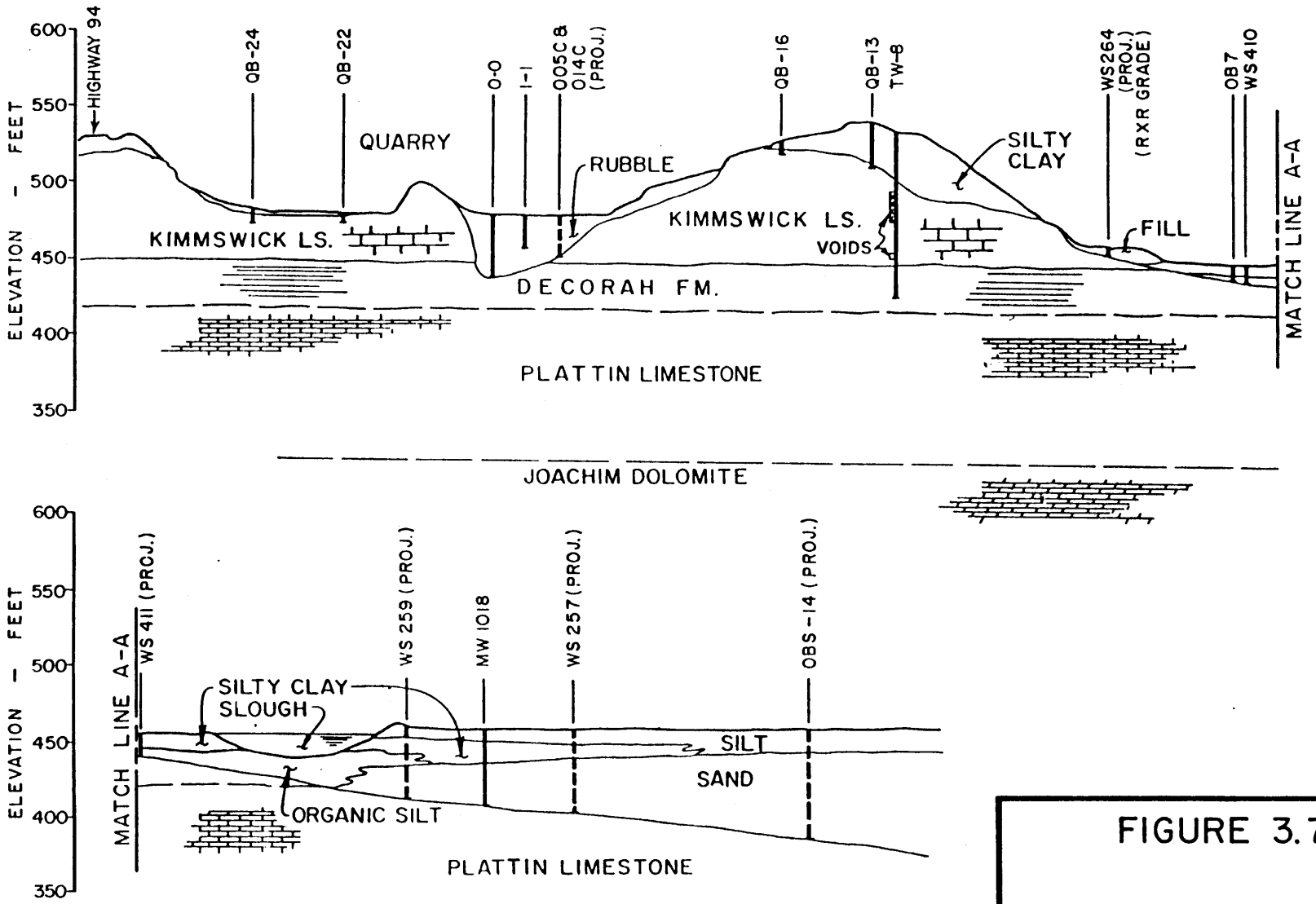


NOTE:
SEE FIGURE 3.5 FOR LOCATION OF CROSS-SECTION.

0 100 200
SCALE FEET

FIGURE 3.6

GEOLOGIC CROSS-SECTION A ACROSS QUARRY



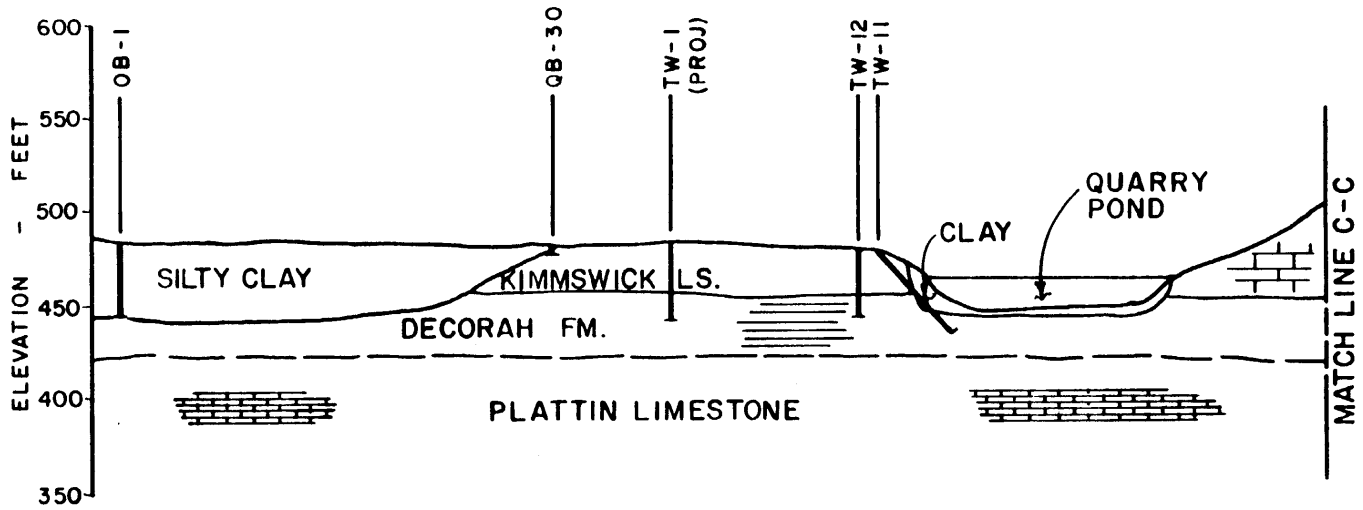
NOTE:

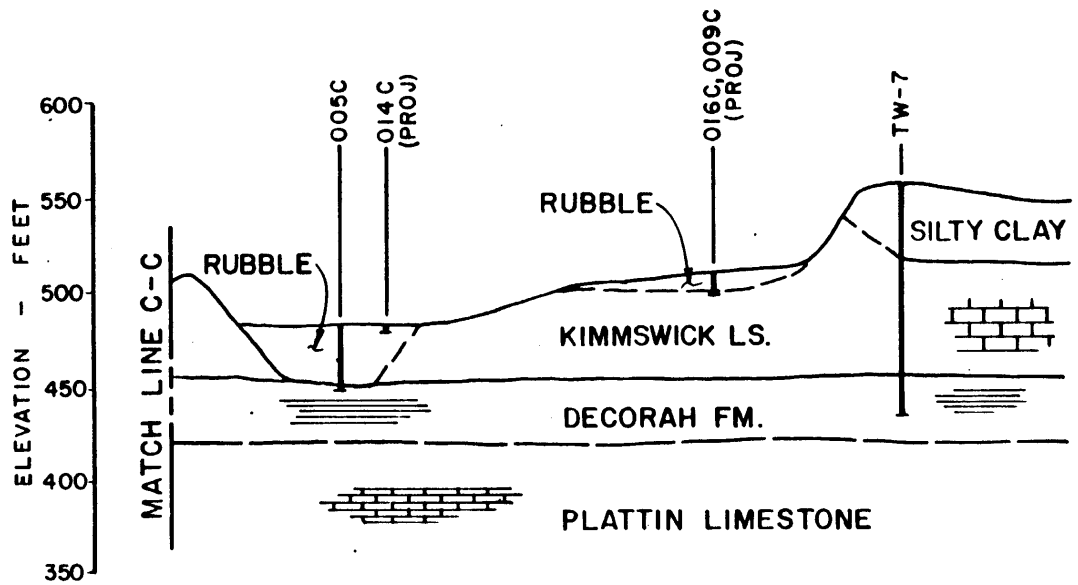
SEE FIGURE 3.5 FOR LOCATION OF CROSS-SECTION.

0 100 200
SCALE FEET

FIGURE 3.7

GEOLOGIC CROSS-SECTION B ACROSS QUARRY





NOTE:

SEE FIGURE 3.5 FOR LOCATION OF CROSS-SECTION.

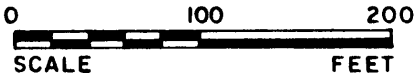
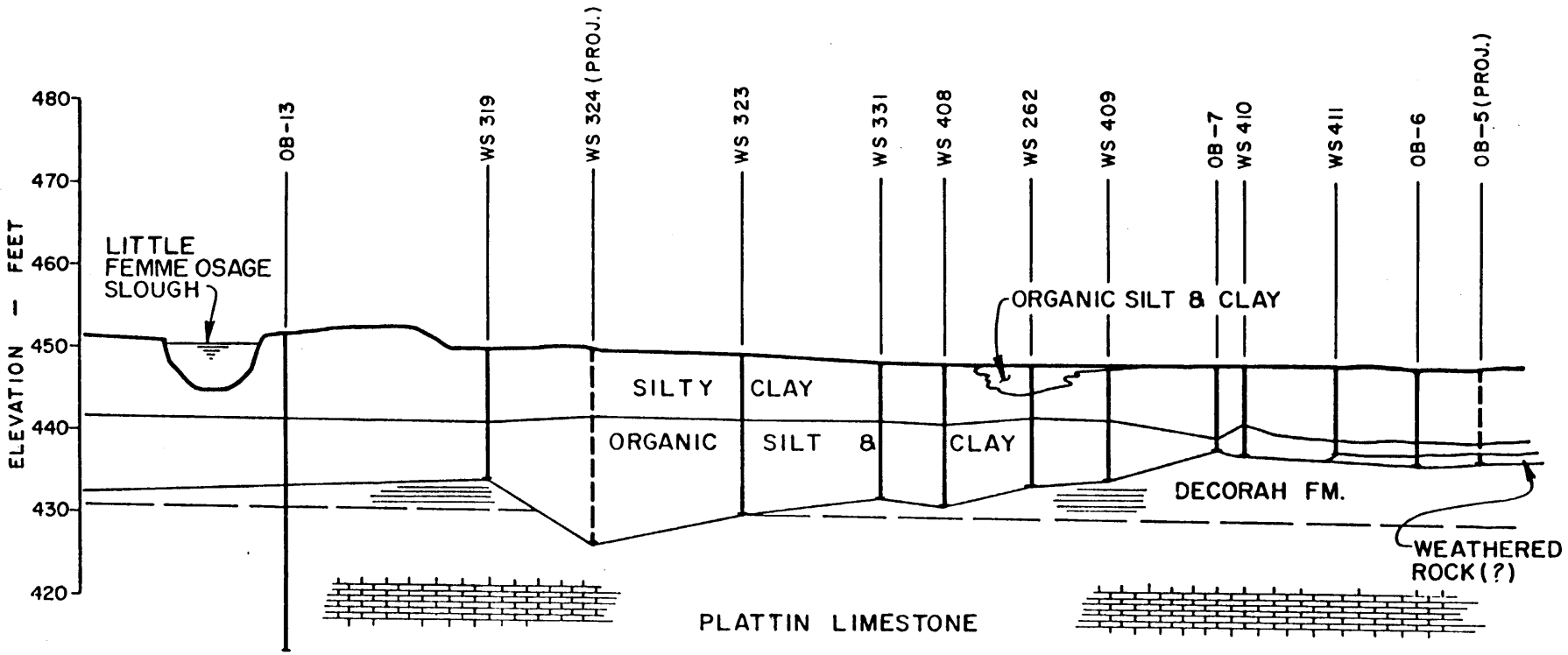


FIGURE 3.8

GEOLOGIC CROSS-SECTION C
EAST-WEST ACROSS QUARRY

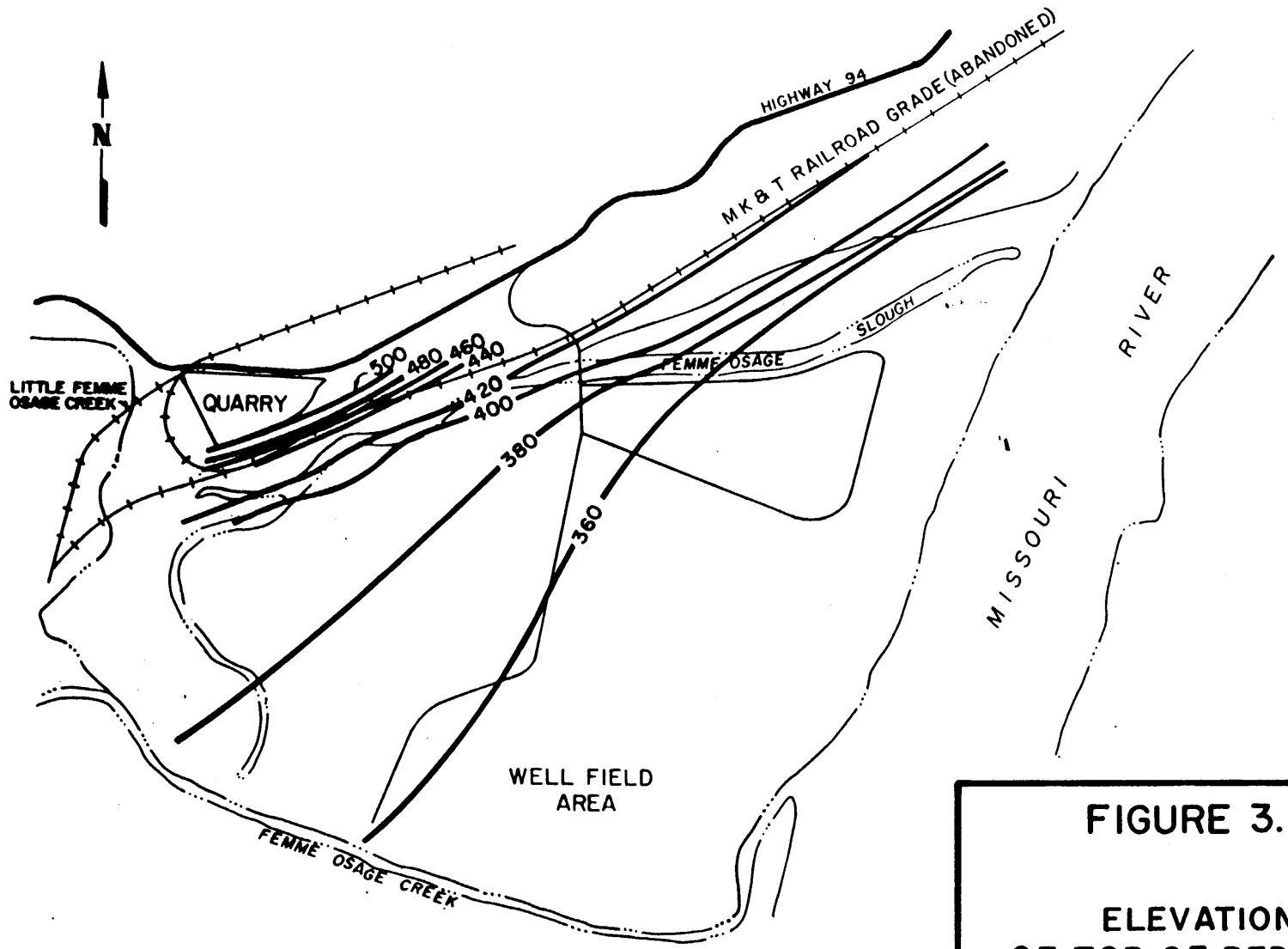


0 200 400
HORIZONTAL SCALE FEET

NOTE:
SEE FIGURE 3.5 FOR LOCATION OF CROSS-SECTION.

FIGURE 3.9

GEOLOGIC CROSS-SECTION D PARALLEL TO SLOUGH

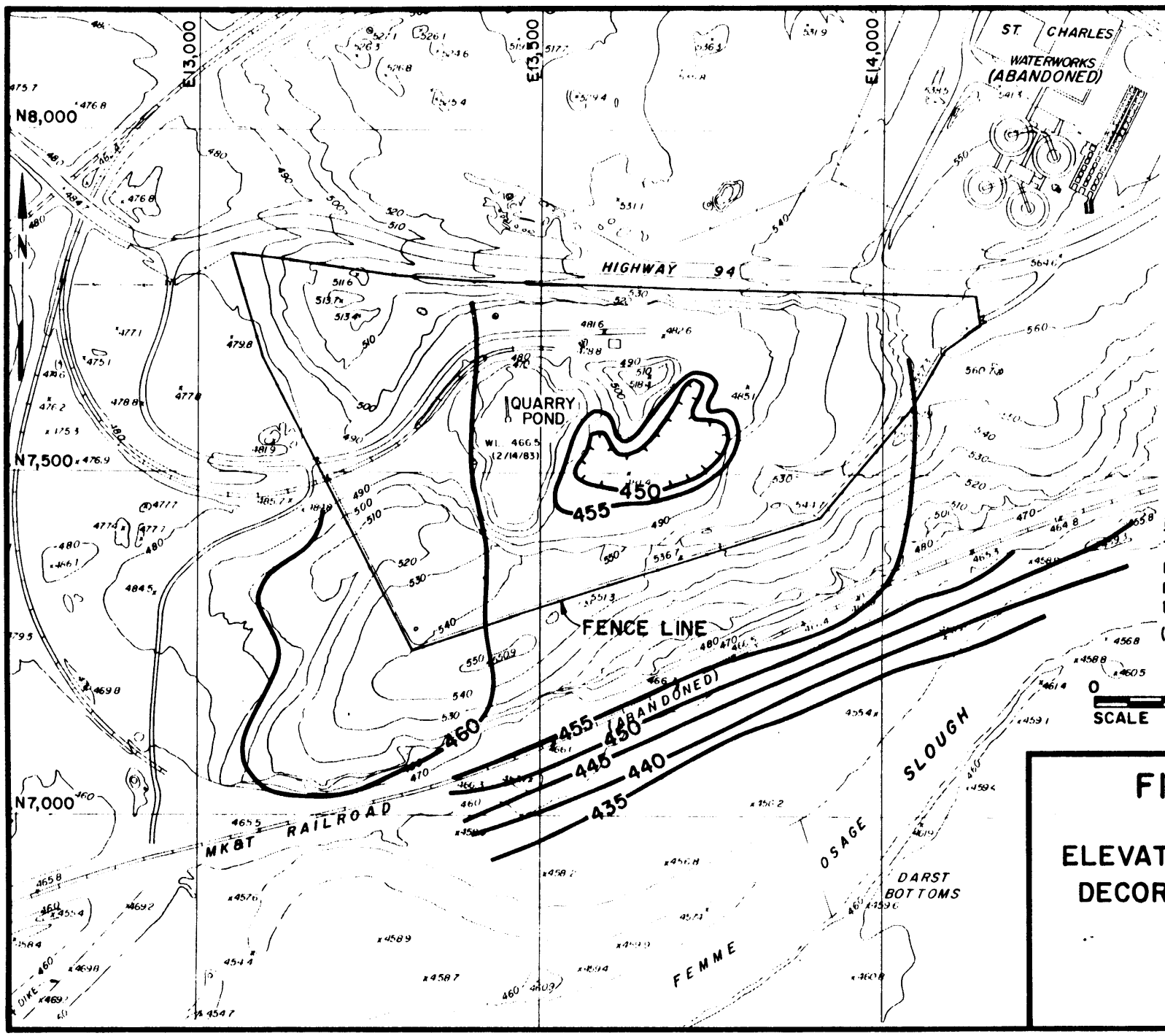


NOTE:
ELEVATIONS IN FEET, MSL.

0 1000 2000
SCALE FEET

FIGURE 3.10

ELEVATION OF TOP OF BEDROCK



NOTE:

ELEVATIONS IN FEET, MSL

REFERENCE:

TOPOGRAPHY BASED ON BECHTEL NAT'L. INC. MAP 14501-AA-SC-41 PREPARED BY SURDEX CORP., DATE OF MAPPING MARCH 1983.

(CONTOUR INTERVAL 10 FEET)

0 200 400
SCALE FEET

FIGURE 3.11

ELEVATION OF TOP OF DECORAH FORMATION

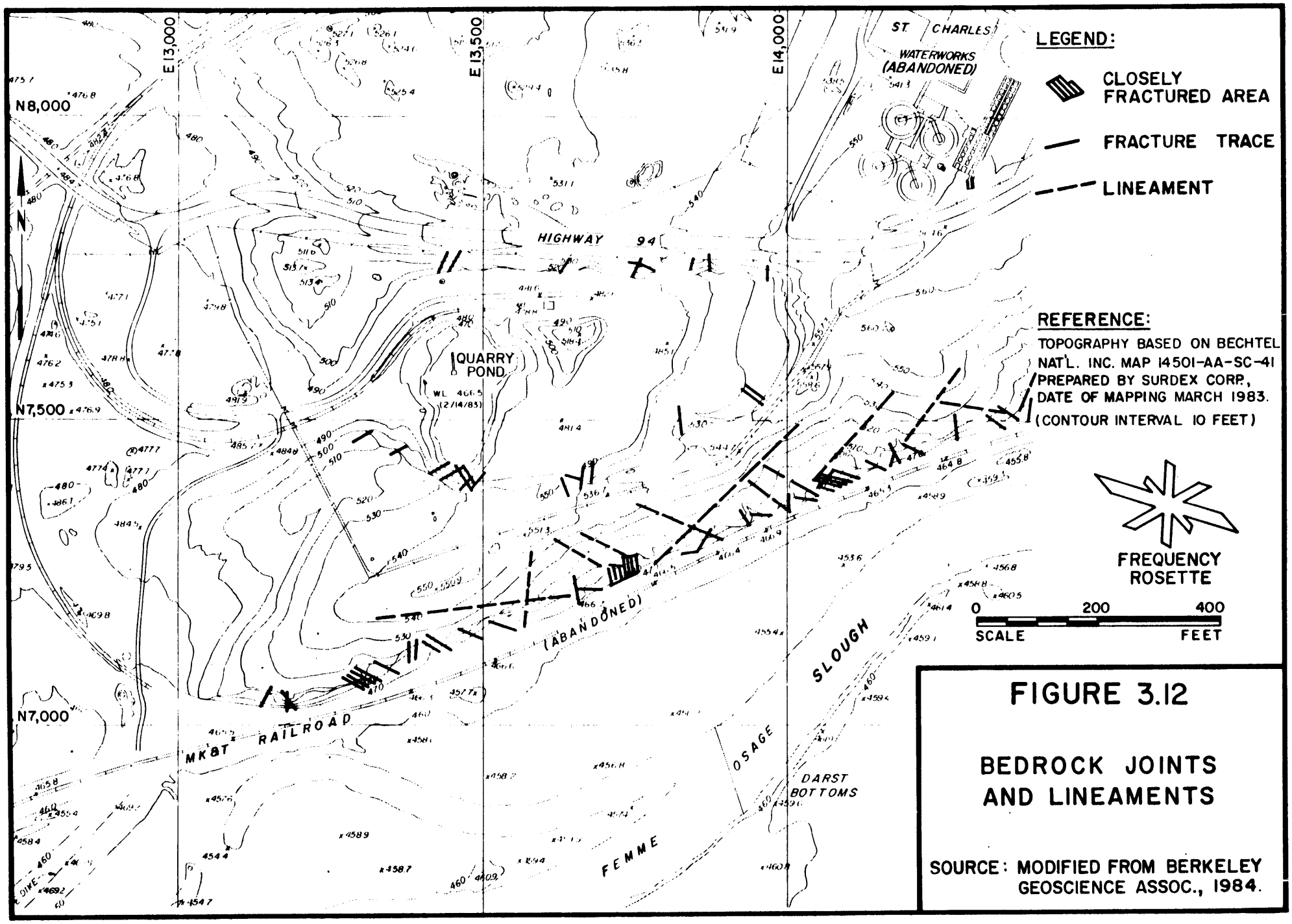
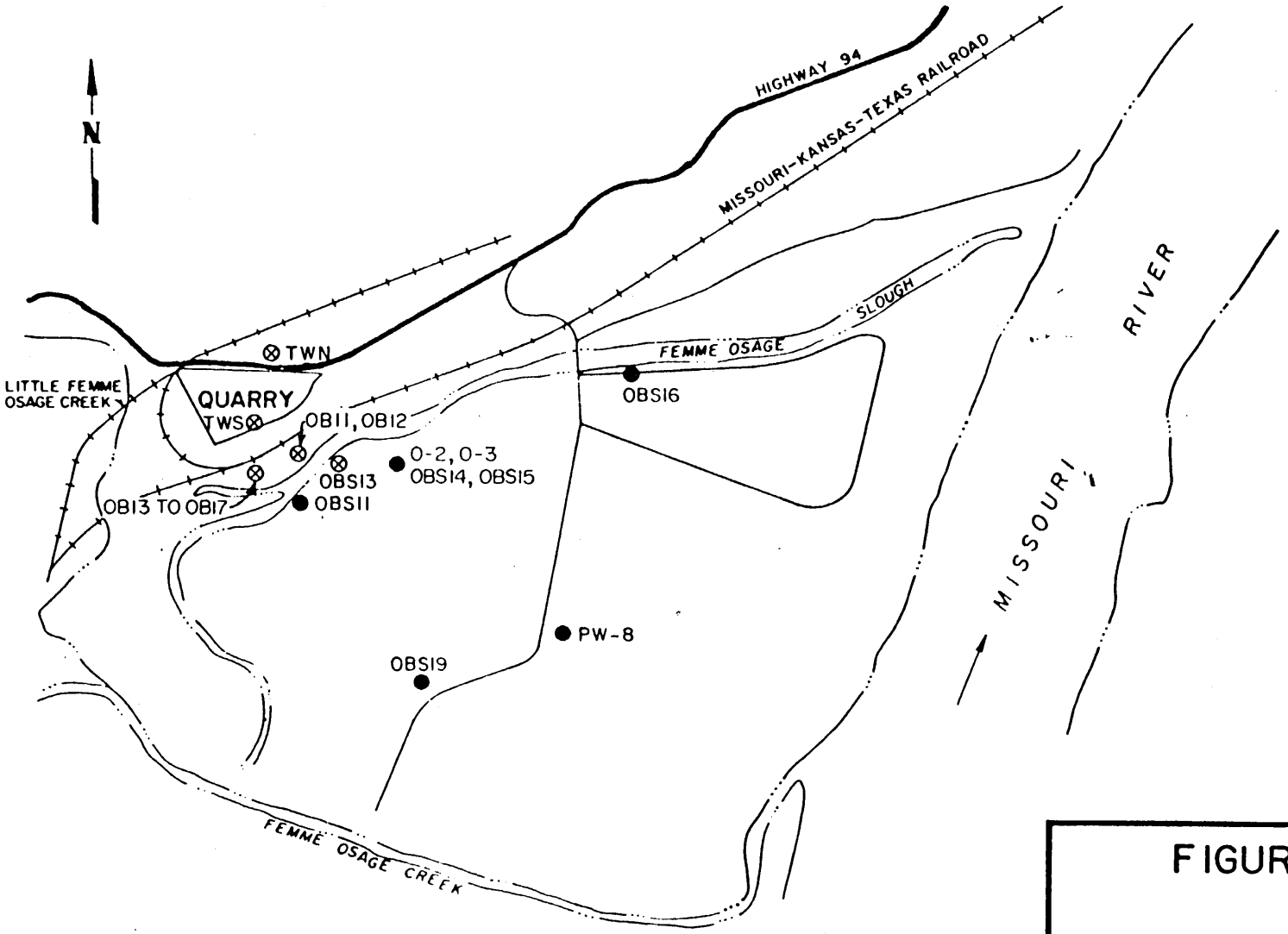


FIGURE 3.12

BEDROCK JOINTS AND LINEAMENTS

SOURCE: MODIFIED FROM BERKELEY GEOSCIENCE ASSOC., 1984.



LEGEND:

