DOE/OR/21949-280

REMEDIAL INVESTIGATION REPORT

FOR THE

ST. LOUIS SITE

ST. LOUIS, MISSOURI

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EXECUTIVE SUMMARY

Characterization activities were conducted at St. Louis, Missouri, properties under the jurisdiction of the Department of Energy (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP). The objective of FUSRAP is to identify and clean up or otherwise control sites where residual radioactive contamination (exceeding current guidelines) remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

Located in the cities of Hazelwood, Berkeley, and St. Louis, the St. Louis Downtown Site (SLDS), the St. Louis Airport Site (SLAPS), the Latty Avenue Properties, and associated vicinity properties are collectively referred to as the St. Louis site.

Analytical results for radiological and chemical characterization surveys conducted on these properties serve as the basis for this report. Field investigations were performed to determine the extent of radioactive contamination, to delineate any chemical contamination associated with such radioactive contamination, and to characterize the properties' geological and hydrogeological features.

SLAPS and the Hazelwood Interim Storage Site (HISS), a Latty Avenue Property, are on the Environmental Protection Agency's National Priorities List (NPL), a list of sites identified for remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended. SLDS, while not on the NPL, is included in this report because it contains contaminants similar to those found on the other properties and will likely require similar response actions.

The characterization surveys were conducted from 1982 through 1991 for DOE by Bechtel National, Inc., the FUSRAP project management contractor, and its radiological subcontractor, Thermo Analytical/Eberline. Additional data for the St. Louis site obtained from Oak Ridge National Laboratory and Oak Ridge Associated Universities were factored into the conclusions drawn in this report. A brief summary of the characterization survey results follows.

SLDS

Characterization results for soil samples collected at SLDS indicate that contamination is widespread across the property. Radioactive material is present in areas near or beneath buildings that were associated with Manhattan Engineer District/Atomic Energy Commission (MED/AEC) operations. Two exceptions are Plant 5 and the city property, which were not associated with MED/AEC operations but contain levels of radioactivity exceeding DOE guidelines. The radioactive contaminants at SLDS are uranium-238, radium-226, thorium-232, and thorium-230. Depths of contamination range from the surface to 7 m (23 ft) at SLDS proper and to 13 m (42 ft) at an adjacent property that is owned by the City of St. Louis. In general, results for chemical characterization conducted to date indicate that radioactively contaminated soil at the property does not exhibit any hazardous waste characteristics as defined by the Resource Conservation and Recovery Act (RCRA). Only a small percentage of the samples taken failed the extraction procedure toxicity criterion for lead. Volatile organic compounds (VOCs) were detected across the property at concentrations ranging from 1 to 430 ppb; base/neutral and acid extractable (BNAE) compounds were found in higher concentrations (from 310 to 300,000 ppb) than were VOCs, but they are typically not very mobile in soil. Metals were found in soil above, within, and beneath areas of radioactive contamination.

Groundwater monitoring results for SLDS show that all radionuclide levels, except uranium levels in Well B16W02S, are near typical background values. Well B16W02S consistently showed elevated levels of total uranium (107 to 193 pCi/L), which indicates that uranium in this area may be leaching into the groundwater. Chemical results for groundwater monitoring indicate very low concentrations (5 to 150 mg/L) of ten VOCs, seven of which were found in one well (B16W03S). Twelve metals were detected in groundwater; with the exception of zinc, the metals found in groundwater do not correspond with the metals found most frequently in soil.

Sediment samples taken from the manholes at SLDS exhibited radioactive contamination; therefore, remedial action will be required on portions of the stormwater and sanitary sewers at the property.

Building surveys show that uranium-238 is the primary radioactive contaminant in the majority (15) of the onsite buildings that contain radioactive contamination exceeding DOE guidelines. Radium-226 is the primary contaminant in two of the buildings surveyed. Short-term screening measurements (made with activated charcoal canisters) indicate that two buildings (K1E and 101) have radon concentrations exceeding the DOE annual guideline of 3 pCi/L for habitable structures. Long-term measurements (made with alpha track detectors) indicate that three buildings (K1E, 25, and 101) rather than two, have radon concentrations above 3 pCi/L. Building K1E is used only for storage; personnel do not regularly work inside the structure.

SLDS VICINITY PROPERTIES

Analytical results for radiological surveys at the six vicinity properties indicate that the primary contaminant of concern is thorium-230; average concentrations of thorium-230 range from 3.1 to 70.3 pCi/g.

SLAPS

Radiological characterization results for soil at SLAPS reveal that essentially all of the ground surface is contaminated with uranium-238, radium-226, thorium-230, and thorium-232 in excess of DOE guidelines. Examined depths of contamination range from the ground surface to 5.4 m (18 ft), but the contamination was generally found at 1.2 to 2.4 m (4 to 8 ft). Results for chemical characterization conducted to date indicate that radioactively contaminated soil does not exhibit any RCRA-hazardous waste characteristics. VOCs are, in general, unevenly distributed across the property at varying depths, but none of the VOCs found are believed to have been used during uranium processing. BNAE compounds were detected in 52 of 90 soil samples collected. Most of the metals with concentrations that exceed background appear to be confined to near-surface depths [0 to 2 m (0 to 6 ft)].

Groundwater monitoring results for SLAPS show that concentrations of total uranium, radium-226, and thorium-230 in several of the shallow wells at SLAPS are elevated compared to concentrations in background locations. The groundwater monitoring wells with elevated concentrations are believed to be near pockets of buried radioactive residues. Other nearby wells have substantially lower concentrations. Because SLAPS is fenced, the public does not have access to these wells; furthermore, there is no known consumption of groundwater in the vicinity of the property. Groundwater samples collected and analyzed for chemicals had very low concentrations (0.06 to 430 mg/L) of five organics, which may account for the slightly elevated levels of total organic halides found during sampling. Some of the metals detected in groundwater are the same as those found in soil at the property. Total organic carbon and pH values are within the range of background levels for these constituents.

Surface water samples collected from the property since 1985 indicate that radionuclide concentrations have remained stable and similar to upstream concentrations.

Average annual radon concentrations at SLAPS range from 0.1 to 3.6 pCi/L.

SLAPS VICINITY PROPERTIES

Elevated levels of uranium-238, radium-226, thorium-230, and thorium-232 were detected on some of the properties, with thorium-230 being the primary contaminant of concern. The highest concentrations of thorium-230 were found on the Norfolk and Western Railroad property adjacent to 9200 Latty Avenue (26,000 pCi/g) and in the ditches adjacent to SLAPS (15,000 pCi/g). Limited chemical characterization was conducted at the ball field area and Coldwater Creek. To date, chemical results for the ball field area indicate that none of the waste exhibits characteristics of a RCRA-hazardous waste. Ten metals were detected in excess of background levels. VOC concentrations at the property are extremely low (1.3 to 48 ppb), with all compounds on the Target Compound List (TCL) at sample detection limits. One sample analyzed for pesticides/ polychlorinated biphenyls had levels of dieldrin above the sample detection limit.

Four sediment samples were taken from Coldwater Creek and analyzed for chemicals. Metals results revealed four analytes that exceed both the sample detection limits and background levels. Nine BNAE compounds (all polyaromatic hydrocarbons) and one VOC (acetone in low concentrations) were detected in the samples.

HISS

Thorium-230 is the primary contaminant in soil at the property, with lesser amounts of uranium-238 and radium-226 present. The depth of contamination explored ranges from the ground surface to 2 m (6 ft) with an average depth of 1 m (3 ft). Chemical results for soil indicate that 16 metals at concentrations greater than background are typically found in areas containing radioactive waste. Only one sample contained a VOC (toluene) exceeding the detection limit, but it occurred at a low concentration (2.9 ppb). No TCL compounds were detected at concentrations exceeding the sample detection limit. BNAE analyses revealed two samples with hydrocarbon compounds that were unidentifiable. Analytical results obtained so far show that none of the samples exhibits the characteristics of a RCRA-hazardous waste.

In general, analytical results for quarterly sampling of the monitoring wells indicate that the radionuclides in groundwater are at or slightly exceed background levels. The total uranium concentration in a well in the northwestern corner of the property is an exception, with the highest annual average from 1985 through

1989 of 82 pCi/L. The only organic compound found above detection limits during chemical sampling was bis(2-ethyl hexyl)phthalate. This compound was also detected in laboratory blanks at comparable levels and is thought to be the result of laboratory contamination. Seven metals were detected at background levels, and four metals were found at slightly elevated concentrations.

Analytical results for surface water and sediment samples collected during quarterly environmental monitoring indicate that radionuclide concentrations have remained near background levels since 1985. The only exception is sediment samples taken from Coldwater Creek, downstream of HISS, which have concentrations of thorium-230 ranging from 0.1 to 300 pCi/g.

Radon monitoring at HISS indicates that levels are below the DOE guideline of 3 pCi/L.

FUTURA

At Futura Coatings, Inc., another Latty Avenue property, uranium-238, radium-226, thorium-232, and thorium-230 were all found in soil at concentrations exceeding guidelines. Thorium-230 was detected at levels as high as 2,000 pCi/g and may be greater than indicated because the samples analyzed were primarily those with no associated gamma-emitting radionuclides present in above-guideline concentrations. The depth of contamination explored ranges from the surface to approximately 4.6 m (15 ft). Chemical sampling conducted so far indicates that the waste does not exhibit RCRA-hazardous waste characteristics, the chemicals appear to be primarily associated with the radioactive waste, and chemical levels are low. Fourteen metals are present at concentrations exceeding background levels, two VOCs (toluene and trichlorofluoromethane) were detected at very low concentrations (15 and 1.3 ppb, respectively), and two BNAE compounds were detected. No TCL compounds were found above detection limits.

No radioactive contamination was found in Futura buildings in excess of maximum concentrations specified by DOE guidelines. Radon and air particulate monitoring in the buildings demonstrate that these structures are in compliance with DOE guidelines for radon and the DOE radiation protection standard.

LATTY AVENUE VICINITY PROPERTIES

Radiological characterization of soil at the six vicinity properties has revealed elevated levels of both thorium-230 and radium-226, with thorium-230 (at a maximum concentration of 5,700 pCi/g) being the primary contaminant of concern.

TRANSPORTATION ROUTES BETWEEN HISS AND WEST LAKE LANDFILL AND BETWEEN SLDS AND SLAPS

Between HISS and West Lake Landfill, samples from 28 intersections (231 samples) were collected and analyzed for uranium-238, radium-226, thorium-232, and thorium-230. Only 2 of the 231 samples exhibited thorium-230 (the primary contaminant of concern) concentrations exceeding the DOE cleanup guideline. A mobile gamma scan was conducted on the suspected haul roads between SLDS and SLAPS; no residual radioactivity related to past AEC/MED operations was detected.

SUMMARY

In general, analytical results of the surveys indicate that the highest contamination levels are at SLDS, SLAPS, and HISS, with the principal radioactive contaminants being uranium-238, radium-226, and thorium-230. Access to these properties is restricted. The vicinity properties, which were not directly associated with uranium processing or waste storage, exhibit lower concentrations of radionuclides, primarily thorium-230. Results for the surveys also demonstrate that the waste, except for samples from three boreholes, does not exhibit RCRA characteristics, based on extraction procedure toxicity results.

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ACRONYMS

AEC	Atomic Energy Commission
BNAE	base/neutral and acid extractable
BNI	Bechtel National, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CME	Central Mine Equipment
COC	chain of custody
COE	Corps of Engineers
DI	deionized
DOE	Department of Energy
EP	extraction procedure
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
GC/MS	gas chromatography/mass spectrometry
HISS	Hazelwood Interim Storage Site
ICPAES	inductively coupled plasma atomic emission spectrophotometry
MED	Manhattan Engineer District
NEPA	National Environmental Policy Act
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
PAH	polynuclear aromatic hydrocarbon
PCBs	polychlorinated biphenyls
PIC	pressurized ionization chamber

ACRONYMS
(continued)

PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI/FS-EIS	remedial investigation/feasibility study-environmental impact statement
RFW	Roy F. Weston, Inc.
SARA	Superfund Amendments and Reauthorization Act
SLAPS	St. Louis Airport Site
SLDS	St. Louis Downtown Site
SRM	Standard Reference Material
TLD	thermoluminescent dosimeter
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TMA/E	Thermo Analytical/Eberline
TOC	total organic carbon
TOX	total organic halides
VOC	volatile organic compound

ABBREVIATIONS

cfs	cubic feet per second
cm	centimeter
cms	cubic meters per second
cpm	counts per minute
dpm	disintegrations per minute
ft	foot
g	gram
h	hour
ha	hectare
in.	inch
kg	kilogram
km	kilometer
L	liter
lb	pound
m	meter
meq	milliequivalent
mg	milligram
mi	mile
ml	milliliter
mm	millimeter
mR	milliroentgen
mrem	millirem
mCi	microcurie
mg	microgram
mmho	micromho
mR	microroentgen

ABBREVIATIONS
(continued)

pCi	picocurie
ppb	parts per billion
ppm	parts per million
pcf	pounds per cubic foot
s	second
yd	yard
yr	year

1.0 INTRODUCTION

1.1 PURPOSE

The remedial investigation/feasibility study at the St. Louis site is being conducted as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), which was instituted in 1974 by the Atomic Energy Commission (AEC), a predecessor of the U.S. Department of Energy (DOE). The goal of FUSRAP, now managed by DOE, is to identify and clean up or otherwise control sites where residual radioactive contamination (exceeding current guidelines) remains from activities carried out under contract to the Manhattan Engineer District (MED) and AEC during the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. The St. Louis Downtown Site (SLDS) and the St. Louis Airport Site (SLAPS) were among the first properties to be designated for remediation under FUSRAP. The Hazelwood Interim Storage Site (HISS) was added to FUSRAP by Congress through the 1984 Energy and Water Development Appropriations Act. SLAPS and HISS were added to the Environmental Protection Agency's (EPA) National Priorities List (NPL) in 1989.

A remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) is being prepared to determine the type and extent of contamination at the properties and the best method for conducting the remedial action. The RI was conducted from 1986 through 1990 to support the RI/FS-EIS by determining the extent of radioactive and chemical contamination. The purposes of this RI report are to document the field activities that were conducted and summarize and report the results of the field investigations.

Interim response actions (i.e., removal actions taken before completion of the RI/FS-EIS process) are possible for the St. Louis site. Typically, these interim actions involve removal of contaminated materials from an area and subsequent interim storage pending selection of a comprehensive remedy for wastes generated by cleanup of the St. Louis site. Appropriate documentation to comply with the National Environmental Policy Act (NEPA) (DOE 1985) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (CERCLA 1980) will be prepared before these interim measures are implemented. Specifically, engineering evaluation/cost analysis reports will be prepared and submitted for public review before interim removal actions begin. Removal actions currently projected include cleanup of contaminated materials from vicinity properties of SLAPS and SLDS and subsequent temporary storage of the resulting materials.

1.2 SITE BACKGROUND

SLDS and its vicinity properties, SLAPS and its vicinity properties, and the Latty Avenue Properties are collectively referred to as the St. Louis site; Figure 1-1 shows their regional setting. The following subsections provide brief descriptions of the locations and history of operations at the properties.

1.2.1 SLDS and Vicinity Properties

SLDS is in an industrial area on the eastern border of St. Louis, approximately 90 m (300 ft) west of the Mississippi River and 17.7 km (11 mi) southeast of SLAPS. The population within 48.3 km (30 mi) of the property is 1,300,000, including 22,000 within 1.6 km (1 mi) of the property. SLDS is presently owned by Mallinckrodt, Inc., which produces various chemical products. The property covers approximately 18.2 ha (45 acres) and contains many buildings and facilities (Figure 1-2). Mallinckrodt maintains 24-h security at the property. SLDS is traversed by three railroad lines and numerous spurs. Runoff from the property is controlled by a system of combined sewers that direct excess flow to the Mississippi River. There is an extensive network of utility lines both above and below the ground. Underground utilities include sewer, sprinkler, water, and natural gas lines; overhead utilities include electricity, telephone, and plant process pipes.

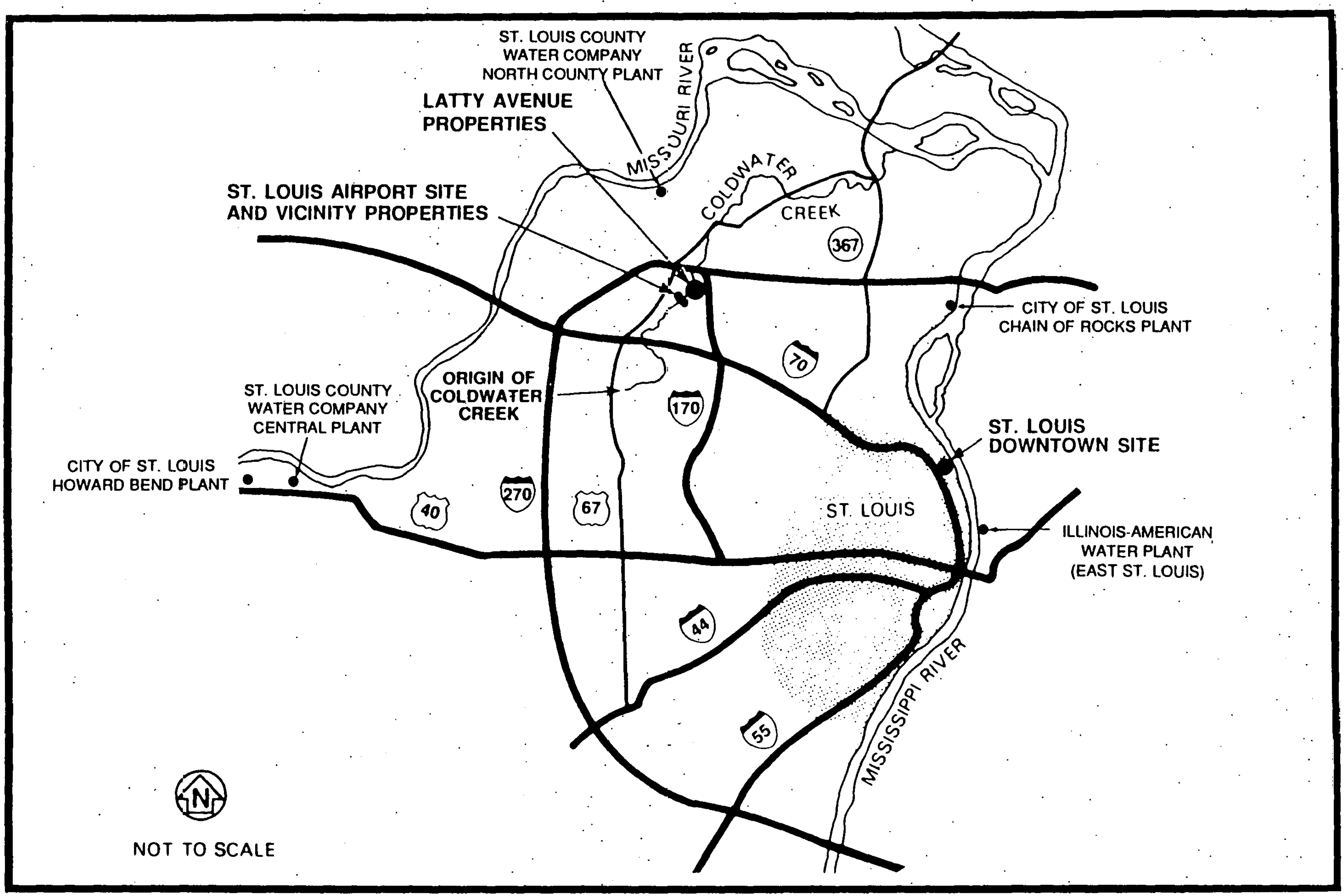


FIGURE 1-1 LOCATIONS OF FUSRAP PROPERTIES IN THE ST. LOUIS, MISSOURI, AREA

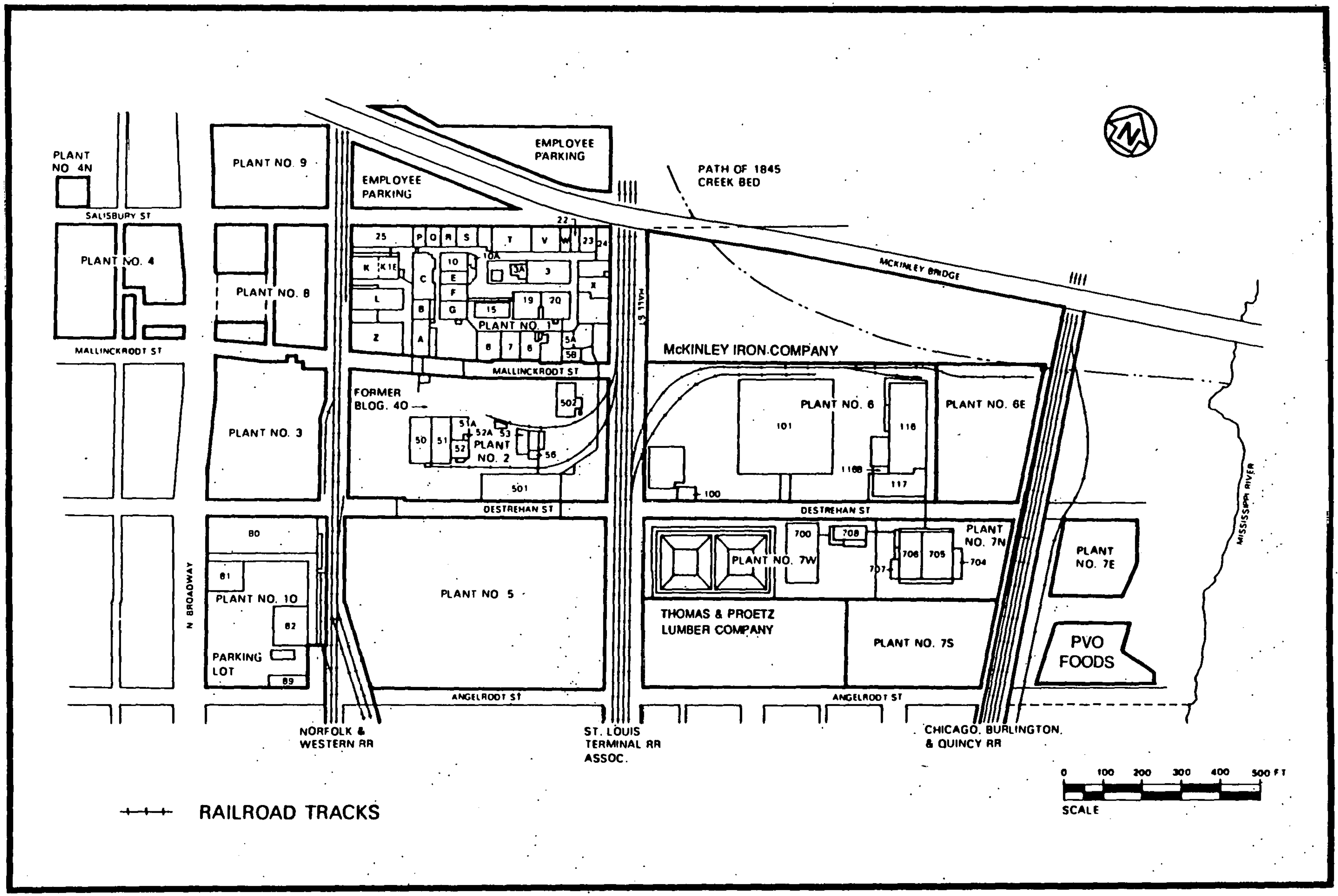


FIGURE 1-2 PLAN VIEW OF SLDS AND ITS VICINITY PROPERTIES

From 1942 to 1957, the former Mallinckrodt Chemical Works performed work at SLDS under contracts with MED and AEC. The work included development of uranium-processing techniques, production of forms of uranium compounds and metal, and recovery of uranium metal from residues and scrap.

From 1942 to 1945, work was performed in Plants 1, 2, and 4 (now Plant 10). In 1946, manufacturing of uranium dioxide from pitchblende ore began at the newly constructed Plant 6. During the processing, uranium ore was digested in acid and filtered to form uranyl nitrate; then, a solvent extraction procedure and denitration were conducted to create uranium oxide. Hydrofluoric acid was then used to fluorinate the uranium oxide to create uranium tetrafluoride (green salt), which was subsequently reduced with heat and magnesium to produce uranium metal.

Mallinckrodt personnel conducted decontamination activities at Plants 1 and 2 from 1948 through 1950. These decontamination efforts were focused to meet AEC criteria in effect at that time, and the plants were released for use without radiological restrictions in 1951; however, no documentation of the results of these activities has been found.

During 1950 and 1951, operations began at Plants 6E and 7, and Plant 4 was modified and used as a metallurgical pilot plant for processing uranium metal until it was closed in 1956. AEC operations in Plant 6E ended in 1957; AEC managed decontamination efforts (removal of contaminated buildings, equipment, and soil) in Plants 4 and 6E to meet AEC criteria in effect at that time and returned the plants to Mallinckrodt in 1962 for use without radiological restrictions. Since 1962, some buildings have been razed, and new buildings have been constructed at Plants 4 and 6.

Plant 7 was designed to produce green salt and was also used for storing reactor cores and removing metallic uranium from slag by a wet grinding/mill flotation process (Mason 1977). Plant 7 was released for use with no radiological restrictions in 1962 following decontamination that met AEC criteria in effect at that time and is now used primarily for storage.

In 1977, Oak Ridge National Laboratory (ORNL) conducted a radiological survey of portions of SLDS at the request of DOE (ORNL 1981). Results of this survey show that alpha and beta-gamma contamination levels exceeded guidelines for release of the property for use without radiological restrictions. Elevated gamma radiation levels were measured at some outdoor locations and in some of the buildings that had been used to process the uranium ore. Uranium-238 concentrations as high as 20,000 pCi/g and radium-226 concentrations as high as 2,700 pCi/g were found in subsurface soil. Radon and radon daughter concentrations in three buildings exceeded guidelines for nonoccupational radiation exposure. Based on results of the ORNL survey, Bechtel National, Inc. (BNI) performed the RI activities described in this report.

The RI revealed offsite areas containing radioactive contamination that may be associated with MED/AEC activities at SLDS. The following areas bordering SLDS are referred to as vicinity properties: McKinley Iron Company; PVO Foods, Inc.; Thomas and Proetz Lumber Company; St. Louis Terminal Railroad Association; Norfolk and Western Railroad; and Chicago, Burlington, and Quincy Railroad (Figure 1-2).

1.2.2 SLAPS and Vicinity Properties

SLAPS is in St. Louis County, approximately 24 km (15 mi) from downtown St. Louis, 17.7 km (11 mi) from SLDS, and immediately north of Lambert-St. Louis International Airport (Figure 1-3). SLAPS is bounded by the Norfolk and Western Railroad and Banshee Road on the south, Coldwater Creek on the west, and McDonnell Boulevard and adjacent recreational fields on the north and east. The property covers 8.8 ha (21.7 acres) and is surrounded by security fencing. Within a half mile of the property, more than two-thirds of the land is used for transportation-related purposes because of its proximity to the airport; the remaining land is used primarily for commercial and recreational functions (Figure 1-4).

There are no utility lines on SLAPS. A water main crosses the northwestern corner and runs parallel to the property on the

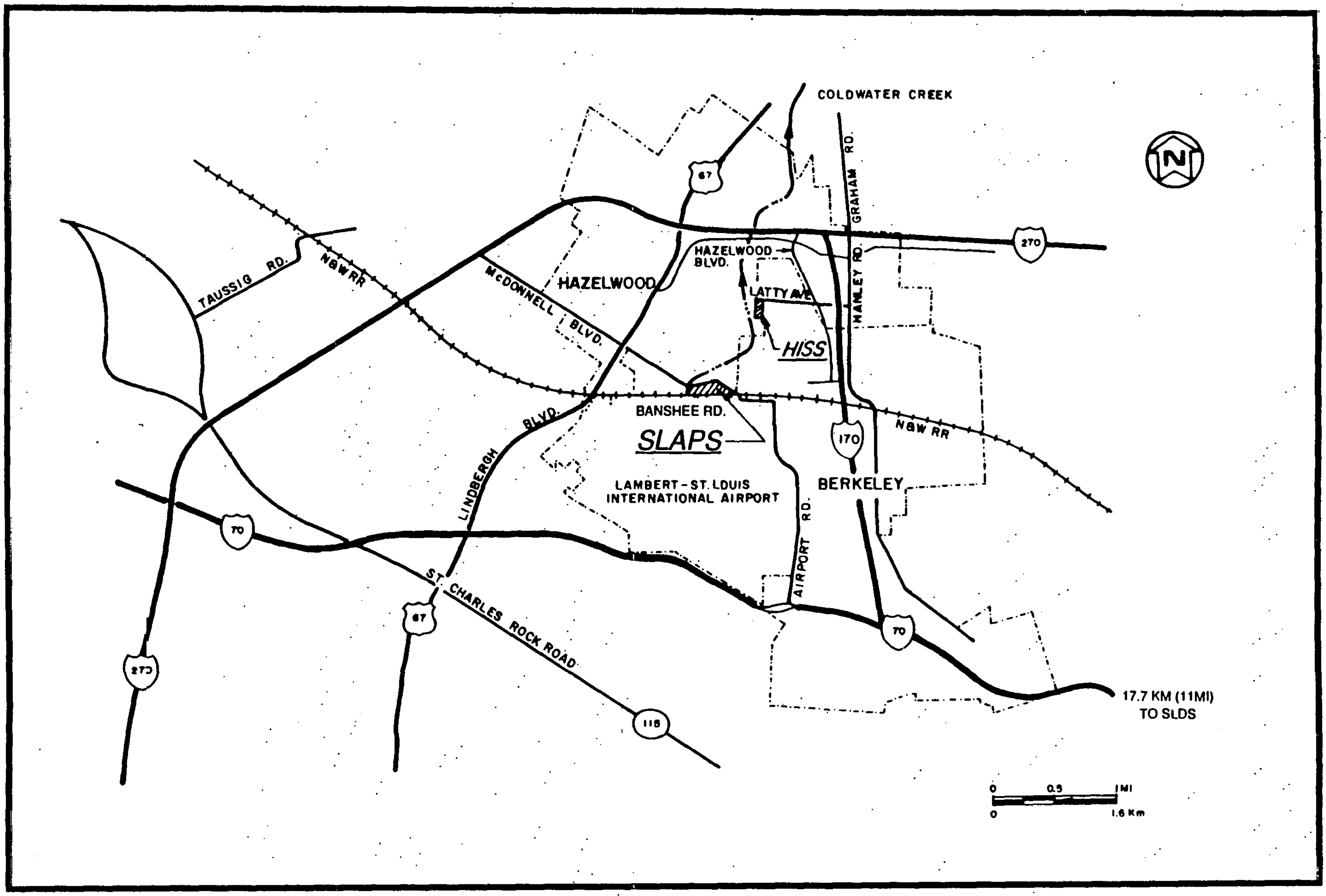
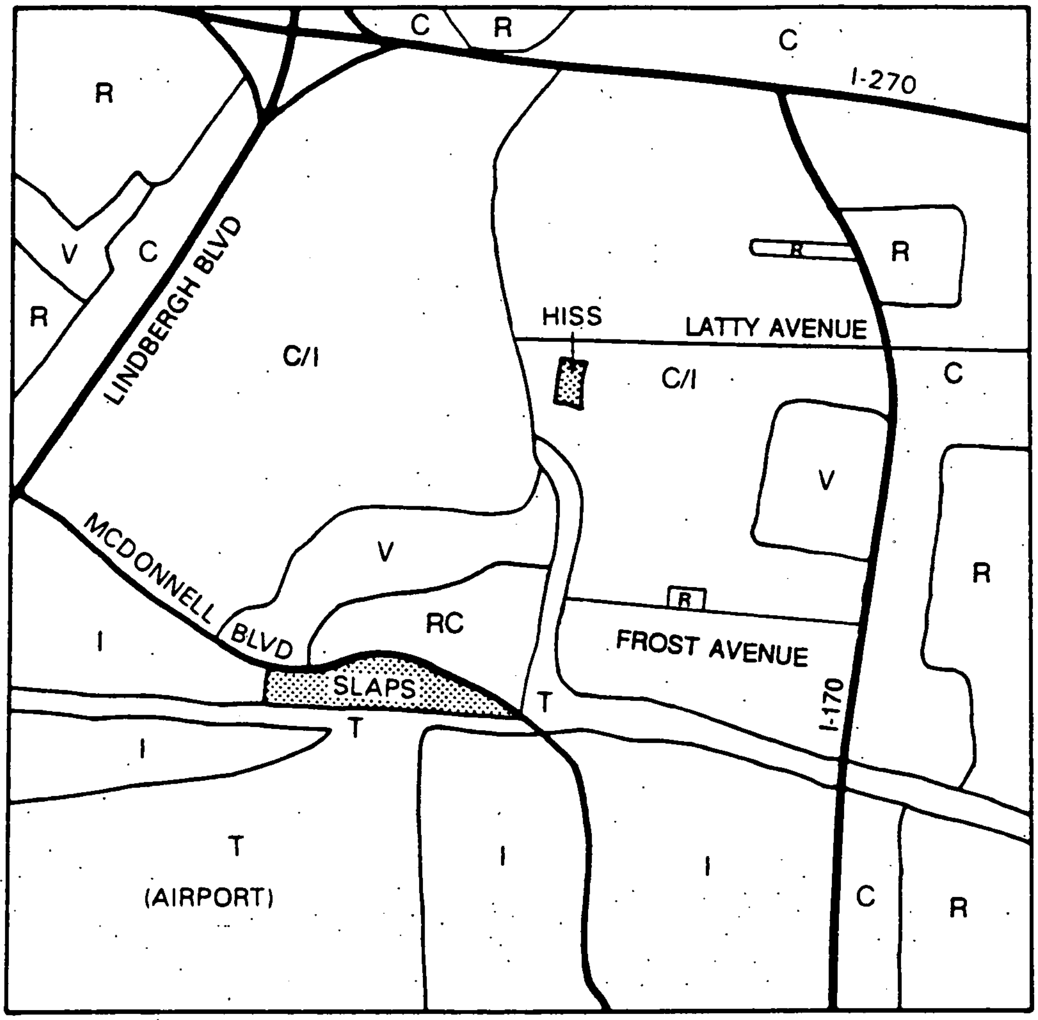


FIGURE 1-3 LOCATION OF SLAPS



BASED ON AERIAL PHOTOGRAPHS, SITE VISITS AND USGS TOPOGRAPHIC MAP 1:24000 SCALE, FLORISSANT, MO (PHOTO REVISED 1982)

R RESIDENTIAL
C COMMERCIAL
T TRANSPORTATION
I INDUSTRIAL
C/I MIXED COMMERCIAL AND INDUSTRIAL
V VACANT
RC RECREATIONAL

0 0.5 MI
0 0.8 KM

N

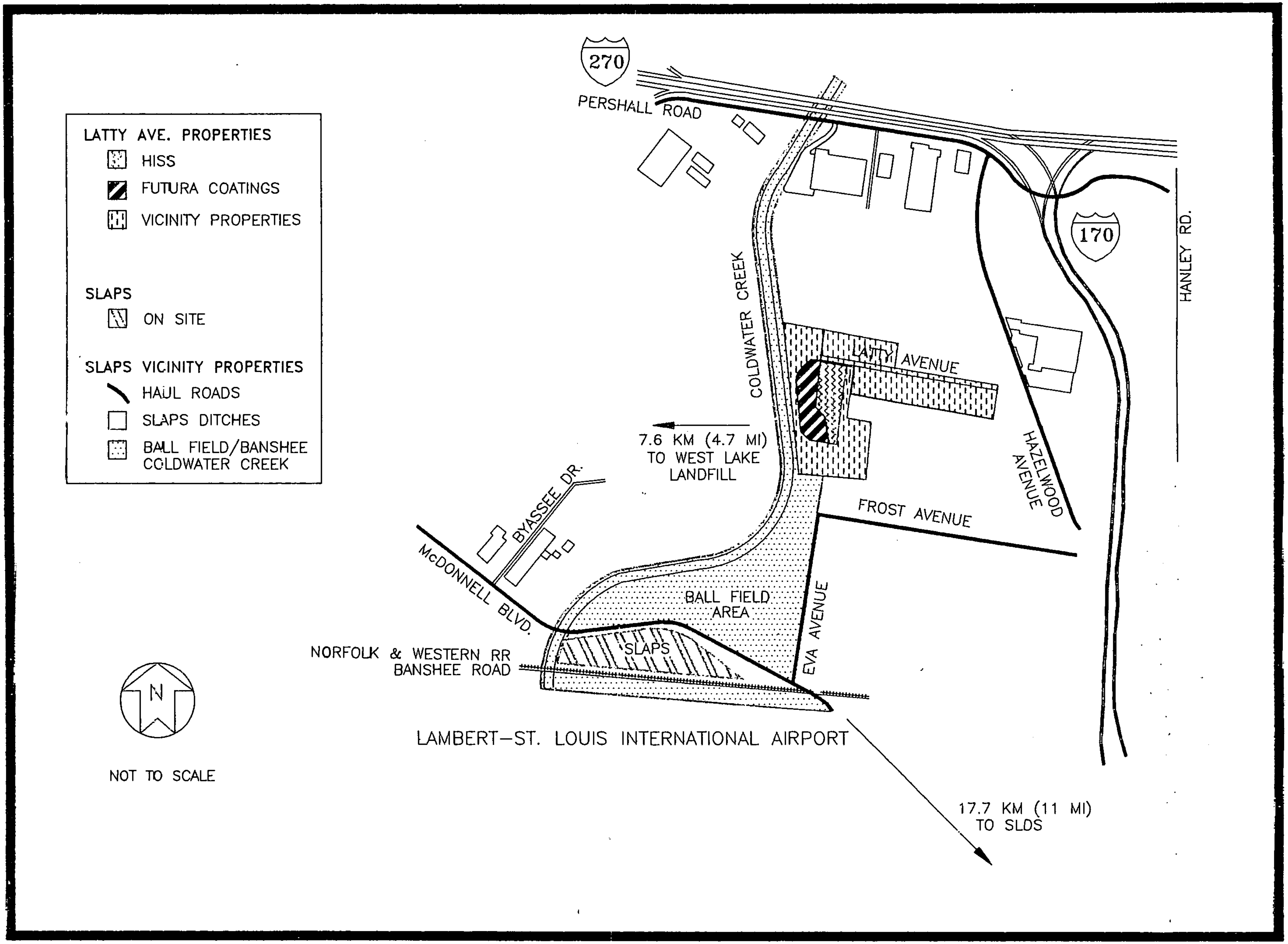
FIGURE 1-4 GENERALIZED LAND USE IN THE VICINITY OF SLAPS north; a small onsite line connected to the water main supplies the mobile site facility. There are no sewer lines on the property; the facility is serviced by a holding tank.

No sizeable residential population centers exist within 1.6 km (1 mi) of SLAPS; the nearest population center (75 to 100 people) is approximately 0.8 km (0.5 mi) west of the property in an industrially zoned area of Hazelwood. The next nearest is approximately 1.6 km (1 mi) northwest of SLAPS along Chapel Ridge Drive, with about 1,500 people. Most of the Hazelwood population is north of Interstate 270, more than 2.4 km (1.5 mi) north of SLAPS.

SLAPS vicinity properties include Coldwater Creek and its vicinity properties to the west; adjacent ball fields to the north and east; Norfolk and Western Railroad properties adjacent to Coldwater Creek; Banshee Road to the south; ditches to the north and south; and St. Louis Airport Authority property to the south. Also included are the transportation routes: Latty Avenue, McDonnell Boulevard, Pershall Road, Hazelwood Avenue, Eva Avenue, Frost Avenue, and vicinity properties. These routes (referred to as the haul roads) are believed to have been used during waste transfer among the St. Louis properties. Figure 1-5 shows the locations of SLAPS vicinity properties.

Radioactive contamination on the vicinity properties may have resulted from movement of contaminated soils from SLAPS by surface runoff or by spillage from transport vehicles. In addition, road and underground utility improvements may have caused migration of contamination onto adjacent land. Railroad cars were used to transport contaminated wastes to and from SLAPS, and material from these cars may have spilled onto the railroad property and then migrated onto adjacent properties.

SLAPS was acquired by MED in 1946 and was used to store uranium-bearing residues from SLDS from 1946 until 1966. In 1966, the wastes were purchased by Continental Mining and Milling Company of Chicago, removed from SLAPS, and placed in storage at Latty Avenue under AEC license. After most of the residues were removed from SLAPS, the structures were demolished and buried on the



B1:SLAPGEN1:V1

FIGURE 1–5 LOCATIONS OF SLAPS VICINITY PROPERTIES property, and 0.3 to 1.0 m (1 to 3 ft) of clean fill material was spread over the entire area to achieve surface radioactivity levels acceptable at that time.

By agreement between the U.S. Government and the City of St. Louis, ownership of SLAPS was transferred by quitclaim deed from AEC to the St. Louis Airport Authority in 1973. The 1985 Energy and Water Development Appropriations Act authorized DOE to reacquire the property for use as a permanent disposal site; the need for reacquisition will be determined after completion of the RI/FS for the St. Louis site.

In 1982, DOE directed BNI to perform a radiological characterization of the ditches to the north and south of SLAPS and of portions of Coldwater Creek (BNI 1983). Results of this survey indicated gamma-emitting contamination exceeding DOE remedial action guidelines (Table 1-1). This survey did not include measuring thorium-230 concentrations in soils. Subsequent analysis of additional radionuclides showed thorium-230 in concentrations exceeding guidelines; therefore, all field work conducted later at the St. Louis site involved analysis for thorium-230. Characterization efforts continued in 1986 in the ditches; archived soil samples from the 1982 survey were also analyzed for thorium-230. The results of these analyses indicated the need to collect soil samples beyond the area surveyed in 1982 (on the ball field near Coldwater Creek) to adequately determine the areal extent of contamination.

In December 1984, ORNL conducted a mobile gamma scanning survey of potential transportation routes to and from SLAPS and the Latty Avenue Properties and found anomalies on McDonnell Boulevard, Hazelwood Avenue, and Pershall Road (ORNL 1985). Results of the ORNL survey of the roadsides showed areas where gamma exposure rates exceed background radiation levels. Gamma exposure rates of up to 90 μR/h were found on the surface of McDonnell Boulevard; these results are summarized in Appendix C. Based on the results of the ORNL gamma scan, additional sampling along these roads was initiated to detect thorium-230 in excess of DOE guidelines because

TABLE 1-1
SUMMARY OF RESIDUAL CONTAMINATION GUIDELINES

BASIC DOSE LIMITS

The basic limit for the annual radiation dose (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, DOE applies as low as reasonable achievable principles to set site-specific guidelines.

SOIL GUIDELINES

Radionuclide	Soil Concentration (pCi/g) Above Background[a,b,c]
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g when averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
Other Radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use.

STRUCTURE GUIDELINES

Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that has no radiological restrictions on its use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL[d]. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restrictions on its use shall not exceed the background level by more than 20 μR/h and will comply with the basic dose limits when an appropriate-use scenario is considered.

Indoor/Outdoor Structure Surface Contamination

	Allowable Surface Residual Contamination[e] (dpm/100 cm^2)		
Radionuclide[f]	Average[g,h]	Maximum[h,i]	Removable[h,j]
Transuranics, Ra-226, Ra-228, Th-230, Th-228 Pa-231, Ac-227, I-125, I-129[k]	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224 U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[l]	5,000 β - γ	15,000 β - γ	1,000 β - γ

4.46 3367.1

TABLE 1-1
(CONTINUED)

[a]These guidelines take into account ingrowth of radium-226 from thorium-230 and of radium-228 from thorium-232, and assume secular equilibrium. If either thorium-230 and radium-226 or thorium-232 and radium-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit, or (2) the sum of ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity").

[b]These guidelines represent allowable residual concentrations above background averaged across any 15-cm-thick layer to any depth and over any contiguous 100-m^2 surface area.

[c]If the average concentration in any surface or below-surface area less than or equal to 25 m^2 exceeds the authorized limit or guideline by a factor of $(100/A)^{1/2}$, where A is the area of the elevated region in square meters, limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the DOE Manual for Implementing Residual Radioactive Materials Guidelines, DOE/CH/8901. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

[d]A working level (WL) is any combination of short-lived radon decay products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

[e]As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[f]Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[g]Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[h]The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[i]The maximum contamination level applies to an area of not more than 100 cm^2.

[j]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping tehniques to measure removable contamination levels if direct scan surveys indicate that total residual surface cotamination levels are within the limits for removable contamination.

[k]Guidelines for these radionuclides are not given in DOE Order 5400.5; however, these guidelines are considered applicable until guidance is provided.

[l] This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

thorium-230 (an alpha radiation emitter) cannot be detected in-situ.

In 1985, a radiological survey was performed on McDonnell Boulevard, Hazelwood Avenue, and Pershall Road (ORNL 1986a). Analytical results for soil samples showed thorium-230 to be the major contaminant.

An extensive radiological and limited chemical characterization was conducted at SLAPS in 1986 by BNI; results showed radioactive contamination extending as deep as 5.5 m (18 ft) (BNI 1987a).

A radiological characterization of the SLAPS vicinity properties was performed from 1986 through 1990 to define the extent and boundaries of the contamination and to evaluate disposal alternatives (BNI 1990d).

1.2.3 Latty Avenue and Vicinity Properties

The Latty Avenue Properties are located along Latty Avenue and include HISS, Futura Coatings, Inc., and six vicinity properties (Figures 1-6 and 1-7). HISS and Futura cover a 4.5-ha (11-acre) tract in Hazelwood and are approximately 3.2 km (2 mi) northeast of the control tower of Lambert-St. Louis International Airport. The vicinity properties are adjacent to HISS and Latty Avenue, mostly within the corporate limits of Berkeley.

HISS is a level, grassy area with access roads, a vehicle decontamination facility, and two stockpiles of contaminated soil and debris in interim storage. In preparing the western portion of the property for commercial use by Futura, the present owner demolished one building, excavated several areas to level the property, paved several areas, and erected new buildings. The excavated material was placed in interim storage at HISS, which is currently leased by DOE. A chain-link fence completely surrounds HISS and Futura.

The Latty Avenue Properties are zoned for industrial use, and the surrounding area is primarily industrial and commercial. Stormwater runoff flows into ditches that drain into Coldwater Creek. HISS is served by city water and electricity, with overhead

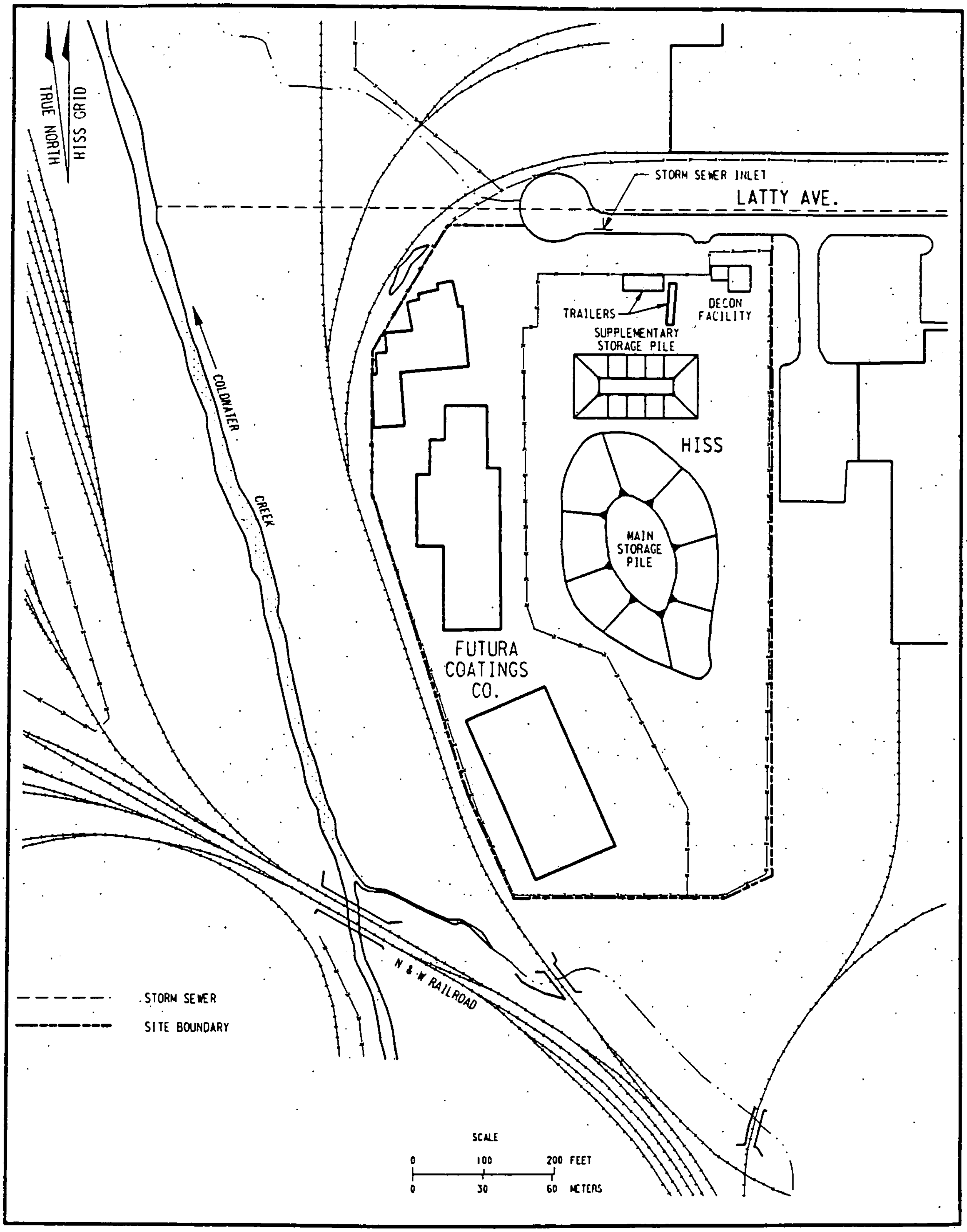


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FIGURE 1-6 LOCATIONS OF HISS AND FUTURA COATINGS

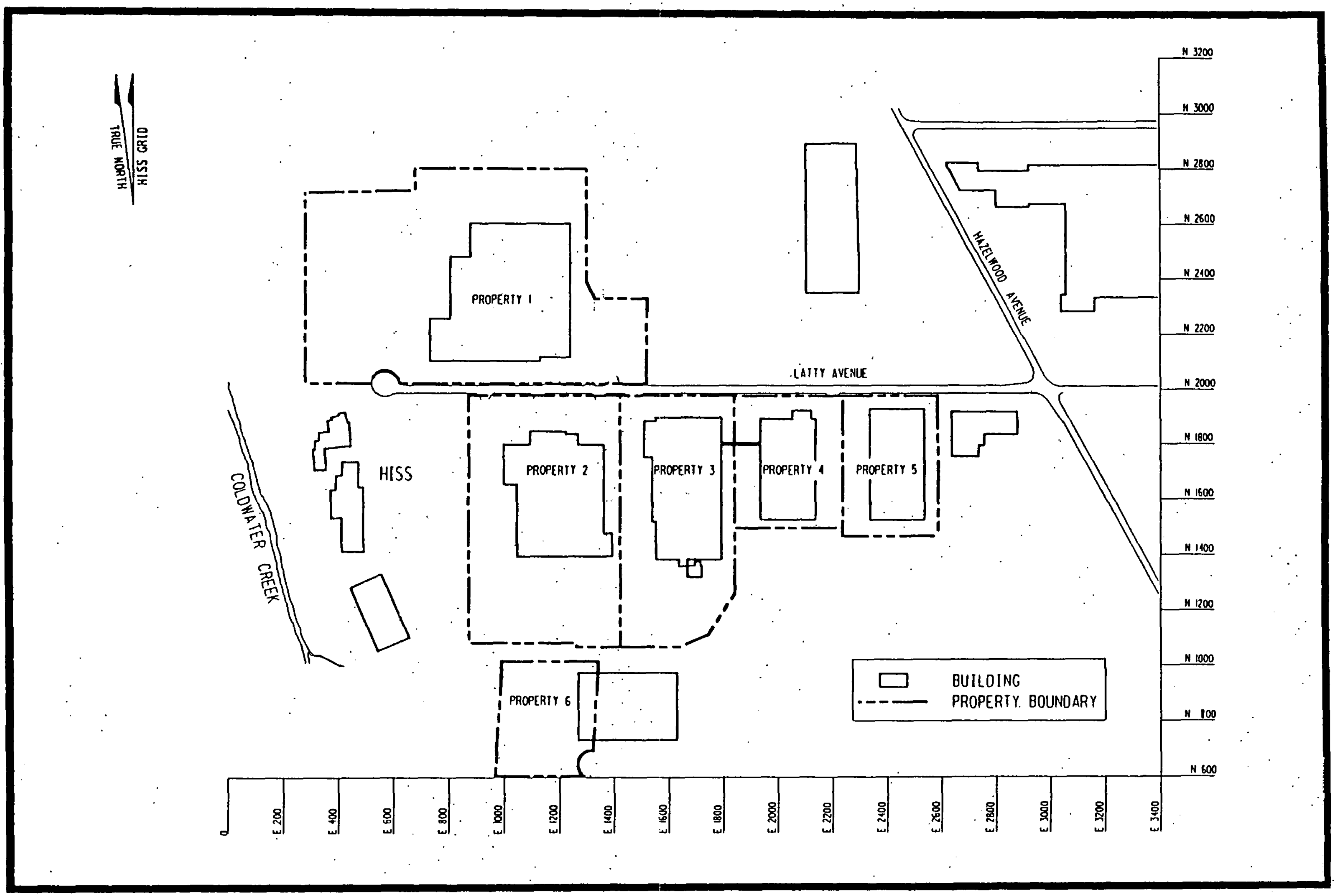

FIGURE 1-7 LOCATIONS OF LATTY AVENUE AND VICINITY PROPERTIES

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electric and telephone lines and underground gas and sanitary sewer lines extending to the Futura buildings; however, there are no sanitary sewer lines to HISS and the site facilities use holding tanks. Storm sewer lines are located along the eastern boundary. The vicinity properties are relatively level and have been developed with commercial buildings, paved parking lots, and open, grassy areas along Latty Avenue.

The residues transferred from SLAPS to HISS in 1966 included 13 tons of uranium and 32,500 tons of leached barium sulfate containing 7 tons of uranium. All of these residues and wastes were placed directly on the ground. The Commercial Discount Corporation of Chicago purchased the residues in January 1967, dried them, and shipped much of the material to Cotter Corporation facilities in Canon City, Colorado. The material remaining at Latty Avenue was sold to Cotter in 1969. In 1970, Cotter dried and shipped some of the remaining residues to its mills in Canon City. These residues included approximately 10,000 tons of Colorado raffinate (a term given to the residue by those who did the original processing at Mallinckrodt) and 8,700 tons of leached barium sulfate.

In 1973, Cotter shipped undried Colorado raffinate to Canon City and transported the leached barium sulfate, diluted with 30 to 40 cm (12 to 18 in.) of topsoil, to the West Lake Landfill in St. Louis County. Cotter informed the Nuclear Regulatory Commission (NRC) of this activity in early 1974.

In 1976, measurements taken at HISS and Futura by NRC indicated residual uranium and thorium concentrations and gamma exposure levels exceeding existing guidelines for release of the property without radiological restrictions. ORNL performed a radiological characterization of HISS in 1977, before the property was occupied by the present owner. Surface contamination exceeding DOE guidelines for thorium and radium was found in and around the buildings and in the soil to depths of 45 cm (18 in.) (ORNL 1977).

In June 1977, the building and grounds at Latty Avenue were purchased by Mr. E. Dean Jarboe, who currently operates Futura Coatings, Inc. (located on the western portion of the property).

Mr. Jarboe prepared the property for use by demolishing some buildings, erecting some new ones, and clearing a 1.4-ha (3.5-acre) tract of land surrounding them. Material resulting from this cleanup was placed in interim storage on the eastern portion of the property (ORAU 1981).

In 1981, Oak Ridge Associated Universities (ORAU) characterized the storage pile at HISS and performed a radiological survey of the northern and eastern boundaries of HISS for NRC (ORAU 1981).

In 1981, DOE directed BNI to provide radiological support for workers involved in street improvements along Latty Avenue. Based on results of surveys performed during that time, 3,517 m^3 (4,600 yd^3) of contaminated soil was removed and placed in a second storage pile at HISS. Sampling performed in the excavated areas after the removal action showed no radioactive contamination exceeding DOE remedial action guidelines. Approximately 24,500 m^3 (32,000 yd^3) of contaminated soil and debris is contained in the two covered piles at HISS.

In September 1983, ORNL performed a preliminary survey of properties in the vicinity of HISS to determine whether radioactive contamination in excess of guidelines was present. The areas identified as potentially contaminated were more thoroughly surveyed by ORNL in January and February 1984.

1.3 REPORT ORGANIZATION

This RI report is organized to provide the information required by NEPA and CERCLA. Before the Superfund Amendments and Reauthorization Act (SARA) of 1986 was enacted, FUSRAP activities were primarily conducted in accordance with NEPA requirements. With the enactment of SARA, CERCLA was amended, and the responsibilities of federal agencies under CERCLA were clarified. DOE established a policy integrating the requirements of CERCLA and NEPA; the NEPA elements are incorporated in the CERCLA documents, and the resulting documentation is the RI/FS-EIS report.

Section 2.0 of this document describes radiological and chemical sample collection methods and sampling locations for surface and subsurface soil, groundwater, surface water and sediments, air, and geological and hydrogeological samples. Section 3.0 summarizes the field data and describes the nature and extent of contamination at each of the St. Louis properties. Section 4.0 describes the potential transport pathways of contaminants at the St. Louis site. Section 5.0 summarizes the major types, locations, and extent of contamination at each of the properties. A list of references follows Section 5.0.

The St. Louis RI differs from most FUSRAP site RIs in that most of the field work is already complete, and the remaining RI field activities will be completed before the RI/FS-EIS work plan (BNI 1991) is issued for public review. Accordingly, the work plan summarizes completed field activities rather than providing a field sampling plan. In many cases, such topics as land use and demography are presented in the work plan in more detail than in the RI report. The work plan includes sections on potential risks of exposure, contaminants of concern, and other topics that were originally to be included in the RI report. The RI report does include a section on potential contaminant transport pathways.

2.0 STUDY AREA INVESTIGATIONS

In general, the field investigations conducted at the St. Louis site consisted of the following steps:

- Establishing a reproducible grid system
- Clearing the area to be surveyed
- Performing gamma radiation walkover scans and near-surface gamma radiation measurements
- Taking direct alpha and beta-gamma measurements on structure surfaces
- Collecting and analyzing samples for radiological and chemical constituents
- Collecting and analyzing geologic and hydrogeologic data for SLDS, SLAPS, and HISS to characterize subsurface transport pathways

The primary goal of the field investigations was to identify areas containing residual radioactive contamination in excess of the DOE residual contamination guidelines (Table 1-1). Table 2-1 presents a summary of characterization objectives, field activities, and references in which the field data are presented and interpreted.

During these investigations, QA objectives and requirements (as described in Appendix A) were identified and followed.

2.1 FIELD ACTIVITIES

In general, the field activities consisted of investigating the following potential media of contamination: surface and subsurface soils, groundwater, surface water and sediments, building surfaces, and air. These media were investigated at each property, with the following exceptions. No building investigations were conducted at SLAPS and HISS because there are no buildings on these properties. No surface water and sediment investigations were conducted at Futura Coatings because the results of these investigations at HISS also apply to Futura Coatings because of its proximity to HISS.

Table 2-1

Summary of Data Objectives and Field Activities for the St. Louis Site

Operable Unit/ Data Objective	Status	Chemical Characterization[a]	Radiological Characterization	Geological/ Physical Characterization	Reference
SLDS					
Determine nature and extent of contamination; identify indicator contaminants; determine presence of RCRA-hazardous wastes.	Complete		ORNL radiological survey.		(ORNL 1981)
	Complete (1987-1988) except for radiological surveys of sumps/drains and building interiors.	Phase I - Analyzed soil samples from 59 boreholes for metals, VOCs, semivolatiles, and RCRA characteristics. Phase II - Sampled and analyzed soil from 51 boreholes for chemical constituents to further define boundaries of chemical contamination by testing for metals and RCRA characteristics.	BNI characterization, which included walkover gamma scans conducted on the city property and portions of SLDS, gamma logging in boreholes to identify areas of elevated radioactivity in subsurface soils. 297 surface samples collected and 218 boreholes sampled; analyzed for uranium-238, radium-226, thorium-232, and thorium-230.	BNI installed 10 geologic boreholes (9 of which were completed as monitoring wells).	(BNI 1990a)
Investigate potential migration of contaminants from soil into groundwater.	Complete (1987-1988)	BNI analysis of groundwater from 8 wells (4 deep, 4 shallow) for various chemical parameters including VOCs, semivolatiles, pesticides, PCBs, metals, pH, specific conductance, TOX, and TOC.	BNI analysis of samples from 9 wells quarterly for uranium-238, radium-226, thorium-230, and thorium-232.		(BNI 1990a)

Operable Unit/ Data Objective	Status	Chemical Characterization[a]	Radiological Characterization	Geological/ Physical Characterization	Reference
SLAPS					
Determine extent and nature of surface and subsurface radioactive and chemical contamination including RCRA wastes.	Complete (1986, 1988)	BNI limited characterization to provide information regarding the nature and potential presence of hazardous wastes in soil. 30 boreholes sampled and 109 samples analyzed for metals, mobile ions, VOCs, semivolatiles, and RCRA wastes.	ORNL radiological investigation of drainage ditches designated for remedial action. BNI radiological survey of ditches. BNI radiological characterization of the property, which included walkover gamma scans, near-surface gamma radiation levels, gamma radiation exposure rates, downhole gamma logging to identify areas of elevated radioactivity in subsurface soils. Analyzed samples from 102 boreholes for uranium-238, radium-226, thorium-232, and thorium-230 in some cases.	18 geologic boreholes (backfilled with grout).	(ORNL 1979, BNI 1990c, BNI 1990b, BNI 1987a)
Determine baseline conditions of and monitor changes in groundwater and surface water, radon concentrations, and gamma radiation levels to determine whether leakage of contaminants is occurring.	Ongoing (1984-present)	BNI environmental monitoring: quarterly analysis of groundwater for pH, specific conductance, TOC, TCX, and metals (1988-1989) BNI analysis for metals in groundwater for 5 quarters.	BNI environmental monitoring includes groundwater, sediment, and surface water for uranium, radium-226, thorium-232, thorium-230, radon, and external gamma radiation levels. 12 radon monitoring locations.		(BNI 1990c, BNI 1991)
	Complete			10 monitoring wells for environmental monitoring program.	(BNI 1991)
	Complete			Canvass area wells.	
	Complete (1989)	BNI priority pollutant analysis of groundwater			(BNI 1990c)

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization[a]	Radiological Characterization	Geological/ Physical Characterization	Reference
HISS					
Determine nature and extent of surface and subsurface contamination; identify indicator contaminants; determine presence of RCRA-hazardous wastes.	Complete (1986, 1988)	BNI characterization included analysis for RCRA waste characteristics, mobile ions, metals, VOCs, and semivolatiles. 15 samples analyzed (3 random boreholes and 3 biased boreholes).	NRC radiological survey. ORNL radiological characterization. ORAU radiological characterization of storage pile at HISS. ORNL detailed radiological survey of north and south shoulders of Latty Avenue. BNI radiological characterization included walkover surveys, near-surface gamma measurements, gamma exposure rates, downhole gamma logging in all boreholes, continuous sampling at 1-ft increments in each borehole, and analysis for uranium-238, radium-226, and thorium-232. Selected samples from 36 boreholes analyzed for thorium-230.		(ORNL 1986b, ORAU 1981, BNI 1990e, BNI 1987b, BNI 1990b)
Determine baseline conditions of and monitor changes in groundwater and surface water, radon concentrations, and gamma radiation levels to determine whether leakage of contaminants is occurring.	Ongoing (1984-present)	BNI environmental monitoring: quarterly analysis of groundwater for pH, specific conductance, TOC, TOX, and metals (for 5 quarters during 1988 and 1989).	BNI environmental monitoring includes groundwater, sediment, and surface water for uranium, radium-226, thorium-230, radon, and external gamma radiation levels. 13 radon monitoring locations.	10 monitoring wells.	(BNI 1990e)
	Complete			Canvass area wells.	
	Complete (1989)	BNI priority pollutant analysis of groundwater			(BNI 1990e)

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization[a]	Radiological Characterization	Geological/ Physical Characterization	Reference
Futura Coatings, Inc.					
Determine nature and extent of surface and subsurface contamination; identify indicator contaminants; determine extent of contamination inside buildings.	Complete (1986, 1988)	BNI characterization included analysis for RCRA waste characteristics, mobile ions, metals, VOCs, and semivolatiles. 3 random boreholes and 3 biased boreholes.	ORNL radiological characterization. BNI characterization. Phase I - Environmental monitoring inside buildings for radon and gamma levels and gross alpha concentrations. Phase II - Included walkover surveys, near-surface gamma measurements, gamma exposure rates, downhole gamma logging allowing selected samples to be analyzed for uranium-238, radium-226, thorium-232, and thorium-230. Forty-eight exterior boreholes were drilled. All samples taken from 10 boreholes beneath the building were analyzed.		(ORNL 1986b, BNI 1987c). (BNI 1990b)

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization[a]	Radiological Characterization	Geological/ Physical Characterization	Reference
VICINITY PROPERTIES					
Ball field near SLAPS					
Determine nature and extent of contamination; identify indicator contaminants; determine presence of RCRA-hazardous wastes; determine the boundaries of contamination.	Complete (1988)	BNI chemical characterization. Samples from 11 boreholes analyzed for mobile ions, VOCs, semivolatiles, RCRA characteristics, pesticides/PCBs, and metals.	BNI radiological characterization included near-surface gamma measurements and downhole gamma logging, and analysis of 680 soil samples (some composites) for uranium-238, radium-226, thorium-232, and/or thorium-230.	27 monitoring wells.	(BNI 1989a, BNI 1990d).
Ditches north and south of SLAPS					
Determine nature and extent of radioactive contamination.	Complete (1988-1991)	None	BNI radiological characterization included near-surface gamma measurements, downhole gamma logging, and analysis of surface and subsurface samples from 87 radiological boreholes for uranium-238, radium-226, thorium-232, and/or thorium-230.		(BNI 1990d)
St. Louis Airport Authority property					
Determine nature and extent of radioactive contamination.	Complete (1988-1991)	None	BNI radiological characterization included near-surface gamma measurements, downhole gamma logging, and analysis of soil samples from 66 radiological boreholes for uranium-238, radium-226, thorium-232, and/or thorium-230.		(BNI 1990d)

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization	Radiological Characterization	Geological/ Physical Characterization	Reference
Coldwater Creek					
Determine boundaries and extent of radioactive contamination and determine whether chemical contamination exists along the creek.	Complete (1982-1991)	Analyzed 4 samples for metals, mobile ions, volatiles, and semivolatiles.	BNI radiological characterization of ditches and portions of Coldwater Creek.		(BNI 1990d)
			BNI radiological characterization of Coldwater Creek from SLAPS to HISS included drilling 519 radiological boreholes, walkover gamma survey, downhole gamma logging, sediment sampling, and analyzing samples for uranium-238, radium-226, thorium-232, and/or thorium-230.		(BNI 1990d)
			Analyzed 125 samples for all radionuclides of interest from areas on either side of Coldwater Creek extending to the Missouri River.		
			Analyzed 100 samples for all radionuclides of interest extending 1.5 mi past previous survey.		
			Analyzed 100 samples for all radionuclides of interest extending 4.8 mi from Bruce Drive in Florissant to Old Halls Ferry Road.		