⊗ BEDROCK TEST LOCATIONS

● ALLUVIAL TEST LOCATIONS

0 1000 2000
SCALE FEET

FIGURE 3.13

AQUIFER TEST LOCATIONS

SOURCE: BERKELEY GEOSCIENCES ASSOCIATES, 1984

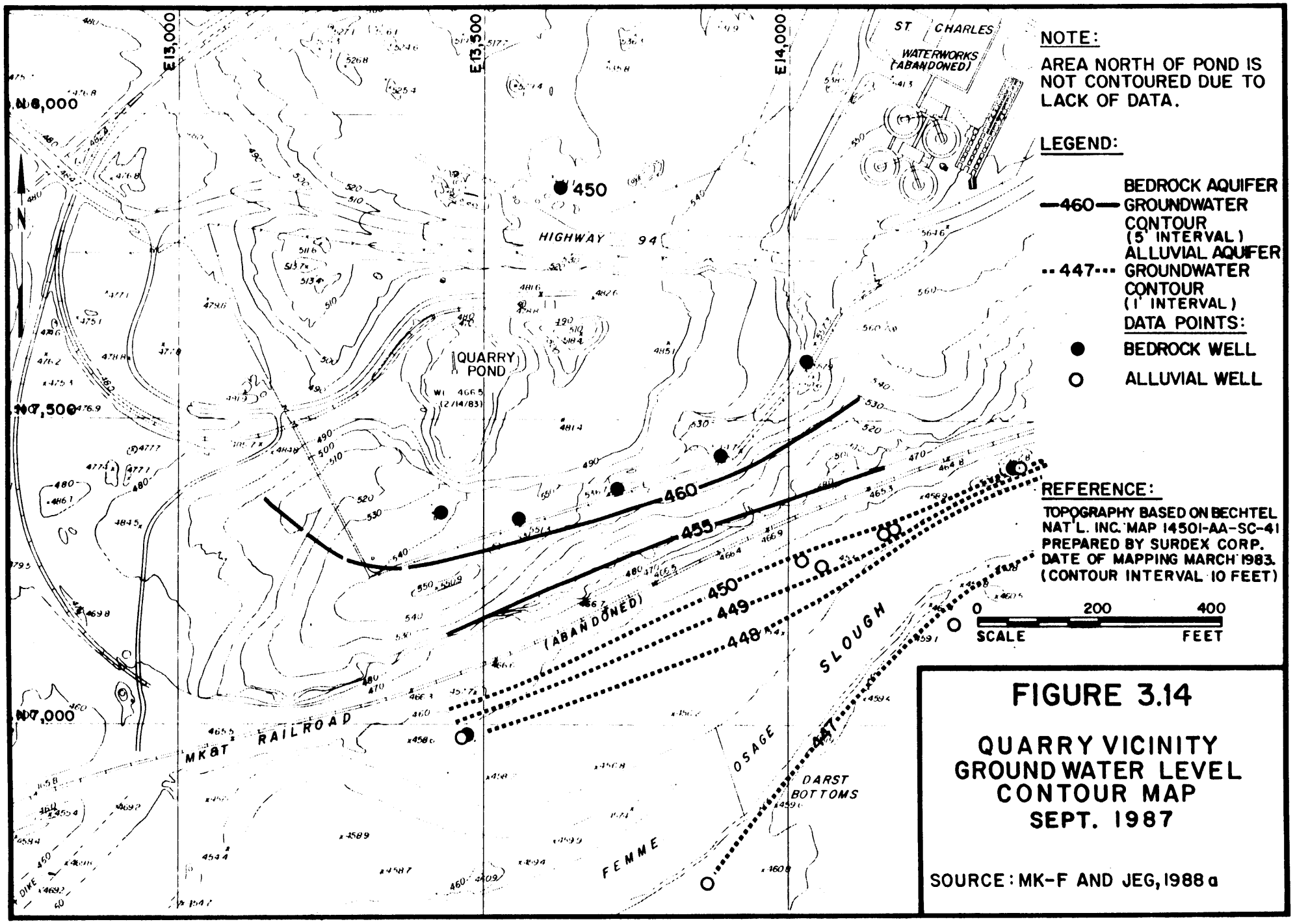


FIGURE 3.14

QUARRY VICINITY GROUNDWATER LEVEL CONTOUR MAP SEPT. 1987

SOURCE: MK-F AND JEG, 1988a

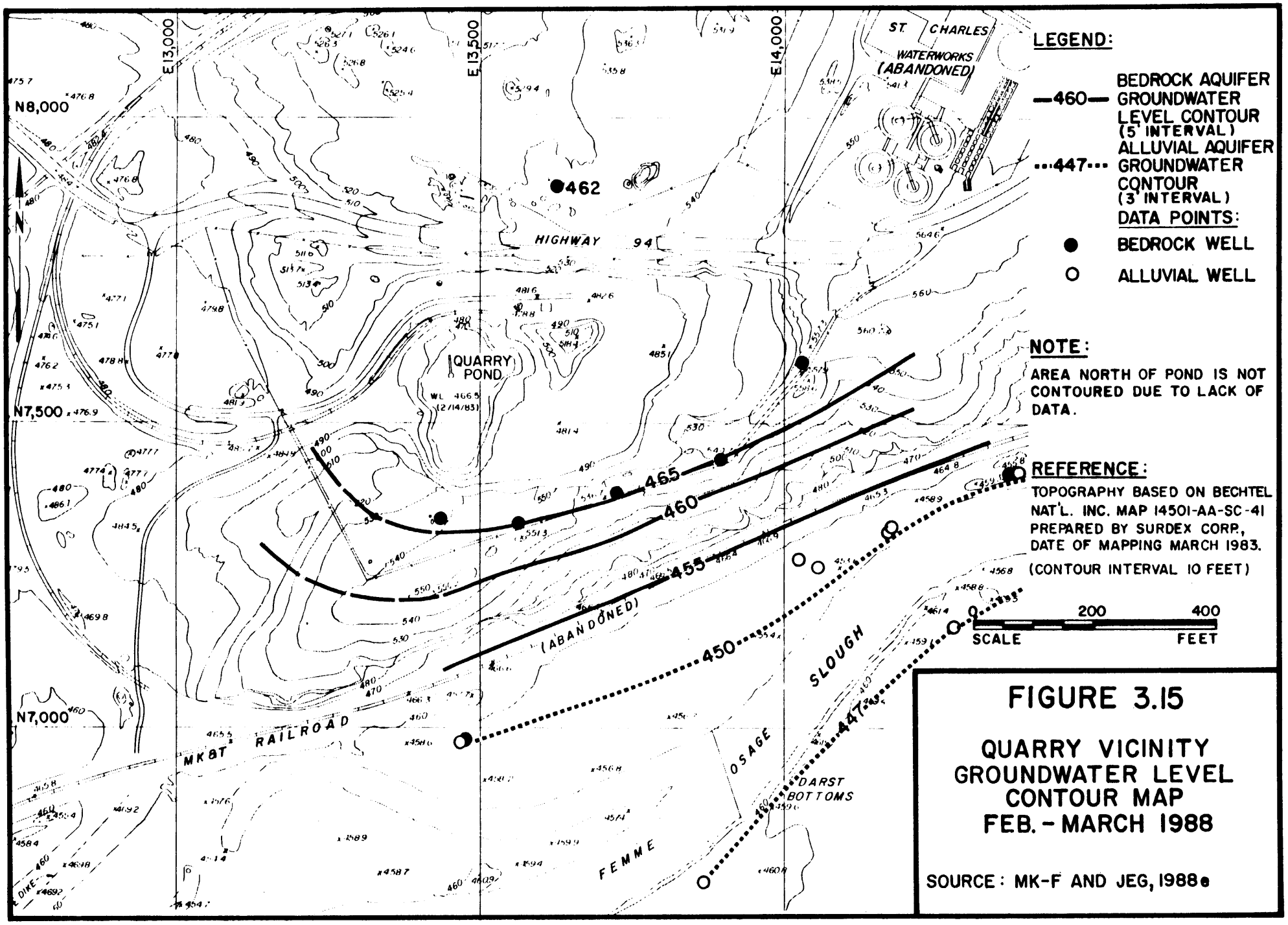
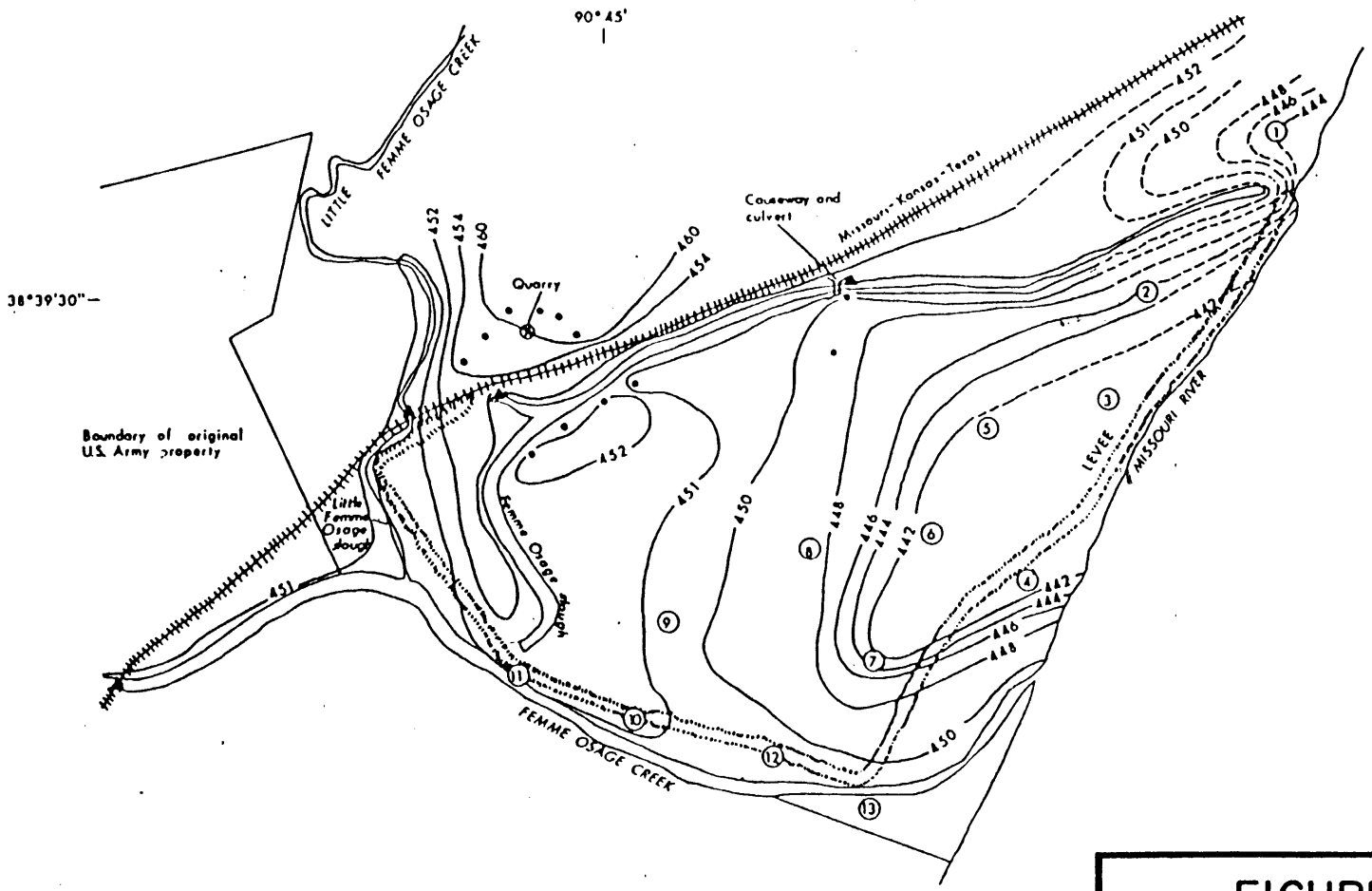


FIGURE 3.15

QUARRY VICINITY GROUNDWATER LEVEL CONTOUR MAP FEB. - MARCH 1988

SOURCE: MK-F AND JEG, 1988e



LEGEND:

- • OBSERVATION WELL
- (8) ST. CHARLES COUNTY MUNICIPAL WELL AND NUMBER
- —450-- WATER-TABLE CONTOUR--Shows altitude of water table. Dashed where approximately located. Contour interval, in feet, is variable. Datum is sea level
- ▲ SURFACE-WATER SITE

0 1000 2000 FEET
0 500 METERS

FIGURE 3.16

WATER TABLE CONTOUR MAP OCTOBER 30, 1984

SOURCE: KLEESCHULTE AND EMMETT, 1986

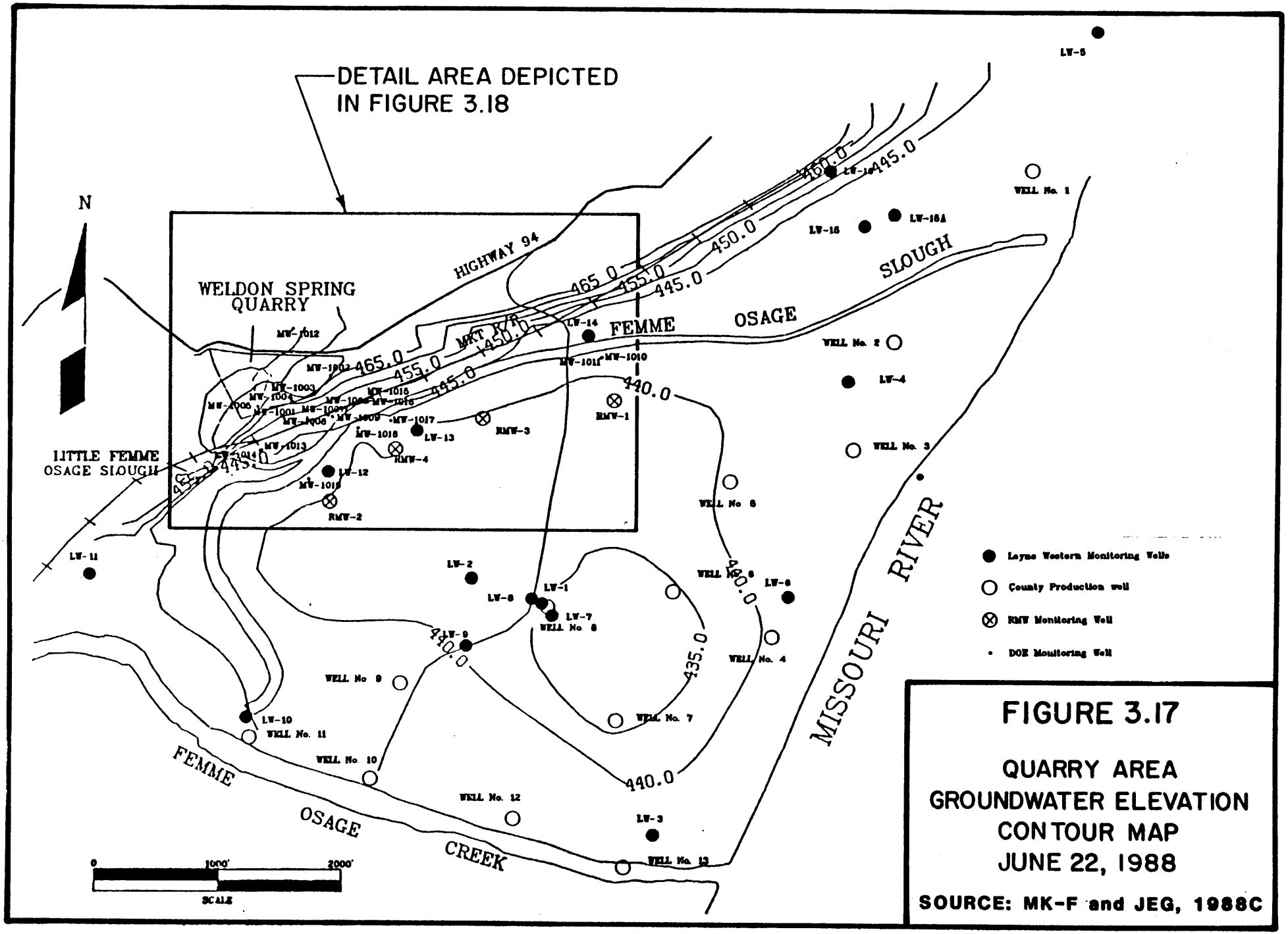


FIGURE 3.17

QUARRY AREA GROUNDWATER ELEVATION CONTOUR MAP JUNE 22, 1988

SOURCE: MK-F and JEG, 1988C

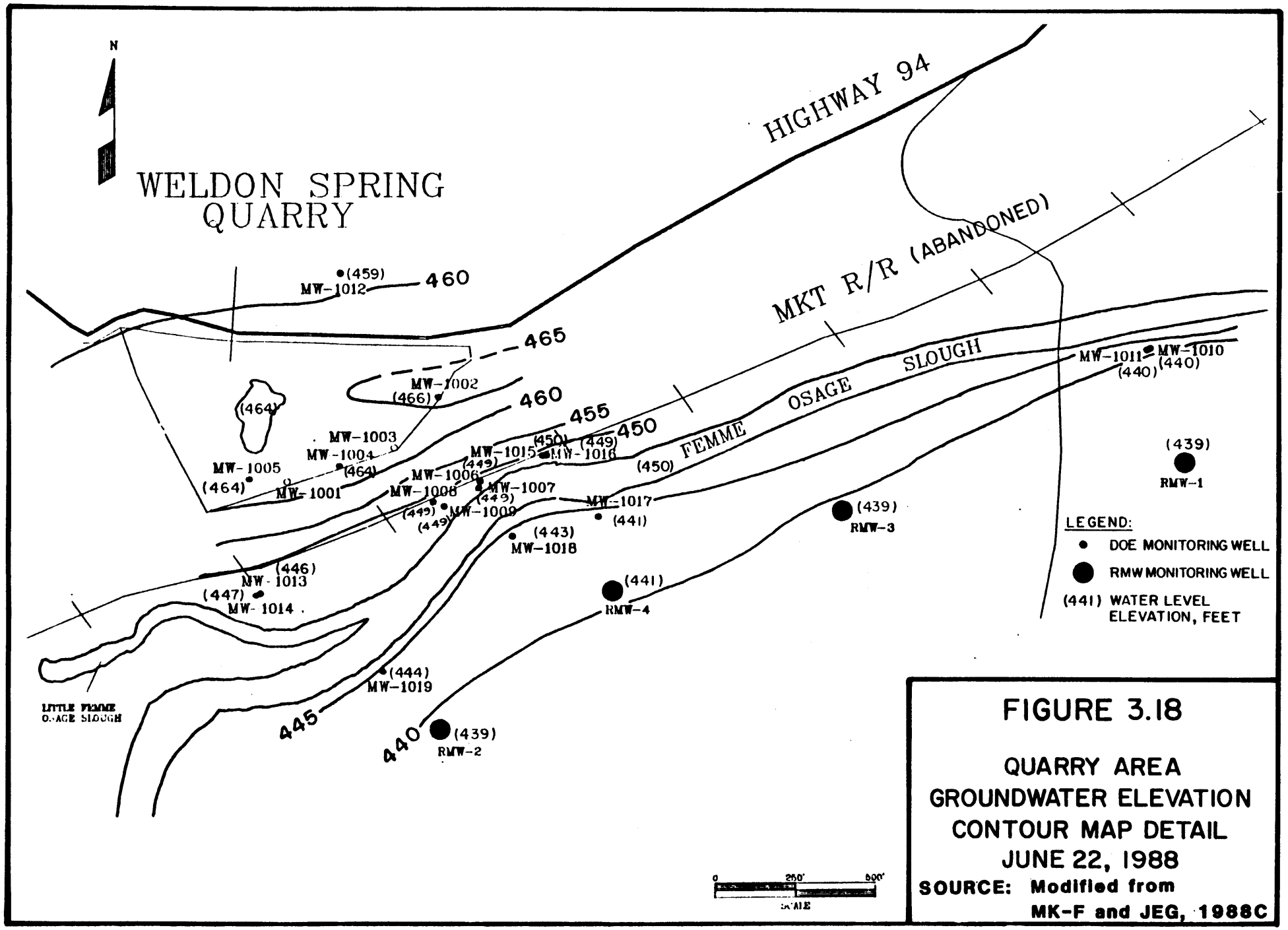
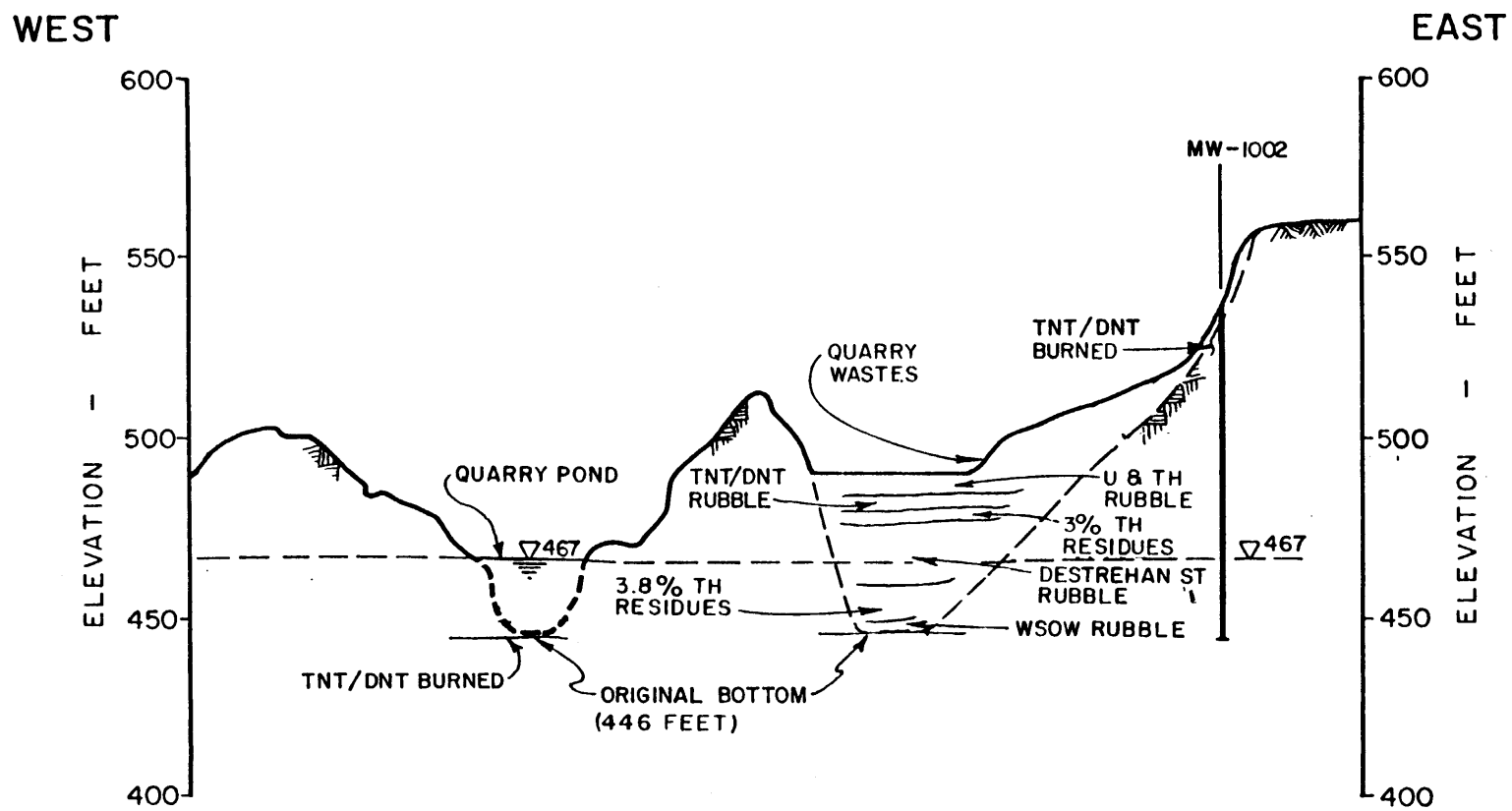


FIGURE 3.18

QUARRY AREA GROUNDWATER ELEVATION CONTOUR MAP DETAIL JUNE 22, 1988

SOURCE: Modified from MK-F and JEG, 1988C



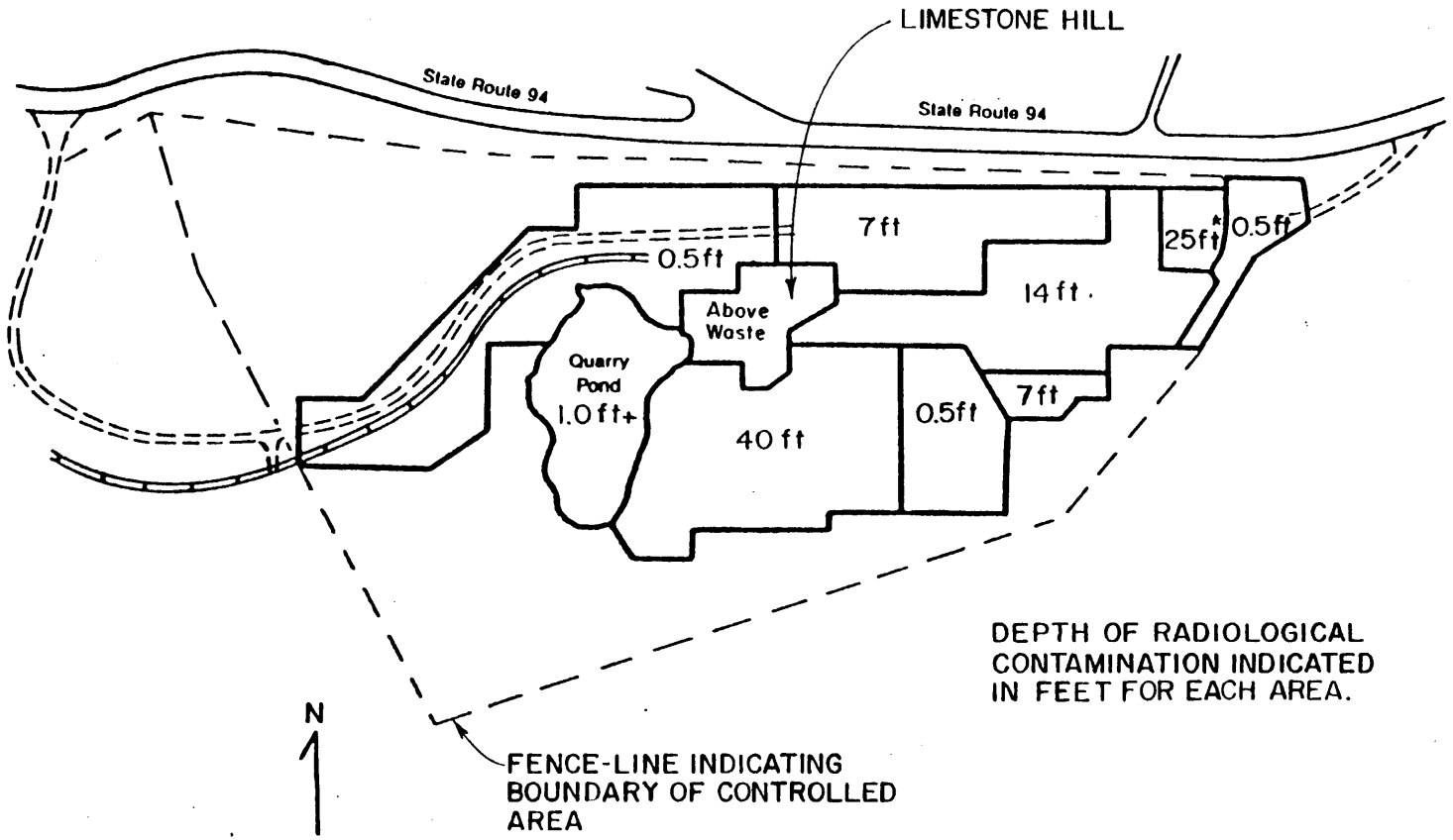
NOTE:

- CROSS-SECTION IS GENERALIZED AND BASED ON VARIOUS SOURCES (SEE SECTION 4.1 OF TEXT)

0 150 300
HORIZONTAL SCALE FEET

FIGURE 4.1

PRESUMED WASTE CROSS-SECTION, WELDON SPRING QUARRY



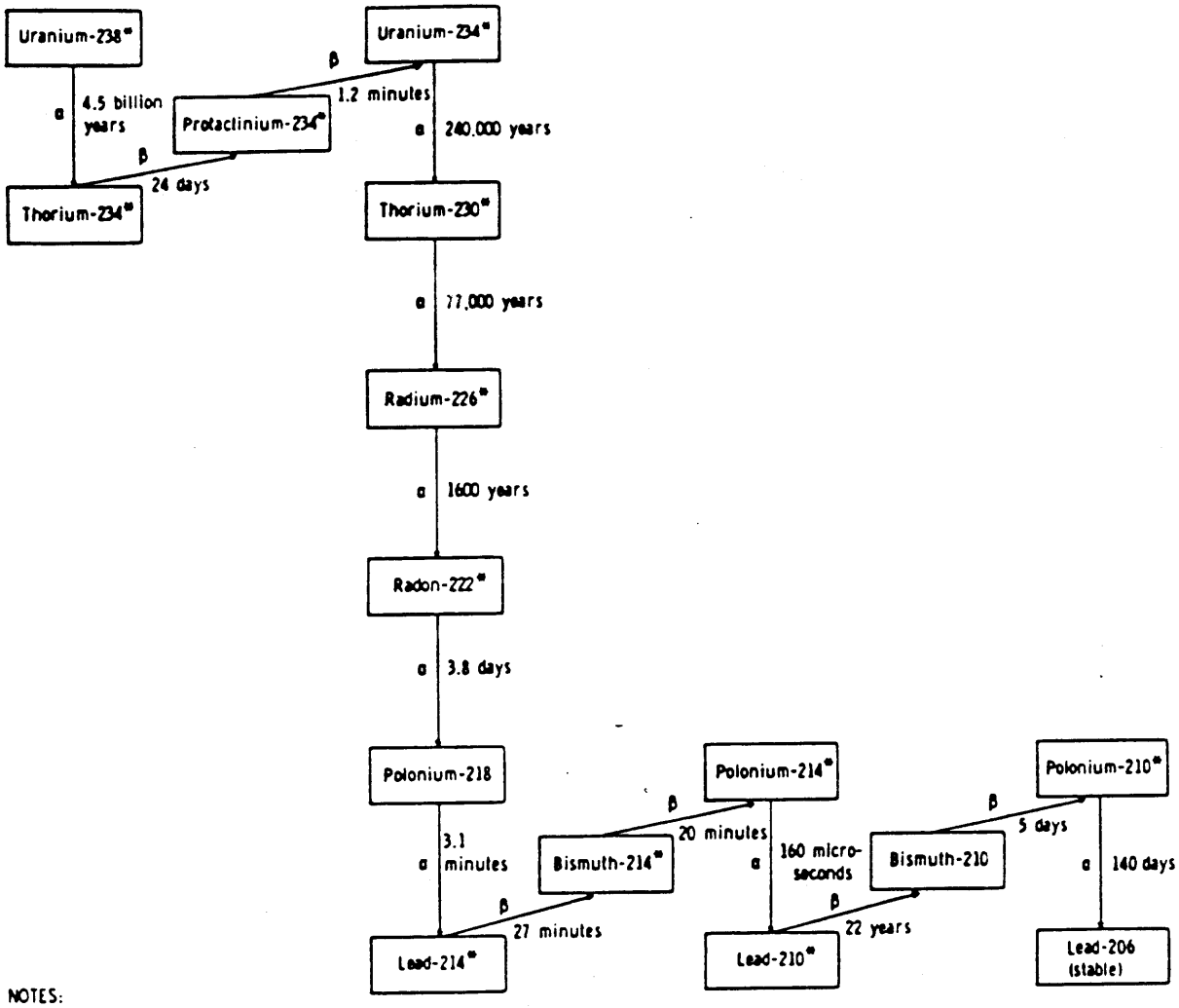
*SLOPED AREA

0 150 300
SCALE FEET

FIGURE 4.2

AREAS OF SUBSURFACE RADIOLOGICAL CONTAMINATION IN THE WELDON SPRING QUARRY

SOURCE: BECHTEL NATIONAL, 1985 c



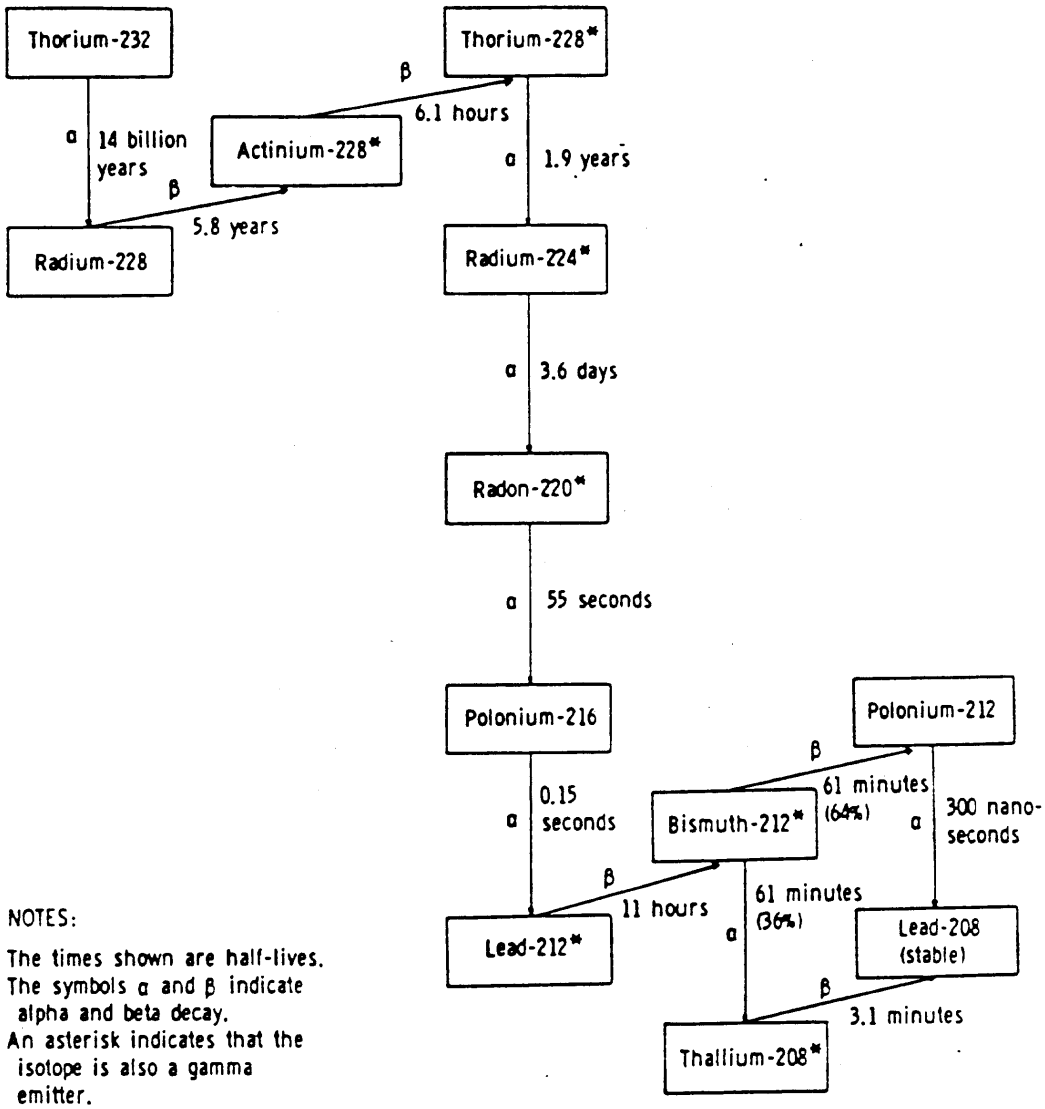
NOTES:

Only the dominant decay mode is shown.
The times shown are half-lives.
The symbols α and β indicate alpha and beta decay.
An asterisk indicates that the isotope is also a gamma emitter.

FIGURE 4.3

URANIUM-238 RADIOACTIVE DECAY SERIES

SOURCE: DOE, 1987a



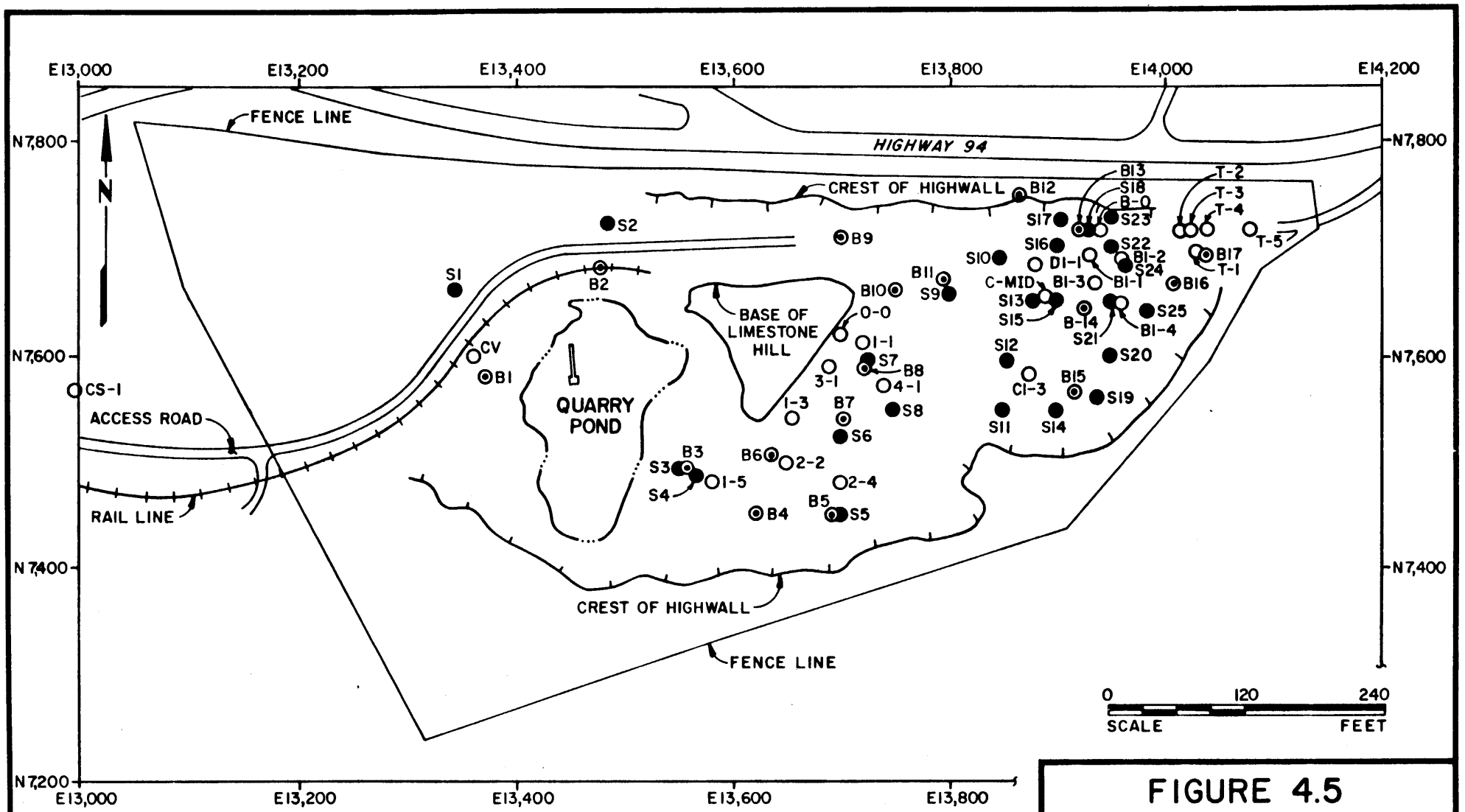
NOTES:

The times shown are half-lives.
The symbols α and β indicate alpha and beta decay.
An asterisk indicates that the isotope is also a gamma emitter.