Operable Unit/ Data Objective	Status	Chemical Characterization	Radiological Characterization	Geological/ Physical Characterization	Reference
<u>Coldwater Creek vicinity properties</u>					
Determine extent and boundaries of radioactive contamination.	Complete (1988-1991)	None	BNI radiological characterization included walkover gamma scans and downhole gamma logging. Analyzed 120 samples for uranium-238, radium-226, thorium-232, and thorium-230.		(BNI 1990d)
Determine nature of chemical contamination present in sediment in Coldwater Creek.	Complete (1988)	BNI collected sediment samples at 4 locations. Analyzed for metals, mobile ions, VOCs, semivolitiles.			
<u>Haul roads vicinity properties</u>					
Determine extent and boundaries of radioactive contamination.	Complete (1988-1991)	None	ORNL radiological survey. BNI analyzed 3,000 soil samples for thorium-230. Further characterization of 13 properties involved analyzing 240 soil samples (to a depth of 3 ft) for uranium-238, radium-226, thorium-232, and thorium-230.		(ORNL 1986a, BNI 1990d)
<u>Norfolk and Western Railroad property</u>					
Determine extent and boundaries of radioactive contamination.	Complete (1988-1991)	None	BNI characterization included gamma exposure rates, downhole gamma logging, analysis of soil samples from 200 radiological boreholes for uranium-238, radium-226, thorium-232, and/or thorium-230.		(BNI 1990d)

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization	Radiological Characterization	Geological/ Physical Characterization	Reference
Railroad property adjacent to Coldwater Creek					
Determine extent and boundaries of radioactive contamination.	Complete (1988-1991)	None	Radiological characterization included analyzing 120 samples from 30 radiological boreholes for uranium-238, radium-226, thorium-232, and thorium-230.		(BNI 1990d)
Banshee Road					
Determine extent and boundaries of radioactive contamination.	Complete (1988-1991)	None	BNI radiological characterization included downhole gamma logging in 47 boreholes. Analyses for uranium-238, radium-226, thorium-232, and/or thorium-230 were conducted for soil samples from 48 boreholes.		(BNI 1990d)
SLDS vicinity properties					
Determine nature and extent of radioactive contamination.	Complete (1990-1991)	None	BNI preliminary radiological characterization included analyses of soil samples for uranium-238, radium-226, thorium-232, and thorium-230.		

Table 2-1
(continued)

Operable Unit/ Data Objective	Status	Chemical Characterization	Radiological Characterization	Geological/ Physical Characterization	Reference
Hanley Road at intersection with Latty Avenue					
Determine extent and boundaries of radioactive contamination.	Complete (1990-1991)	None	Further radiological characterization included analysis of soil samples from 12 boreholes for uranium-238, radium-226, thorium-232, and thorium-230.		(BNI 1990d)
Pathway from SLDS to SLAPS					
Determine whether radioactive contamination exists on possible transportation routes.	Complete (1990)	None	ORNL conducted gamma scan from SLDS to SLAPS.		
Intersections from HISS to West Lake Landfill					
Determine whether radioactive contamination exists on possible transportation routes.	Complete (1990-1991)	None	ORNL conducted gamma scan from HISS to West Lake Landfill. BNI collected 212 soil samples from 28 intersections and analyzed them for uranium-238, radium-226, thorium-232, and thorium-230.		

[a]VOC - volatile organic compound; RCRA - Resource Conservation and Recovery Act; PCB - polychlorinated biphenyl; TOX - total organic halides; TOC - total organic carbon; BNAE - base/neutral and acid extractable.

Similarly, no groundwater, surface water and sediment, or air investigations were conducted at the vicinity properties of SLDS, SLAPS, and Latty Avenue (except for the ball field area of SLAPS and Coldwater Creek) because of their proximity to these properties and because environmental monitoring has indicated no need to monitor offsite.

Geological and hydrogeological characterization activities were conducted to:

- Identify subsurface geological materials
- Determine distribution and relationship of subsurface materials
- Determine water table or potentiometric surfaces of aquifers in the groundwater system
- Establish access for the collection of water samples
- Determine potential for contaminants to migrate offsite

Installation of geologic boreholes was dependent on property access and physical plant obstructions. Monitoring wells were sited to establish a representative geological profile, background groundwater quality, hydraulic gradients, and flow direction. No geological or hydrogeological investigations were conducted at the vicinity properties of SLDS, SLAPS (except for the ball field), and Latty Avenue because of their proximity to these properties, which were investigated.

2.1.1 Investigations at SLDS

Surface and subsurface soils

Based on previous surveys and walkover gamma scans, large areas of SLDS were thought to be contaminated; therefore, the field investigation was divided into two phases. Phase I consisted of determining the horizontal and vertical extent of contamination in the areas previously known to be contaminated and identifying other areas of contamination at the property. Phase II focused on the new areas identified during Phase I.

In Phase I, the surface and subsurface soils investigation was initiated in 1987 by determining the locations of underground utilities and surveying the property to establish a 15-m (50-ft) grid system. A walkover gamma scan was then performed to identify areas of elevated gamma radiation. Using a PRS-1 scaler coupled to an unshielded Eberline SPA-3 probe, 15- by 15-m (50- by 50-ft) grid sections were scanned, and the ranges of radioactivity in each section were recorded for each plant.

Using stainless steel spoons and/or motor-driven augers, surface soil samples were collected from 297 locations from areas where drill rigs could not enter and from areas identified during the walkover gamma scan as requiring biased sampling (Figure 2-1). Subsurface soil samples were collected from the 109 boreholes drilled during Phase I in 1987 (Figure 2-2); all chemical samples were collected with stainless steel split-spoon samplers.

Soil samples from 59 boreholes were analyzed for chemical constituents to characterize subsurface conditions; composite and discrete samples were taken from each plant area where radioactive contamination had been detected. (Composite samples are samples taken from several locations or depths and then consolidated into one sample for analysis.) These samples, taken from ground surface to undisturbed soil, were collected and analyzed for metals, Resource Conservation and Recovery Act (RCRA)-hazardous waste characteristics [extraction procedure (EP) toxicity, ignitibility, reactivity, and corrosivity], and base/neutral and acid extractable (BNAE) organic compounds. Discrete samples collected randomly in 23 of the holes were analyzed for volatile organic compounds (VOCs) because compositing the sample could have resulted in the loss of VOC constituents due to evaporation before analysis.

The Phase II activities conducted in 1988 and 1989 included drilling and sampling an additional 109 boreholes (Figure 2-2) Samples from 51 of these boreholes were also analyzed for chemical constituents to determine whether chemical contaminants were mixed with the radioactive contamination. Boreholes were drilled in

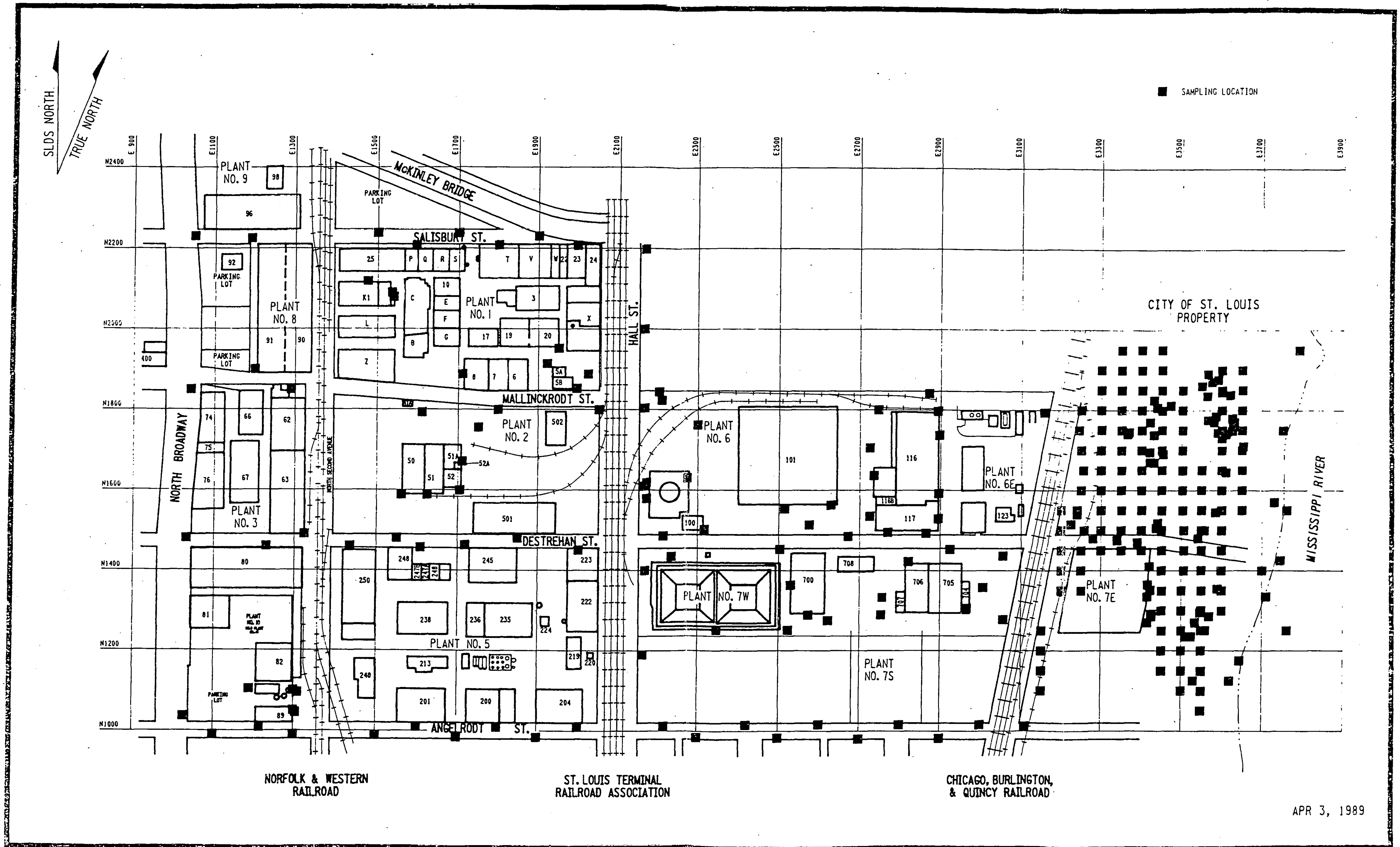

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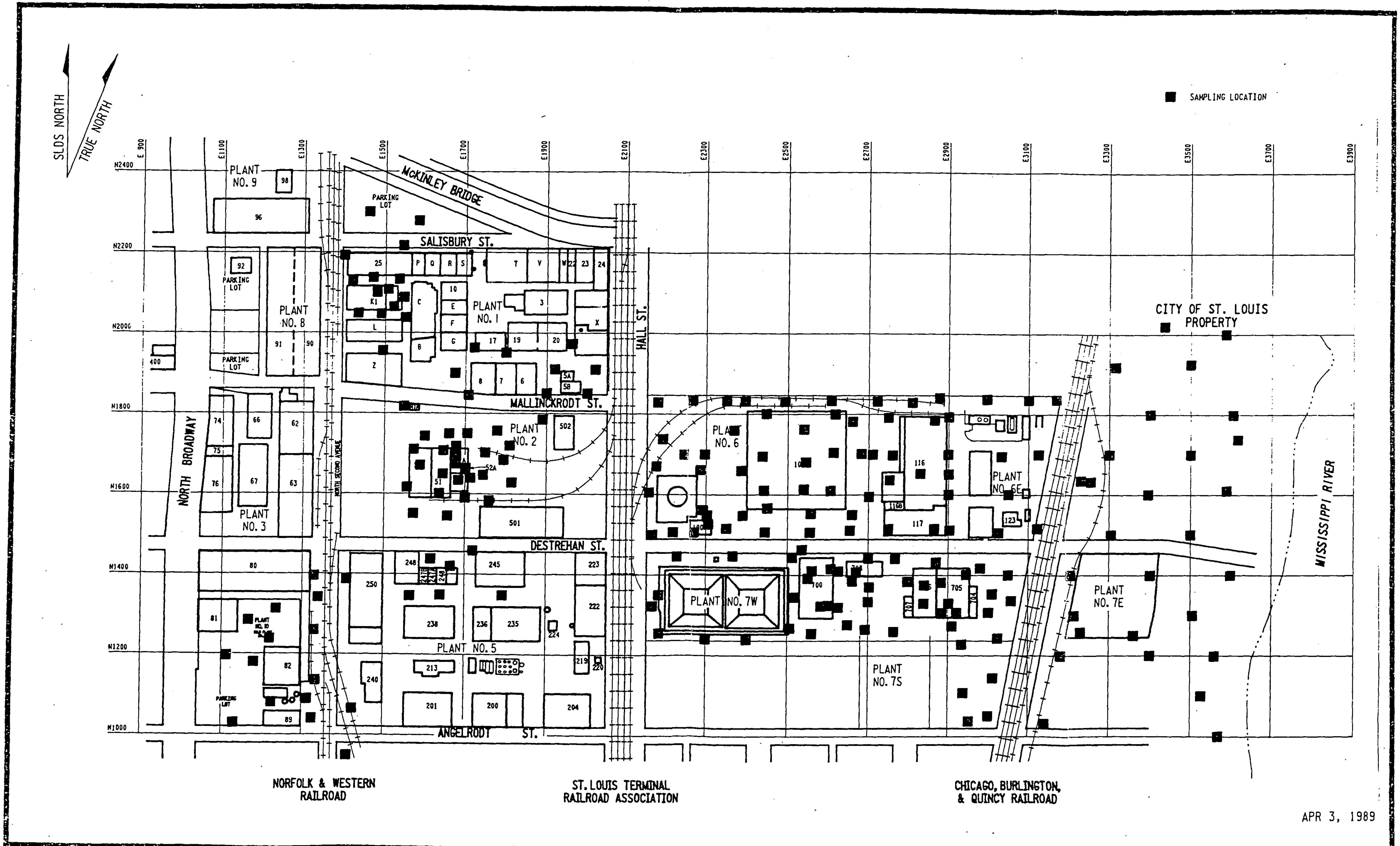
FIGURE 2-1 SURFACE SOIL SAMPLING LOCATIONS AT SLDS



116F022.DGN BORE

FIGURE 2-2 PHASE I AND PHASE II BOREHOLE LOCATIONS AT SLDS undisturbed soil to a depth of 0.7 m (2 ft). Samples were collected from two or three intervals per borehole and analyzed for metals. Seven composite samples, taken from ground surface to undisturbed soil, were collected and analyzed for RCRA-hazardous waste characteristics.

The 218 boreholes installed at SLDS during Phases I and II were gamma-logged, and continuous samples were collected to ascertain whether radiation levels in subsurface soil were elevated. Gamma logging involves lowering a Bicron BHP-2 detector coupled to an MS-2 scaler into the hole. The BHP-2 probe consists of an NaI(Tl) crystal coupled to a photomultiplier tube with a section of lead attached to the bottom of the crystal for geometric compensation at the bottom of the hole; the MS-2 scaler determines instrument response at a particular depth in the hole. Samples obtained from intervals selected based on the gamma logs were analyzed for uranium-238, radium-226, thorium-232, and thorium-230. The vertical extent of contamination was determined assuming 50 pCi/g as the uranium guideline. Samples that were not analyzed for radiological parameters were archived for later retrieval and analysis, if necessary.

All samples were stored, packed, and shipped in the appropriate laboratory-supplied containers to the laboratory for analysis.

For more information regarding the soils investigation at SLDS, refer to BNI 1990a.

Groundwater

Nine of the ten geologic boreholes at SLDS were converted into groundwater monitoring wells (Figure 2-3) and were monitored quarterly for radiological and chemical parameters for one year.

Groundwater sampling was conducted by purging the wells, decontaminating the bailer, and collecting the water sample. Purging ensures that fresh aquifer water enters the well, and decontamination of the sampling equipment ensures that no cross-contamination occurs between wells. The wells were purged by hand-bailing three casing volumes of water with a Teflon bailer.

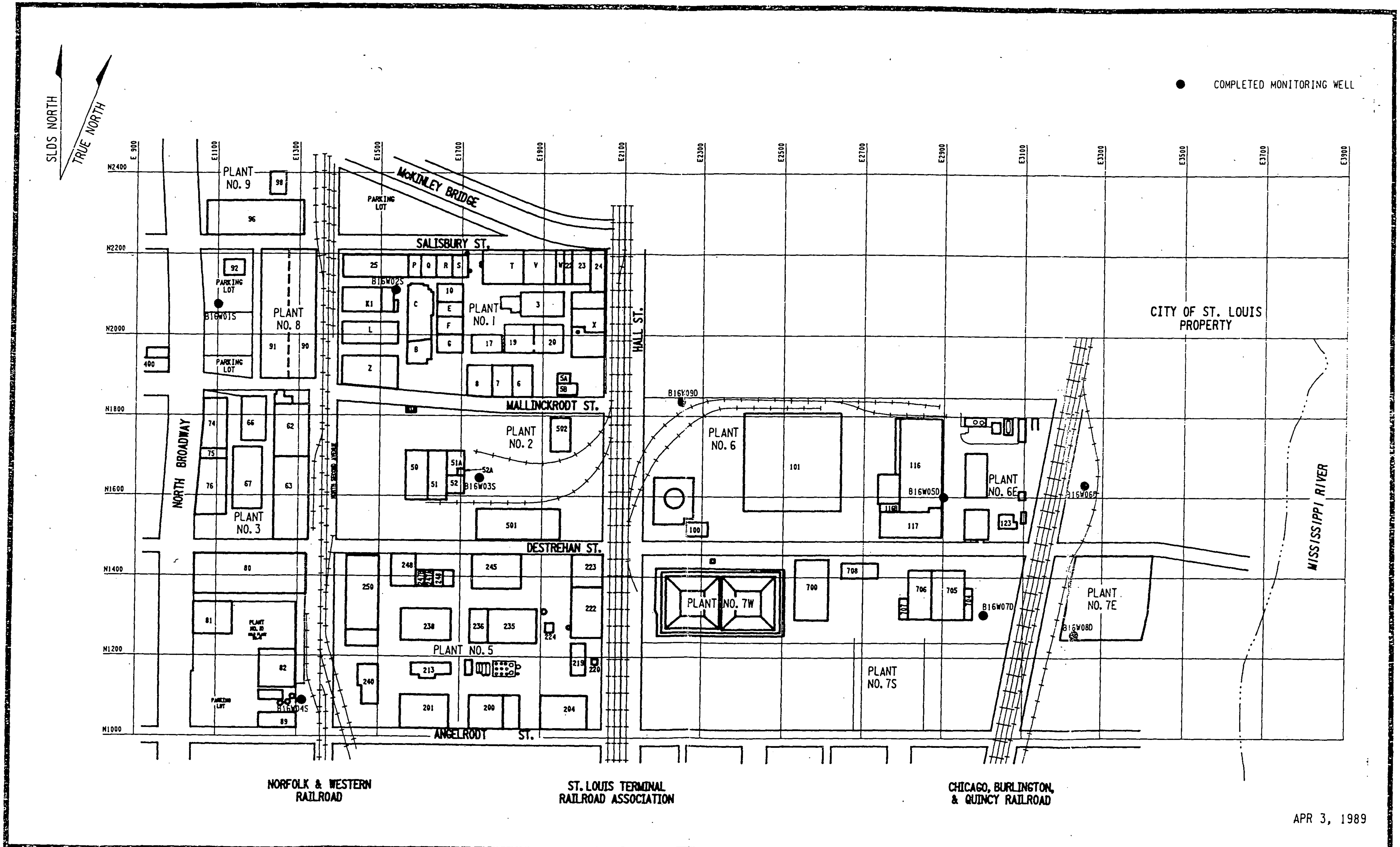


FIGURE 2-3 GROUNDWATER MONITORING WELL LOCATIONS AT SLDS

The geologic boreholes were reamed to 29 cm (11.5 in.) using a 2-ft-long bucket auger. A 10-in. polyvinyl chloride (PVC) conductor casing was installed and tremie-grouted with bentonite cement. The boreholes were advanced into undisturbed material using 8.25-in. hollow-stem augers and completed as monitoring wells in the unconsolidated alluvium above bedrock. Samples were obtained by using the standard penetration test method with 2-in. split spoons at 1.5-m (5-ft) intervals to refusal at the top of rock. At monitoring well locations B16W06D, B16W07D, and B16W09D (Figure 2-3), the drill hole was advanced and core samples were retrieved using an NX split-barrel tube and coring equipment, which bore a 91.8-cm (3.62-in.) hole. Drill holes at B16W06D and B16W07D were advanced 3 m (10 ft) into bedrock, and the drill hole at B16W09D was advanced 1.1 m (3.5 ft). The drilling fluid was hydrant water, which was sampled and analyzed for chemicals. Constant-head, packer permeability tests were performed in the cored 1.5-m (5-ft) intervals of locations B16W06D and B16W07D.

Samples were collected at the screen level of the well and were analyzed for total uranium, radium-226, and thorium-230. Groundwater samples were not analyzed for thorium-232 because soil samples had shown only minimal residual thorium-232.

The wells were also sampled for a wide range of chemical parameters, including VOCs, BNAEs [including polynuclear aromatic hydrocarbons (PAHs)], metals, pH, specific conductance, total organic carbon (TOC), and total organic halogens (TOX). Fluoride and nitrate samples were also collected during one quarter.

For more information regarding the groundwater investigation, refer to BNI 1990a.

Surface water and sediments

Eighty-four manholes at SLDS were surveyed to determine whether residual radioactivity is present. They were surveyed by lowering the Bicron BHP-2/MS-2 (the same instrument used to gamma-log boreholes) into the drainage pathway and recording the instrument response. If access permitted, sludge and/or sediment samples were collected from the drainage pathway and analyzed for radioactive constituents.

For more information on this investigation, refer to BNI 1990a. Additional sediment sampling will be conducted along the banks of the Mississippi River to better define the boundaries of contamination.

Buildings

The buildings were investigated to determine whether radioactivity exceeding guideline levels existed on building surfaces; precise boundaries of contamination were not determined. Based on previous FUSRAP experience, performing final building surveys immediately before remedial action is more practical than during preliminary characterization -- especially in operating facilities -- because of the potential for changing processes, uses, and operations that could alter the nature and extent of surface contamination. Based on the limited surveys that were performed, general areas of contamination were identified and levels of radioactivity on building surfaces were measured.

Buildings K1E, 25, 50, 51, 51A, 52, 52A, 81, 82, 100, 101, 116, 116B, 117, 700, 704, 705, 706, 707, and 708 at SLDS were surveyed as part of Phase I to determine whether radioactivity exists on structure surfaces and to confirm the extent determined during previous surveys. Floors, walls, ceilings, and roofs were investigated for direct alpha, direct beta-gamma, and removable contamination using spot surveys, where appropriate. Direct alpha measurements were taken using an AC-3 detector coupled to a PRS-1 scaler, and direct beta-gamma measurements were taken using an HP-210 detector coupled to a PRS-1 scaler.

Samples collected in these buildings were analyzed for uranium-238, radium-226, thorium-232, and thorium-230. Sampling in Buildings 51A and 52A was deemed unnecessary because they adjoin Buildings 51 and 52, respectively. Building 100 was not sampled because it was constructed after MED/AEC activities ceased. The samples were collected from horizontal surfaces such as window ledges, overhead beams, stairs, and floors where surface deposit buildup was observed. To locate areas of removable contamination, surface areas of about 100 cm^2 (15.5 $in.^2$) were wiped by applying moderate pressure to a smear cloth. The smears were placed in a light-tight smear holder, and the alpha levels were counted by an SAC-4 alpha counter (a ZnS detector coupled with a photomultiplier tube). The SAC-4 measures alpha contamination to levels of a few disintegrations per minute (dpm). The analytical results aided in determining the major contaminant(s) in each building.

For more information regarding the radiological investigation of buildings at SLDS, refer to BNI 1990a.

Air

Radon measurements were taken in 19 buildings at SLDS that were associated with MED/AEC activities, once in March 1990 and again in September 1990. Twenty-nine charcoal canisters were placed on the basement or ground floors in the following buildings: K1E, 25, 50, 51, 51A, 52, 52A, 81, 82, 100, 101, 116, 117, 700, 704, 705, 706, 707, and 708; the canisters were left for three days before being evaluated.

In addition, 22 Terradex cups were placed in these same buildings (except for Building 52) for 30 days to obtain radon data. Terradex Type F Track-Etch monitors consist of alpha-sensitive film contained in small plastic cups covered by membranes through which radon can diffuse. Radon will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, it will equilibrate with radon in the outside air. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. When returned to the Terradex Corporation for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification, the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm^2) is related through calibration to the concentration of radon in air. Fresh Track-Etch monitors are obtained from Terradex for each sampling period. Site personnel place a new unit in each sampling station and return the exposed monitors to Terradex for analysis. For more information about radon monitoring at SLDS, refer to BNI 1991 (draft).

Geology and hydrogeology

The geological investigation at SLDS was conducted by gathering information during the installation of 218 boreholes (Figure 2-2). Ten geologic boreholes were installed by drilling a minimum of 0.7 m (2 ft) into undisturbed soil using hollow-stem augers and cutter heads. Nine of the ten boreholes were converted to groundwater monitoring wells to help define hydrogeological conditions at the property. Static water levels were measured before the temporary casing was removed.

Construction methods, elevations, dimensions, and intervals for each monitoring well are described in BNI 1990a.

2.1.2 Investigations at the SLDS Vicinity Properties

Areas exhibiting radioactive contamination that may have originated at SLDS are referred to as vicinity properties (Figure 1-2). The soils investigation at each of the seven properties was carried out by conducting gamma scans to identify areas of elevated gamma radiation and then taking samples from a maximum depth of 1 m (3 ft), using hand-held sampling equipment. The samples from each property were analyzed for uranium-238, radium-226, thorium-230, and thorium-232. The following is a brief discussion of the sampling program used at each of the SLDS vicinity properties.

McKinley Iron Company property

The McKinley Iron Company is immediately north of SLDS Plant 6, adjacent to the SLDS property boundary. This property was investigated by collecting 42 samples from 39 locations (Figure 2-4).

PVO Foods, Inc., property

The PVO Foods, Inc., property is immediately south of SLDS Plant 7E and is bordered on the west by railroad tracks. Thirteen samples were collected from nine locations at this property (Figure 2-5).

Thomas and Proetz Lumber Company property

The Thomas and Proetz Lumber Company is immediately south of SLDS Plant 7, adjacent to the SLDS property boundary. The eastern portion of the property (formerly SLDS Plant 7S) is leased by Thomas and Proetz from Mallinckrodt, Inc. This property was investigated by collecting 65 samples from 48 locations (Figure 2-6).

St. Louis Terminal Railroad Association property

The St. Louis Terminal Railroad Association property is a narrow strip of land running north and south, bisecting SLDS, adjacent and parallel to Hall Street. The property consists solely of railroad tracks used for commercial transport. It was investigated by collecting 32 samples from 29 locations (Figure 2-7).

Norfolk and Western Railroad property

The Norfolk and Western Railroad property is located in the western portion of SLDS. The property is a narrow strip of land running north and south, adjacent and parallel to North Second Avenue, and containing railroad tracks used for commercial transport. Thirty-four samples were collected from 24 locations (Figure 2-8).

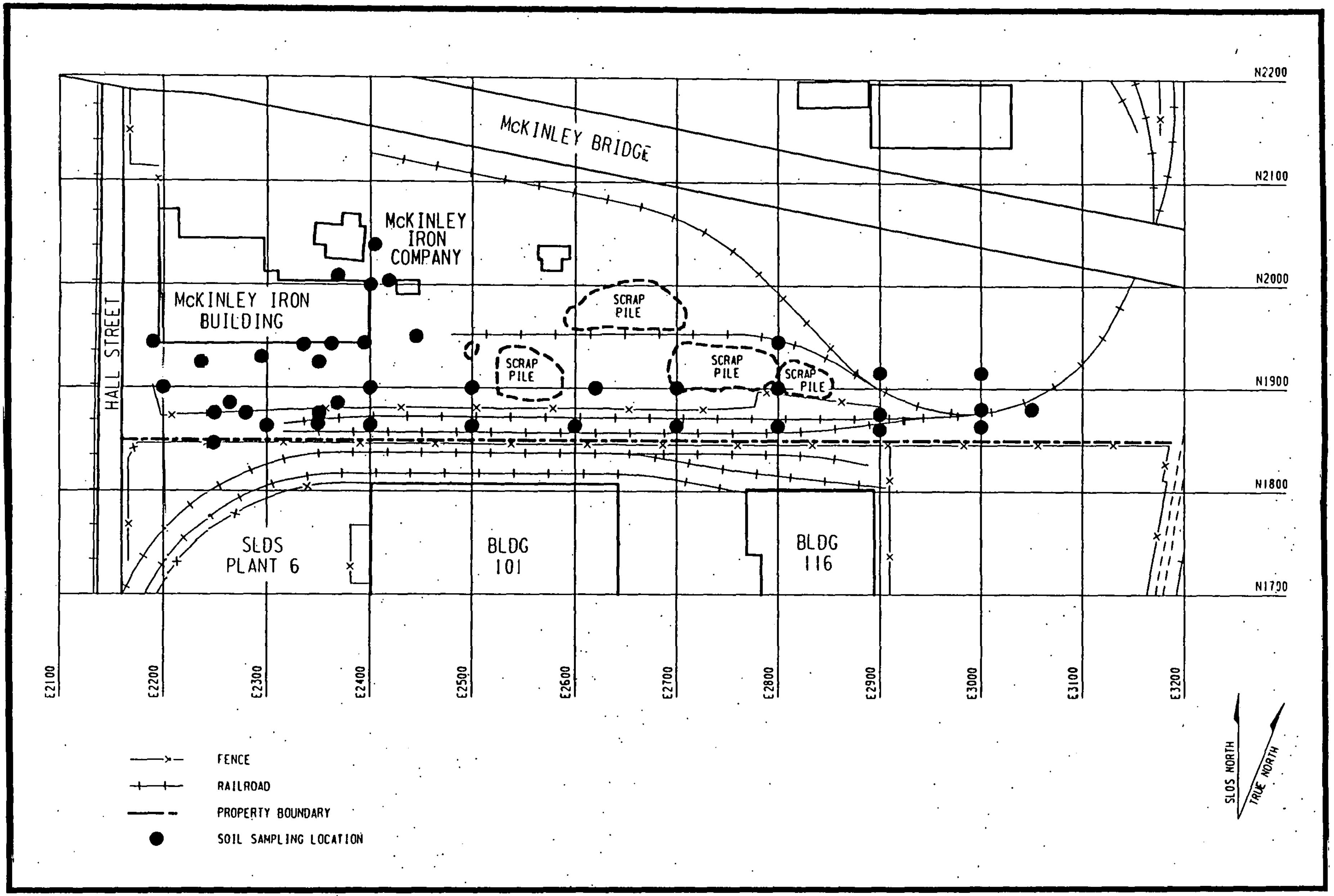


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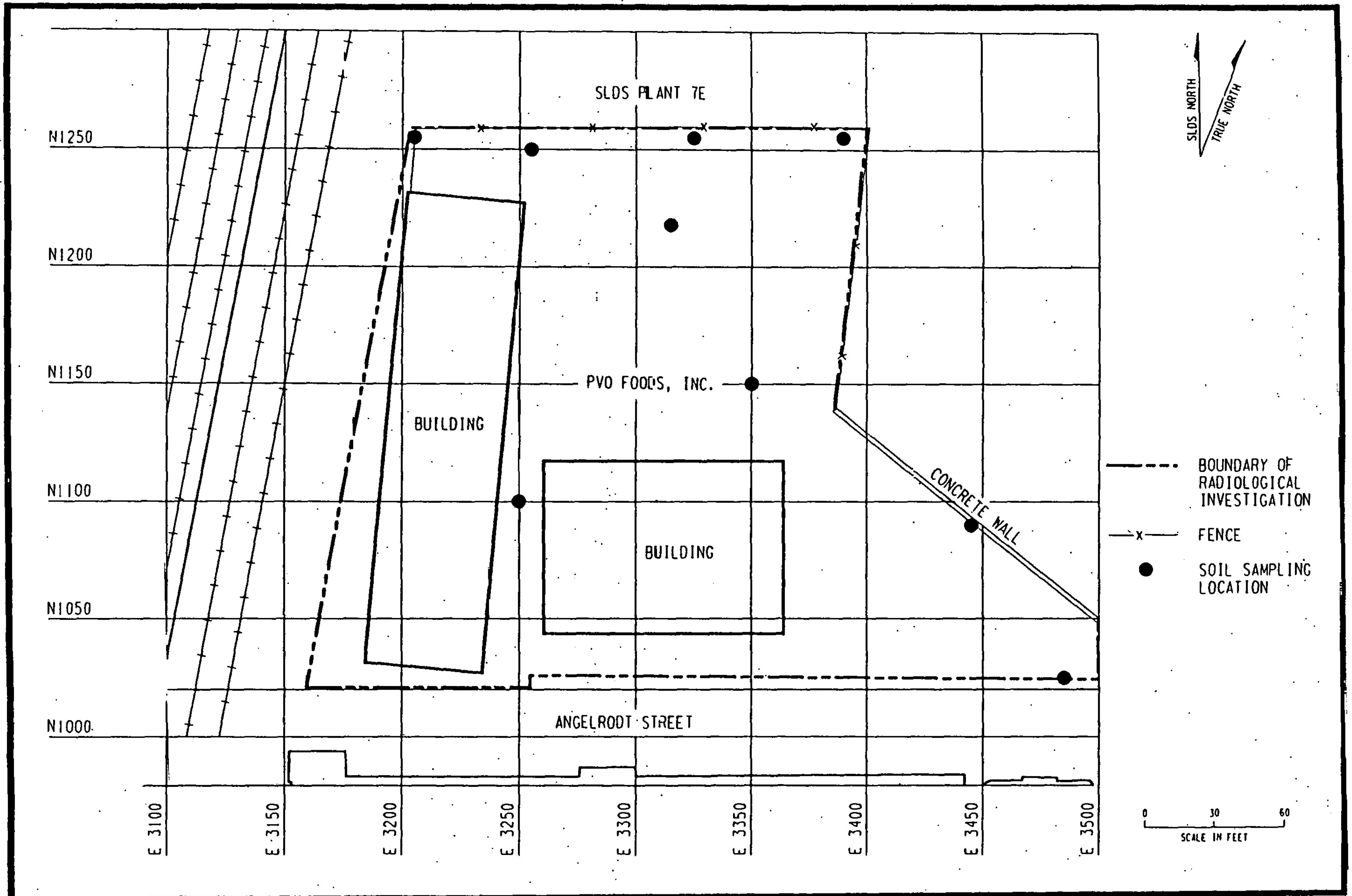
FIGURE 2-4 SOIL SAMPLING LOCATIONS AT THE McKINLEY IRON COMPANY PROPERTY



116F013.DGN F2

FIGURE 2-5 SOIL SAMPLING LOCATIONS AT THE PVO FOODS, INC., PROPERTY

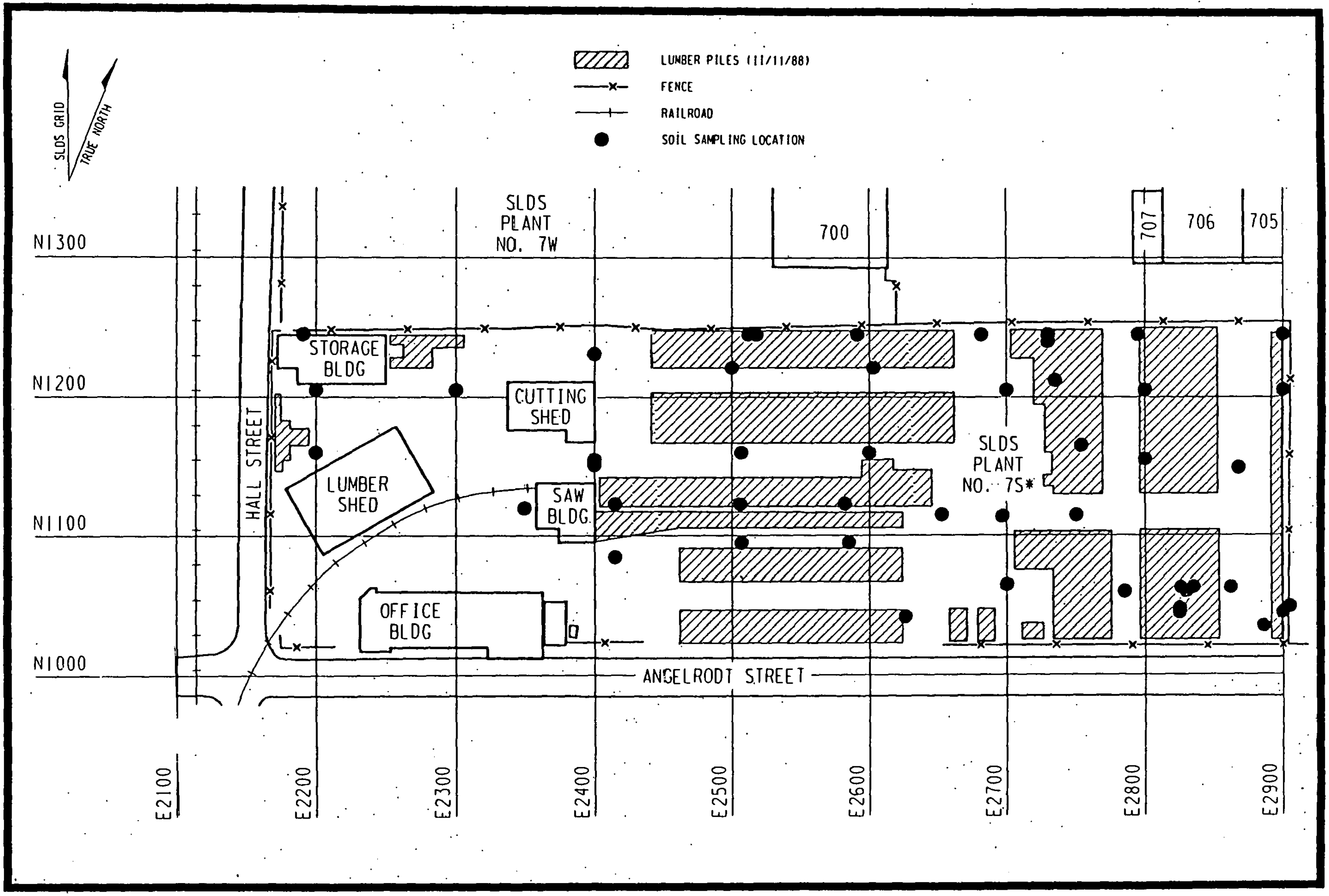


FIGURE 2-6 SOIL SAMPLING LOCATIONS AT THE THOMAS AND PROETZ LUMBER COMPANY PROPERTY

116F062.DGN

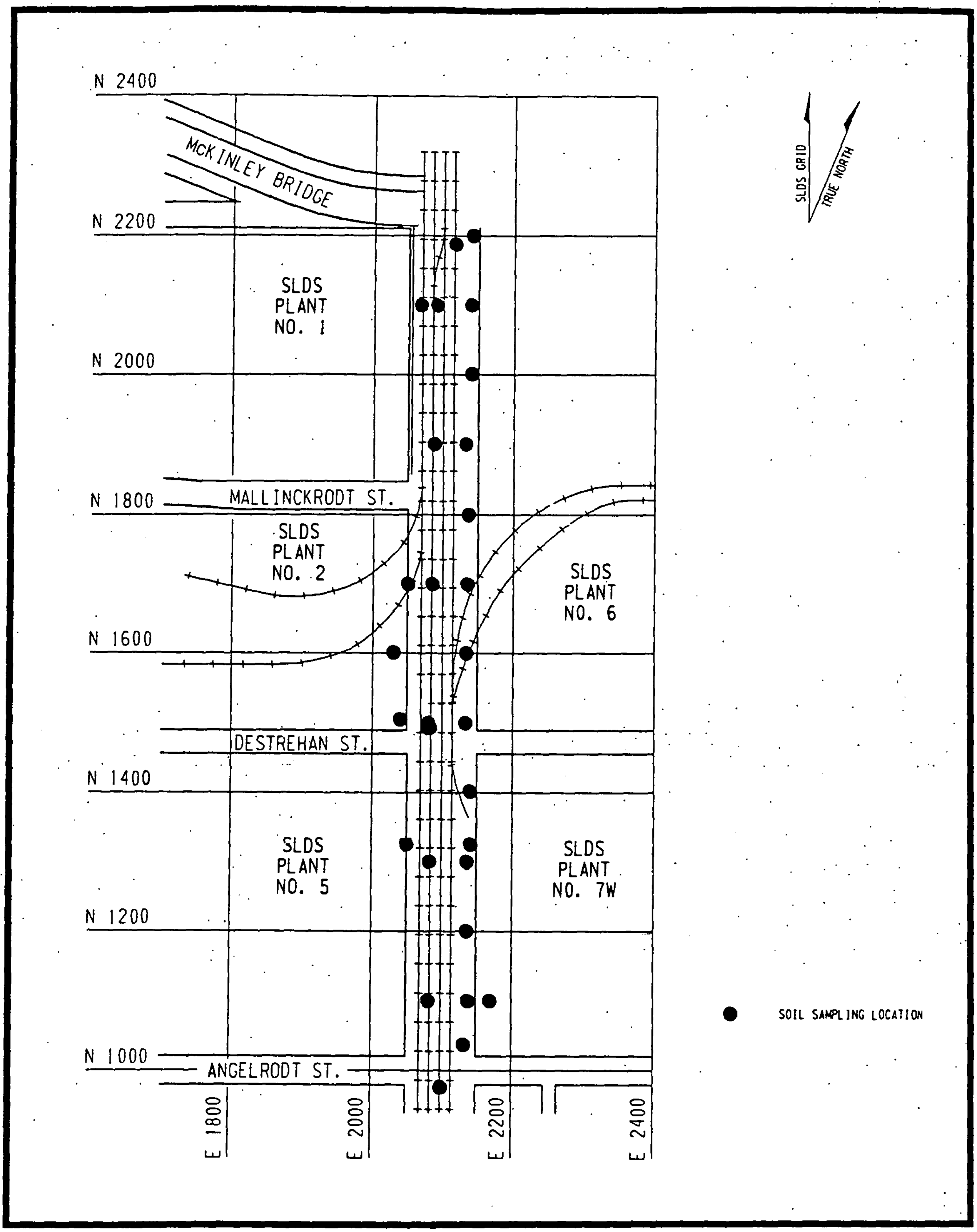


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FIGURE 2-7 SOIL SAMPLING LOCATIONS AT THE ST. LOUIS TERMINAL RAILROAD ASSOCIATION PROPERTY

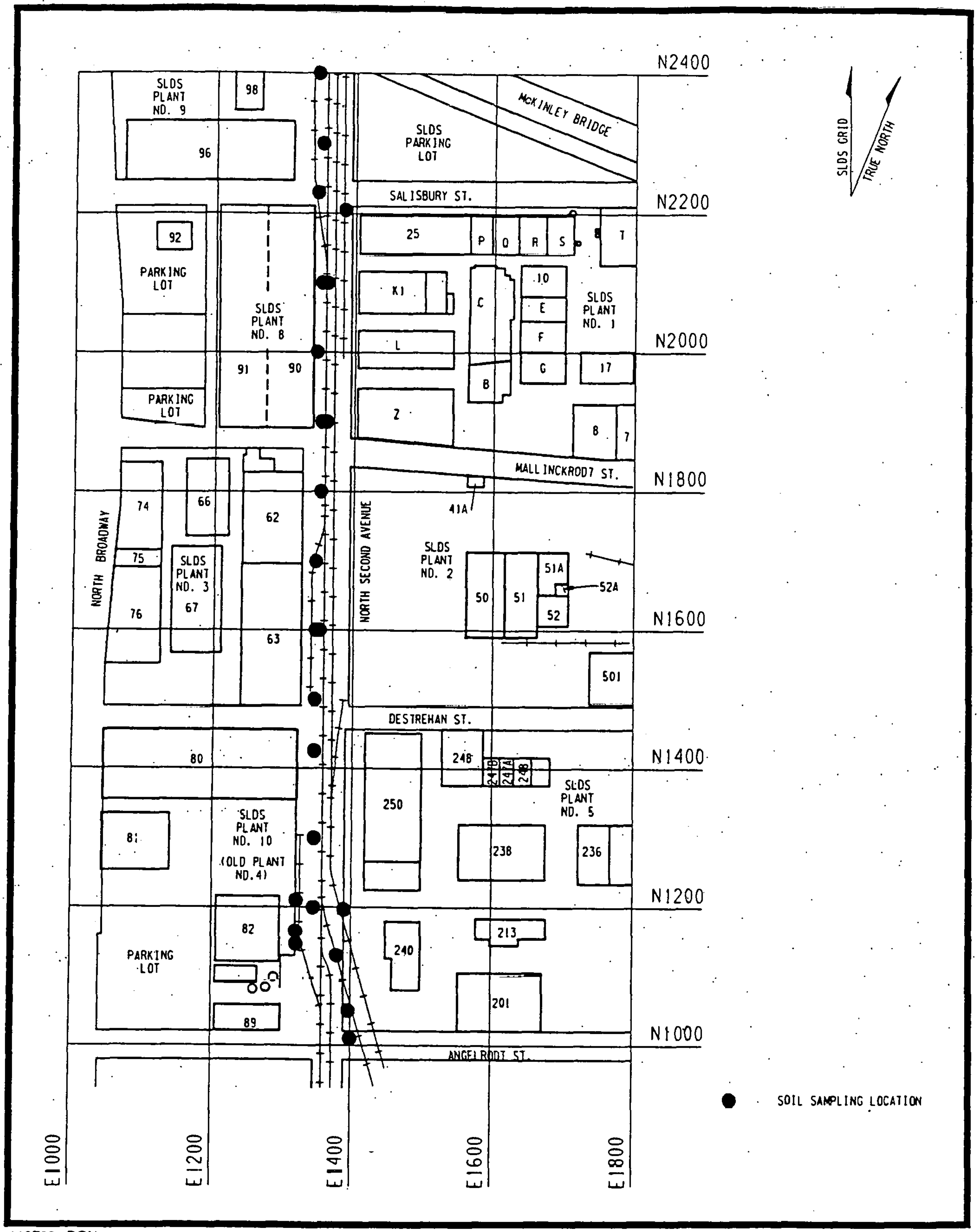

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FIGURE 2-8 SOIL SAMPLING LOCATIONS AT THE NORFOLK AND WESTERN RAILROAD PROPERTY

Chicago, Burlington, and Quincy Railroad property

The Chicago, Burlington, and Quincy Railroad property is located on the eastern portion of SLDS. The property is on a narrow strip of land running northeast and southwest and is adjacent to SLDS Plants 6E and 7S; it consists solely of railroad tracks that are used for commercial transport. The property was investigated by collecting 40 samples from 26 locations (Figure 2-9).

2.1.3 Investigations at SLAPS

Surface and subsurface soils

Based on previous surveys of SLAPS, the entire property was thought to be radioactively contaminated; however, little was known about chemical conditions at the property. Therefore, the characterization of SLAPS was divided into two phases: Phase I focused on the radiological conditions; Phase II focused on the chemical conditions.

The Phase I investigation was initiated by locating the waterline that crosses the property and establishing a 15-m (50-ft) grid system. A walkover gamma scan was then conducted by scanning 15- by 15-m (50- by 50-ft) grid sections and recording the ranges of radioactivity with a PRS-1 scaler coupled to an unshielded Eberline SPA-3 probe. Next, near-surface gamma measurements were taken at 4-m (12.5-ft) intervals in the areas identified as containing elevated levels of radioactivity during the walkover gamma scan.

Also during Phase I, surface soil samples were collected from 21 locations along the SLAPS boundary, using either split-spoon samplers or hand-sampling tools. Subsurface soil samples were collected from the 102 boreholes installed at the property (Figure 2-10). These samples were analyzed for uranium-238, radium-226, thorium-232, and thorium-230.

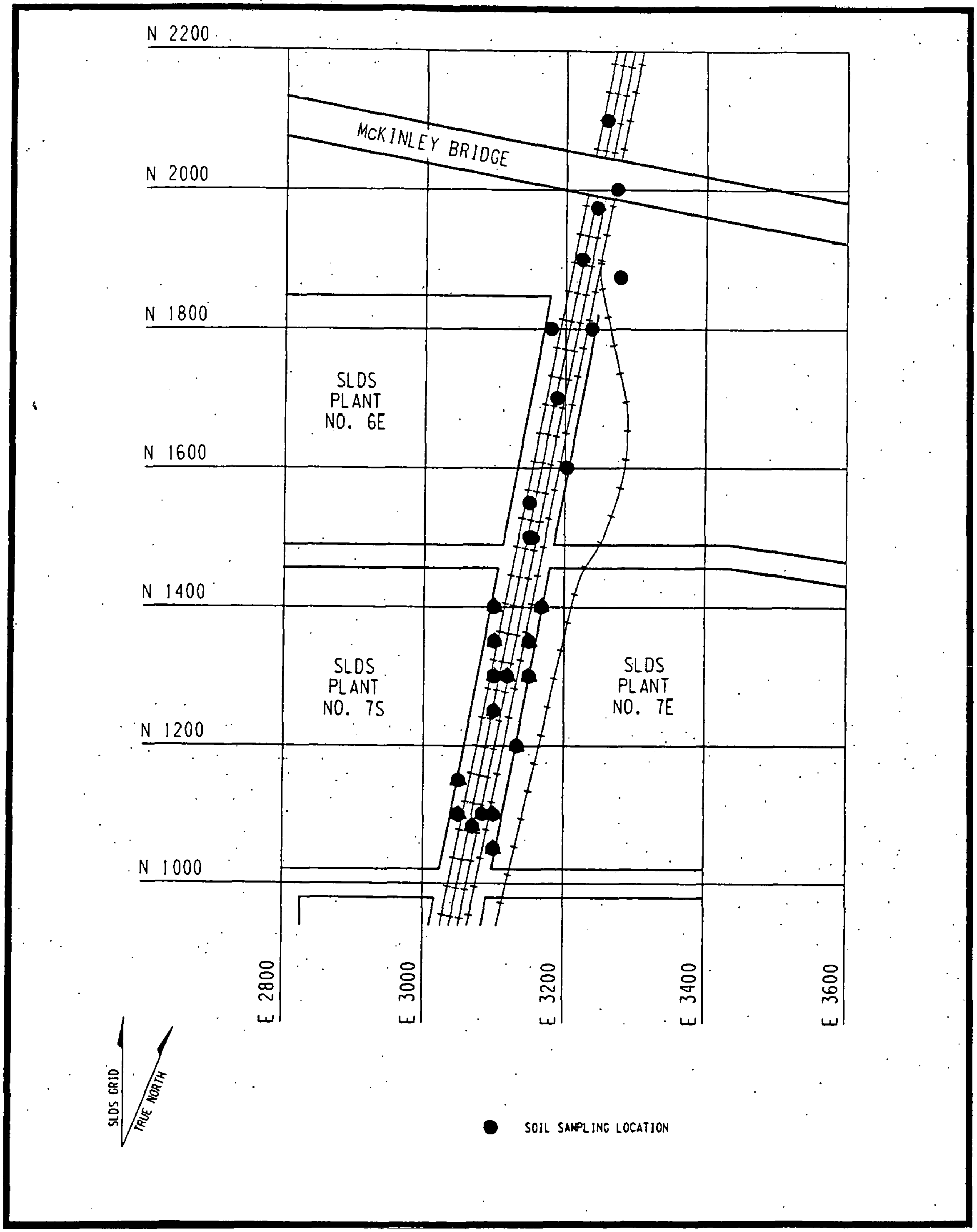

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FIGURE 2-9 SOIL SAMPLING LOCATIONS AT THE CHICAGO, BURLINGTON, AND QUINCY RAILROAD PROPERTY

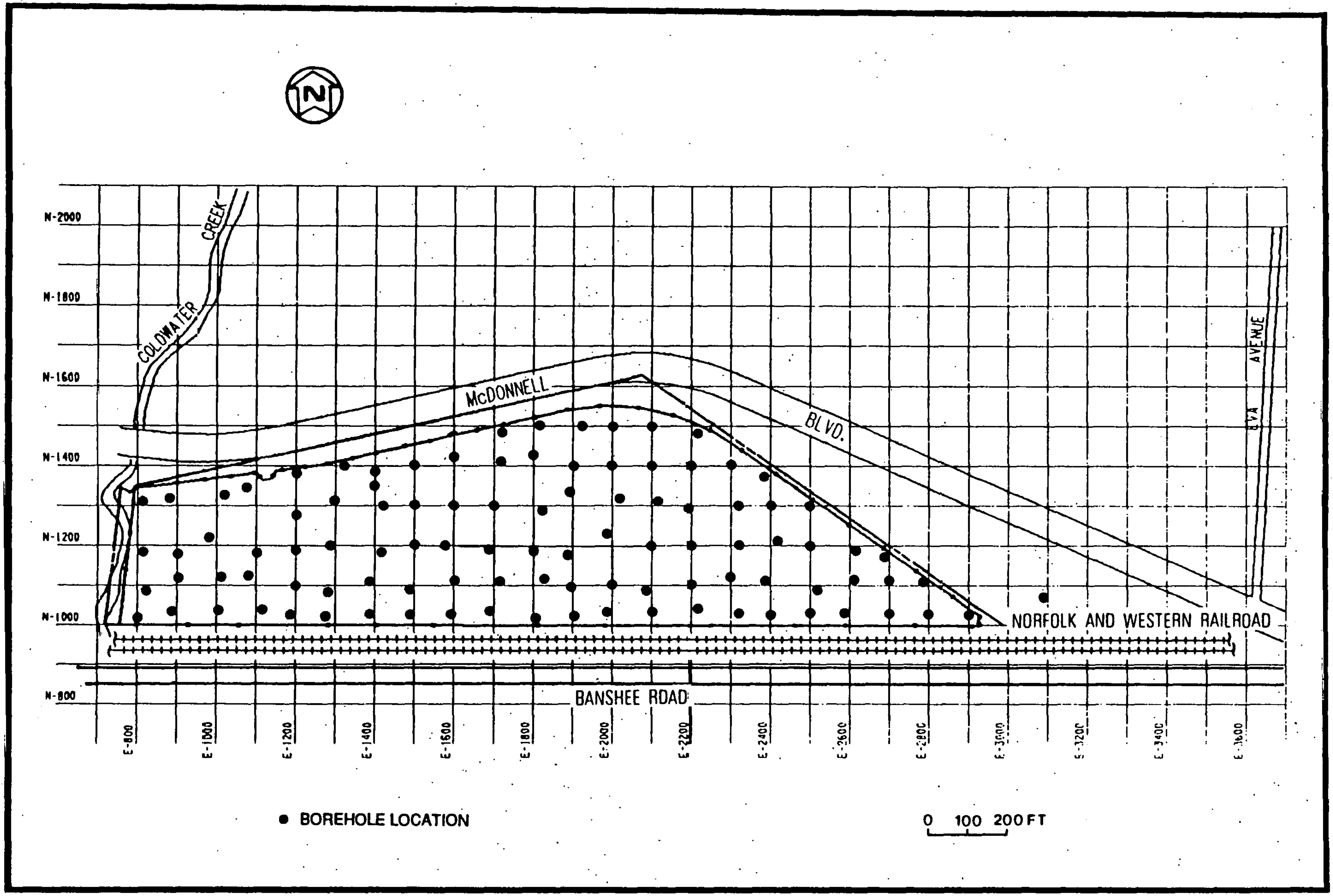


FIGURE 2-10 BOREHOLE LOCATIONS FOR RADIOLOGICAL CHARACTERIZATION OF SLAPS

A limited chemical investigation conducted to provide precursory information regarding the potential presence and nature of hazardous wastes, and to guide Phase II sampling, consisted of collecting three samples from each of ten randomly selected onsite boreholes and one offsite borehole. All chemical samples were collected with stainless steel split-spoon samplers and analyzed for heavy metals, TOC, and TOX.

During Phase II, 22 boreholes were drilled at random locations; 8 were drilled in biased locations where wastes are known to have been disposed of (Figure 2-11). In general, three 0.6-m (2-ft) samples were collected from each borehole: two from soil known to contain radioactive contaminants and one from beneath the area of known contamination. The samples taken from radioactively contaminated areas were analyzed for RCRA-hazardous waste characteristics, heavy metals, VOCs, and BNAEs. Samples taken from beneath these areas were analyzed for VOCs, BNAEs, and metals.

All samples were stored, packed, and shipped in the appropriate laboratory-supplied containers to the laboratory for analysis.

Additional information regarding the soils investigation is available in BNI 1987a and BNI 1990b.

Groundwater

The groundwater characterization conducted at SLAPS was part of the ongoing environmental monitoring program conducted there. Since 1984, samples have been collected quarterly from 16 onsite wells (in the same manner as described in Subsection 2.1.1) and analyzed for total uranium, radium-226, and thorium-230 (Figure 2-12). The wells have also been sampled since 1987 and analyzed for chemical parameters, such as pH, specific conductance, TOC, and TOX. During 1988 and 1989, the wells were sampled and analyzed for metals, as well.

For more details on the groundwater investigation at SLAPS, refer to BNI 1990c and BNI 1991.

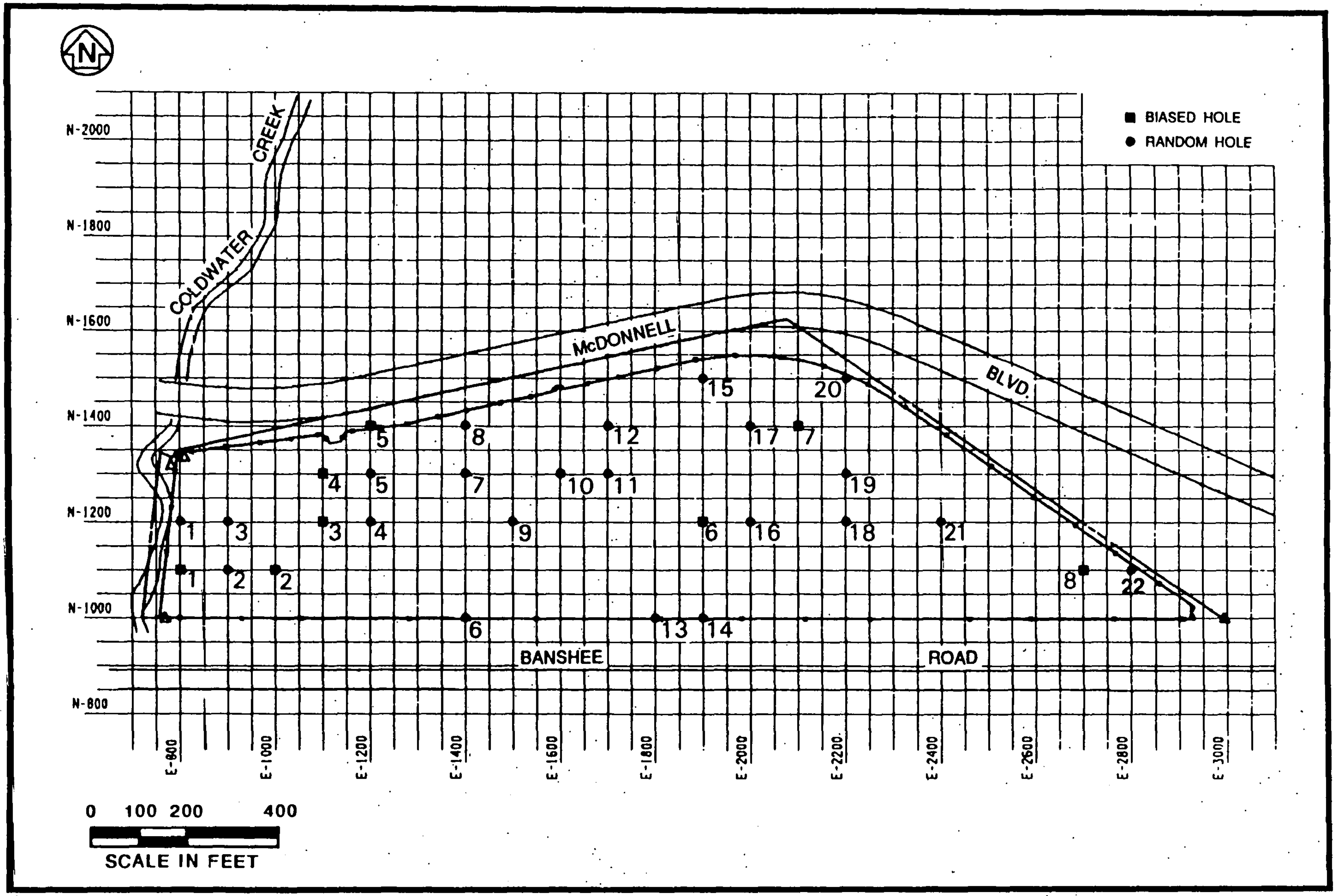
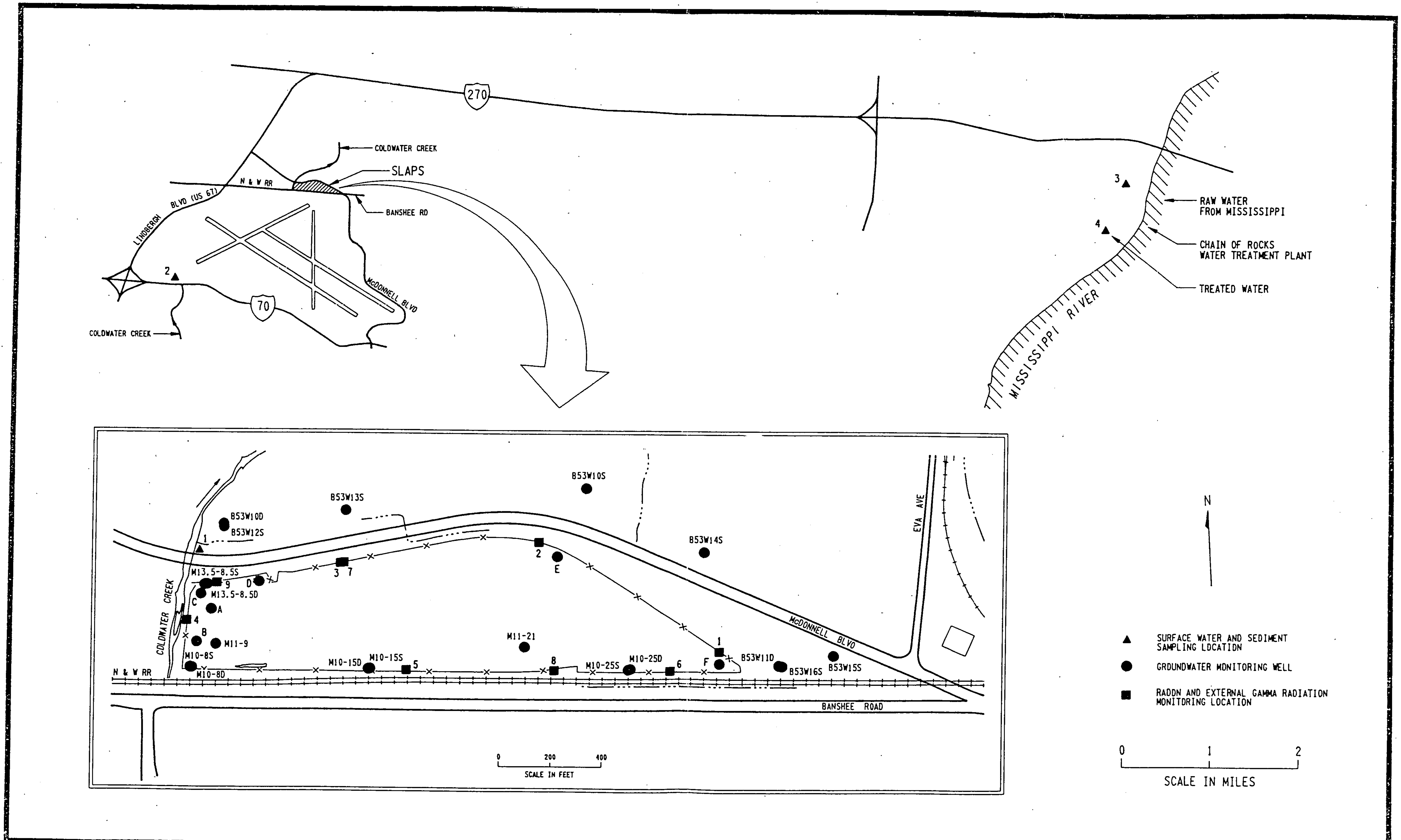


FIGURE 2-11 SOIL SAMPLING LOCATIONS FOR CHEMICAL CHARACTERIZATION OF SLAPS



134F132.DGN GIGO

FIGURE 2-12 LOCATIONS OF ENVIRONMENTAL MONITORING STATIONS AT SLAPS

Surface water and sediments

Surface water and sediments in the drainage pathways from SLAPS have been sampled quarterly from four locations as part of the ongoing environmental monitoring program (Figure 2-12). The samples were analyzed for total uranium, radium-226, and thorium-230.

For more information on this investigation, refer to BNI 1990c.

Air

Nine radon detectors (Terradex Type F Track-Etch Monitors, as described in the air portion of Subsection 2.1.1) are maintained along the property boundary as part of year-round air monitoring conducted at SLAPS (Figure 2-12); they are spaced in a manner designed to ensure adequate detection capability under most atmospheric conditions. Three additional detectors are maintained offsite to measure background levels at Florissant, Missouri, 24 km (15 mi) northeast of SLAPS; McDonnell Boulevard, 0.8 km (0.5 mi) east of SLAPS; and St. Charles County, 32 km (20 mi) southwest of SLAPS.

External gamma radiation levels were measured using thermoluminescent dosimeters (TLDs) at the nine locations corresponding to the radon monitoring locations. Gamma exposure rates were also measured using a pressurized ionization chamber (PIC) along the SLAPS boundary that runs parallel to McDonnell Boulevard to determine whether the general public was being exposed to radiation levels above the DOE radiation protection standard of 100 mrem/yr.