FIGURE 4.4

THORIUM-232
RADIOACTIVE DECAY SERIES

SOURCE: DOE, 1987a



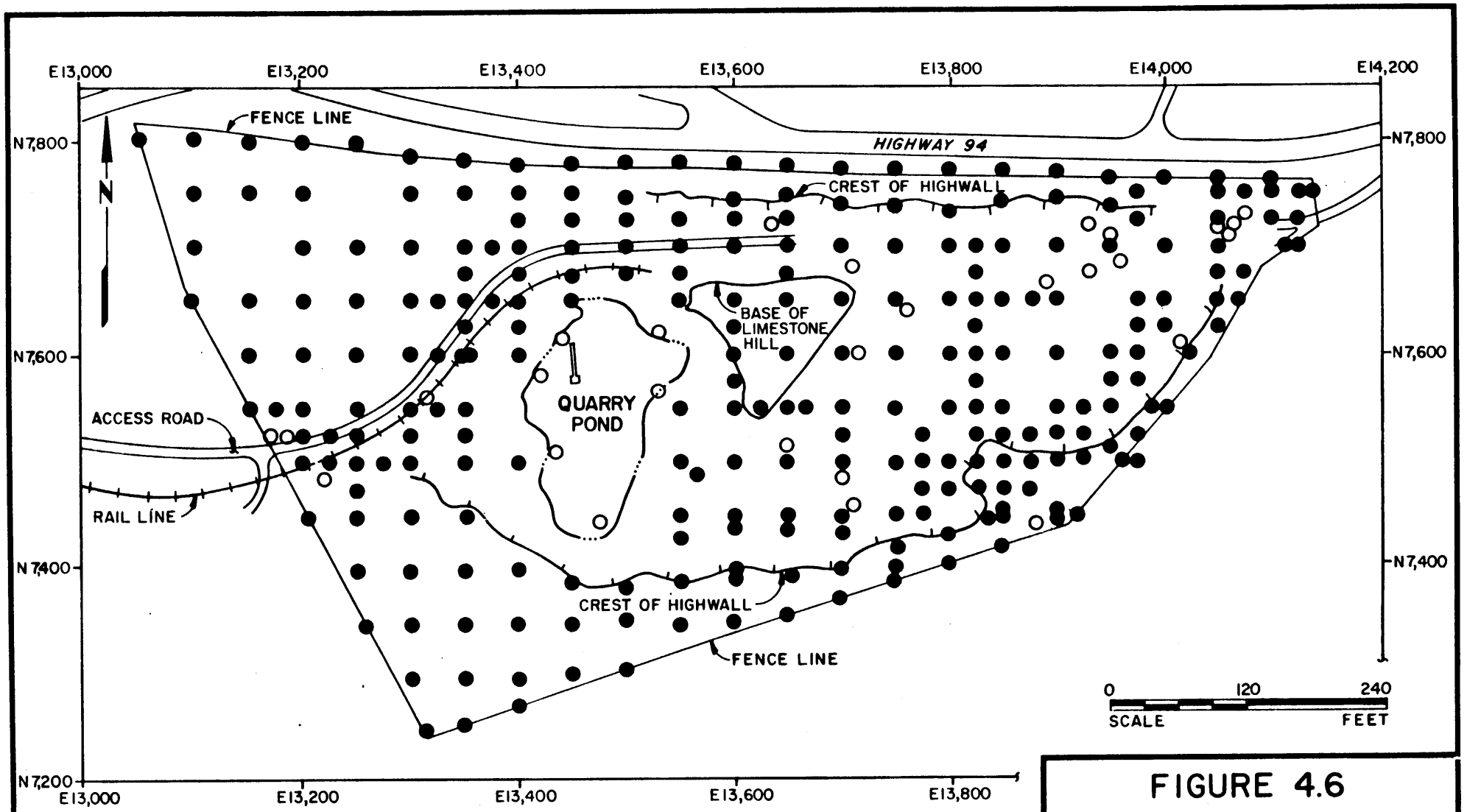
LEGEND:

- ○ BGA, 1984
- ● BNI, 1985C
- ◉ KAYE AND DAVIS, 1987 (17 BOREHOLES DRILLED FOR CHEMICAL CHARACTERIZATION)

FIGURE 4.5

SUBSURFACE SAMPLE LOCATIONS AT THE WSQ

SOURCES: BGA, 1984; BNI, 1985 C AND KAYE AND DAVIS, 1987



LEGEND:

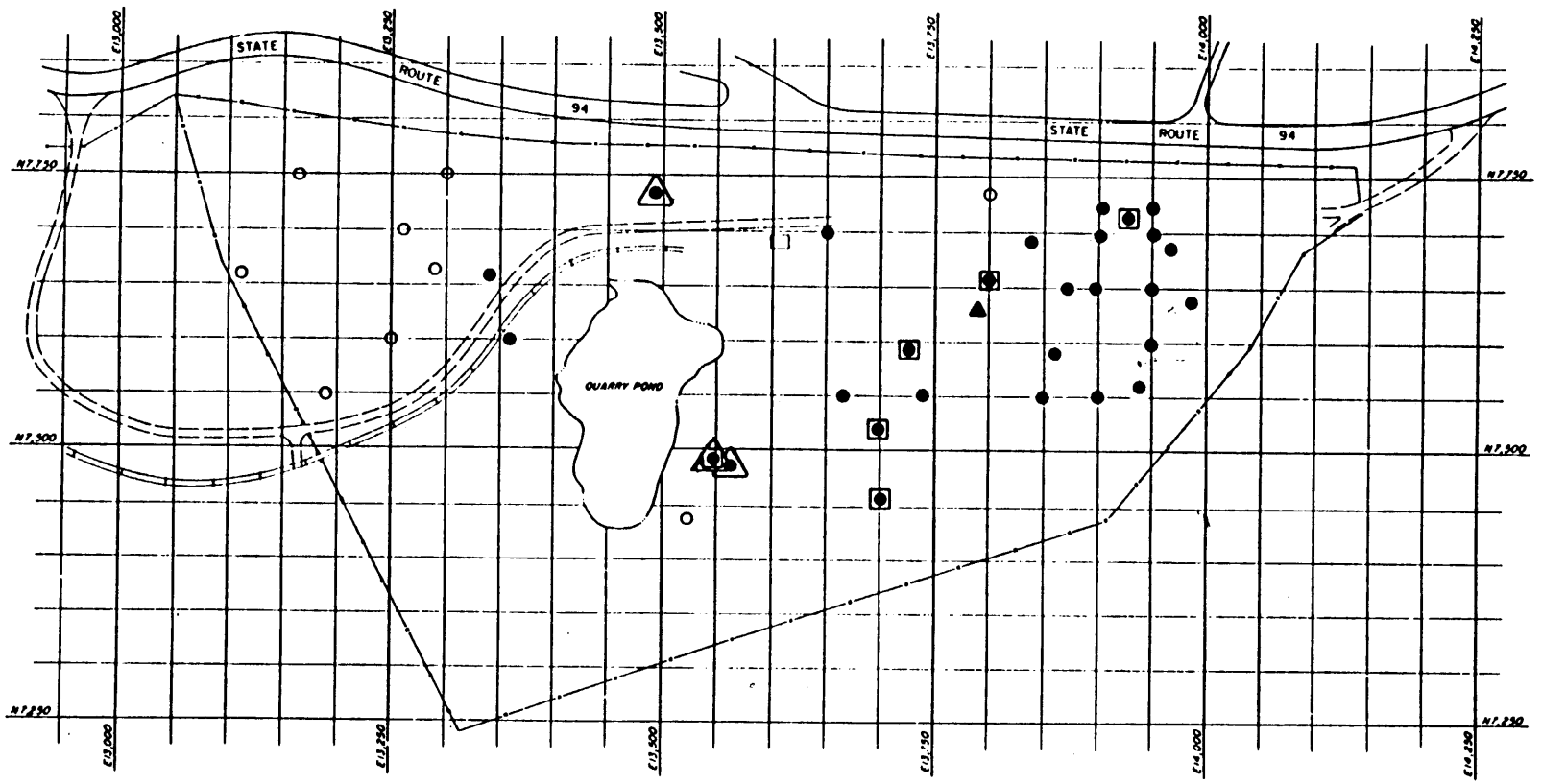
○ BGA, 1984

● BNI, 1985C

FIGURE 4.6

SURFACE SAMPLE LOCATIONS AT THE WSQ

SOURCES: BGA, 1984 AND BNI, 1985C



△ LOCATIONS WITH U-235 CONCENTRATIONS ABOVE NATURAL URANIUM LEVELS

● SUBSURFACE SOIL SAMPLE

□ SUBSURFACE SOIL SAMPLE CHEMICALLY ANALYZED

○ SAMPLE TAKEN FROM BOREHOLE SPOILS

▲ SURFACE SAMPLE CHEMICALLY ANALYZED

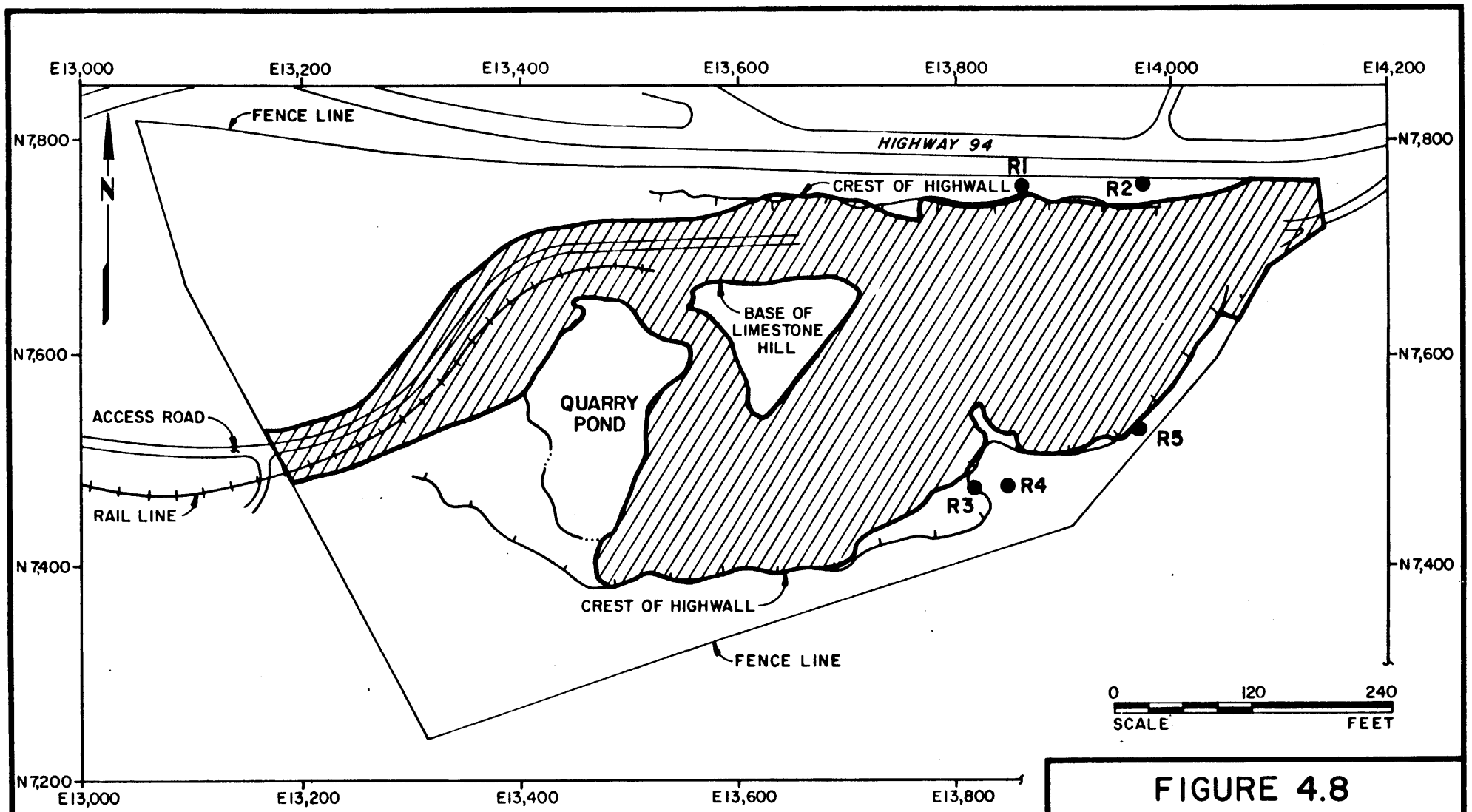
50 0 50 100
SCALE FEET

N

FIGURE 4.7

LOCATIONS OF SUBSURFACE SOIL SAMPLES AT THE WSQ BY BNI

SOURCE: BNI, 1985c



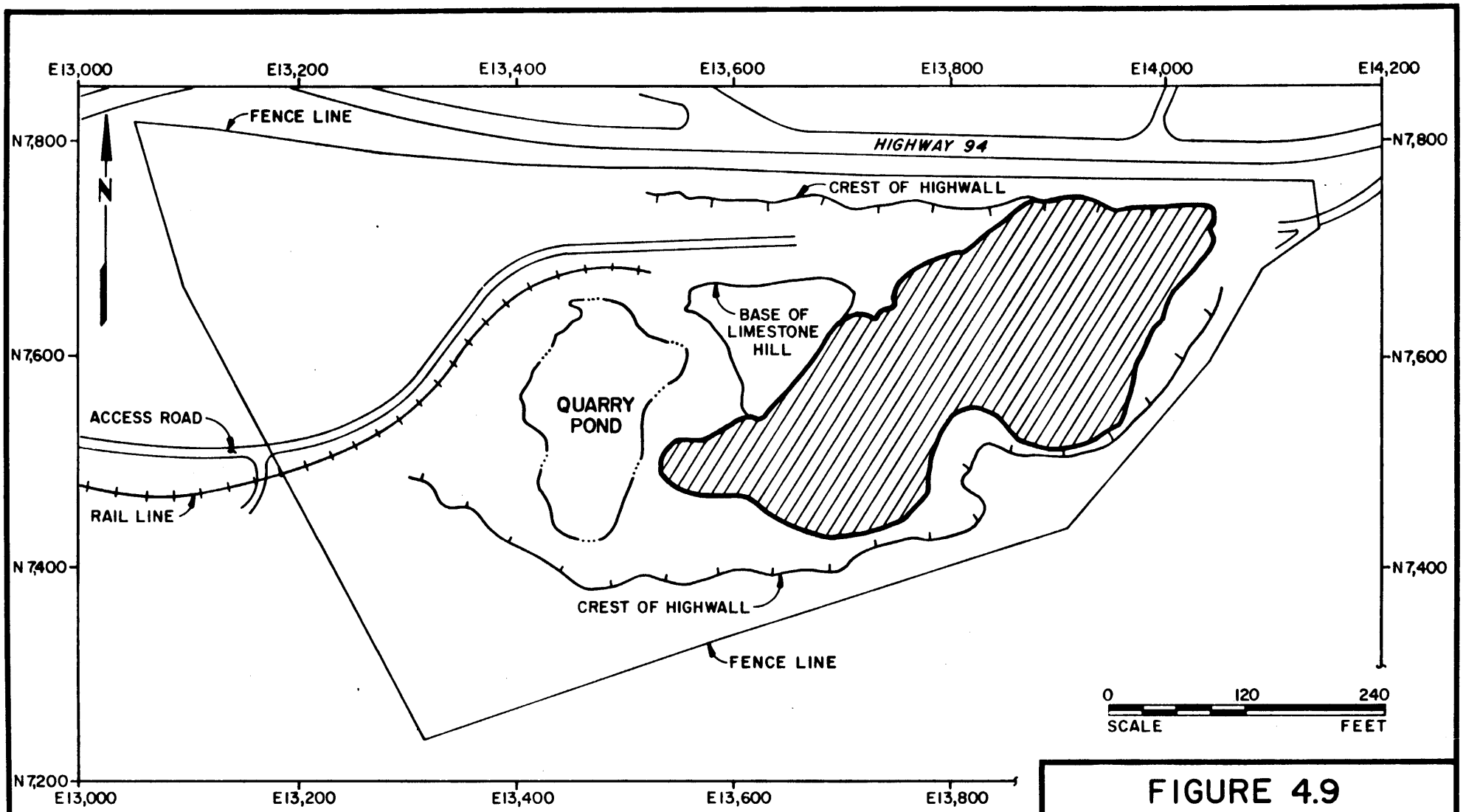
LEGEND:

● R1 SMALL AREA OF RADIOLOGICAL CONTAMINATION

▨ AREA OF CONFIRMED SURFACE RADIOLOGICAL CONTAMINATION, 0-0.5 FEET.

FIGURE 4.8

CONFIRMED SURFACE RADIOLOGICAL CONTAMINATION 0 TO 0.5 FOOT DEPTH

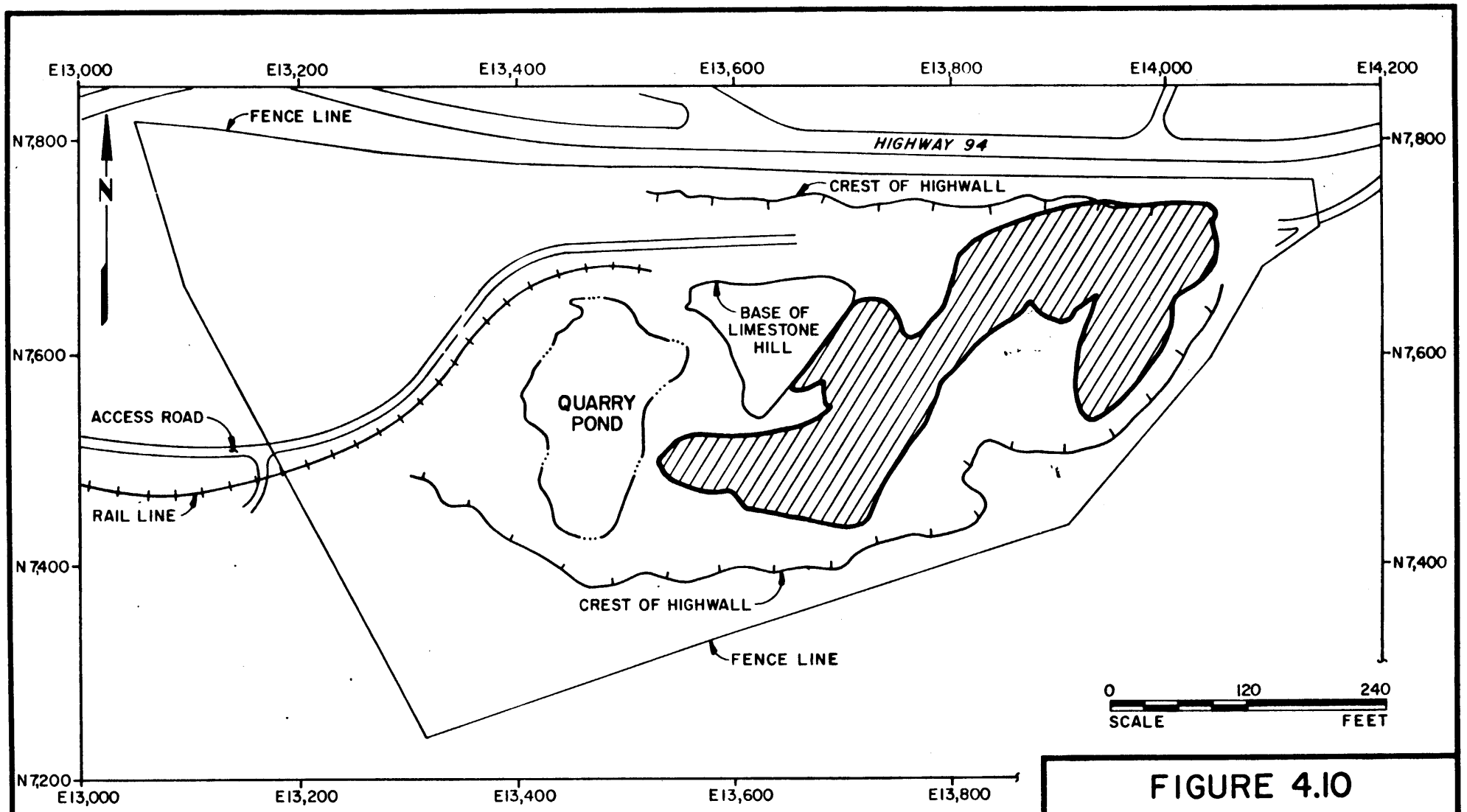


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 0.5 –5 FEET.

FIGURE 4.9

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 0.5 TO 5 FOOT DEPTH

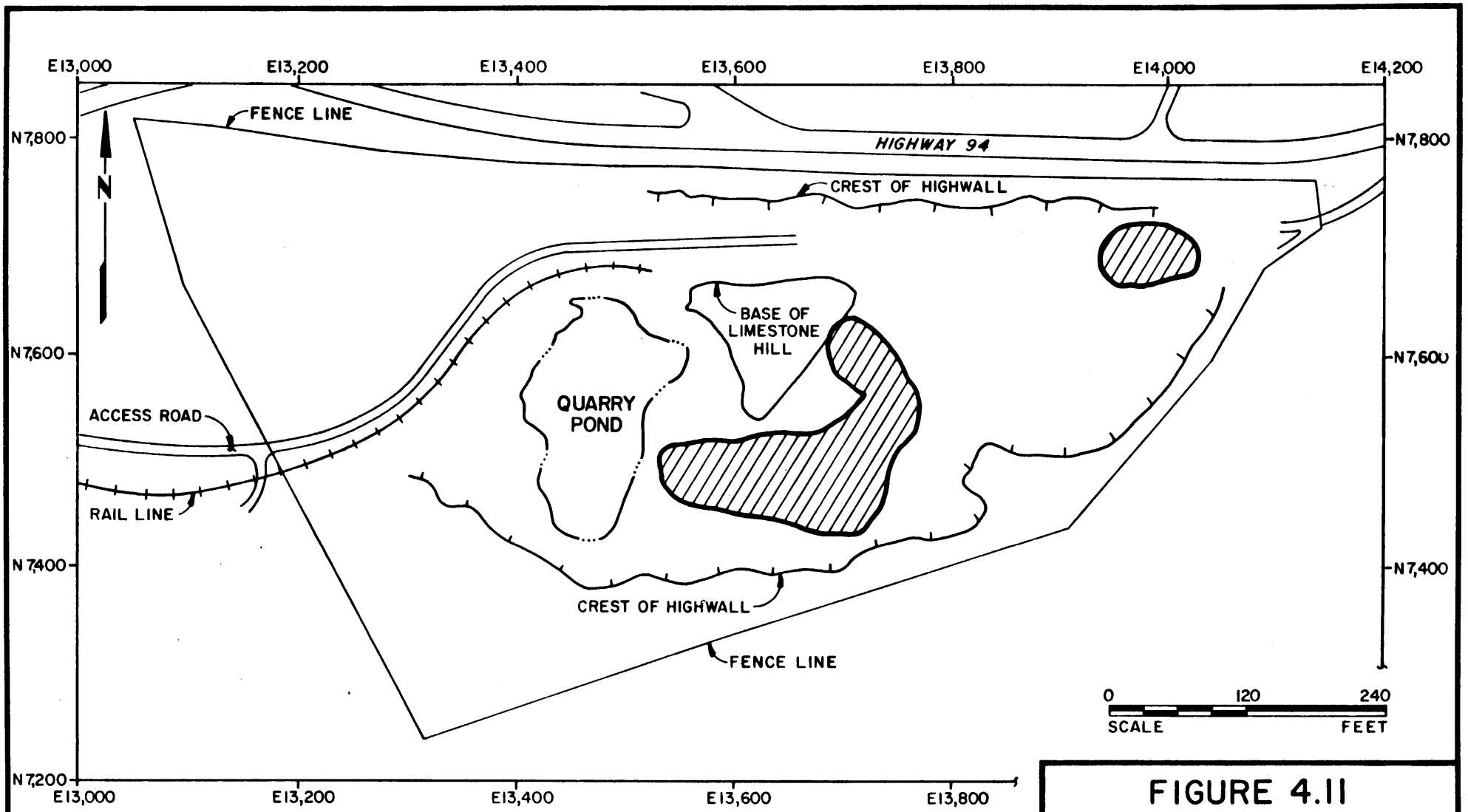


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 5-10 FEET

FIGURE 4.10

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 5 TO 10 FOOT DEPTH

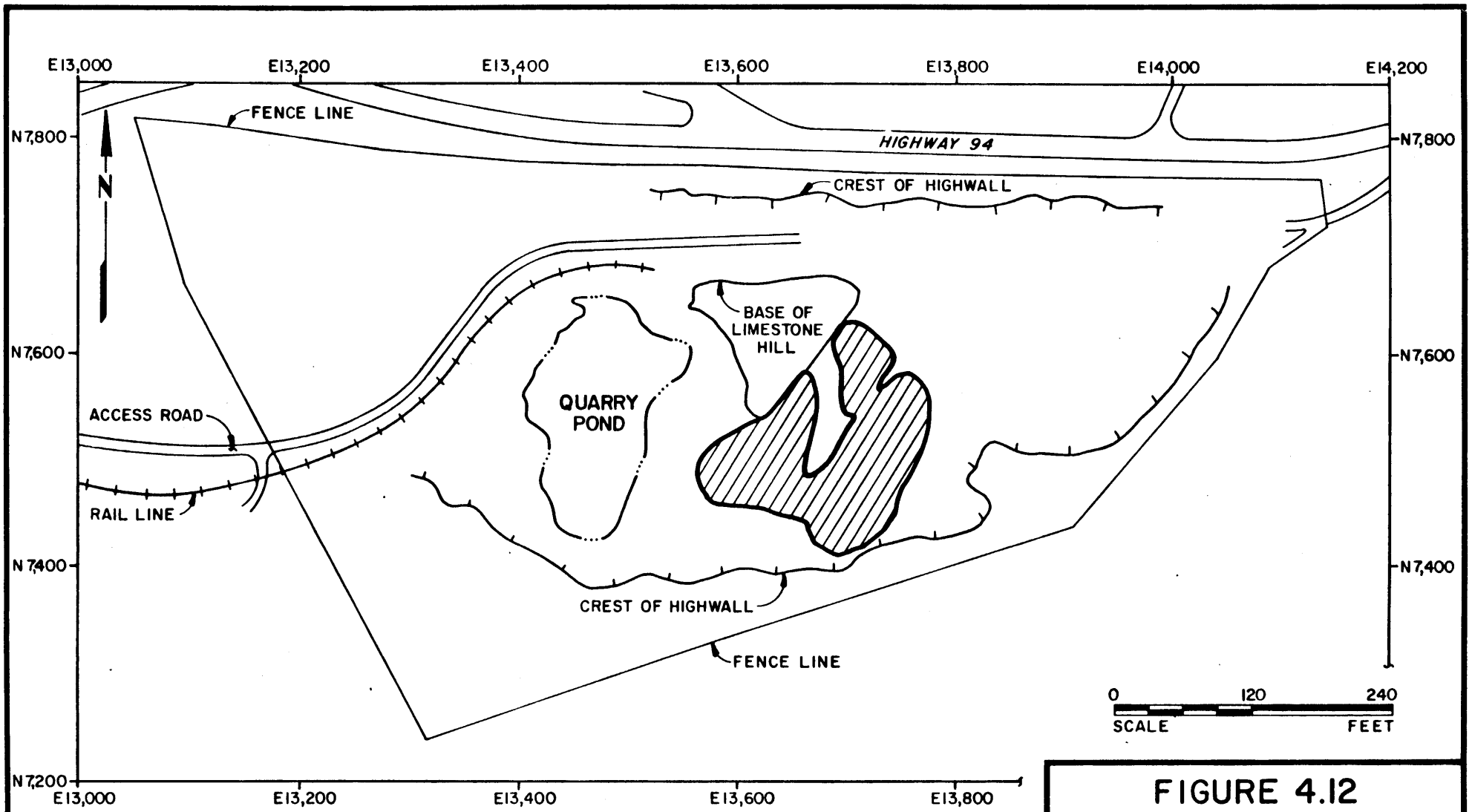


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 10-15 FEET.

FIGURE 4.11

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 10 TO 15 FOOT DEPTH

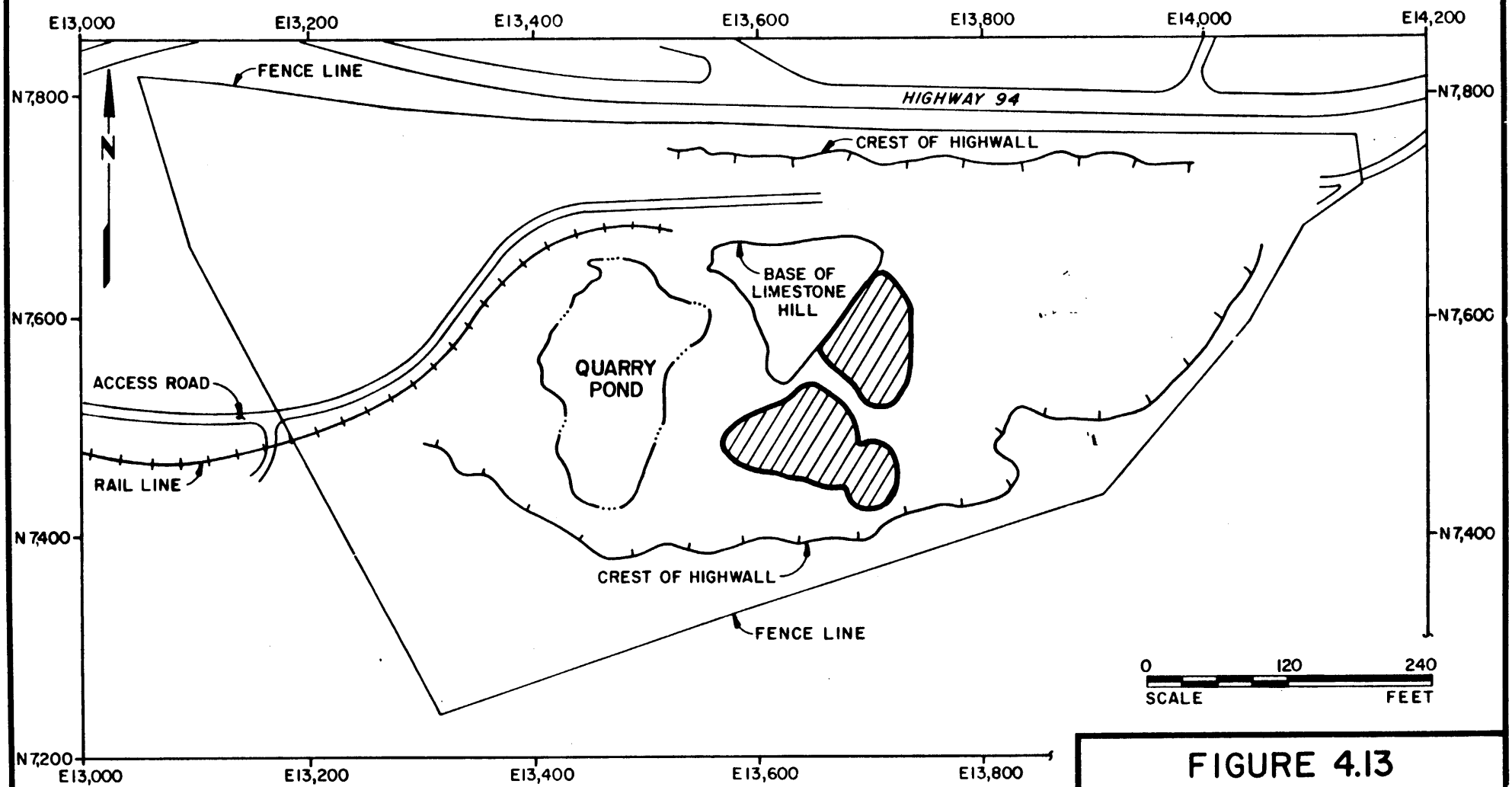


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 15-20 FEET.

FIGURE 4.12

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 15 TO 20 FOOT DEPTH

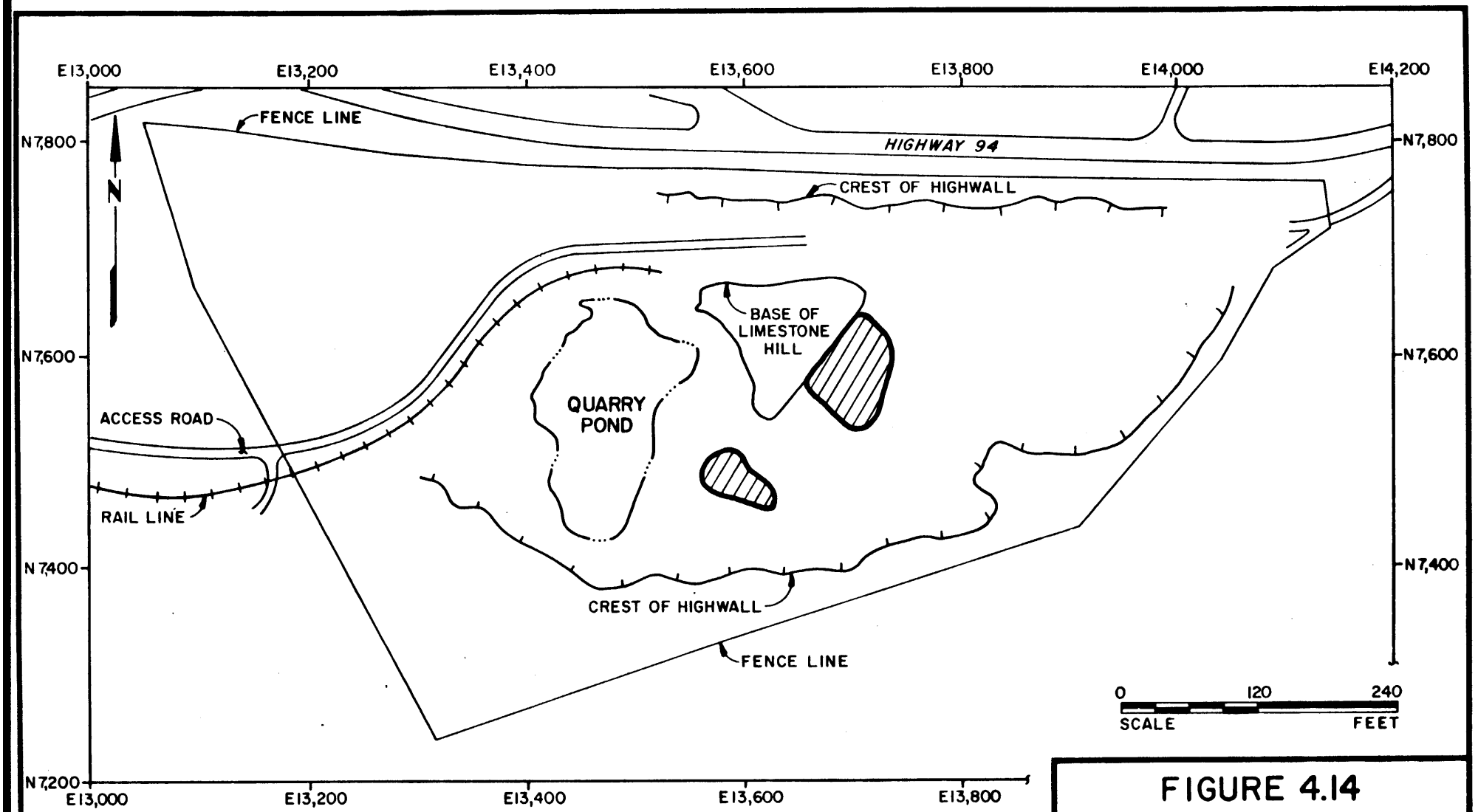


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 20-25 FEET.

FIGURE 4.13

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 20 TO 25 FOOT DEPTH

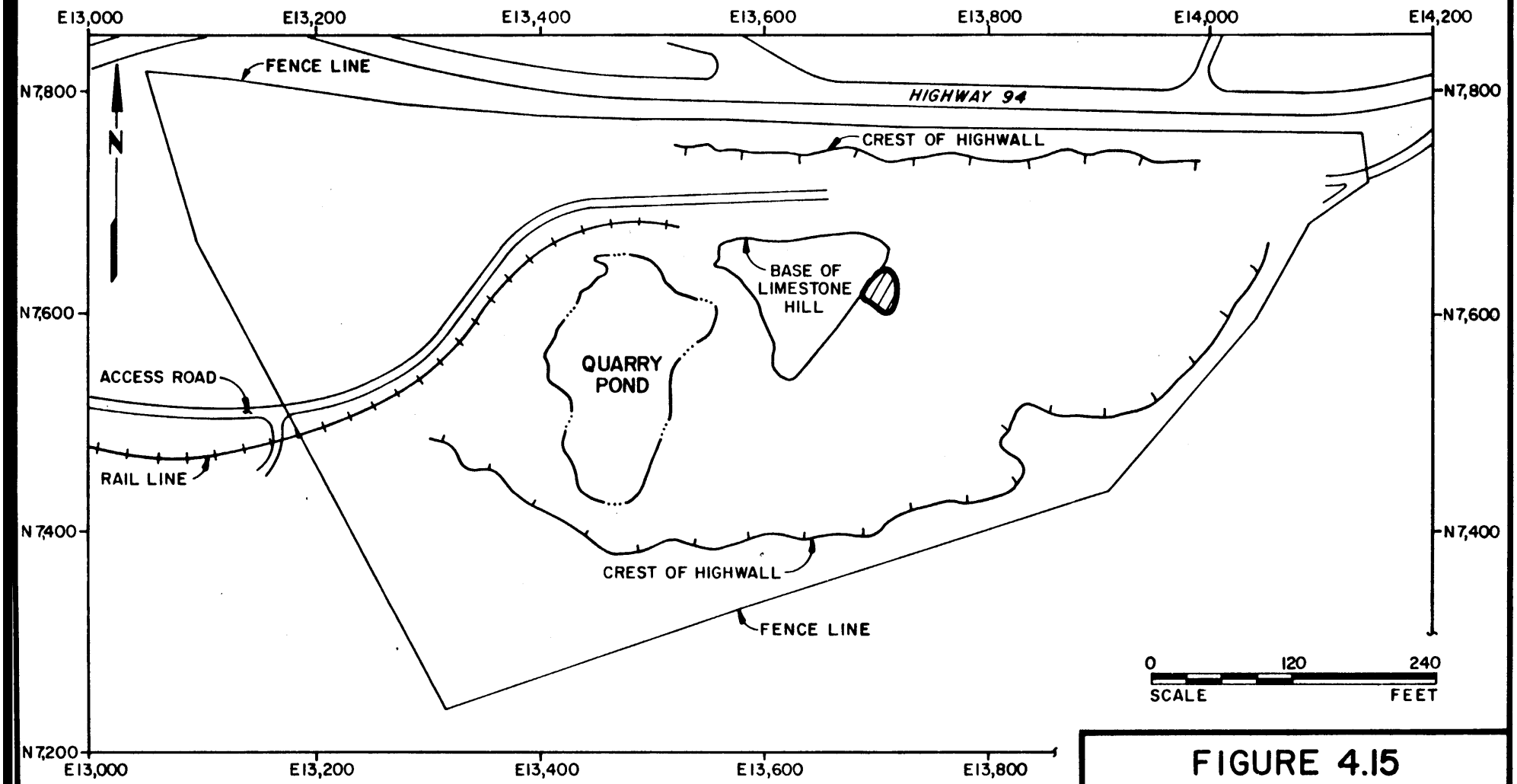


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 25-30 FEET.

FIGURE 4.14

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 25 TO 30 FOOT DEPTH



LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 30-35 FEET.

FIGURE 4.15

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 30 TO 35 FOOT DEPTH

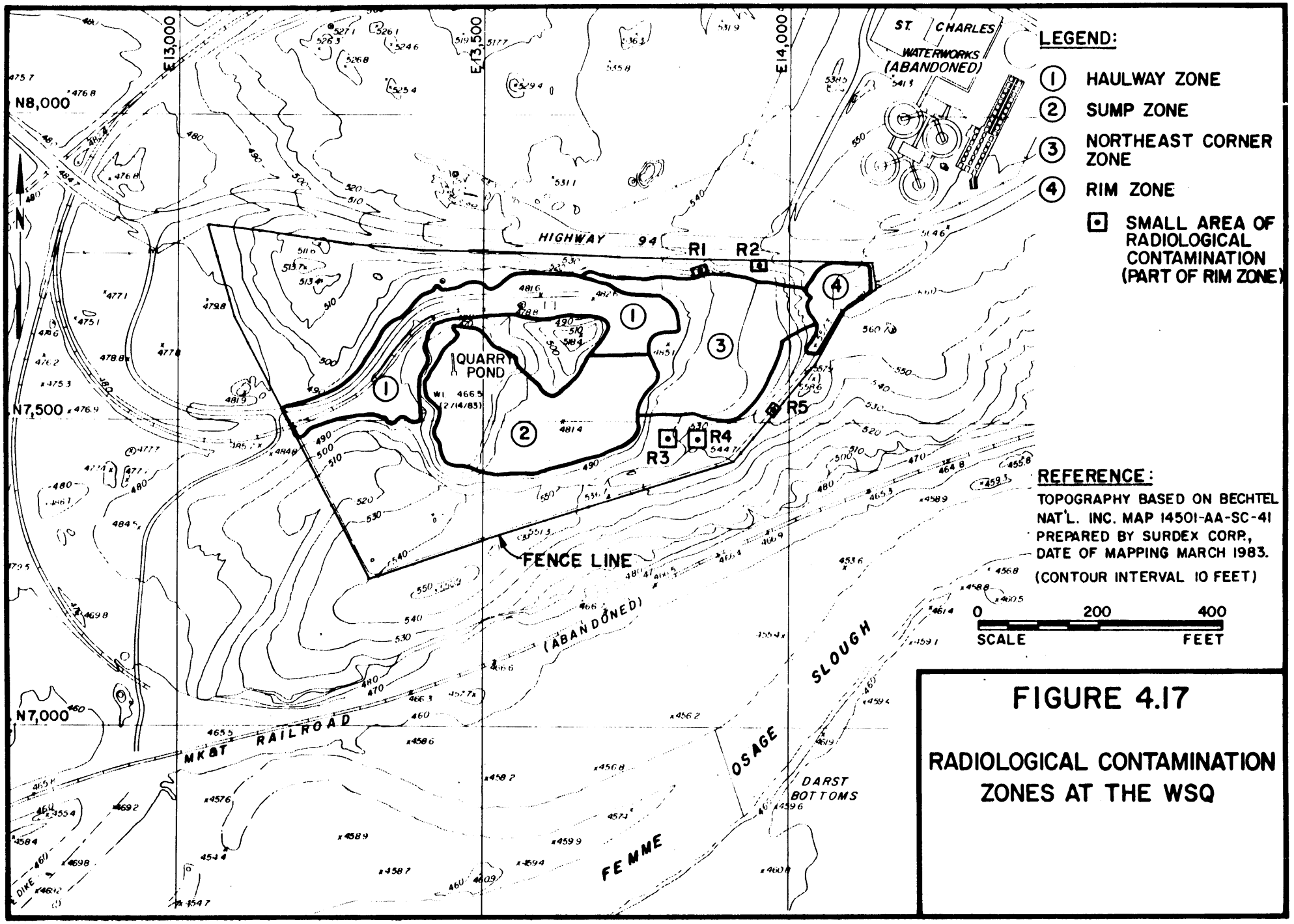
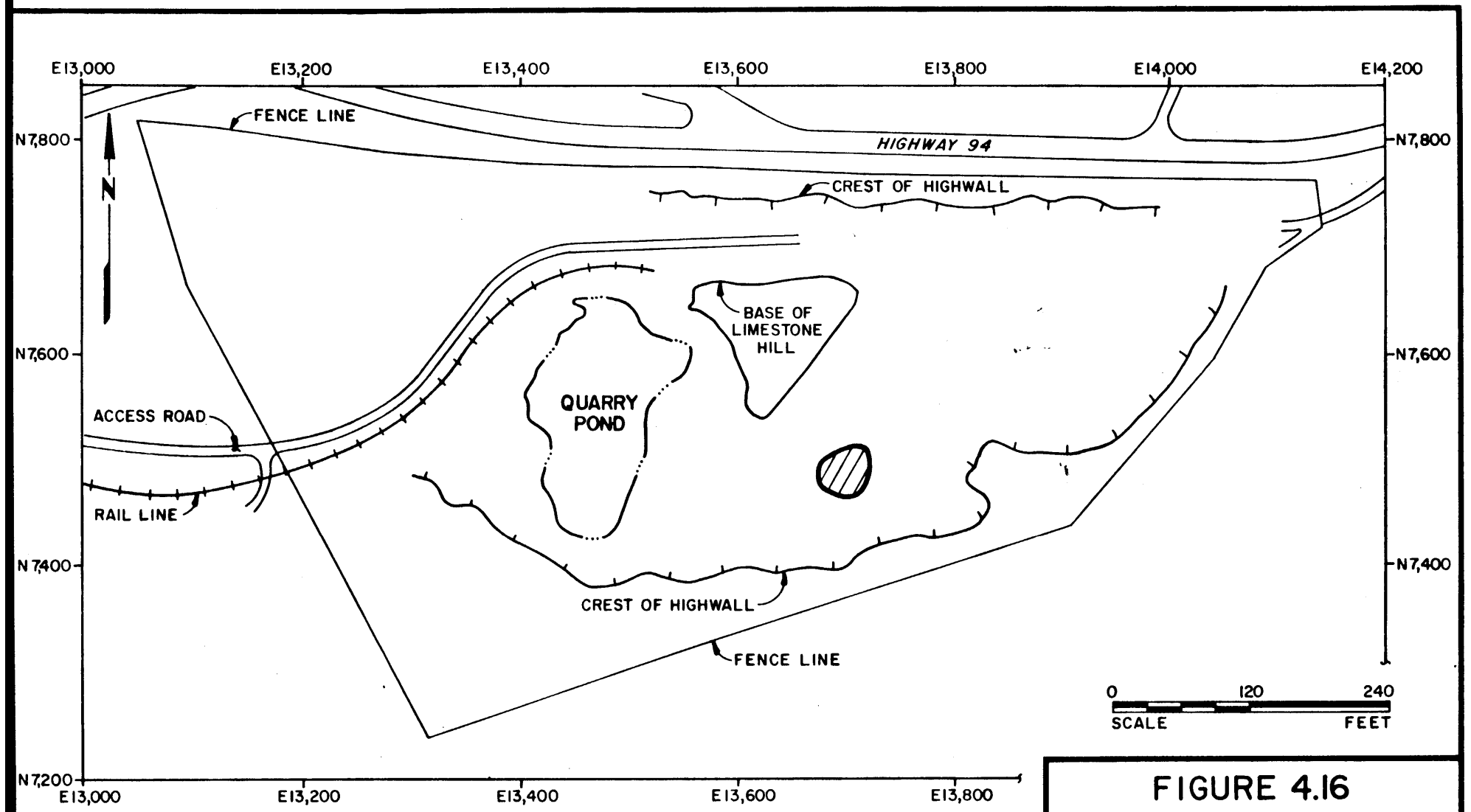


FIGURE 4.17

RADIOLOGICAL CONTAMINATION ZONES AT THE WSQ

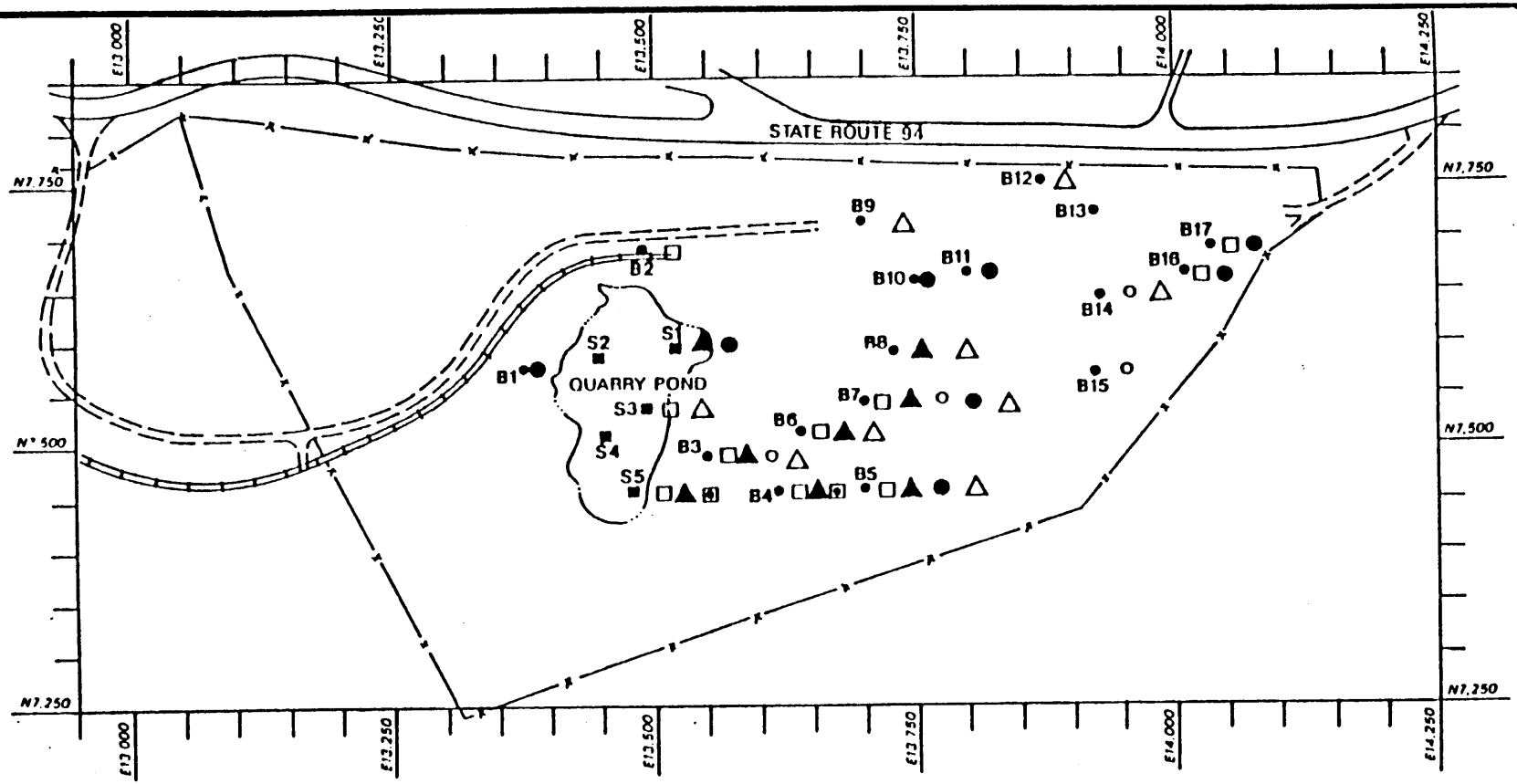


LEGEND:

AREA OF CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION, 35-40 FEET.

FIGURE 4.16

CONFIRMED SUBSURFACE RADIOLOGICAL CONTAMINATION 35 TO 40 FOOT DEPTH



N

- BORING (eg. B1)
- SEDIMENT
- VOLATILES
- COMBUSTION PRODUCTS
- NAPTHALENE
- PHTHALATE
- TNT, DNT, & BREAKDOWN PRODUCTS
- PCBs

NOTES:

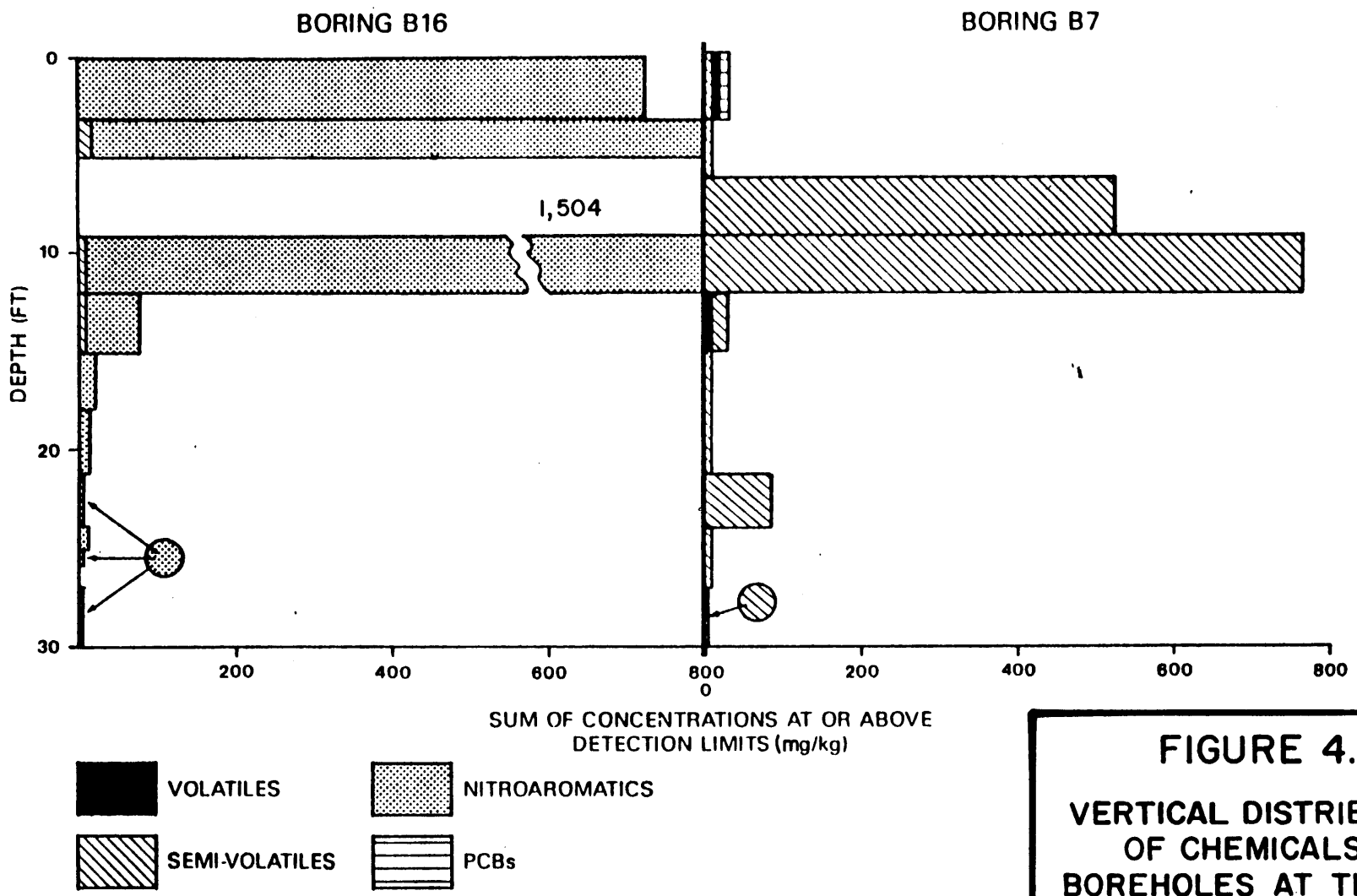
- BASED ON THE PHASE II CHEMICAL CHARACTERIZATION SURVEY OF THE WELDON SPRING QUARRY.
- VOLATILES ARE BELIEVED TO BE LABORATORY ARTIFACTS.

0 50 100 200 300
SCALE FEET

FIGURE 4.18

CHEMICAL CONSTITUENTS DETECTED AT THE WELDON SPRING QUARRY

SOURCE: KAYE AND DAVIS, 1987



NOTE:
SEE FIGURE 4.5 FOR LOCATION OF BORINGS.

FIGURE 4.19

VERTICAL DISTRIBUTION OF CHEMICALS IN BOREHOLES AT THE WSQ

SOURCE: KAYE AND DAVIS, 1987

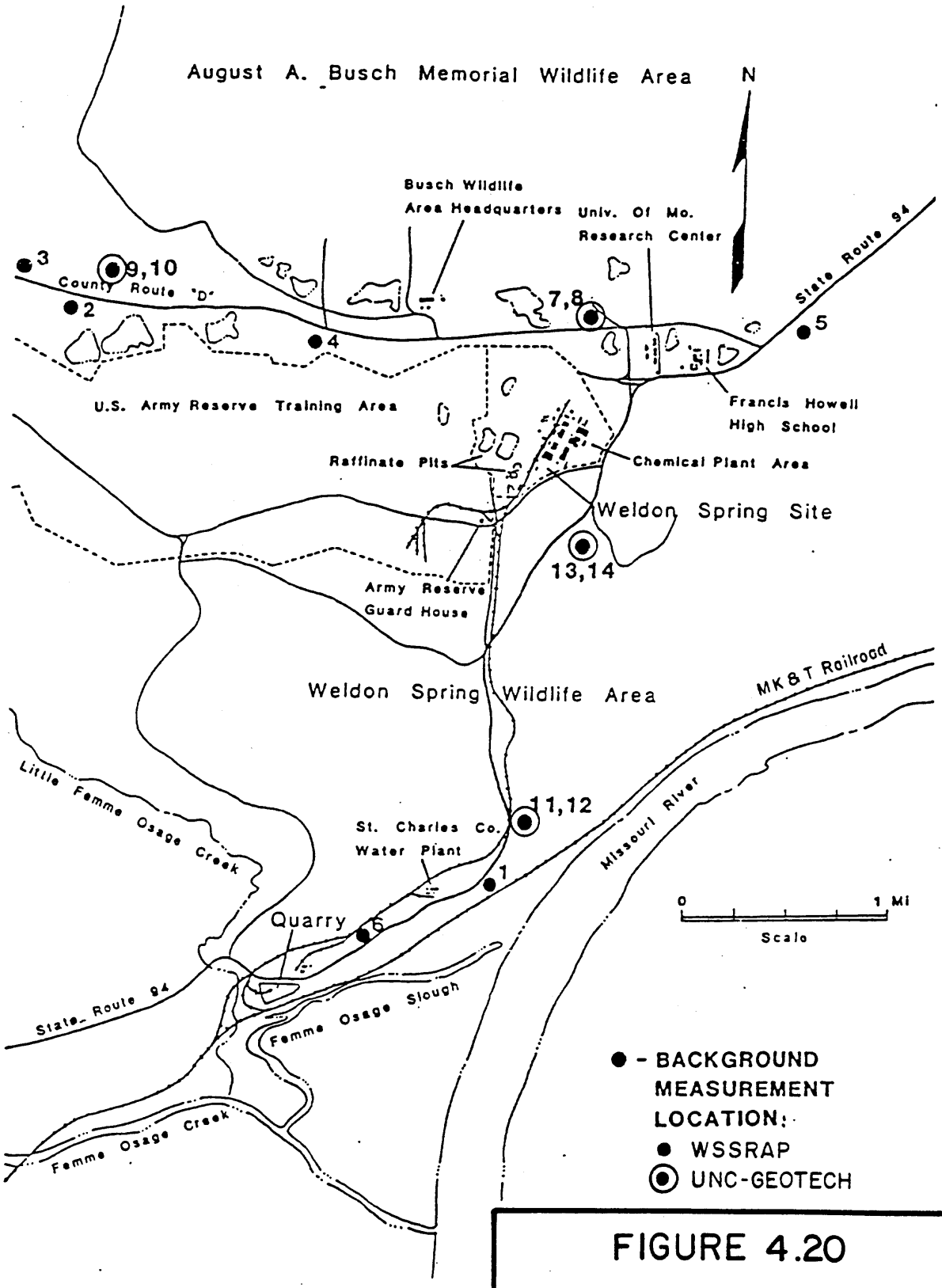
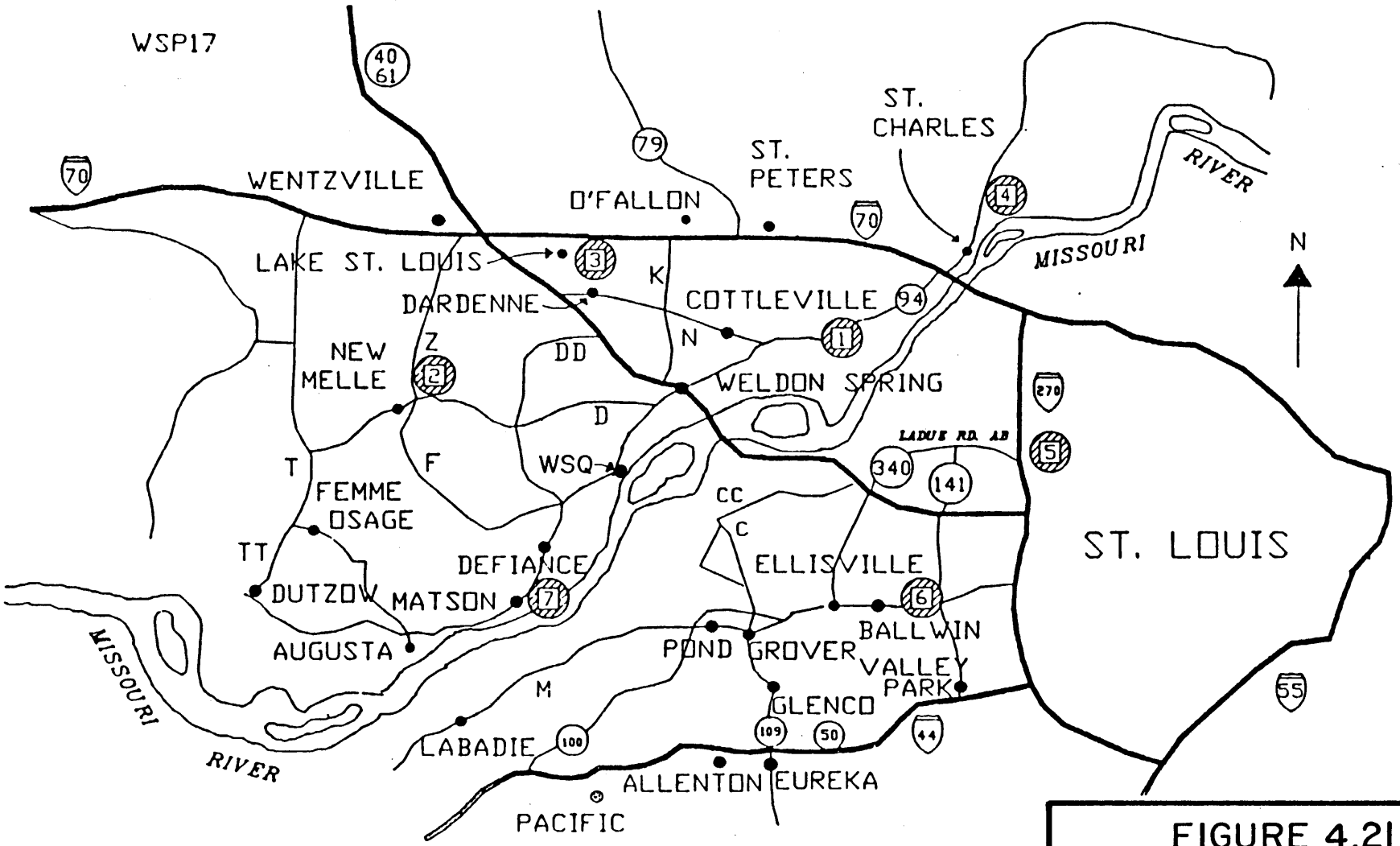


FIGURE 4.20

LOCATIONS OF WSSRAP AND UNC-GEOTECH BACKGROUND MEASUREMENTS

SOURCE: MK-F AND JEG, 1988 b



NOTE:
SEDIMENT SAMPLES: LOCATIONS 2,3,4,6 AND 7
SURFACE WATER SAMPLES: LOCATIONS 2,3,4,5,6 AND 7
SOIL SAMPLES: LOCATIONS 1,2,3,4,5 AND 6