For more information regarding the air investigation, refer to BNI 1990c.

Geology and hydrogeology

Sixteen of the sampling boreholes were developed into geologic boreholes to provide detailed stratigraphic information for developing a geologic model of the property. Samples from disturbed and undisturbed soil taken with standard 2-ft split-barrel samplers and thin-walled (Shelby) tubes were immediately extruded for logging and packaging. Samples of undisturbed soil were acquired for laboratory analysis to provide data on mineralogic, sedimentologic, and hydrologic properties of selected zones. Boreholes were drilled to the base of the unconfined groundwater system, defined by a clayey aquitard, and permeability tests were conducted at selected intervals. Continuous samples were collected from the top 3 to 4.5 m (10 to 15 ft) of each geologic borehole and analyzed for radiological parameters. At depths greater than 4.5 m (15 ft), samples were obtained at changes in strata or as determined necessary by the BNI geologist. Water level measurements were taken before the boreholes were backfilled with grout.

For more information regarding this investigation, refer to BNI 1989.

2.1.4 Investigations at the SLAPS Vicinity Properties

Areas exhibiting radioactive contamination that may be associated with SLAPS are referred to as vicinity properties (Figure 1-5). All of these properties, except the ball field area and a portion of Coldwater Creek, were investigated for radioactive contamination only. Chemical investigation was deemed unnecessary because of the low chemical contamination results obtained from the characterization of SLAPS. If, after the baseline risk assessment is completed, metals are considered a risk, further sampling will be conducted. The samples collected were analyzed for uranium-238, radium-226, thorium-232, and thorium-230, except where noted.

The investigations conducted at these vicinity properties are summarized in the following subsections. For more information, refer to BNI 1990d.

Ditches to the north and south of SLAPS

Near-surface gamma radiation measurements were taken at the ditches to the north and south of SLAPS, and contamination was found along the length of them. To investigate the depth and extent of contamination, 42 boreholes and hand-augered holes were installed and sampled.

St. Louis Airport Authority property

The northern portion of the St. Louis Airport Authority property, which is south of SLAPS, was surveyed to determine the extent of radioactive contamination. Near-surface gamma radiation measurements revealed radioactive contamination in the surface soils; 65 hand-augered holes were sampled to investigate subsurface contamination.

Coldwater Creek and vicinity properties

A walkover gamma radiation survey was performed on all accessible areas of the creek banks and on the associated vicinity properties (Figure 2-13). Near-surface gamma radiation measurements were not taken because results from the walkover survey showed only a few isolated areas in which radiation levels were elevated (exceeding twice the background levels). Biased surface soil samples were then collected from these areas.

In 1986, surface sediment samples from the sides and center of Coldwater Creek, beginning at SLAPS and continuing downstream to HISS, were collected and analyzed. Analytical results indicated spotty contamination along the entire distance; therefore, additional characterization activities were required.

In 1987, characterization of Coldwater Creek continued and included collection and analysis of surface soil samples from the center of the creek (where accessible), from 30.5 m (100 ft) to the east and west of this centerline, and from 61 m (200 ft) to the east and west of this centerline. Soil samples collected from

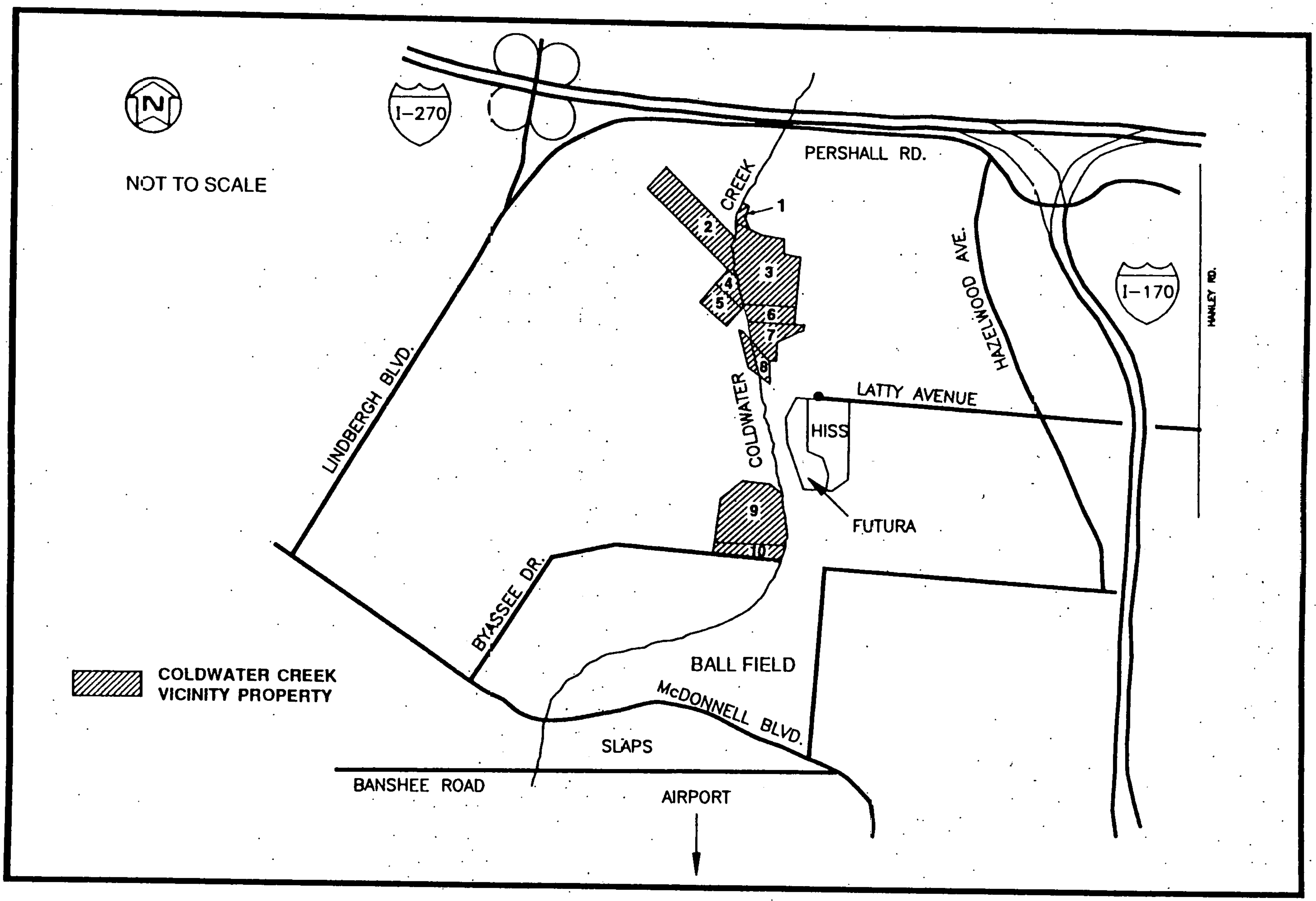


FIGURE 2-13 LOCATIONS OF COLDWATER CREEK AND VICINITY PROPERTIES

these same locations at a depth of 15 to 30 cm (0.5 to 1 ft) were archived. Soil samples were collected from the area between the McDonnell Boulevard bridge and Pershall Road.

In conjunction with the 1986 and 1987 radiological surveys of Coldwater Creek, ten vicinity properties were investigated by gamma-logging and collecting soil samples (Figure 2-13).

In 1989, characterization continued along a section of the creek north of Pershall Road to Bruce Drive and included collection and analysis of soil samples from the creek banks at the edge of the water for a distance of 2.4 km (1.5 mi). Soil samples were collected from both sides of the creek at 30.5-m (100-ft) intervals for the first 0.8 km (0.5 mi) and at 61-m (200-ft) intervals thereafter.

In addition, DOE conducted a radiological survey for the Army Corps of Engineers (COE) in 1989 along the creek for about 7.7 km (4.8 mi) between Bruce Drive and Old Halls Ferry Road (Figure 2-14). Soil samples were collected at 152.4-m (500-ft) intervals from both sides of the creek at the edge of the water. Additional soil samples were collected in 1990 at 152.4-m (500-ft) intervals from the termination point of the COE survey to the point at which Coldwater Creek meets the Missouri River. Samples were collected from both sides of the creek at the water's edge.

Four sediment samples were also collected along Coldwater Creek for chemical analysis. The first was just north of Banshee Road, the second just north of McDonnell Boulevard, the third just south of the Latty Avenue Properties, and the fourth downstream of the Latty Avenue Properties.

Ball field area

Characterization activities at the ball field were much more extensive than those on the other vicinity properties because radioactive materials reportedly had been transported across this area from SLAPS to HISS. In addition, the property was investigated to determine its suitability as an engineered disposal facility for waste from the St. Louis site.

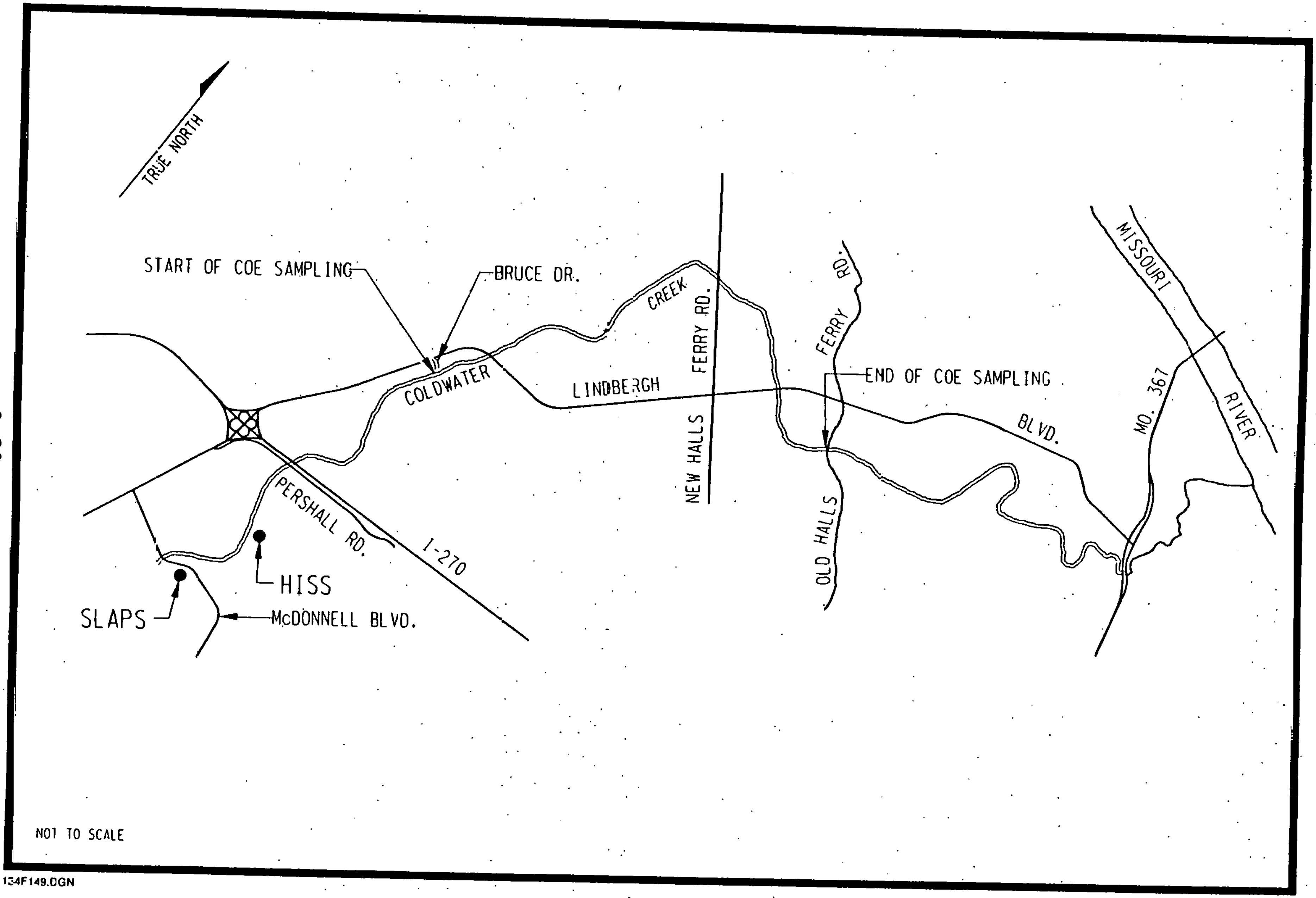


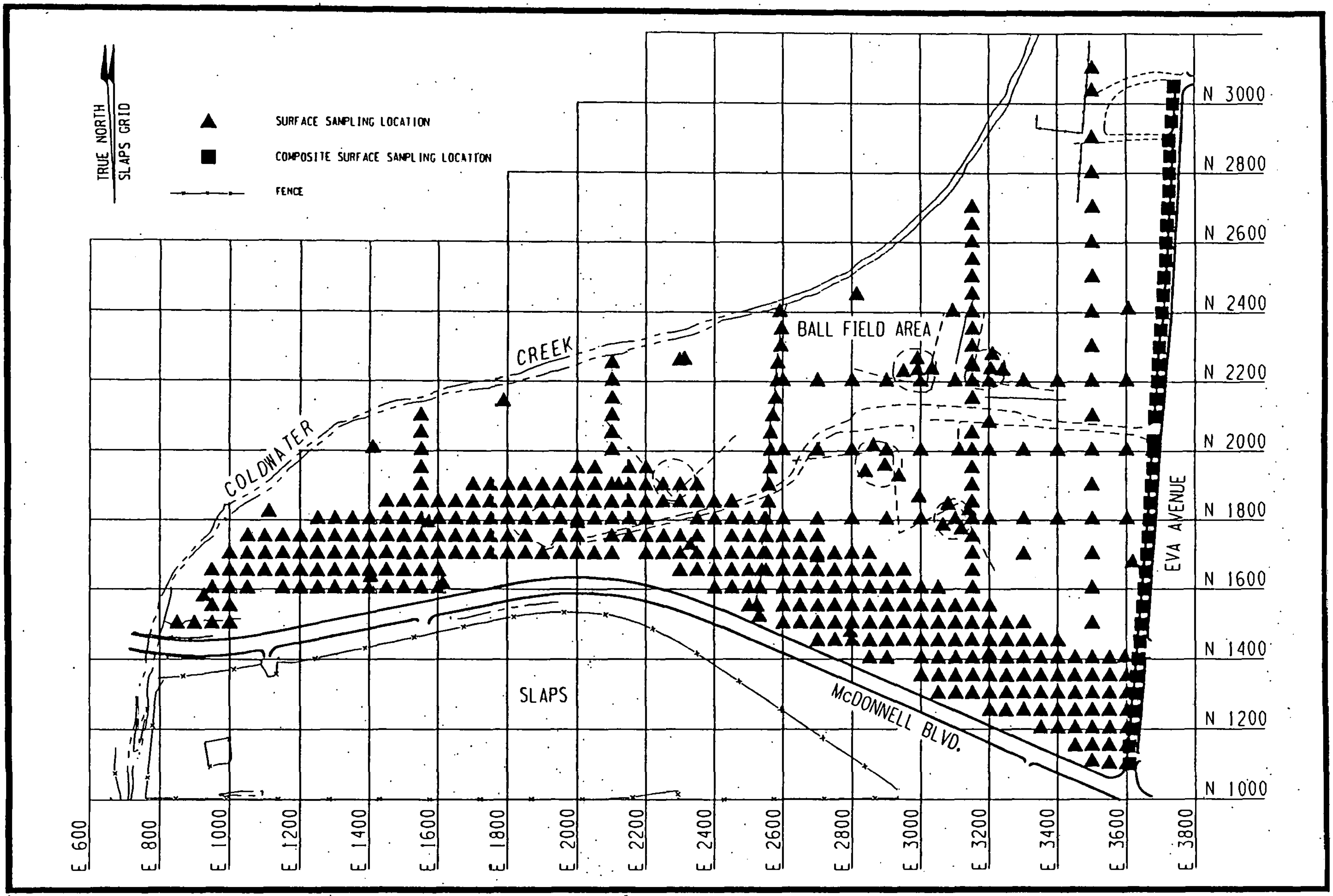
FIGURE 2-14 LOCATION OF THE RADICLOGICAL SURVEY ALONG COLDWATER CREEK

Therefore, characterization included extensive radiological, chemical, and geological investigations.

The radiological investigation of surface and subsurface soils in the ball field area involved walkover gamma scans and sample collection. The scans (conducted as described in Subsection 2.1.3) indicated that most of the radioactive contamination is adjacent to McDonnell Boulevard. Soil samples were collected from 568 surface locations and 145 boreholes, primarily from the area adjacent to McDonnell Boulevard (Figures 2-15 and 2-16).

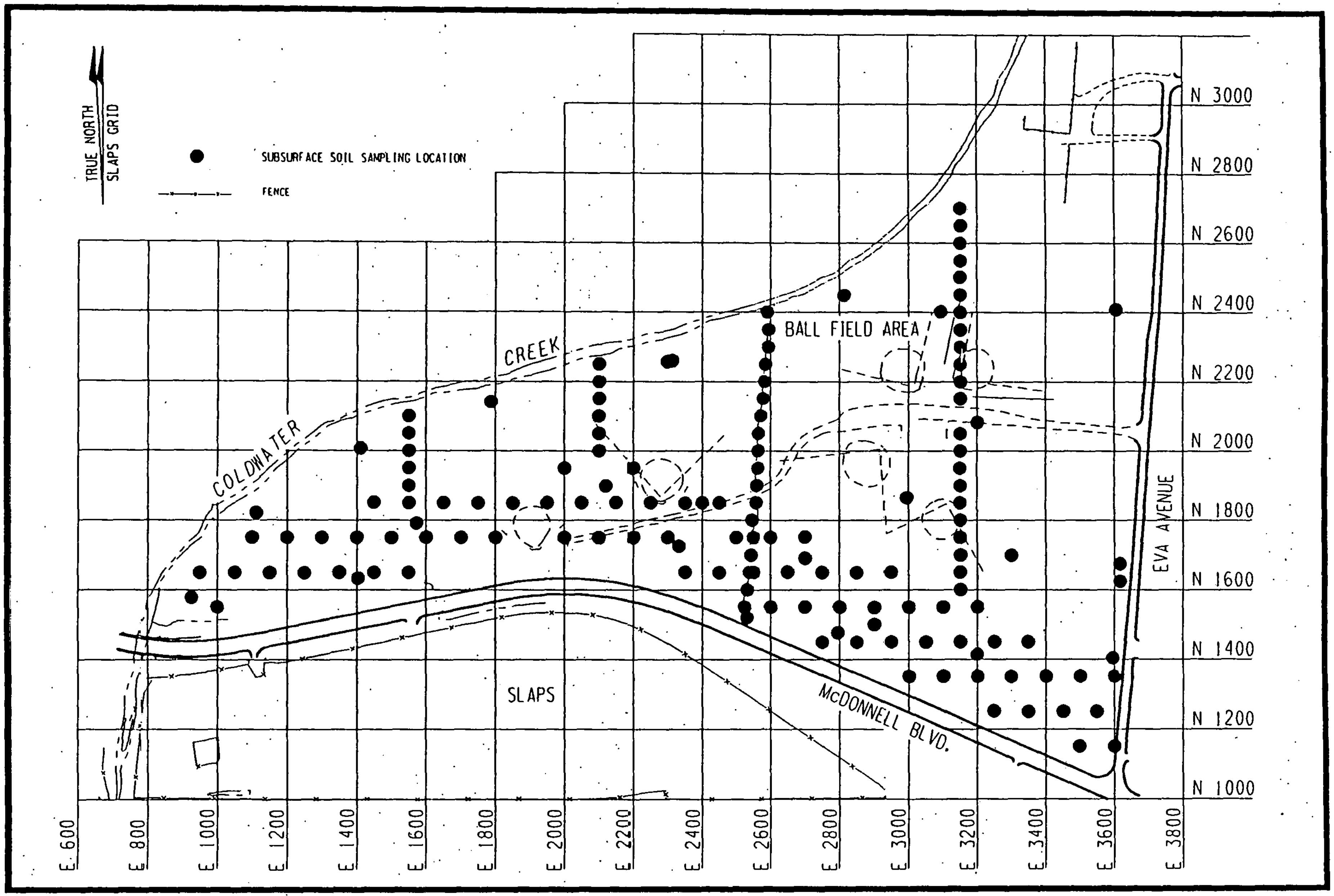
Eleven of the boreholes were sampled for chemical constituents. These chemical sampling locations (Figure 2-17) were chosen to characterize the subsurface chemical conditions across the property and to identify construction-related wastes reportedly buried there. Samples were collected from a depth of 0.6 m (2 ft) into undisturbed soil at intervals selected using a random numbers table. Two intervals per borehole were sampled and analyzed for metals, VOCs, and BNAEs. An additional interval per borehole was sampled in seven of the holes and analyzed for the same parameters. A composite sample was taken from each of the 11 boreholes and analyzed for RCRA-hazardous waste characteristics.

As part of the geological investigation, 18 geologic boreholes and 27 monitoring wells were installed at the locations shown in Figure 2-18. All boreholes were sampled continuously from the ground surface to undisturbed material and then were reamed a minimum of 0.6 m (2 ft) into undisturbed material and to a 30.5-cm (12-in.) diameter. A PVC conductor casing with a 25-cm (10-in.) diameter was installed and grouted with bentonite cement by the tremie method before the casing was advanced into undisturbed material. Beneath the surficial fill material, shallow wells and geologic boreholes were sampled continuously at the initial 3-m (10-ft) level and then at 1.5-m (5-ft) intervals, stratum changes, or as directed by the onsite geologist. At locations of paired wells, the deep wells were sampled continuously to total depth using a Central Mine Equipment (CME) sampler. The first four geologic boreholes drilled (G01-G04) did not penetrate bedrock; subsequent boreholes were advanced to refusal at the top of rock.



S53WMS18.DGN FIG2

FIGURE 2-15 SURFACE SOIL SAMPLING LOCATIONS FOR RADIOLOGICAL CHARACTERIZATION OF THE BALL FIELD AREA



S53WMS18.DGN FIG4

FIGURE 2-16 SUBSURFACE SOIL SAMPLING LOCATIONS FOR RADIOLOGICAL CHARACTERIZATION OF THE BALL FIELD AREA

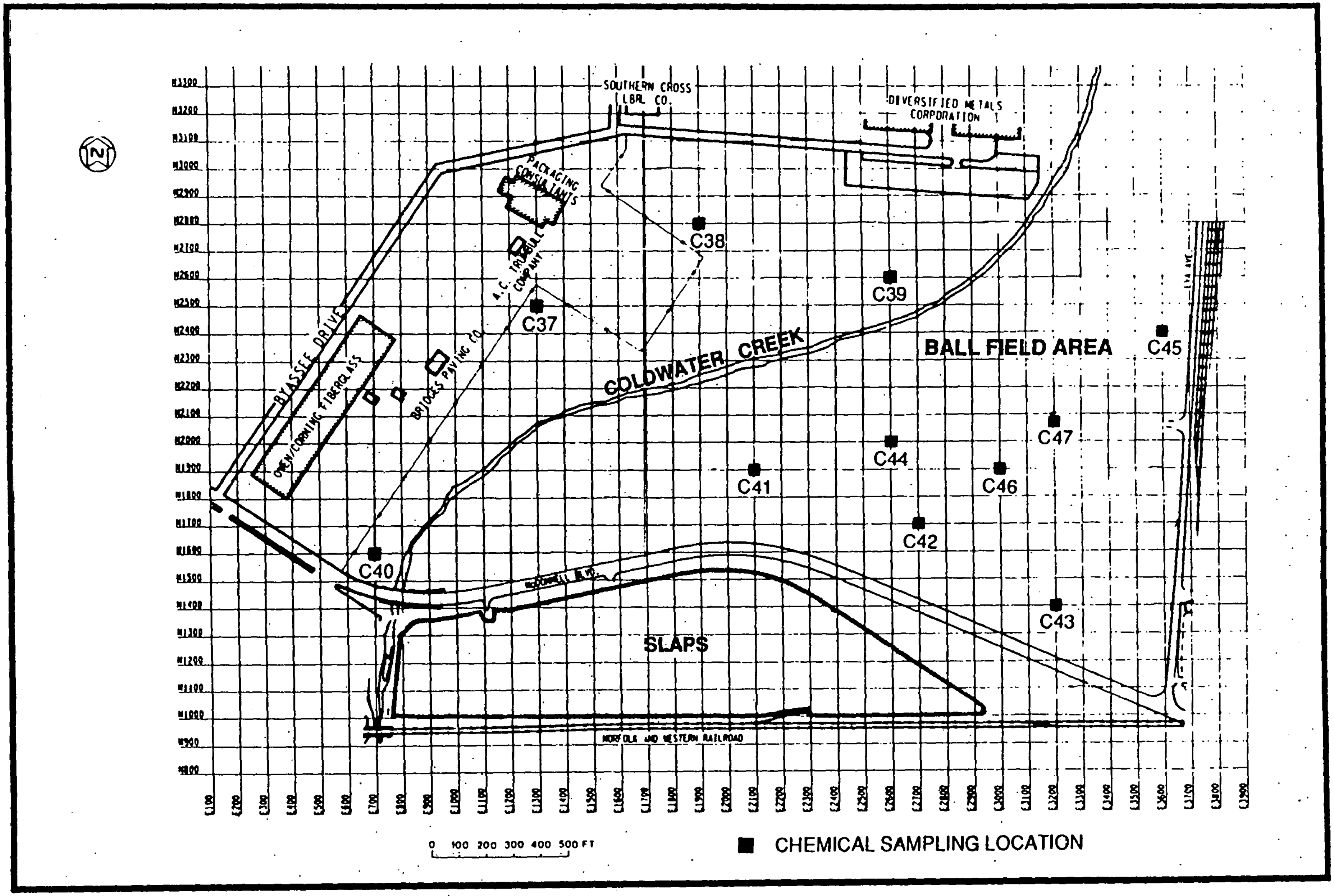


FIGURE 2-17 CHEMICAL SAMPLING LOCATIONS AT THE BALL FIELD AREA

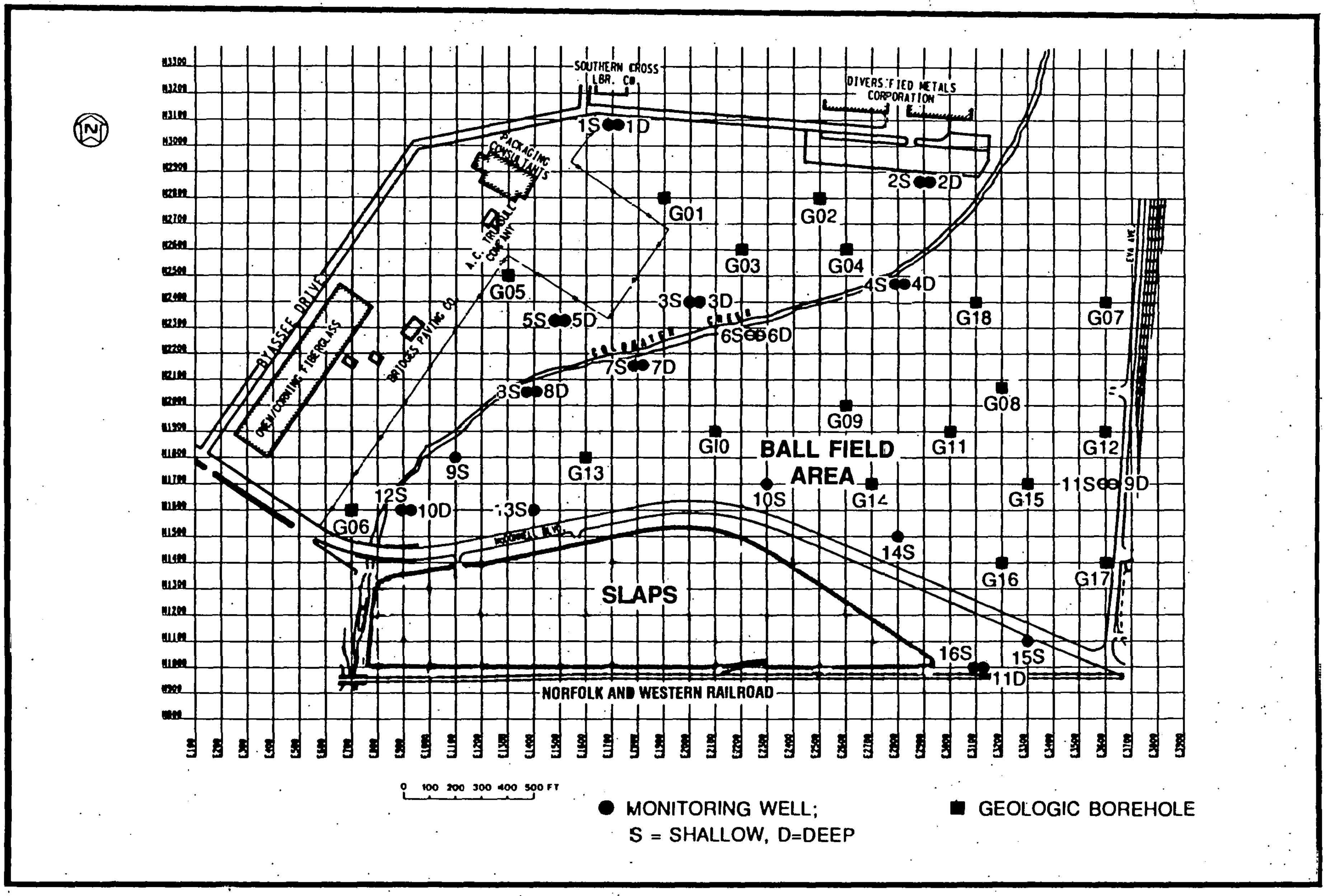


FIGURE 2-18 LOCATIONS OF GEOLOGIC BOREHOLES AND SHALLOW AND DEEP MONITORING WELLS AT THE BALL FIELD AREA

Two boreholes, G16 and G18, were advanced 4.5 m (15 ft) into bedrock using NX coring apparatus; single-packer, constant head permeability tests were conducted in these drill holes.

Monitoring wells were installed in the unconsolidated overburden: 16 at shallow depths [averaging 9.3 m (31 ft)] and 11 at deeper intervals [averaging 24.3 m (81 ft)]. These wells were installed primarily to support the geological investigation.

Construction elevations, dimensions, and monitored intervals for each monitoring well are provided in BNI 1989.

Haul roads and associated properties

The transportation routes (haul roads) over which radioactive material was moved among the St. Louis properties consist of Latty Avenue, McDonnell Boulevard, Hazelwood Avenue, Pershall Road, Eva Avenue, Frost Avenue, and associated properties. After near-surface gamma scans were performed to identify radioactive contamination along Latty Avenue, samples were collected from the 151 boreholes installed in those areas where contamination had been detected. McDonnell Boulevard was investigated by collecting soil samples from 17 surface locations and 46 subsurface locations. The investigation of Hazelwood Avenue was conducted by collecting 47 surface soil samples and 26 subsurface soil samples. Pershall Road was investigated by collecting 272 surface samples and by sampling 183 boreholes. No samples were collected directly under the edges of Frost and Eva Avenues. However, vicinity properties adjacent to these roads were sampled to determine the concentrations of surface and subsurface contaminants resulting from movement of contaminated materials along these haul roads.

No gamma walkover scans were conducted on the haul roads vicinity properties because thorium-230 (the primary contaminant on the properties) cannot be detected in the field. These properties were contaminated by material falling from trucks during transport. The contamination tends to be concentrated along the edge of the property directly adjacent to the haul roads. Based on this, sampling concentrated on the areas adjacent to the roads at intervals of approximately 15.2 m (50 ft), with additional samples being collected approximately 15.2 and 45.7 m (50 and 150 ft) away from the edges of the roads to determine the extent of contamination. The general sampling scheme for the 66 haul roads vicinity properties is shown in Figure 2-19. Approximately 3,000 soil samples were collected from these properties and analyzed.

Norfolk and Western Railroad properties

Near-surface gamma radiation measurements were taken at the Norfolk and Western Railroad properties adjacent to 9200 Latty Avenue and south of SLAPS, but none were taken at the other properties because thorium-230 (the primary contaminant already identified) cannot be detected by gamma radiation scans.

At the railroad properties, soil samples were collected from:

- 266 surface and 96 subsurface locations adjacent to 9200 Latty Avenue
- 17 surface and 4 subsurface locations adjacent to Hanley Road
- 119 surface and 78 subsurface locations south of SLAPS
- 97 surface and 28 subsurface locations adjacent to Coldwater Creek
- 26 surface locations adjacent to Hazelwood Avenue and south of Latty Avenue
- 6 surface locations adjacent to Hazelwood Avenue and north of Latty Avenue
- 72 surface locations adjacent to Eva Avenue

The samples from the railroad properties were analyzed for uranium-238, radium-226, thorium-232, and thorium-230, except for the properties adjacent to Hazelwood Avenue south of Latty Avenue, adjacent to Hazelwood Avenue north of Latty Avenue, and adjacent to Eva Avenue; at these properties, samples were collected only from the surface and were analyzed for thorium-232 only.

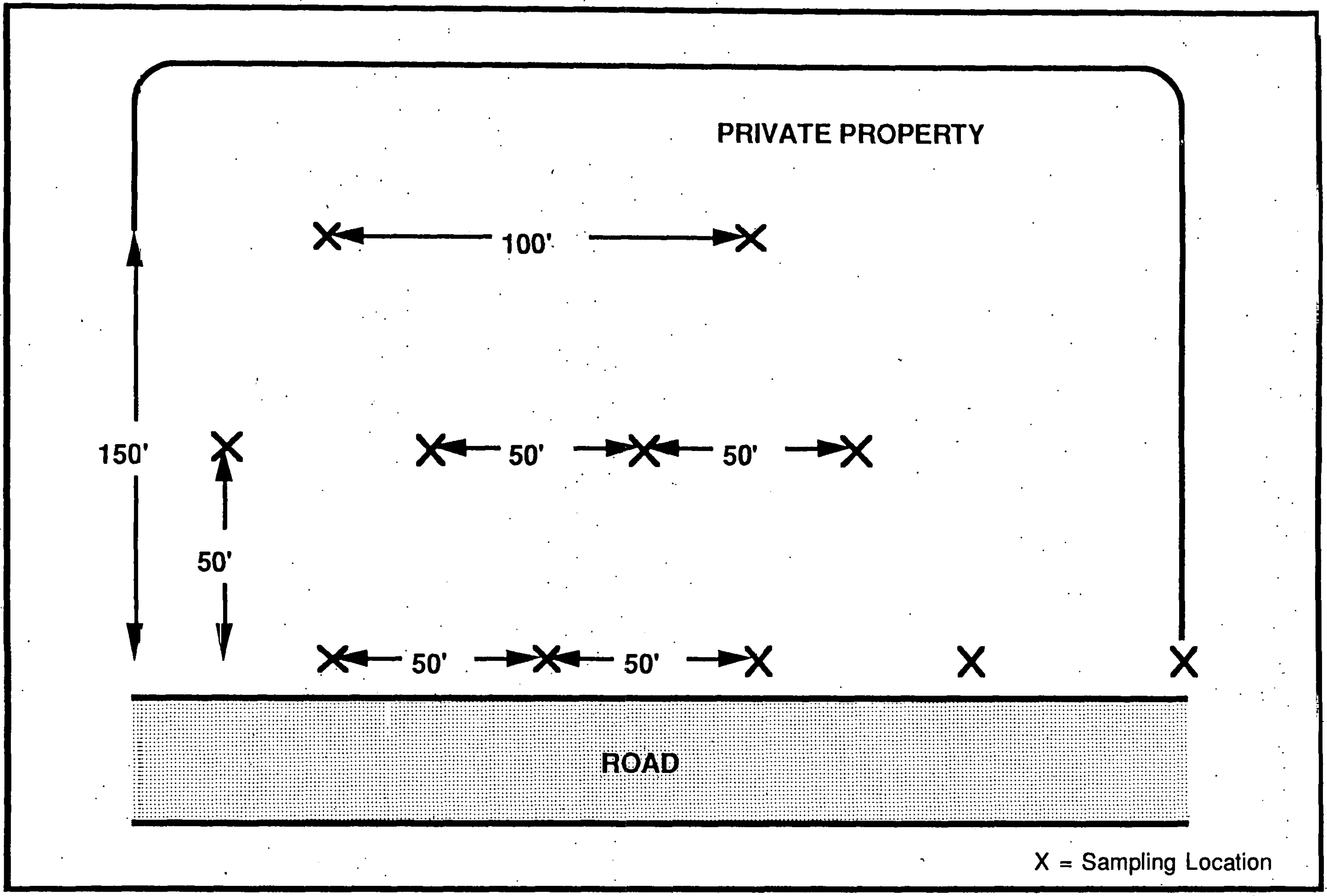


FIGURE 2-19 SAMPLING SCHEME FOR RADIOLOGICAL CHARACTERIZATION OF HAUL ROADS VICINITY PROPERTIES

4.39 23'9.12

Banshee Road

Forty-eight boreholes were drilled through Banshee Road during the radiological characterization survey. Downhole gamma logging was performed in 47 of these boreholes to determine the general depth of contamination from gamma-emitting radionuclides. No significant variations in count rates were observed as gamma logging progressed in these boreholes. Surface and subsurface soil samples were then collected from each borehole.

2.1.5 Investigations at HISS

Surface and subsurface soils

Based on previous surveys of HISS, the entire property was thought to be radioactively contaminated; however, little was known about chemical conditions. Therefore, characterization of HISS was divided into two phases: the Phase I investigation focused on radiological conditions, and Phase II focused on chemical conditions.

Phase I, conducted in 1986, was initiated by locating all underground utilities and establishing a 15-m (50-ft) grid system. Next, a walkover gamma scan was conducted by taking measurements from 15- by 15-m (50- by 50-ft) grid sections and recording the ranges of radioactivity using a PRS-1 scaler coupled to an unshielded Eberline SPA-3 probe.

The next stage of the Phase I investigation involved collecting near-surface gamma measurements at 4-m (12.5-ft) intervals in the contaminated areas identified during the walkover gamma scan.

Finally, surface and subsurface samples were collected at 30-cm (1-ft) intervals from 36 boreholes that were drilled to an average depth of 3 m (10 ft) (Figure 2-20). They were collected using either split-spoon samplers or appropriate hand-sampling tools. The soil samples were analyzed for uranium-238, radium-226, thorium-232, and thorium-230.

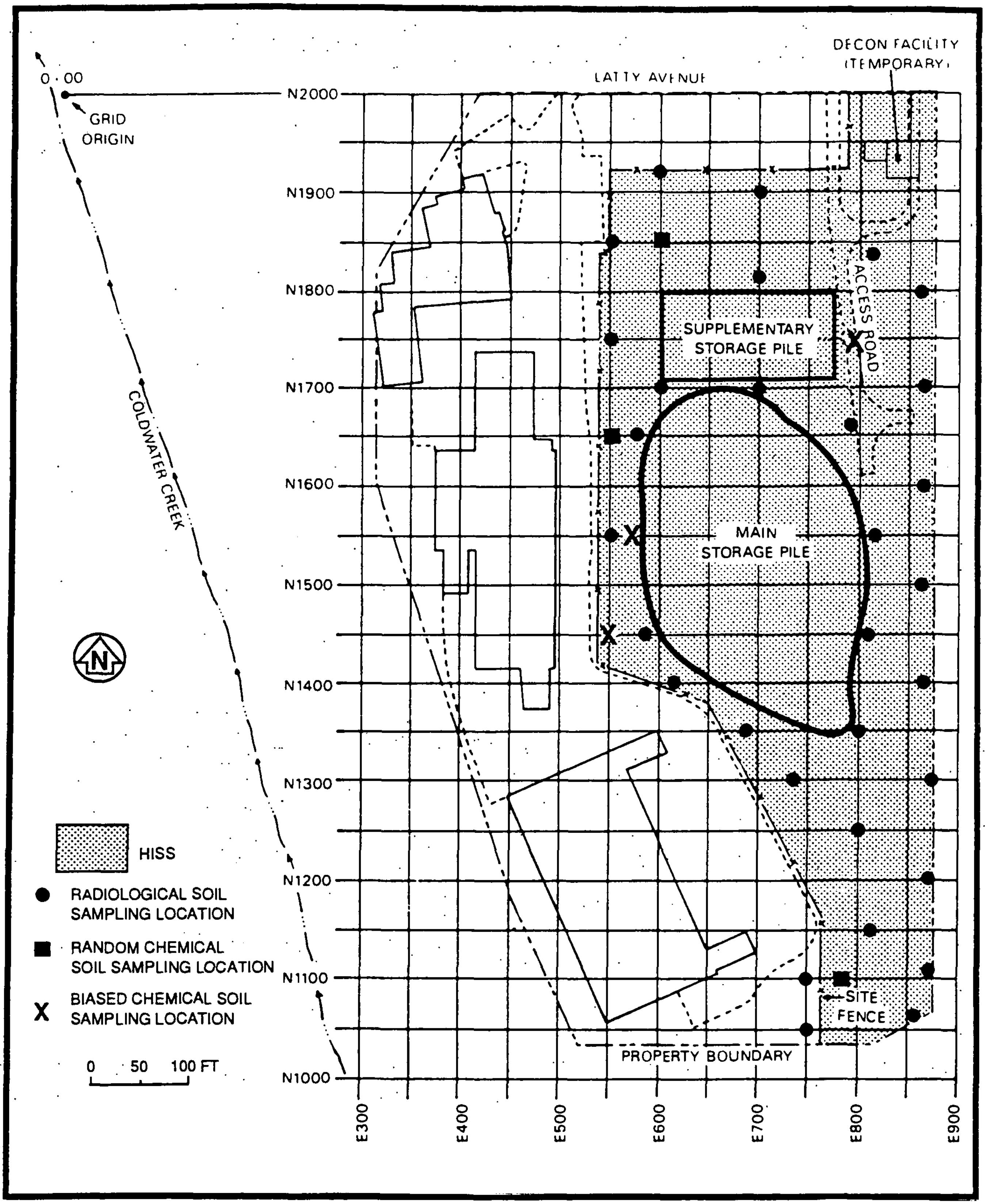


FIGURE 2-20 SOIL SAMPLING LOCATIONS AT HISS

Phase II, conducted in 1988, was a chemical characterization of HISS, during which three boreholes were installed at random locations and three were installed at biased locations (near both of the storage piles). In general, two samples were collected from the biased holes and three samples from the random holes; one or two samples were taken from soil known to contain radioactive contaminants. An additional sample was taken from underneath the area of known radioactive contamination. Samples taken from surface soil were collected with stainless steel split-spoon samplers. All samples were analyzed for heavy metals, VOCs, and BNAEs. Samples collected from the area known to be radioactively contaminated were also analyzed for RCRA-hazardous waste characteristics.

All samples were stored, packed, and shipped in appropriate laboratory-supplied containers to the laboratory for analysis.

For more details on soil sampling methodology at HISS, refer to BNI 1987b and 1990b.

Groundwater

The groundwater characterization was part of the ongoing environmental monitoring program conducted at HISS since 1984. Seven of the eight geologic boreholes along the perimeter of the property were completed as monitoring wells (Figure 2-21) above bedrock in overburden material; the total, screen, and seal depths were determined based on subsurface stratigraphic data obtained during drilling.

Samples have been collected quarterly from these seven wells and from two offsite background wells. Currently, Wells 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, and 16 are used to monitor groundwater (four of these wells are actually located on the Futura property). Background wells are located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS. The unfiltered samples were collected in the same manner as those described in Subsection 2.1.1. All samples were analyzed for total uranium, radium-226, and thorium-230. In addition, the wells have been

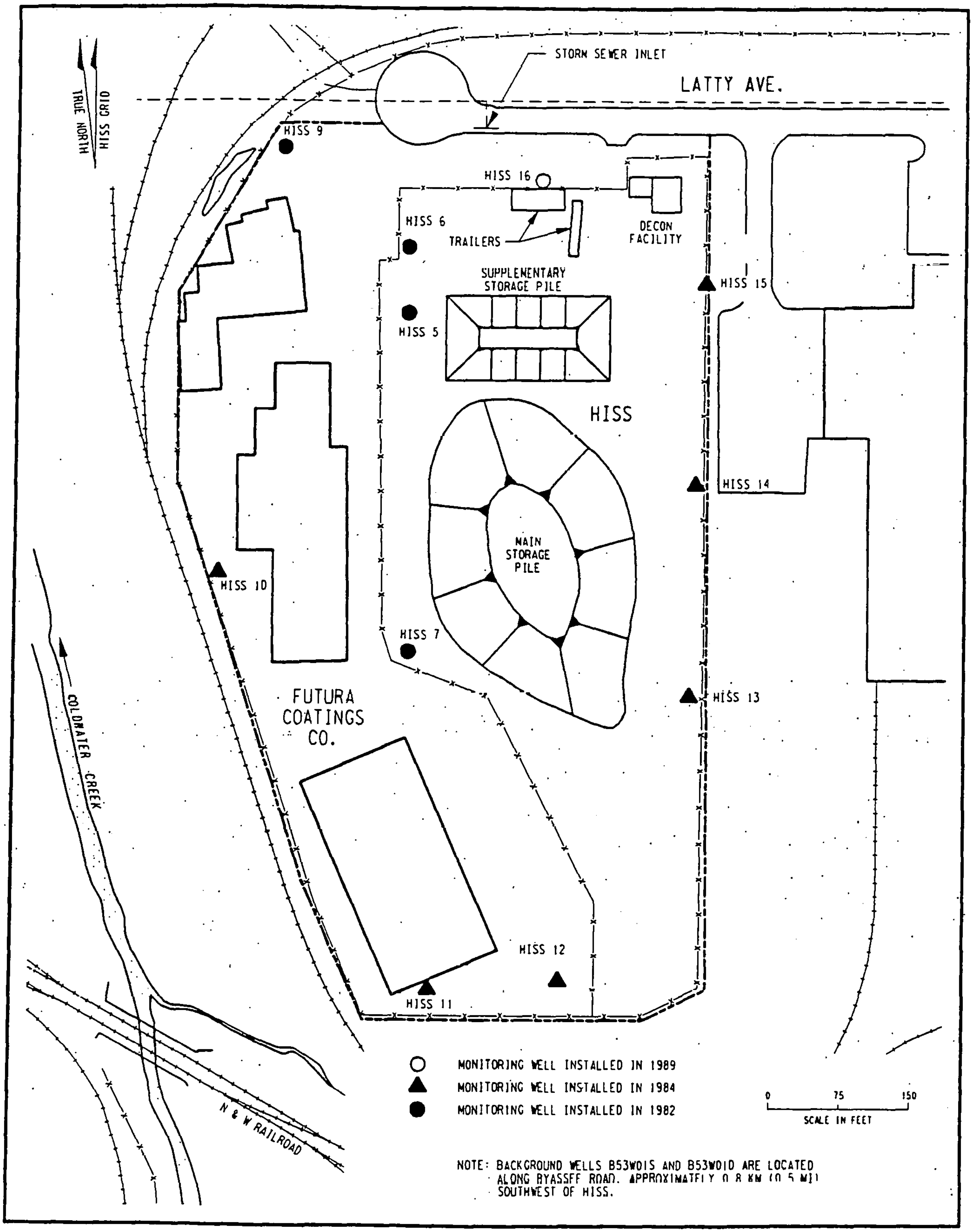


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FIGURE 2-21 MONITORING WELL LOCATIONS AT HISS AND FUTURA monitored since 1987 for chemical parameters, pH, specific conductance, TOX, and TOC. Wells 1 through 15 were sampled and analyzed for metals during 1988 and 1989.

For more information regarding the groundwater investigation, refer to BNI 1990e and 1991.

Surface water and sediments

The surface water and sediments in the drainage pathways from HISS have also been monitored as part of the ongoing environmental monitoring program. These pathways have been sampled quarterly at four locations: two (Locations 5 and 6) along the stream south of HISS that empties into Coldwater Creek, one (Location 4) from Coldwater Creek south of HISS, and one (Location 3) from Coldwater Creek north of HISS (Figure 2-22). Composite sediment samples weighing approximately 500 g (1.1 lb) were collected quarterly at surface water sampling locations where sediment was present. The samples were analyzed for total uranium, radium-226, and thorium-230.

For more information regarding this investigation, refer to BNI 1990e and 1991.

Air

Radon detectors were maintained at ten locations on the property and along the boundary to ensure adequate detection capability under most atmospheric conditions (Figure 2-22). Detectors were also maintained approximately 24 km (15 mi) northeast and 8 km (5 mi) east of HISS to measure background radon levels. In addition to the radon monitoring conducted as part of the environmental monitoring program, charcoal canisters were placed in the two trailers onsite to measure radon in October 1990. One trailer is utilized as the BNI office, and the other serves as a public information facility.

Gamma exposure rates were also monitored around the HISS boundary and on each of the onsite storage piles using a PIC.

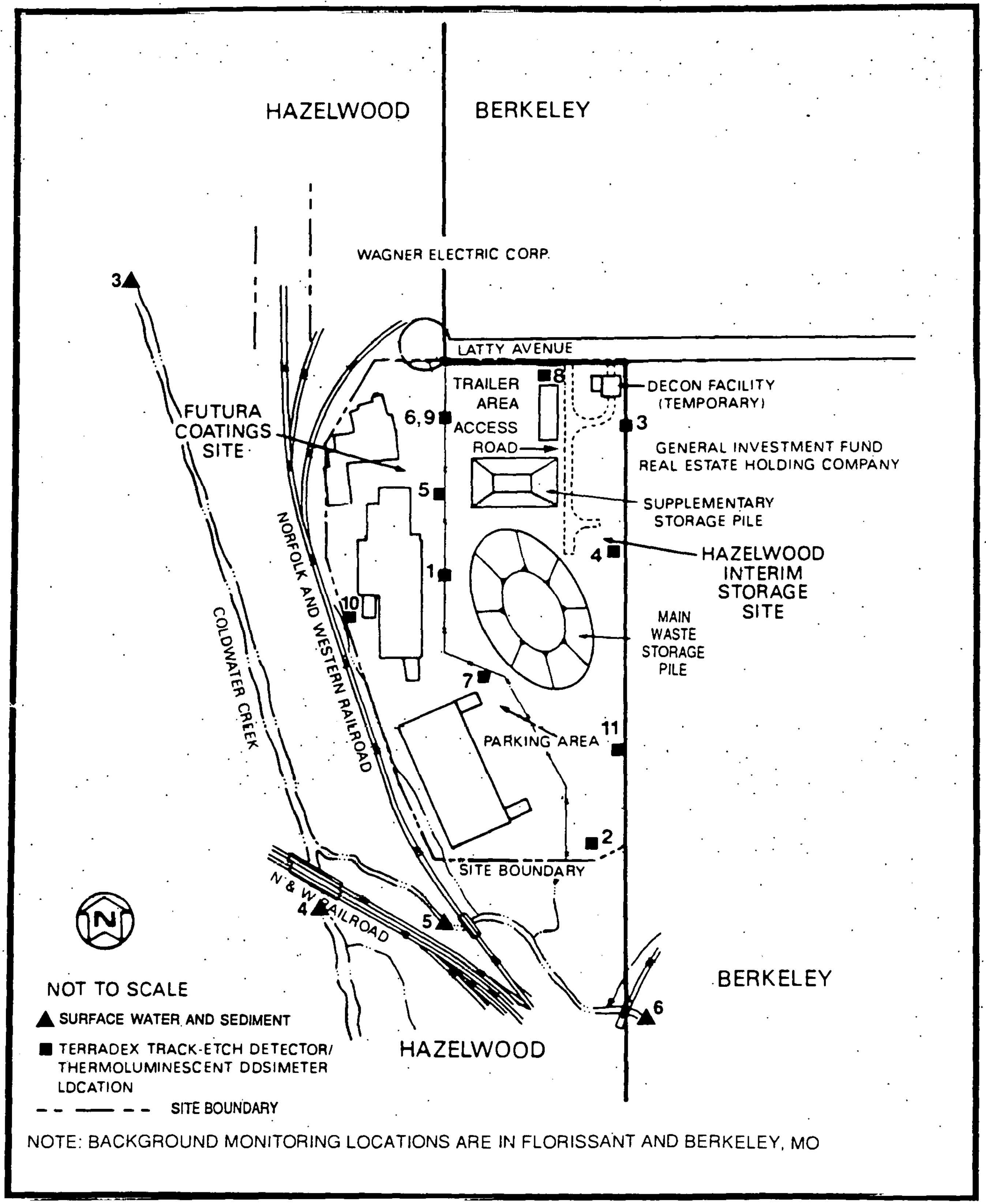

FIGURE 2-22 MONITORING LOCATIONS FOR RADON, EXTERNAL GAMMA RADIATION, SURFACE WATER, AND SEDIMENT AT HISS

Details on the air investigation are provided in BNI 1990e.

Geology and hydrogeology

Eight geologic boreholes were drilled at the property using 7-in. outside diameter hollow-stem augers (Figure 2-21) (BNI 1985a).

The initial borehole (HISS-9A) was drilled to a depth of 18 m (60 ft) to determine general stratigraphy. Shallow groundwater was found at a depth of less than 9 m (30 ft). The depths of succeeding boreholes were adjusted according to visual inspection of the soil types encountered, using the parameters established from the initial borehole log as a guide.

Samples were obtained at 1.5-m (5-ft) intervals using split-spoon samplers and the standard penetration test method. Four samples from disturbed soil, considered to be representative of the soil types encountered in all eight borings, were submitted to a laboratory for gradation testing.

Rising-head permeability tests were conducted in the seven boreholes that were completed as monitoring wells to determine in situ hydraulic conductivities at depths corresponding to the monitored intervals.

Details of the well installation are discussed in BNI 1985.

2.1.6 Investigations at Futura

Surface and subsurface soils

Based on previous surveys at Futura Coatings, the entire property was thought to be radioactively contaminated; however, little was known about chemical conditions. Therefore, the characterization of the property was divided into two phases: Phase I, conducted in 1986, was a detailed surface and subsurface radiological investigation, and Phase II, conducted in 1988, was a chemical characterization.

The Phase I radiological investigation was initiated by locating all underground utilities and establishing a 15-m (50-ft) grid system. Next, a walkover gamma scan was conducted by collecting measurements from 15- by 15-m (50- by 50-ft) grid sections and recording the ranges of radioactivity using a PRS-1 scaler coupled to an unshielded Eberline SPA-3 probe.

Near-surface gamma measurements were taken at 4-m (12.5-ft) intervals in the areas identified during the walkover gamma scan as being contaminated.

The remainder of the radiological investigation involved collection of subsurface soil samples at 30-cm (1-ft) intervals from 58 boreholes (Figure 2-23). The samples were collected using either split-spoon samplers or appropriate hand-sampling tools and were analyzed for uranium-238, radium-226, thorium-232, and thorium-230.

As part of the chemical characterization, three boreholes were installed at biased locations near the most radioactively contaminated areas, and three boreholes were installed at random locations. In general, two or three samples were collected from each borehole -- at least one from the soil known to contain radioactive contaminants, and one from underneath the area of known contamination when accessible. Surface soil samples were collected with stainless steel split-spoon samplers. All samples within the area of radioactive contamination were analyzed for RCRA-hazardous waste characteristics, heavy metals, VOCs, and BNAEs. Samples from below radioactively contaminated areas were analyzed for volatiles and semivolatiles.

All samples were stored, packed, and shipped in appropriate laboratory-supplied containers to the laboratory for analysis.

For a more detailed description of soil sampling methodologies, refer to BNI 1987c and 1990b.

Groundwater

Groundwater characterization was part of the ongoing environmental monitoring program conducted at HISS and Futura since

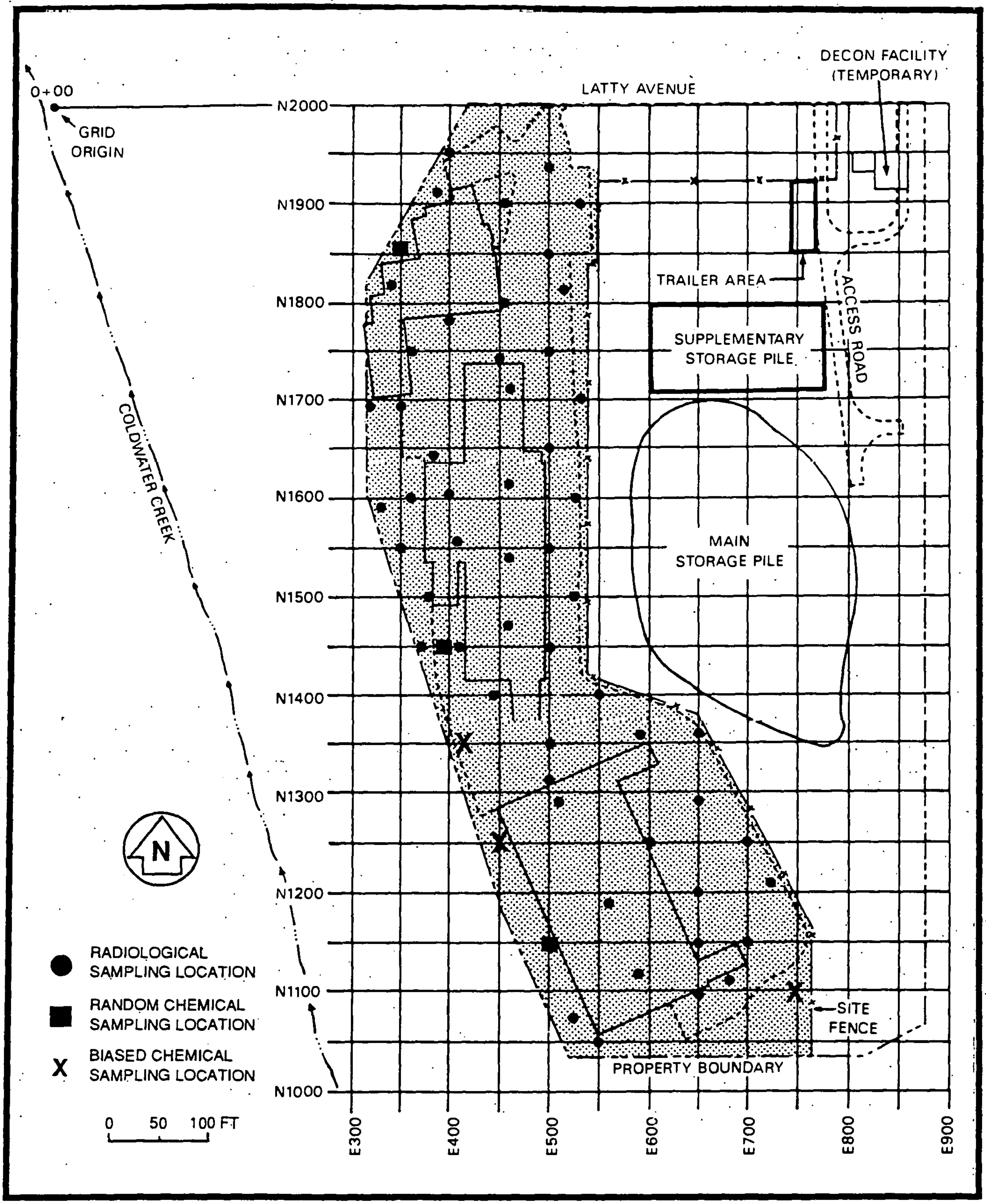

FIGURE 2-23 SOIL SAMPLING LOCATIONS AT THE FUTURA COATINGS PROPERTY

1984. The discussion of groundwater in Subsection 2.1.5 also applies to Futura because four of the wells are located on the Futura property (Figure 2-21).

For more information regarding the groundwater investigation, refer to BNI 1990e and 1991.

Buildings

The interior and exterior surfaces of the buildings were surveyed by spot-checking for nonremovable and removable alpha and beta-gamma contamination. The procedures are described in the buildings investigation portion of Subsection 2.1.1.

More detail on the buildings investigation is included in BNI 1987c.

Air

The air investigation involved establishing TLD monitoring stations in each building to measure external gamma radiation, collecting integrated radon measurements using Track-Etch detectors, and using air particulate samplers to determine gross alpha concentrations. Gamma exposure rates were also monitored around each of the three buildings on the property using a PIC.

For more information on the air surveys, refer to BNI 1987c.

2.1.7 Investigations at the Latty Avenue Vicinity Properties

Six vicinity properties were identified as potentially having elevated levels of radioactivity that could be associated with Latty Avenue. These properties (Figure 1-7) were surveyed for uranium-238, radium-226, thorium-232, and thorium-230. Chemical sampling was deemed unnecessary because of the low levels of chemical contamination found at SLAPS and HISS.

A walkover gamma scan was conducted on each property to identify areas of elevated gamma activity. In general, contamination was found on portions of the properties adjacent to Latty Avenue or to HISS. Surface and subsurface soil samples were collected from these areas and from surrounding locations where elevated gamma readings had been detected.

Soil samples were collected from 109 surface and 45 subsurface locations on Property 1; from 117 surface and 55 subsurface locations on Property 2; from 27 surface and 12 subsurface locations on Property 3; from 18 surface and 9 subsurface locations on Property 4; from 16 surface and 8 subsurface locations on Property 5; and from 55 surface and 7 subsurface locations on Property 6.

Details regarding the soils investigation are provided in BNI 1990d.

2.1.8 Investigations at the Transportation Routes Between HISS and West Lake Landfill and Between SLDS and SLAPS

Potential waste transportation routes were identified based on historical and recent maps. Thirty-one intersections on these routes between HISS and West Lake Landfill were selected (Figure 2-24), and a walkover gamma radiation scan was conducted at each. Only 28 of the 31 intersections were sampled due to inaccessibility of three locations: Intersection 1 no longer exists; Intersection 14 is an overpass where Fee Road crosses I-70; and Intersection 31 is an overpass where McDonnell Boulevard crosses I-70. Two sampling locations were selected at each corner of each intersection (where accessible), and 212 surface soil samples were collected and analyzed for uranium-238, radium-226, thorium-232, and thorium-230.

A mobile gamma scanning van with an on-board computer system was used to identify possible anomalies on public roadways and suspected haul routes used to move wastes from HISS to West Lake Landfill and from SLDS to SLAPS. Public roadways, accessible commercial parking areas surrounding SLDS, and railroad crossings were also scanned. Some intersections and roads near the airport that were previously surveyed were investigated again (ORNL 1991).

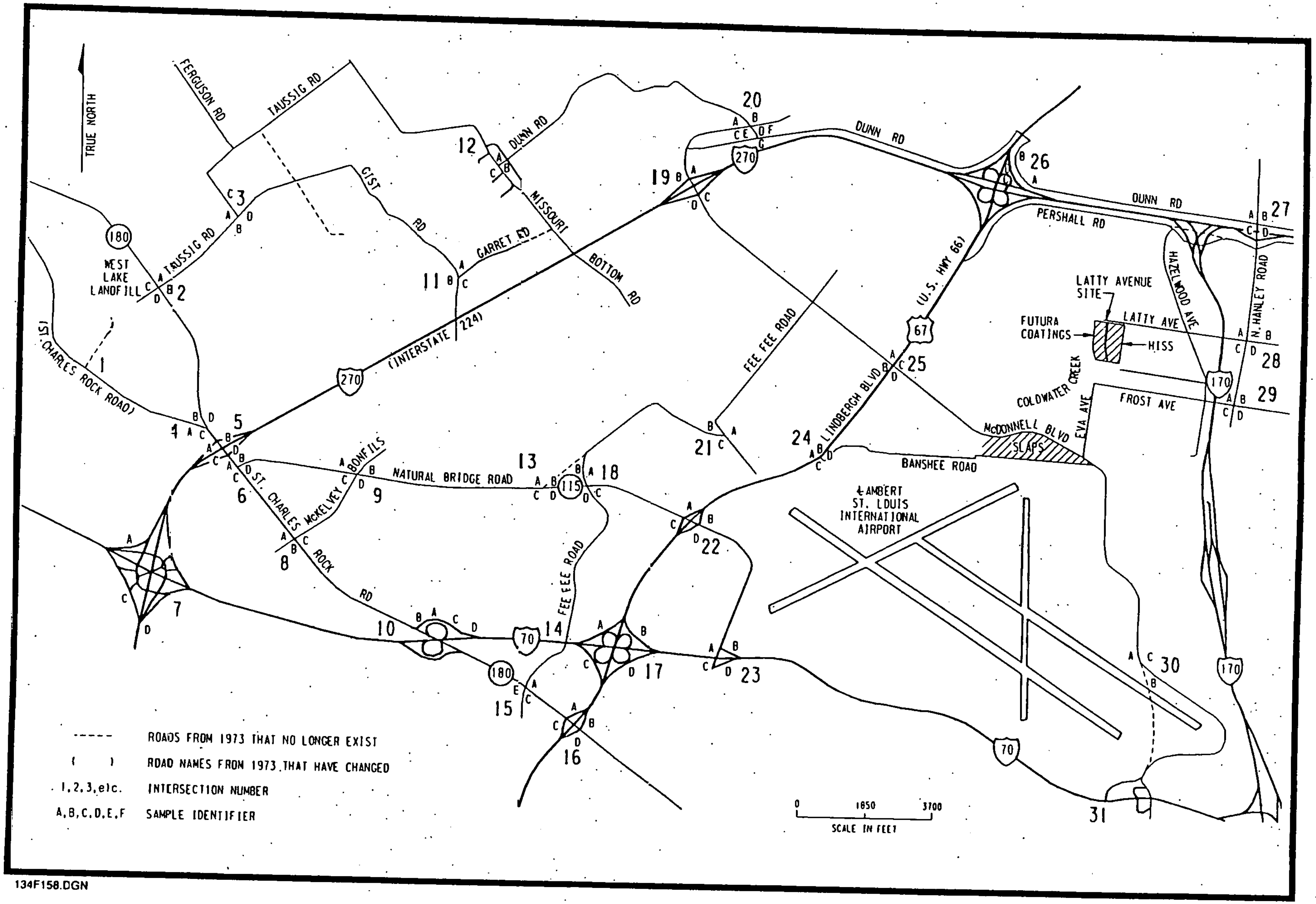

FIGURE 2-24 TRANSPORTATION ROUTES BETWEEN HISS AND WEST LAKE LANDFILL

2.2 METEOROLOGICAL INVESTIGATION

The meteorological investigation of the St. Louis area consisted of reviewing published reports and evaluating historical data collected by the National Oceanic and Atmospheric Administration and the Lambert-St. Louis International Airport. Real-time monitoring methods employed during the field RI activities included monitoring for ambient toxic organic vapors and explosive conditions.

3.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the analytical results of the field investigations and describes the nature and extent of contamination at the St. Louis site. In addition, the relationship between radioactive and chemical contaminants at the primary properties is described.