1 4
KILOMETERS

SAMPLE LOCATIONS

FIGURE 4.21

LOCATIONS OF ORAU BACKGROUND SAMPLES

SOURCE: BOERNER, 1986

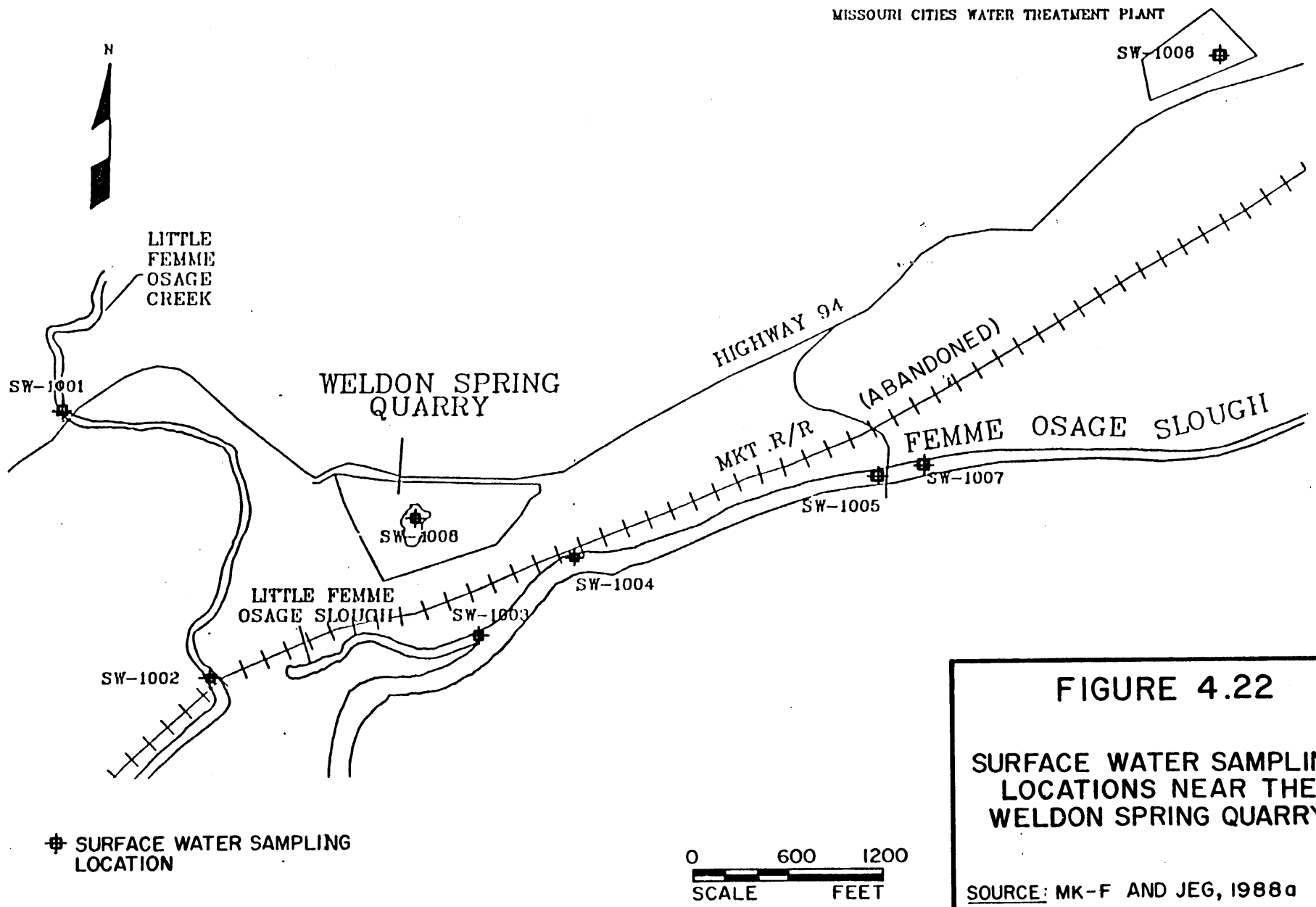


FIGURE 4.22

SURFACE WATER SAMPLING LOCATIONS NEAR THE WELDON SPRING QUARRY

SOURCE: MK-F AND JEG, 1988a

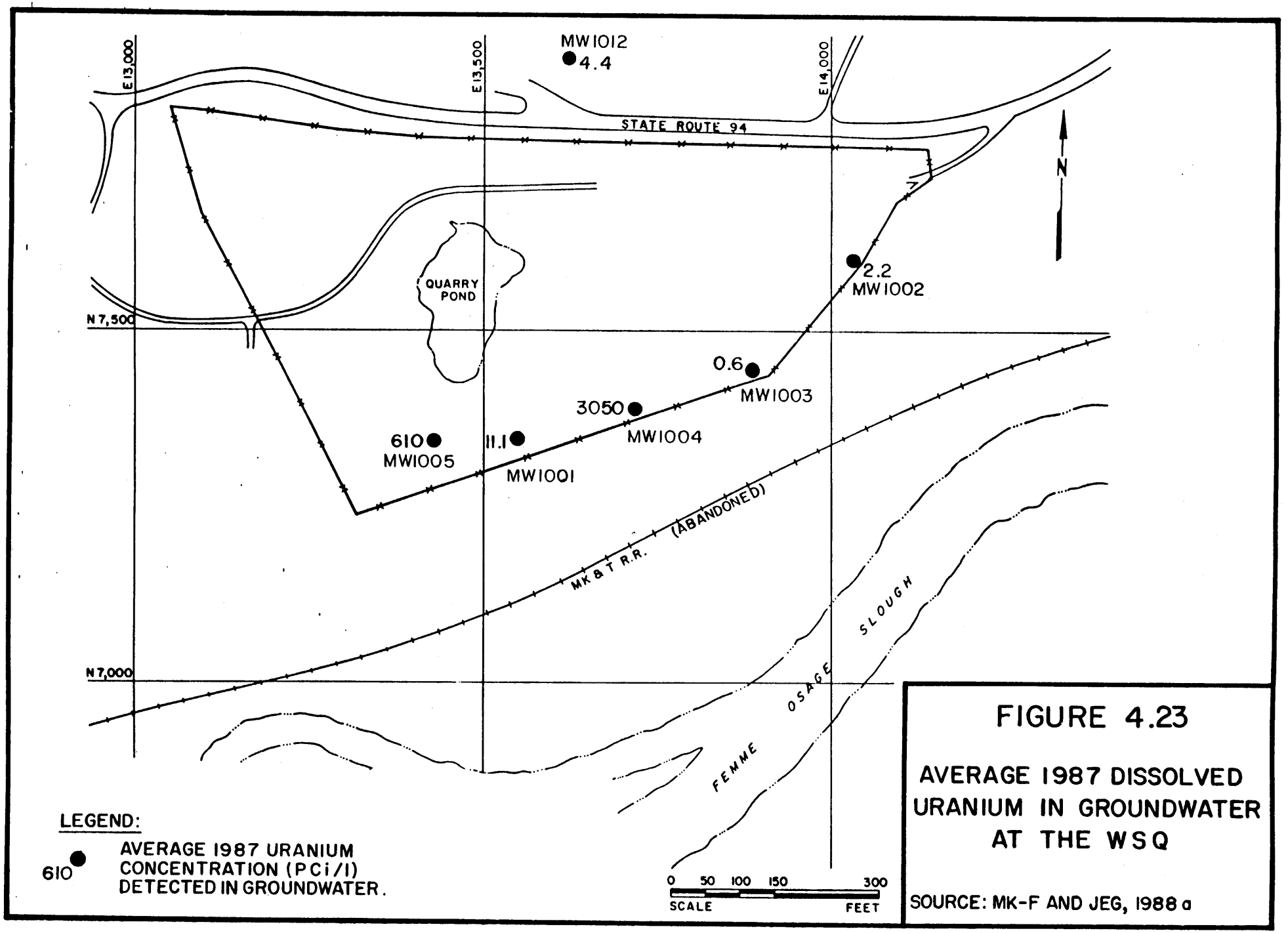


FIGURE 4.23

AVERAGE 1987 DISSOLVED URANIUM IN GROUNDWATER AT THE WSQ

SOURCE: MK-F AND JEG, 1988 a

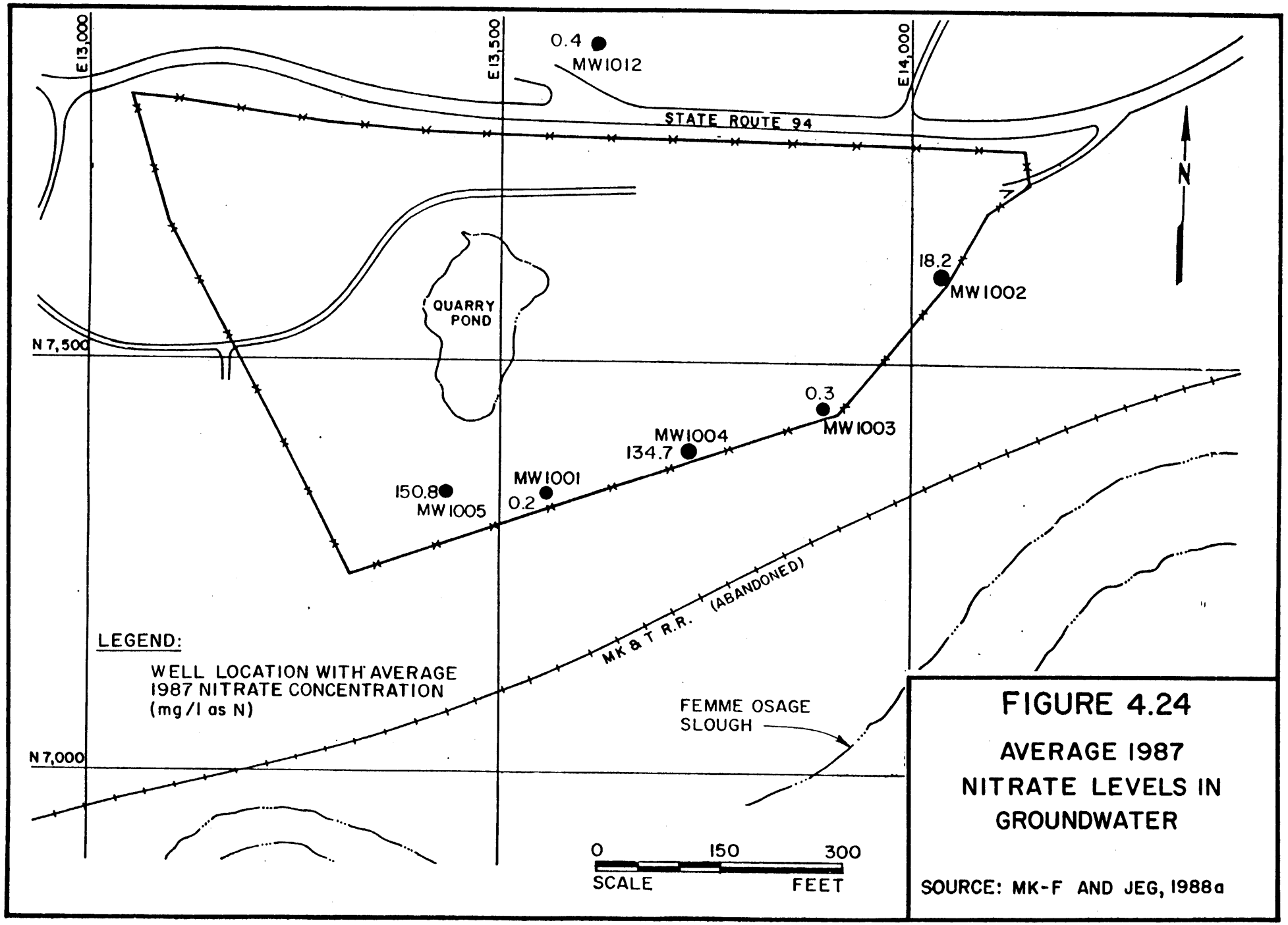


FIGURE 4.24

AVERAGE 1987 NITRATE LEVELS IN GROUNDWATER

SOURCE: MK-F AND JEG, 1988a

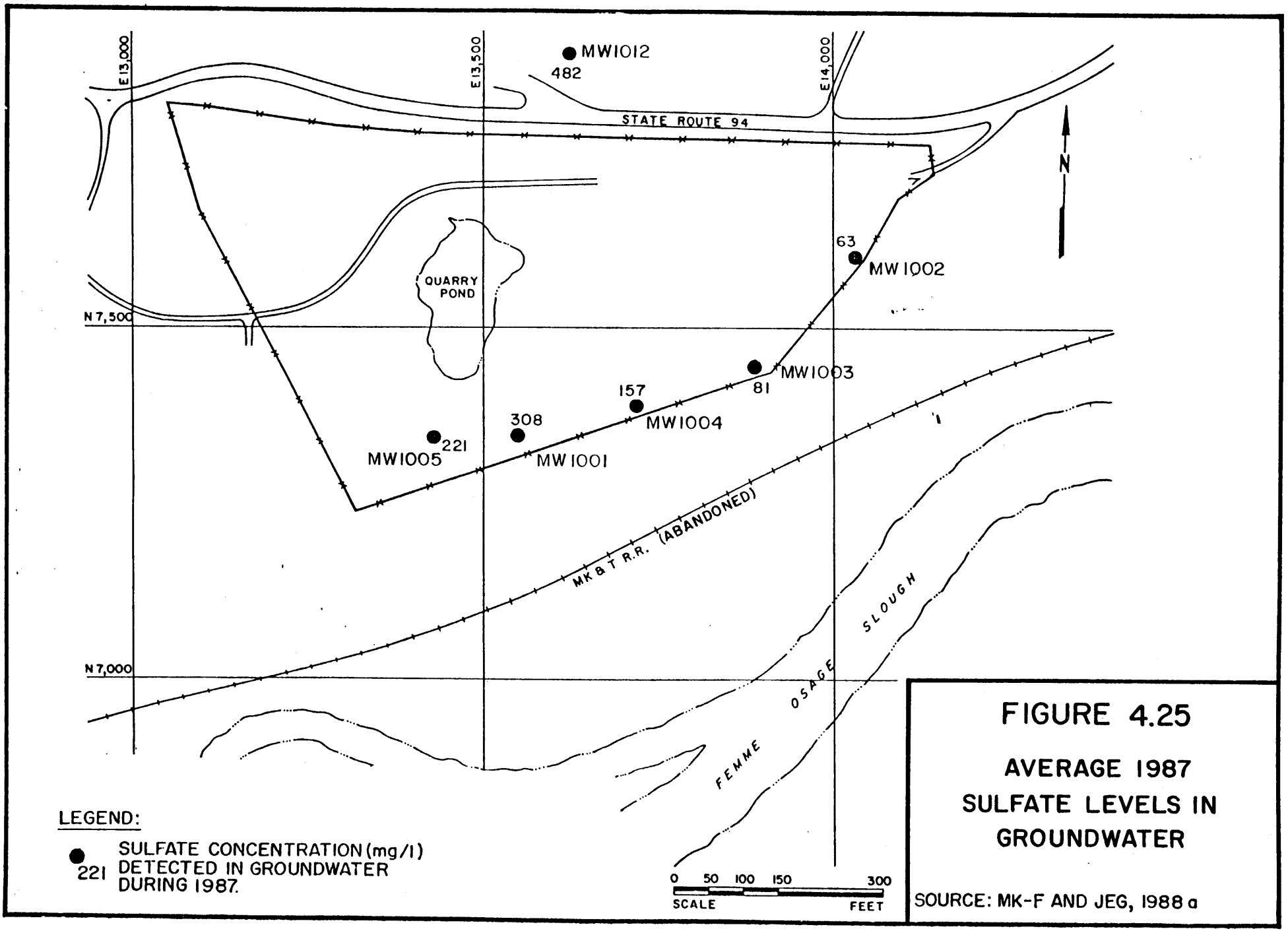
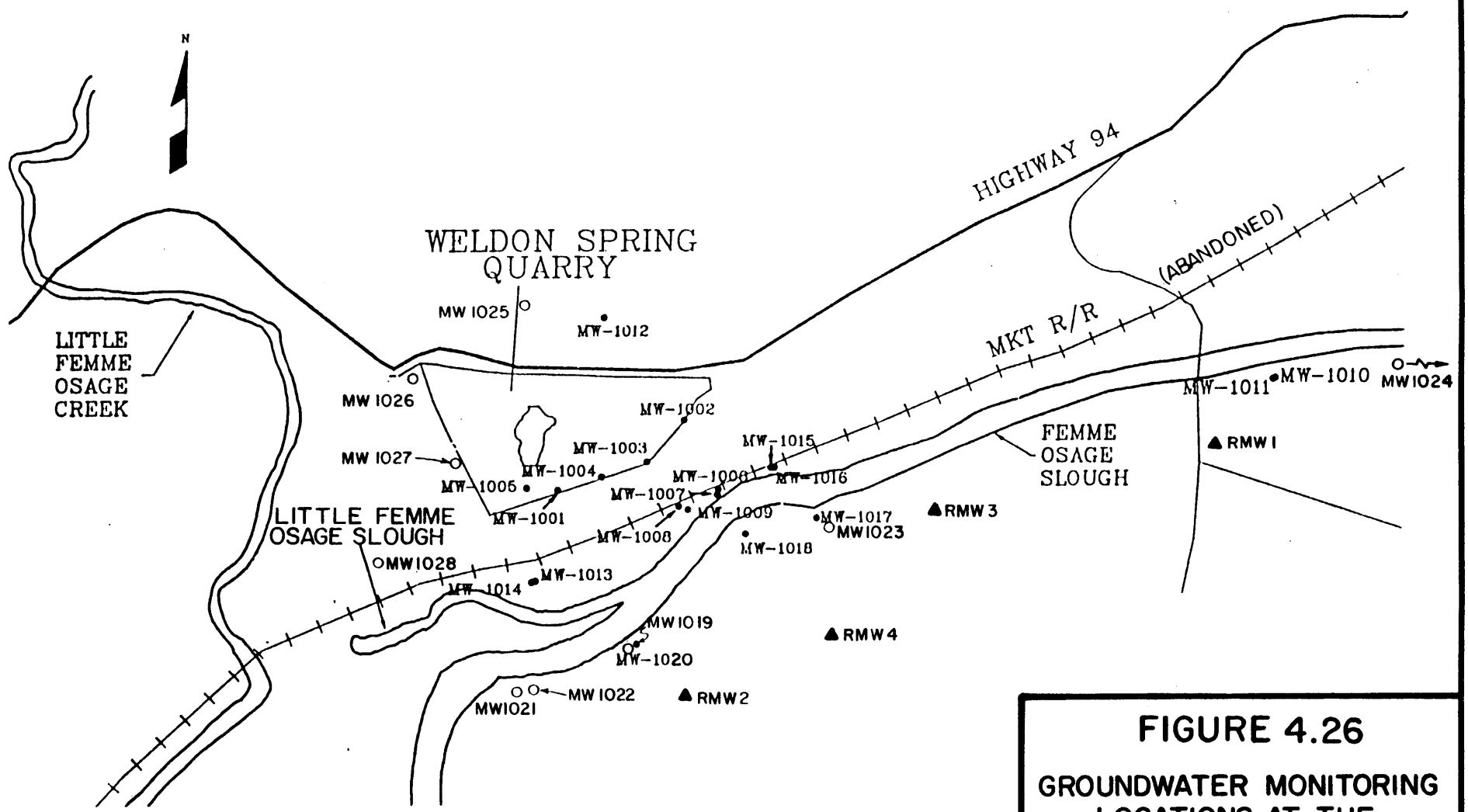


FIGURE 4.25

AVERAGE 1987 SULFATE LEVELS IN GROUNDWATER

SOURCE: MK-F AND JEG, 1988 a



LEGEND:

- • DOE MONITORING WELLS (INSTALLED PRIOR TO 1988)
- o DOE MONITORING WELLS (INSTALLED 1988)
- ▲ COUNTY MONITORING WELLS

FIGURE 4.26

GROUNDWATER MONITORING LOCATIONS AT THE WELDON SPRING QUARRY

SOURCE: MK-F AND JEG, 1988a

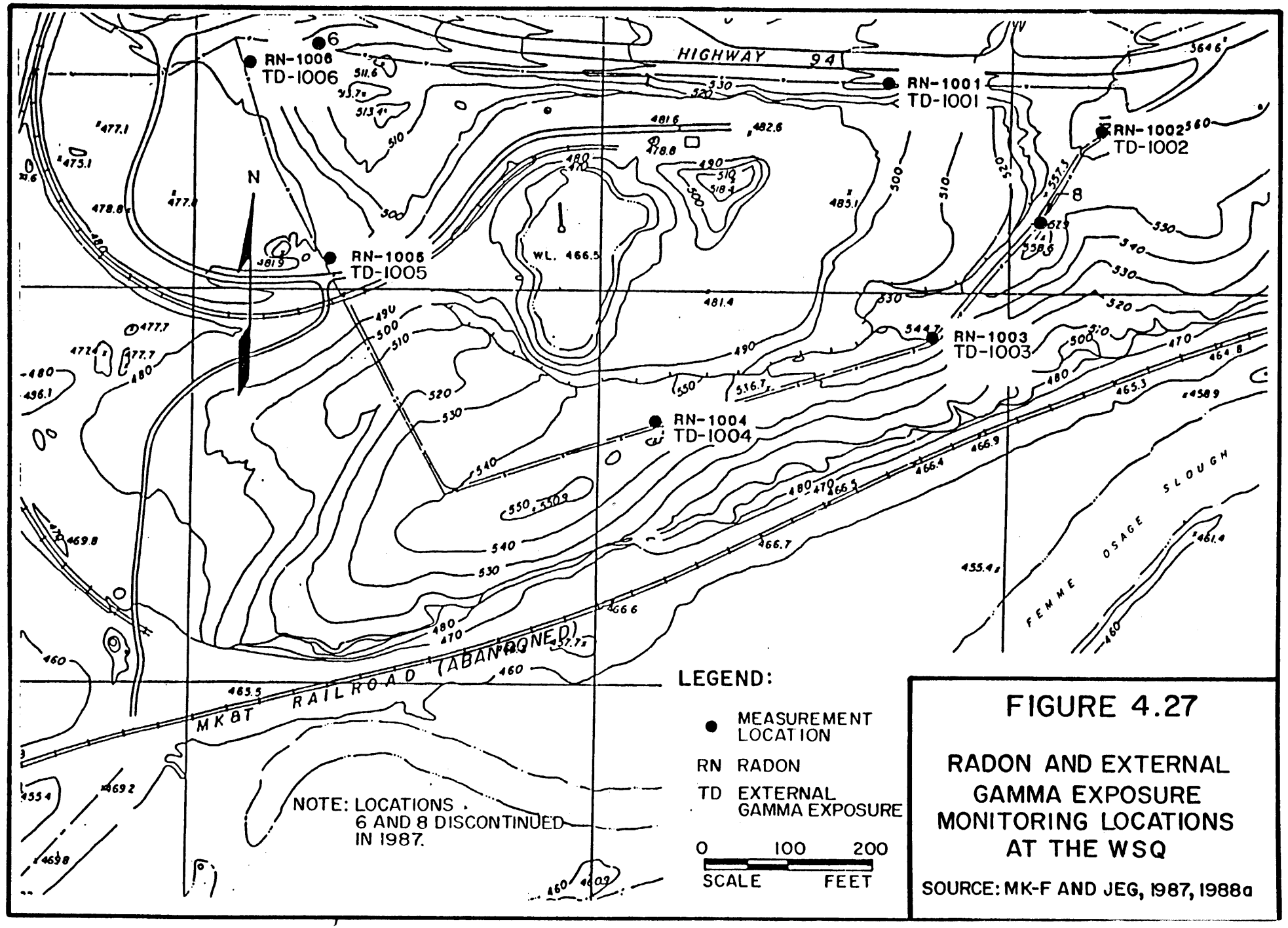


FIGURE 4.27

RADON AND EXTERNAL GAMMA EXPOSURE MONITORING LOCATIONS AT THE WSQ

SOURCE: MK-F AND JEG, 1987, 1988a

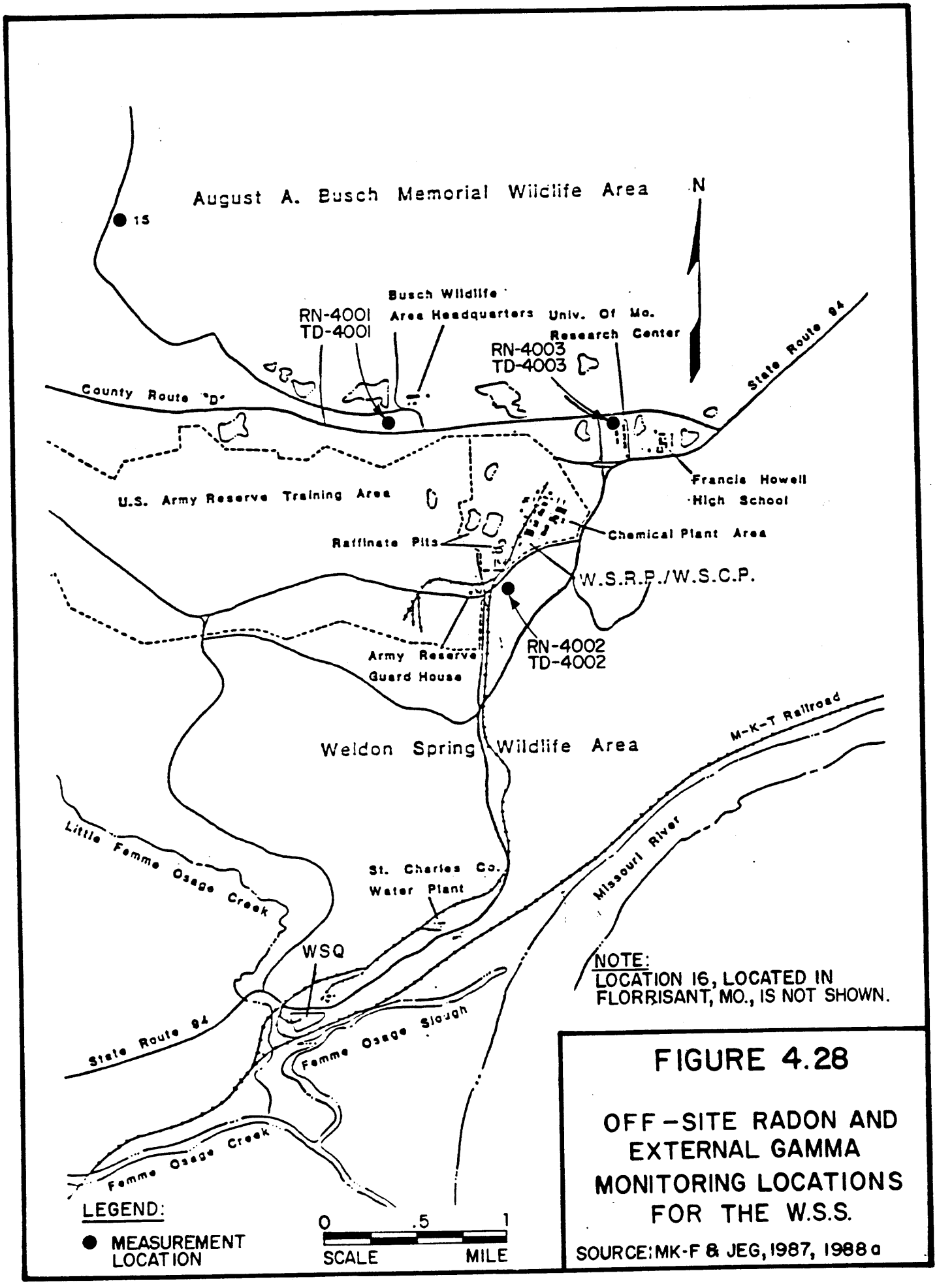
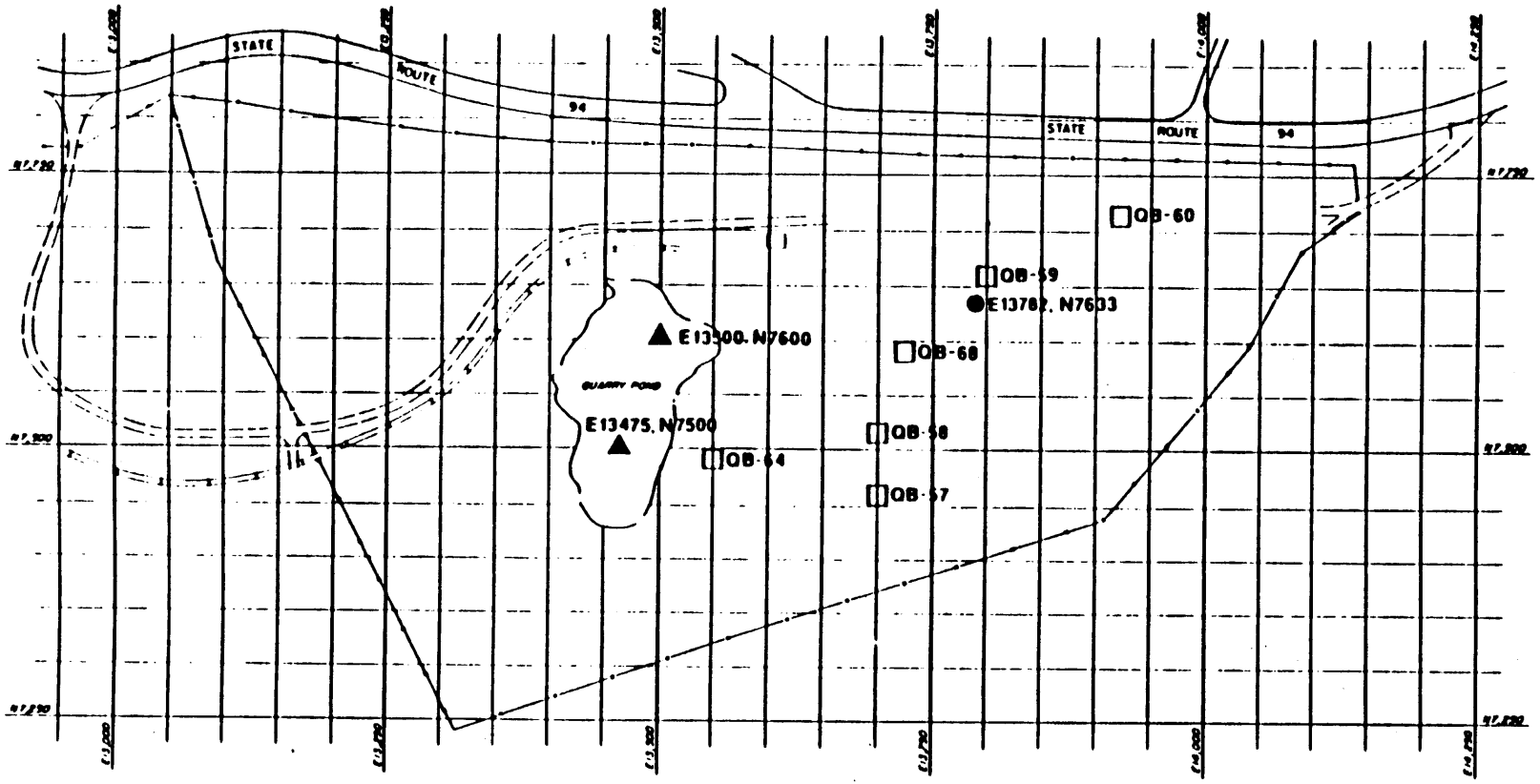


FIGURE 4.28

OFF-SITE RADON AND EXTERNAL GAMMA MONITORING LOCATIONS FOR THE W.S.S.

SOURCE: MK-F & JEG, 1987, 1988a



☐ QUARRY BORING NUMBER CORRESPONDING WITH CHEMICAL SAMPLES

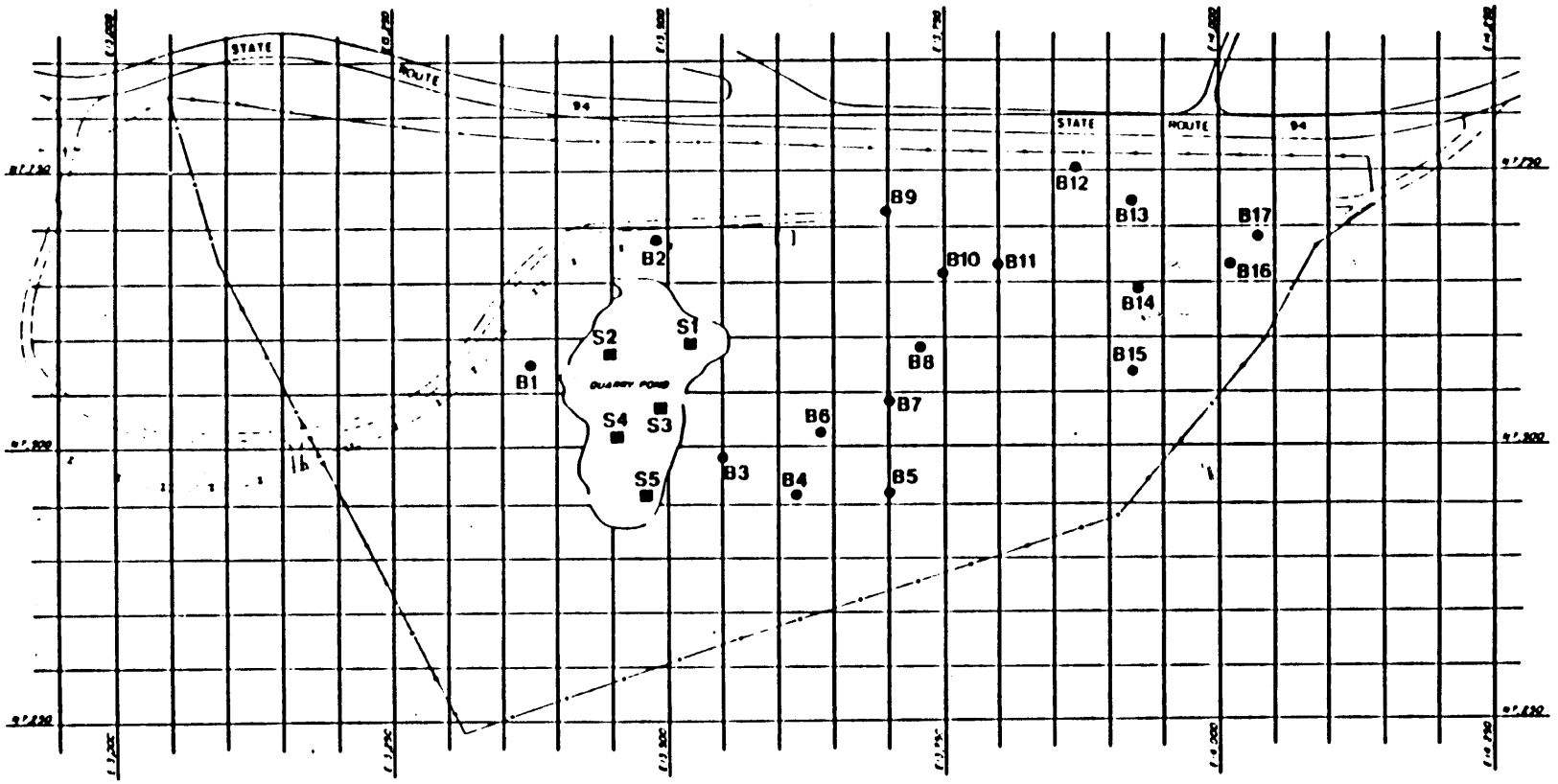
● SURFACE SAMPLE TAKEN FROM RESIDUE PILE

▲ WATER SAMPLE LOCATIONS

FIGURE A.I

SAMPLING LOCATIONS FOR 1984 CHEMICAL ANALYSES

SOURCE: BNI, 1985c



● BORING

■ SEDIMENT

FIGURE A.2

SAMPLING LOCATIONS FOR 1986 CHEMICAL ANALYSES

SOURCE: KAYE AND DAVIS, 1987

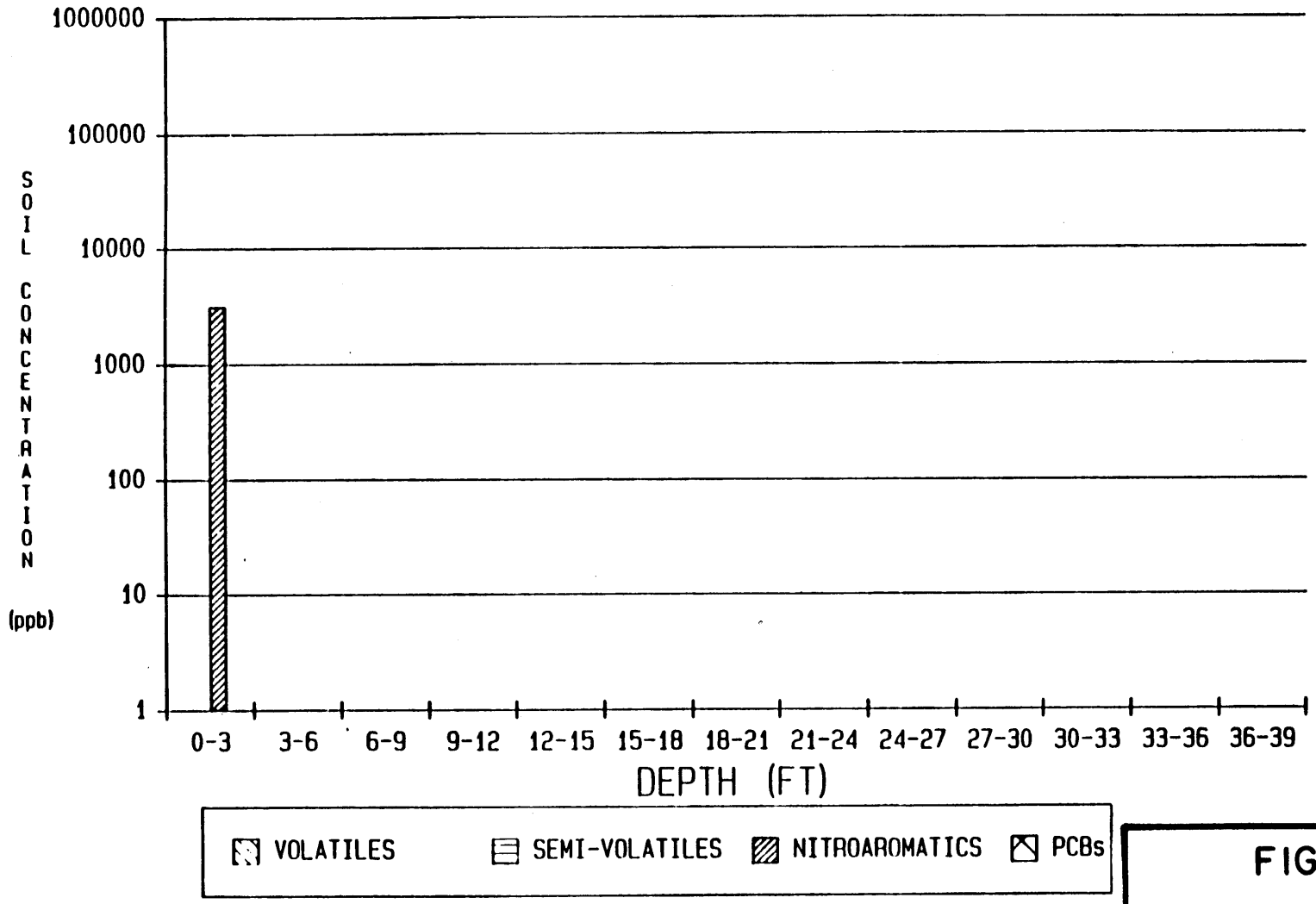


FIGURE A.3

CHEMICALS DETECTED AT LOCATION B-1

SOURCE: KAYE AND DAVIS, 1987

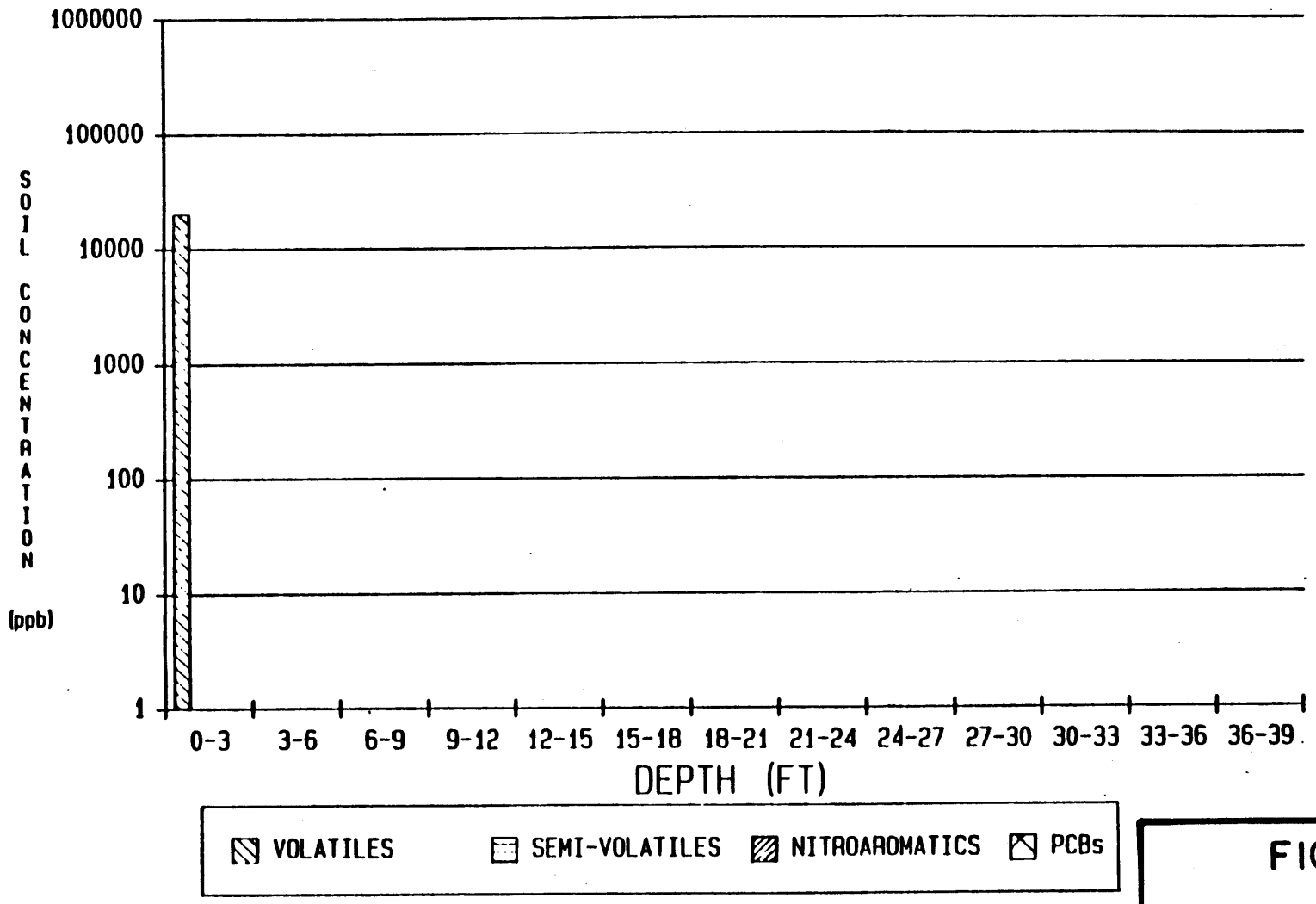


FIGURE A.4

CHEMICALS DETECTED AT LOCATION B-2

SOURCE: KAYE AND DAVIS, 1987

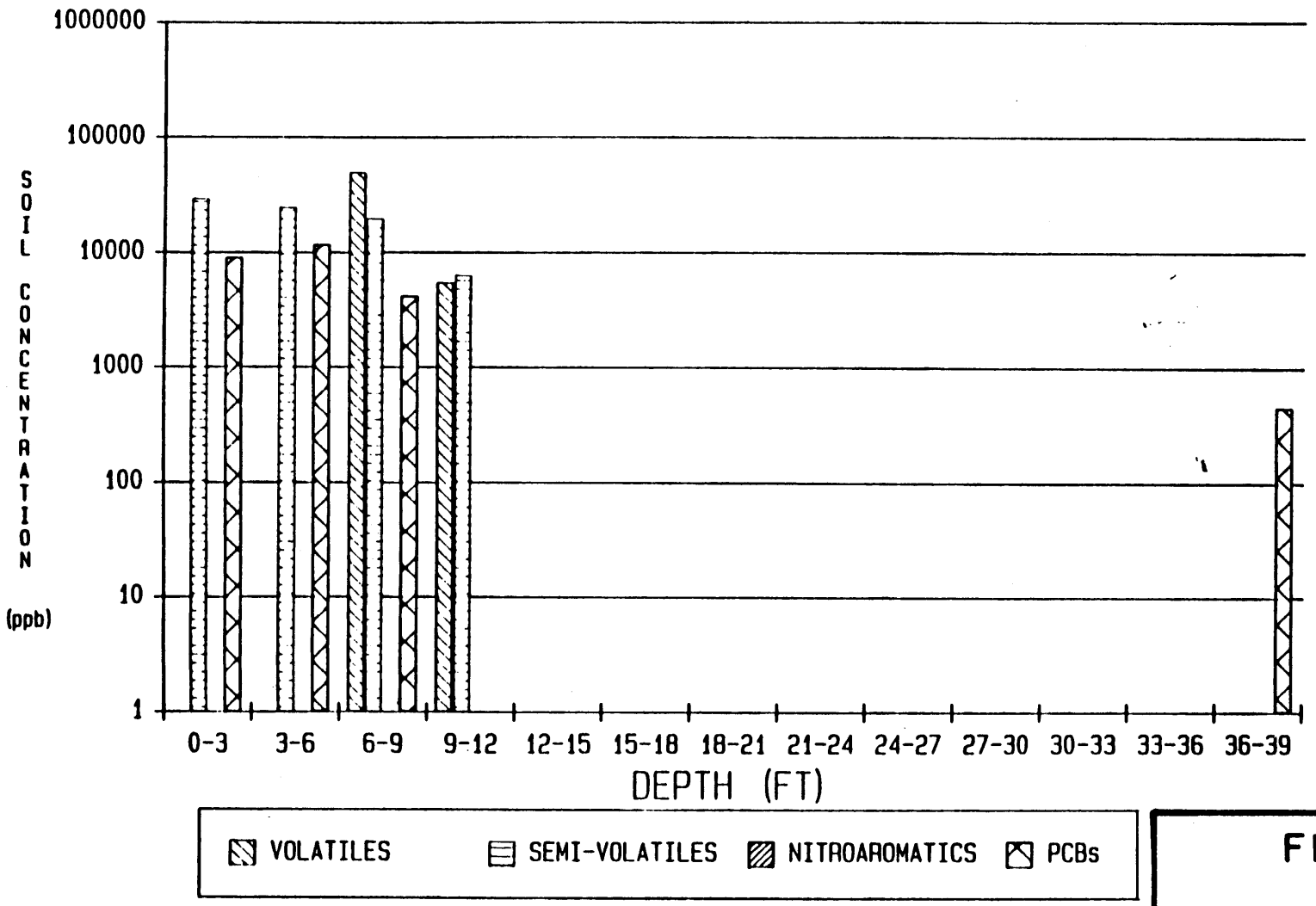


FIGURE A.5

CHEMICALS DETECTED AT LOCATION B-3

SOURCE: KAYE AND DAVIS, 1987

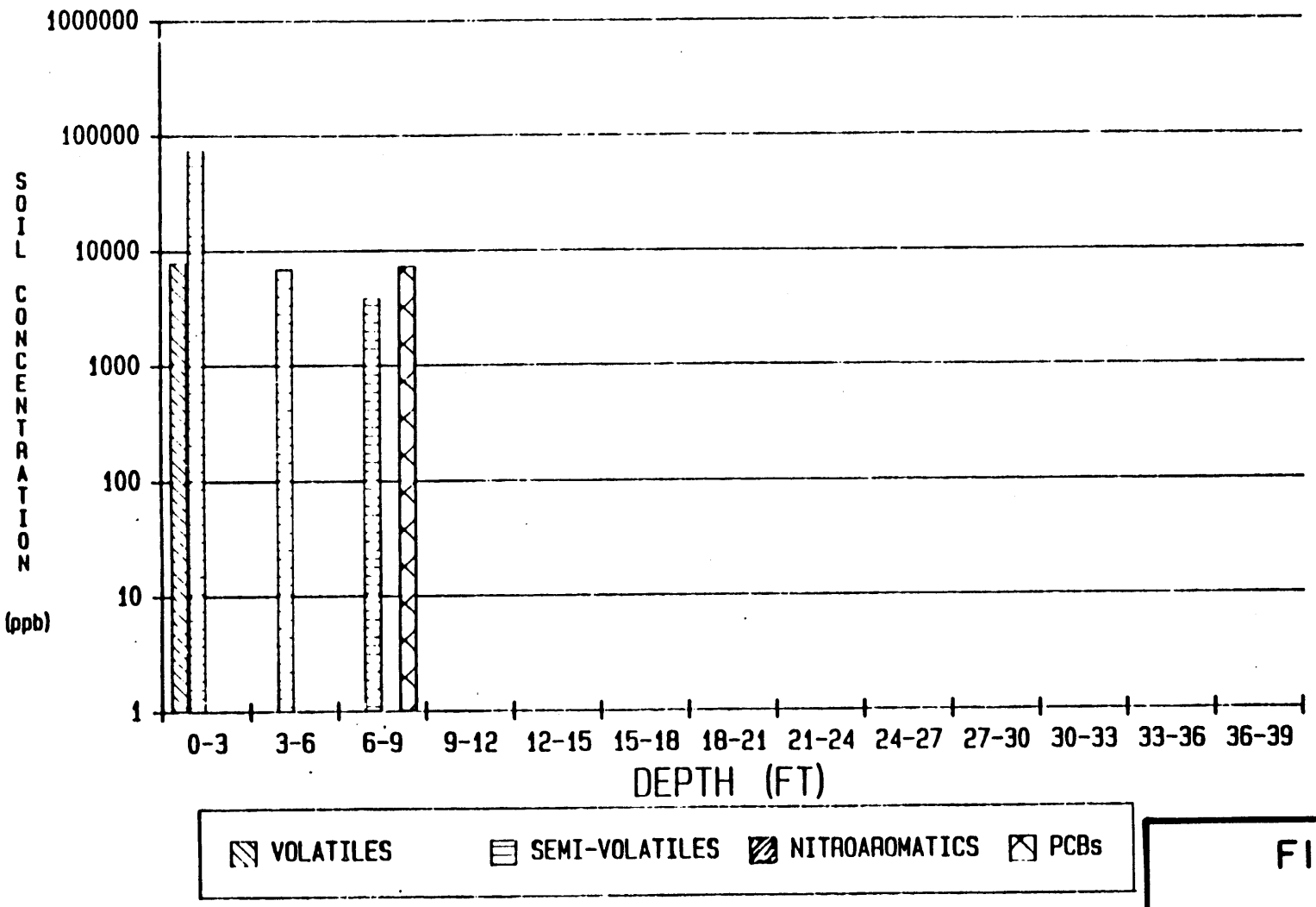


FIGURE A.6

CHEMICALS DETECTED AT LOCATION B-4

SOURCE: KAYE AND DAVIS, 1987

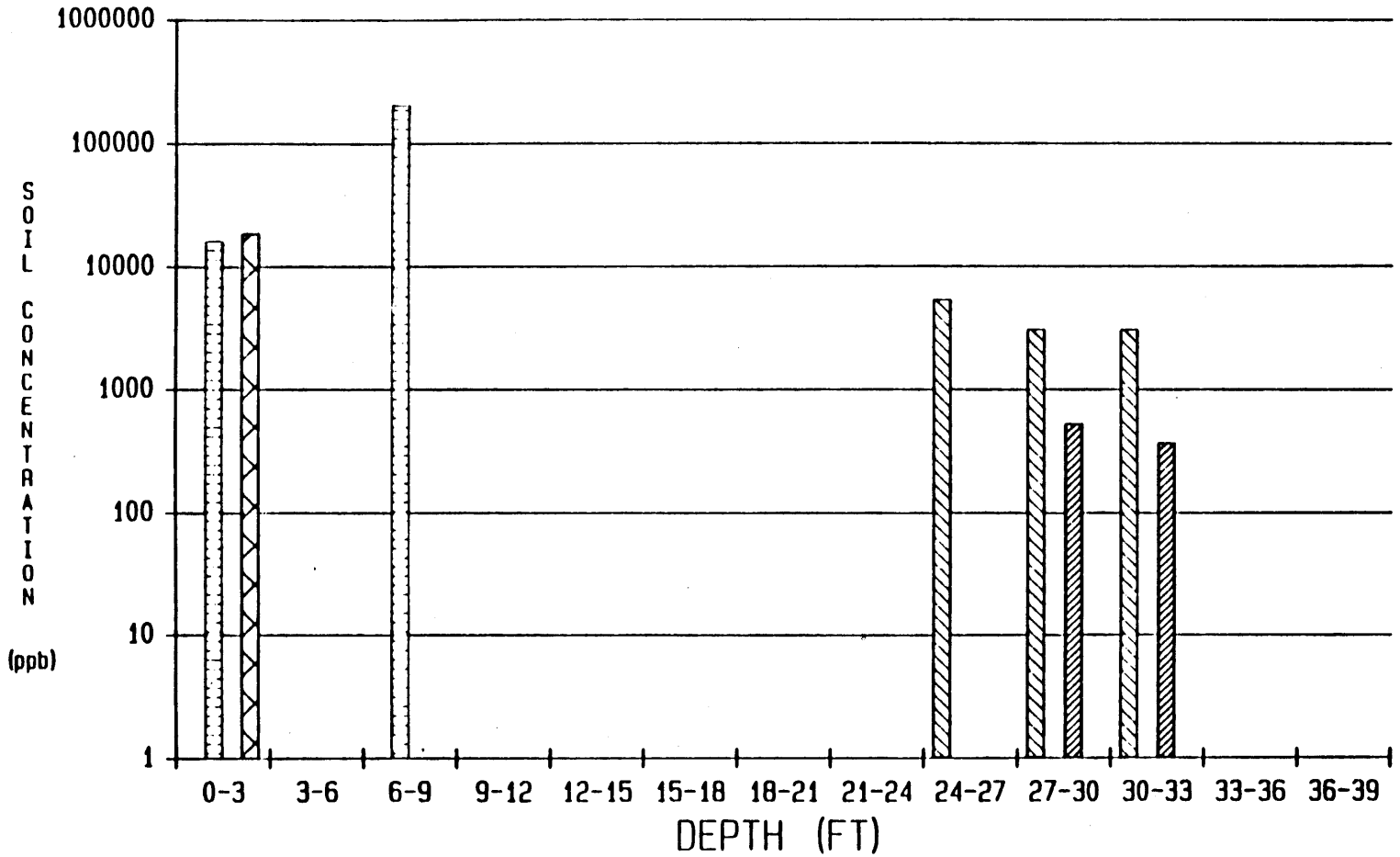


FIGURE A.7

CHEMICALS DETECTED AT LOCATION B-5

SOURCE: KAYE AND DAVIS, 1987

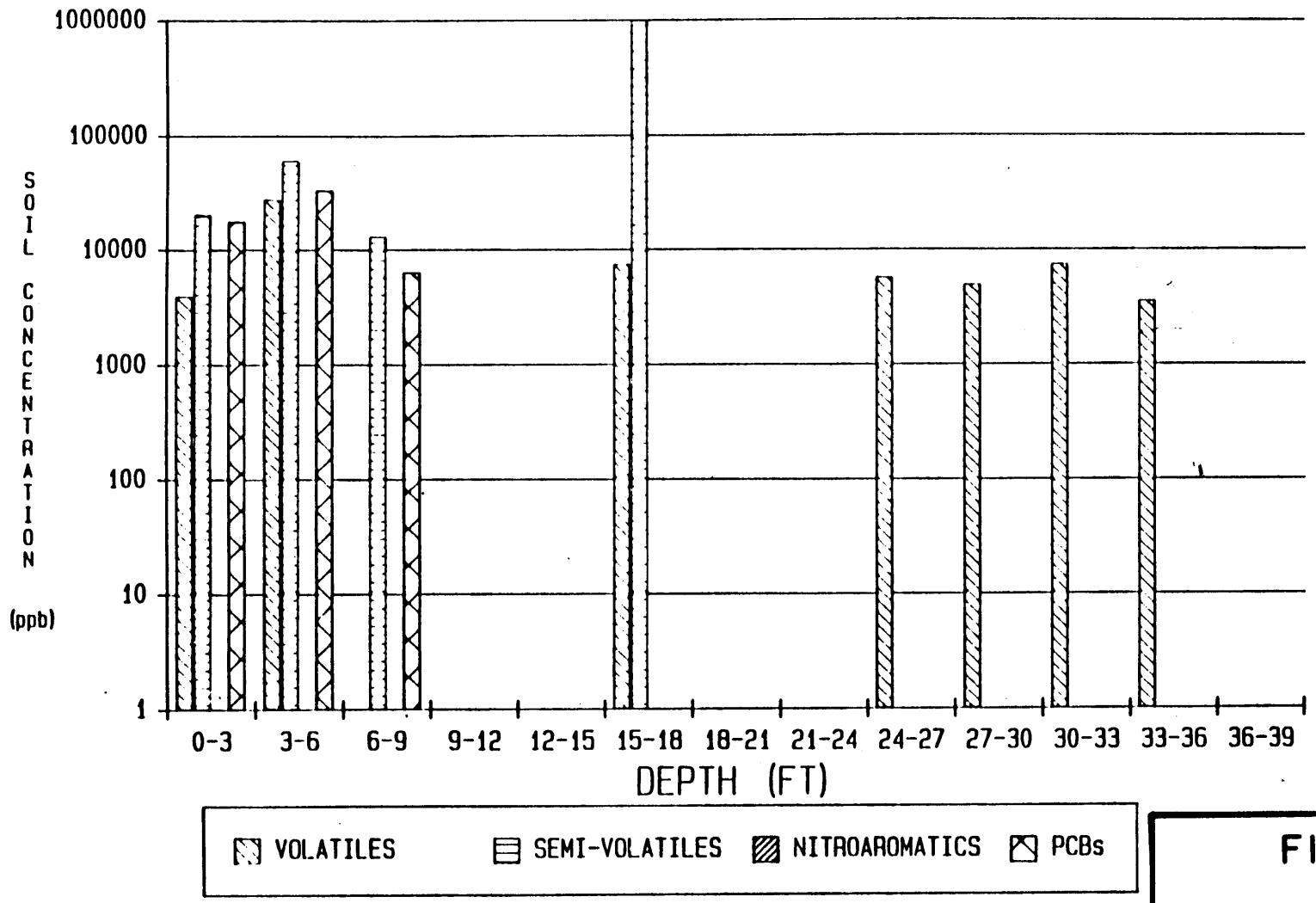


FIGURE A.8

CHEMICALS DETECTED AT LOCATION B-6

SOURCE: KAYE AND DAVIS, 1987

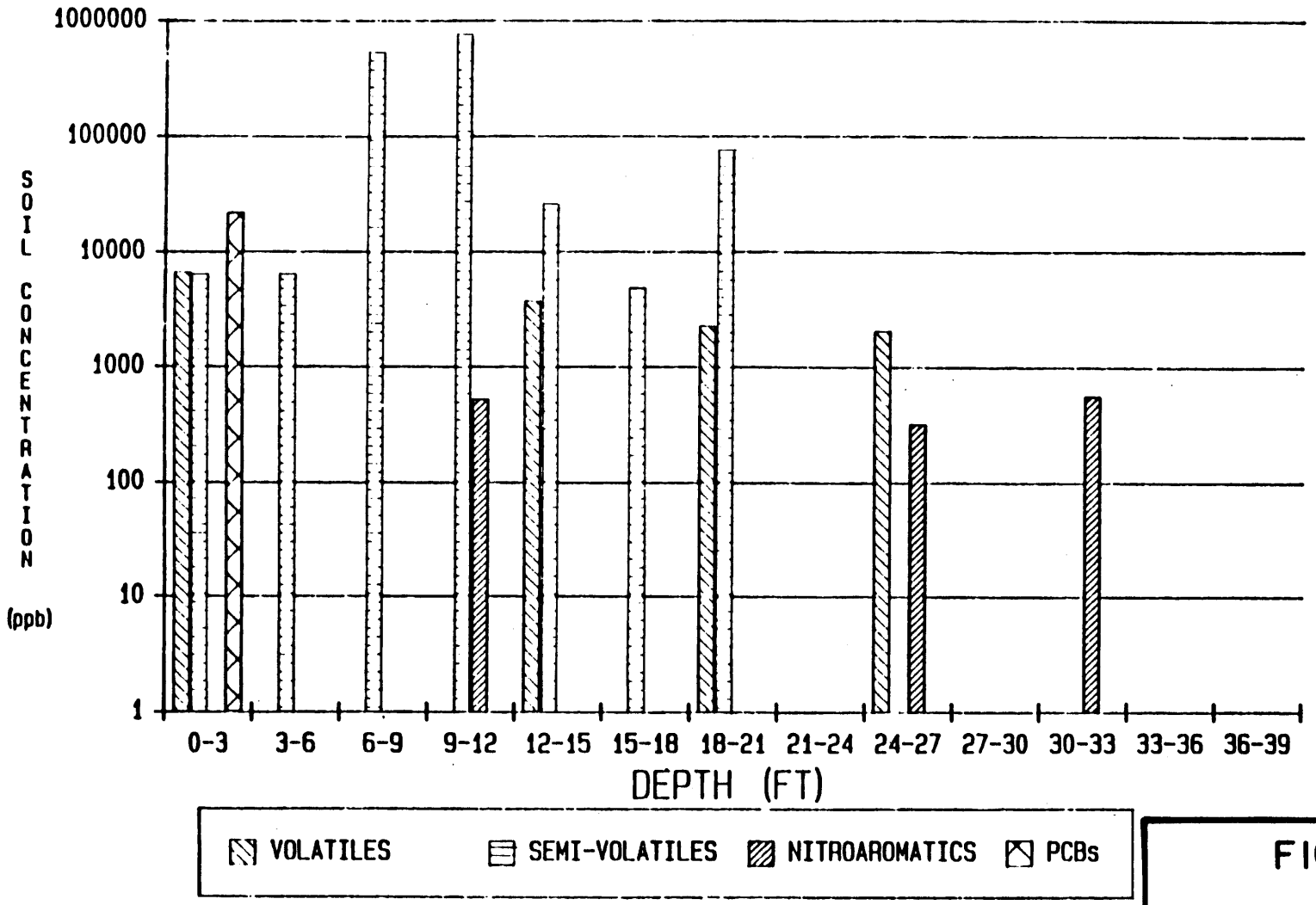


FIGURE A.9

CHEMICALS DETECTED AT LOCATION B-7

SOURCE: KAYE AND DAVIS, 1987

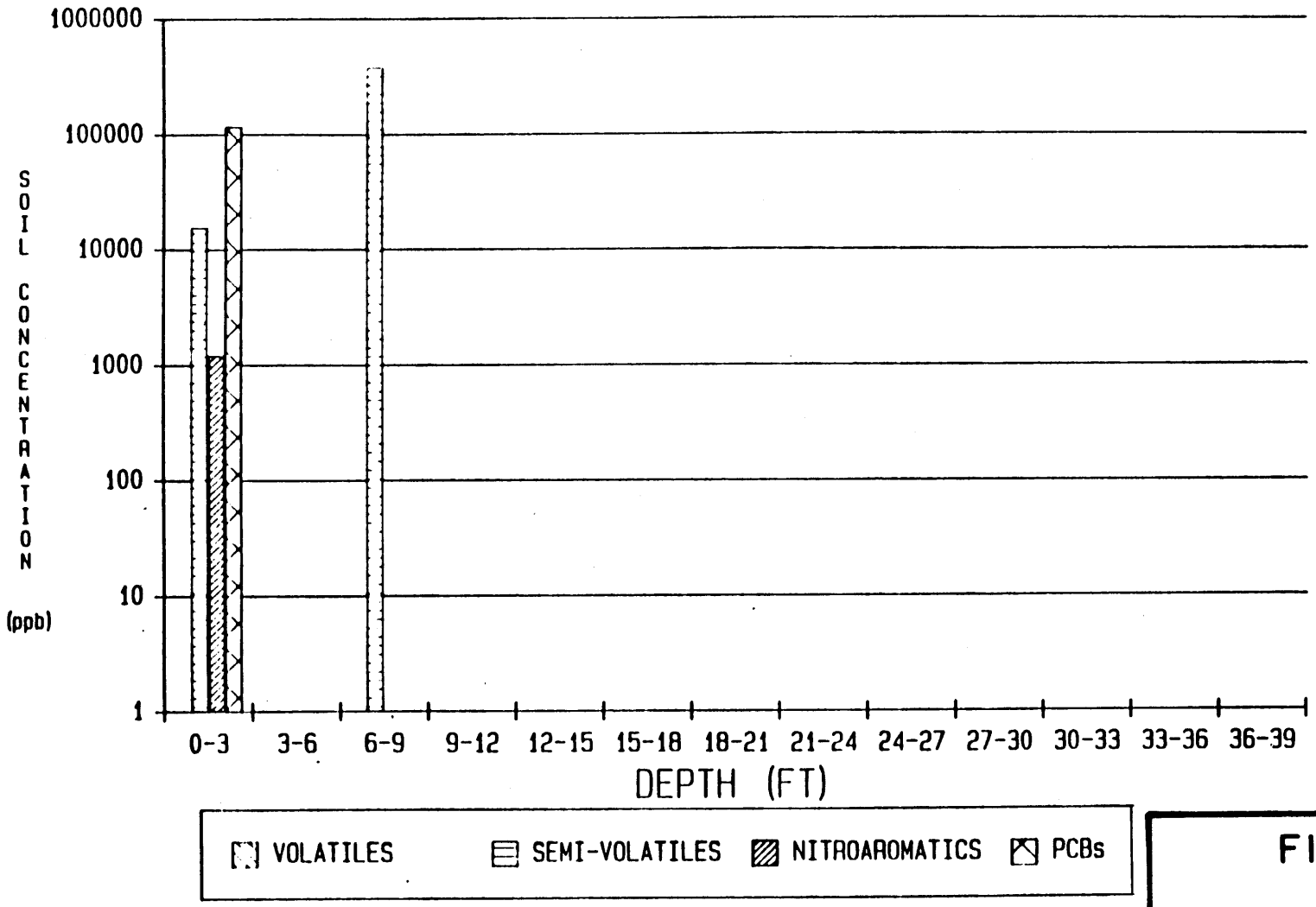


FIGURE A.10

CHEMICALS DETECTED AT LOCATION B-8

SOURCE: KAYE AND DAVIS, 1987

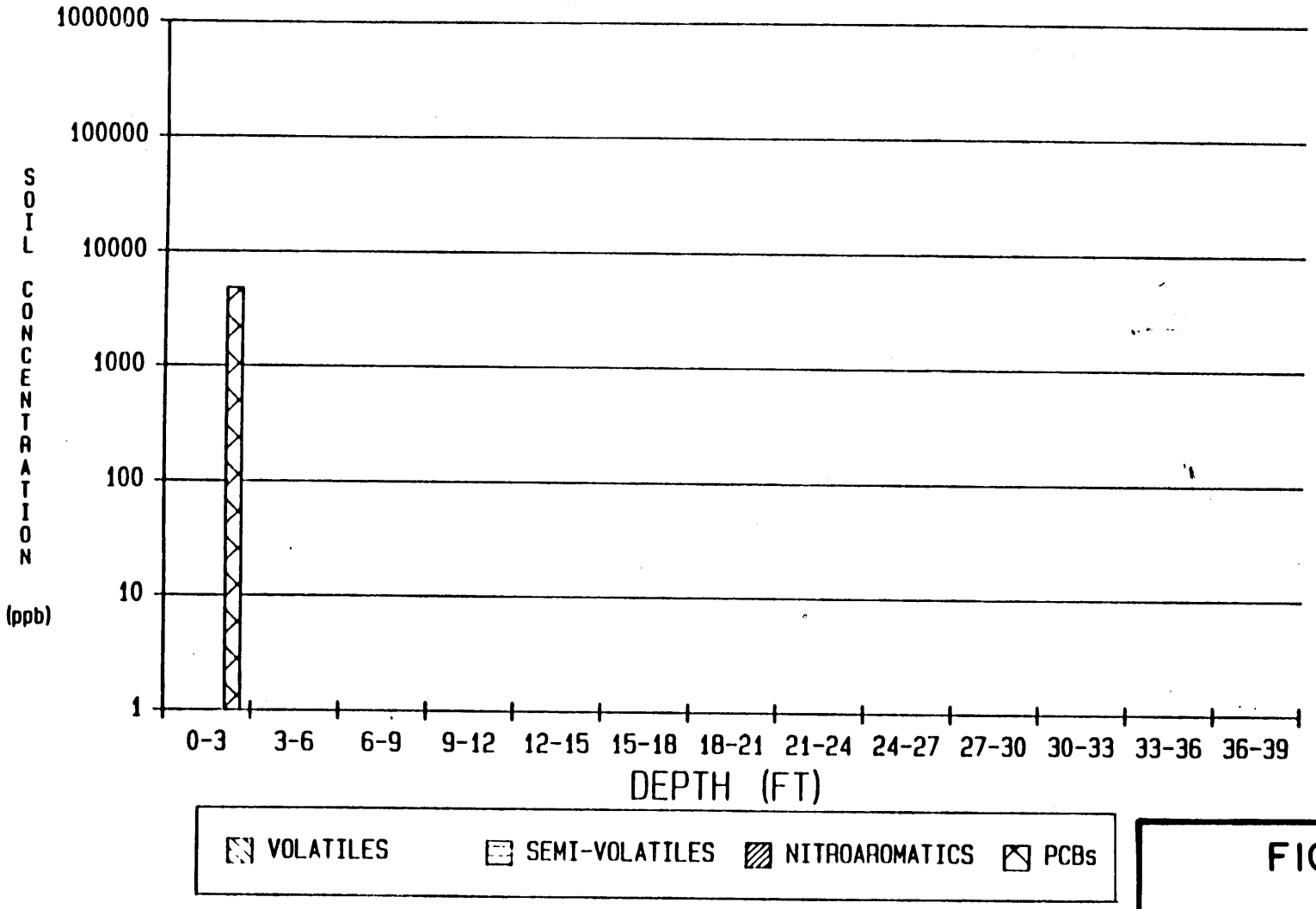


FIGURE A.11

CHEMICALS DETECTED AT LOCATION B-9

SOURCE: KAYE AND DAVIS, 1987

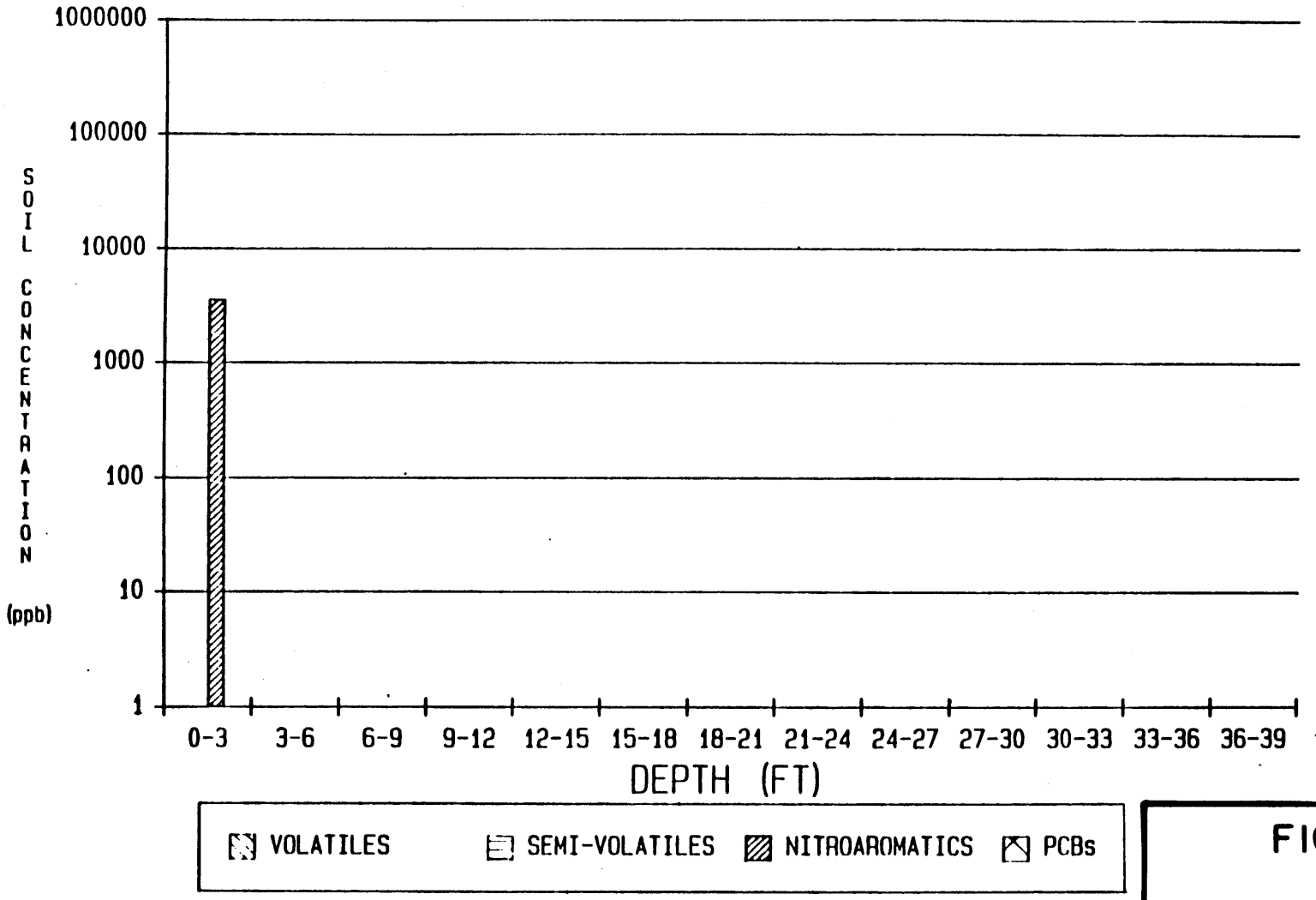


FIGURE A.12

CHEMICALS DETECTED AT LOCATION B-10

SOURCE: KAYE AND DAVIS, 1987

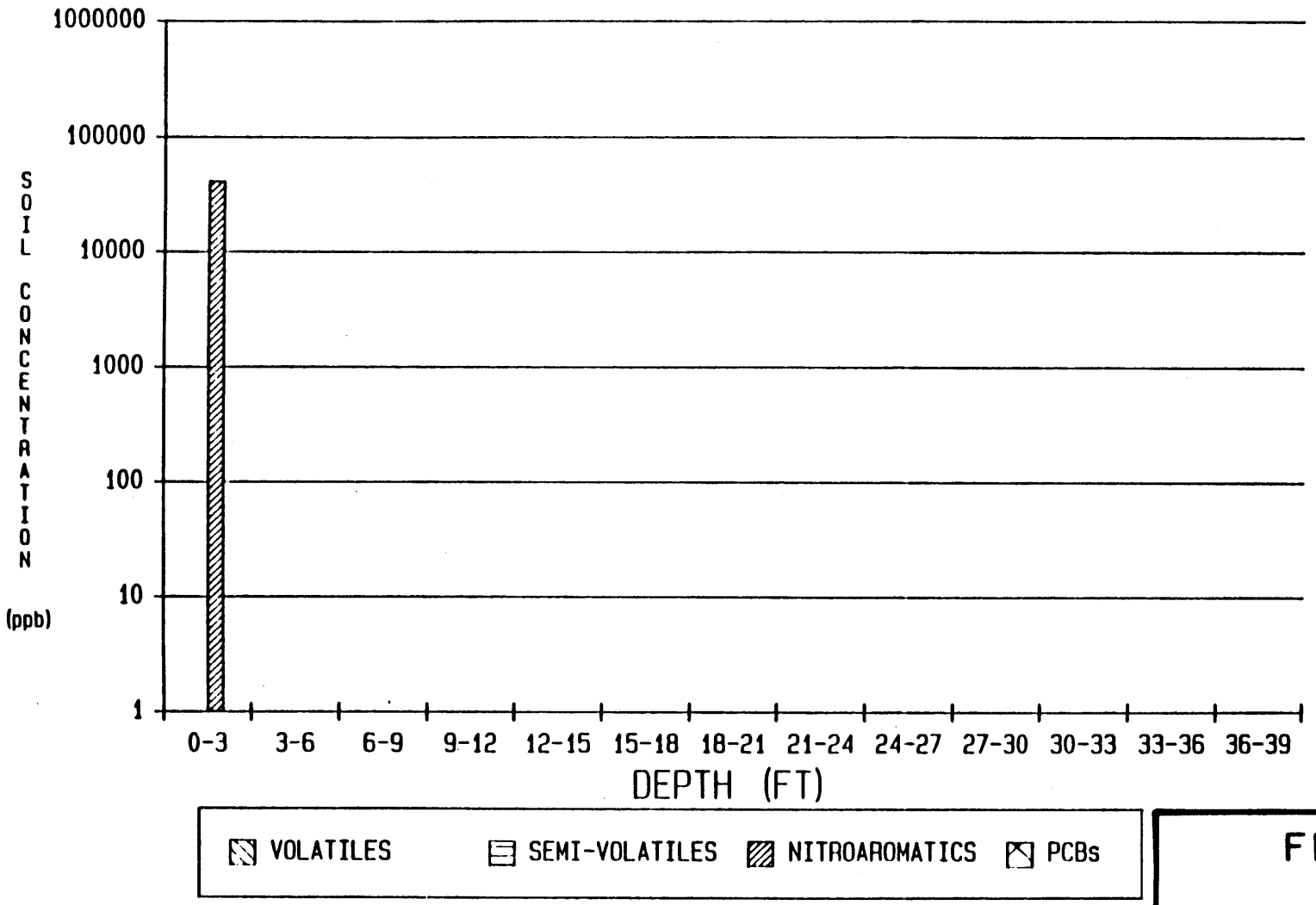


FIGURE A.13