All radiological laboratory results in this report represent gross readings. Background measurements and concentrations have not been subtracted from field measurements or laboratory results.

DOE guidelines are presented in Table 1-1. Guidelines for uranium in soil are calculated by DOE on a site-specific basis; for the St. Louis site, 50 pCi/g of residual uranium-238 activity in soil is assumed.

Radioactive contamination is considered to be any level of radioactivity exceeding the guidelines established in DOE Order 5400.5 or uranium guidelines established by DOE on a site-specific basis. For the purposes of this document, chemical contamination will include any chemical constituents present at concentrations that exceed background values. After the baseline risk assessment is published and representative background concentrations are established, this definition may change.

3.1 BACKGROUND MEASUREMENTS

Low levels of uranium-238, radium-226, thorium-232, and thorium-230 occur naturally in soil in the St. Louis area. To determine these natural levels, background data were collected before characterization activities began.

Background data are compared with site data to determine whether site radiological measurements are elevated. Background data are also important because DOE guidelines governing remedial action are typically presented in terms of acceptable levels in excess of background.

Background radiological measurements were collected at distances of approximately 2.8 km (1.8 mi) (at Locations 1 and 2) and 1.6 km (1 mi) (at Location 3) from Lambert-St. Louis International Airport (Figure 3-1). Location 1 is open, grassy land with no trees and with no structures within 0.2 km (0.1 mi). It is owned by the City of St. Louis and is expected to become part of the airport during planned expansion. Location 2 is also open, grassy land with no trees; there are no structures within 0.5 km (0.3 mi). Location 3 is an open, grassy area with trees; it is near a school surrounded by a park and near a gasoline station.

Near-surface gamma radiation levels and gamma exposure rates were measured at these locations to establish naturally occurring radiation levels. The average near-surface gamma radiation level is approximately 10,000 cpm, and the average background gamma exposure rate is 10 mR/h. Gamma radiation levels at 1 m (3 ft) above the ground surface average approximately 10,000 cpm. Average background concentrations of uranium-234, uranium-235, and uranium-238 measured in surface soils at the three background locations are 1.1, 0.1, and 1.1 pCi/g, respectively. The average background concentrations of radium-226, thorium-230, and thorium-232 are 0.9, 1.3, and 1.0 pCi/g, respectively.

No background measurements have been taken yet to determine the naturally occurring levels of metals, VOCs, or BNAEs in the St. Louis area; background chemical sampling will be done before remedial action begins and is outlined in a field sampling plan that is being prepared. Analytical results for metal samples from SLAPS, SLDS, and the Latty Avenue Properties were compared with concentration ranges for metals in soil at various locations in the United States and other parts of the world. These concentrations are listed in Appendix B.

Groundwater background values were established at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS and 2.4 km (1.5 mi) southwest of SLAPS. Concentrations of total uranium, radium-226, and thorium-230 range from less than 3 to 4, 0.6 to 1.1, and 0.2 to 0.4 pCi/L, respectively. Background concentrations for metals, VOCs, and BNAEs were not determined. Background values for groundwater indicator parameters are: pH - 6.8 to 7.3, TOC - 2.7

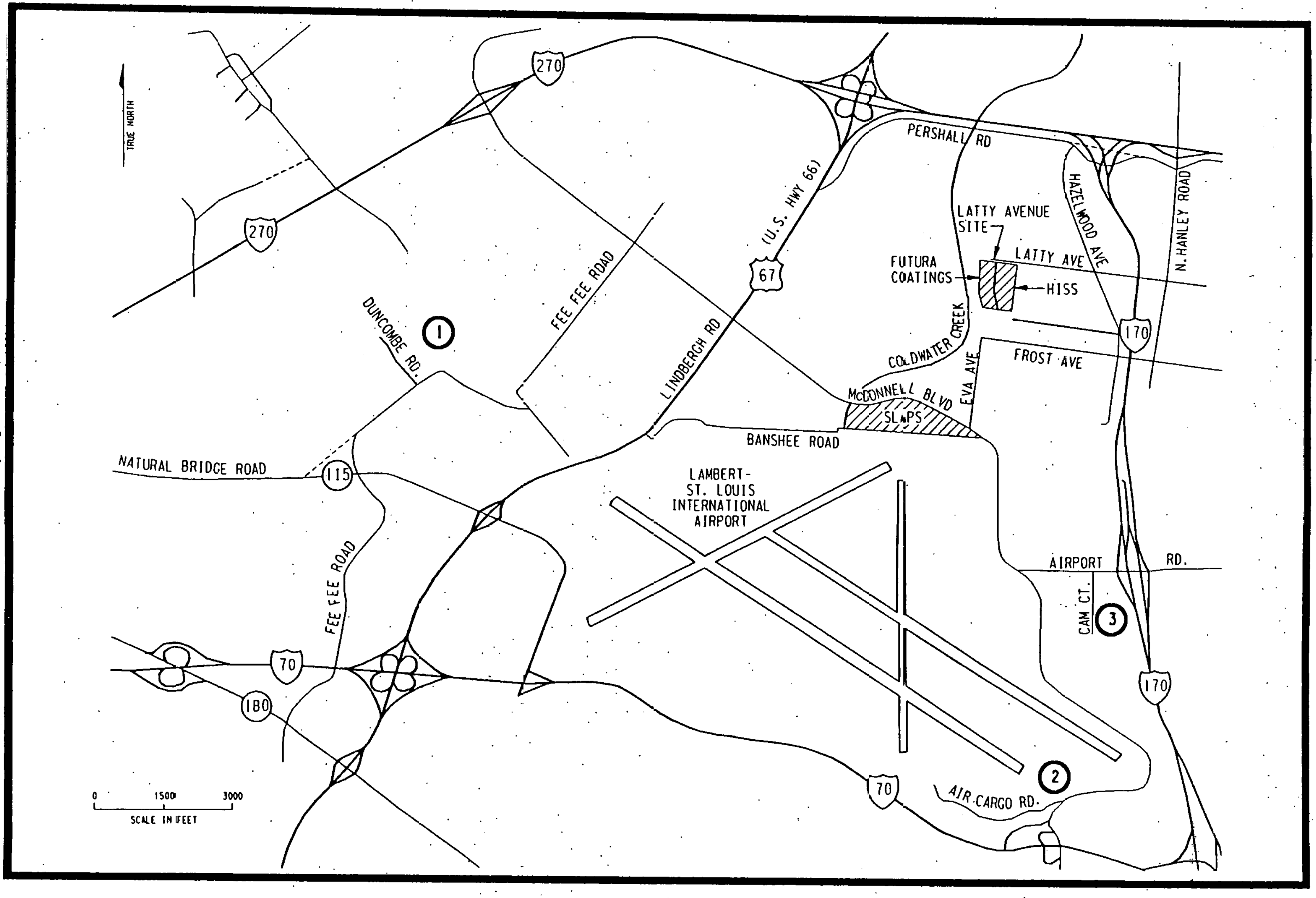

FIGURE 3-1 BACKGROUND SAMPLING LOCATIONS IN THE ST. LOUIS AREA

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to 44.8 mg/L, TOX - nondetectable to 45 mg/L, and specific conductance - 909 to 1,100 mmhos/cm.

A source term analysis was developed for the St. Louis site that included analysis of chosen soil samples for radionuclides from the uranium-235, uranium-238, and thorium-232 series. All of these radionuclides contribute to site contamination to some degree. All components from all decay chains will be factored into the baseline risk assessment. The source term analysis may be found in Appendix C of the work plan (BNI 1991). An additional study concerning preferential migration of actinides (protactinium and actinium) showed no migration of these radionuclides below the defined zone of radioactivity.

Additional information regarding this background survey is provided in BNI 1990a.

3.2 CHARACTERIZATION RESULTS FOR SLDS

3.2.1 Surface and Subsurface Soils at SLDS

Radiological results

In general, radionuclide concentrations exceeding DOE guidelines for residual radioactivity were found in areas where expected based on previous radiological surveys and site operations: primarily near or beneath buildings where MED/AEC operations had been carried out (Figure 3-2). Two exceptions are Plant 5 and the city property, which were not associated with MED/AEC activities but still contain levels of radioactivity exceeding DOE guidelines.

Radioactivity was found mostly in the rubble and fill zone and, in some instances, extending to undisturbed material. Uranium and metals, in general, are soluble in acidic environments such as those associated with decomposed organic materials found in the fill zone. These organic materials are very porous, which allows uranium-containing compounds to enter and react in the acidic environment. This reaction can allow the contaminants to migrate,

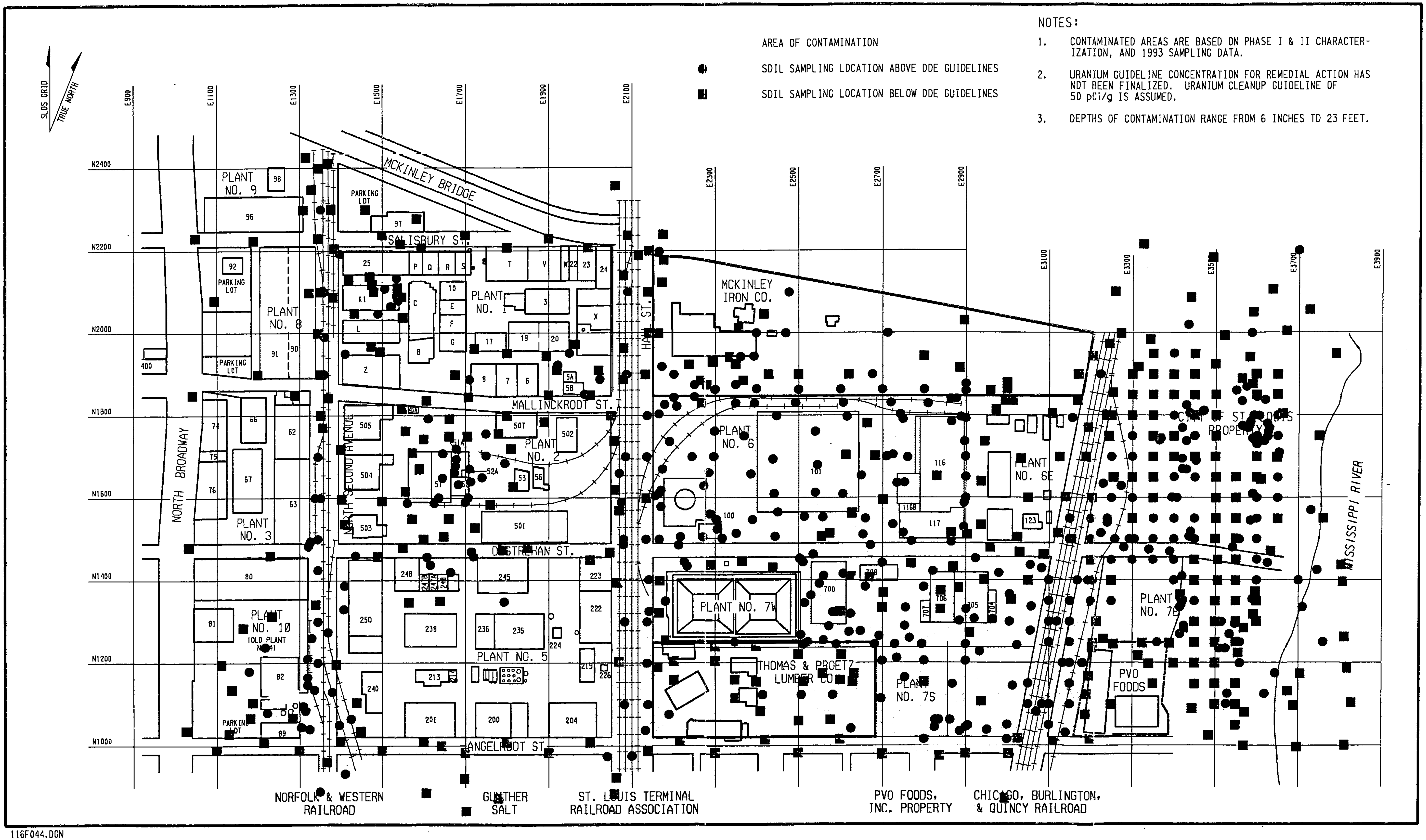


FIGURE 3-2 AREAS OF RADIOACTIVE CONTAMINATION AT SLDS

and contamination was typically found in silty clay soil or in silty sand materials below the fill zone.

Table 3-1 provides a summary, by plant, of the characterization results from the radiological soil investigation at SLDS.

Soil samples from 7 of the 22 boreholes at Plant 1 are contaminated. The majority of the contaminated boreholes are around Buildings K1E and 25, and contamination was found to a depth of 3.5 m (12 ft).

Thirteen of the 27 boreholes at Plant 2 are contaminated to a depth of 7 m (23 ft). The contamination was found near and beneath Buildings 51, 51A, 52, and 52A, which are connected.

At Plant 5, samples from seven of the eight boreholes are contaminated to a depth of approximately 4.5 m (15 ft). The contaminated boreholes are along the northern edge of Plant 5 near Plant 2.

Fifty-three of the 64 boreholes at Plants 6 and 6E are contaminated to a depth of 6 m (20 ft). The majority of the contaminated boreholes are in Plant 6, most of which was found to be contaminated, including the soil under and around Building 101.

Thirty-two of the 45 boreholes at Plant 7 are contaminated to a depth of 6 m (20 ft). The contamination was primarily found around Building 700 and adjacent to the railroad tracks.

Contamination was found in 9 of the 13 boreholes at Plant 10 to a depth of 2 m (6 ft). It was generally found around Building 82 and adjacent to the railroad tracks.

Nineteen of the 24 boreholes at the city property adjacent to SLDS between SLDS and the Mississippi River are contaminated to a depth of 13 m (42 ft). The contamination is generally to the north and east of Plant 7E and adjacent to the railroad tracks.

The current estimated volume of radioactively contaminated soil and building material at SLDS and its vicinity properties is approximately 188,000 m^3 (246,000 yd^3).

More detailed results of the radiological investigation of soil at SLDS are given in BNI 1990a.

Table 3-1

Radiological Characterization Results for SLDS

Location[a]/ Parameter	Radionuclide Concentration Range (pCi/g)	Radionuclide Concentration Average (pCi/g)
Plant 1		
U-238	3.0 - 310	22
Ra-226	0.7 - 5,400	87
Th-232	0.5 - 14	2.2
Th-230	0.3 - 330	17
Plant 2		
U-238	3.0 - 33,000	1,300
Ra-226	0.4 - 500	13
Th-232	0.5 - 9	2.3
Th-230	0.4 - 14,000	270
Plant 5		
U-238	4.0 - 170	23
Ra-226	1.0 - 290	21
Th-232	0.7 - 130	7
Th-230	0.5 - 1000	57
Plants 6 and 6E		
U-238	1.3 - 15,000	140
Ra-226	0.5 - 2,800	27
Th-232	0.4 - 440	6.6
Th-230	0.4 - 3,000	52
Plant 7		
U-238	2.0 - 310	21
Ra-226	0.4 - 490	13
Th-232	0.4 - 210	5
Th-230	0.4 - 670	14
Plant 10		
U-238	2.0 - 1,100	44
Ra-226	0.5 - 300	11
Th-232	0.5 - 56	3.7
Th-230	0.3 - 2,100	48

Table 3-1

(continued)

Location[a]/ Parameter	Radionuclide Concentration Range (pCi/g)	Average (pCi/g)
City property and Plant 7E		
U-238	1.0 - 20,000	75
Ra-226	0.6 - 1,300	20
Th-232	0.8 - 46	2.2
Th-230	0.5 - 590	19

[a]Sampling locations are shown in Figure 2-2.

Chemical results

During Phases I and II of the soil investigation at SLDS, 110 boreholes were sampled for chemical constituents; 23 were sampled for VOCs, 56 for BNAEs, 63 for RCRA-hazardous waste characteristics, and 109 for metals.

Results of tests for RCRA-hazardous waste characteristics indicate that soil on a few small, isolated areas contains levels of lead that exceed the EP criterion for lead (5 mg/L). These areas are surrounded by larger volumes of soil that satisfy the EP toxicity test.

In general, concentrations of VOCs are low, with mean concentrations of 2 to 73 ppb. The VOCs most frequently detected are toluene and trichlorofluoromethane. Twenty-seven BNAE compounds were detected, occurring in most of the boreholes sampled; two-thirds of these are PAHs. In general, average concentrations of BNAE compounds are higher (585 to 14,900 ppb) than the VOCs measured at the property. No pattern of BNAE distribution in soil is discernible across the property; the compounds appear to be randomly distributed. BNAEs are not expected to migrate appreciably, given their chemical characteristics. The most frequently found BNAE compounds are pyrene, fluoroanthene, phenanthrene, and benzo(a)anthracene.

The potential for migration of PAHs from property soil to surface water or groundwater is minimal because these compounds exhibit strong tendencies to partition to the soil and will not readily leach into the water phase. These tendencies can be determined by examining the organic carbon partition coefficient (K_{oc}) values for these compounds. The K_{oc} is a compound-specific parameter that defines the linear relationship between the liquid phase concentration and the mass of chemical adsorbed by the organic carbon in the solid phase. Using an estimate of 2 percent by weight for the organic carbon in soil (Swann 1983) and by knowing the concentration of chemical in soil and the coefficient K_{oc}, it is possible to calculate the expected chemical concentration for the water phase that would result from the contact of water with the compound in the soil. For example: for benzo(a)pyrene with K_{oc} = 5,550,000, concentration in soil (K_p) = 110,000 (i.e., for K_p = 5,550,000 x 2% carbon, the concentration of benzo(a)pyrene in the soil would have to be 110,000 ppb to produce a leachate with a concentration equal to 1 ppb). The low mobility of these compounds is also supported by groundwater sampling results for SLDS because PAHs were not detected. Hence, many factors such as the percent moisture in soil and the organic nature of the soil itself could drastically modify the mobility of these PAHs.

Metals were found in soil above, within, and beneath areas of radioactive contamination. Eighteen metals exceed maximum expected background concentrations: antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, molybdenum, selenium, silver, sodium, thallium, and zinc. Expected background concentrations were derived from concentration ranges for metals in soil at various locations in the United States and other parts of the world (Appendix B). The elevated metal concentrations may have resulted from uranium processing at SLDS and/or from the potential presence of coal and ash in fill used at the property and at other locations along the Mississippi River. Some metals (selenium, cadmium, lead, and zinc) found at above-background concentrations, are common to some uranium ores that were stored and handled at SLDS. Also, thallium is often a constituent of coal and fly ash from coal combustion.

Based on chemical characterization of SLDS, the following conclusions have been drawn:

- In general, the radioactively contaminated soil does not exhibit any RCRA-hazardous waste characteristics, according to testing done so far.

- VOCs (averaging 2 to 13 ppb) were detected across the property.

- BNAEs (average concentrations of 585 to 14,900 ppb), primarily PAHs, were detected. These compounds, however, do not exhibit high mobility, given their chemical characteristics.

- Metals were found in radioactively contaminated soil and in soil that is not radioactively contaminated.

As noted, a few samples collected and analyzed for RCRA characteristics failed the EP toxicity test for lead (i.e., upon leaching, the concentration of lead exceeded 5 mg/L). Soil from B16C02, B16C30, and B16C37 (composite samples taken during Phase I sampling) failed this test with values of 20.9, 6.3, and 18.7 mg/L, respectively. Borehole B16C02 is located at the western side of Plant 1; B16C30 and B16C37 are located at the northern and southern sides of the Plant 6 and 6E area. Additional sampling is planned for areas that failed the EP toxicity test for lead. These samples will be analyzed using the newly required toxicity characteristic leaching procedure (TCLP), which has replaced the EP toxicity test. Discrete samples were collected for RCRA characteristic analysis during Phase II, but none failed the EP toxicity test.

Although samples taken during both phases were not analyzed using TCLP, the change of methods is not expected to affect remedial action at the property. Research of results for discrete samples taken from the boreholes that initially failed the EP toxicity test did not show any other compounds that are on the TCLP list of contaminants.

Only chemicals associated with MED/AEC activities or those mixed with radioactive waste will be remediated. For more information regarding results of the chemical investigation, refer to BNI 1990a.

3.2.2 Groundwater at SLDS

Radiological results

The groundwater monitoring wells at SLDS (Figure 2-3) were sampled for total uranium, radium-226, and thorium-230. Uranium values vary from 3×10^{-9} to 1.9×10^{-7} μCi/ml (3 to 193 pCi/L), radium-226 values range from 3×10^{-10} to 3.2×10^{-9} μCi/ml (0.3 to 2.3 pCi/L), and thorium-230 values range from less than 1×10^{-10} to 3.7×10^{-9} μCi/ml (0.1 to 3.7 pCi/L). All measurements, except the uranium levels in Well B16W02S, are near typical background values. Well B16W02S, in Plant 1 near Building K1E, consistently showed elevated levels of total uranium (107 to 193 pCi/L), which indicates that uranium in this area may be leaching into the groundwater. A potential applicable or relevant and appropriate requirement for the St. Louis site is the Uranium Mill Tailings Radiation Control Act (40 CFR 192), which proposes 30 pCi/L as a guideline for concentrations of uranium in groundwater.

Detailed results for the radiological investigation of groundwater are provided in BNI 1990a.

Chemical results

Ten different organic compounds were found in six of the eight wells. Benzene was found most frequently (in 6 of 24 samples); followed by 1,2-dichlorobenzene, 1,2-dichloroethene, and 1,2-dichloropropane, each detected in 3 of 24 samples; and chlorobenzene, bis(2-ethylhexyl)phthalate, aroclor-1254, and vinyl chloride, each detected in 2 of 24 samples. Seven of the ten organic compounds were detected in samples from Well B16W038 (Plant 2). Bis(2-ethylhexyl)phthalate was detected at 1,100 and 340 μg/L, the highest concentrations found. It was also detected at low concentrations in the blanks used to verify the samples but was not present in the following quarter's monitoring results, which indicates that its presence in the blanks was probably a laboratory artifact. Table 3-2 is a summary of organics detected during one year of groundwater monitoring at SLDS; Table 3-3 lists the results for organics analyses for each well.

Sixteen metals were found above detection limits in groundwater at SLDS; Table 3-4 summarizes the results. With the exception of zinc, those metals detected most frequently in soils (thallium, selenium, cadmium, lead, and zinc) were not found frequently in groundwater.

For more information regarding the chemical results, refer to BNI 1990a.

3.2.3 Surface Water and Sediments at SLDS

Sediment from 35 of the 84 manholes surveyed at SLDS shows residual radioactivity exceeding DOE guidelines (Figure 3-3). Uranium-238 concentrations range from less than 2 to 270 pCi/g; radium-226 concentrations range from 0.8 to 930 pCi/g; and concentrations of thorium-232 and thorium-230 range from 0.7 to 640 and less than 0.5 to 2,600 pCi/g, respectively. Therefore, portions of the stormwater and sanitary sewers will require remedial action.

The results of the manhole surveys are provided in Tables 6-7 and 6-8 in Volume II of BNI 1990a.

3.2.4 Buildings at SLDS

Radioactive contamination exceeding DOE guidelines was found in 17 of the 20 buildings surveyed at SLDS. Analytical results for the samples collected from the buildings revealed uranium-238 as the primary radioactive contaminant.

Table 3-5 provides a summary of the radiation measurements from the buildings investigation and the areas within each building where the greatest levels of contamination were found. The alpha and beta-gamma contamination is considered nonremovable (not easily removed by light wiping or vacuuming).

Table 3-2

Summary Statistics for VOCs, BNAEs, and Pesticides/PCBs Detected in Groundwater at SLDS

Compound[a]	Concentration (µg/L) Mean[b]	Min.	Max.	Number of Samples Analyzed	Exceeding Detection Limit
<u>VOCs</u>					
Benzene	8	< 5	21	24	6
Chlorobenzene	5	< 5	8	24	2
1,2-dichloroethene	12	< 5	150	24	3
1,2-dichloropropane	13	< 5	130	24	3
Trichloroethene	5	< 5	5	24	1
Vinyl chloride	11	<10	29	24	2
<u>BNAEs</u>					
1,2-dichlorobenzene	20	<10	93	24	3
Bis(2-ethylhexyl)-phthalate	69	<10	1,100	24	2
<u>Pesticides/PCBs</u>					
4,4'DDT	0.17	< 0.10	0.98	24	1
Aroclor-1254	1.6	< 1	<5.3	24	2

[a]VOC - volatile organic compound; BNAE - base/neutral and acid extractable; PCB - polychlorinated biphenyl.

[b]All values, including those reported as sample detection limit, were used to calculate the mean.

Table 3-3

Ranges of VOCs, BNAEs, and Pesticides/PCBs Detected in Groundwater at SLDS[a] from July 1988 to April 1989

Compound[b]	Sampling Location (Well No.)[c]							
	B16W01S	B16W02S	B16W03S	B16W04S	B16W05D	B16W06D	B16W07D	B16W08D
<u>VOCs (µg/L)</u>								
Benzene	ND[d]	6[e]	18-21	21	ND	9	ND	ND
Chlorobenzene	ND	ND	7-8	ND	ND	ND	ND	ND
1,2-dichloroethene	ND	ND	7-150	ND	ND	ND	ND	ND
1,2-dichloropropane	ND	ND	29-130	ND	ND	ND	ND	ND
Trichloroethylene	ND	ND	5	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	23-29	ND	ND	ND	ND	ND
<u>BNAEs (µg/L)</u>								
1,2-dichlorobenzene	ND	ND	87-93	ND	ND	ND	ND	ND
Bis(2-ethylhexyl)-phthalate	ND	ND	ND	ND	340[f]	ND	1,100[f]	ND
<u>Pesticides/PCBs(µg/L)</u>								
4,4'DDT	ND	ND	ND	ND	ND	ND	0.98	ND
Aroclor-1254	ND	ND	ND	1.2-1.5	ND	ND	ND	ND

[a]Does not include parameters for which the concentrations were below the limit of sensitivity of the analytical method used.

[b]VOC = volatile organic compound; BNAE = base/neutral and acid extractable; PCB = polychlorinated biphenyl.

[c]Sampling locations are shown in Figure 2-3.

[d]ND - not detectable at levels exceeding the detection limit.

[e]A single value indicates that the compound was present during one quarter's sampling.

[f]Compound was detected in the blank.

Table 3-4

Ranges of Metal Ion Concentrations Detected in Groundwater at SLDS[a,b]

from July 1988 to April 1989

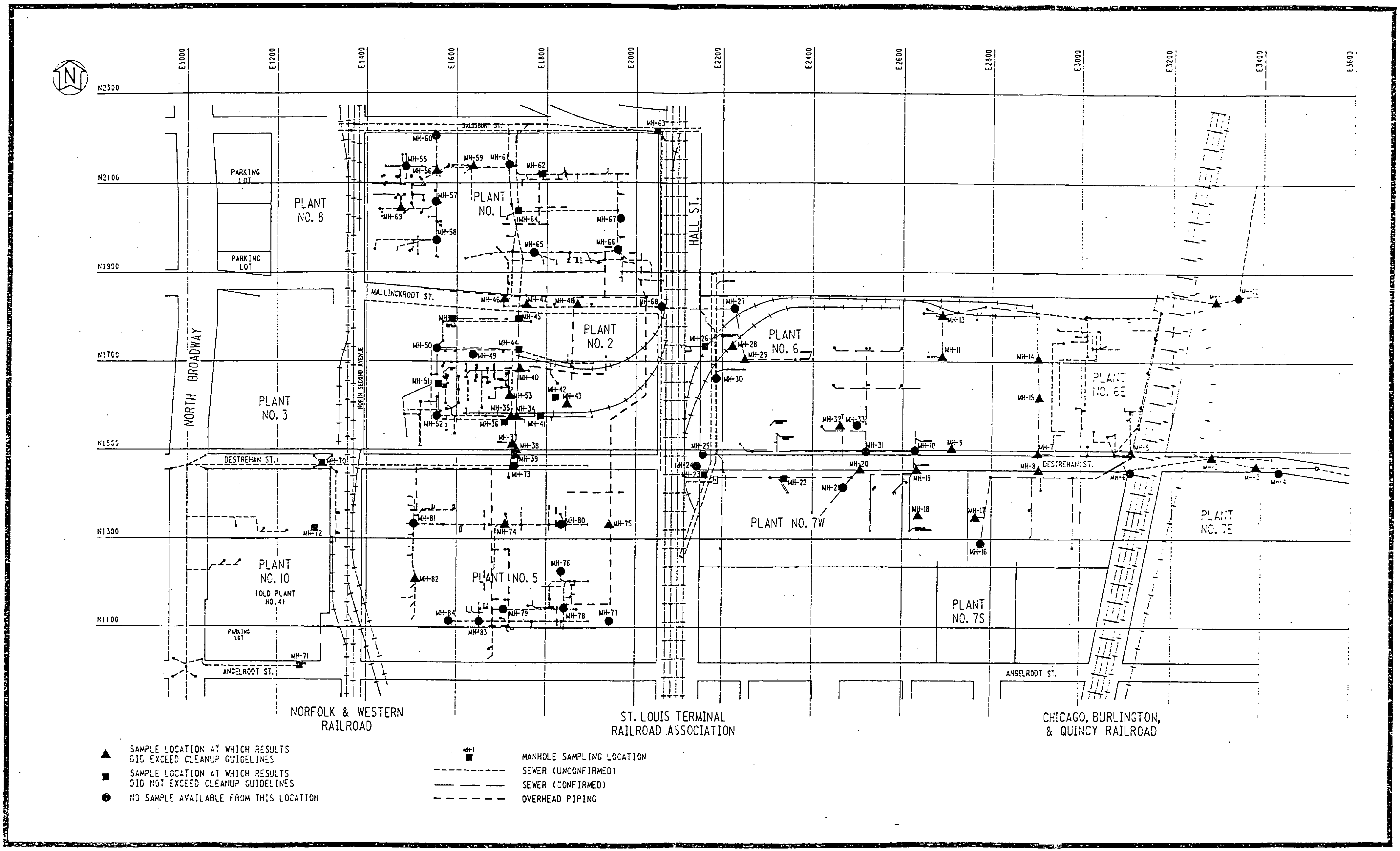
Metal Ion	Concentrations at each Sampling Location (Well No.)[c]							
	B16W01S	B16W02S	B16W03S	B16W04S	B16W05D	B16W06D	B16W07D	B16W08D
Aluminum	<200-258	<200	<200	<200-400	<200-238	<200-240	<200-262	<200-217
Arsenic	<100-115	<100	<100-126	<100	<100	<100	<100	<100
Barium	<200	<200	<200	<200	345-453	334-536	<200	<200
Boron	233-519	743-814	659-857	551-897	1170-1310	1370-1550	<100-1750	1550-1850
Cadmium	<5-10.9	<5	<5	<5	<5	<5	<5-5	<5
Calcium (x 1000)[d]	100-256	101-118	43.4-124	100-143	247-294	246-260	25.7-290	270-283
Chromium	<10	<10	<10	<10-50	<10	<10	<10	<10
Copper	<25-27.4	<25	<25	<25-37.3	<25-30.9	<25	<25-27.3	<25
Iron	<100-611	<100-304	137-8920	<100-274	<100-9440	199-9820	<100-9570	248-20800
Magnesium (x 1000)[d]	14.9-46.4	20-22	9.96-25.7	15-24.5	60.8-65.8	64.2-69.8	<5-59.1	42.3-47.1
Manganese	372-1480	2860-3840	846-2160	1630-4520	1460-1740	1060-1690	<15-1850	2240-2580
Nickel	<40-176	<40	<40	<40-42.3	<40-714	<40	<40	<40-66.9
Potassium (x 1000)[d]	<5-7.17	14.8-18.5	42.1-62.7	<5-8.10	10.2-13.4	11.2-14.7	5.37-21.1	28.3-34.9
Selenium	<100	<100	<100	<100	<100	<100	<100	<100-108
Sodium (x 1000)[d]	41.6-139	70.9-89.3	267-506	18.3-35.1	140-167	96.8-236	8.57-128	97.4-118
Zinc	35-193	<20-54.9	<20-179	20.7-301	29.1-126	48.9-99.1	<20-198	21.9-182

[a]Does not include parameters for which the concentrations were below the limit of sensitivity of the analytical method used.

[b]Concentrations given in µg/L; where only one value is shown, all samples had that value.

[c]Sampling locations are shown in Figure 2-3.

[d]Indicates concentrations are 1000 times greater than the values shown.



116F002.DGN MANHOL

FIGURE 3-3 RESULTS FOR MANHOLES SURVEYED AT SLDS

Table 3-5

Summary of Radiological Building Survey Results at SLDS[a]

Building	Area of Greatest Surface Contamination	Fixed Radiation Range (dpm/100 cm^2) Alpha	Fixed Radiation Range (dpm/100 cm^2) Beta-Gamma
K1E	Roof[b]	6-1,100	70-35,000
25	Walls and floors	2-13,200	30-620,600
50	Floors[c]	6-600	40-43,600
51	Walls and floors[c]	6-2,500	40-268,400
51A	Walls and floors[c]	7-1,500	170-51,900
52	Walls	7-5,400	170-98,900
52A	Walls[b,c]	70-11,000	1,400-250,800
81	None[d]	6-600	20-2,900
82	None[d]	6-1,400	40-2,800
100	All surfaces	7-23,500	290-75,600
101	None[e]	No measurements taken	
116	Walls and floors[f]	5-3,000	40-929,100
116B	Ceilings and roof	20-2,600	850-73,700
117	All surfaces	5-6,400	40-117,300
700	All surfaces	6-1,600	130-254,800
704	Floors and roof	8-5,000	900-42,300
705	All surfaces	3-16,300	50-529,900
706	Floors and ceiling	30-2,100	40-150,700
707	Roofs and floors	20-2,100	800-12,900
708	Roofs and floors	160-3,700	130-11,800

[a]All surveys were conducted between 1987 and 1989.

[b]No floor measurements were taken due to inaccessibility.

[c]No ceiling measurements were taken due to inaccessibility.

[d]No surfaces exceeded uranium guidelines.

[e]Only floor measurements were taken, and they did not exceed DOE uranium guidelines.

[f]No ceiling measurements were taken.

Additional roof surveys revealed residual radioactive contamination on some of the adjacent buildings; however, all direct alpha measurements are below DOE guidelines, and only a few beta-gamma readings exceed guidelines.

A detailed description of the investigation at each building is available in BNI 1990a.

3.2.5 Air at SLDS

Radon measurements were taken in 19 buildings at SLDS in March 1990 using charcoal canisters. Results range from nondetectable to 8.98 pCi/L, with an average of 2.78 pCi/L. Two results exceed the DOE annual guideline for average radon concentrations, which is 3 pCi/L. Both concentrations (4.84 and 8.98 pCi/L) were found on the lower level of Building K1E, to which access is restricted.

Radon measurements were taken again in September 1990 in the same 19 buildings, and results range from nondetectable to 73.42 pCi/L, with an average of 4.93 pCi/L. Five locations showed radon levels exceeding the DOE guideline. All three measurements taken in Building K1E exceed the guideline: two on the lower level at 46.85 and 73.42 pCi/L and one on the upper level at 3.54 pCi/L. Two of the four locations measured in Building 101 exceed the guideline, with concentrations of 4.75 and 4.25 pCi/L.

The increased average radon concentrations measured in September can be attributed to temperature. Because the ground is much warmer in September than in March, more radon is released.

Also in September 1990, 22 Terradex cups were placed in Buildings K1E, 25, 50, 51, 51A, 52A, 81, 82, 100, 101, 116, 117, 700, 704, 705, 706, 707, and 708 to measure radon. Results range from 0.7 to 31.2 pCi/L, with an average of 2.7 pCi/L. Radon levels exceed the DOE guideline in four locations: the lower level of Building K1E (31.2 pCi/L), Building 25 (5.0 pCi/L), and Building 101 (4.0 and 3.3 pCi/L).

3.2.6 Geology and Hydrogeology at SLDS

A generalized stratigraphic section and geologic description of the subsurface materials encountered during site investigations at SLDS is shown in Figure 3-4. A layer of rubble and fill (disturbed material) with an average thickness of 4 m (13 ft) is present over most of the property. Beneath the disturbed materials, unconsolidated deposits composed of stratified clays, silts, sands, and gravels are present. The unconsolidated deposits have been divided into an upper and lower unit. The upper unit is a clayey silt with interbedded silty clay, clay, silt, and sandy silt. The thickness of this unit ranges from 3 to 9 m (10 to 30 ft). Evaluation of soil boring data suggests that this unit is laterally continuous across the property. The lower unit is a silty sand that grades laterally to a sand toward the Mississippi River and is present only in the eastern portion of the property. The observed thickness of the unit ranges from 0 to 18.3 m (0 to 60 ft), increasing in thickness with increasing depth to bedrock and proximity to the Mississippi River. A limestone bedrock unit is present beneath the unconsolidated deposits. The depth to bedrock ranges from 5.9 m (19.5 ft) on the western side of the property to 24.4 m (80 ft) near the Mississippi River. The limestone is hard and microcrystalline and contains chert nodules. Examination of rock core samples indicates that the upper 1.5 m (5 ft) of the limestone is moderately fractured (200- to 600-mm spacing), with the discontinuities oriented normal to the core axis.

The dominant surface water feature at SLDS is the Mississippi River, which is located near the eastern edge of the property. Rivers are the major water supply source for the St. Louis area. All but one of the water supply intakes for the area are located upstream of SLDS; East St. Louis draws a portion of its water from an intake located on the eastern bank of the river, approximately 3.2 km (2 mi) downstream of SLDS.

SLDS is underlain by a portion of the Mississippi River alluvial aquifer. The alluvial aquifer at SLDS is composed of the upper and lower units of the unconsolidated deposits. The silt and

Unit Designation	Graphic Column	Approximate Thickness (ft)	Description
NOT DESIGNATED		0-25	**RUBBLE and FILL** Grayish black (N2)to brownish black (5YR2/1). Dry to slightly moist, generally becoming moist at 5-6 ft and saturated at 10-12 ft. Slight cohesion, variable with depth, moisture content and percentage of fines present. Consistency or relative density is unrepresentative, due to large rubble fragments. Rubble is concrete, brick, glass, and coal slag. Percentage of fines as silt or clay increases with depth from 5 to 30 percent. Some weakly cemented aggregations of soil particles. Adhesion of fines to rubble increases with depth and higher moisture content. Degree of compaction is slight to moderate with frequent large voids.
UPPER UNIT		0-10	**Silty CLAY (CH)** Layers are mostly olive gray (5Y2/1), with some olive black (5Y2/1). Predominantly occurs at contact of undisturbed material, or at boundary of material with elevated activity. Abundant dark, decomposed organics. Variable percentages of silt and clay compostion.
		0-3	**CLAY (CL)** Layers are light olive gray (5Y5/2), or dark greenish gray (5GY4/1). Slightly moist to moist, moderate cohesion, medium stiff consistency. Tends to have lowest moisture content. Slight to moderate plasticity.
		0-15	**Interbedded CLAY, Silty CLAY, SILT and Sandy SILT (CL, MM, SM)** Dark greenish gray (5GY4/1) to Light olive gray (5Y6/1). Moist to saturated, dependent on percentage of particle size. Contacts are sharp, with structure normal to sampler axis to less than 15 degrees downdip. Layer thicknesses are variable, random in alternation with no predictable vertical gradation or lateral continuity. Some very fine-grained, rounded silica sand as stringers. Silt is dark mafic, biotite flakes. Some decomposed organics.
		0-10	**Sandy SILT (ML)** Olive gray (5Y4/1). Moist with zones of higher sand content saturated. Slight to moderate cohesion, moderate compaction. Stiff to very stiff consistency, rapid dilatancy, nonplastic. Sand is well sorted, very fine and fine-grained rounded quartz particles.
LOWER UNIT		0-30	**Silty SAND and SAND (SM, SP, SW)** Olive gray (5Y4/1). Saturated, slight cohesion, becoming noncohesive with decrease of silt particles with depth. Dense, moderate compaction. Moderate to well-graded, mostly fine- and medium-grained, with some fine- and coarse-grained particles. Mostly rounded with coarse grains slightly subrounded. Gradual gradation from upper unit, Silty SAND has abundant dark mafic/biotite flakes. Sand is well-graded, fine gravel to fine sand. Mostly medium-grained, with some fine-grained and few coarse-grained and fine gravel.
BEDROCK UNIT		0.5-12	**LIMESTONE** Light olive gray (5Y4/1) with interbedded chert modules. Generally hard to very hard; difficult to scratch with knife. Slightly weathered, moderately fresh with little to no discoloration or staining. Top 5 ft is moderately fractured, with 99 percent of joints normal to the core axis. Joints are open, planar, and smooth. Some are slightly discolored with trace of hematite staining.

Note: The codes in parenthesis following lithologies are the Unified Soil Classification System codes.

FIGURE 3-4 GENERALIZED STRATIGRAPHIC COLUMN FOR SLDS sandy silt layers within the upper unit represent water-bearing strata that are thought to be in hydraulic connection with the silty sand and sand of the lower unit. The alluvial aquifer is underlain by limestone bedrock. The upper portion of the bedrock is a water-bearing zone with groundwater occurring in secondary porosity features (fractures). Primary (matrix) porosity of the limestone is low, resulting in groundwater flow primarily through secondary porosity features. The boreholes penetrating the bedrock did not reveal any strata that could act as an aquitard to isolate the bedrock from the alluvial aquifer. Thus, the upper bedrock is thought to be hydraulically connected to the alluvial aquifer.

The relationship of the alluvial aquifer to the Mississippi River was investigated using groundwater level and river stage data. Figures 3-5 and 3-6 are hydrographs showing groundwater elevations from four wells monitoring the lower unit and river stage elevations. The hydrographs suggest that there is a correlation between river stage fluctuations and groundwater level fluctuations. To quantify this correlation, regression analyses were performed. Correlation coefficients obtained from the regression analyses ranged from 0.93 to 0.99, indicating good correlation between the data (a correlation coefficient of 1 indicates perfect correlation). This suggests that the alluvial aquifer is in hydraulic connection with the Mississippi River.

Figure 3-7 is a potentiometric surface map created from groundwater level and river stage measurements taken on June 9, 1989. The figure shows that the general direction of groundwater flow is toward the Mississippi River. However, near the river, there is an anomalous depression in the potentiometric surface that is thought to represent a transient condition created by river stage fluctuations. When the river stage rises, a temporary reversal of groundwater flow occurs, created by recharge from the river.

The potentiometric surface map and available site data were used to develop a conceptualization of groundwater flow at the property. Recharge to the area groundwater system is thought to occur by offsite inflow through the upper unconsolidated unit and

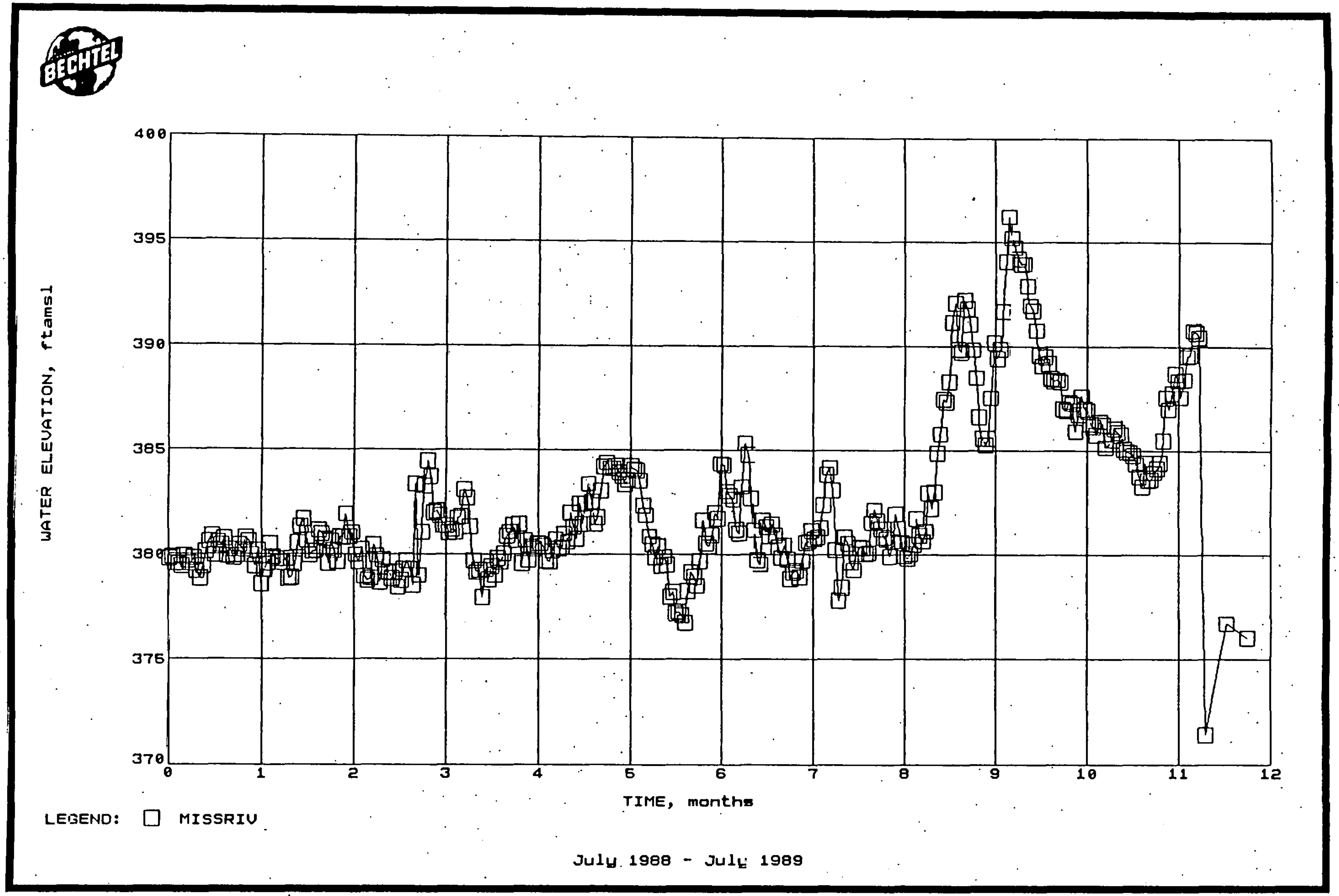


FIGURE 3-5 HYDROGRAPH OF MONITORING WELLS OF UNCONSOLIDATED DEPOSITS AT SLDS

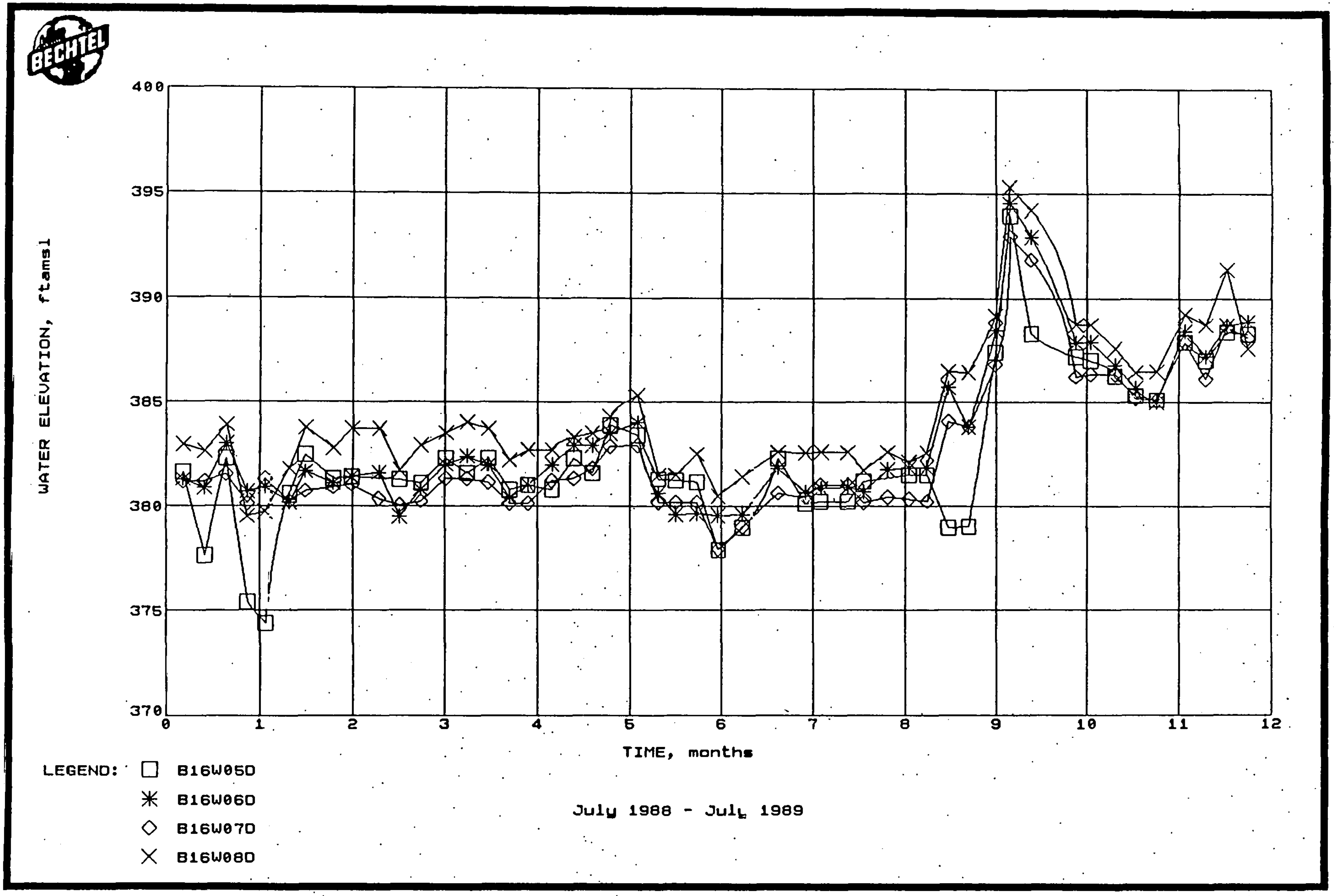


FIGURE 3-6 HYDROGRAPH OF MISSISSIPPI RIVER WATER LEVELS NEAR SLDS

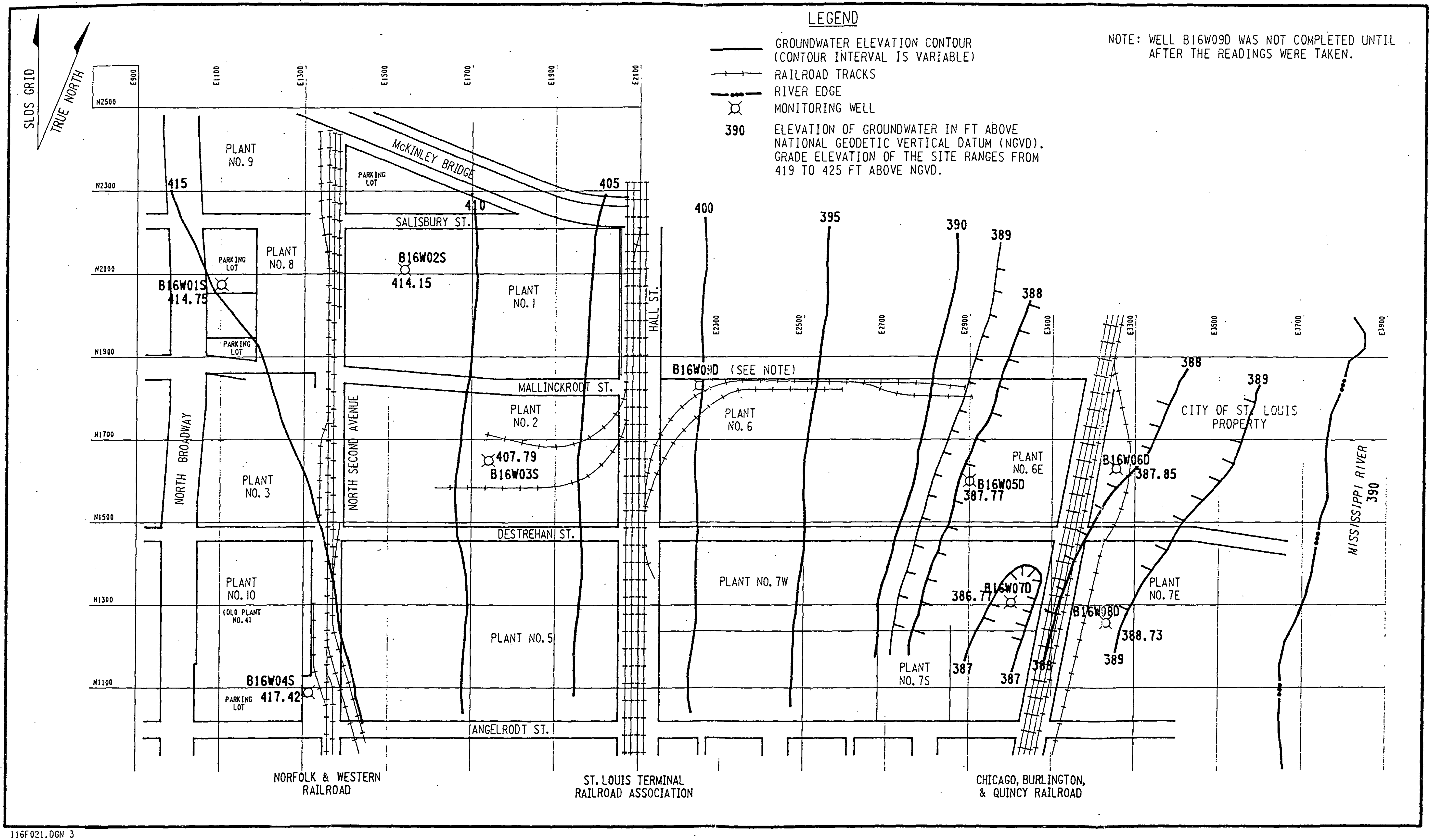


FIGURE 3-7 POTENTIOMETRIC SURFACE FOR SLDS, JUNE 9, 1989

bedrock, from infiltration of precipitation, and through river bed infiltration at the Mississippi River. Infiltration of precipitation at SLDS appears to be a minor source of recharge because of the large percentage of surface area that contains impervious or diversionary features (i.e., asphalt roads, parking lots, and buildings). The area groundwater system discharges to the Mississippi River during low river stage, as underflow beneath the river, and, possibly, as recharge to the bedrock groundwater system.

Investigations conducted at the property include measurement of aquifer characteristics that are related to groundwater flow and solute transport in the groundwater system. A summary of these measurements is presented in Table 3-6. The measurement methodologies and results are discussed in BNI 1990a. Available information is insufficient to quantify the average linear groundwater velocity at the property; however, based on the materials present and the measured hydraulic gradients, the average linear groundwater velocity is estimated to be 3 to 6 m/yr (10 to 20 ft/yr) in the lower unit and 0.03 to 0.3 m/yr (0.1 to 1 ft/yr) in the upper unit. The uranium distribution ratio for the upper unit indicates that transport of uranium would be significantly retarded relative to groundwater movement. Based on soil properties from similar geologic settings and on the uranium distribution ratio, the uranium migration rate is estimated to be 300 to 400 times slower than the groundwater velocity.

3.3 CHARACTERIZATION RESULTS FOR THE SLDS VICINITY PROPERTIES

Table 3-7 summarizes the analytical results for the radiological surveys conducted at the SLDS vicinity properties. Further sampling activities are planned in the future to better delineate contamination; these are described in a separate field sampling plan.

Table 3-6
Summary of Groundwater Flow and Solute Transport
Parameters for SLDS

Aquifer Characteristics	Hydrogeologic and Geochemical Properties
Upper Unit	
Observed saturated thickness	3 to 9 m (10 to 30 ft)
Hydraulic conductivity	9.9×10^{-5} cm/s (10 ft/yr)[a]
Distribution ratio for uranium	146 ml/g[a]
Effective cation exchange capacity	200 meq/100 g of soil[a]
Lower Unit	
Observed saturated thickness	0 to 10.3 m (0 to 60 ft)
Hydraulic conductivity	Not determined
Bedrock	
Observed thickness	Not determined
Hydraulic conductivity	1.1×10^{-3} to 5.1×10^{-4} cm/s (1,190 to 535 ft/yr)
Hydraulic gradient	0.01 to 0.02 [dimensionless]

[a]Only one test was conducted for this parameter.

Table 3-7

Summary of Radiological Survey Results for SLDS Vicinity Properties

Property Parameter	Range (pCi/g)	Average (pCi/g)	No. of Samples Exceeding Guidelines	No. of Samples Analyzed
McKinley Iron Company				
U-238	2.5 - 88	13.3	19	42
Ra-226	0.7 - 65	5.8		
Th-232	<0.7 - 3	1.2		
Th-230	0.5 - 84	8.4		
PVO Foods, Inc.				
U-238	<3.0 - 11.0	5.5	0	13
Ra-226	0.9 - 5	2.6		
Th-232	0.9 - 2	1.2		
Th-230	1.3 - 5.8	3.1		
Thomas and Proetz Lumber Company				
U-238	1.9 - 82	12.9	26	65
Ra-226	0.7 - 1,800	52.9		
Th-232	<0.7 - 160	5.3		
Th-230	0.6 - 290	20.3		
St. Louis Terminal Railroad Association				
U-238	4.1 - 45	9.8	19	32
Ra-226	1.2 - 48	6.1		
Th-232	<0.7 - 160	6.3		
Th-230	1.7 - 51	8.6		
Norfolk and Western Railroad				
U-238	3.0 - 1,100	45.5	18	34
Ra-226	0.5 - 300	14.6		
Th-232	0.9 - 56	4.4		
Th-230	1.2 - 2,100	70.3		

Table 3-7

(continued)

Property Parameter	Range (pCi/g)	Average (pCi/g)	No. of Samples Exceeding Guidelines	No. of Samples Analyzed
Chicago, Burlington, and Quincy Railroad				
U-238	2.5 - 120	16.7	21	40
Ra-226	0.6 - 9	3.2		
Th-232	<0.7 - 3	1.4		
Th-230	0.8 - 450	29.5		

3.3.1 McKinley Iron Company Property

At the McKinley Iron Company property, 19 of the 42 samples taken from 39 sampling locations have radionuclide concentrations exceeding remedial action guidelines. These contaminated samples were taken from areas between the property fences and adjacent to the company building (Figure 3-8).

3.3.2 PVO Foods, Inc., Property

At the PVO Foods, Inc., property, none of the 13 samples collected from the 9 sampling locations exhibits radionuclide concentrations exceeding guidelines (Figure 3-9).

3.3.3 Thomas and Proetz Lumber Company Property

Twenty-six of the 65 samples collected from the 48 sampling locations at the Thomas and Proetz Lumber Company property have radionuclide concentrations exceeding guidelines. These 26 samples were found at locations near the fence at the northern and eastern property boundary and across the entire width of the eastern two-thirds of the property (Figure 3-10).

3.3.4 St. Louis Terminal Railroad Association Property

At the St. Louis Terminal Railroad Association property, 19 of the 32 samples taken from 29 sampling locations exhibit radionuclide concentrations exceeding guidelines; they were found at locations along the entire length of property (Figure 3-11).

3.3.5 Norfolk and Western Railroad Property

Eighteen of the 34 samples taken from 24 sampling locations at the Norfolk and Western Railroad property have radionuclide concentrations exceeding guidelines. These 18 samples were found along the entire length of the property (Figure 3-12).