CHEMICALS DETECTED AT LOCATION B-11

SOURCE: KAYE AND DAVIS, 1987

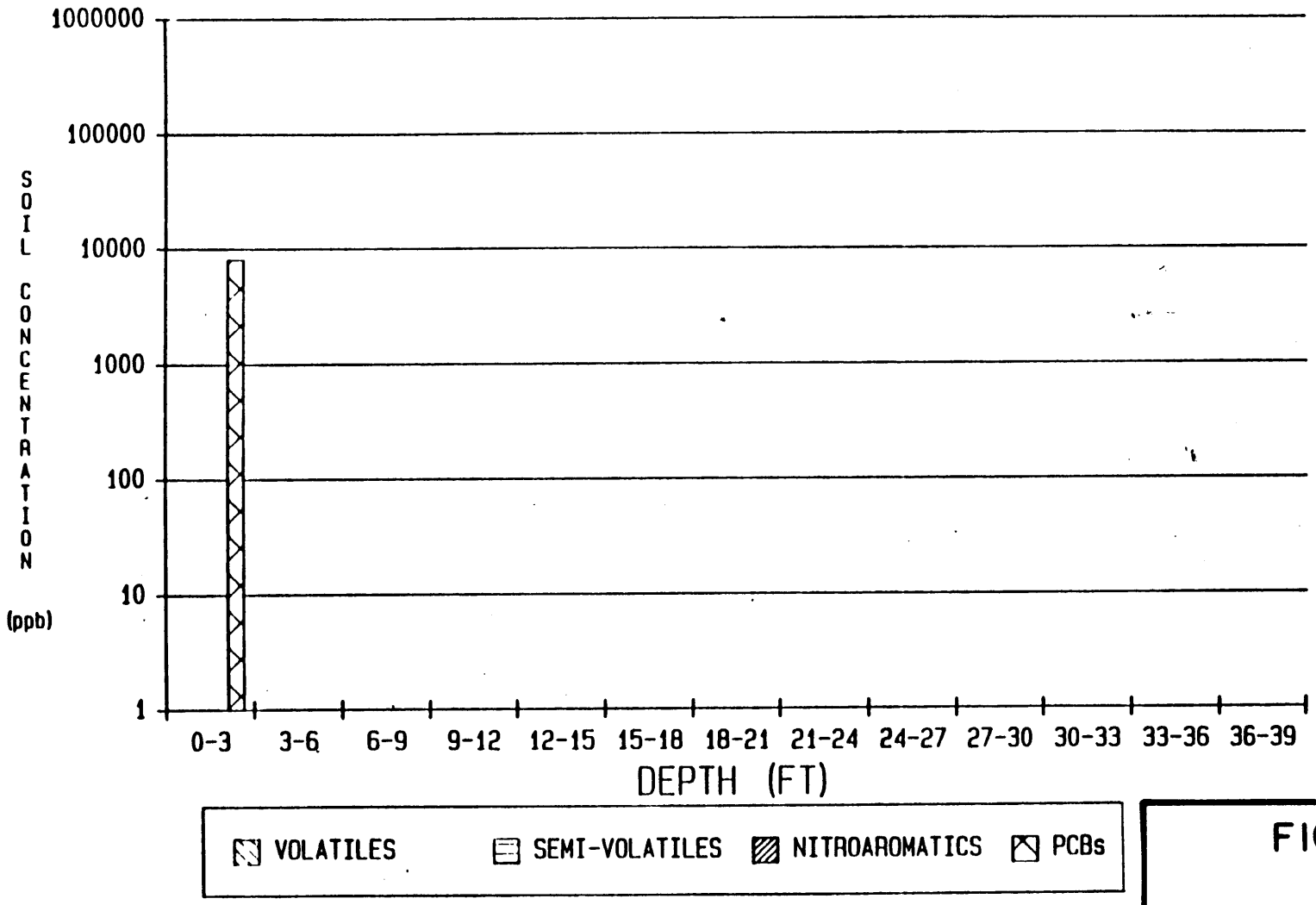


FIGURE A.14

CHEMICALS DETECTED AT LOCATION B-12

SOURCE: KAYE AND DAVIS, 1987

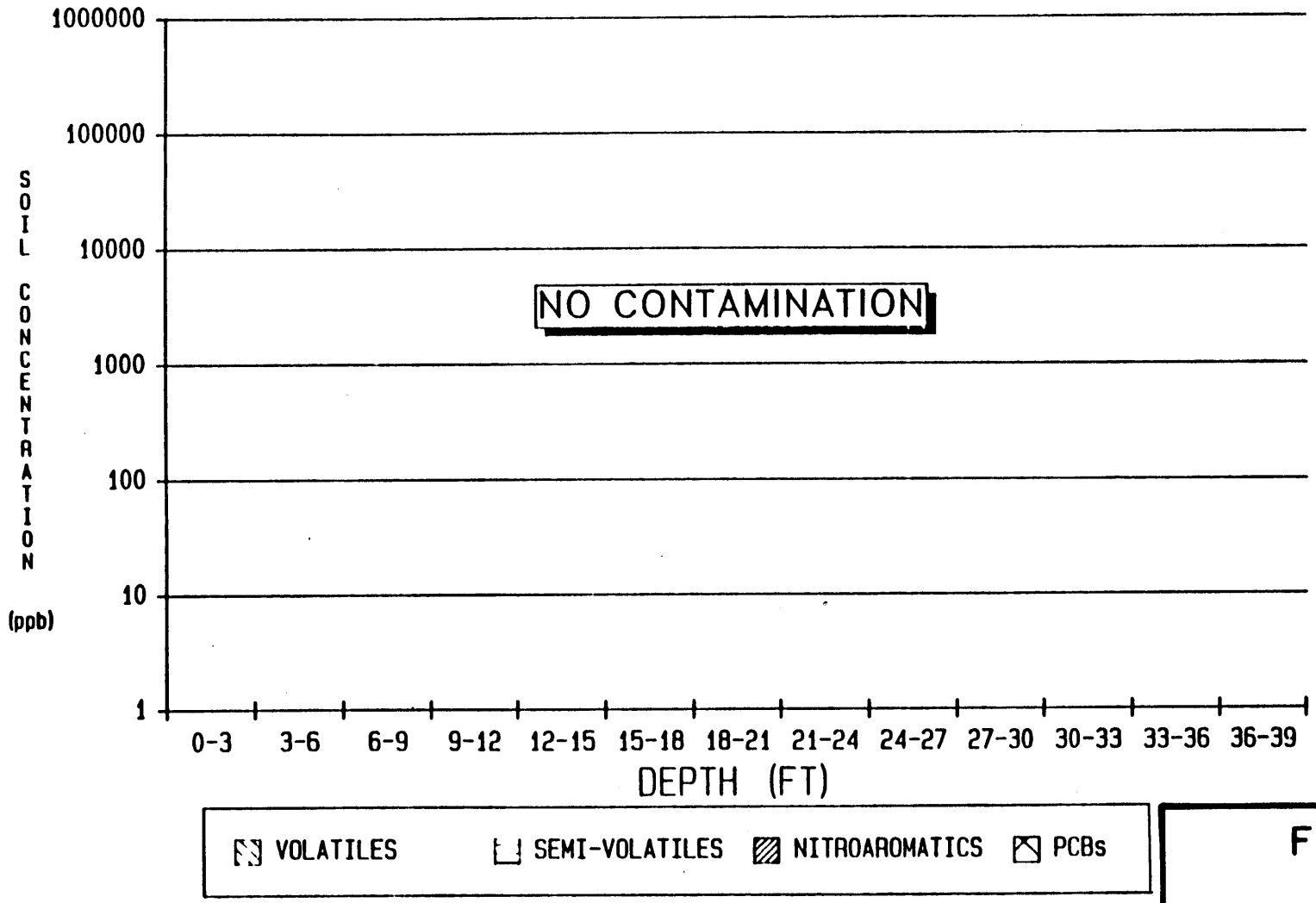


FIGURE A.15

CHEMICALS DETECTED AT LOCATION B-13

SOURCE: KAYE AND DAVIS, 1987

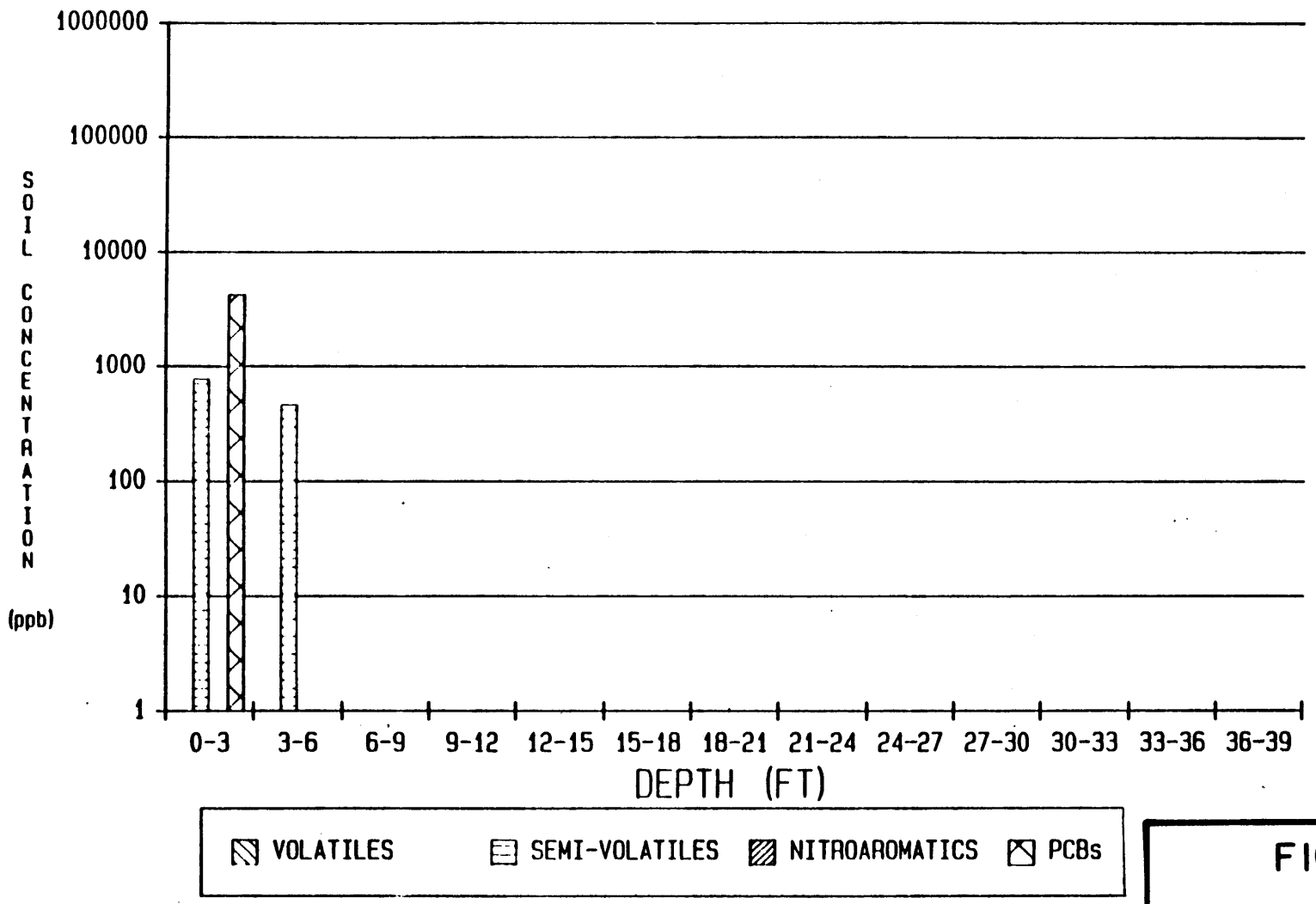


FIGURE A.16

CHEMICALS DETECTED AT LOCATION B-14

SOURCE: KAYE AND DAVIS, 1987

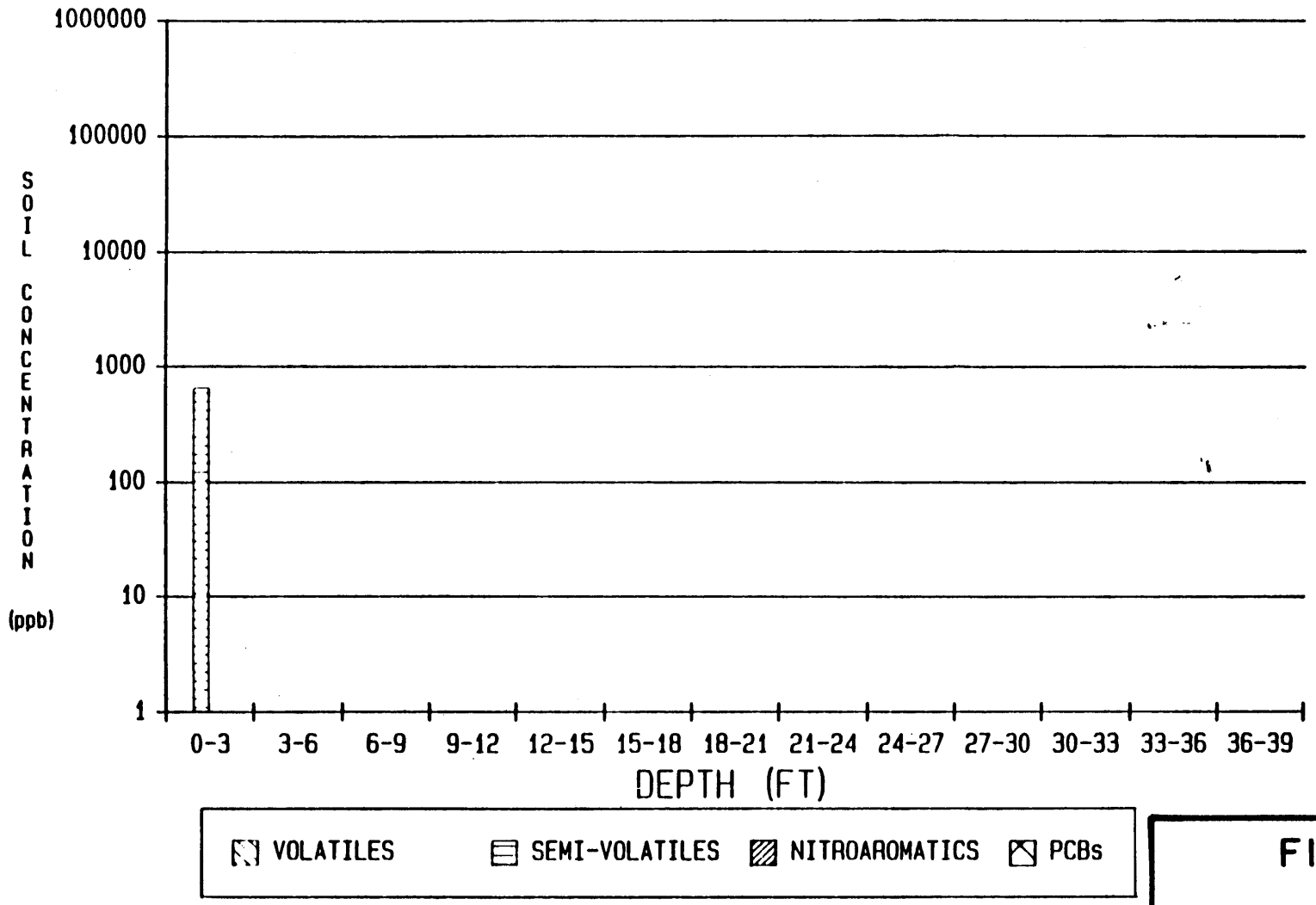


FIGURE A.17

CHEMICALS DETECTED AT LOCATION B-15

SOURCE: KAYE AND DAVIS, 1987

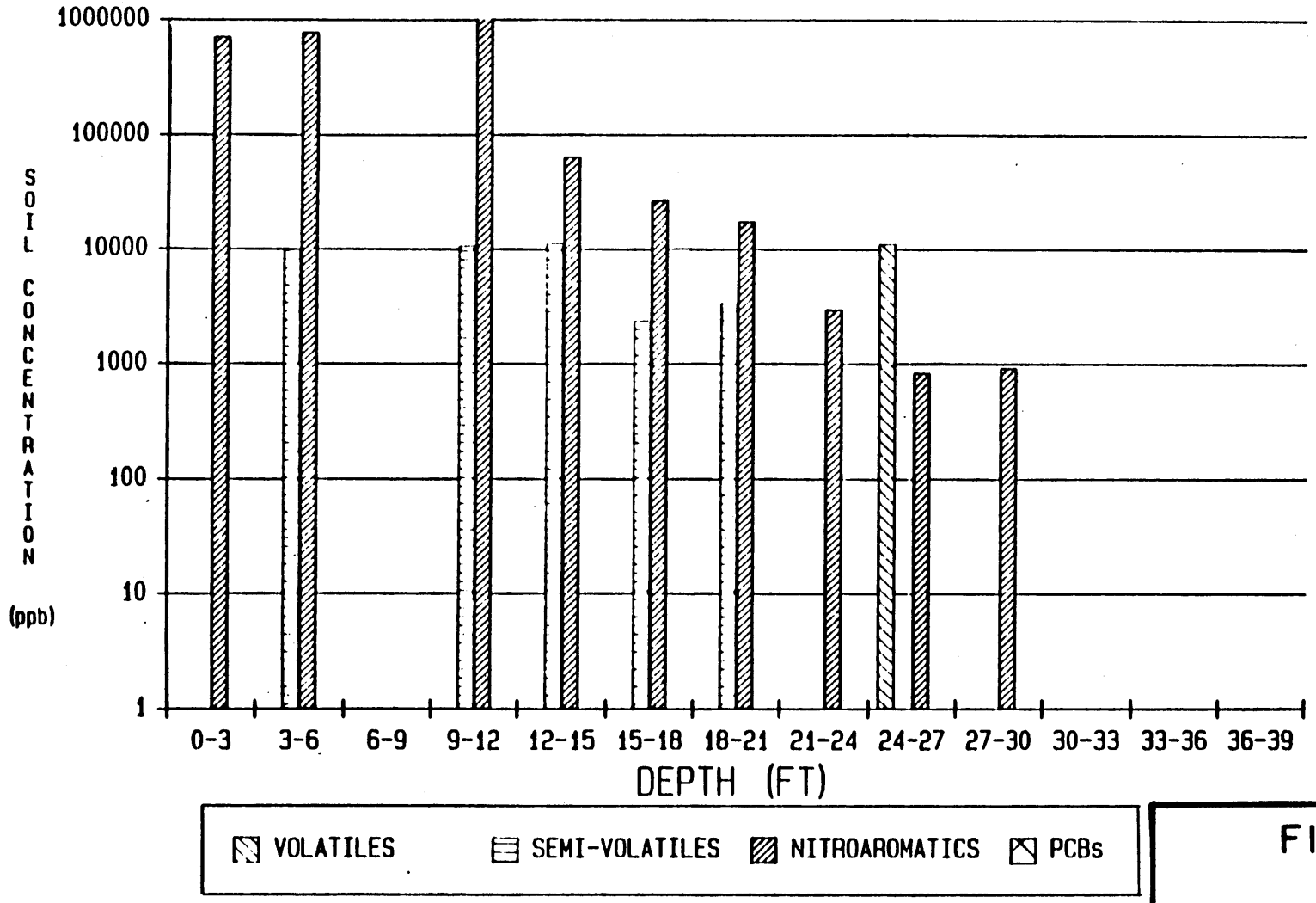


FIGURE A.18

CHEMICALS DETECTED AT LOCATION B-16

SOURCE: KAYE AND DAVIS, 1987

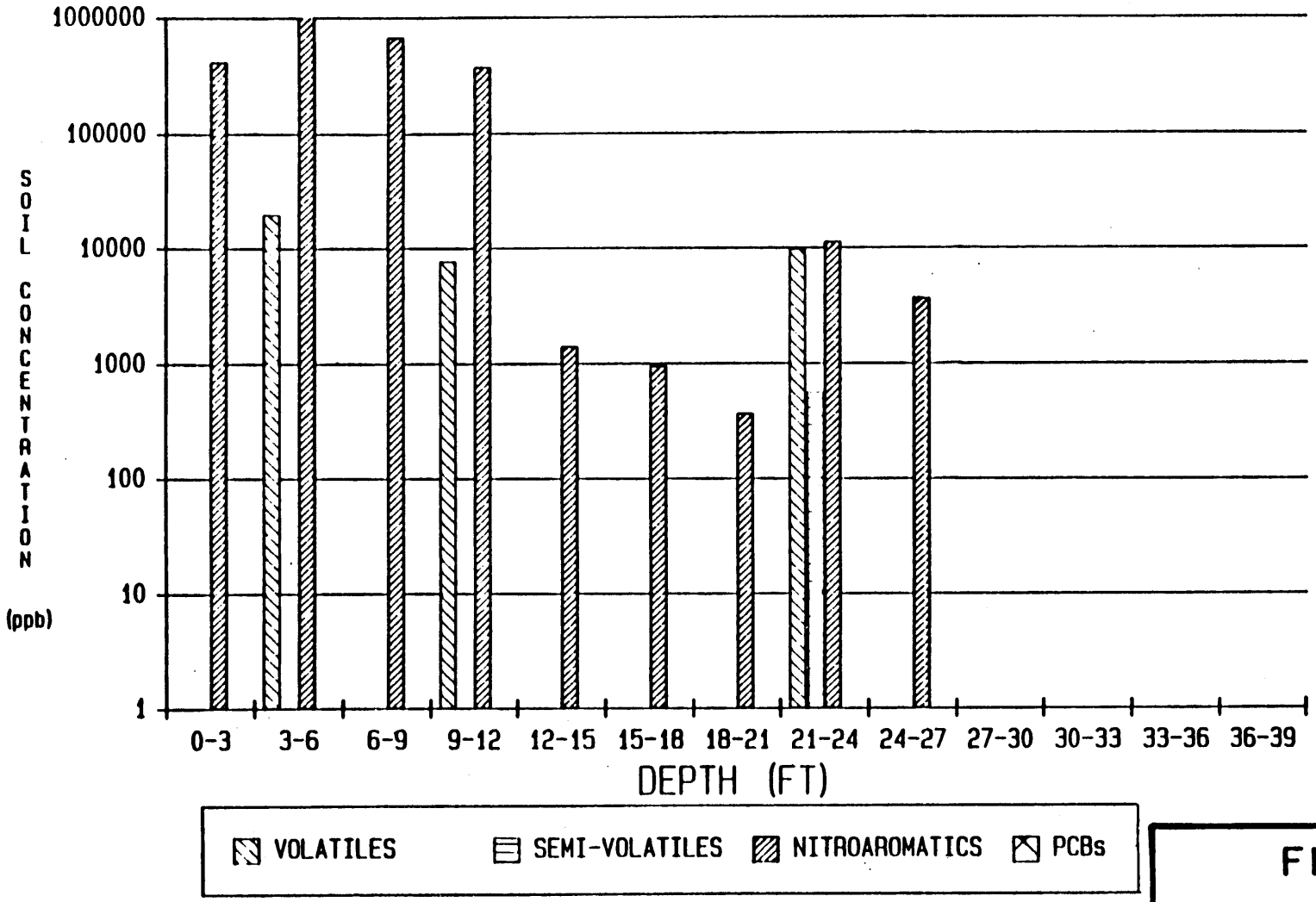
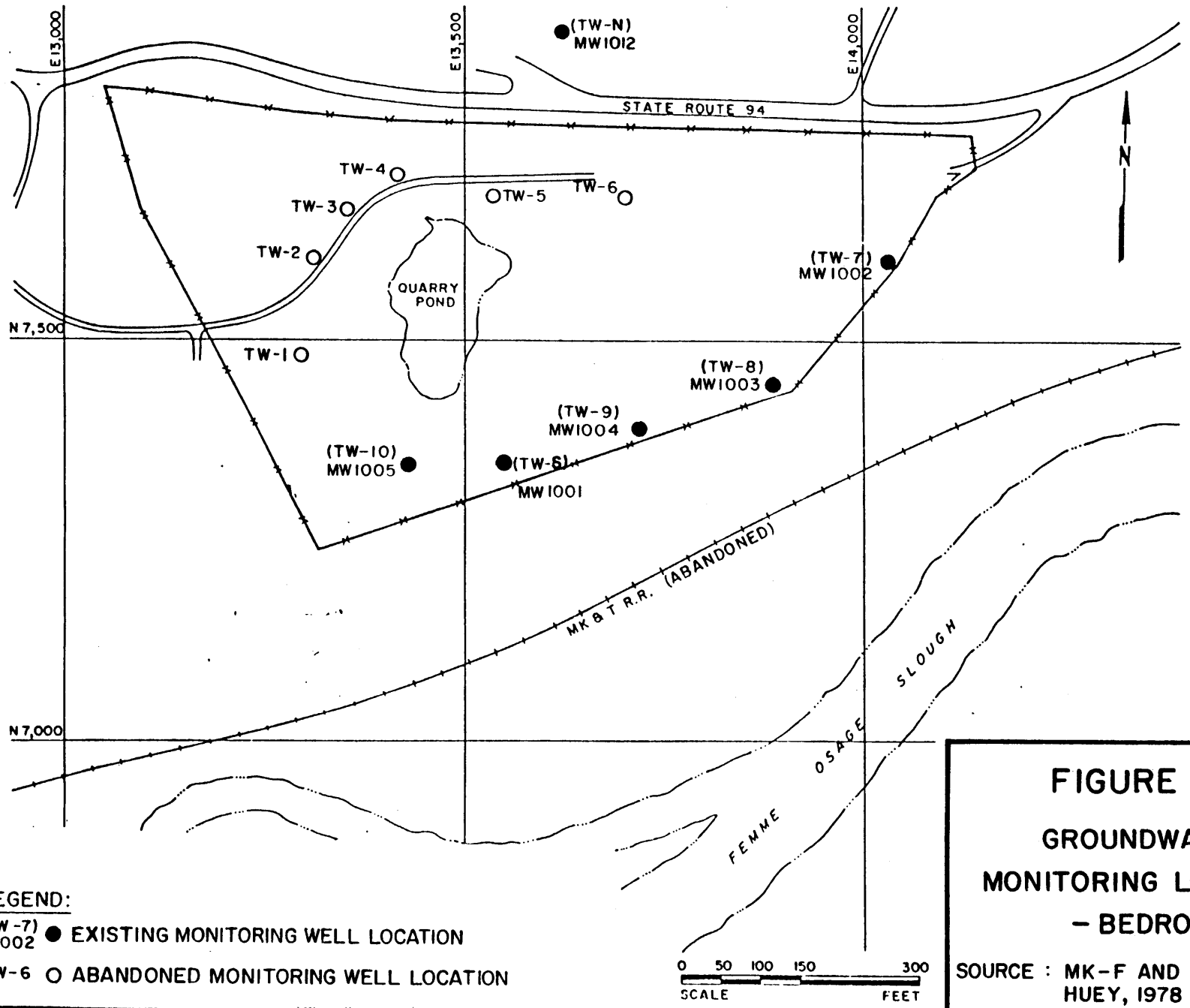


FIGURE A.19

CHEMICALS DETECTED AT LOCATION B-17

SOURCE: KAYE AND DAVIS, 1987



LEGEND:

(TW-7) MW1002 ● EXISTING MONITORING WELL LOCATION

TW-6 O ABANDONED MONITORING WELL LOCATION

FIGURE D.1

GROUNDWATER MONITORING LOCATIONS – BEDROCK

SOURCE : MK-F AND JEG, 1988 a; HUEY, 1978

DOE/OR/21548-066

Remedial Investigations for Quarry Bulk Wastes

December 1989

prepared by

MK-Ferguson Company and Jacobs Engineering Group

prepared for

U.S. Department Of Energy, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, under Contract DE-AC05-86OR21548

Comment 16

Pg. 4-44, Section 4.3.4 - How does the Environmental Monitoring Program Plan fit into the RI/FS-NEPA process? Will it be based on EPA guidance?

Response 16

The Environmental Monitoring Program Plan is mandated through and based on DOE Order 5400.1 which establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for assuring compliance with Federal, State and local environmental protection laws and regulations, Executive orders, and internal Department policies. The program collects routine environmental monitoring data and is not a part of the RI/FS process per se.

Comment 17

Page 4-51, First paragraph, last sentence - the DAC for Rn-220 for radiation exposures to general public and the environment is 3 pCi/l (DOE Order 5480.XX, 1988, which is 5400.3). DOE Order 5480.11 is for occupational exposures.

Response 17

The reference will be changed from DOE Order 5480.11 to DOE Order 5400.XX.

Comment 18

The data presented in the Draft RI concerning the level of volatile organics at the site are inconclusive. The draft RI suggests because volatiles were not detected in the first study of the site but were detected in the second, the compounds detected may be laboratory artifacts and not actually present at the site. QA/QC procedures described in the draft RI show that six of seven volatile organic compounds detected in samples of quarry wastes were also detected in method blanks at the same order of magnitude concentrations. These compounds include methylene chloride, ethylbenzene, toluene, styrene, and mixed xylenes. The same compounds were also detected in similar concentration in the field blanks. Further, maximum holding times were exceeded for 83 percent of the quarry waste samples analyzed for volatiles, indicating that volatiles may have been lost from the samples.

Response 18

Concur. The data concerning the level of volatile organics at the site are inconclusive.

Comment 19

Additional characterization of quarry wastes is required to demonstrate the existence of volatile organic compounds at the site, as the existing data are not adequate. The draft RI considers the existing data adequate for initiating removal of the bulk waste, however, further characterization of wastes may be required to develop an adequate health and safety plan for the waste removal effort and to conduct the FS.

Response 19

The depositional history of volatile organics provide adequate information. No further characterization is needed in order to conduct the FS.

Comment 20

The determination of the levels of PCBs an pesticides in quarry wastes is also inconclusive. The recovery of PCBs from waste samples, as determined by matrix spike results, was between zero and three percent. Although this low recovery is attributed to matrix interference rather than sampling and analytical techniques, the low recovery determined through the matrix spike procedure renders the PCB data inconclusive. Maximum holding times were exceeded for 100 percent of the quarry waste samples analyzed for PCBs and 93 percent of the samples analyzed for semi-volatiles. Further, it was reported that the presence of PCBs at the site interfered with the detection of certain pesticides during the 1984-1985 sampling program, however, waste samples were not analyzed for pesticides during the 1986 sampling program.

Response 20

The comment is noted.

Section 5

Comment 1

Pg. 5-1, First paragraph of Section 5.2 - Need to clearly state that contaminant persistence at the site is currently unknown. Will it be characterized in the future, and if so, under which WSSRAP phase?

Response 1

The section has been modified to clearly state that chemical contaminant persistence is currently unknown. The residual characterization studies (i.e., contaminant persistence) will be discussed on the fact sheet as described previously.

RESPONSIVENESS SUMMARY FOR THE REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES

December 1989

RESPONSES TO THE COMMENTS MADE BY MDNR ON THE
REMEDIAL INVESTIGATION FOR QUARRY BULK WASTE
Dated February 1989

Comment 1

Pg. 1-1 to 1-3, Section 1.1, I presume that the references to "contaminated vicinity properties" includes the Femme Osage Slough and the contaminated soil between the slough and the bluff. I suggest clarifying these references by explicitly mentioning these areas.

Response 1

The "contaminated vicinity properties" referred to on pg. 1-1 to 1-3 includes the slough and the radiologically contaminated soil between the quarry and the slough (see the WSSRAP RI/FS Work Plan - DOE/OR.21548-033). The focus of this Remedial Investigation is to compile the existing data pertinent to the removal of the quarry bulk waste. The "vicinity properties" will be explicitly addressed in the follow-on Remedial Investigation for the entire quarry area.

Comment 2

Pg. 3-14, Table 3.8, In this table alluvium and residual soils are combined as one unit and described as "predominantly silty Clay." You may not want to mention the residual soils as they are not of concern in the contaminant migration at the site. The Missouri River alluvium at a depth south of the slough is predominantly sand and gravel. Of course, this is all explained in the text, but the table is misleading.

Response 2

The description of the "Alluvium and Residual Soils" will be modified to read "Predominantly silty clay grading to sands and gravels toward the Missouri River."

Comment 3

Pg. 3-26, Section 3.6.3, MDNR strongly agrees with the statements in this section. Removal of water and bulk wastes in the quarry should proceed as quickly as practical in order to remove a major source of contaminants that could potentially affect the St. Charles County well field. Additional hydrologic work will be necessary later, but the water and bulk wastes in the quarry must be removed first.

2. The scenarios and parameters selected to derive the dose equivalent limit are conservative and are aimed at a single hypothetical maximally exposed individual not a representative subset of the population.

The DOE is committed to ALARA policy. This means that a cost-benefit analysis must be completed to balance costs of remediation with dose reduction. Costs of remediation include construction related accidents as well as monetary costs. We feel that a priority setting a dose equivalent limit as low as 4 or 25 mrem/yr may circumvent ALARA because costs associated with remediation to these levels may not always be reasonably achievable.

A second important point to consider when evaluating a does equivalent limit for remedial action is the manner in which the limit is derived. First of all the limit is derived for a hypothetical individual who receives the highest possible dose equivalent. Since it is hard to predict future exposure scenarios, a highly unlikely set of circumstances is usually proposed as an exposure scenario. In addition, uncertainties in physical parameters chosen to model future exposure many times lead to selection of conservative or worst case parameters. This tends to exaggerate the modeled does equivalent. For these reasons, modeled doses can be expected to be higher than actual does received by a representative fraction of the general population.

The 100 mrem/yr dose equivalent limit is within the recommendations of both the International Commission on Radiation Protection and the National Council on Radiation Protection. Both of these groups are made up of some of the foremost experts on health risks associated with ionizing radiation. We feel that the WSSRAP can protect the health of the public and the environment in the most cost effective manner by use of a basic dose equivalent limit 100 mrem/yr.

Comment 3

The Derived Concentration Guides (DCGs) for drinking water established by the DOE should be considered in light of the above comment, and are not the appropriate bases for comparison where EPA drinking water standards are available.

Response 3

See "Response to Comment 2" above.

RESPONSES TO THE COMMENTS MADE BY U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION VII ON THE REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES
Dated February 1989

Comment 1

The appearance of enriched uranium in the quarry is disturbing, and the explanation provided does not seem to adequately account for the amount of enrichment found. This information could be considered supportive of historical contentions that some spent nuclear fuel reprocessing occurred at Weldon Spring. If not otherwise explained, the DOE should indicate if the radiological analyses performed would have detected fission products. If not, future characterization work will need to consider that objective.

Response 1

The existence of a relatively small amount of enriched uranium in the quarry bulk wastes is consistent with historical records as described in Section 4.1.2.2 of the RI. The Weldon Spring Chemical Plant was never used for nuclear fuel reprocessing and does not contain the necessary facilities for doing so (e.g., shielded hot cells, master-slave manipulators). The existence of significant quantities of fission products in the quarry bulk wastes resulting from fuel reprocessing at the chemical plant would have resulted in much higher exposure rates than have been measured in the quarry. The exposure rates are consistent with the measured concentrations of radium-226 in the bulk wastes.

Comment 2

We note, again, that we are not in agreement with the DOE's use of the annual radiation protection standard of 100 mrem/yr. We believe that this value is too high for unrestricted access by the general public, and that a more appropriate value is between 4 and 25 mrem/yr above natural background. This is based on several EPA rules and proposed rules: 40 CFR 61, 40 CFR 290, and 191 (25 mrem/yr), 40 CFR 141 (4 mrem/yr), and proposed 40 CFR 61 (10 mrem/yr). Each of these rules may be applicable to various aspects of the Weldon Spring cleanup.

Response 2

Two important points must be evaluated when considering a dose equivalent standard for use during remedial action. These are:

1. Any dose equivalent limit will be tempered by ALARA; and

Response 3

The DOE concurs with MDNR.

Comment 4

Pg. 4-50, Section 4.4.5, MDNR also agrees with the statement that there may be a " . . . need for the installation and monitoring of one or two bedrock wells west of the quarry and one southeast of the quarry and south of the slough (between MW-1020 and MW-1023) to detect potential excursions of contaminants in bedrock during the bulk waste removal".

Response 4

This comment has been duly noted. Prior to bulk waste excavation the inplace monitoring system will be evaluated for adequacy to detect excursions during bulk waste removal. It is currently planned to add several additional monitoring wells to supplement the existing monitoring wells. Detailed plans and locations will be developed in the coming months.

Comment 5

Pg. 6-4, Section 6.2.2, This section states that " . . . contamination is apparently limited to the area north of the slough . . . " should be modified to include a discussion of the apparent detection of nitroaromatics in wells south of the slough.

Response 5

Characterization of off-site groundwater is not within the scope of this report. However, the statement that " . . . contamination is apparently limited to the area north of the slough . . ." will be modified to read " . . . contamination is apparently limited to the vicinity of the slough . . ."

RESPONSES TO THE COMMENTS MADE BY DOE HEADQUARTERS
ON THE REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES
Dated February 1989

COVER MEMO COMMENTS

Comment 1

With regard to the Remedial Investigation (RI), there is limited data analysis in the document so that our complete review of the RI must wait until the Feasibility Study is available: The RI repeatedly states that the "available data are adequate with respect to the proposed action" and that "no further investigations are necessary prior to the proposed action." Until a satisfactory assessment of environmental impacts has been completed, there does not seem to be any basis for these conclusions about the adequacy of the data.

Response 1

The statements regarding the adequacy of the data reflect only the requirements to complete the RI/FS process. Based on the assessment of environmental impacts in the Feasibility Study, additional information would be added, as needed, to meet the procedural and documentational requirements of NEPA.

Comment 2

The RI refers to a study of the proposed temporary storage area and states that study results will be presented in a separate report (page 1-1). Temporary storage of the quarry wastes is an integral part of the proposed action to remove the wastes from the quarry and the study results referred to should be in the RI/FS-EA for the bulk waste removal.

Response 2

The temporary storage area study results are presented in a separate report, "Temporary Storage Area Characterization Report" which was developed to support the Quarry Bulk Wastes RI/FS.

RESPONSES TO THE COMMENTS MADE BY DOE HEADQUARTERS
ON THE REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES
Dated February 1989

GENERAL COMMENTS

Comment 1

The Remedial Investigation (RI) report appears to provide sufficient information and data on the Weldon Spring Quarry (WSQ) and the bulk wastes to proceed with the RI/FS - NEPA process for the removal of bulk wastes (i.e., a feasibility study for waste removal). The document, however, does not provide sufficient information and data of any residual materials, groundwater restoration, and/or cleanup of contaminated vicinity properties). In some places in the text, it is confusing as to what the scope and limits of the proposed action actually are. In places, the scope appears to include actions for which not enough information and data are provided. A more concise and comprehensive overview of the WSSRAP is needed (i.e., one that discusses more clearly how other studies and documents fit together).

Response 1

Concur. A more concise and comprehensive overview of the interaction of other studies and documents will be presented to the public in a "fact sheet" format along with the RI,FS, and BRE. This fact sheet will include such items as definitions pertinent to the RI/FS process; explanation of the NEPA/CERCLA process; and scope of the studies and relationship to overall WSSRAP remediation.

Comment 2

An overview should be provided that explains the CERCLA/NEPA interface and where it is (or will be) presented (e.g., in an overall WSSRAP document). If no other document addresses the NEPA interface and presents NEPA elements (e.g. scoping). This RI document is incomplete.

Response 2

The WSSRAP RI/FS-EIS Work Plan presents an overview of the NEPA/CERCLA process and interaction. The FS summarizes specific applications to the quarry.

Comment 3

The overview should also discuss EPA's and/or the State's role(s) in establishing the WSSRAP phases and identifying

operable units. References should be provided that document agency approvals, concurrences, etc.

Response 3

EPAs and the State of Missouri role(s) in establishing the WSSRAP phases and identifying operable units is established through the review process for the Work Plan for the Remedial Investigation/Feasibility Study - Environmental Impact Statement and will also be discussed on the fact sheet. No formal references are available to document agency approvals.

Comment 4

A preliminary identification of ARARs (chemical- and location-specific) an To-Be-Considered Requirements (TBCs) for the subject operable unit would be helpful. Sections 4.2.2, 4.3.2, and 4.5.2 indirectly address ARARs, but the sections do not represent a concise and comprehensive discussion (e.g., Sections 4.2.2, and 4.5.2 only deal with radionuclides). Knowledge of ARARs also helps in the presentation of analytical data i.e.,) so that only pertinent data are included). ARARs are usually used in the selection of RI analytical parameters and detection limits.

Response 4

A discussion of ARARs and "To-Be-Considered" (TBCs) requirements is presented in the Feasibility Study. The use of ARARs in scoping data collection activities is not appropriate for this action since the RI relies on historical data.

Comment 5

In several places in the text, the choice of words makes the proposed action appear to be a "removal action." The language needs to be changed to avoid any possible confusion. A related question why is this action a remedial action and the removal of quarry water a removal action? Can this be accomplished as an interim response action? Is it because removal of wastes will exceed a certain dollar ceiling? An explanation would be appropriate.

Response 5

The text will be modified to delete any references to a "removal action." An explanation of why removing bulk wastes from the quarry is a remedial action and the removal of quarry water is a removal action is provided in the WSSRAP RI/FS-EIS Work Plan.

Comment 6

Section 4.5 of the remedial investigation report for the Weldon Spring Site discusses only radioactive air contaminants. Although radioactive emissions are the major concern at Weldon Spring, the waste characterization data and sampling and analysis results included in the RI report indicate the presence of both radioactive and non-radioactive constituents in the waste disposed at the site. Therefore, it is expected that non-radioactive air contaminants may be emitted to the atmosphere, particularly if the site is disturbed. Non-radioactive constituents identified include metals, organic priority pollutants (e.g. Lindane, PCBs), nitroaromatics and other semi-volatile organics, polynuclear aromatic hydrocarbons (PAHs), and possibly volatile organics. The existence of and potential for off-site transport of these non-radioactive air contaminants should be discussed in the RI report in the same manner as are radioactive contaminants, and the necessity for monitoring of these constituents should be evaluated.

Response 6

Air monitoring is currently being conducted by the PMC on a quarterly basis. Results are provided in the Annual Environmental Monitoring Reports for the Weldon Spring Site. The existence of non-radioactive constituents and potential for off-site transport were not discussed in the same capacity as the radioactive contaminants due to the lack of historical data concerning these particular constituents. During bulk waste removal air monitoring will be performed at site perimeter locations. The text will not be modified since the report utilizes available data.

Comment 7

The data base for the radiological characterization is sparse but the assumptions that contamination extends to bedrock and should be removed to bedrock is both conservative and prudent based on the history of disposal in the quarry. The actual volumes of contaminated material may vary from the estimates based on variations in depth to the bedrock not delineated in the data base. It is commendable that the authors did not include data whose collection techniques can not be validated and/or assumptions are not valid.

Response 7

No response necessary.

Comment 8

Sections need an introductory paragraph to let readers know what the sections are about, where they are going, what the context is, etc.

Response 8

An introductory paragraph is not necessary since an overview is provided in Section 1 and most chapters are self explanatory.

Comment 9

Well borings/logs should be added in an Appendix to the report.

Response 9

Well boring/logs will be available as a stand-alone support document. Due to the volume of this information it will not be included with the general distribution.

RESPONSES TO THE COMMENTS MADE BY DOE HEADQUARTERS
ON THE REMEDIAL INVESTIGATIONS FOR QUARRY BULK WASTES
Dated February 1989

SPECIFIC REVIEW COMMENTS

Cover Page

Comment

Change Remedial Investigations to Remedial Investigation to match title page.

Response

The cover and title page match, to read "Remedial Investigations for Quarry Bulk Wastes."

Table of Contents

Comment 1

Study Area Investigations - title should be modified to indicate that information is from previous studies of WSS -- that no investigations were conducted under this RI.

Response 1

The section title will be changed to read "Previous Study Area Investigations". The text will indicate that no investigations were conducted under this RI.

Comment 2

Change 3.2 Meteorological Investigations to Meteorology --no investigations were conducted.

Response 2

The title of Section 3.2 Meteorological Investigations will be changed to Section 3.2 Meteorology.

Comment 3

A section on preliminary identification of ARARs and To-Be-Considered requirements (TBCs) would be helpful (see forth general comment)

Response 3

An identification of ARARs and TBC requirements are presented in the Feasibility Study.

Executive Summary

Comment 1

Pg. 1 - Need to define the RI/FS-EA process, especially the CERCLA/NEPA interface (e.g., that the environmental assessment component is different than an endangerment assessment, which is part of a risk assessment). Has there been NEPA scoping? Provide appropriate reference(s). (See second general comment.)

Response 1

The fact sheet described in response to the first general comment will include definitions and clarifications of the processes. The WSSRAP FI/FS-EIS Work Plan discusses NEPA scoping. The language in the RI will not be changed.

Comment 2

Pg. 1 - Will there only be one ROD for the site or a ROD for each operable unit? Has there been an agreement between the US EPA, the State, and DOE? (See third general comment.) A more comprehensive overview of the RI/FS-NEPA process is necessary to investigations/studies (see first general comment).

Response 2

A separate ROD will be issued for this action. An overview of the RI/FS-NEPA process will be included in the fact sheet.

Comment 3

Pg. 2 - Will the characterization of the groundwater regime be the focus of a separate RI on that operable unit? (See first general comment).

Response 3

A separate RI is anticipated for the follow-on work which includes groundwater. The text will be modified, "The groundwater regime will be further characterized in subsequent investigations."

Section 1

Comment 1

Pg. 1-1 - Need to indicate when the RI on this operable unit was initiated. Was the RI initiated as a result of the site being placed on the NPL in 1987: Clarify how RI fits into the long history of activities at the site.

Response 1

The WSSRAP RI/FS-EIS Work Plan clarifies how the RI fits into the long historical activities at the site.

Comment 2

Pg. 1-1 - Has the temporary storage of wastes been agreed upon by EPA/State?

Response 2

EPA/State will not formalize the agreement of the temporary storage of waste until the Record of Decision is issued.

Comment 3

Pg. 1-1, Paragraph 2 - The first sentence states that "quarry wastes are the major sources of contamination that has been detected in the quarry area." The second sentence states that "The potential migration of contaminants from the quarry to surface water and groundwater is <u>also</u> a concern." How does quarry area contamination differ from surface water and groundwater contamination?

Response 3

The subject wording will be revised to read, "... it can reasonably be concluded that the quarry wastes are the major source of contamination that has been detected in the surface water and groundwater in the quarry area."

Comment 4

Pg. 1-1, Paragraph 3 - This activity is not a "removal action" in the Superfund sense of the work; the language should be modified to read "removal of quarry wastes."

Response 4

The language will be changed from "removal action" and modified to read "removal of quarry wastes".

Comment 5

Pg. 1-1, Paragraph 4 - Is the investigations of the proposed temporary storage area part of an RI on another operable unit or is it part of the FS?

Response 5

The investigation of the proposed temporary storage area is being developed as a stand-alone characterization report. The language will be modified to "...presented in a separate stand-alone report."

Comment 6

Pg. 1-2, Paragraph 1 - These Executive Summary refer to the RI/FS-EA process, and this page refers to the RI/FS-EIS process. Which is it? There are significant differences between an EA and EIS. An EIS is prepared only after it has been determined that a proposed action will have a significant adverse impact. Have significant environmental impacts associated with the proposed action been identified? If so, in what document?

Response 6

As stated in the WSSRAP RI/FS-EIS Work Plan (pg. 118), the level of environmental review associated with an action of this nature would typically be included in an EA. The DOE is planning to use this hybrid documentation process, termed the RI/FS-EA process for this action." This action is referring to the removal of quarry bulk waste. The decision on ultimate disposition of the quarry bulk waste will be included in the overall RI/FS-EIS process for the project. The language will not be modified.

Comment 7

Pg. 1-2, Paragraph 1 - Will the four distinct response actions referred to in Paragraph 1 be handled as separate operable units? If so, need to state this.

Response 7

The four distinct response actions stated will be managed as separate operate units as described in the WSSRAP RI/FS-EIS Work Plan. This statement provides a general overview of what actions may be required at the quarry, the verbage will not change.

Comment 8

Pg. 1-2, Paragraph 3 - What is being referred to in "one Phase" (e.g., bulk waste removal or all four actions referred to in the first paragraph)?

Response 8

One phase refers to bulk waste removal. The sentence will be modified to read, "...requirements for operable unit remedial investigations..."

Comment 9

Pg. 1-3, Paragraph 1 - What are the separate environmental compliance documents referred to in this paragraph?

Response 9

The particular environmental documentation for residual work at the quarry and the surrounding areas has not been completely identified at this time. A follow-on RI/FS which addresses groundwater, vicinity properties, and residual materials is anticipated.

Comment 10

Page 1-5, Paragraph 2 - The March 1988 draft guidance was used, however, the interim final guidance, dated October 1988, could have been used.

Response 10

The final guidance, dated October 1988, was not available at the time when this document was initiated.

Section 2

Comment 1

Pg. 2-4 - Why was only one sample taken in the March 1987 Phase I Water Quality Assessment?

Response 1

The Phase I Water Quality Assessment was performed for all water bodies associated with the Weldon Spring Site. The effort was scoped to provide a snap shot of water quality data.

Section 3

Comment 1

Pg. 3-2, Data Adequacy: Will roads into the quarry support trucks/dozers and other equipment that will be used in the construction of the pond water treatment facility, and that will be used in the excavation of quarry wastes?

Response 1

This issue is not discussed in the RI or FS. It will be addressed during the design phase after the ROD.

Comment 2

Pg. 3-3, Paragraph 1 - The statement "Since meteorological data are not recorded at the WSQ" appears to contradict statements made on page 2-2. Clarification is required.

Response 2

The text on page 2-2 will be modified to state, "No specific meteorological data has been collected at the quarry."

Comment 3

Pg. 3-11, Paragraph 1 - Will microclimatological conditions be potentially addressed during subsequent RI activities?

Response 3

Argonne National Laboratory has completed a draft document "Comparison of Surface Meteorological Data Representativeness for the Weldon Spring Transport and Dispersion Modeling Analysis" (June 1989) which assesses the most representative meteorological data. No site-specific data will be collected.

Comment 4

Pg. 3-18, Section 3.6.1.1, Paragraph 1 - Summarize in a couple of sentences the results from Kleeschulte, 1986.

Response 4

This section will be expanded to include a brief summary of the Kleeschulte report as it pertains to the quarry area.

Comment 5

Pg. 3-21, Paragraph 2 - Need to add sentence "Additional tests will be conducted, as necessary, to further characterize site conditions during subsequent RI activities..."

Response 5

Text will be revised to read, "However, additional tests will be conducted, as necessary, to further characterize conductions during subsequent investigations."

Comment 6

Pg. 3-26, second paragraph of Section 3.6.3 - Need to indicate the operable unit and RI under which such work would be conducted.

Response 6

Concur. A sentence will be added to read, "The residual wastes (i.e., within bedrock fractures) and the groundwater will be managed as additional separate operable units. These operable units will be investigated in a subsequent RI.

Comment 7

Pg.3-28, Institutions - Refer to Section 3.7.4 for groundwater use information.

Response 7

Comment was noted, but reference to Section 3.7.4 is inappropriate.

Comment 8

Pg. 3-29, Paragraph 4 - Need to state if there is any evidence of contamination in the County well field from this or any other site?

Response 8

Groundwater migration is not within the scope of this document. The County wellfield is discussed briefly due to the topic of the section - Use of Groundwater, therefore, the text was not modified.

Comment 9

Pg. 3-31, Paragraph 1 - Note that critical habitat classification are ARARs and TBCs.

Response 9

The Feasibility Study for Quarry Bulk Waste Remedial Action discusses the ARARs and the TBC requirements.

Comment 10

Pg. 3-31, Land and Water Use Characteristics - this heading does not match with the information provided in the paragraph.

Response 10

This section will be modified. Section 3.8.3 Land and Water Use Characteristics has been renamed 3.8.3 Biocontamination and the section which discussed biocontamination was integrated into this section.

Comment 11

Pg. 3-31, Biocontamination - Need to clearly state that the extent of or potential for biocontamination is currently not known.

Response 11

The text will be revised as noted. The extent of or potential for biocontamination will be determined in the follow-on reports.

Section 4

Comment 1

Pg. 4-3, Paragraph 4 - Clarify "covers TNT-contaminated rubble... " Does this mean that the 50,000 cubic yards of material covers the TNT waste from 1946-47 and Th-232 waste from 1959?

Response 1

The statement that "... and covers TNT-contaminated rubble..." will be modified to read "...and waste now covers TNT-contaminated rubble...".

Comment 2

Pg. 4-6, Paragraph following Table 4.2 - Need to refer to Section 4 pond contamination discussion.

Response 2

The paragraph has been revised and incorporates a discussion concerning quarry pond contamination.

Comment 3

Page 4-8, First Paragraph, second sentence - Explain quick estimate method used by LBL.

Response 3

The text will be modified as follows, qualitative information will replace quick estimates.

Comment 4

Page 4-11, First paragraph, third line - Typographical error; loging should be logging.

Response 4

As Noted.

Comment 5

Page 4-13, First full paragraph, last sentence - Reference to secular equilibrium is confusing.

Response 5

The last sentence will be modified as follows, "However, chemically separated Ra-228 and subsequent daughters, (with no parent Th-232) will not yield accurate Th-232 concentration when analyzed by HpGe gamma spectroscopy."

Comment 6

Page 4-17, Last paragraph - Th-232 concentrations are not discussed in relation to the haulway zone. Were values obtained? If no information is available, this should be addressed.

Response 6

Th-232 concentrations values in relation to the haulway zone were not obtained. This information will be included in the discussion.

Comment 7

Page 4-18, Second paragraph - Actual depth of the contamination may vary widely from the average value of depth to bedrock. Of the three samples shown, two had contamination no deeper than 0.5 ft.

Response 7

Because of the limited amount of data on contamination depth, it was assumed that contamination extends to bedrock at the average depth of 3.7 ft. This is a conservative assumption.

Comment 8

Page 4-18, Second paragraph - Arithmetic average for bedrock depth of haulway zone may not be valid.

Response 8

The assumption that depth to bedrock in the haulway zone considered as valid due to the inspection of geotechnical boring logs which indicate the depth to bedrock in the haulway zone ranges from 0.5 to 5.0 and averages these figures the average is 2.7 ft.

Comment 9

Pages 4-19 & 20, Last paragraph - Effectively, only three boreholes were used in calculating contaminated volumes in the sump area. Actual volumes may vary widely.

Response 9

The depth to bedrock should not vary widely, therefore, the waste volume estimates are reasonable.

Comment 10

Pages 4-22 & 23, Last paragraph - The nature of the northeast corner contamination is such that it is difficult to predict the actual volumes of contaminated material with limited sampling data. Actual contaminated volumes could be expected to vary widely from those predicted.

Response 10

The actual volumes of contaminated material could be expected to vary widely from those predicted therefore, everything in the northeast corner will be removed.

Comment 11

Pg. 4-27, Paragraph 3 - Were quality control measures instituted during the 1986 sampling event?

Response 11

The sentence will be modified to read, "Quality Control measures instituted during the 1986 sampling event include..."

Comment 12

Pg. 4-30, Paragraph 1 - Do the volatiles detected in the second study correlate at all to volatiles detected in lab/field blanks?

Response 12

Refer to page 4-28, footnote b, which states "six of seven volatile compounds detected in the samples were also found in

method blanks. Only Trichloroethene was not detected in method blanks."

Comment 13

Pg. 4-31, Paragraph 2 - Clarify what is meant by "vertical distribution of chemicals is controlled by previous disposal practices."

Response 13

The meaning of "vertical distribution of chemicals is controlled by previous disposal practices" is clarified by the sentences that follow the statement. The wastes disposed of in the early filling operations (i.e., nitroaromatics) are found at greater depths than the wastes disposed of in the later filling operations (i.e., PCBs). Text modifications are unnecessary.

Comment 14

Pg. 4-32, Last paragraph - Need to state that enough information is available to proceed to the FS phase of the waste removal remedial action. Also need to make clear under which phase of the WSSRAP residuals will be characterized.

Response 14

PMC concurs and will add a statement that enough information is available to proceed to the FS phase of waste removal remedial action. As explained in the Work Plan for the RI/FS-EIS for the WSS "the need to remove any residual materials following bulk waste removal and the need to restore groundwater at the quarry cannot be determined until the bulk wastes have been removed and the remaining conditions evaluated. The DOE will address this issue (of removing any residuals) following bulk waste removal and will involve EPA Region VII and the state of Missouri in its determination."

Comment 15

Pg. 4-37, First paragraph of Section 4.3.2 - Standards and criteria presented could potentially be used as ARARs for other RIs of other operable units.

Response 15

The Feasibility Study will discuss standards and criteria that could be used as ARARs.

Comment 16

Pg. 4-44, Section 4.3.4 - How does the Environmental Monitoring Program Plan fit into the RI/FS-NEPA process? Will it be based on EPA guidance?

Response 16

The Environmental Monitoring Program Plan is mandated through and based on DOE Order 5400.1 which establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for assuring compliance with Federal, State and local environmental protection laws and regulations, Executive orders, and internal Department policies. The program collects routine environmental monitoring data and is not a part of the RI/FS process per se.

Comment 17

Page 4-51, First paragraph, last sentence - the DAC for Rn-220 for radiation exposures to general public and the environment is 3 pCi/l (DOE Order 5480.XX, 1988, which is 5400.3). DOE Order 5480.11 is for occupational exposures.

Response 17

The reference will be changed from DOE Order 5480.11 to DOE Order 5400.XX.

Comment 18

The data presented in the Draft RI concerning the level of volatile organics at the site are inconclusive. The draft RI suggests because volatiles were not detected in the first study of the site but were detected in the second, the compounds detected may be laboratory artifacts and not actually present at the site. QA/QC procedures described in the draft RI show that six of seven volatile organic compounds detected in samples of quarry wastes were also detected in method blanks at the same order of magnitude concentrations. These compounds include methylene chloride, ethylbenzene, toluene, styrene, and mixed xylenes. The same compounds were also detected in similar concentration in the field blanks. Further, maximum holding times were exceeded for 83 percent of the quarry waste samples analyzed for volatiles, indicating that volatiles may have been lost from the samples.

Response 18

Concur. The data concerning the level of volatile organics at the site are inconclusive.

Comment 19

Additional characterization of quarry wastes is required to demonstrate the existence of volatile organic compounds at the site, as the existing data are not adequate. The draft RI considers the existing data adequate for initiating removal of the bulk waste, however, further characterization of wastes may be required to develop an adequate health and safety plan for the waste removal effort and to conduct the FS.

Response 19

The depositional history of volatile organics provide adequate information. No further characterization is needed in order to conduct the FS.

Comment 20

The determination of the levels of PCBs an pesticides in quarry wastes is also inconclusive. The recovery of PCBs from waste samples, as determined by matrix spike results, was between zero and three percent. Although this low recovery is attributed to matrix interference rather than sampling and analytical techniques, the low recovery determined through the matrix spike procedure renders the PCB data inconclusive. Maximum holding times were exceeded for 100 percent of the quarry waste samples analyzed for PCBs and 93 percent of the samples analyzed for semi-volatiles. Further, it was reported that the presence of PCBs at the site interfered with the detection of certain pesticides during the 1984-1985 sampling program, however, waste samples were not analyzed for pesticides during the 1986 sampling program.

Response 20

The comment is noted.

Section 5

Comment 1

Pg. 5-1, First paragraph of Section 5.2 - Need to clearly state that contaminant persistence at the site is currently unknown. Will it be characterized in the future, and if so, under which WSSRAP phase?

Response 1

The section has been modified to clearly state that chemical contaminant persistence is currently unknown. The residual characterization studies (i.e., contaminant persistence) will be discussed on the fact sheet as described previously.