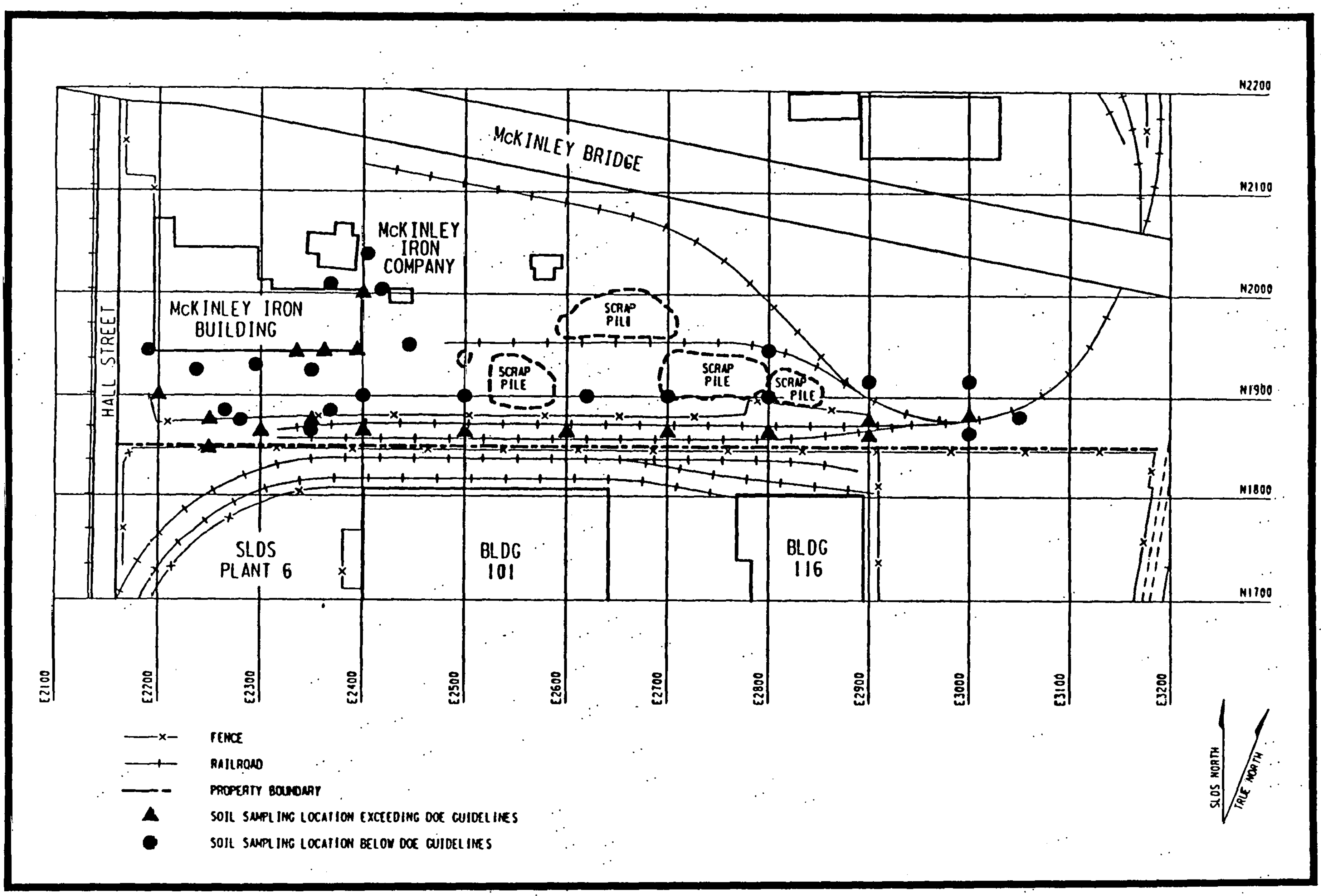


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FIGURE 3-8 SOIL SAMPLING RESULTS FOR THE McKINLEY IRON COMPANY PROPERTY

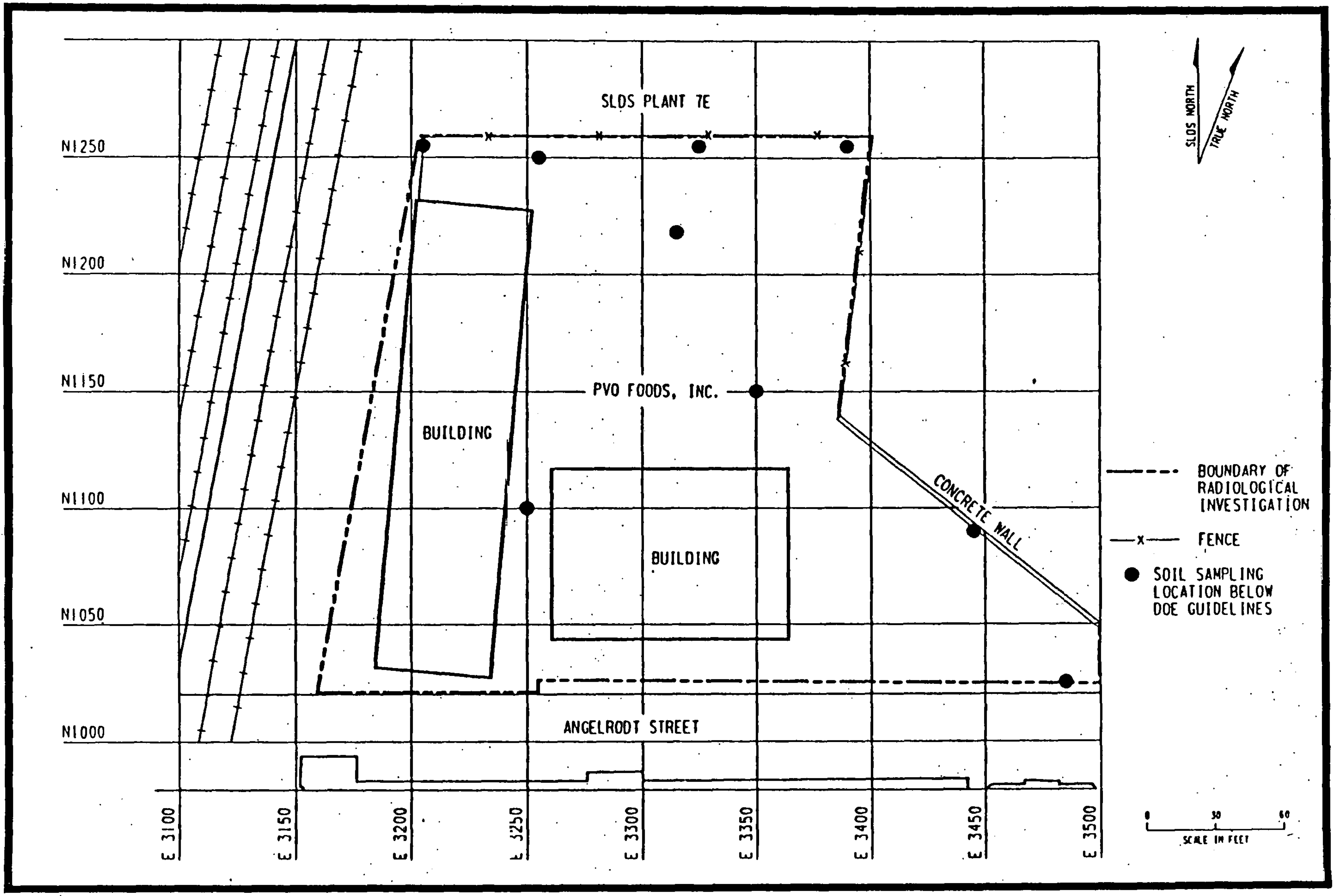

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FIGURE 3-9 SOIL SAMPLING RESULTS FOR THE PVO FOODS, INC., PROPERTY

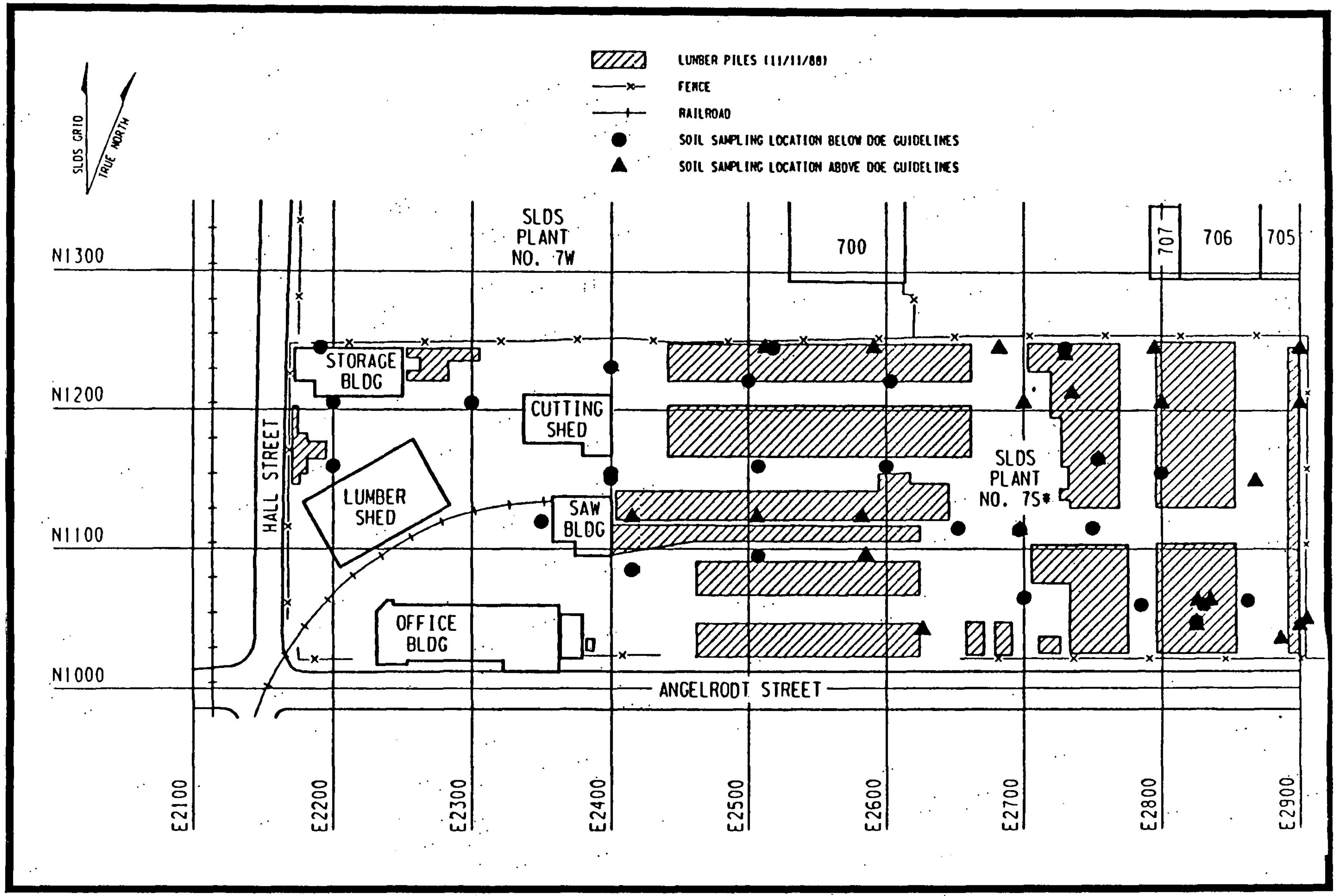

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FIGURE 3-10 SOIL SAMPLING RESULTS FOR THE THOMAS & PROETZ LUMBER COMPANY PROPERTY

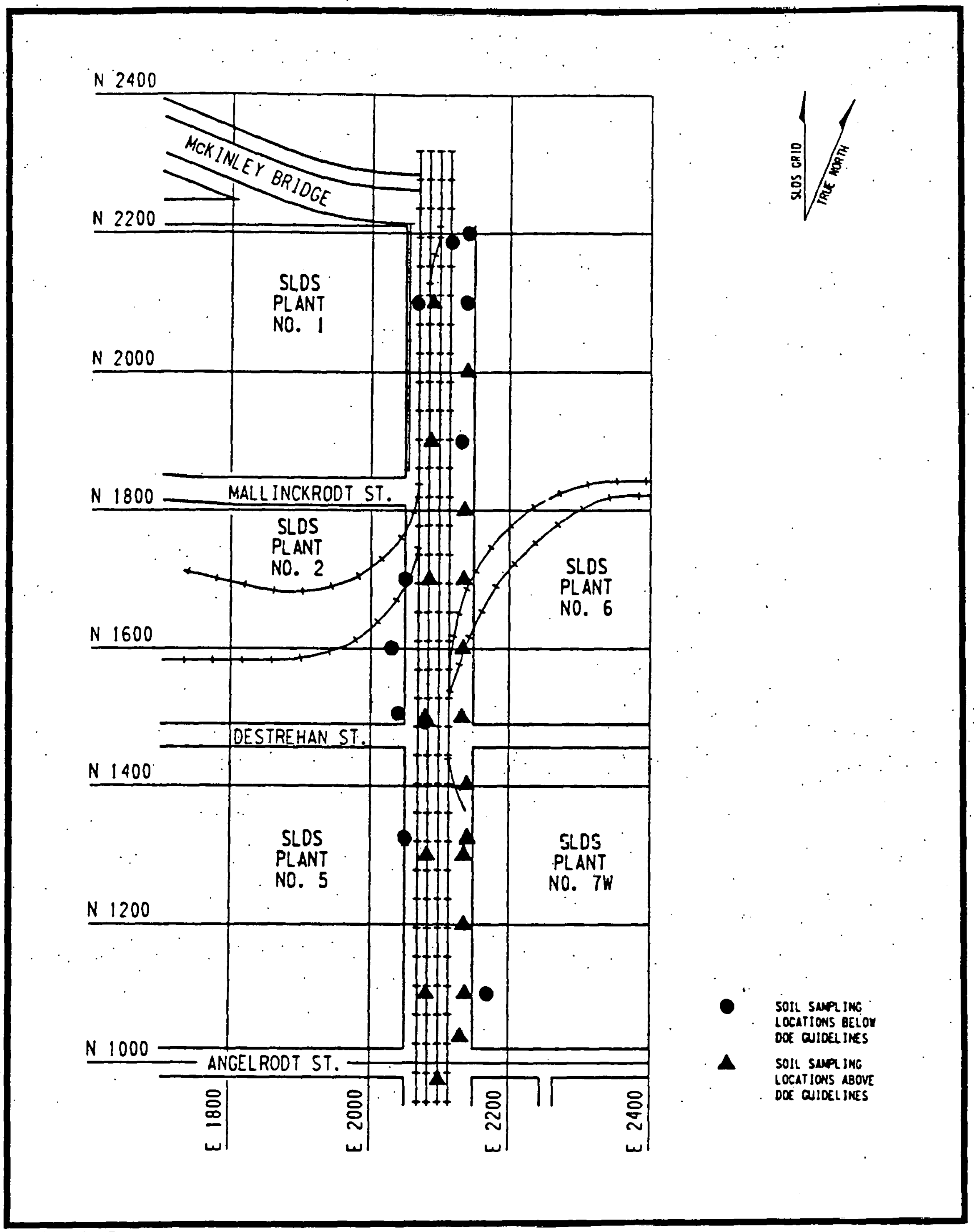

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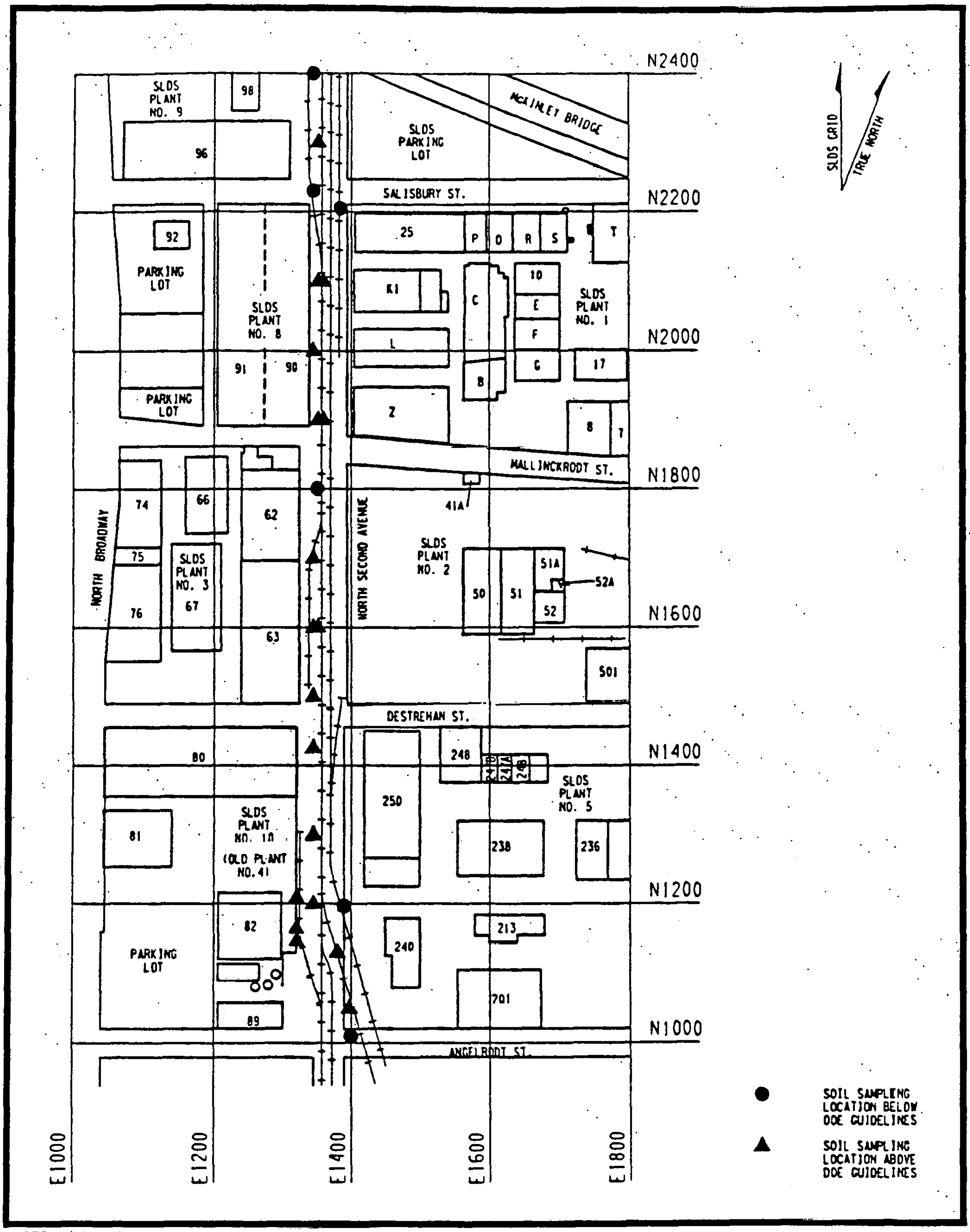
FIGURE 3-11 SOIL SAMPLING RESULTS FOR THE ST. LOUIS TERMINAL RAILROAD ASSOCIATION PROPERTY



116FO14.DGN F1

FIGURE 3-12 SOIL SAMPLING RESULTS FOR THE NORFOLK AND WESTERN RAILROAD PROPERTY

3.3.6 Chicago, Burlington, and Quincy Railroad Property

At the Chicago, Burlington, and Quincy Railroad property, 21 of the 40 samples collected from 26 sampling locations have radionuclide concentrations exceeding guidelines. The contamination was generally found on the southern two-thirds of the property (Figure 3-13).

3.4 CHARACTERIZATION RESULTS FOR SLAPS

3.4.1 Surface and Subsurface Soils at SLAPS

Radiological results

Walkover gamma scans indicate that essentially all of the ground surface at SLAPS is contaminated in excess of DOE guidelines (Table 1-1). Gamma radiation exposure rates range from 9 to 261 mR/h (including background), with the average being 84 mR/h. For comparison, the DOE basic dose limit of 100 mrem/yr in excess of background is equivalent to an exposure rate of approximately 11 mR/h in excess of background assuming exposure for a full year (8,760 h).

Contamination was encountered at depths of up to 5.4 m (18 ft) during the soil investigation, but the contamination was generally found at 1.2 to 2.4 m (4 to 8 ft). Uranium-238, radium-226, thorium-230, and thorium-232 were found at elevated concentrations over the majority of the property. Uranium-238 concentrations range from less than 3 to 1,600 pCi/g with an average of 141 pCi/g. Radium-226 concentrations range from background levels to 5,620 pCi/g with an average of 61 pCi/g. Thorium-232 concentrations range from background levels to 63 pCi/g with an average of 4 pCi/g. Concentrations of thorium-230 range from 0.6 to 2,600 pCi/g with an average of 138 pCi/g. Approximately 250,000 yd^3 (191,150 m^3) of contaminated soil is present at SLAPS. The areas and depths of contamination are shown in Figure 3-14.

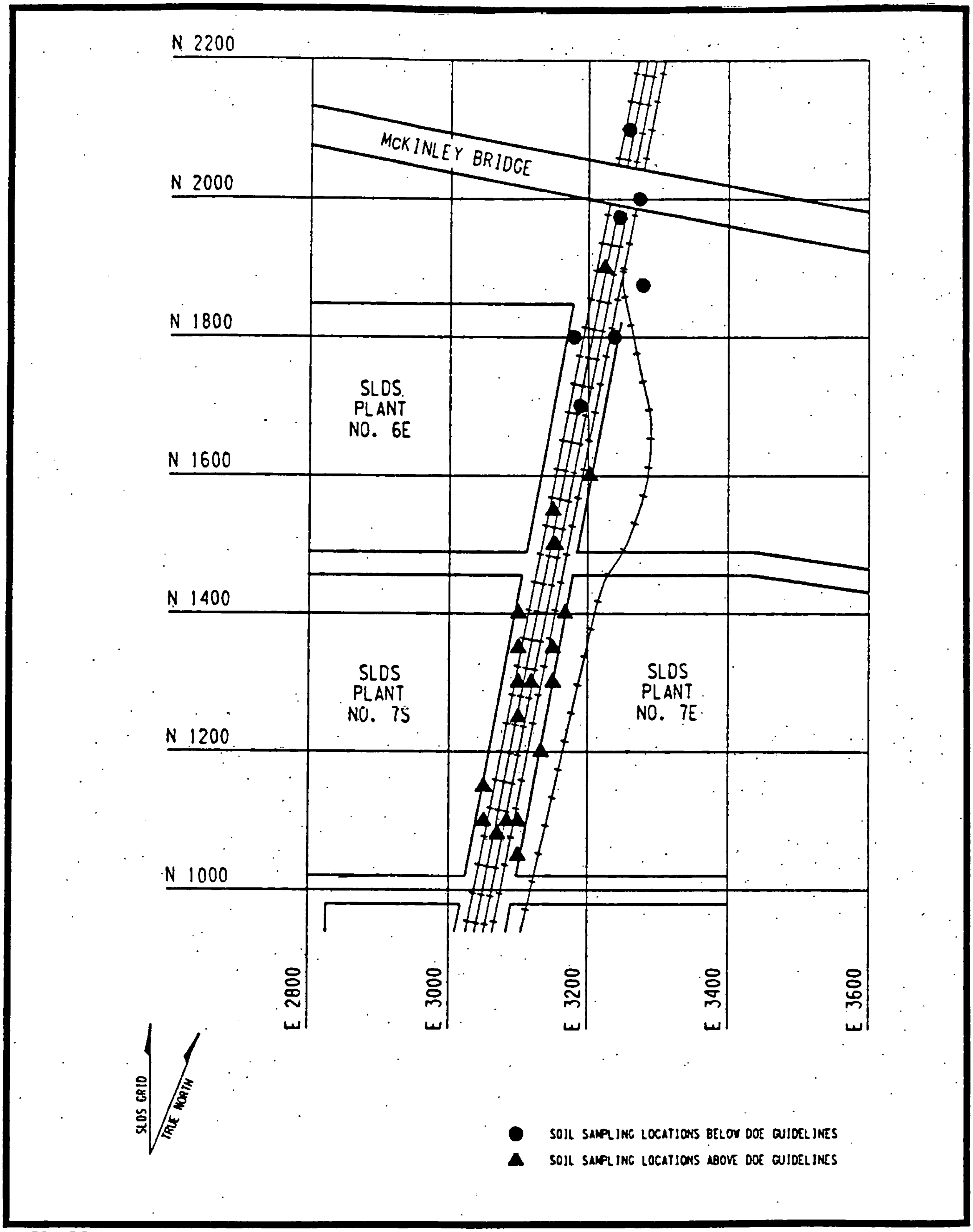


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FIGURE 3-13 SOIL SAMPLING RESULTS FOR THE CHICAGO, BURLINGTON, AND QUINCY RAILROAD PROPERTY

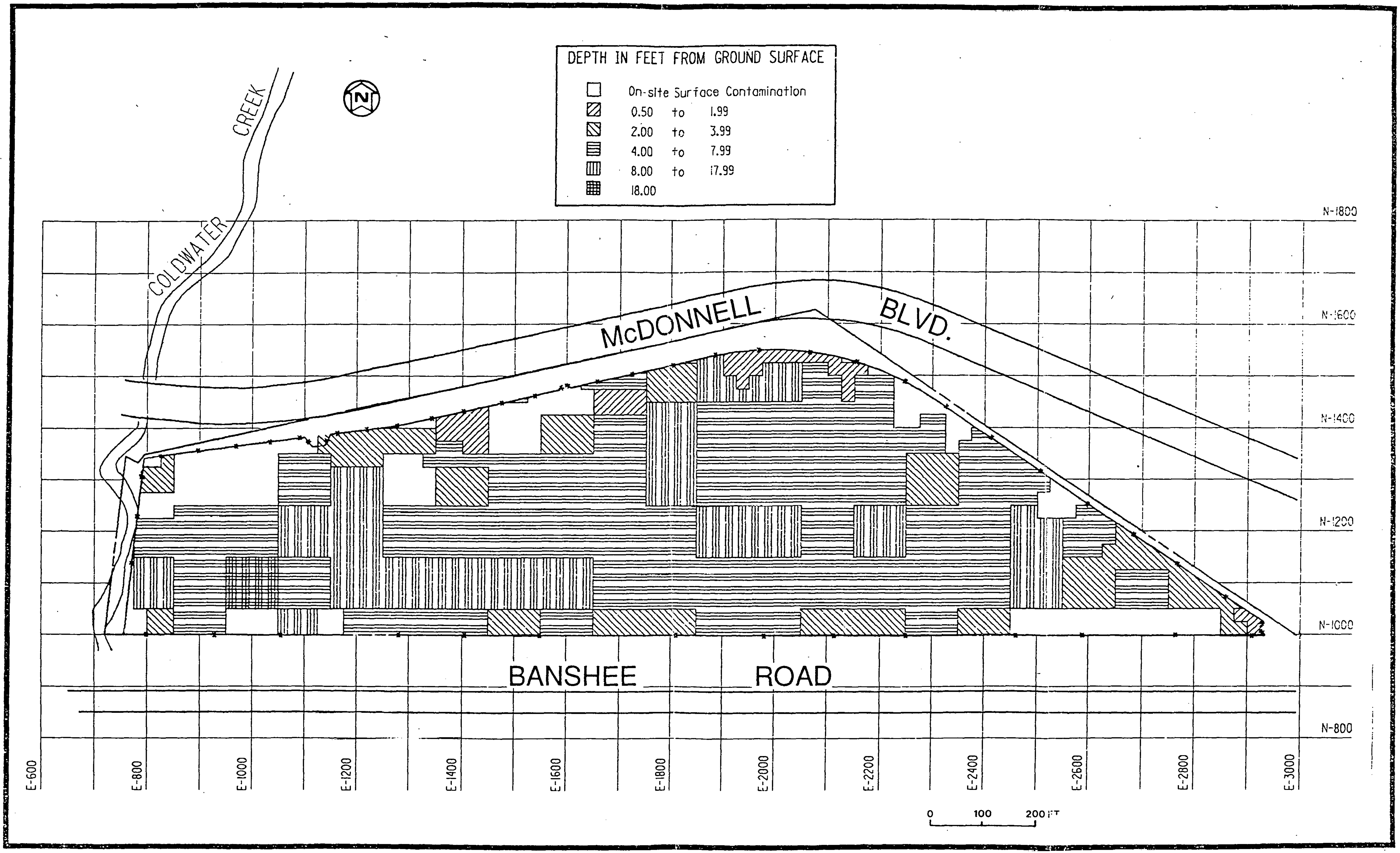

FIGURE 3-14 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT SLAPS

More information regarding the radiological survey results is provided in BNI 1987a.

Chemical results

In 1986, a limited chemical investigation was conducted at SLAPS; samples were analyzed for TOC, TOX, heavy metals, and RCRA-hazardous waste characteristics. Results of the inductively coupled plasma atomic emission spectrophotometry (ICPAES) scan indicate metals in concentrations exceeding the upper range of background levels presented in Appendix B. Of the samples submitted for TOC analysis, three contain concentrations of greater than 10,000 mg/kg. The TOX concentrations range from less than 0.5 to 3.8 mg/kg, except for one sample with a concentration of 19 mg/kg.

More detailed chemical characterization in 1988 revealed 15 metals in soil at concentrations exceeding background levels (Appendix B). Antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, magnesium, molybdenum, nickel, selenium, thallium, vanadium, and zinc were found at levels varying from slightly to substantially greater than background concentrations.

Of the 90 samples analyzed, cobalt and magnesium occur in 22 and 30, respectively, in concentrations exceeding background. Cobalt is associated with sandstone uranium ores stored at the property.

The presence of barium at SLAPS is also of interest because of its use during uranium processing. Barium exceeds the background level in only 5 of the 90 samples, with the highest concentrations found in the northeastern portion of SLAPS near Borehole R20 (Figure 2-11); this location corresponds closely with the known storage area of barium sulfate cake.

Most of the metals found at levels greater than the detection limit appear to be confined to near-surface depths [0 to 2 m (0 to 6 ft)]. Magnesium was detected as deep as 6.7 m (22 ft), which is below the depth of radioactive contamination [down to 5.5 m (18 ft)] previously defined at locations from which biased samples were collected. Magnesium, cadmium, molybdenum, nickel, cobalt, copper, lead, zinc, arsenic, selenium, vanadium, and barium were detected within the known boundaries of radioactive wastes in these same boreholes. At the random borehole locations, radioactive contamination was detected at depths between 0.15 and 5.5 m (0.5 and 18 ft). Arsenic, cadmium, cobalt, copper, molybdenum, chromium, lead, antimony, zinc, magnesium, barium, nickel, selenium, and vanadium were detected within the radioactive waste. Magnesium, cadmium, and cobalt were detected in the sample obtained from a depth greater than 5.5 m (18 ft) (BNI 1990b).

Thirty-seven of the 90 soil samples submitted for volatile organics analyses have concentrations that exceed detection limits: toluene was found in 26 of the samples at concentrations ranging from 1.5 to 1,200 ppb; trichloroethene was found in 6 samples at concentrations ranging from 1.6 to 15 ppb; and trans-1,2-dichloroethene was found in 5 samples at concentrations ranging from 1.3 to 7.7 ppb. VOCs are, in general, unevenly distributed across SLAPS and at varying depths. The highest concentrations of toluene, however, were found in boreholes in the eastern portion of the property (R18, R19, and R21; see Figure 2-11). None of the VOCs found are believed to have been used in the uranium processing carried out at SLDS, although they may have been used as solvents. Fifty-two of the 90 soil samples contain BNAEs. One unidentified, nontarget compound was detected. The levels of VOCs and BNAEs are believed to be low enough to be of little risk or concern; this will be determined after the baseline risk assessment is complete.

Biased samples taken from within the radioactive waste and composite samples from random boreholes were tested for RCRA-hazardous waste characteristics (reactivity, ignitability, corrosivity, and EP toxicity). These analytical results indicate that the material at SLAPS is not RCRA-hazardous waste.

As mentioned earlier, chemical contamination will be re-evaluated after the baseline risk assessment is conducted and/or true background chemical samples are obtained. For more information regarding chemical results, refer to BNI 1990b and BNI 1991.

3.4.2 Groundwater at SLAPS

Radiological results

Annual averages for radium-226 in groundwater at SLAPS range from 4 to 9 x 10^{-10} μCi/ml (0.4 to 0.9 pCi/L). For thorium-230, annual averages range from 1 x 10^{-10} to 5.2 x 10^{-8} μCi/ml (0.1 to 52 pCi/L). Annual averages for total uranium range from less than 3 x 10^{-9} to 6.5 x 10^{-6} μCi/ml (less than 3 to 6,570 pCi/L).

Concentrations of total uranium, radium-226, and thorium-230 in several of the shallow wells at SLAPS are elevated compared to concentrations in background locations because the wells are located in areas of known subsurface contamination. Groundwater monitoring wells with elevated concentrations are believed to be near pockets of buried radioactive residues. Other nearby wells have substantially lower concentrations. Because SLAPS is fenced, the public does not have access to these wells; furthermore, there is no known consumption of groundwater in the vicinity of the property.

Detailed radiological results for the groundwater investigation are provided in BNI 1990c and BNI 1991.

Chemical results

Chemical indicator parameters (pH, specific conductance, TOC, and TOX) were monitored in SLAPS groundwater to detect possible changes in inorganic and organic chemical composition. Analytical results indicate groundwater of poor quality, i.e., water with a greater than normal amount of dissolved solids of a noninjurious nature. Groundwater was analyzed for metals to determine whether metals present in the original uranium ore had leached into the groundwater. Many of the metals detected in soil samples obtained from the property were also found in groundwater.

Elevated TOX values (in excess of background levels) were found in several wells from 1987 to 1989. These elevated values indicate that halogenated organics are present in excess of background levels in at least three wells. The source of these organics is unknown. From a review of the history of uranium processing at SLDS, there is no indication that halogenated organics were used in any of the processes related to AEC/MED activities; however, these three wells are in locations where barrels of wastes and pitchblende raffinate were stored. Also, elevated specific conductance values, which indicate dissolved solids in groundwater, occur in all wells except MD10-8D and M10-25S. In 1989, a one-time sampling effort was conducted as part of the environmental monitoring program to determine the presence of priority pollutants in groundwater. Five organic compounds were detected at low concentrations: Endosulfin I, 1,2-dichloroethene, trichloroethene, toluene, and bis(2-ethylhexyl)phthalate. These compounds may account for the elevated TOX values.

Analyses for TOC and pH show levels within the range of those in the background wells (B53W01S and B53W01D).

For more details on the chemical results in groundwater at SLAPS, refer to BNI 1990c and BNI 1991.

3.4.3 Surface Water and Sediments at SLAPS

Measured concentrations of total uranium, radium-226, and thorium-230 in surface water at SLAPS have remained relatively stable since 1985 and are about equal to the upstream (background) values. Refer to Subsection 3.5 regarding the SLAPS ditches and Coldwater Creek; surface runoff from SLAPS can be found in the ditches.

More detailed results are available in BNI 1990c.

3.4.4 Air at SLAPS

Based on measured radon concentrations at SLAPS, the onsite radon source has a minimal effect on radon concentrations in the area.

The annual average concentrations of radon at SLAPS range from 1×10^{-10} to 3.6×10^{-9} mCi/ml (0.1 to 3.6 pCi/L). Background concentrations ranging from 5 to 6 x 10^{-10} mCi/ml (0.5 to 0.6 pCi/L) are included in the average.

External gamma exposure rates were measured at the same locations where radon levels were measured. The annual average external gamma radiation levels at SLAPS range from 3 to 2,157 mR/yr. Background levels range from 45 to 99 mR/yr (BNI 1991). Gamma exposure rates, measured at SLAPS in 1987 using a PIC, range from 9 to 261 mR/h and average 84 mR/h (BNI 1987a). External gamma radiation levels have been influenced by radioactive contamination at the property, particularly at location 2, which is shown in the annual environmental report (BNI 1990c). The average background gamma exposure rate in the St. Louis area is 10 mR/h.

Radon results for SLAPS are included in BNI 1990c.

3.4.5 Geology and Hydrogeology at SLAPS

Figure 3-15 presents a generalized stratigraphic column for SLAPS and the ball field area, based on information collected from site investigations. The site stratigraphy is divided into six units. The upper four units are composed of Holocene and Pleistocene unconsolidated materials including fill, loess, lacustrine, and glacial deposits. These unconsolidated materials range in thickness from 15.2 to 24.4 m (50 to 80 ft) across the properties. Beneath the unconsolidated deposits, bedrock units include Pennsylvanian undifferentiated cyclothem deposits and Mississippian limestone. Pennsylvanian undifferentiated rocks comprise the upper bedrock unit in the eastern portion of the SLAPS/ball field properties. Mississippian limestone comprises the rest of the unit.

Soil samples were collected and analyzed to characterize the physical and geochemical properties of the undisturbed unconsolidated deposits. Table 3-8 summarizes the results of these tests. Discussions of test methodology are presented in BNI 1989 and Weston 1982. A listing of individual test results is presented in Appendix D. Results of the laboratory soil testing and visual observations of the samples indicate that the lacustrine deposits

Hydro-Geologic Unit	Period	Epoch	Formation	Columnar Section	Approximate Thickness (ft)	Description
UPPER GROUNDWATER SYSTEM	QUATERNARY	RECENT	FILL		0-14	**UNIT 1** Fill – Sand, silt, clay, concrete, rubble Topsoil – Organic silts, clayey silts, wood, fine sand.
		PLEISTOCENE/HOLOCENE	LOESS (CLAYEY SILT)		11-32	**UNIT 2** Clayey silts, fine sands, mottled with frequent iron oxide staining, scattered roots, and organic material. Occasional fossils. Low to moderate plasticity.
			LACUSTRINE SERIES: SILTY CLAY		19-75 9-27	**UNIT 3** Silty clay with scattered organic blebs and peat stringers. Moderate plasticity. Moist to saturated. (3T)
CLAYEY AQUITARD			VARVED CLAY		0-8	Two boreholes only. (3M)
			CLAY		0-26	Dense, stiff, moist, plastic clay. (3M)
LOWER GROUNDWATER SYSTEM			SILTY CLAY		10-29	Similar to upper silty clay. Probable un-conformity with highly plastic clay. (3B)
			CLAYEY& SANDY GRAVEL		0-6	**UNIT 4** Glacial clayey gravels, sands, and sandy gravels. Mostly chert.
	PENNSYLVANIAN		PENNSYL-VANIAN (Undifferentiated)		0-35	**UNIT 5** BEDROCK, cycles of silty clay/shale, lignite/coal, sandstone, and siltstone. Erosionally truncated by glaciolacustrine sequences.
	MISSISSIPPIAN		ST. GENEVIEVE (?) LIMESTONE		10+	**UNIT 6** BEDROCK, hard, white to olive, well cemented limestone with interbedded shale laminations.

FIGURE 3-15 GENERALIZED STRATIGRAPHIC COLUMN FOR SLAPS AND THE BALL FIELD AREA

Table 3-8

Laboratory Soil Testing Summary for SLAPS and the Ball Field Area

Unit[a]	Specific Gravity	Water Content (%)	Gradation Sand (%)	Gradation Fines (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Atterberg Limits Plasticity Index	Dry Density (pcf)	Geometric Mean Vertical Lab Permeability (cm/s)	Uranium Distribution Ratio (ml/g)	Effective Cation Exchange Capacity (meq/100 g soil)	Void Ratio	Unified Soil Classification[b]
2	2.52	24	10	90	33	24	9	94	1.0E-06	168	149	0.697	ML-CL
3T and 3B	2.42	22	10	90	35	20	15	95	2.0E-06	11	172	0.647	CL
3M	2.34	24	8	92	66	25	41	82	5.5E-08	8	200	0.856	CH
4	2.30	23	47	53	--[c]	--[c]	--[c]	92	1.0E-06	--[d]	--[d]	0.799	GC-SM-CL

[a]All values are arithmetic means except as noted.

[b]Unified soil classification: ML = Inorganic silts, silty or clayey fine sands
CL = Low plasticity clays, gravelly clays, silty clays, sandy clays
CH = High plasticity clays, fat clays
GC = Clayey gravels, poorly graded gravel-sand-clay mixtures
SM = Silty sand, sand-silt mixtures.

[c]Not tested due to high sand content.

[d]Not tested.

(unit 3) are, based on their physical properties, divided into three subunits (3T, 3M, and 3B). Subunits 3T and 3B (top and bottom of unit 3) have similar properties, but subunit 3M (middle of unit 3) exhibits different physical properties. This subunit is a high plasticity clay whose permeability is one to two orders of magnitude lower than the remainder of unit 3. Subunit 3M is thought to play a major role in groundwater flow and solute transport at the SLAPS/ball field properties. The areal distribution of this subunit was found to be discontinuous. Figure 3-16 is a map of the approximate areal distribution of subunit 3M. [Note: The well identifiers on Figure 3-16 and other figures provide information about the locations of each well. For example, B16W02S (or D) may be broken down as follows: B - Bechtel-installed borehole or well; 16 - last two digits of work breakdown structure (WBS) (i.e., SLDS WBS number is 116); W - well; 02 - well number; S - shallow aquifer (or D - deep aquifer).]

Table 3-8 also shows that the uranium distribution ratios for unit 2 (loess) are 10 to 20 times higher than those for unit 3 (lacustrine deposits). Uranium was the only radionuclide used in distribution ratio measurements because, under normal geochemical conditions, uranium is the most mobile of the common radionuclides at the properties. Roy F. Weston, Inc. (RFW) examined the clay mineralogy of loess and the lacustrine deposits using X-ray diffraction data (Weston 1982). Their investigation revealed that the clay mineralogy of the loess is dominated by smectite (and other complex mixed layer silicates) while the lacustrine deposits are dominated by illite or illite-chlorite assemblages. The complex mixed layer silicates have greater sorptive capacity than illite or chlorite. The effective cation exchange capacities for the two units do not show a significant disparity, indicating that the dominant sorptive mechanism is adsorption rather than ion exchange.

The primary surface water feature at the SLAPS/ball field properties is Coldwater Creek, which is approximately 30 km (19 mi) long and drains an area of about 118 km^2 (46 mi^2); at McDonnell

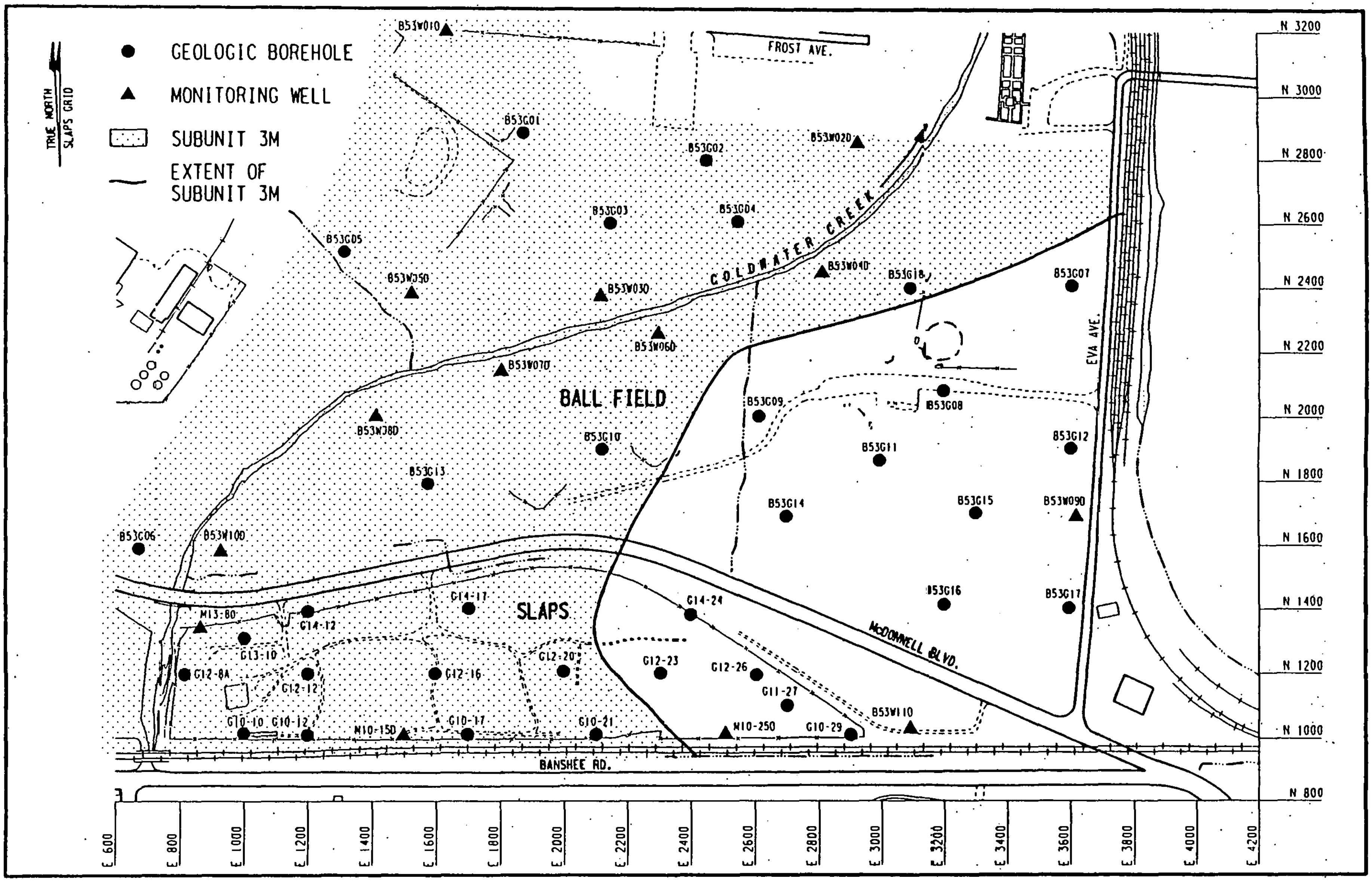

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FIGURE 3-16 APPROXIMATE EXTENT OF SUBUNIT 3M IN THE SLAPS/BALL FIELD AREA

Boulevard, the creek has a drainage area of approximately 32 km^2 (12.3 mi^2) (Hauth and Spencer 1971). RFW performed a base flow survey of Coldwater Creek at SLAPS and determined that the average base flow was 0.07 cms (2.5 cfs) (Weston 1982). The creek discharges into the Missouri River, north of its confluence with the Mississippi River (Figure 1-1). Coldwater Creek is not used for drinking water; however, two municipal water intakes are present on the Mississippi River, downstream of the discharge of Coldwater Creek: the City of St. Louis Chain-of-Rocks Plant and the East St. Louis Plant. Coldwater Creek empties into the Missouri River at mile 7 (Coldwater Creek mile 0) (Department of the Army 1977). The Missouri River empties into the Mississippi River at Mississippi River mile 195 (mile 0 on the Missouri River), about 8.1 km (5 mi) upriver of the two municipal water intakes. Water quality data for Coldwater Creek at high and low flow are presented in Table 3-9. The water samples were collected at crossing points of the creek with I-70 and I-270, which are upstream and downstream, respectively, of the properties. The pollutants of major concern are oil products transported into the stream by surface runoff from surrounding areas.

Hydrogeologic investigations indicate that two groundwater systems exist in the unconsolidated deposits at the properties. The upper groundwater system is contained in unit 2 and subunit 3T (loess and lacustrine deposits). The lower groundwater system is present in subunit 3B and unit 4 (lacustrine and glacial deposits). The two groundwater systems are separated by an aquitard composed of subunit 3M (lacustrine deposits). However, in the eastern portion of the properties, the aquitard is absent and the upper and lower systems become a single groundwater system. Comparison of groundwater level measurements from two monitoring wells screened in the Pennsylvanian undifferentiated bedrock with those from wells screened in the lower overburden suggests that the bedrock is hydraulically connected to the unconsolidated deposits.

Typical hydrographs for monitoring wells screened in the upper and lower portions of the unconsolidated deposits are shown in Figures 3-17 and 3-18. The hydrographs for monitoring wells

Table 3-9

Results of Water Quality Sampling in Coldwater Creek

Parameter[a]	September 28, 1981 (Dry Weather) I-70	I-270	July 11, 1981 (Stormwater) I-70	I-270
pH	7.7	7.8	--[b]	--[b]
Suspended solids	10-20	10-20	354	719
Total solids	582	531	--[b]	--[b]
Chemical oxygen demand	30	<20	--[b]	--[b]
Phenols	<0.05	0.05	--[b]	--[b]
Cyanide	<0.1	<0.1	--[b]	--[b]
Ammonia	<0.5	<0.5	--[b]	--[b]
Mercury	0.0003	0.0001	<0.0002	<0.0002
Arsenic	0.02	0.01	<0.02	0.02
Barium	0.29	0.21	0.08	0.09
Cadmium	<0.01	<0.01	<0.001	<0.001
Chromium	0.1	<0.01	0.01	0.004
Copper	<0.01	0.05	0.02	0.01
Lead	0.07	0.08	0.25	0.03
Nickel	0.03	0.02	0.006	<0.005
Selenium	<0.01	<0.01	<0.02	<0.02
Zinc	0.09	0.09	0.15	0.06
Aluminum	--[b]	--[b]	2.66	1.35
Iron	--[b]	--[b]	2.88	1.32
Manganese	--[b]	--[b]	0.23	0.27

Source: Rains 1981.

[a]pH is expressed in standard units; all other parameters are expressed in mg/L.

[b]Not measured.

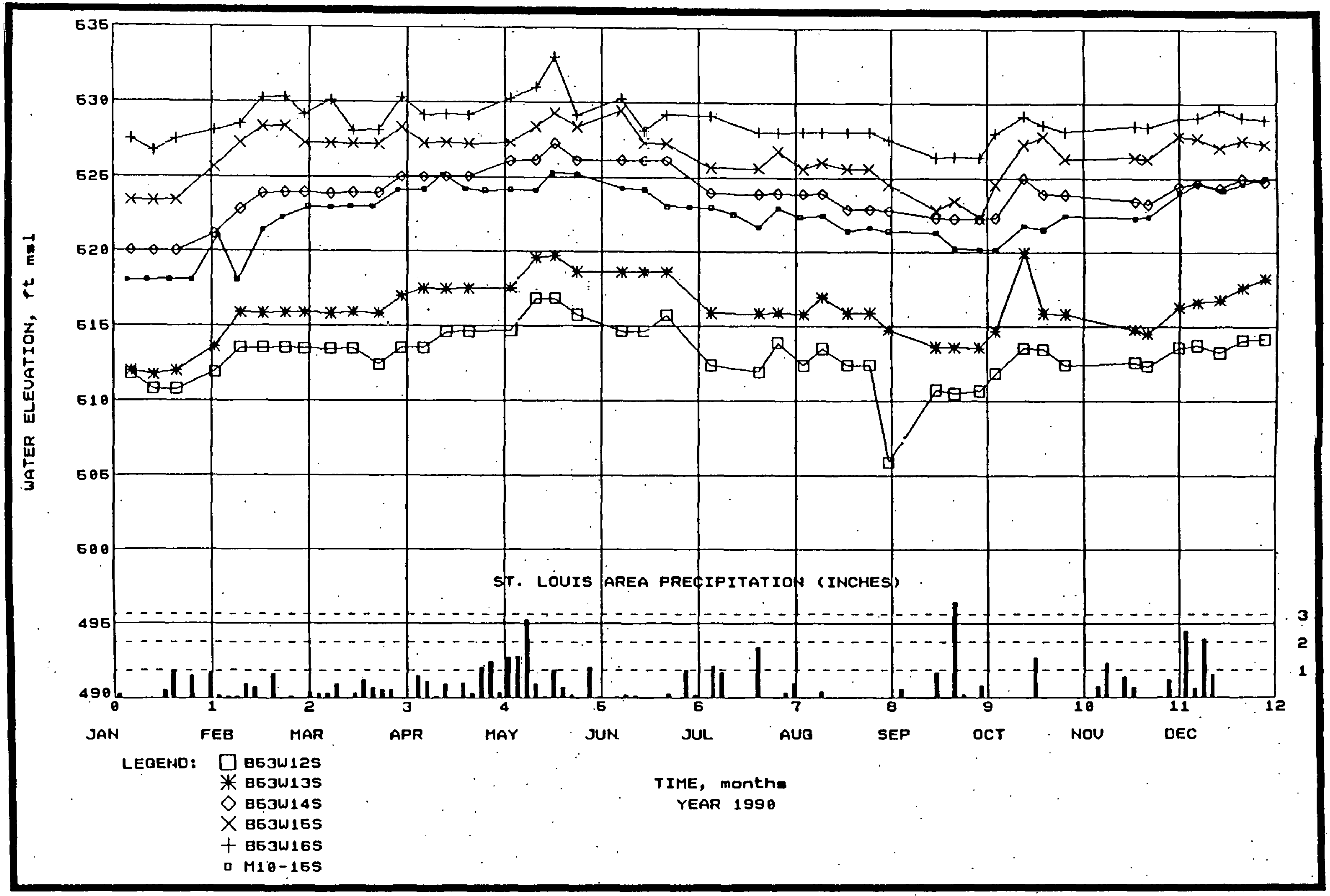

FIGURE 3-17 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS B53W12S, B53W13S, B53W14S, B53W15S, B53W16S, AND M10-15S

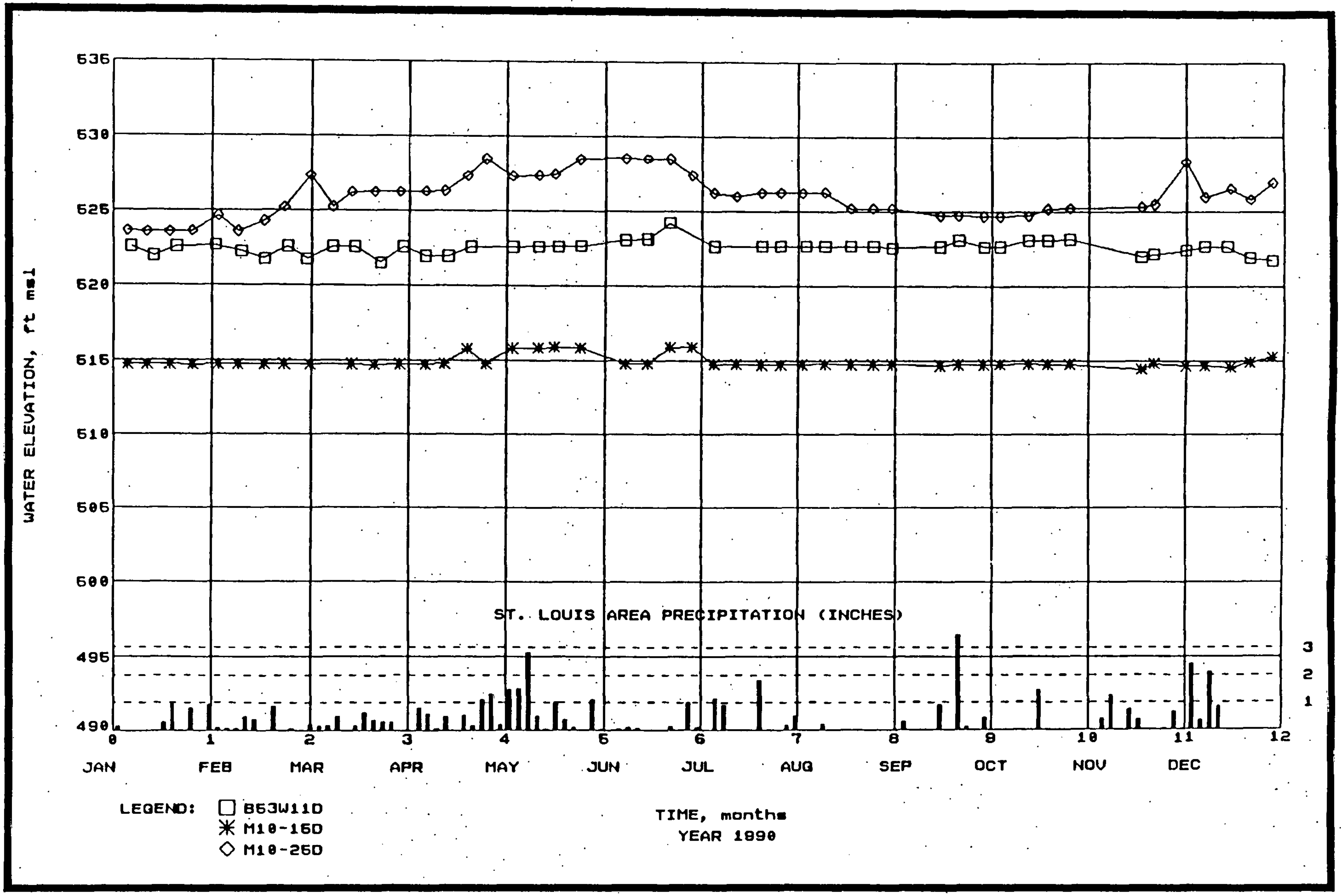

FIGURE 3-18 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS B53W11D, M10-15D, AND M10-25D

screened in the upper system show the groundwater levels to be variable, with up to 2.7 m (9 ft) of variation over the course of a year. The hydrographs for monitoring wells screened in the lower groundwater system show less variability, approximately 1.5 m (5 ft) or less during a year. The higher variability in the upper system is thought to be a result of the greater influence of individual precipitation events and evapotranspiration effects on the upper groundwater system.

Figures 3-19 and 3-20 present potentiometric surface maps of the upper and lower groundwater systems for August 24 and August 3, 1990. The upper groundwater system shows a north-northwest and a north-northeast flow direction, generally toward Coldwater Creek. The lower groundwater system shows flow to the north, northwest, and west. Both potentiometric surfaces indicate that the southeastern corner of SLAPS is the upgradient end of the properties.

Comparison of groundwater level elevations for shallow and deep monitoring well pairs shown on the potentiometric surface maps indicates the presence of a head differential between the upper and lower systems. In the eastern and central portions of SLAPS, the groundwater level elevations show a head differential of between 0.3 and 2.4 m (1.2 and 7.7 ft), which is indicative of a downward flow potential (from the upper to the lower groundwater system). In the western portion of SLAPS, head differentials of -0.6 to -1.2 m (-2 to -4 ft) occur, which is indicative of an upward flow potential (from the lower to the upper groundwater system). The change from downward to upward flow potential is probably a result of a lowering of the head in the upper groundwater system by seepage into the Coldwater Creek channel.

The available hydrogeologic data for the properties were used to develop a conceptualization of the groundwater flow. Recharge to the upper groundwater system is thought to occur from offsite inflow of groundwater, infiltration of precipitation, vertical seepage from the lower groundwater system where upward flow potentials exist, and, during high creek stage, from creek bed infiltration. Discharge from the upper groundwater system probably

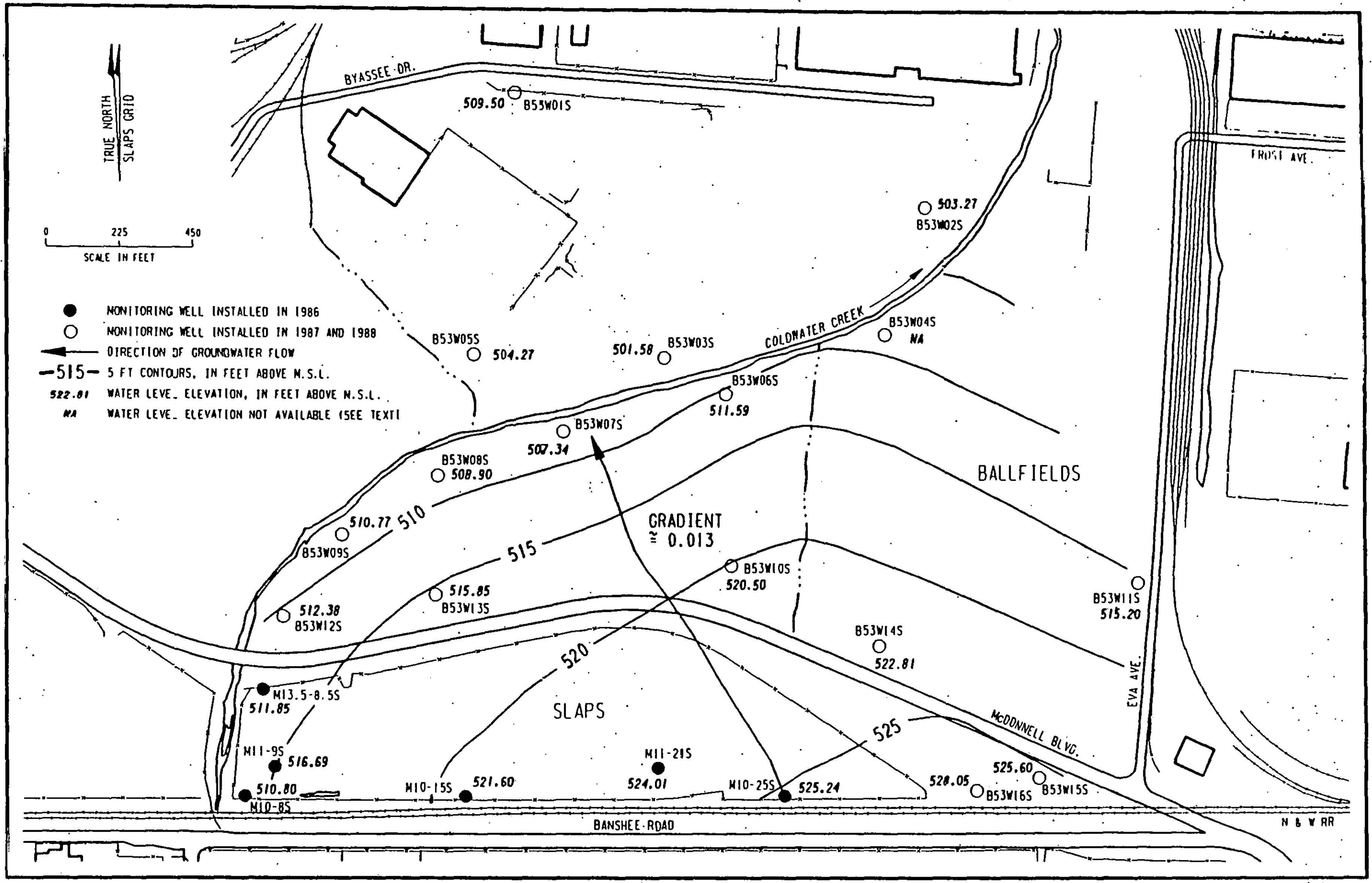

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FIGURE 3-19 UPPER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE OF SLAPS (08/24/90)

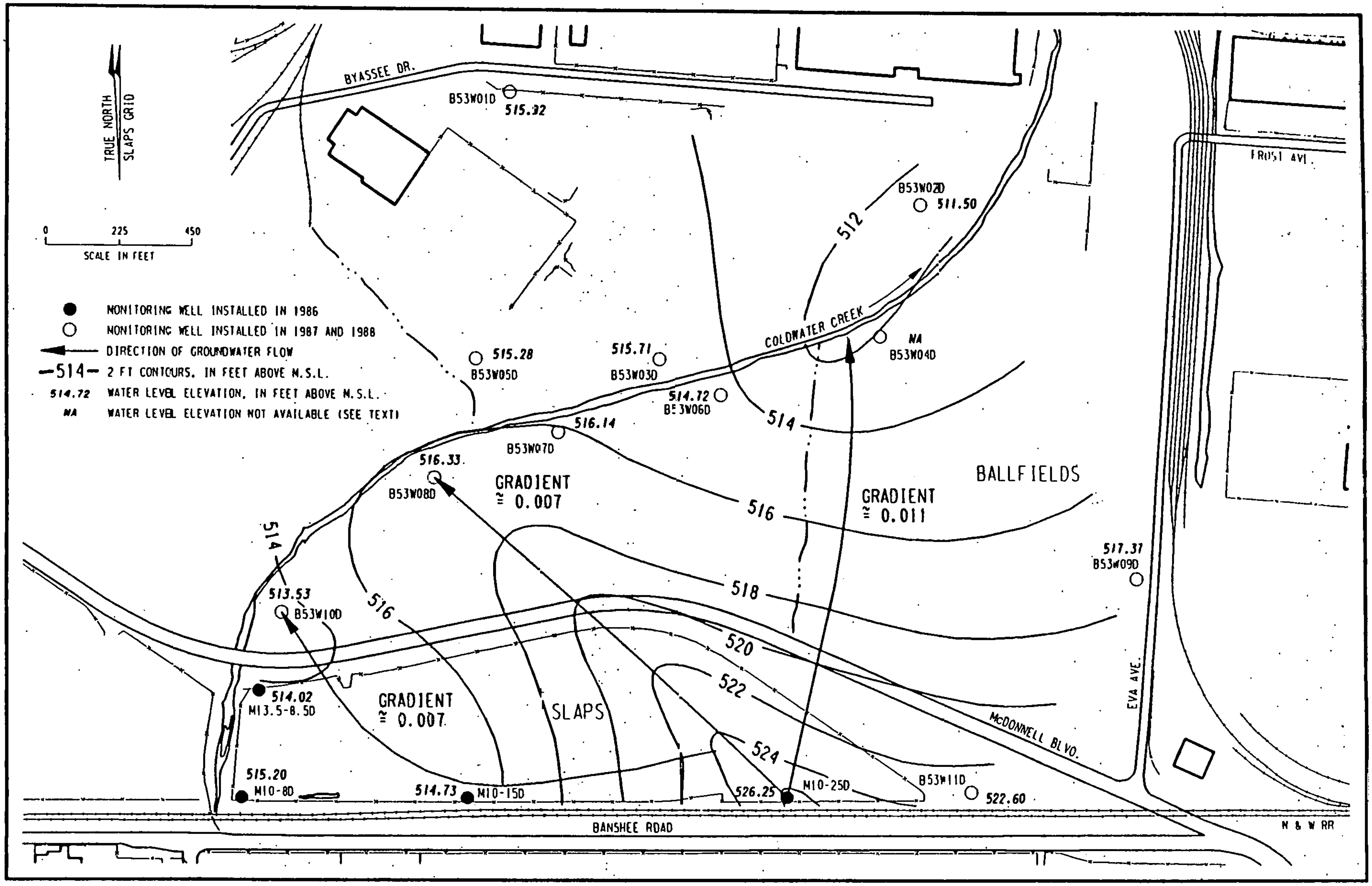

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FIGURE 3-20 LOWER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE OF SLAPS (08/03/90) occurs by offsite outflow, seepage into Coldwater Creek during low creek stage, and vertical seepage into the lower groundwater system where downward flow potentials exist. Recharge to the lower groundwater system is thought to occur by offsite inflow, infiltration of precipitation (in the eastern portions of the properties, where the aquitard is absent), and vertical seepage from the upper groundwater system, where a downward flow potential exists. Discharge from the lower groundwater system probably occurs by offsite groundwater outflow and vertical seepage into the upper groundwater system where there is an upward flow potential.

Investigations conducted at the properties include measurement of hydrogeologic and hydrogeochemical parameters to determine the groundwater flow and solute transport characteristics of the site materials. These measurements are summarized in Table 3-10. Measurement methodologies and individual test results are presented in BNI 1989b, Weston 1982, and Appendix D. The calculated average linear groundwater velocities, shown on the table, for the upper groundwater system range from 2 to 10 times faster that those calculated for the lower groundwater system. The slower groundwater velocity in the lower system probably reflects the heterogeneity of the glacial deposits (unit 4), which vary from a clayey gravel to a silty clay. Calculation of vertical velocity through the aquitard (unit 3M) was not included on the table because of the number of variables associated with this unit (e.g. thickness, hydraulic gradient, flow direction, variations in depth of monitored intervals relative to the aquitard, and hydraulic conductivity variations). An estimate of the vertical velocity through the aquitard at well pair M10-15S and D can be made by using an aquitard thickness of 7.6 m (25 ft) and a head differential of 2.3 m (7.7 ft). The resulting average linear velocity (based on vertical hydraulic conductivities in Table 3-10) ranges from 0.003 to 0.2 m/yr (0.01 to 0.5 ft/yr). Thus, it would take a water molecule between 50 and 2,500 years to pass through the aquitard. The distribution ratios presented in Table 3-10 indicate that uranium migration is retarded relative to groundwater

Table 3-10

Summary of Groundwater Flow and Solute Transport Parameters for SLAPS and the Ball Field Area

Aquifer Characteristics	Hydrogeologic and Geochemical Properties
Upper Groundwater System (Units 2 and 3T)	
Observed saturated thickness[a]	7.9 to 13.7 m (26 to 45 ft)
Mean hydraulic conductivity[b]	1.5×10^{-4} to 6.1×10^{-6} cm/s (0.42 to 0.02 ft/day)
Vertical hydraulic conductivity	2.0×10^{-4} to 1.4×10^{-8} cm/s (0.57 to 4×10^{-5} ft/day)
Hydraulic gradient	0.0071 to 0.015 [dimensionless]
Distribution ratio for uranium	19 to 329 ml/g
Effective cation exchange capacity	98 to 200 meq/100 g of soil
Bulk density	1.50 g/cm^3 (94 pcf)
Total porosity[c]	0.40
Average linear velocity[d]	0.04 to 1.75 m/yr (0.13 to 5.75 ft/yr)
Aquitard (Unit 3M)	
Observed thickness	0 to 7.9 m (0 to 26 ft)
Mean hydraulic conductivity[b]	3.1×10^{-5} cm/s (0.09 ft/day)[e]
Vertical hydraulic conductivity	7×10^{-7} to 1.4×10^{-8} cm/s (0.002 to 4×10^{-5} ft/day)
Head differential across aquitard[f]	-1.2 to 2.3 m (-4 to 7.7 ft)
Distribution ratio for uranium	8 ml/g[g]
Effective cation exchange capacity	187 to 214 meq/100 g of soil
Bulk density	1.31 g/cm^3 (82 pcf)
Total porosity[c]	0.46
Lower Groundwater System (Units 3B and 4)	
Observed saturated thickness[a]	2.4 to 9.1 m (8 to 30 ft)
Mean hydraulic conductivity[b]	2.0×10^{-4} to 1.3×10^{-6} cm/s (0.57 to 0.003 ft/day)
Vertical hydraulic conductivity	1.7×10^{-5} to 2×10^{-8} cm/s (0.05 to 5.7×10^{-5} ft/day)
Hydraulic gradient	0.0034 to 0.0064 (dimensionless)
Bulk density	1.47 g/cm^3 (92 pcf)
Total porosity[c]	0.44
Average linear velocity[d]	0.003 to 0.92 m/yr (0.01 to 3.03 ft/yr)
Bedrock (Units 5 and 6)	
Pennsylvanian undifferentiated	
Observed thickness	0 to 10 m (0 to 33 ft)
Horizontal hydraulic conductivity	Not determined
Mississippian limestone	
Observed thickness	Not determined
Horizontal hydraulic conductivity	1.1×10^{-5} to 7.5×10^{-7} cm/s[g] (0.03 to 0.002 ft/day)

Table 3-10

(continued)

[a]Thicknesses are exclusive of areas where aquitard is missing.

[b]$K_m = (K_h\ K_v)^{0.5}$, where K_m is the mean hydraulic conductivity, K_h is the horizontal hydraulic conductivity, and K_v is the vertical hydraulic conductivity.

[c]Total porosity determined from mean void ratios presented on Table 2-2 in BNI 1991 using the relation: porosity = void ratio/(1 + void ratio).

[d]Average linear velocity = $(K_m i)/n$, where K_m is the mean hydraulic conductivity, i is the hydraulic gradient, and n is the total porosity.

[e]Only one test was conducted for this parameter.

[f]Based on 6/28/89 water level measurements. Negative values indicate upward flow potential and positive values indicate downward flow potential.

[g]Two tests were conducted for this parameter.

flow. The retardation factors for the upper groundwater system and aquitard can be estimated, assuming the distribution ratio approximates the distribution coefficient, from:

$$R = (1 + (p/n)\ K_d)$$

where:

R = retardation factor (dimensionless)

p = bulk density (g/cm^3)

n = porosity (dimensionless)

K_d = distribution coefficient $\approx$ distribution ratio (ml/g) (Gillham 1982)

The velocity of solute transport is related to the average linear groundwater velocity and the retardation factor by the expression:

$$V_s = V_g / R$$

where:

V_s = velocity of solute transport (length/time)

V_g = average linear groundwater velocity (length/time)

R = retardation factor (dimensionless)

The retardation factors for the upper groundwater system range from 72 to 1,234, and for the aquitard is 23. Thus, the uranium migration rates are between 72 and 1,234 times slower than the average linear groundwater velocity. The uranium migration rate through the aquitard is approximately 23 times slower than groundwater movement. Thus, for the previously described conditions at wells M10-15S and D, dissolved uranium would take between 1,150 and 57,500 years to migrate through the aquitard.

3.5 CHARACTERIZATION RESULTS FOR THE SLAPS VICINITY PROPERTIES

Analytical results for each property are summarized in the following subsections; detailed results are provided in BNI 1990d.

3.5.1 Ditches to the North and South of SLAPS

Essentially all of the ditch area north and south of SLAPS is contaminated, extending to a depth of 4.3 m (14 ft). Analytical results reveal areas with elevated concentrations of radium-226 and thorium-230 in surface and subsurface soils. Thorium-230 was identified as the major contaminant; concentrations range from 0.9 to 15,000 pCi/g. Concentrations of uranium-238, radium-226, and thorium-232 range from less than 1 to 94, 0.7 to 130, and 0.7 to 6 pCi/g, respectively. The current volume estimate for radioactively contaminated soil at the ditches is approximately 21,562 m^3 (28,200 yd^3). Areas and depths of radioactive contamination in the ditches are shown in Figure 3-21.

3.5.2 St. Louis Airport Authority Property

Analytical results for surface soil samples reveal some areas at the St. Louis Airport Authority property with elevated concentrations of thorium-230. Concentrations of thorium-230 for all samples analyzed range from less than 0.7 to 58 pCi/g. All uranium-238 concentrations are less than 11 pCi/g. Radium-226 concentrations range from 0.8 to 3.3 pCi/g, and concentrations of thorium-232 range from 0.8 to 5 pCi/g. The estimated volume of radioactively contaminated soil at this property is 19,360 m^3 (25,320 yd^3). Areas and depths of radioactive contamination are shown in Figure 3-22; the contamination is shallow [0 to 0.6 m (0 to 2 ft)] and confined to the area adjacent to Banshee Road.

3.5.3 Coldwater Creek and Vicinity Properties

Analytical results for the 1986 characterization of sediment from SLAPS to HISS via Coldwater Creek reveal some areas with elevated concentrations of thorium-230; concentrations for all samples analyzed range from 0.5 to 110 pCi/g. Concentrations of uranium-238, radium-226, and thorium-232 range from 0.2 to 4.8, 0.3 to 3.1, and less than 0.1 to 1.5 pCi/g, respectively.

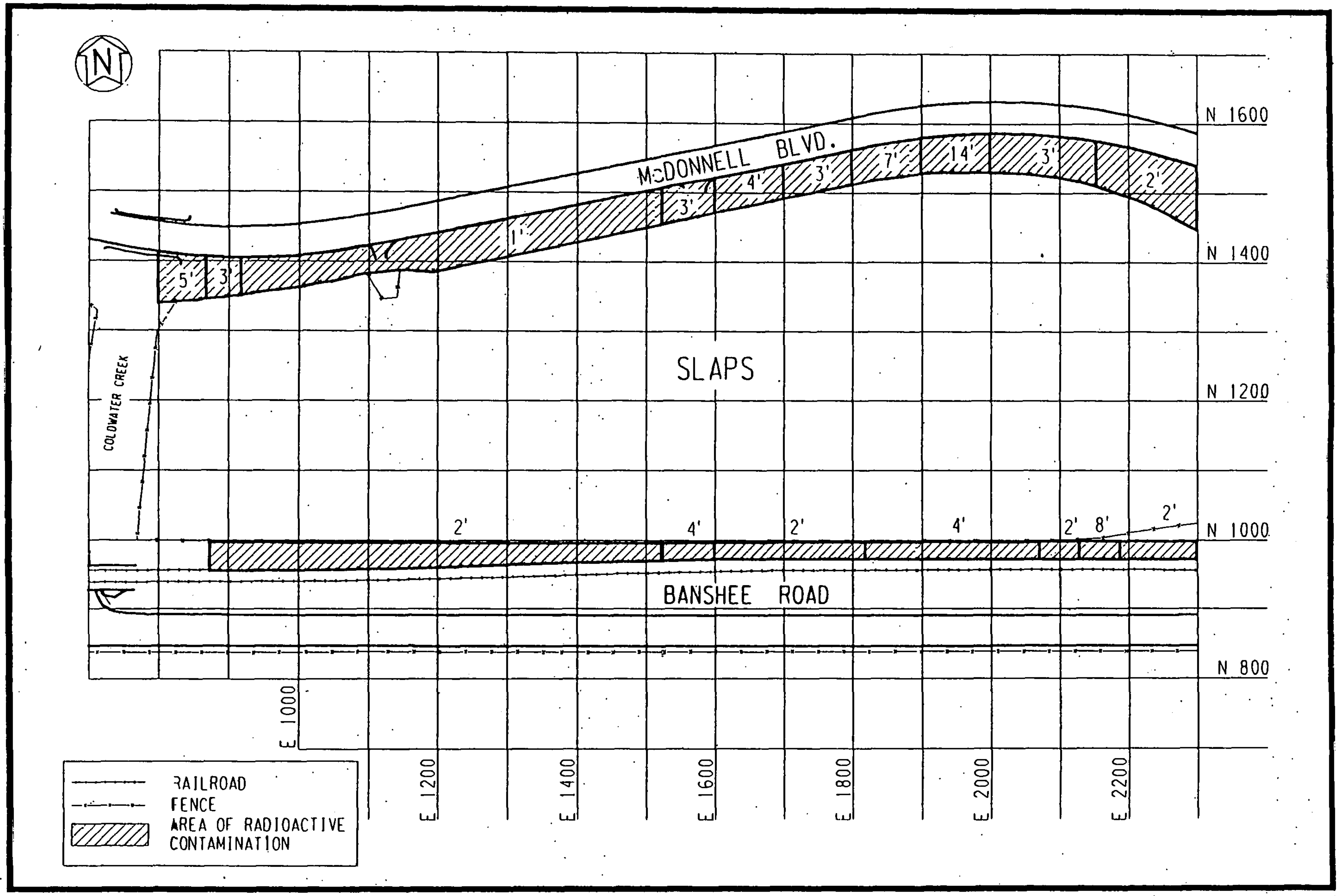

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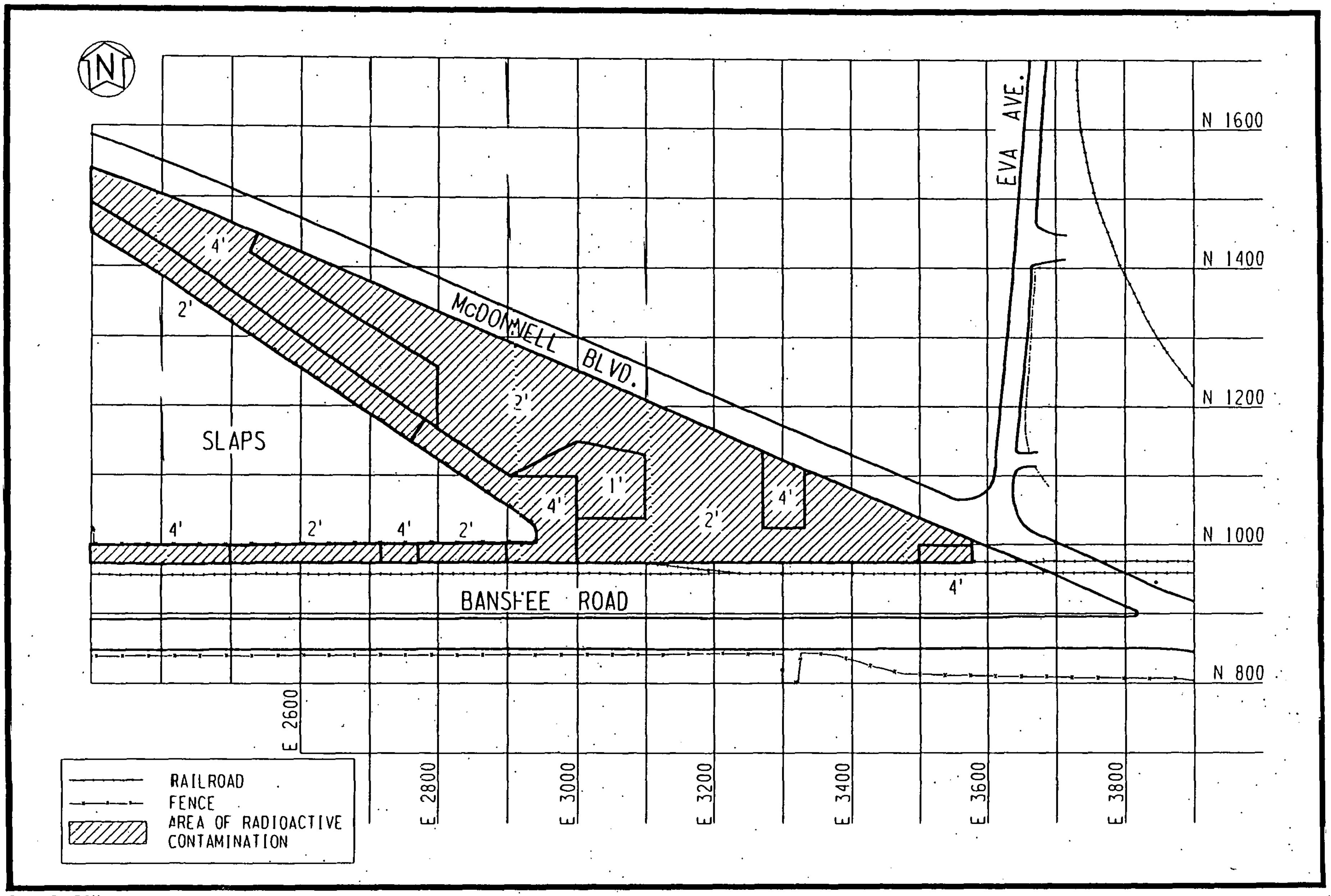
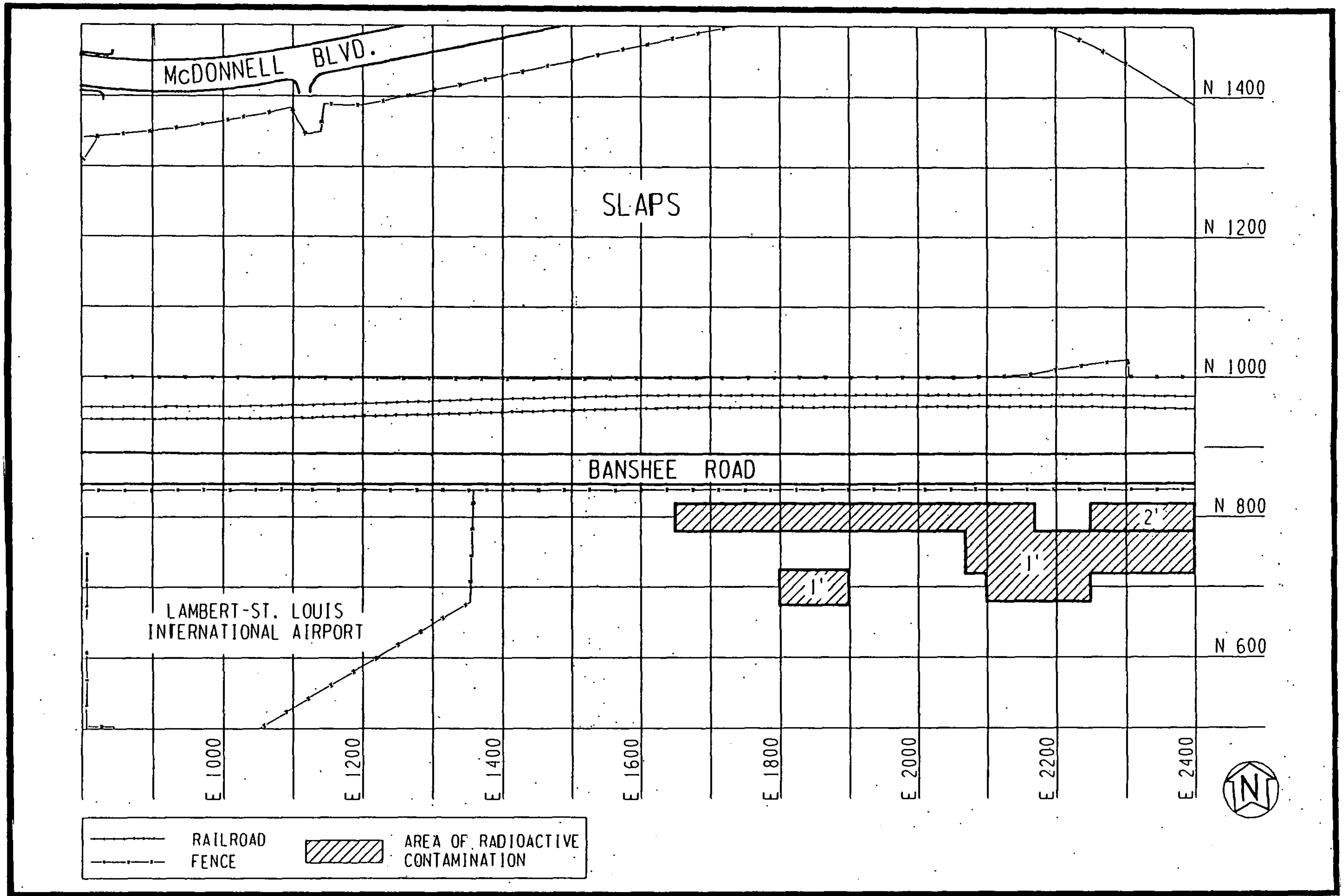
FIGURE 3-21 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION IN THE DITCHES TO THE NORTH AND SOUTH OF SLAPS



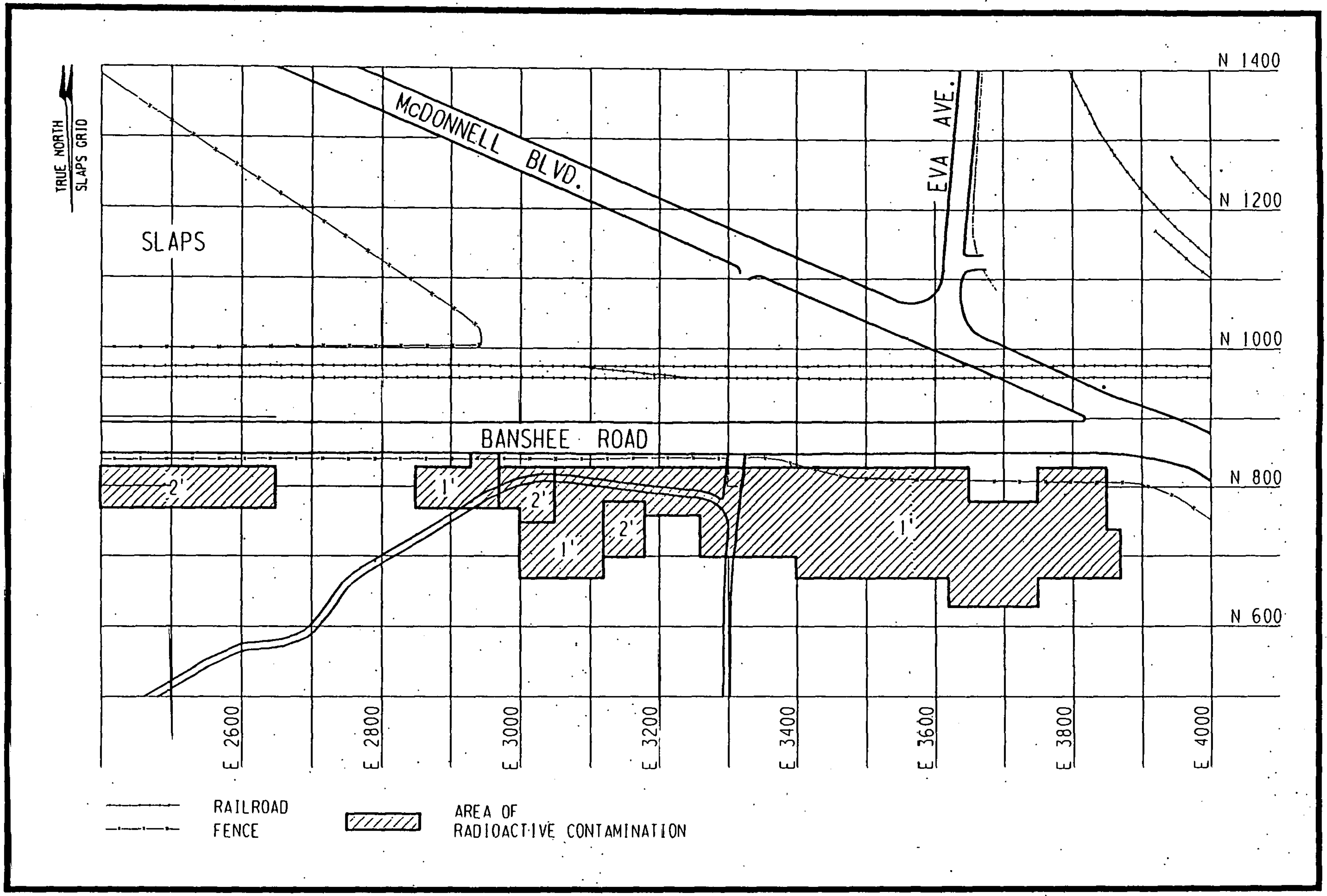
S34WMS38.DGN

FIGURE 3-21 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION IN THE DITCHES TO THE NORTH AND SOUTH OF SLAPS (CONTINUED)



S34WMS39.DGN

FIGURE 3-22 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE ST. LOUIS AIRPORT AUTHORITY PROPERTY



S34WMS40.DGN FIG 7

FIGURE 3-22 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE ST. LOUIS AIRPORT AUTHORITY PROPERTY (CONTINUED)

Analytical results for the 1987 soil characterization from SLAPS to Pershall Road indicate some areas with elevated concentrations of radium-226 and thorium-230. Concentrations of all samples analyzed for radium-226 range from 0.6 to 71 pCi/g and for thorium-230 range from 0.8 to 5,100 pCi/g. Uranium-238 concentrations range from less than 2 to 78 pCi/g, and thorium-232 concentrations range from 0.7 to 5 pCi/g.

During the 1989 characterization extending 0.94 km (1.5 mi) north of Pershall Road, 64 of the 175 samples exhibited radionuclide concentrations exceeding DOE remedial action guidelines. Concentrations of uranium-238, thorium-232, and thorium-230 range from 1.8 to 25, 0.4 to 14, 0.4 to 8.8, and 0.2 to 200 pCi/g, respectively. Average concentrations for uranium-238, radium-226, thorium-232, and thorium-230 are 7.2, 1.9, 2.1, and 9.9 pCi/g, respectively.

Analytical results for the soil survey conducted in 1989, on the 7.7-km (4.8-mi) section of the creek from the termination point of the 2.4-km (1.5-mi) characterization effort to Old Halls Ferry Road, show elevated concentrations of thorium-230 in some surface samples. Concentrations of thorium-230 for all samples analyzed range from less than 0.6 to 29 pCi/g. All uranium-238 concentrations are below 13 pCi/g; radium-226 concentrations range from less than 0.6 to 3.3 pCi/g; and concentrations of thorium-232 range from less than 1 to 5 pCi/g.

Based on results of the survey conducted on the 7.7-km (4.8-mi) section of Coldwater Creek, soil samples were collected on the 9.5-km (5.9-mi) section of Coldwater Creek downstream of the previously surveyed 7.7-km (4.8-mi) section. Sampling began at Coldwater Creek mile 5.86 (Old Halls Ferry Road) and extended to Coldwater Creek mile 0, where the creek discharges into the Missouri River. Samples were collected at 167-m (500-ft) intervals from both sides of the creek at the water's edge at a depth of 0 to 0.2 m (0 to 0.5 ft). Other samples collected to greater depths were archived and analyzed on an as-needed basis.

Concentrations of uranium-238, radium-226, thorium-232, and thorium-230 range from 2.7 to 9.5, 0.6 to 5.5, 0.8 to 4.6, and

0.4 to 29 pCi/g, respectively, with average concentrations of 5.0, 2.1, 2.4, and 2.1 pCi/g, respectively.

Thorium-230 contamination along the edges and centerline of Coldwater Creek from SLAPS to Pershall Road is shown in Figure 3-23. This figure, compiled using data from the 1986 through 1989 characterizations, illustrates points that exceed the DOE surface guideline of 5 pCi/g for thorium-230.

Radioactive contamination is spotty along the banks of Coldwater Creek and is elevated where expected on the inside bank of bends in the creek. It is also elevated where expected near SLAPS and HISS, but contamination levels decrease greatly downstream.

Ten vicinity properties were sampled in conjunction with the radiological surveys of Coldwater Creek. Analytical results reveal that six of the ten vicinity properties have low levels of radioactive contamination exceeding DOE remedial action guidelines. Radionuclide concentration ranges for each property are summarized in Table 3-11.

Metals analyses for the four sediment samples collected along Coldwater Creek showed cadmium, magnesium, molybdenum, selenium, thallium, and zinc in excess of maximum expected background concentrations. Only cadmium, magnesium, selenium, and zinc were found to exceed background levels and sample detection limits. The only volatile found in samples 2, 3, and 4 in excess of the detection limit was acetone in concentrations of 34 to 37 mg/kg. Nine semivolatiles on the Target Compound List (TCL) were found in the four samples. All of the BNAEs detected were PAHs at levels ranging from nondetectable to 13,000 mg/kg. These organic compounds are believed to result from runoff from the airport.

3.5.4 Ball Field Area

Radiological results

Analytical results for soil reveal some areas with elevated concentrations of radium-226 in surface samples and thorium-230 in

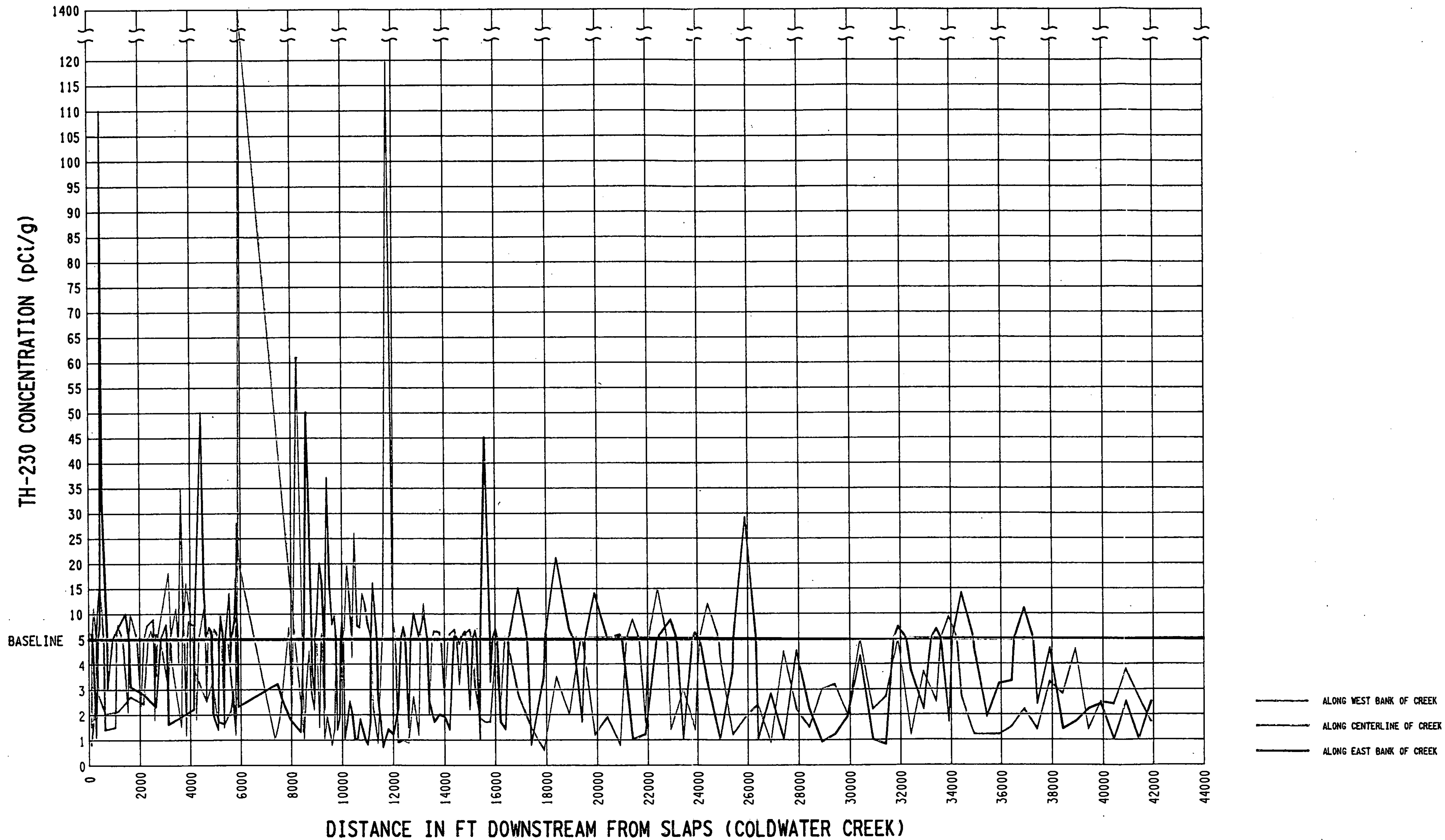


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FIGURE 3-23 THORIUM-230 CONCENTRATION ALONG COLDWATER CREEK

Table 3-11

Characterization Results for Coldwater Creek Vicinity Properties

Property Number	Concentration Range (pCi/g)[a]			
	U-238	Ra-226	Th-232	Th-230
1	3 - 14	0.8 - 2.7	0.7 - 5	1.4 - 38
2	5 - 20	0.7 - 3	0.9 - 4	<1 - 17
3	2 - 16	0.3 - 4	0.8 - 4.0	<0.8 - 79
4	3 - 11	0.6 - 1.9	0.9 - 3	<0.6 - 9.7
5	2 - 16	0.9 - 3.0	0.9 - 4.0	<0.7 - 61
6	6 - 13	1.2 - 1.7	<0.4 - 3	1.1 - 5.2
7	4 - 6.0	0.9 - 2.2	<0.3 - 3	0.9 - 3.7
8	3 - 11	0.4 - 3.8	<1 - 4	1.3 - 23
9	5 - 10	<0.5 - 2.3	<1 - 3	1 - 6.5
10	7 - 11	1.6 - 1.8	1.7 - 3	1.5 - 5.7

[a]Background values have not been subtracted.

surface and subsurface samples. Concentrations of all samples analyzed for radium-226 range from less than 5 to 190 pCi/g; thorium-230 concentrations range from less than 0.1 to 2,300 pCi/g. Concentrations of uranium-238 and thorium-232 range from less than 3 to 42 and 0.6 to 5 pCi/g, respectively. The radioactive contamination averages 0.3 m (1 ft) in depth (Figure 3-24), and the estimated volume of contaminated material is 38,026 m^2 (49,730 yd^3). Contamination was not detected on the baseball infields.

Chemical results

A broad spectrum of chemical analyses was performed on samples from the ball field as from other areas previously used for storage of waste material such as SLAPS. Given the use of the property, the VOCs detected in soil at the ball field are likely to have originated from landfilling activities. The presence of metals detected at levels exceeding background may or may not have been a result of MED/AEC activities. The degree of risk presented by these metals can better be determined when the baseline risk assessment is completed. Other chemical analyses showed concentrations that only slightly exceed detection limits; therefore, chemical contamination (other than metals) resulting from MED/AEC activities is assumed to be minimal at the ball field.

Thirty-one samples were analyzed for metals. Ten metals were detected at concentrations slightly to substantially in excess of background levels: antimony, arsenic, boron, cadmium, cobalt, magnesium, molybdenum, selenium, silver, and thallium.

Composite samples were analyzed for RCRA-hazardous waste characteristics. All samples submitted are below criteria for ignitability, corrosivity, reactivity, and EP toxicity (now replaced by TCLP); therefore, the material at the ball field is not RCRA-hazardous.

Samples from eight boreholes contain the VOCs toluene and 1,1,1-trichloroethane. However, concentrations are low, with

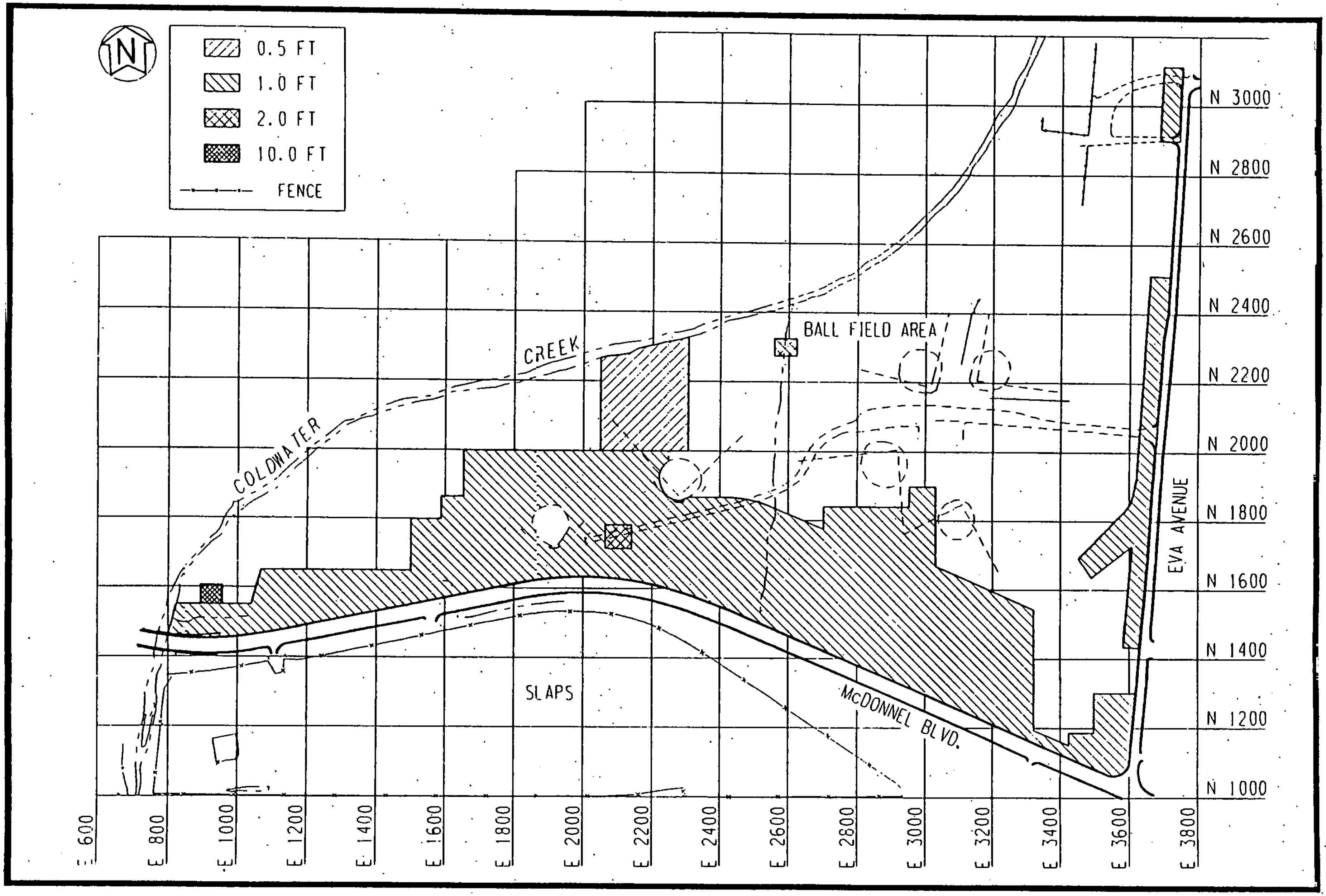


FIGURE 3-24 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE BALL FIELD AREA

maximums of 48 and 1.7 ppb for toluene and 1,1,1-trichloroethane, respectively.

To better define a massive hydrocarbon and large, late peak identified in the first analysis for VOCs, two holes were selected for a second analysis for semivolatiles. Results of this second analysis for each borehole reveal a nontarget compound (one not listed on the TCL); an unspecified benzene compound was found in Borehole C37 at a depth of 1.0 to 1.7 m (3 to 5 ft) at a concentration of 12,000 ppb and in C47 at 0.7 to 1.3 m (2 to 4 ft) at concentrations of 6,700 and 5,900 ppb (see Figure 2-17 for borehole locations). Analytical results show that all compounds on the TCL are at sample detection limits.

Because the ball field area was used as a demolition debris landfill, a pesticide/PCB analysis was performed to confirm that no chemical wastes were disposed of along with demolition materials. Only one sample contains a compound, dieldrin at 230 ppb, which exceeds the sample detection limit; all other compounds are reported at sample detection limits.

3.5.5 Haul Roads and Associated Properties

For ease of reporting, all vicinity properties have been assigned a numerical identifier, and results from all soil samples collected from the rights-of way are reported with the property immediately adjacent to them even though the actual property boundary does not extend to the road. Figure 3-25 shows the locations of the haul roads and associated properties and indicates which properties are radioactively contaminated. Thorium-230 was identified as the primary contaminant.

Latty Avenue

Analytical results for soil reveal some areas with elevated concentrations of radium-226 and thorium-230 in surface and subsurface samples. Concentrations of all samples analyzed for radium-226 range from 0.6 to 39.9 pCi/g and for thorium-230 range

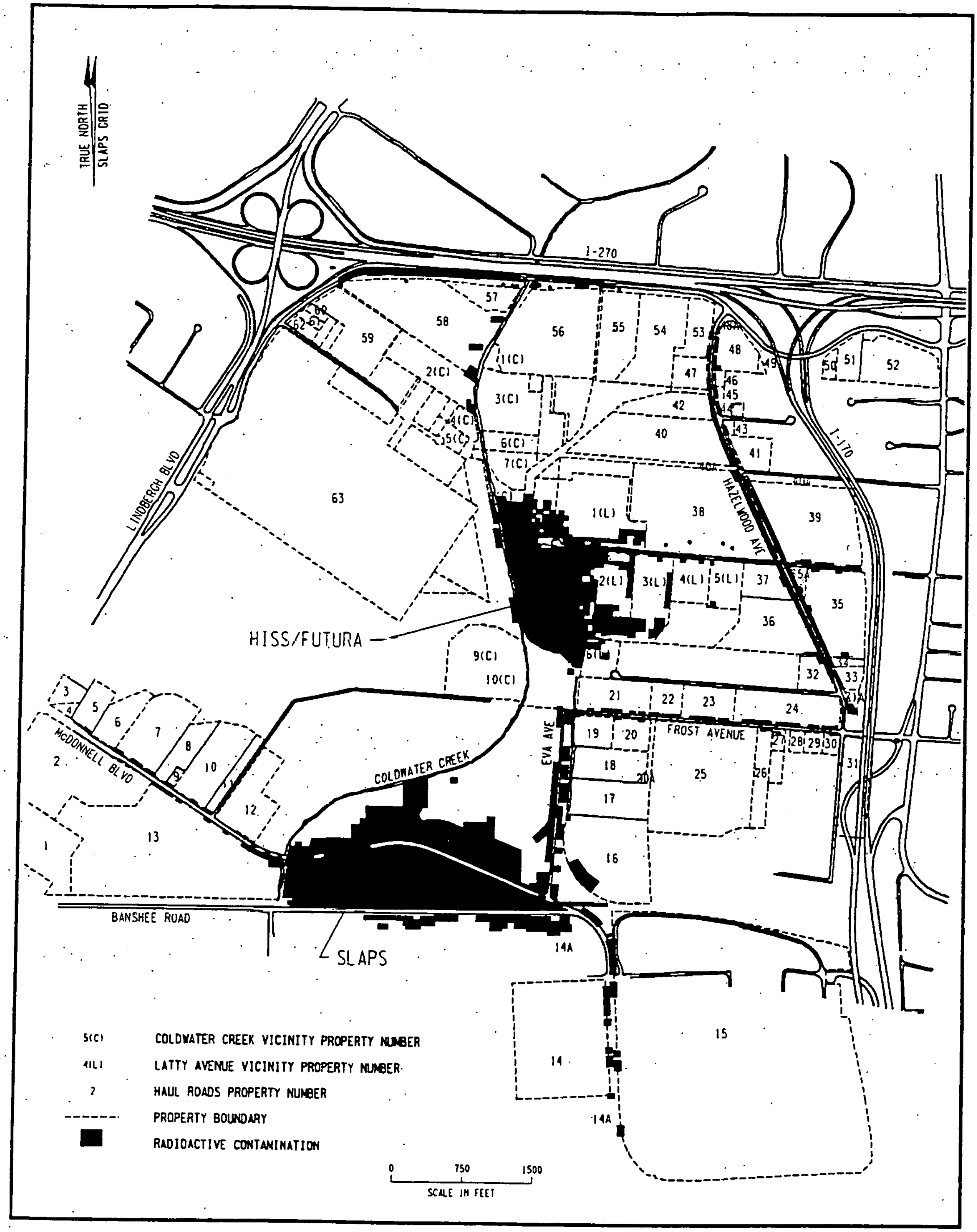


FIGURE 3-25 CONTAMINATED VICINITY PROPERTIES ALONG THE HAUL ROADS

from less than 0.2 to 1,413 pCi/g. Concentrations of uranium-238 and thorium-232 range from less than 3 to 48.2 pCi/g and 0.4 to 9.5 pCi/g, respectively. Areas and depths of contamination are shown in Figure 3-26. In most instances, contamination is confined to the surface soil [0 to 0.3 m (0 to 1 ft)].

McDonnell Boulevard

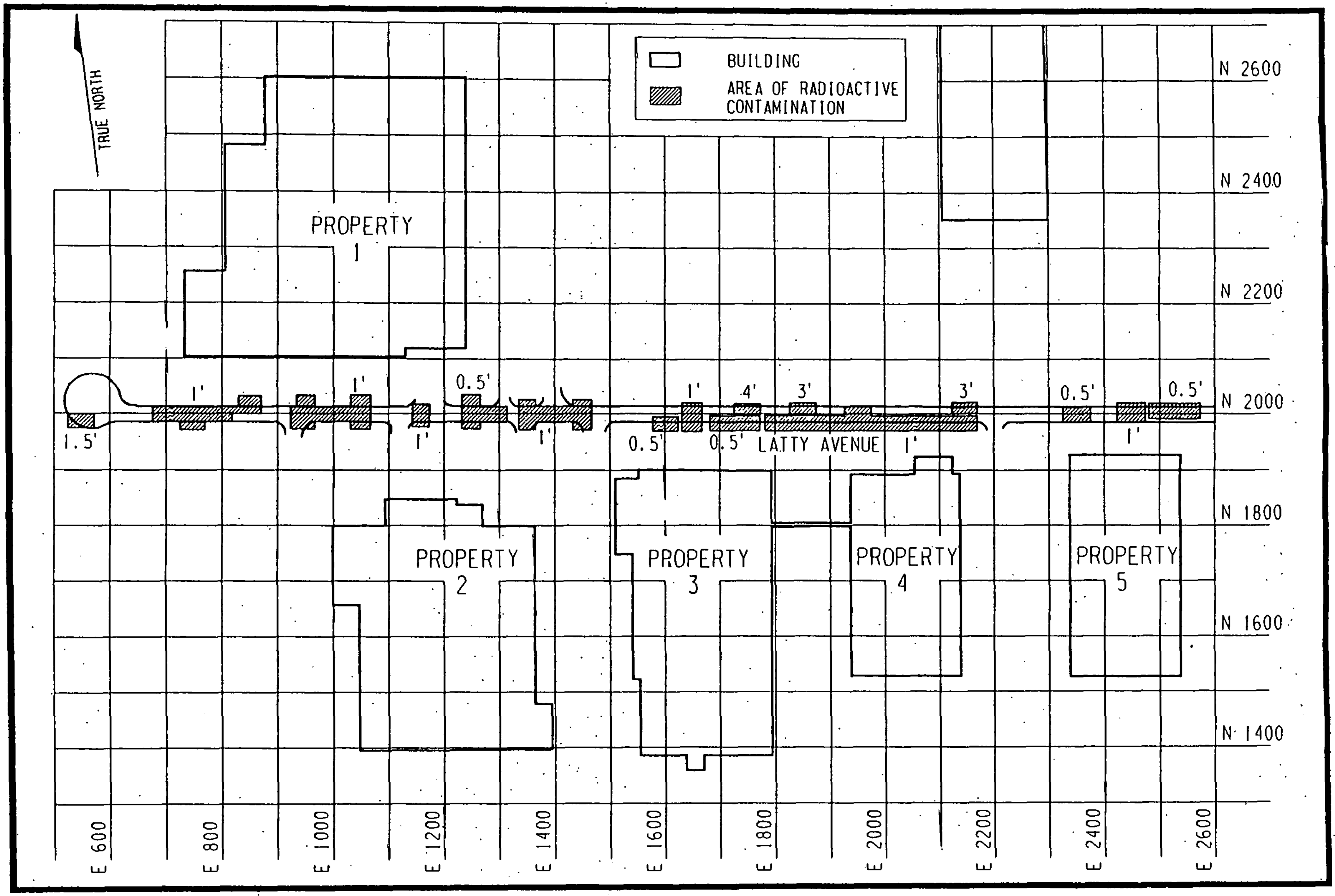
Analytical results for surface soil reveal areas with elevated concentrations of radium-226, thorium-232, and thorium-230; elevated concentrations of thorium-230 were also detected in subsurface samples. Uranium-238 concentrations range from less than 2 to 59 pCi/g, and radium-226 concentrations range from 0.7 to 64 pCi/g. Thorium-232 and thorium-230 concentrations range from less than 0.7 to 9 and 0.7 to 2,900 pCi/g, respectively.

Areas and depths of contamination are depicted in Figure 3-27. Contamination was found extending from the surface to a depth of 4.5 m (15 ft), from approximately 275 m (900 ft) east of Coldwater Creek to 122 m (400 ft) west of the creek. In addition, one isolated area of contamination, extending to a depth of 1.5 m (5 ft), was found near the intersection of McDonnell Boulevard and Eva Avenue.

Hazelwood Avenue

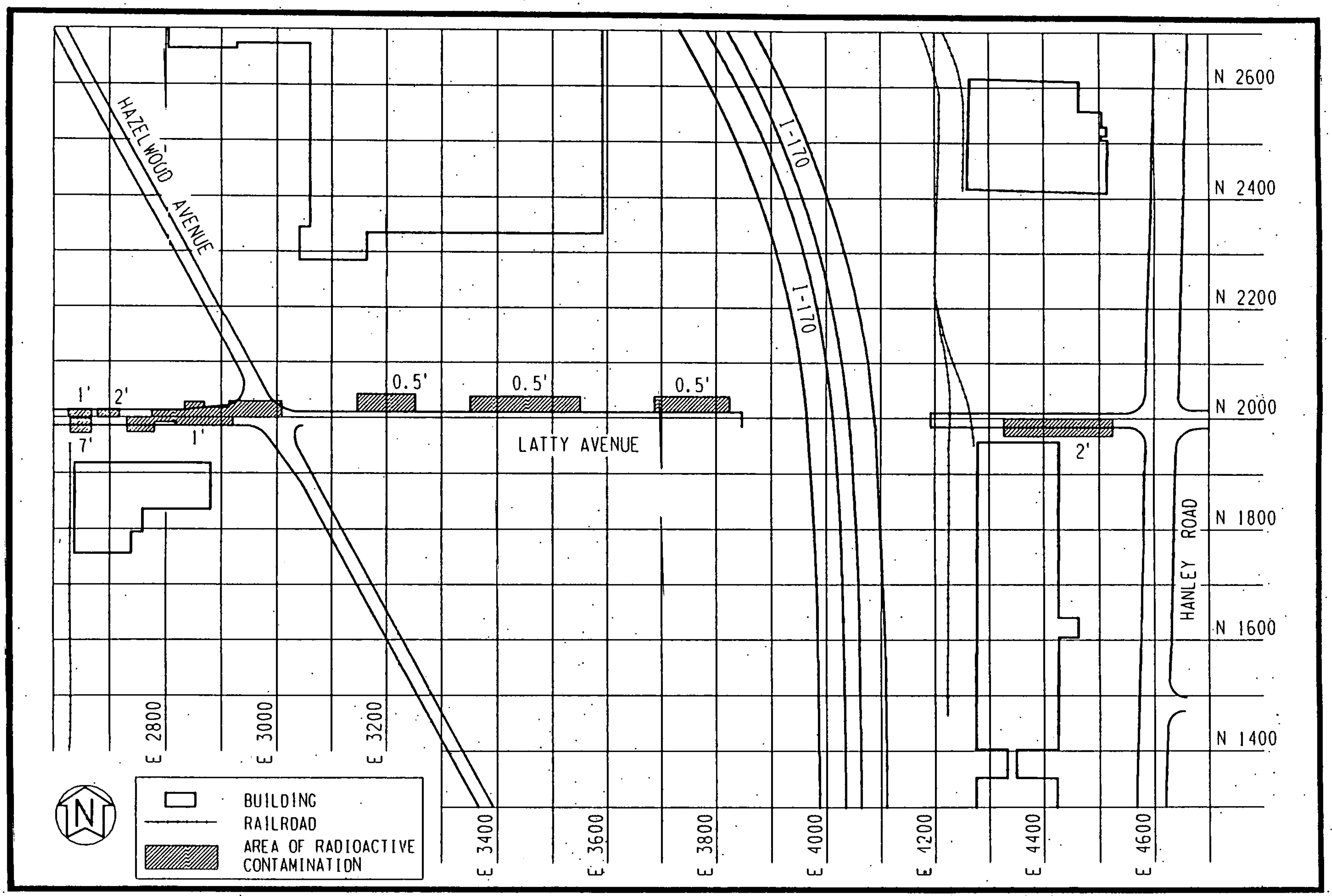
Analytical results show areas with elevated concentrations of radium-226, thorium-232, and thorium-230. Uranium-238 concentrations range from less than 4 to 72 pCi/g, and radium-226 concentrations range from 0.6 to 42 pCi/g. Thorium-232 and thorium-230 concentrations range from 0.8 to 9 and 0.9 to 4,810 pCi/g, respectively.

Figure 3-28 shows the areas and depths of radioactive contamination at Hazelwood Avenue. Contamination was found along both sides of Hazelwood Avenue from Frost Avenue to Pershall Road to an average depth of 0.3 m (1 ft).



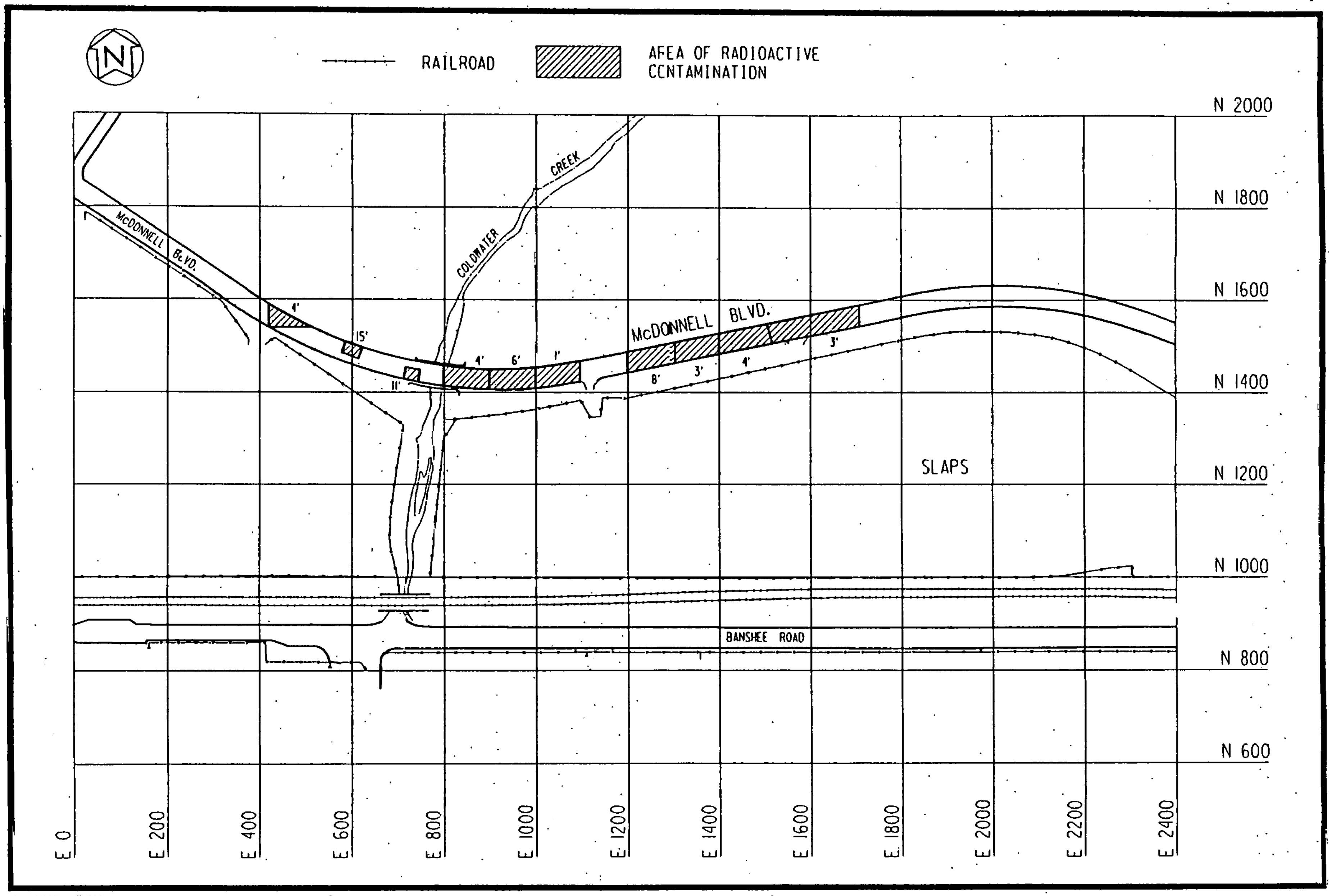
S34WMS28.DGN FIG7

FIGURE 3-26 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT LATTY AVENUE



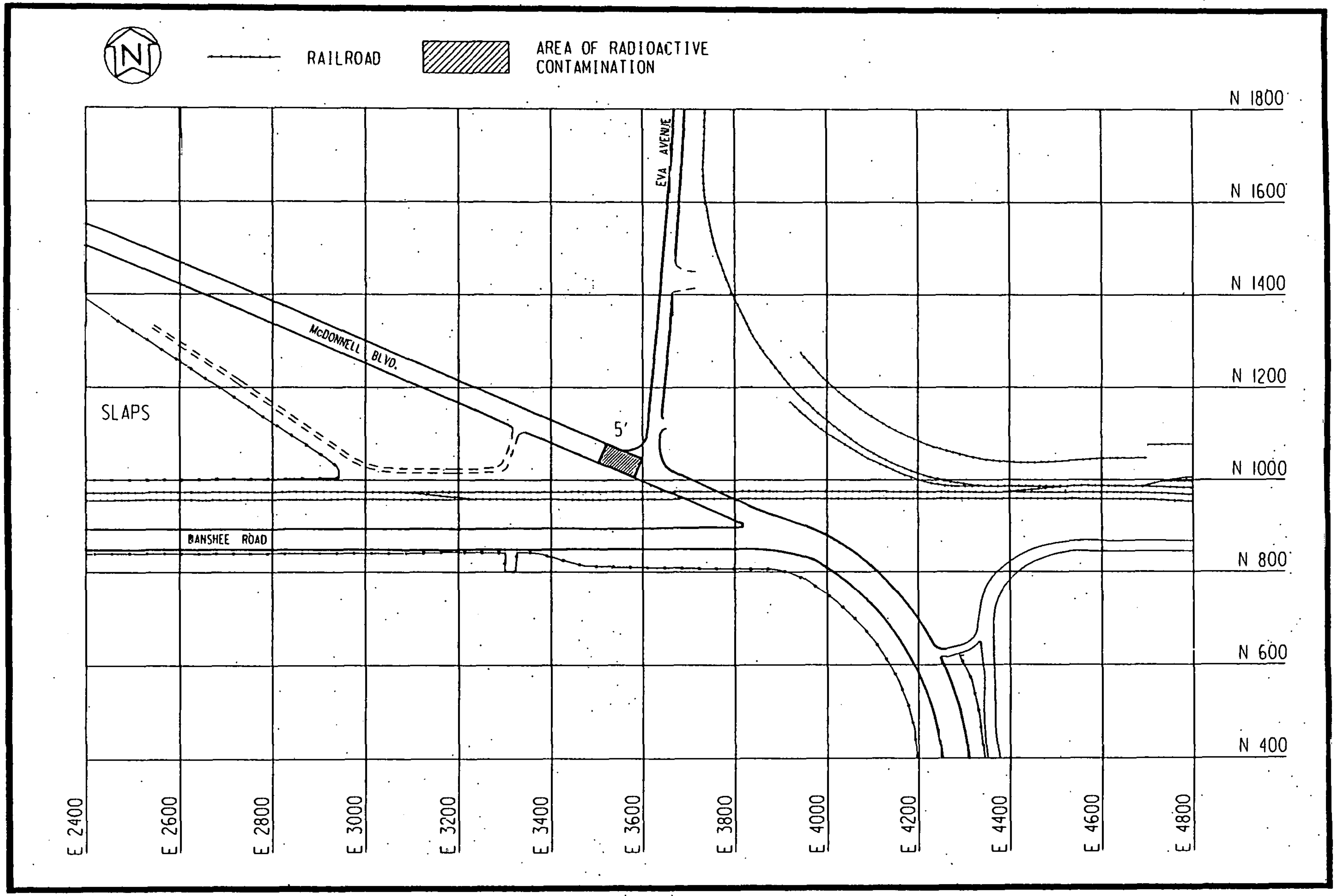
S34WMS29.DGN

FIGURE 3-26 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT LATTY AVENUE (CONTINUED)



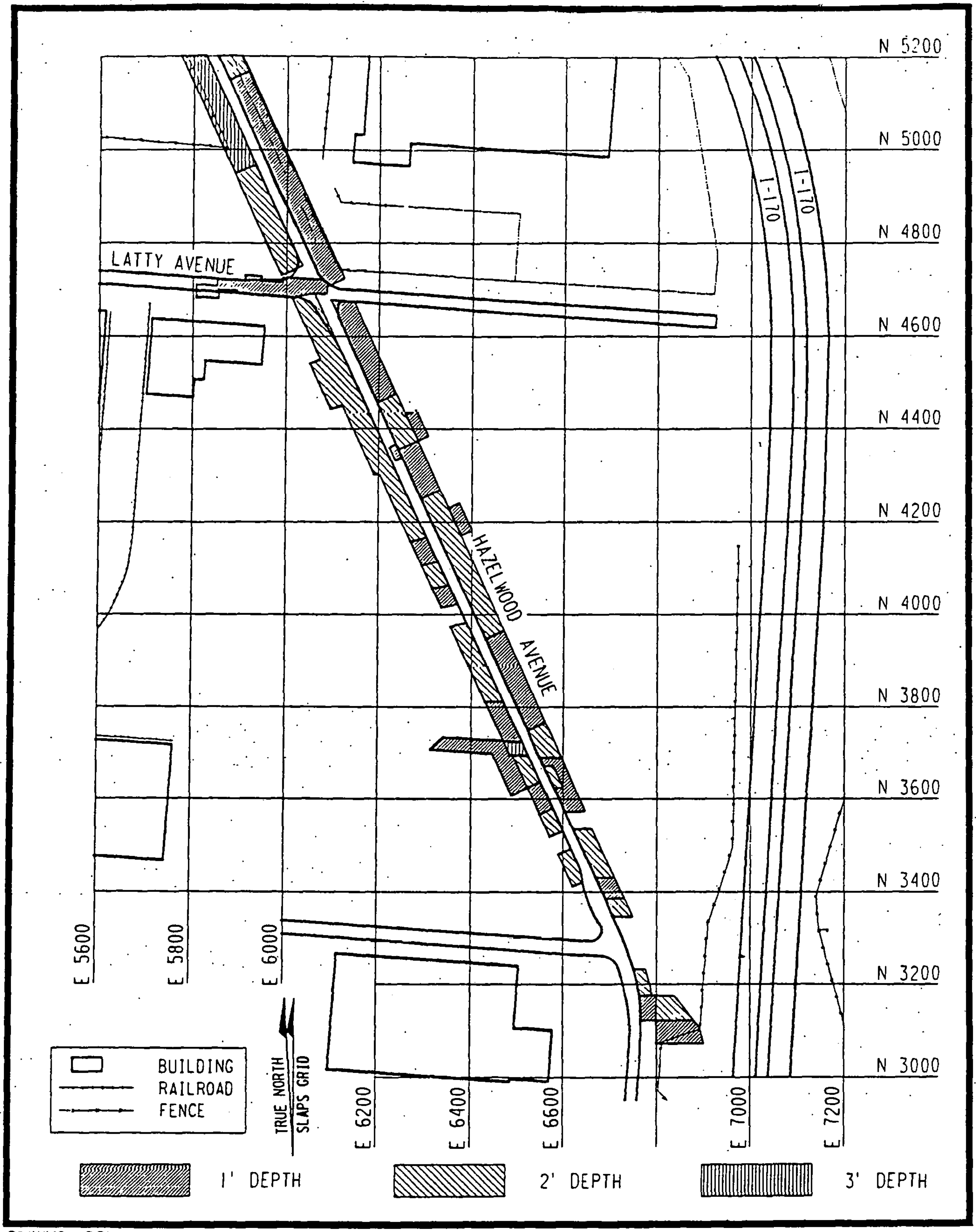
S34WMS24.DGN

FIGURE 3-27 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT McDONNELL BOULEVARD



S34WMS25.DGN

FIGURE 3-27 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT McDONNELL BOULEVARD (CONTINUED)



S34WMS31.DGN

FIGURE 3-28 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION ALONG HAZELWOOD AVENUE

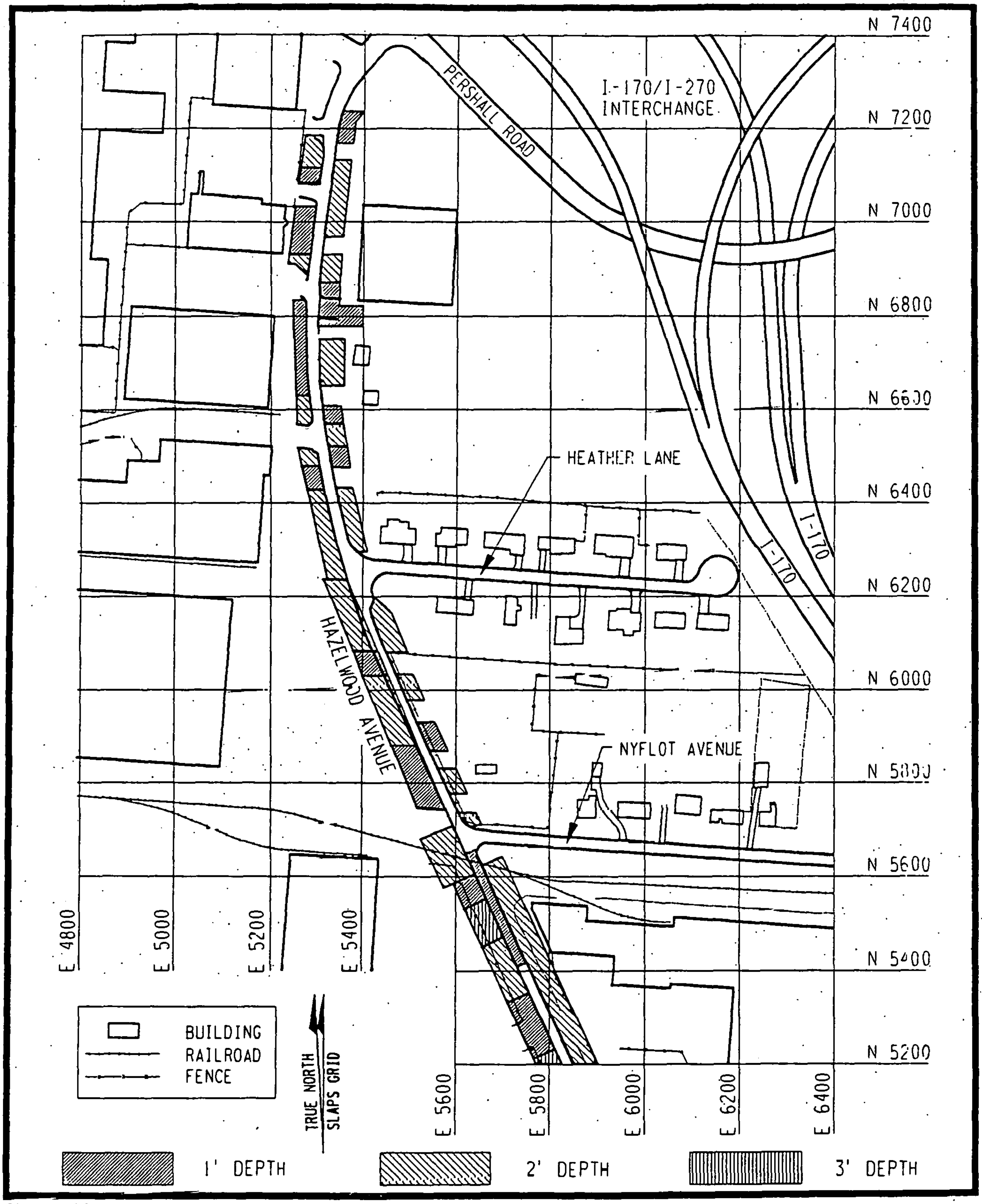


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FIGURE 3-28 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION ALONG HAZELWOOD AVENUE (CONTINUED)

Pershall Road

Analytical results reveal areas with elevated concentrations of radium-226, thorium-232, and thorium-230 in surface soil samples. Elevated concentrations of thorium-230 were also detected in subsurface samples. Uranium-238 concentrations range from less than 3 to 73 pCi/g, and radium-226 concentrations range from 0.4 to 92 pCi/g. Thorium-232 and thorium-230 concentrations range from less than 0.7 to 8 and 0.6 to 4,900 pCi/g, respectively. Figure 3-29 shows the areas and depths of radioactive contamination along Pershall Road. The average depth is 1 m (3 ft), but one isolated area of contamination extends to 4 m (13 ft).

Associated properties

Radioactive contamination on the properties bordering McDonnell Boulevard (Properties 2 through 15) (Figure 3-25) is generally confined to areas immediately adjacent to the boulevard and is generally shallow [less than 0.6 m (2 ft)].

Properties near Eva Avenue (Properties 16 through 19) exhibit only small areas of contamination, confined to locations immediately adjacent to the avenue.

Areas and levels of radioactive contamination are greater on the properties to the north of Frost Avenue than to the south (Properties 20 through 31). In general, contamination is shallow [0.6 m (2 ft)] and spotty along the length of Frost Avenue.

The properties bordering Hazelwood Avenue (Properties 31A through 48A and Property 53) contain radioactive contamination generally confined to areas immediately adjacent to the avenue. The contamination is shallow [0.6 m (2 ft)] and spotty along Hazelwood Avenue from its intersection with Frost Avenue to Pershall Road.

Radioactive contamination on the properties bordering Pershall Road (Properties 49 through 63A) is generally confined to areas immediately adjacent to the road and is shallow [0.6 m (2 ft)]. Elevated levels of thorium-230 were not detected in any of the soil

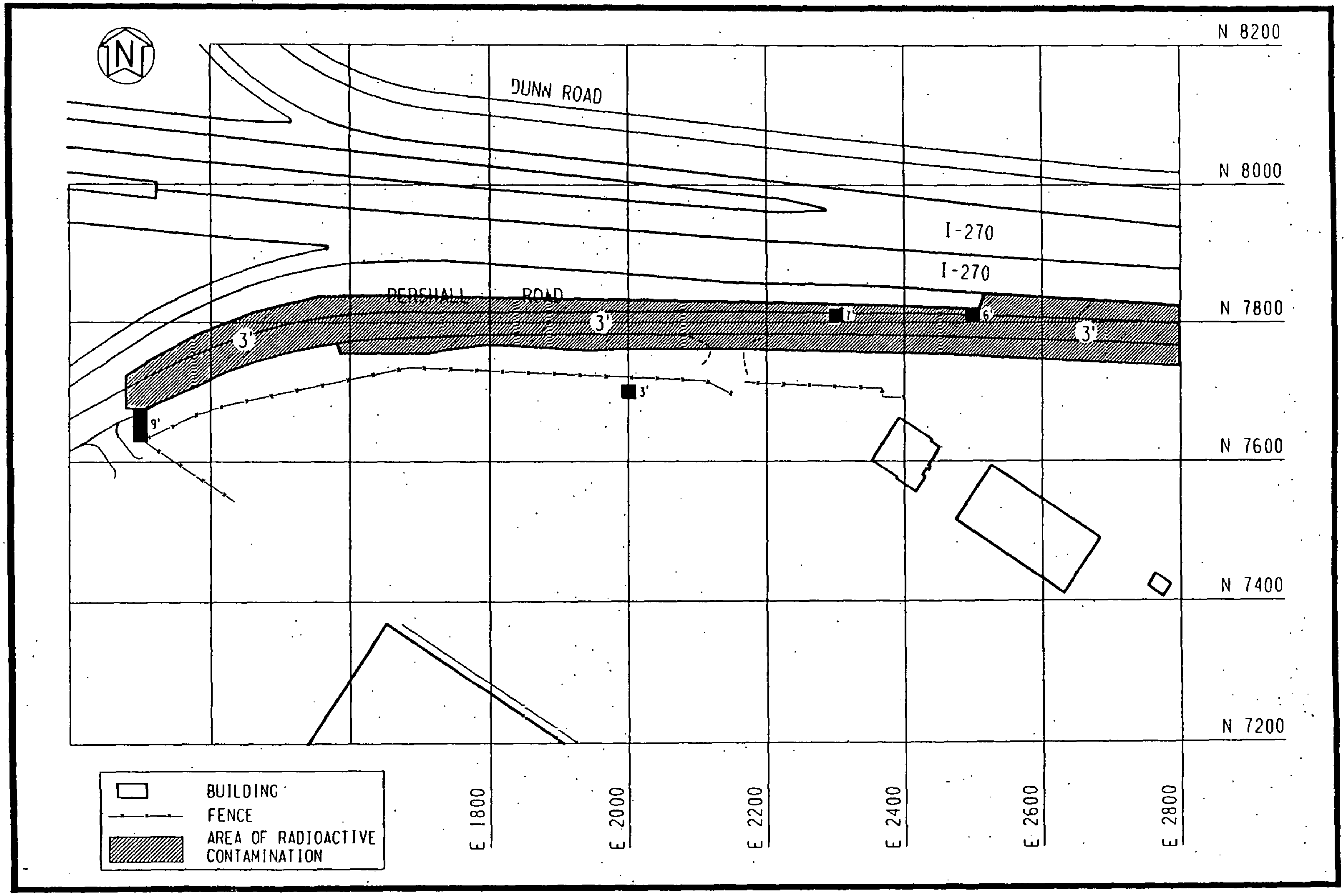

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FIGURE 3-29 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION ALONG PERSHALL ROAD

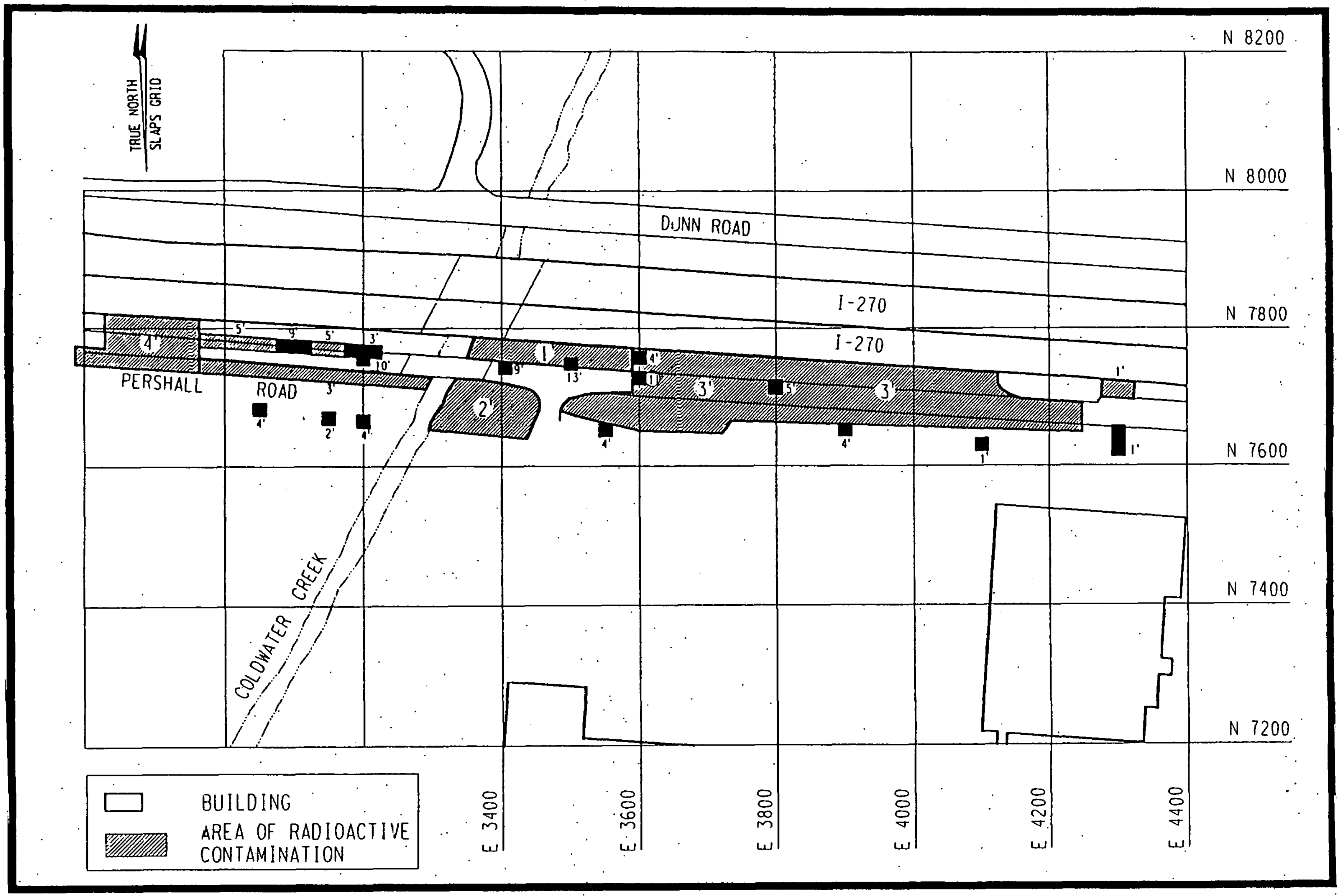


FIGURE 3-29 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION ALONG PERSHALL ROAD (CONTINUED)

S34W4S33.DGN AREA

samples from the area east of the intersection of Hazelwood Avenue and Pershall Road. Only one soil sampling location on Property 63 exhibits an elevated level of thorium-230, and 30 soil samples from south of this location reveal no elevated levels. Radioactive contamination on the properties adjacent to Pershall Road is extremely spotty from Property 53 to Property 63.

Table 3-12 summarizes the analytical results for the haul roads vicinity properties radiological surveys (BNI 1990d).

3.5.6 Norfolk and Western Railroad Properties

At the Norfolk and Western Railroad property adjacent to 9200 Latty Avenue, analytical results reveal areas with elevated concentrations of radium-226 and uranium-238 in surface soil samples and thorium-230 in surface and subsurface soil samples (Figure 3-30). Analytical results for the soil samples collected at the property adjacent to Hanley Road reveal no areas exhibiting elevated radionuclide concentrations. At the property south of SLAPS, elevated concentrations of radium-226 were found in surface soil samples and thorium-230 in surface and subsurface soil samples (Figure 3-31). Surface soil samples from the property adjacent to Coldwater Creek exhibit areas with elevated concentrations of radium-226 and thorium-230. Soil sample results for the property adjacent to Hazelwood Avenue and south of Latty Avenue reveal 15 areas with elevated concentrations of thorium-230 (Figure 3-32). Analytical results for soil at the property adjacent to Hazelwood Avenue and north of Latty Avenue reveal no areas exhibiting elevated concentrations of thorium-230. At the property adjacent to Eva Avenue, 23 locations exhibit elevated concentrations of thorium-230 (Figure 3-33).

Table 3-13 is a summary of the radiological results for the Norfolk and Western Railroad properties.

Table 3-12
Concentrations of Thorium-230
at the Haul Roads Associated Properties Near SLAPS

Property No.	Contamination Exceeding Guidelines Yes	No	Concentration Range (pCi/g)	Average (pCi/g)
1[a]			Analysis not performed	
2[b]		X	<0.6 - 3.5	1.5
3		X	<0.6 - 2.4	1.3
4		X	1.4 3.9	2.3
5	X		1.1 - 14	4.5
6		X	<1.1 - 2.8	1.5
7	X		0.6 - 32	5.5
8		X	1.2 - 2.2	1.6
9	X		<0.5 - 12.0	5.5
10	X		1.2 - 7.2	3.1
11	X		<0.8 - 18	6.3
12	X		<1 - 570	34.0
13	X		<0.7 - 370	34.0
14	X		<0.9 - 33	6.1
14A	X		<0.4 - 36	6.2
15	X		<0.6 - 460	12.7
16[c]	X		1.5 - 6.6	3.8
17		X	<0.9 - 1.4	1.3
18[d]			Analysis not performed	
19	X		<0.7 - 11	2.6
20[e]	X		0.7 - 8.4	3.1
20A		X	0.6 - 2.6	1.6
21	X		<0.5 - 230	22.4
22	X		<0.6 - 110	15.2
23	X		<0.8 - 710	37.3
24	X		<0.4 - 710	26.2
25		X	1 - 4.8	2.2
26	X		1.4 - 6.9	3.0
27	X		1.4 - 8.1	3.1
28		X	1.5 - 4.6	2.9
29		X	0.7 - 3.2	1.7
30	X		1 - 8.8	3.4
31		X	1.2 - 2.1	1.6
31A[f]	X		<1 - 41	7.8
32	X		<0.3 - 540	39.4
33	X		1.1 - 170	27.6
34	X		1.3 - 140	17.9
35	X		0.8 - 1014	13.6
37	X		<0.8 - 600	28.4
38	X		0.5 - 1200	20.6
39	X		<0.8 - 200	23.6
40	X		<0.5 - 110	15.4

Table 3-12

(continued)

Property No.	Contamination Exceeding Guidelines Yes	No	Concentration Range (pCi/g)	Average (pCi/g)
41	X		0.8 - 53	5.2
42	X		1.4 - 63	13.8
43	X		0.8 - 22	4.6
44	X		1.1 - 91	20.2
45	X		1 - 21	5.2
46	X		<0.8 - 7	2.0
47	X		0.9 - 110	12.3
48	X		0.7 - 34	5.7
48A		X	1.4 - 1.9	1.6
49[g]		X	0.8 - 1.5	1.1
50		X	1 - 1.4	1.2
51		X	1 - 1.7	1.3
52		X	1 - 4.3	1.5
53	X		0.8 - 21	3.7
54		X	0.7 - 1.7	1.2
55		X	1.3 - 2.3	1.6
56	X		0.7 - 1100	94.6
57	X		1.3 - 19	4.8
58	X		<0.9 - 8.5	2.7
59		X	1.3 - 2.2	1.7
60		X	<0.9 - 1.5	1.3
61		X	0.8 - 1.7	1.3
62		X	1 - 3.4	2.1
63	X		1 10	2.4
63A	X		0.6 - 200	3.6

[a]Property 1 borders Lindbergh Boulevard. (Soil samples from Property 1 were not analyzed because no contamination was found between McDonnell Blvd. and the property.)

[b]Properties 2 through 15 border McDonnell Boulevard.

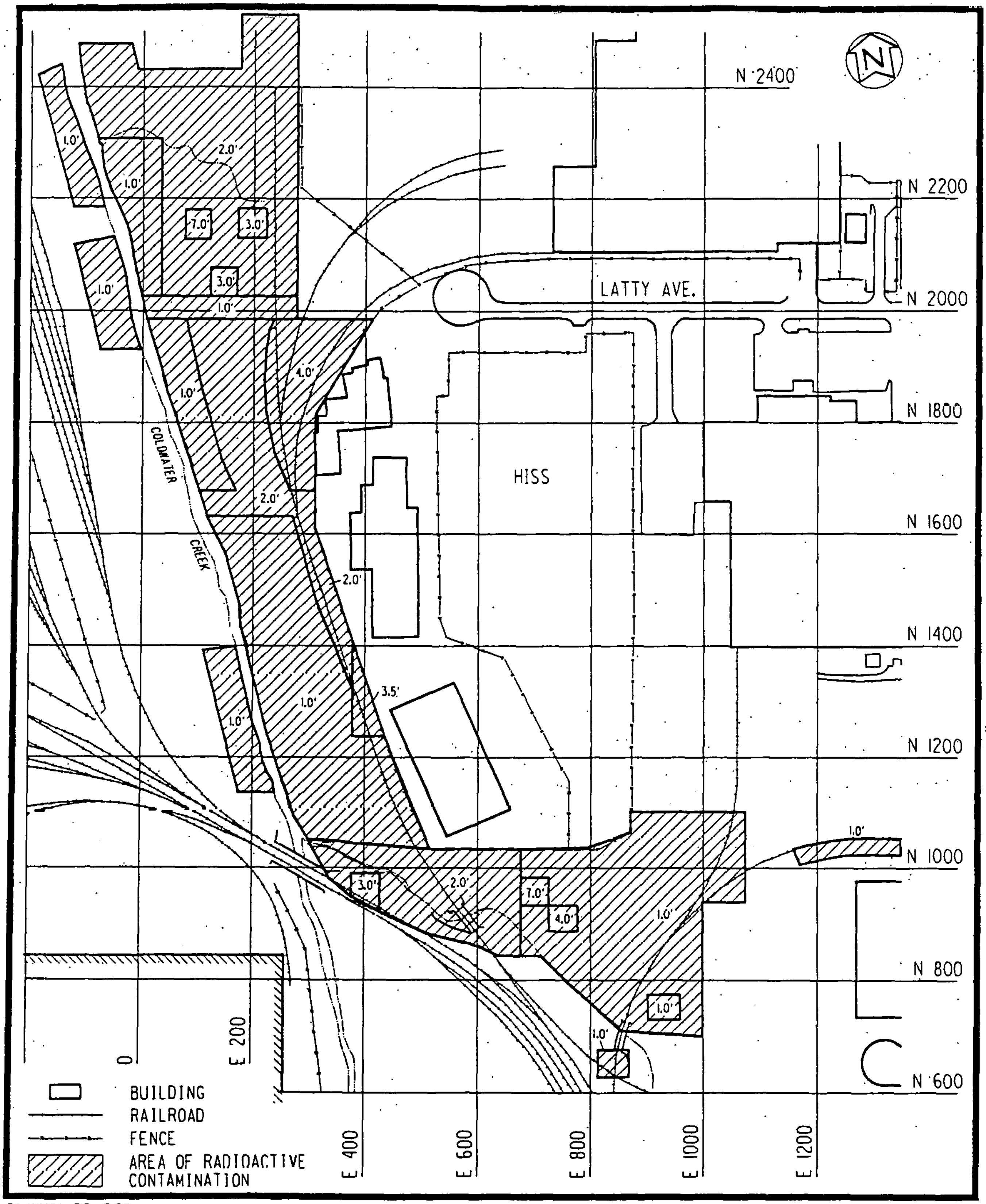
[c]Properties 16 through 19 are near Eva Avenue.

[d]Soil samples from Property 18 were not analyzed because the extent of contamination was found between Eva Avenue and Property 18.

[e]Properties 20 through 31 are located along Frost Avenue.

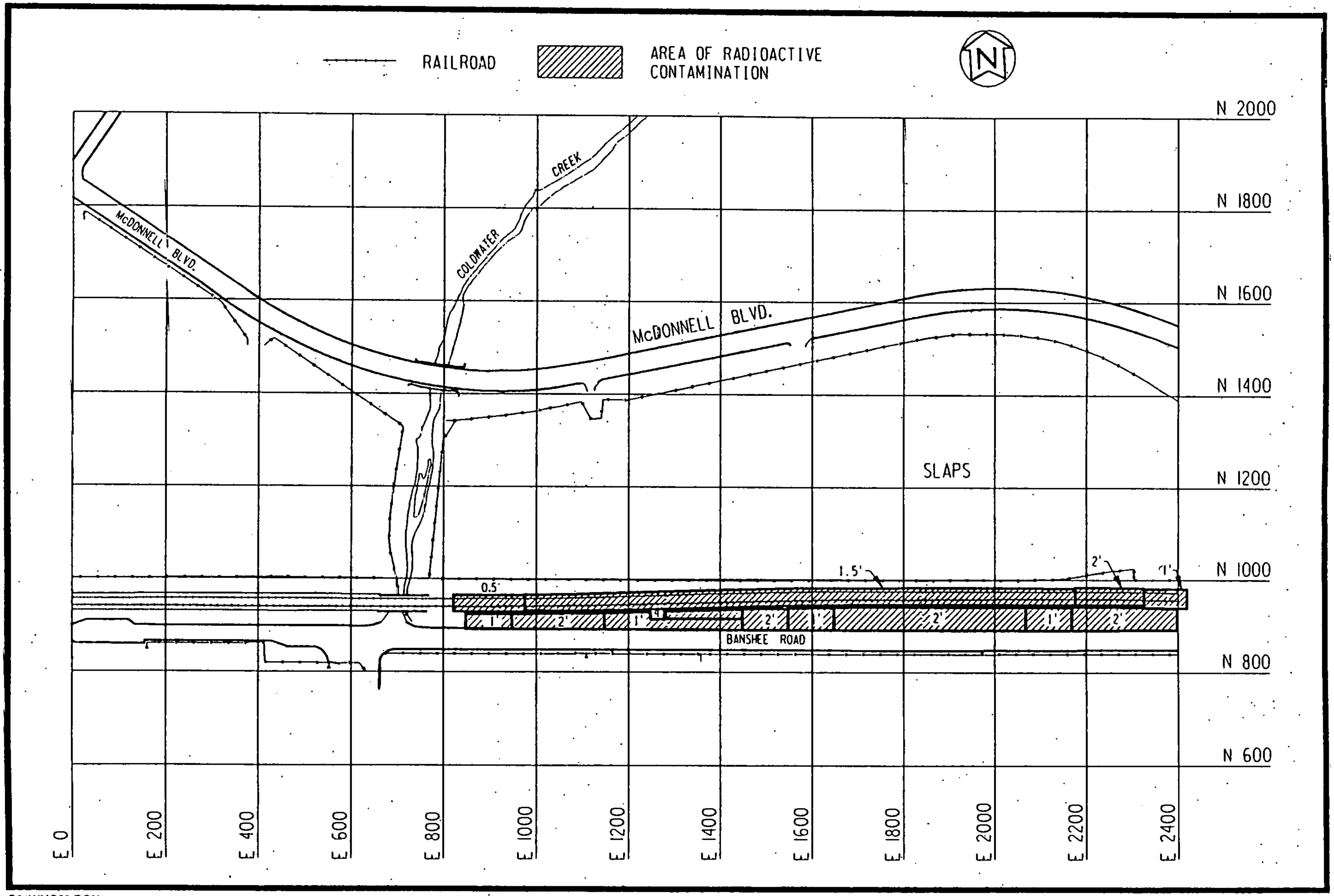
[f]Properties 31A through 48A border Hazelwood Avenue.

[g]Properties 49 through 63A border Pershall Road.



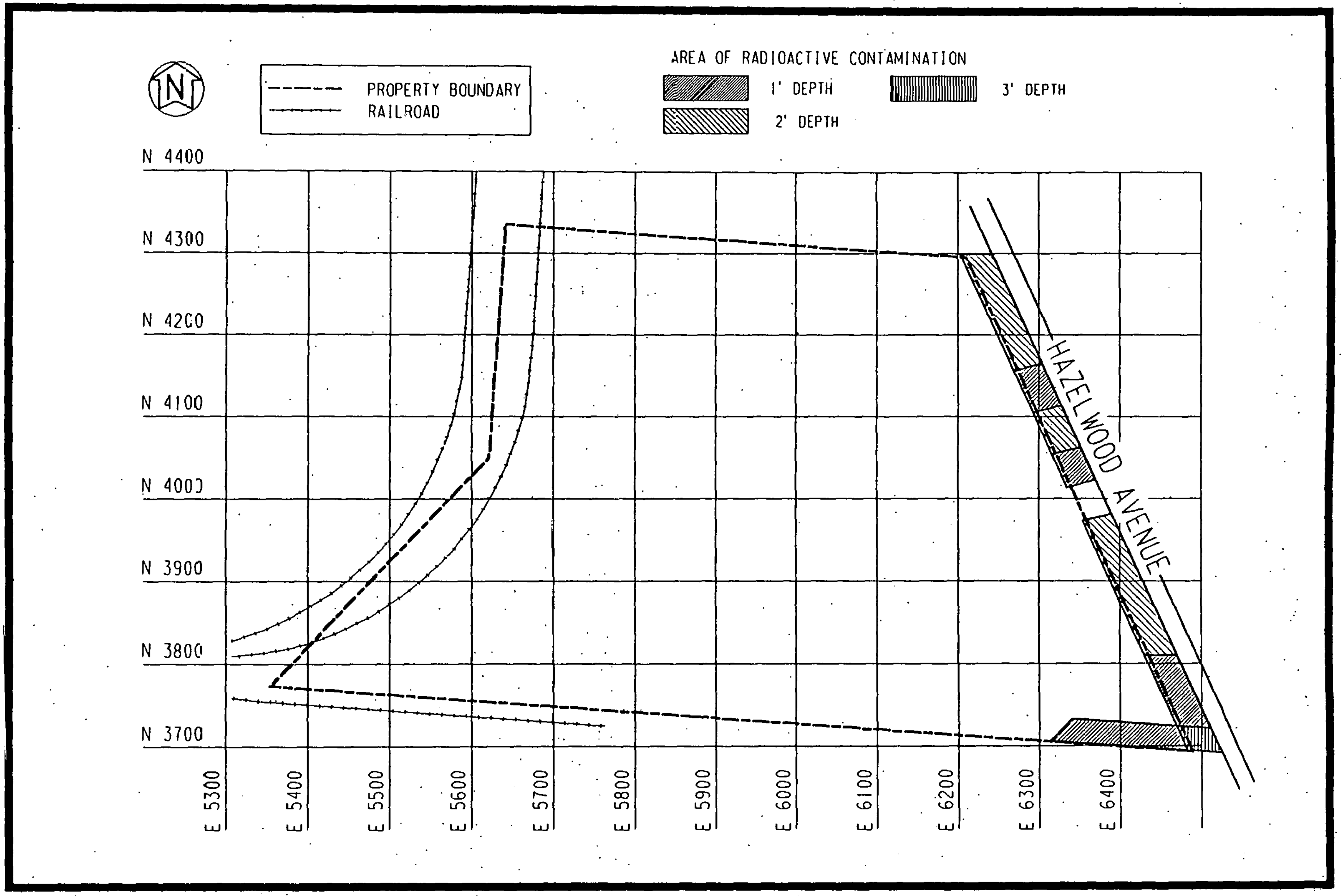
S34WMS20.DGN FIG7

FIGURE 3-30 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE NORFOLK AND WESTERN RAILROAD PROPERTY ADJACENT TO 9200 LATTY AVENUE



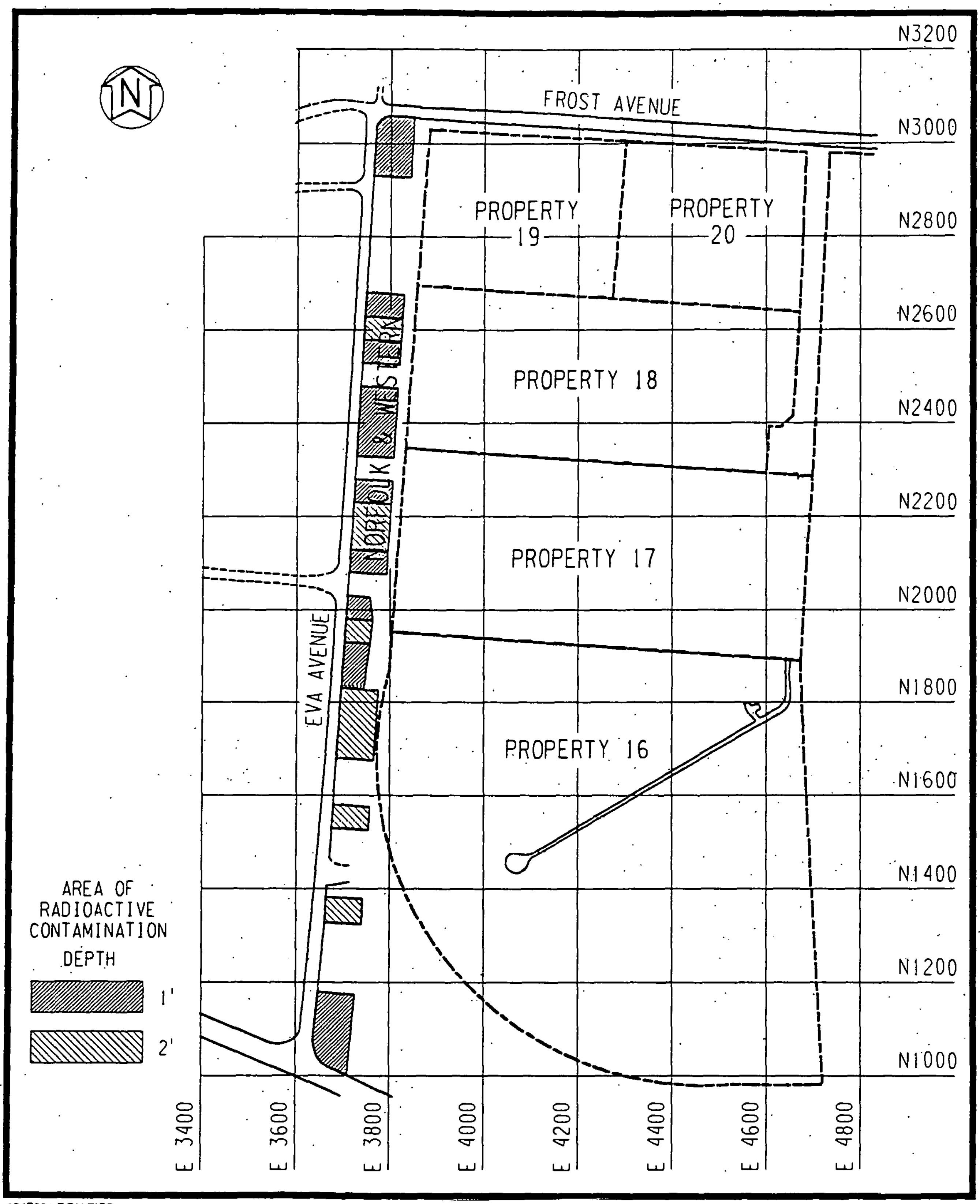
S34WMS58.DGN

FIGURE 3-31 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE NORFOLK AND WESTERN RAILROAD PROPERTY SOUTH OF SLAPS



134F061.DGN

FIGURE 3-32 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE NORFOLK AND WESTERN RAILROAD PROPERTY ADJACENT TO HAZELWOOD AVENUE AND SOUTH OF LATTY AVENUE



134F091.DGN FIG7

FIGURE 3-33 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE NORFOLK AND WESTERN RAILROAD PROPERTY ADJACENT TO EVA AVENUE

Table 3-13
Summary of Radiological Survey Results for the
Norfolk and Western Railroad Properties

Property Parameter	Range (pCi/g)	Average (pCi/g)	No. of Samples Exceeding Guidelines	No. of Samples Analyzed
Adjacent to 9200 Latty Avenue				
U-238	<4 - 390	8.0	199	550
Ra-226	0.6 - 1,100	4.0		
Th-232	0.6 - 7	1.6		
Th-230	0.7 - 26,000	85.1		
Adjacent to Hanley Road				
U-238	<7[a]	0.6	0	29
Ra-226	1.6 - 2.2	0.1		
Th-232	2 - 2.5	0.2		
Th-230	0.8 - 6	2.1		
South of SLAPS				
U-238	<3 - 27	8.9	85	224
Ra-226	0.6 - 8	2.2		
Th-232	0.6 - 5	1.7		
Th-230	1.5 - 170	22.7		
Adjacent to Coldwater Creek				
U-238	<23[a]	9.0	23	111
Ra-226	0.7 - 15	2.5		
Th-232	<0.1 - 4	2.0		
Th-230	<0.3 - 1,300	34.1		
Adjacent to Hazelwood Avenue and South of Latty Avenue				
Th-230	1.2 - 210	15.8	16	44
Adjacent to Hazelwood Avenue and North of Latty Avenue				
Th-230	1.9 - 3.8	2.5	0	6
Adjacent to Eva Avenue				
Th-230	<0.8 - 85	8.6	23	73

[a]All measured values are less than the value indicated.

3.5.7 Banshee Road

Analytical results for soil reveal two areas containing thorium-230 concentrations that exceed DOE guidelines (Figure 3-34). Thorium-230 concentrations for all samples collected range from less than 0.4 to 34 pCi/g and were found to a depth of 0.3 m (1 ft). Uranium-238 concentrations are less than 46 pCi/g, and radium-226 and thorium-232 concentrations are less than 7.1 pCi/g. The estimated volume of radioactively contaminated soil at Banshee Road is approximately 2,401 m^3 (3,140 yd^3) (BNI 1990d).

3.6 CHARACTERIZATION RESULTS FOR HISS

3.6.1 Surface and Subsurface Soils at HISS

Radiological results

Fifteen gamma exposure rates were measured at HISS in the areas not covered by the two interim storage piles. Gamma radiation exposure rates range from 13 to 55 μR/h with an average of 24 μR/h (including background). The highest reading was obtained east of the northeast corner of the small storage pile. Near-surface gamma measurements indicate that the entire property, excluding the decontamination pad area, contains surface contamination (BNI 1987b).

Based on analysis of soil samples, thorium-230 was identified as the primary contaminant; elevated levels of radium-226 and uranium-238 were also found. Thorium-232 concentrations range from background levels to 5 pCi/g, radium-226 was found at concentrations of up to 700 pCi/g, and uranium-238 concentrations range from 4 to 800 pCi/g. Concentrations of thorium-230 range from 0.8 to 790 pCi/g in the selected samples analyzed; however, because only those samples with no associated gamma-emitting radionuclides were analyzed for thorium-230, the maximum

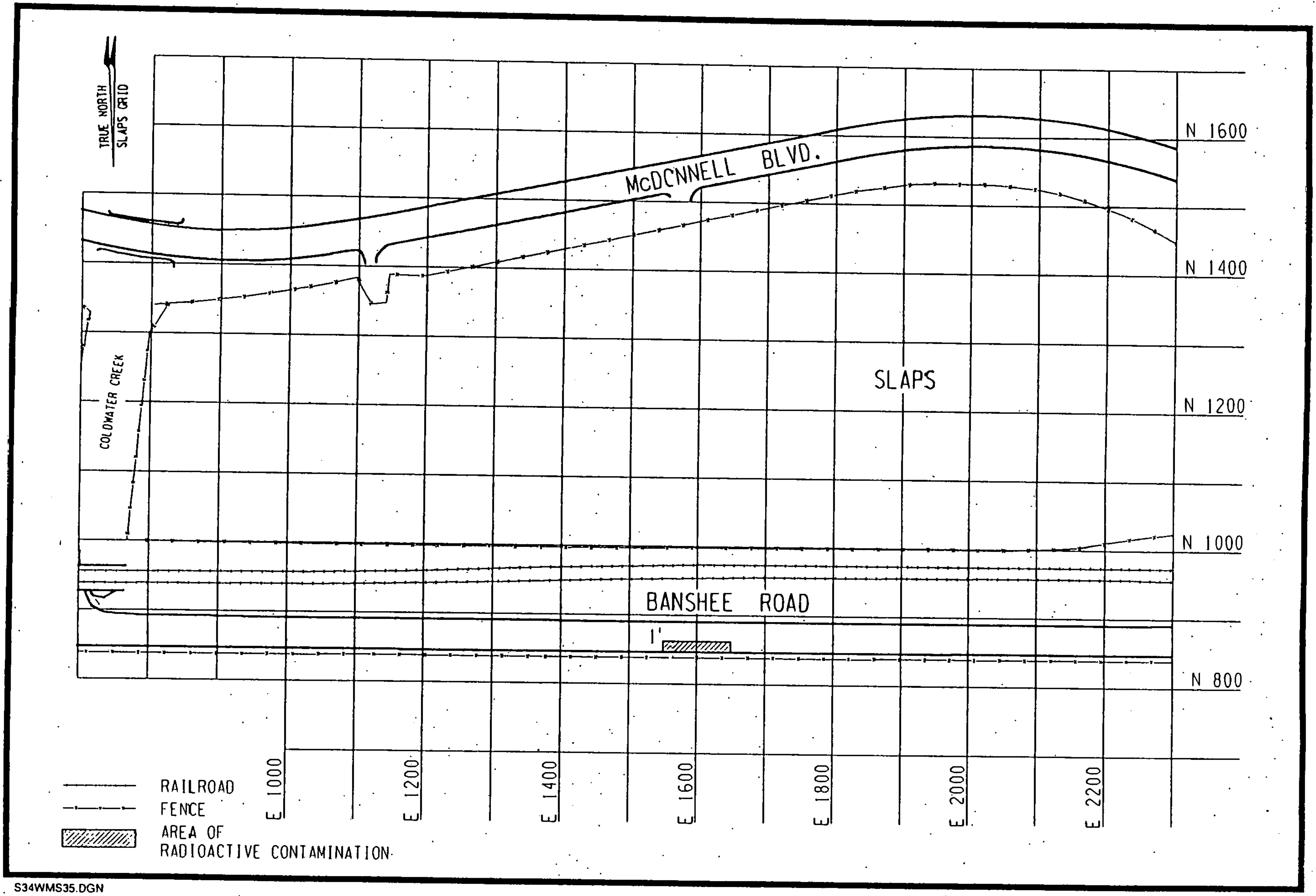


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FIGURE 3-34 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT BANSHEE ROAD

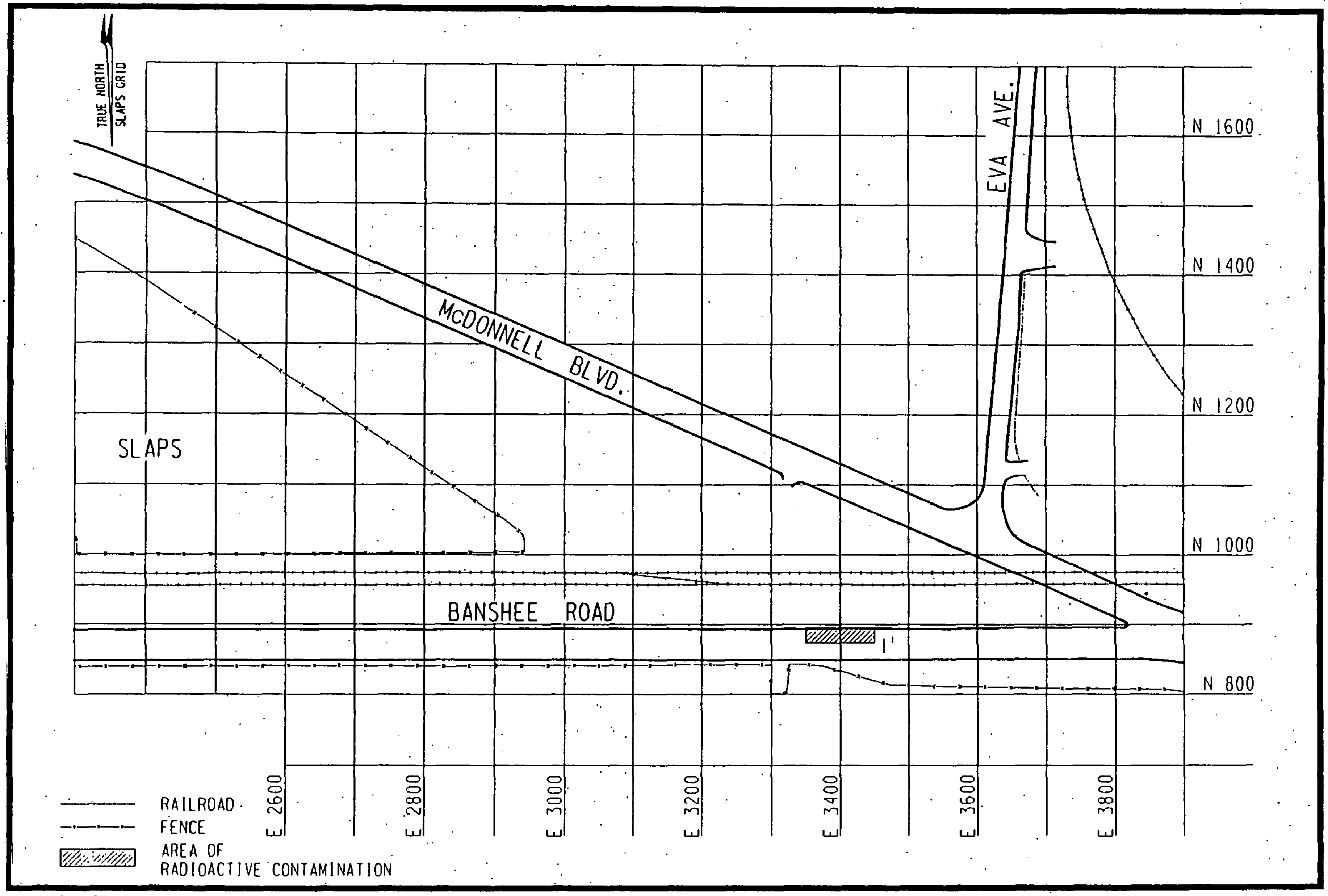

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FIGURE 3-34 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT BANSHEE ROAD (CONTINUED) concentration at the property may be much greater than the analytical results indicate.

Soil survey results confirm that radioactive contamination is present over the entire property from the surface to a depth of 2 m (6 ft) and an average depth of 1 m (3 ft). The current estimated volume of radioactively contaminated soil at HISS, including the soil and debris in the storage piles, is approximately 53,520 m^3 (70,000 yd^3). Figure 3-35 shows the areas and depths of contamination.

Detailed results for the soils investigation are provided in BNI 1987b.

Chemical results

Results of the metals analyses for HISS indicate that 16 metals are present in the soil at concentrations exceeding background levels (Appendix B). Levels of antimony, arsenic, barium, boron, cadmium, cobalt, copper, lead, magnesium, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc vary from slightly exceeding background to approximately 18,000 ppm. Most of the metals appear to be confined to depths at or near the surface, similar to the distribution of metals at SLAPS. For more information about the metals that exceed background levels, refer to BNI 1990b.

To determine whether chemicals have migrated underneath the average depth of radioactive contamination, soil samples from six intervals below this depth were tested for metals; cadmium and magnesium were detected at concentrations exceeding background. The analytical results for metals demonstrate that the chemicals are, in general, associated with the radioactive waste.

Only 1 of the 12 samples submitted for VOC analysis exhibits a concentration exceeding sample detection limits -- toluene at 2.9 ppb. Therefore, VOCs are not thought to present a problem at HISS.

Initial BNAE results identified two peaks grossly defined as massive hydrocarbons. Two boreholes were resampled in March 1988,

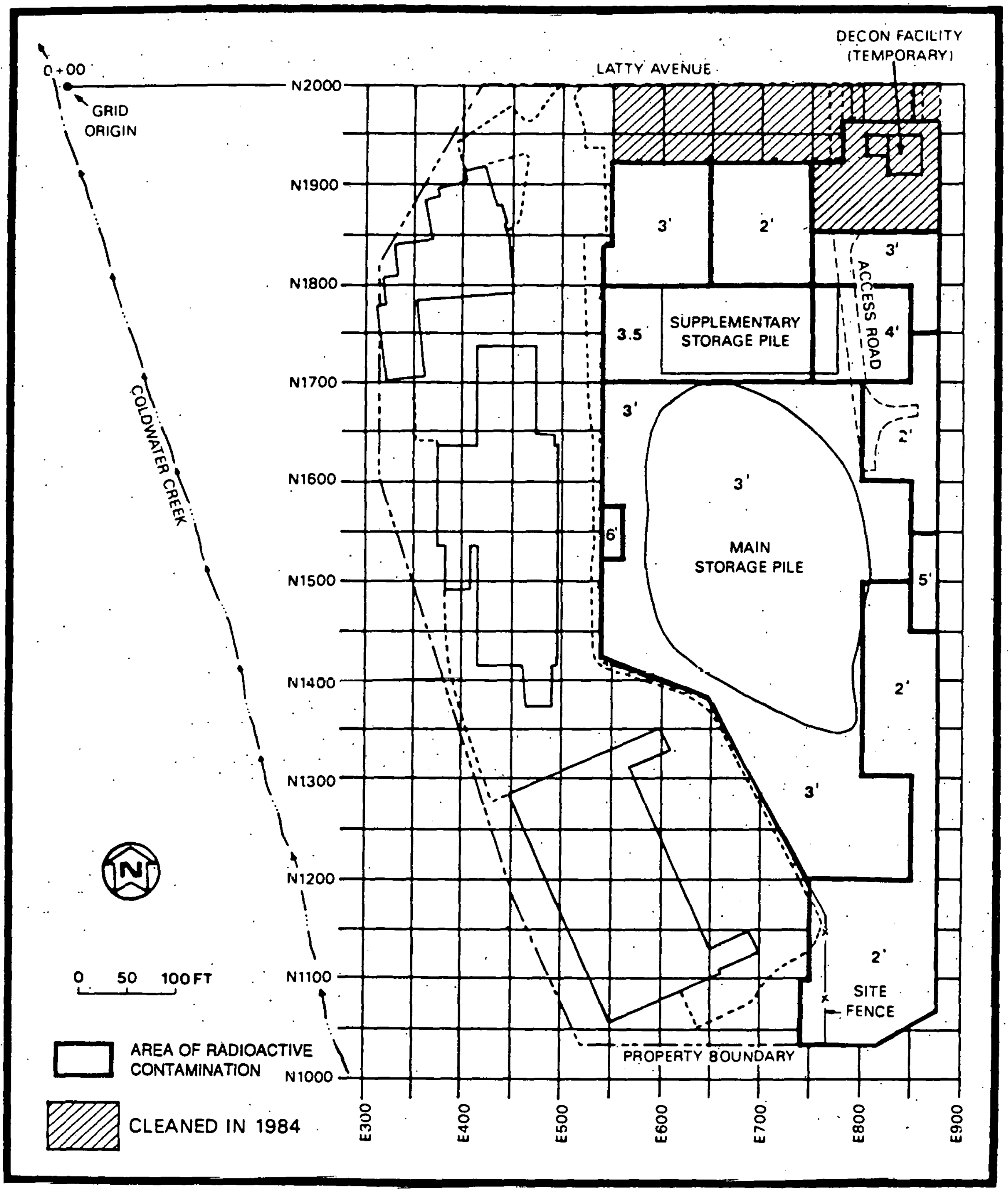

FIGURE 3-35 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT HISS

and the samples were submitted for full gas chromatography/mass spectroscopy (GC/MS) analysis to completely identify the peaks. Although the full analysis failed to identify the compounds, one peak was identified as a benzene compound. The chemical analyses may have detected the weathered remains of fuel that had spilled on the property. No TCL compounds were detected at concentrations exceeding the sample detection limit.

Three samples taken from within the area of radioactive and chemical waste and three samples composited over the depth of the boreholes were tested for RCRA-hazardous waste characteristics. Results for reactivity, ignitability, EP toxicity, and corrosivity do not exceed criteria. Analytical results for samples collected to date indicate that the material is not RCRA-hazardous.

Detailed chemical results are provided in BNI 1990b.

3.6.2 Groundwater at HISS

Radiological results

In general, analytical results for quarterly sampling of the monitoring wells indicate that the radionuclides in the groundwater are at background levels (3.0 to 4.0 pCi/L for total uranium, 0.6 to 1.1 pCi/L for radium-226, and 0.2 to 0.4 pCi/L for thorium-230). The total uranium concentration in a well in the northwestern corner of the property is an exception, with the highest annual average from 1985 to 1989 of 82 pCi/L. This concentration may be compared with the proposed 30 pCi/L uranium guideline for groundwater.

For more information regarding the results of the groundwater investigation, refer to BNI 1990e and BNI 1991.

Chemical results

In 1989, a one-time sampling effort to determine the presence of priority pollutants in groundwater was conducted as part of the environmental monitoring program. Bis(2-ethylhexyl)phthalate is the only organic compound found above detection limits. Because it was also detected in laboratory blanks at comparable levels, it is thought to be the result of laboratory contamination.

Metals analyses showed concentrations of barium, calcium, iron, magnesium, manganese, sodium, and zinc at levels approximating those found in background groundwater samples. Metals that exceed background in HISS groundwater include aluminum, boron, chromium, and selenium. After background soil samples from the area are analyzed and the baseline assessment is completed, metal contamination will be more easily assessed.

3.6.3 Surface Water and Sediments at HISS

Analytical results for the continuous monitoring program at HISS demonstrate that the levels of total uranium, radium-226, and thorium-230 in surface water (Figure 2-22) have remained near background levels since 1985. Total uranium concentrations range from less than 3 to 5 pCi/L (1984 measurements are an exception, with total uranium ranging from 67 to 116 pCi/L), radium-226 concentrations range from 0.1 to 0.4 pCi/L, and thorium-230 concentrations range from less than 0.1 to 2.9 pCi/L.

Analytical results for sediment sampling also show levels of these radionuclides at near-background levels in most cases. The only exception is samples taken from Coldwater Creek, downstream of HISS, at which uranium-238 concentrations range from 1.2 to 19.0 pCi/g, radium-226 concentrations range from 0.8 to 5.6 pCi/g, and thorium-230 concentrations range from 0.1 to 300 pCi/g.

Additional details are provided in BNI 1990e and BNI 1991.

3.6.4 Air at HISS

Annual average radon concentrations at HISS range from 2 to 22 x 10^{-10} mCi/ml (0.2 to 2.2 pCi/L), including background [5 x 10^{-10} mCi/ml (0.5 pCi/L)]. This average is below the DOE guideline of 3 pCi/L.

Radon concentrations measured in the HISS trailers are below the DOE guideline: 1.21 pCi/L in the BNI FUSRAP office trailer and 1.25 pCi/L in the public information office trailer.

External gamma radiation levels were measured with TLDs at HISS at the same locations where radon was measured. Results in 1984 ranged from 0 to 1,106 mR/yr. Since 1985, concentrations have ranged from 0 to 287 mR/yr.

For more information regarding the results of air monitoring at HISS, refer to BNI 1990e and BNI 1991.

3.6.5 Geology at HISS/Futura

The stratigraphy of HISS and Futura is similar to that observed at the SLAPS/ball field properties. A single geologic borehole (HISS-9A) was drilled to a depth of 18.3 m (60 ft) to facilitate characterization of the site stratigraphy. The stratigraphy is divided into:

- 0 to 6.7 m (0 to 22 ft) of loess (analogous to unit 2 at SLAPS)
- 6.7 to 14.6 m (22 to 48 ft) of lacustrine deposits (analogous to unit 3T)
- 14.6 to 18.3 m (48 to 60 ft) of lacustrine deposits (analogous to unit 3M)

The presence of glacial deposits underlying the lacustrine deposits and the depth to bedrock at the Latty Avenue properties has not been determined. Because of the proximity of HISS and Futura to SLAPS and the ball field area, the soil properties at each are thought to be similar.

The primary surface water feature in the HISS/Futura area is Coldwater Creek. The hydrologic features of the creek are discussed in the SLAPS/ball field hydrogeology section (Subsection 3.4.5). Surface water quality samples were collected from drainage ditches at HISS and Futura and from Coldwater Creek, 1.6 km (1 mi) downstream of the property, to determine concentrations of radioactive constituents. Concentrations of lead-210, radium-226, and thorium-230 in the samples range from less than 1 to 7, less than 1 to 2, and less than 1 to 2 pCi/L, respectively [all values are below the maximum permissible concentrations specified in 10 CFR Part 20].

Hydrogeologic investigations at the property have focused on the uppermost groundwater system. Figure 3-36 presents typical hydrographs for groundwater levels in wells monitoring this system. The hydrographs indicate that groundwater levels typically do not vary by more than 1.5 m (5 ft) over the course of a year.

Figure 3-37 is a potentiometric surface map of HISS and Futura for January 19, 1990. The map shows that the groundwater flow direction is radial, i.e. flow is away from the property in all directions. The mechanism creating this radial flow pattern is under investigation, but the center of the radial pattern appears to be associated with an area of poor surface drainage on the eastern edge of the HISS stockpile area. It may also be related to a leaking water line that crosses HISS between the two piles.

Groundwater flow patterns suggest that recharge to the upper groundwater system is occurring in the eastern central area of the property. Discharge from the uppermost groundwater system occurs as offsite outflow of groundwater, with a portion of this groundwater probably discharging into Coldwater Creek during low creek stage. Discharge may also be occurring as vertical flow to a lower groundwater system, but available information is insufficient to characterize this potential flow path.

Hydrogeologic parameters, measured to determine the groundwater flow characteristics of the uppermost groundwater system, are summarized in Table 3-14. Measurement methodologies and results are presented in BNI 1985c and 1990d. The average linear velocities fall within the same general range as those determined at the SLAPS/ball field properties for the upper groundwater system. Although no distribution ratio measurements have been taken on property soils, the proximity of HISS and Futura to the SLAPS/ball field properties and the similar appearance of the soils

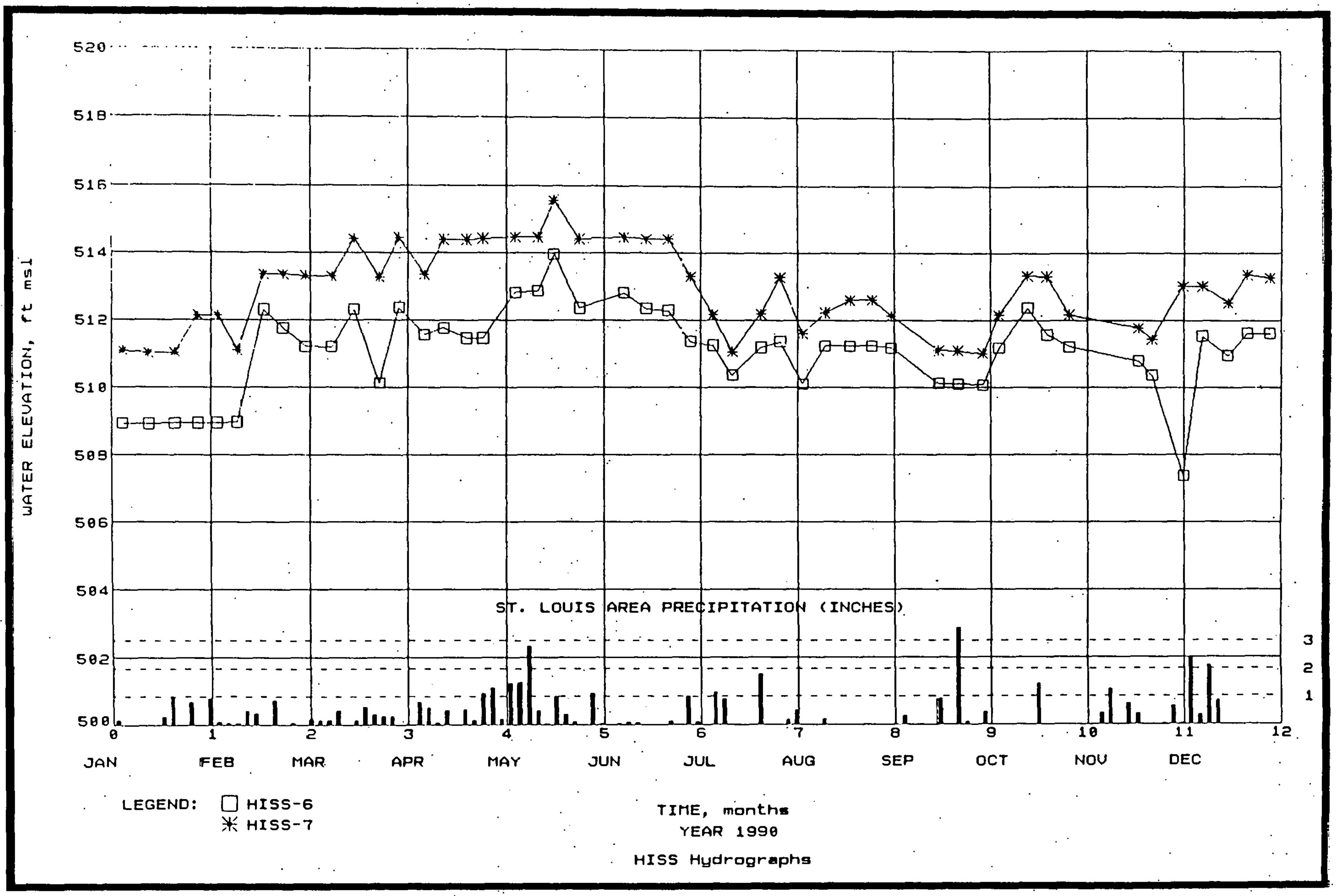

FIGURE 3-36 HYDROGRAPHS OF WELLS HISS-6 AND HISS-7

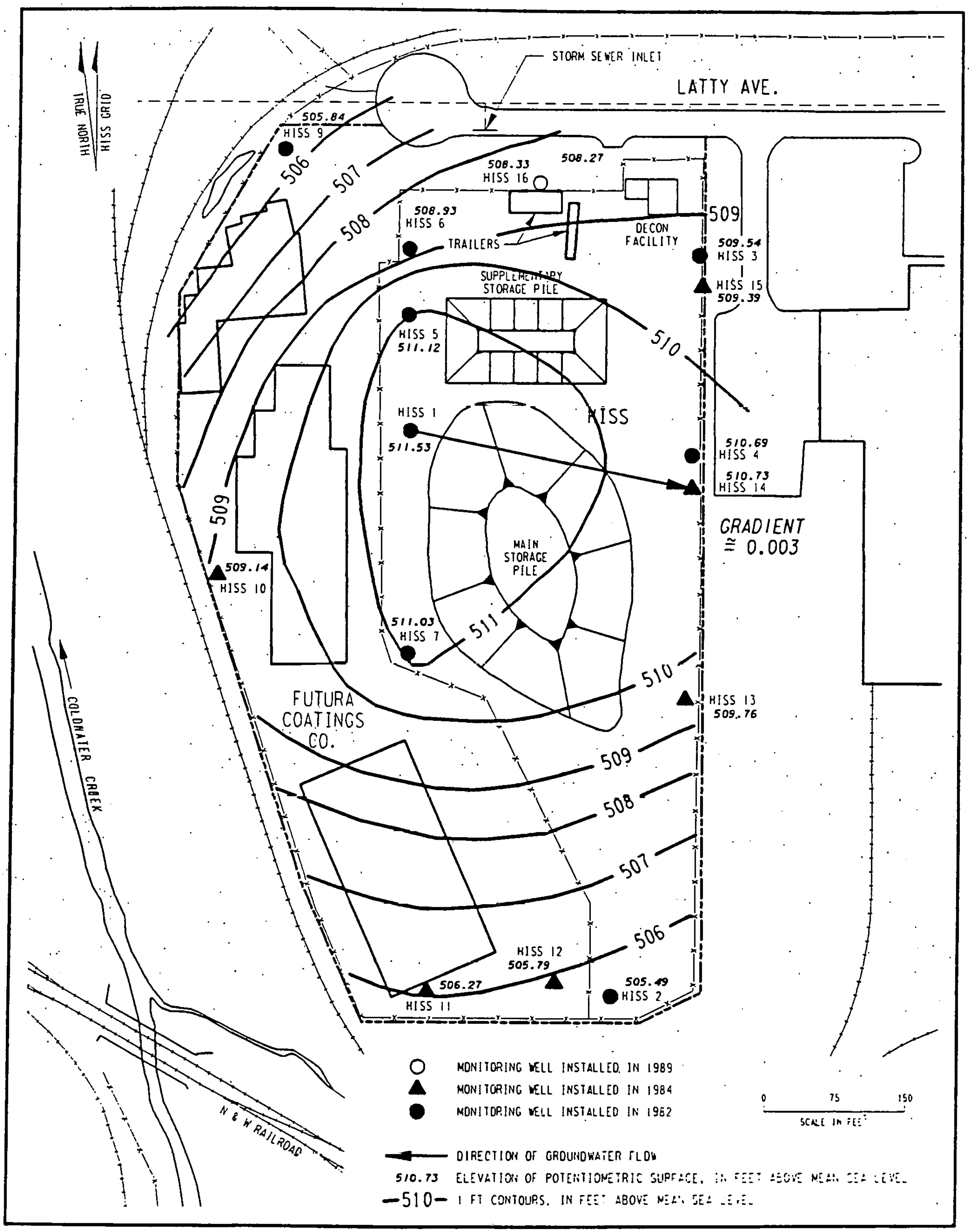

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FIGURE 3-37 POTENTIOMETRIC SURFACE MAP OF HISS AND FUTURA (1/19/90)

Table 3-14

Summary of Groundwater Flow Parameters for HISS and Futura

Aquifer Characteristics	Hydrogeologic and Geochemical Properties
Observed saturated thickness	3 to 6.7 m (10 to 22 ft)
Hydraulic conductivity	1.1×10^{-5} to 1.0×10^{-3} cm/s (0.03 to 2.9 ft/day)
Hydraulic gradient	0.007 to 0.013
Average linear groundwater velocity[a]	0.06 to 10 m/yr (0.02 to 34 ft/yr)

[a]Average linear groundwater velocity = Ki/n, where: n = porosity, which is assumed to be 0.4 (value for unit 2 at the SLAPS/ball field properties).

suggest that the distribution ratios are similar. Thus, uranium migration is significantly retarded relative to groundwater flow.

3.7 CHARACTERIZATION RESULTS FOR FUTURA

3.7.1 Surface and Subsurface Soils at Futura

Radiological results

Gamma radiation exposure rates range from approximately 8 to 27 mR/h (including background) with an average of approximately 12 mR/h. Near-surface gamma radiation measurements show radioactive surface contamination on the majority of the property.

Uranium-238, radium-226, thorium-232, and thorium-230 were found in soil at concentrations exceeding guidelines. Thorium-232 concentrations range from background levels to 26 pCi/g. Radium-226 was found in several samples, with concentrations as great as 2,300 pCi/g. Uranium-238 concentrations range from background levels to 2,500 pCi/g. Concentrations of thorium-230 range from less than 1.1 to 2,000 pCi/g in the selected samples analyzed for thorium-230; however, the maximum thorium-230 concentrations on the property may be greater than indicated because the samples analyzed for thorium-230 were primarily those with no associated gamma-emitting radionuclides present in above-guideline concentrations.

Analytical results for subsurface samples indicate no consistency in the depths of contamination based on systematic drilling. The depth of contamination ranges from the surface to approximately 4.6 m (15 ft). The variable depth of contamination can be attributed to the disturbance of soils caused by previous excavations and subsequent placement of fill material and to the natural variations in the topography of the property. The estimated volume of radioactively contaminated soil at Futura is approximately 25,996 m^3 (34,000 yd^3). Figure 3-38 shows the areas and depths of contamination.

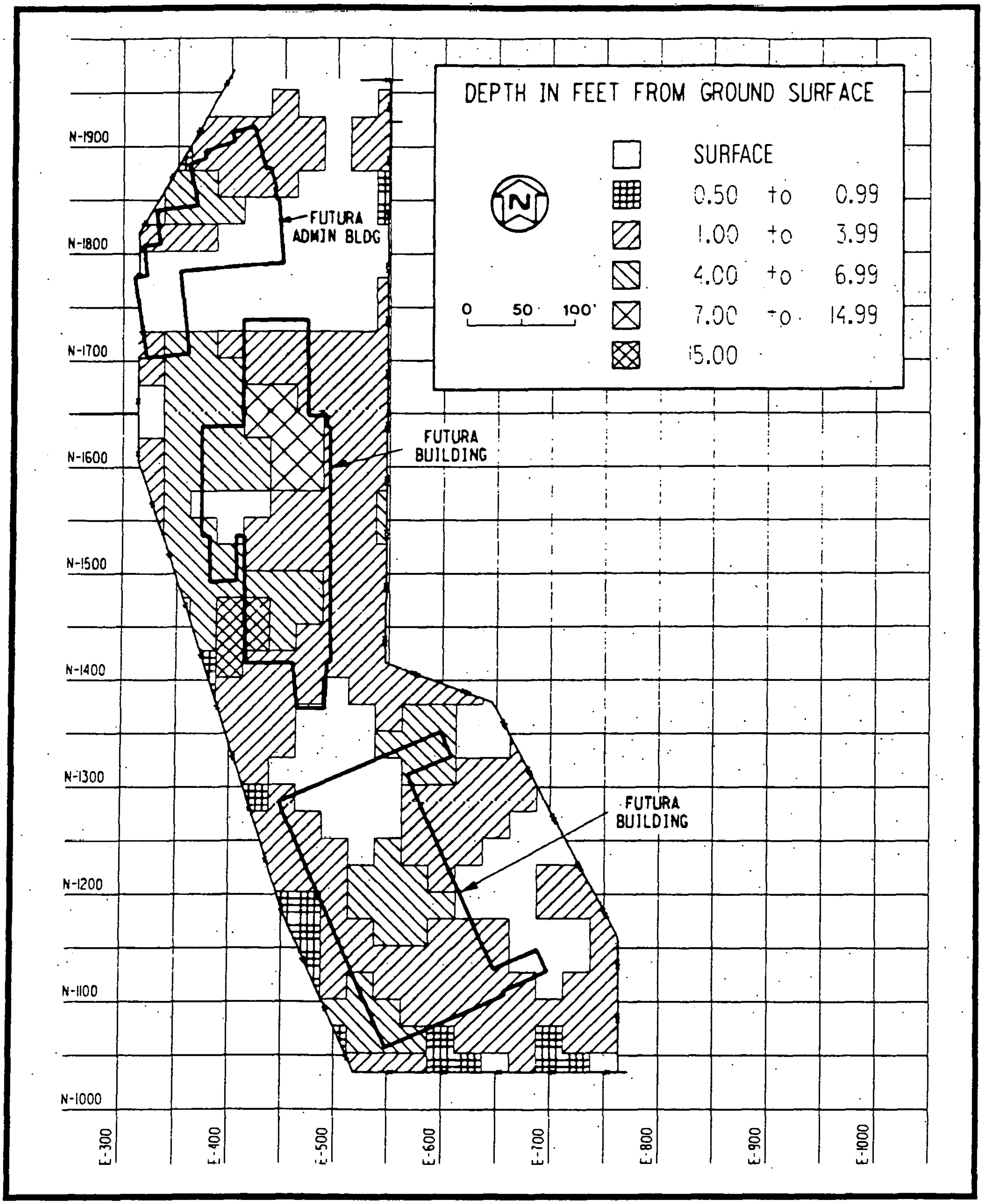


FIGURE 3-38 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT THE FUTURA COATINGS PROPERTY

Detailed radiological results for Futura are provided in BNI 1987c.

Chemical results

Based on the results of the chemical investigation, the radioactive waste does not appear to be RCRA-hazardous, and the chemicals appear to be primarily associated with the radioactive waste.

Analytical results for metals indicate that 14 metals are present at concentrations exceeding background levels (Appendix B). Antimony, arsenic, barium, boron, cadmium, cobalt, copper, lead, magnesium, molybdenum, nickel, selenium, thallium, and vanadium were found in measurable concentrations that range from background levels to approximately 17,000 ppm (except for one sample with a magnesium concentration of 43,000 ppm).

The metals that exceed background levels were found at depths greater than at HISS, consistent with the greater depth at which radioactive material was found at Futura. Elevated molybdenum and magnesium concentrations were found to a maximum depth of 4.7 m (14 ft). After background soil samples from the area are analyzed and the baseline risk assessment is completed, metal contamination will be more easily assessed.

Four of the 16 soil samples submitted for analyses exhibit low concentrations of volatile organics. Toluene was detected in each of the four samples at concentrations ranging from 1.5 to 15 ppb, and trichlorofluoromethane was detected in one sample at 1.3 ppb.

Initial GC analysis of the samples identified two peaks grossly defined as massive hydrocarbons and a large, late peak. Soil from one borehole (B2) was resampled in March 1988 and was submitted for GC/MS analysis to verify the previously identified peaks. The analysis identified a benzene compound at a concentration of 6,300 ppb and 2-propanol-1,3-dichlorophosphate at 250,000 ppb. No TCL compounds were detected at levels exceeding the sample detection limits.

Ten samples were submitted for RCRA-hazardous waste characteristics analysis, and none exceeds the criteria for reactivity, ignitability, corrosivity, or EP toxicity (now replaced with the TCLP). Therefore, results so far indicate that none of the material at Futura is RCRA-hazardous.

Additional details on chemical results are available in BNI 1990b.

3.7.2 Buildings at Futura

Thirty-eight biased locations on the interior surfaces of the Futura buildings were checked for nonremovable and removable alpha contamination. The maximum direct alpha contamination measured is 149 dpm/100 cm^2; the maximum removable alpha contamination is approximately 11 dpm/100 cm^2. The minimum concentrations of direct and removable alpha contamination are below the 31- to 38-dpm/100 cm^2 limit of sensitivity of the instrument used to measure this parameter. An extensive survey was not performed inside the buildings; measurements were obtained in suspect areas to determine whether further characterization would be required. Twenty-two exterior locations were checked for removable contamination, and these measurements range from less than 1 to approximately 9 dpm/100 cm^2. These values can be compared with the DOE guidelines for nonremovable and removable contamination of 300 and 20 dpm/100 cm^2, respectively. No contamination on the interior or exterior surfaces of the buildings was found in excess of maximum concentrations specified by DOE guidelines.

Calculated radiation doses inside the buildings measured with TLDs range from 2 to 22 mrem/yr in excess of background levels, assuming continuous exposure for one year. The DOE radiation protection standard for all sources of radiation is 100 mrem/yr in excess of background levels.

More detailed building results are provided in BNI 1987c.

3.7.3 Air at Futura

Results from four Track-Etch radon detectors and two TLDs installed inside the Futura buildings show radon concentrations ranging from 0.3 to 0.7 pCi/L, with an average of 0.6 pCi/L. The concentrations are comparable to typical radon levels found in outdoor areas where natural radium is present; results, therefore, indicate minimal intrusion of radon gas into the plant buildings.

Fifty air particulate filter samples were collected, and analytical results indicate airborne gross alpha concentrations ranging from less than 0.001 to 0.004 pCi/m^3. These values can be compared with the DOE guideline of 0.04 pCi/m^3 for a maximum thorium-230 concentration in air in uncontrolled areas (lung retention class W) (DOE Order 5400.5).

Based on the radon and gamma radiation levels measured during one quarter, the Futura buildings are in compliance with DOE guidelines for radon and with the DOE radiation protection standard (BNI 1987c).

3.8 CHARACTERIZATION RESULTS FOR THE LATTY AVENUE VICINITY PROPERTIES

Analytical results for surface and subsurface soil samples show that all six vicinity properties contain elevated concentrations of thorium-230. In addition, elevated levels of radium-226 were found at Properties 1, 2, and 4. All concentrations of thorium-232 are below DOE guidelines. Table 3-15 summarizes the analytical results for each property. The total estimated volume of radioactively contaminated soil for all six Latty Avenue vicinity properties is approximately 81,812 m^3 (107,000 yd^3). Figures 3-39 through 3-44 show the areas and depths of contamination at each property.

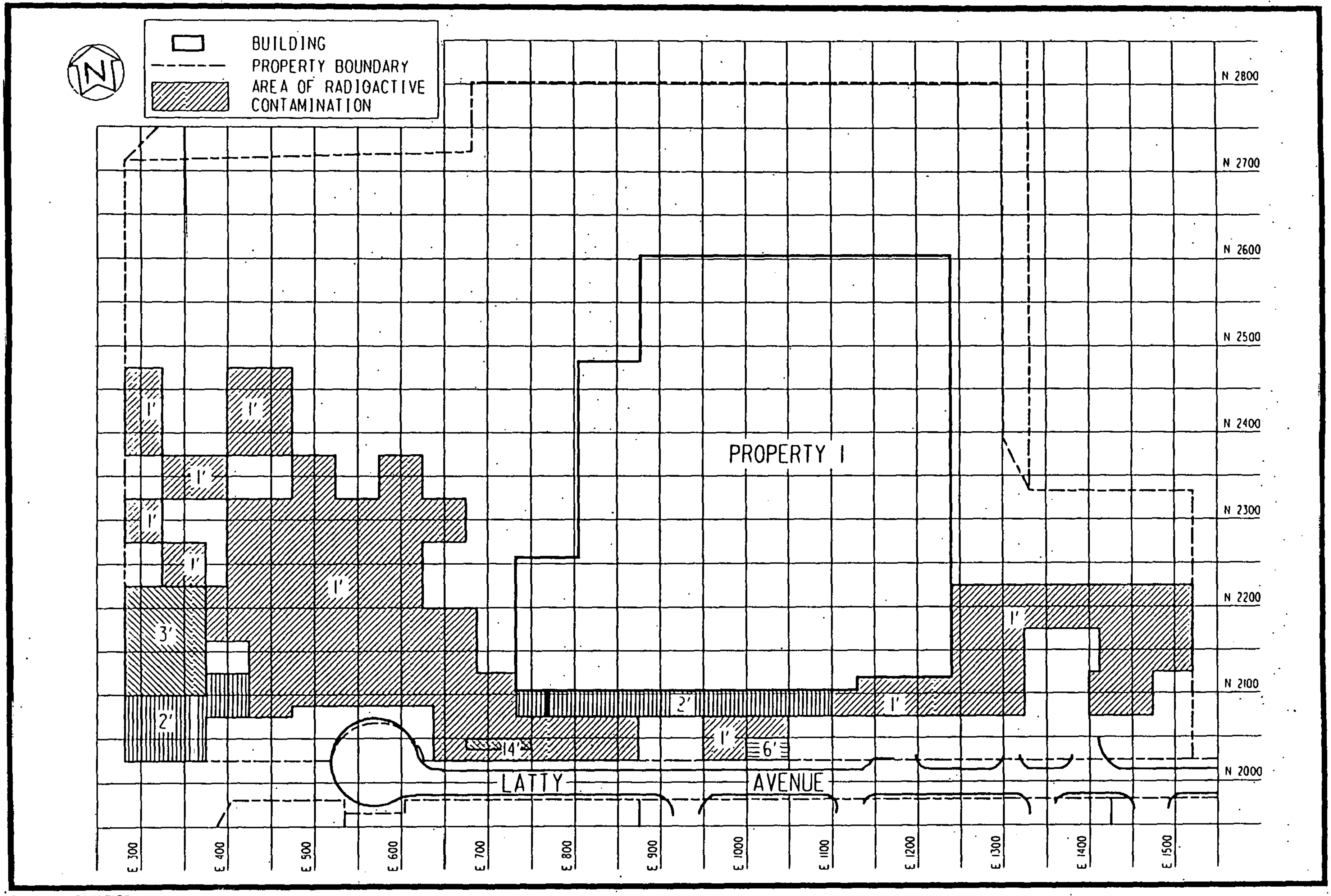
For more information regarding these results, refer to BNI 1990d.

Table 3-15

Summary of Radiological Survey Results For Latty Avenue Vicinity Properties

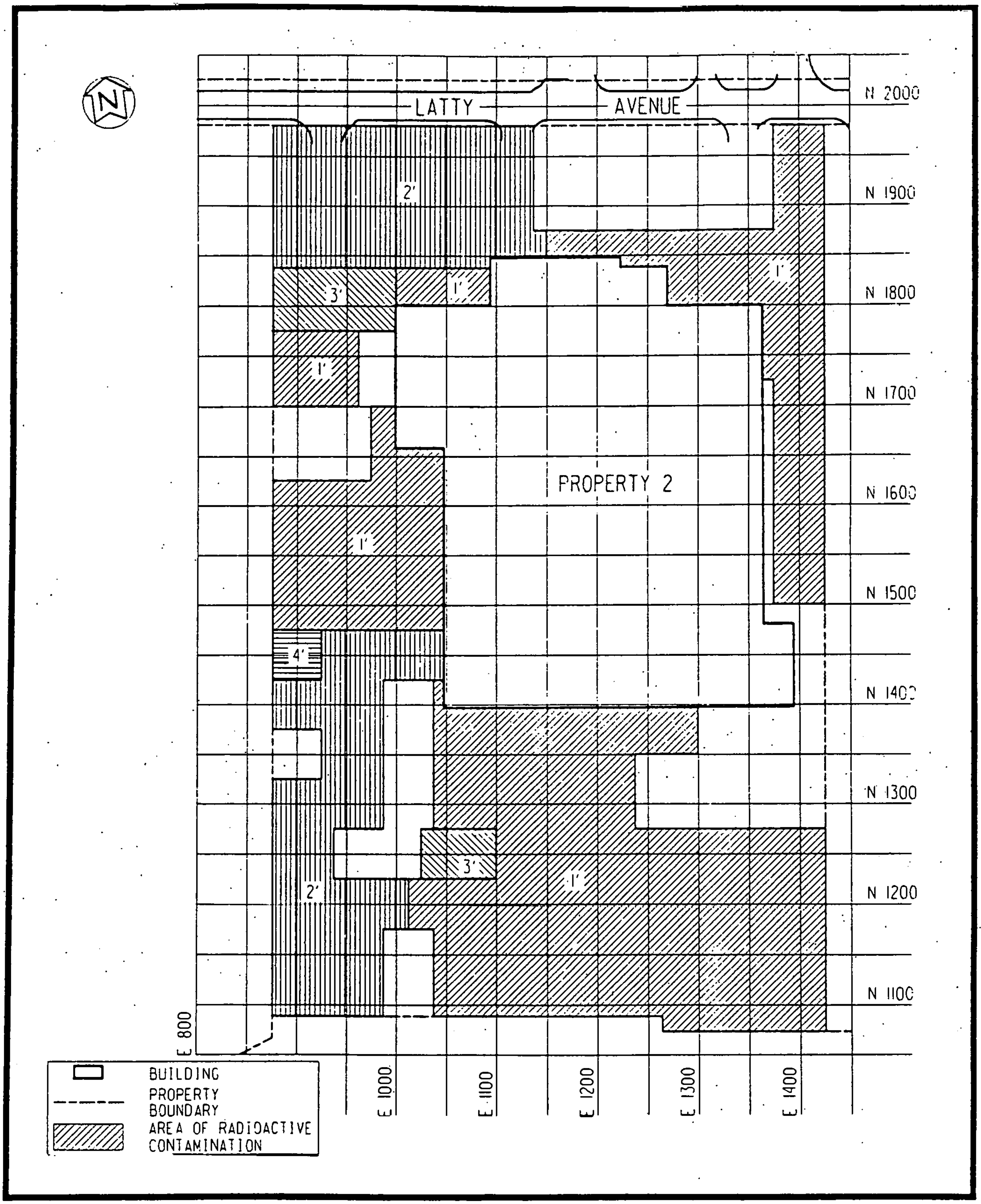
Property Parameter	Range (pCi/g)	Average (pCi/g)	No. of Samples Exceeding Guidelines/ Analyzed
Property 1			
U-238	<30[a]	9	65/228
Ra-226	0.5 - 11	1.8	
Th-232	0.7 - 5	1.8	
Th-230	0.7 - 810	34.9	
Property 2			
U-238	<3 - 100	9.3	117/323
Ra-226	0.6 - 89	2.5	
Th-232	0.7 - 5	1.9	
Th-230	0.4 - 5,700	99	
Property 3			
U-238	<39[a]	9.3	9/54
Ra-226	0.6 - 4	1.7	
Th-232	<1 - 5	2	
Th-230	0.2 - 31	3.6	
Property 4			
U-238	<20[a]	9	3/36
Ra-226	0.5 - 10	1.9	
Th-232	0.5 - 4	1.8	
Th-230	0.7 - 460	23.1	
Property 5			
U-238	<30[a]	10.7	2/32
Ra-226	0.7 - 4	1.7	
Th-232	0.8 - 7	2.3	
Th-230	0.6 - 12	2.5	
Property 6			
U-238	<14[a]	8.5	8/59
Ra-226	0.4 - 3	1.4	
Th-232	0.8 - 4	1.8	
Th-230	<1 - 21	3.5	

[a]All measured values are less than the value indicated.



S34WMS18.DGN FIG7

FIGURE 3-39 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 1 ON LATTY AVENUE



S34WMS16.DGN FIG7

FIGURE 3-40 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 2 ON LATTY AVENUE

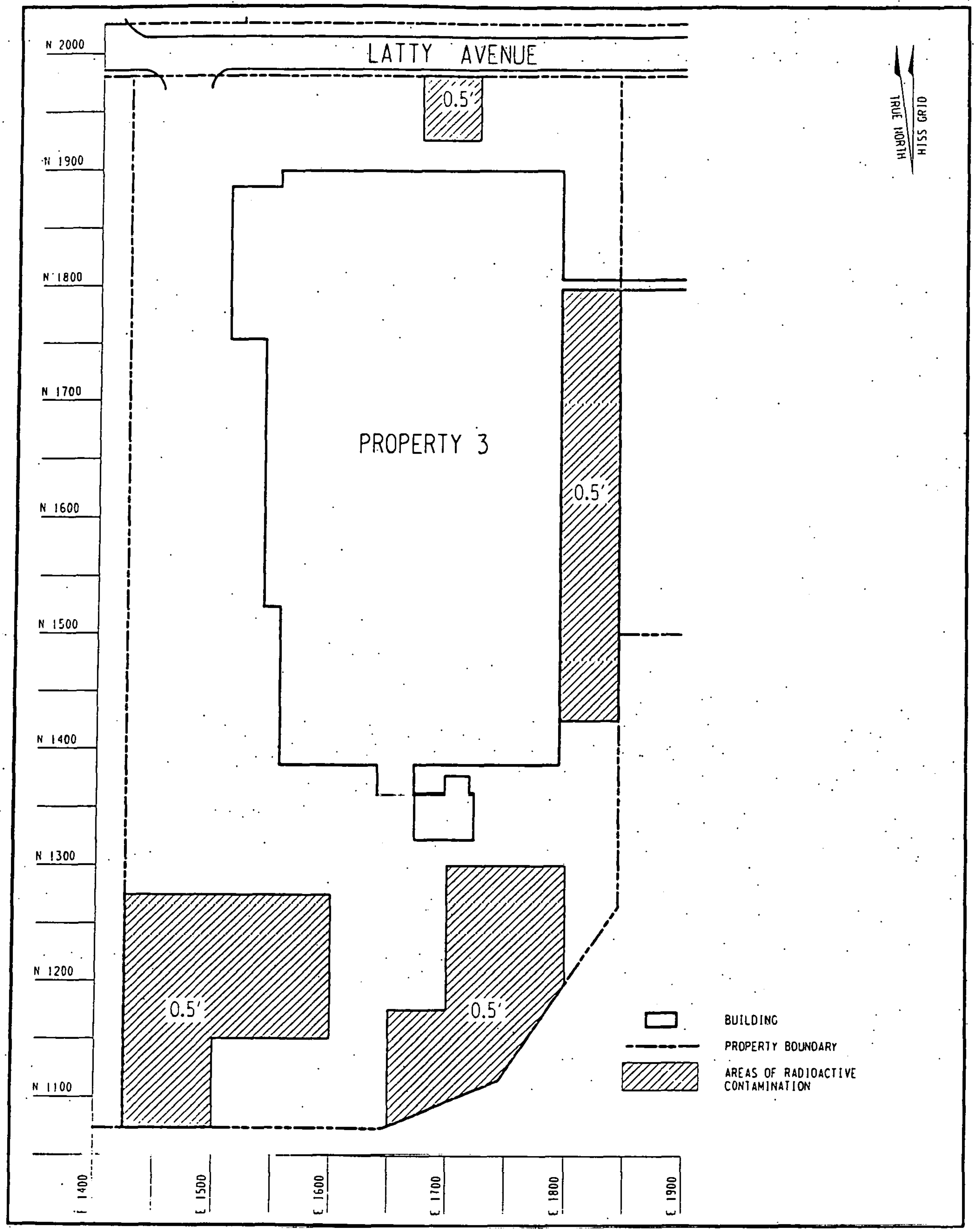


FIGURE 3-41 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 3 ON LATTY AVENUE

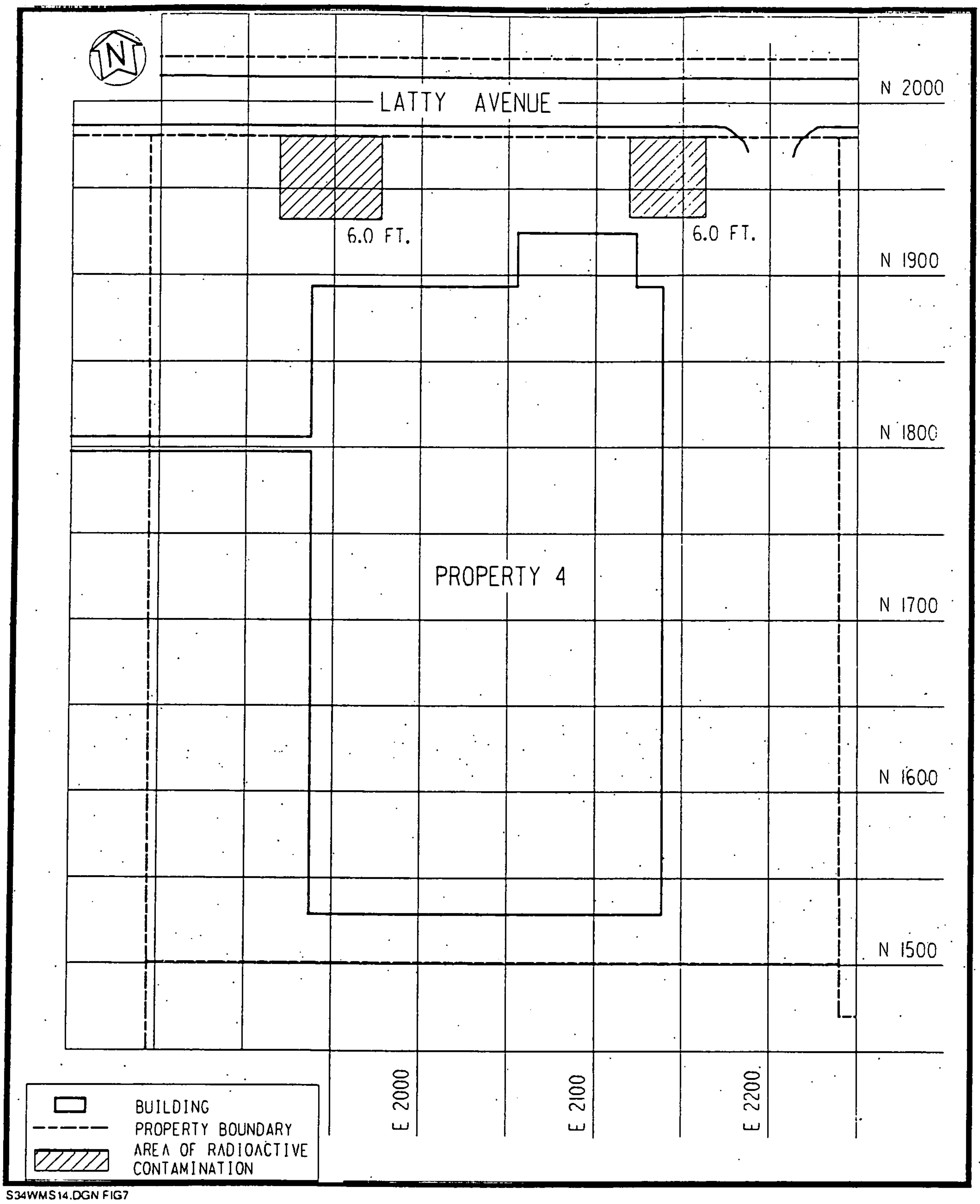
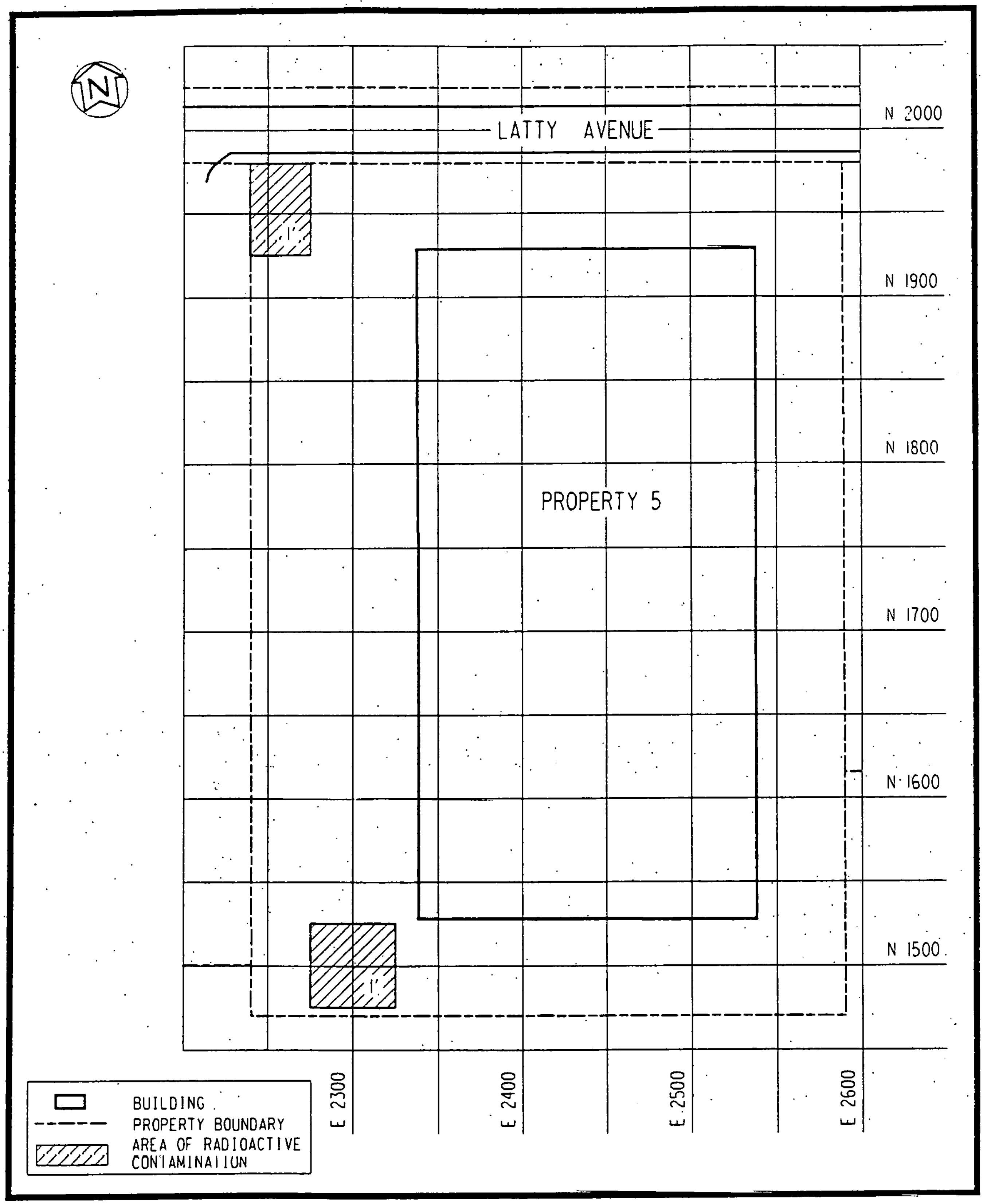


FIGURE 3-42 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 4 ON LATTY AVENUE



S34WMS13.DGN FIG7

FIGURE 3-43 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 5 ON LATTY AVENUE

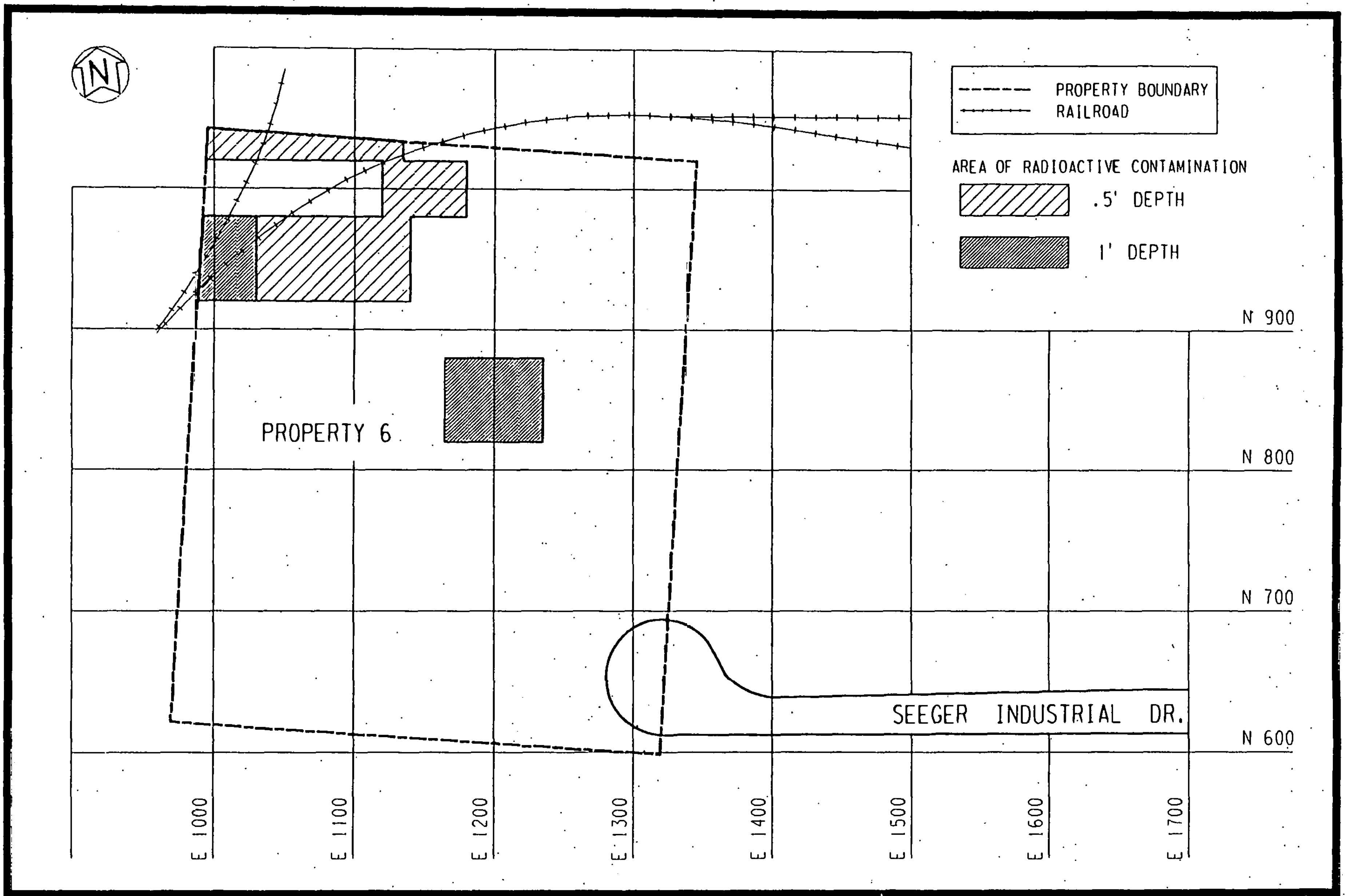


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FIGURE 3-44 AREAS AND DEPTHS OF RADIOACTIVE CONTAMINATION AT PROPERTY 6 ON SEEGER INDUSTRIAL DRIVE

3.9 CHARACTERIZATION RESULTS FOR TRANSPORTATION ROUTES BETWEEN HISS AND WEST LAKE LANDFILL AND BETWEEN SLDS AND SLAPS

Twenty-eight intersections between HISS and West Lake Landfill were sampled (Figure 2-24). A total of 231 surface soil samples were collected and analyzed for uranium-238, radium-226, thorium-232, and thorium-230; the concentrations of these radionuclides range from 1.1 to 10, 0.2 to 3.1, 0.3 to 2.2, and 0.4 to 9.0 pCi/g, respectively. Only 2 of the 231 samples exhibit thorium-230 concentrations exceeding the DOE cleanup guideline. These two sampling locations are on the western side of Intersection 28 and at Intersection 2.

Results of the survey along the suspected haul routes between SLDS and SLAPS showed no evidence of residual radioactivity related to past MED/AEC operations. Anomalies detected were attributed to road-base gravel enhanced with thorium-232, phosphate fertilizers, and emanations from SLAPS (ORNL 1991).

4.0 POTENTIAL CONTAMINANT TRANSPORT PATHWAYS

This section examines the possible transport pathways of contaminants at the St. Louis FUSRAP properties based on the nature and extent of contamination and the physical characteristics of the site. Possible transport pathways include soil, groundwater, surface water and sediments, and air. The pathways will be quantitatively evaluated in the baseline risk assessment to determine the potential for contaminant migration to occur along each route and to determine potential receptors.

4.1 SOIL

Contamination at all of the St. Louis properties is primarily located in soil, both surface and subsurface. This soil could be a potential contaminant transport pathway if contaminated soil particles were ingested or inhaled.

At SLDS there is approximately 215,000 m^3 (280,000 yd^3) of contaminated soil extending to 13 m (42 ft); the contaminants are radioactive and chemical in nature. Radionuclide concentrations in subsurface soil range from 1.3 to 33,000 pCi/g for uranium-238, 0.4 to 5,400 pCi/g for radium-226, 0.5 to 440 pCi/g for thorium-232, and 0.3 to 14,000 pCi/g for thorium-230. Chemicals of concern include metals (18 exceed background concentrations) and PAHs (18 were detected in soil samples).

At SLAPS radioactive contamination extends to a depth of 5.5 m (18 ft). The estimated volume of contaminated soil is 191,000 m^3 (250,000 yd^3). The major radioactive contaminants are radium-226 (less than 0.3 to 5,620 pCi/g), uranium-238 (less than 3.0 to 1,600 pCi/g), and thorium-230 (0.6 to 2,600 pCi/g). Fifteen metals exceeding background levels are present at SLAPS; most of these appear to be confined to near-surface depths. All VOCs detected were in the ppb range with the exception of toluene.

Contamination at HISS was detected to a depth of 1.8 m (6 ft), and at Futura to a depth greater than 4.6 m (15.3 ft). Concentrations range from background to 2,500 pCi/g for uranium-238, from background to 2,300 for radium-226, and from 4.1 to 2,000 for thorium-230. The volume of onsite contaminated soil is estimated to be 26,000 m^3 (38,400 yd^3). Results of metal analyses indicate that 14 metals are present at concentrations exceeding background. Only magnesium was found underneath the known boundary of radioactivity.

Thorium-230 is the major radioactive contaminant at the SLAPS and Latty Avenue vicinity properties. Some properties contain other radionuclides exceeding DOE guidelines (see Table 1-1). Nine metals exceed background levels at the ball field area; toluene was detected in 10 of 11 boreholes analyzed but only in the ppb range. Chemical analyses of soil from Coldwater Creek revealed only four metals exceeding background levels. Results of BNAE analyses showed eight semivolatiles that are on the TCL, all of which are PAHs. The presence of these organic compounds results from runoff from SLAPS.

In general, radionuclides are the primary contaminants at the St. Louis site: thorium-230 at vicinity properties and uranium-238, radium-226, and thorium-230 at SLDS, SLAPS, HISS, and Futura. Metals that exceed background levels, except for magnesium, are found in known areas of radioactive contamination.

4.2 GROUNDWATER

Elevated levels of uranium [concentrations greater than those occurring naturally in groundwater (3 to 4 pCi/L)] were detected in groundwater at the St. Louis site. At SLDS, groundwater characterization data indicate one well with radionuclides exceeding the proposed Uranium Mill Tailings Radiation Control Act (40 CFR 192) guideline of 30 pCi/L. Well B16W02S exhibits a maximum total uranium concentration of 193 x 10^{-9} mCi/ml (193 pCi/L).

Ten organic compounds were detected in the wells sampled at SLDS. Benzene was found most frequently (in 6 of 24 samples) at concentrations ranging from less than 5 to 21 mg/L. Most of the organic compounds (seven of ten detected) appear consistently in

Well B16W03S. Sixteen metals were also detected; those associated with uranium ores (arsenic, barium, nickel, and selenium) generally exhibit concentrations of 100 to 700 mg/L.

At SLAPS, analytical results for samples taken from several wells from 1984 through 1990 indicate that uranium concentrations are considerably higher than those occurring naturally in groundwater. These results also exceed the proposed guideline of 30 pCi/L for uranium in groundwater. The concentrations are probably elevated because the shallow wells are located in an area of known subsurface contamination. All measured values have remained relatively consistent each year in each well.

In groundwater, ion exchange serves to potentially reduce migration of contamination, especially in clayey soils where there are abundant exchangeable cations such as calcium, magnesium, sodium, and potassium. For example, uranium would replace naturally occurring calcium associated with clay. This ionic exchange would therefore bind the uranium to the clay and reduce the ability of the contamination to migrate.

In 1989, five organic compounds were detected at concentrations of 0.06 to 430 mg/L: Endosulfin I; 1,2-dichloroethene; trichloroethene; toluene; and bis(2-ethylhexyl)phthalate.

Many metals that were found in soil samples at SLAPS were also found in groundwater, indicating the possibility that the metals in the uranium ore had leached into the groundwater. In general, results indicate groundwater of poor quality.

At the Latty Avenue Properties, as at SLAPS, several wells exhibit uranium concentrations greater than those occurring naturally in groundwater; however, most measured values have been relatively consistent in each well. An exception is the total uranium concentration in Well HISS-6, which rose steadily from 1986 until 1990, when the concentration dropped but still exceeded the proposed uranium guideline for groundwater.

In general, indicator parameters show groundwater of poor quality (i.e., a high concentration of dissolved solids of a noninjurious nature) at the St. Louis site. Metals detected most frequently in soil were also found in excess (although only slightly in some cases) of background values in groundwater. Contaminated water that moved eastward from SLDS to the Mississippi River would have been greatly diluted. Also, because of the many clay layers in the soil, contaminated groundwater would not likely reach the bedrock aquifer; however, this must be confirmed by monitoring results from wells in this aquifer. Because groundwater is not used as a potable water source in the St. Louis area, the potential for human exposure via this pathway is minimal. Even through limited industrial use of groundwater, human contact is not substantial and therefore would not be considered a significant risk.

The annual environmental monitoring program at the St. Louis site includes sampling for radioactive contaminants in groundwater at HISS and SLAPS. This sampling will continue until final remedial action is completed.

4.3 SURFACE WATER AND SEDIMENTS

The transport of contaminants associated with past operations at the St. Louis site by way of surface water or sediments appears to be the most likely migration route; monitoring results indicate migration of contaminants in some areas.

At SLDS, 84 manholes were surveyed and sampled for residual radioactivity. Results indicate that concentrations of uranium-238, radium-226, thorium-230, and thorium-232 exceed DOE remedial action guidelines. Because there are no DOE guidelines for sediments, these concentrations were compared with the standard DOE guidelines for surface soil.

The environmental monitoring program at SLAPS and HISS includes collection of sediment and surface water samples from Coldwater Creek upstream and downstream of SLAPS. Analytical results indicate that measured values in sediment at these locations have been consistent since environmental monitoring began in 1984 and are within the range of background soil concentrations. An exception is Coldwater Creek adjacent to HISS and SLAPS; however, radionuclide concentrations decrease greatly downstream.

Contamination could spread from the areas along the creek bank containing elevated radioactivity if sediment were disturbed or transported by high flow of the creek. Installation of a gabion wall stabilized the eastern bank of the creek at SLAPS and greatly reduced erosion from the property.

Concentrations of uranium in surface water in the vicinity of HISS have declined substantially to 5 pCi/L or less at all sampling locations since 1984 because of remedial action at the property, consisting primarily of covering the storage pile with a synthetic, low-permeability membrane. Concentrations of radium-226 and thorium-230 are low and have remained relatively stable since environmental monitoring began in 1984.

The transport of contaminants is limited because there are no current activities that would cause the contaminants to become disturbed and most areas with surface contamination are either paved, covered with gravel, or vegetated. The rate at which contaminants might migrate into surface water and/or sediments could increase if any of the surface areas of contamination are disturbed before remedial action begins.

4.4 AIR

There appears to be little potential for the release of contaminants associated with past St. Louis site operations into the atmospheric pathway in the area. This conclusion is based on three facts: there are currently no operations in the area that would cause contaminants to become airborne; most areas of outdoor surface contamination are either vegetated, paved, or covered with gravel; and monitored radon levels indicate that the radon associated with the site is typically low-level. However, the potential for contaminants to become airborne could increase if any of the contaminated surface areas are disturbed before remediation begins. Onsite surveillance and maintenance programs mitigate this possibility by ensuring that contaminated areas onsite are not disturbed.

4.5 SUMMARY

Contaminants at the St. Louis site are generally stable, and little change is expected in the rates of contaminant migration by the routes of soil, groundwater, surface water and sediments, or air. Contaminants may be physically diluted or chemically bound to naturally occurring ions in the soil (such as clay) as they are transported along the various pathways.

A more detailed analysis of contaminant transport and fate is provided in the baseline risk assessment.

5.0 SUMMARY AND CONCLUSIONS

The purpose of this section is to summarize the conclusions drawn from analysis of the radiological, chemical, and geological and hydrogeological data collected during RI field activities. This section also identifies the remedial action objectives.

5.1 NATURE AND EXTENT OF CONTAMINATION

5.1.1 Surface and Subsurface Soils

Based on results of the RI surveys conducted at the St. Louis site, essentially all of the grounds at SLDS, SLAPS, and the Latty Avenue Properties are contaminated in excess of DOE guidelines for residual radioactivity. The primary radioactive contaminants at SLDS are thorium-230 and uranium-238. Radium-226 and thorium-232 are not considered primary contaminants but exceed DOE guidelines at a few locations. Radioactive contamination was found as deep as 12.8 m (42 ft). At SLAPS and the Latty Avenue Properties, elevated concentrations of uranium-238, radium-226, thorium-232, and thorium-230 were detected. Radioactive contamination was found at depths of up to 5.5 m (18 ft), 2 m (6 ft), and 4.6 m (15 ft) at SLAPS, HISS, and Futura, respectively.

All 102 vicinity properties that were characterized were surveyed for radioactive contamination. Thorium-230 was identified as the primary contaminant. In general, contamination is confined to the edges of the properties adjacent to the haul roads and is shallow [to a maximum depth of 0.6 m (2 ft)].

Analytical results for chemical sampling reveal that metals (i.e., antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, molybdenum, selenium, silver, sodium, thallium, and zinc) exceed background concentrations at SLDS, generally at depths of less than 2 m (6 ft). There are a few small isolated areas at SLDS where soil fails the hazardous waste criterion for EP toxicity in lead. Thirteen VOCs were also detected; toluene was detected most frequently (in 20 of 23 boreholes), followed by chloroform and trichlorofluoromethane. In general, concentrations are low, with mean concentrations in the low ppb. Twenty-seven BNAE compounds were detected, 18 of which were PAHs; pyrene was found most frequently, followed by fluoranthene, phenanthrene, and benzo(a)anthracene.

Chemical characterization of soil at SLAPS indicates low concentrations of VOCs and no RCRA-hazardous waste characteristics (from EP toxicity testing). Sixteen metals are present in soil at concentrations exceeding background levels. Most of the metals appear to be confined to near-surface depths; only magnesium, cadmium, and cobalt were detected beneath the areas of radioactive contamination.

Chemical characterization at the Latty Avenue Properties also revealed concentrations of metals exceeding background levels. Analyses for VOCs and BNAEs of samples taken from HISS and Futura identified only two VOCs (toluene and trichlorofluoromethane) and no BNAEs that are on the TCL. No samples at the Latty Avenue Properties exhibit any RCRA-hazardous waste characteristics (from EP toxicity testing).

In general, certain metals may be the only contaminants whose presence at concentrations exceeding background levels could be due to AEC/MED activities. The presence of other constituents (such as VOCs) at levels exceeding background could easily be due to industrial activities in the area. Completion of the baseline risk assessment and analysis of background samples will indicate whether metals are in fact contaminants.

5.1.2 Groundwater

Quarterly groundwater monitoring was conducted at SLDS during one year for pH, specific conductance, TOX, and TOC. Samples were collected and analyzed for VOCs, BNAEs, metals, fluoride, and nitrate during characterization. Ten organic compounds were found, the most frequent of which was benzene. Indicator parameters show groundwater of poor quality. Sixteen metals were detected; those associated with uranium ores (arsenic, barium, nickel, and selenium) are present at concentrations of 100 to 700 mg/L. The majority of the metals detected most frequently in soil were not found in excess of background values in groundwater.

At SLDS, concentrations of total uranium, radium-226, and thorium-230 range from less than 3 x 10^{-9} to 1.62 x 10^{-7}, 5 x 10^{-10} to 2.3 x 10^{-9}, and 1 x 10^{-10} to 1.9 x 10^{-9} mCi/ml, respectively. Only Well B16W02S exhibits uranium levels greater than the proposed guideline (30 pCi/L) for concentrations of uranium in groundwater.

Groundwater at SLAPS was analyzed for pH, specific conductance, TOX, TOC, and metals; results show that groundwater is of poor quality. The same metals detected in soil samples from the property were also found in groundwater.

At SLAPS, eight wells exhibit uranium concentrations greater than 30 pCi/L; all but Well M13.5-8.5D have at one time contained uranium at concentrations exceeding background values (less than 3 to 4 pCi/L). Radium-226 and thorium-230 are typically within the background range (except in Wells SLAPS A and M11-21).

Groundwater at the Latty Avenue Properties was analyzed for pH, specific conductance, TOX, TOC, and metals. Analytical results are similar to those found at SLAPS, i.e., groundwater is of poor quality and the metals found in groundwater are the same as those found in soil at the Latty Avenue Properties.

At HISS, only Well 6 contains total uranium concentrations greater than the 30-pCi/L guideline. Five other wells exhibit concentrations that slightly exceed the background levels for total uranium. Radium-226 and thorium-230 are typically within the background range (except in Well HISS-6).

5.1.3 Surface Water and Sediments

Sludge from manholes at SLDS was surveyed for residual radioactivity. Analytical results indicate that concentrations of uranium-238, radium-226, thorium-232, and thorium-230 exceed DOE remedial action guidelines in 35 of the 84 manholes.

Analytical results for environmental monitoring at SLAPS indicate that measured concentrations of total uranium, radium-226, and thorium-230 in surface water have remained low (less than 5 pCi/L) and relatively constant since monitoring began in 1984.

At the Latty Avenue Properties, results for environmental monitoring indicate that concentrations of uranium, radium-226, and thorium-230 in surface water have been stable since 1985. Average annual concentrations of total uranium have been less than 5 pCi/L since 1985; radium-226 and thorium-230 concentrations have been less than 0.4 pCi/L since 1984.

Analytical results for sediment samples collected from the sides and center of Coldwater Creek beginning at SLAPS and continuing downstream to HISS reveal radioactive contamination at numerous locations, typically in the top 15 cm (6 in.) of sediment. Additional sampling of sediment downstream in Coldwater Creek revealed elevated concentrations of thorium-230 extending approximately 9.6 km (6 mi) north of Pershall Road; however, the contamination is spotty and appears to be located in bends of the creek where natural settling would occur.

5.1.4 Air

Analytical results for environmental monitoring at the St. Louis site indicate that radon levels have remained low and relatively constant since 1984. Radon levels at only one location at SLAPS have been greater than 3 pCi/L (the DOE guideline for radon) during the past six years. Radon concentrations at three SLDS buildings (K1E, 101, and 25) exceed guidelines. Overall, radon concentrations at HISS have remained stable, with the average annual level of radon-222 being less than 2 pCi/L since 1985.

During drilling operations at SLDS, volatile vapors were detected at several borehole openings. In several instances, slightly elevated readings were recorded in the atmosphere and breathing zone. The boreholes that exhibit these elevated readings are C-149, R-108, C-119, R-107, C-127, R-116, C-115, C-114 in Building 51A; C-105 in Building K1E; C-103 and C-139 in

Building 706; C-128; and B16W09. Personal protective equipment was used until effective engineering controls were able to reduce ambient vapor levels in the breathing zone to acceptable ranges. No toxic vapors were detected in the atmosphere or breathing zone during drilling operations at SLAPS, the Latty Avenue Properties, and the ball field area.

External gamma radiation levels were measured at nine locations at the SLAPS property boundary. The levels have not changed notably since monitoring began in 1984. Direct exposure measurements at SLAPS do not appreciably exceed background levels, with the exception of one location that has averaged approximately 1,845 mR/yr since 1984.

Analytical results for environmental monitoring at HISS indicate that external gamma radiation levels have decreased sharply since 1984 at most monitoring locations as a result of remedial action at the property and subsequent storage of contaminated waste in storage piles. Since 1987, average annual external gamma radiation levels have remained less than 85 mR/yr with the exception of the levels at one sampling location.

An environmental monitoring program has not been conducted at SLDS because SLDS is not a DOE-operated facility.

5.1.5 Geology and Hydrogeology

Data from the subsurface investigation at SLDS indicate a basal bedrock unit with two distinct overlying unconsolidated units. A layer of rubble and fill material of variable thickness covers the surface. Groundwater flow direction is consistently eastward toward the Mississippi River. The bedrock unit, consisting of limestone, is shallow [5.8 m (19 ft)] under the western portion of the site, increasing in depth to 24.4 m (80 ft) as it approaches the Mississippi River. Hydraulic conductivity values measured in the bedrock range from 159 to 342 m/yr (530 to 1,140 ft/yr). The unconsolidated material above the bedrock consists of a unit of primarily fine materials (clays, silts, and sands) and a lower hydrostratigraphic unit of coarser materials (silty sands and sands) that is only present beneath the eastern portion of the property. An alluvial aquifer exists under semiconfined conditions and is laterally continuous across the property. Hydraulic conductivity values measured in the upper unit of the unconsolidated materials range from 3 to 357 m/yr (10 to 1,190 ft/yr).

The basal limestone unit at SLAPS is encountered at 70 to 90 ft, with hydraulic conductivity averaging 1×10^{-6} cm/s. The siltstone unit overlying the basal limestone unit is encountered at a shallow depth [15.2 m (50 ft)] beneath only the southeastern portion of the property. The unconsolidated material overlying the siltstone unit, consisting primarily of clays and silty clays, is continuous over the entire property. Hydraulic conductivity values measured in the overburden material range from 0.006 to 77 m/yr (0.02 to 231 ft/yr).

The unconsolidated materials at HISS consist of up to 19.7 m (6 ft) of fill material overlying loess (clayey silt, silty clay) that extends to a depth of 65.6 to 82 m (20 to 25 ft). Beneath the loess is an undetermined thickness of lacustrine deposits, a clayey silt. The hydraulic conductivity values measured in the lacustrine materials range from 3.7 to 347.5 m/yr (11.2 to 1,060 ft/yr).

5.2 DATA LIMITATIONS AND FUTURE WORK

During the RI, the extent and depth of contaminants in soil at the St. Louis site were examined. However, some limited additional sampling of some sumps, drains, soils, and buildings will be necessary to support remedial action. Additional radiological surveys in these areas at SLDS will be most effectively conducted just before remedial action begins and are logical continuations of previous work. In other instances, additional data will be collected if necessary to support property development and site maintenance by utilizing previous plans. Continued investigation of groundwater, surface water and sediments, and air will be conducted, and data will be reported as part of the ongoing environmental monitoring program for the St. Louis site.

5.3 OBJECTIVES FOR REMEDIAL ACTION ALTERNATIVES

The overall remedial action objective is to remove, stabilize, or otherwise control existing radioactive and chemical contamination at the St. Louis site and to ensure overall protection of human health and the environment.

Each proposed remedial action alternative will be analyzed and compared with other alternatives in the feasibility study based on the following criteria:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements
- Long-term effectiveness and permanence
- Short-term effectiveness
- Reduction of toxicity, mobility, and volume
- Implementability
- Cost
- State acceptance
- Community acceptance

The final remedial action plan will be developed based on the results of the feasibility study and the baseline risk assessment.

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APPENDIX A
QUALITY ASSURANCE PROGRAM

APPENDIX A

QUALITY ASSURANCE PROGRAM

The quality assurance (QA) program, implemented during all of the sampling activities at the St. Louis site, had the following objectives:

- To ensure that all samples were collected in an acceptable manner and in accordance with the applicable guidance document
- To ensure that all samples were analyzed in the appropriate manner
- To ensure that the chain-of-custody (COC) of samples was maintained by tracking the samples from collection to reporting of the results
- To ensure that all data were evaluated correctly

In general, compliance with these QA objectives was monitored by using quality control (QC) samples to help determine data quality in terms of precision and accuracy. QC samples were used to verify that sampling procedures (such as COC, decontamination, packaging, and shipping) did not introduce variables into the sampling chain that could render the validity of the samples questionable.

GENERAL QA PROCEDURES

The following subsection is an overview of the FUSRAP QA procedures and methodology. The site-specific QA program conducted at the St. Louis site is discussed in detail later in this appendix.

QC samples are regularly prepared in the field and laboratory so that all phases of the sampling process are monitored. Eleven types of QC samples were used during characterization of the St. Louis site:

- A **trip blank** (also known as travel blank or transport blank) is a laboratory-grade deionized (DI) water sample (acidified to a pH of less than 2 with 1:1 hydrochloric acid) added at the laboratory, shipped to the site (where it remains unopened), and shipped back to the laboratory. These samples are handled and processed in the same manner as other field samples. They are identified clearly on sample tags and chain-of-custody records as trip blanks. The frequency for trip blanks is one per day when aqueous volatile organic samples are collected.

  Trip blanks can provide an indication of interferences introduced in the field, during shipment, or in the laboratory. They do not, however, provide information on matrix effects, accuracy, or precision.

- A **field blank** is a sample of DI water that proceeds through the sample collection and analytical steps (e.g., automatic samplers and bailers) and some sampling equipment, after the sample collection equipment has been decontaminated. The field blank is handled and treated in the same manner as the other field samples.

  A field blank for analytes that require field filtering is run through the same filtering apparatus as the sample. Field blanks are analyzed for the same radiological parameters, volatile organics, semivolatile organics, PCBs, and metals that the field samples are analyzed for.

- A **field duplicate** ensures the reproducibility of the analytical results and representativeness of the samples collected. Field duplicates should not be confused with replicates; field duplicates require re-collection of the sample using the same procedures as for collection of the first sample.

For groundwater samples, it is not necessary to purge the well a second time; the duplicate is collected immediately after the first sample.

- A **method blank** (or reagent blank) measures the interferences that may be introduced during laboratory analysis. A method blank is laboratory-grade DI water or reagents used in the method that are carried through all steps of an analytical process. Method blank(s) are analyzed randomly during analysis of a sample batch sequence. Method blanks are analyzed for the same chemical parameters that the field samples are analyzed for.

  For soil analyses, a sample may be used as a method blank if previous analyses have established that the soil is not contaminated. Method blanks are also used to establish method detection limits.

- A **laboratory duplicate** (a separate aliquot of a sample received for analysis) indicates the precision of an analytical procedure. Analysis of duplicate samples does not indicate matrix interferences or analytical accuracy. Duplicates are analyzed for the same parameters that the field samples are analyzed for (except TOC and TOX).

- A **method spike** (also known as fortified method blank or blank spike) is a method blank to which a known concentration of analyte(s) is added. Analysis of a blank spike provides a measure of analytical precision and accuracy (e.g., percent analyte recovery) and is used to establish analytical accuracy.

- A **matrix spike** (or fortified field sample) is a field sample to which a known concentration of the analyte(s) of interest is added. Typically, an analyte is added to a sample at approximately 10 times the background concentration or at 2 to 5 times the detection limit of the analyte. Analysis of this sample provides information about the performance of an analytical method relative to a particular sample matrix (e.g., the presence or absence of analytical interferences).

  The accuracy and precision of analytical results are determined by analyzing samples (furnished by BNI) and laboratory water blanks. These samples are spiked with known concentrations of the compounds of interest for all parameters for which analyses will be performed.

  The amount of spike material recovered from a matrix spike indicates the best result expected from the method. The recovery of these spikes is compared with the accuracy determined from the method spikes as an indication of matrix effects. The laboratory liaison works with the laboratory QA officer to establish an acceptable deviation range. Matrix spikes falling outside this range are reanalyzed to determine if an actual matrix effect is present or if corrective action is required by the subcontractor.

- A **matrix spike duplicate** (or fortified field sample) is prepared in the same manner as a matrix spike. They are compared and used to determine the long-term precision and accuracy of the analytical method for volatile organics, semivolatile organics, metals, and pesticides/PCBs.

- A **surrogate** is a sample spiked with surrogate compounds prior to sample preparation in order to evaluate laboratory performance and estimate the efficiency of the analytical technique. Surrogate recoveries are analyzed for volatile organics, semivolatile organics, and pesticides/PCBs.

- **Standard reference materials (SRMs)** are standards used to validate a particular analytical procedure. SRMs usually originate from EPA, the National Institute of Occupational Safety and Health, or the National Institute of Standards and Technology.

- A **replicate** is obtained in the field by dividing an original single sample into one or more aliquots. Solid sample replicates are prepared by homogenizing an aliquot of the sample that is large enough for the specified analysis. Each replicate is carried through the entire extraction and analytical process. Replicates are used for performance audits.

All eleven types of QC samples were used during collection and analysis of the chemical samples at the St. Louis site; only laboratory duplicates and SRMs were required for radiological samples. QC sample requirements are shown in Table A-1.

Sample Custody and Chain-of-Custody Procedures

Identification and documentation of the possession history of a sample from collection through analysis and ultimate disposition is important to ensure that the validity of the sample is not compromised. COC procedures are used for all samples collected during field activities. Samples for chemical analysis are handled in accordance with the <u>EPA User's Guide to the Contract Laboratory Program</u> (EPA 1986).

At the St. Louis site, the custody documentation procedure was used for the samples processed through the laboratory to maintain a record of sample collection, transfer between personnel, and shipment and receipt by the laboratory. The COC section of the appropriate analytical request form (Figures A-1 and A-2) was completed for each sample type after containers were packed for shipment.

Table A-1
Quality Control Sample Requirements

QA[a] Objective	Type of Analysis	QC[b] Sample	Frequency
Accuracy	Chemical	Method spike	Meets CLP[c] requirements
		Matrix spike	Meets CLP requirements
		Matrix spike duplicate	Meets CLP requirements
		Surrogates	Meets CLP requirement
		SRMs[d]	Meets CLP requirements
	Radiological	SRMs	5% or 1 minimum of all matrices
Precision	Chemical	Field duplicate	5 % or 1 minimum of all matrices
		Laboratory duplicate	Meets CLP requirements
		Replicate	Meets CLP requirements
	Radiological	Field duplicate	5% or 1 minimum of all matrices
Sample handling	Chemical	Trip blank	1 per shipment per matrix (volatiles)
		Field blank	5% or 1 minimum for all matrices
		Method blank	Meets CLP requirements

[a]QA - quality assurance
[b]QC - quality control
[c]CLP - Contract Laboratory Program
[d]SRMs - standard reference materials

WESTON

Request for Analytical Services

Bechtel Subcontr 14501-191-SC-205

WORK ORDER NUMBER:	SITE:	AREA:	DATA CODE:

PRIORITY LEVEL	TOTAL NO. SAMPLES	TOTAL NO. BOXES	SAMPLES IN THIS BOX	DATE SHIPPED	RFW LOT #	RESULTS RECEIVED

SAMPLE NUMBER	BECHTEL ID	DESCRIPTION	MATRIX	DATE COLLECTED	NUMBER OF CONTAINERS

ANALYSES REQUIRED	
ITEM	DESCRIPTION

REASON	RELINQUISHED BY	RECEIVED BY	DATE	TIME

COMMENTS/INSTRUCTIONS:

WHITE: BECHTEL/WESTON LIAISON YELLOW: SAMPLER PINK: WESTON THEN BECHTEL/WESTON LIAISON CANARY: WESTON

FIGURE A-1 REQUEST FORM FOR ANALYTICAL SERVICES

FORM 4A.1

TMA / Eberline

FIELD SAMPLE COLLECTION FORM

SITE NUMBER __________ SITE NAME ____________________ ACTIVITY SUPPORT ____________________

SAMPLE IDENTIFICATION	TYPE (1)	ON-SITE GRID POINTS (2)		SURF ELEV. (3)	DATE COLL.	DEPTH (CM) ☐ (FT) ☐	PURP. (4)	ANALYSES REQUIRED (5)	SAMPLING NOTES AND W.O. NUMBER
		X - GRID POINT	Y - GRID POINT						

(1) SAMPLE TYPE		(2) GRID POINTS	(4) PURPOSE		(5) ANALYSES REQUIRED	
SURFACE SOIL	SS	+X = EAST	RAD. CHARACT.	RC	TOTAL URANIUM	U
BIAS SOIL	BS	-X = WEST	VERIFICATION	VR	ISOTOPIC URANIUM	Iso U
PROFILE SOIL	PS	+Y = NORTH	QUALITY CONTROL	QC	THORIUM - 230	Th - 230
SEDIMENT SILT	SD	-Y = SOUTH	HOT SPOT	HS	THORIUM - 232	Th - 232
SLUDGE	SL		RESAMPLE	RS	RADIUM - 226	Ra - 226
VEGETATION	VE	(3) SURFACE ELEVATION	BACKGROUND	BG	LEAD - 210	Pb - 210
GROUND WATER	GW		ROUTINE	RT	POLONIUM - 210	Po - 210
SURFACE WATER	SW		SPECIAL	SP	GAMMA ISOTOPIC	GeLI
OTHER	OR				OTHER	SPECIFY

COLLECTED BY __________

RECORDED BY __________

DATE RECORDED __________

TOTAL NO. SAMPLES __________

EIC SITE SUPERVISOR __________

DATE SHIPPED __________

LJ/F - 1073.1

FIGURE A-2 FIELD SAMPLE COLLECTION FORM

Thermo Analytical/Eberline (TMA/E), the radiological analysis subcontractor, routinely used a field sample collection form (Figure A-2), which is equivalent to the COC form. Specific procedures were established for using this form, which was completed for all sample types. The form contains all pertinent information about samples in the TMA/E laboratory, including sample identification number; site name, specific location, surface elevation, and depth at which the sample was collected; date the sample was collected; type and purpose of the sample and analysis required; date the sample was shipped; the names of the person who collected the sample and the TMA/E supervisor; and a COC action.

Sample Identification

Each sample submitted for analysis was uniquely identified to ensure timely, correct, and complete analysis for all parameters requested and to support the use of analytical data in potential enforcement actions. A COC record accompanied each chemical sample submitted for analysis, and a field sample collection form accompanied each radiological sample.

Field/Laboratory Custody and Transfer of Custody

Samples must be traceable from the time they are collected until they, or their derived data, are documented in a report. The final custody documentation procedure was used at the St. Louis site to maintain a record of sample collection, transfer between personnel, and shipment and receipt by the laboratory (Figure A-3). This procedure was used in conjunction with Roy F. Weston, Inc. (the FUSRAP chemical analysis subcontractor) sample documentation for all samples processed through Weston. Each time samples were transferred to another custodian, signatures of the persons relinquishing the sample and receiving the sample, the reason for relinquishing the sample, and the time and date were documented.

WESTON Analytics Use Only

Custody Transfer Record/Lab Work Request

WESTON

Client

Work Order

Date Rec'd. ____ Date Due

RFW Contact

Client Contact/Phone

Refrigerator#	
#/Type Container	
Volume	
Preservative	
ANALYSES REQUESTED →	

WA Use Only Lab ID	Client ID/Description	Matrix	Date Collected									

Matrix: S - Soil, SE - Sediment, SO - Solid, W - Water, O - Oil, A - Air, WI - Wipe, DS - Drum Solids, DL - Drum Liquids, F - Fish, L - EP/TCLP Leachate, X - Other

Special Instructions:

Item/Reason	Relinquished by	Received by	Date	Time	Item/Reason	Relinquished by	Received by	Date	Time

WESTON Analytics Use Only

Samples Were:
1 Shipped or Hand-Delivered
NOTES:
2 Ambient or Chilled
NOTES:
3 Received Broken/Leaking (Improperly Sealed) Y N
NOTES:
4 Properly Preserved Y N
NOTES:
5 Received Within Holding Times Y N
NOTES:

COC Tape Was:
1 Present on Outer Package Y N
2 Unbroken on Outer Package Y N
3 Present on Sample Y N
4 Unbroken on Sample Y N
NOTES:

COC Record Was:
1 Present Upon Receipt of Samples Y N

Discrepancies Between Sample Labels and COC Record? Y N
NOTES:

RFW 21-21-001/A-12/88

7-115

FIGURE A-3 CUSTODY TRANSFER RECORD/LAB WORK REQUEST FORM

Upon receipt of radiological samples in the TMA/E laboratory, samples were checked and logged into the laboratory tracking system, and a specific laboratory number was assigned to each sample. The field sample collection form was then sent to TMA/E's Oak Ridge project office with laboratory documentation that was used to track the status of all samples.

Calibration Procedures and Preventive Maintenance

All field and laboratory equipment and instruments used in the field sampling program were maintained and calibrated to operate within the manufacturers' specifications and to ensure that the required traceability, sensitivity, and precision of the equipment and instruments were maintained. Normally, the manufacturers' instructions were followed for calibration, calibration checks, and maintenance. Any reference calibration standards used were certified to be traceable to the National Institute of Standards and Technology or to other acceptable standards, such as laboratory standards prepared using laboratory procedures.

When equipment was found to be out of calibration, an evaluation was performed to determine the validity of measurements made since the last calibration. When instruments were found to be out of calibration and measurements or tests were suspect, such tests or measurements were repeated. If the data were found to be affected and could not be repeated, such data were annotated. The calibration logbook or calibration/maintenance file, as appropriate for the instrument in question, was annotated with the results of the evaluation.

Quality Assurance Audits

Project QA personnel conducted QA audits to verify adherence to field and laboratory procedures and to evaluate the appropriateness and effectiveness of the procedures. Audit team leaders and auditors were trained and certified in accordance with project procedures. Technical specialists participated as auditors under the direction of the audit team leader when warranted by the nature of the activities being audited. Audit reports were prepared for each audit conducted. Audit findings that required corrective action and follow-up were documented, tracked, resolved, and verified by the project QA supervisor.

SITE-SPECIFIC QA PROCEDURES

Chemical Data

To ensure that chemical data were of sufficient quality for use in evaluating the extent of contamination at the St. Louis site, each data package was reviewed for accuracy, precision, and completeness. The following subsections describe the results of these reviews.

Data Packages. The soil and water data packages contained:

- Results for RCRA characteristics, volatile organics, semivolatile organics, metals, pesticides/PCBs, EP TOX, TOC, and TOX (as requested). The metals fraction of RCRA characteristics included: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The organics fraction included endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP.

- Trip blanks for all samples shipped to the laboratory within a 24-hour period

- Field blanks for all analytes

- A minimum of one method blank or 10 percent of the total number of samples

- A minimum of one replicate per batch

- A minimum of one matrix spike sample or 10 percent of the samples, where applicable

- One matrix spike duplicate sample or 10 percent of the samples, where applicable

After the data package was assembled, the laboratory manager for Weston, or his representative, summarized the QC results and described any problems encountered during sample analysis. If all QA procedures had been followed, the data package was sent to BNI for review and use.

The accuracy and precision of the analytical results were determined by analyzing spiked samples and laboratory water blanks and/or surrogate compounds spiked into the sample. The samples and blanks were spiked with known concentrations of the compounds of interest. The recovery of these spikes was then compared to the accuracy determined from the blank spikes as an indication of matrix effects. Matrix spikes falling outside an acceptable range were reanalyzed. All data packages were approved by the Weston laboratory manager as complying with Weston's QA program.

The precision of the analytical procedure was also ensured by analyzing laboratory duplicates. Data from duplicate sample analyses were used to determine whether a particular analytical procedure was within control limits on a data base established to chart day-to-day variations in the precision or accuracy of routine analyses. The duplicate analyses for all of the final data packages were within the control limits. All data packages were approved by the Weston laboratory manager as complying with Weston's QA program.

The completeness of the data was verified by checking the sample identification numbers on the final analytical reports against the samples recorded on the COC forms. All of the samples collected for analysis were analyzed, and the final results were determined to be acceptable. After all analyses were complete, the samples (if radioactively contaminated) were returned to TMA/E for storage. Nonradioactively contaminated samples were sent for commercial disposal.

The following subsections present the results of the BNI reviews for each property.

St. Louis Downtown Site. Radiological and chemical characterization was conducted in two separate phases. Phase I was performed primarily to identify areas of radioactive contamination. Phase II was conducted to define the dimensional boundaries of such contamination and to fill data gaps identified during evaluation of Phase I data. Chemical sampling was incorporated into both phases of the investigation to determine whether hazardous chemicals were associated with the radioactivity. A total of 103 data packages (sets of samples collected in one day and sent to the laboratory for analysis) were generated during the Phase I and II investigations. These data packages consisted of 200 sets of soil samples and 28 sets of water samples. Of the 38 sets of samples analyzed for semivolatile organics, 11 were for scans only. The chain of custody was not maintained for five of the 228 COC forms. Based on the BNI review of the data sets, all of the results were acceptable for use.

St. Louis Airport Site. Radiological and chemical characterization was conducted in two separate phases. Phase I was performed to identify areas of radioactive contamination, and Phase II was performed to identify areas of chemical contamination. A total of 49 data packages were generated during the Phase I and II investigations. These data packages consisted of 33 sets of soil samples and 22 sets of water samples. Of the three sets of samples analyzed for semivolatile organics, two were for scans only. The chain of custody was maintained for all of the 55 COC forms. Seventeen sets of soil sample results (three RCRA characteristics, two mobile ions, two volatile organics, six semivolatile organics, and four metals) were returned to the laboratory for reanalysis. Sample results were rejected because one or more of the following QC samples were unacceptable: surrogate recoveries, matrix spike recoveries, and/or matrix spike duplicate recoveries. The BNI review of the subsequent data packages verified that all of the final results were acceptable for use.

St. Louis Airport Site Vicinity Properties. Radiological and chemical characterization was conducted in two separate phases. Phase I was performed to identify areas of radioactive contamination, and Phase II was performed to identify areas of chemical contamination. A total of 20 data packages were generated during the Phase I and II investigations. These data packages consisted of 32 sets of soil samples and one set of water samples. Of the four sets of samples analyzed for semivolatile organics, three were for scans only. The chain of custody was not maintained for four of the 33 COC forms. Three sets of analytical results for soil samples (one mobile ions, one EP TOX, and one EP TOX organics) were returned to the laboratory for reanalysis. Sample results were rejected because one or more of the following QC samples were unacceptable: surrogate recoveries, matrix spike recoveries, and/or matrix spike duplicate recoveries. The BNI review of the subsequent data packages showed that all of the final results were acceptable for use.

Hazelwood Interim Storage Site/Futura Coatings. Radiological and chemical characterization was conducted in two separate phases. Phase I was performed to identify areas of radioactive contamination, and Phase II was performed to identify areas of chemical contamination. A total of 36 data packages were generated during the Phase I and II investigations. These data packages consisted of 80 sets of soil samples and 33 sets of water samples. Of the five sets of samples analyzed for semivolatile organics, two were for scans only. The chain of custody was not maintained for four of the 113 COC forms. Eight sets of analytical results for soil samples (one RCRA characteristics, one mobile ions, one volatile organics, three metals, one EP TOX, one EP TOX organics) were returned to the laboratory for reanalysis. Sample results were rejected because one or more of the following QC samples were unacceptable: surrogate recoveries, matrix spike recoveries, and/or matrix spike duplicate recoveries. Based on the BNI review of the subsequent data packages, all of the final results were acceptable for use.

Radiological Data

To ensure that radiological data were of sufficient quality for use in evaluating the extent of contamination at the St. Louis site, each data package was reviewed for accuracy, precision, and completeness. The following subsections describe the results of these reviews.

Soil, Water, and Sediment Data. The soil, water, and sediment data packages contained:

- Results for uranium-238, radium-226, thorium-230, and thorium-232 (as requested)
- Duplicate sample counts for one sample in each batch of 20 or less
- Analytical results of SRMs for each of the radionuclides

In addition, special requests were made for source term analysis of other radionuclides of interest. After each data package was assembled, the TMA/E lab manager reviewed the package to determine compliance with contractual requirements and appropriate lab QA procedures. (Detailed information on QA laboratory procedures is available in the TMA/E procedures manual.) The package was then transmitted to the Oak Ridge TMA/E office for review by the project manager. If the project manager's review found discrepancies in the data, the package was returned to the laboratory for reanalysis. If all QA procedures had been followed, the data package was sent to BNI for review and use.

The accuracy of the radiological data was evaluated by counting SRMs for each radionuclide of interest with each batch of samples. The SRMs were within 20 percent of the known value for all packages. Additionally, all data packages were approved by the TMA/E laboratory manager and project manager as complying with TMA/E's QA program.

The precision of each set of radiological data was evaluated by analyzing a duplicate sample for one sample in each batch of 20 or less. The duplicate analyses for all of the data packages were within 20 percent of the original analysis. Additionally, all data packages were approved by the TMA/E lab manager and project manager as complying with the TMA/E QA program.

The completeness of the data was verified by checking the sample identification numbers on the final analytical reports against the samples recorded on the field sample collection forms. All of the samples collected for analysis were analyzed, and the final results were determined to be acceptable.

The following subsections present the results of the BNI reviews for each property.

St. Louis Downtown Site. A total of 101 data packages (73 soil, 24 water, and 4 sediment) were generated during the Phase 1 and 2 investigations. Five data packages were resubmitted to the laboratory for reanalysis or corrections to the analytical reports. Based on the BNI review of the subsequent data packages, all five of the final reports were acceptable for use.

The reasons that five data packages were rejected and resubmitted for corrections were:

- Incorrect sample coordinates
- Incorrect borehole numbers
- Information on sample depths not included
- Error term not calculated (one value only)
- Incorrectly identified radionuclide

St. Louis Airport Site. A total of 29 data packages (10 soil, 14 water, and 5 sediment) were generated during the Phase I and II investigations. Two data packages were resubmitted to the laboratory for reanalysis or corrections to the reports. The BNI review of the subsequent data packages showed that all of the final reports were acceptable for use.

The reasons that two data packages were rejected and resubmitted for corrections were:

- Uranium-235 value not recorded; report not complete
- Incorrect locations for sediment samples

St. Louis Airport Site Vicinity Properties. A total of 135 data packages (129 soil, 6 water, and 4 sediment) were generated during the Phase I and II investigations. Two data packages were resubmitted to the laboratory for reanalysis or corrections to the report. The BNI review of the subsequent data packages verified that all of the final reports were acceptable for use.

The reasons that two data packages were rejected and resubmitted for corrections were:

- Information on property sampled not included
- Error term not calculated

Hazelwood Interim Storage Site/Futura Coatings. A total of 108 data packages (81 soil, 18 water, and 9 sediment) were generated during the Phase I and II investigations. Based on the BNI review of the data packages, all of the results were acceptable for use.

Surface Scan Survey Data. To verify that the gamma radiation walkover survey data met procedural requirements, data packages were reviewed to ensure that all instruments used were identified, background radiation levels were reported and were within normal range, maps identifying results of surface scans were submitted, and survey grid systems were shown and tied to the Missouri state grid system.

Each of the 167 data packages for the St. Louis site was reviewed by a member of the BNI St. Louis team and confirmed by a QA/QC representative. Every category met procedural requirements for all data packages. When all sample analyses and necessary QA checks were completed in the laboratory, the unused portions of the samples and the sample containers were archived and will be retained until remedial action is complete. The independent verification contractor will archive a fraction of the samples for another five years.

APPENDIX B
COMPOSITION OF SOILS

Composition of Soils[a]

Element	Mean (Range) in Dry Soil (mg/kg)
Aluminum	71,000 (10,000 - 300,000)
Antimony	(2 - 10)[b]
Arsenic	6 (0.1 - 40)
Barium	500 (100 - 3,000)
Beryllium	6 (0.1 - 40)
Boron	10 (2.0 - 100)
Bromine	5 (1 - 10)
Cadmium	0.06 (0.01 - 0.7)
Calcium	137,000 (7,000 - 500,000)
Carbon	200,000
Cerium	50
Cesium	6 (0.3 - 25)
Chlorine	100
Chromium	100 (5 - 3,000)
Cobalt	8 (1 -40)
Copper	20 (2 - 100)
Fluorine	200 (30 - 300)
Gallium	30 (0.4 - 300)
Germanium	1 (1 - 50)
Hafnium	6
Iodine	5
Iron	38,000 (7,000 - 550,000)
Lanthanum	30 (1 - 5,000)
Lead	10 (2 - 200)
Lithium	30 (7 - 200)
Magnesium	5,000 (600 - 6,000)
Manganese	850 (100 - 4,000)
Mercury	0.03 (0.01 - 0.3)
Molybdenum	2 (0.2 - 5)
Nickel	40 (10 - 1,000)
Nitrogen	1,000 (200 - 2,500)
Oxygen	490,000
Phosphorus	650
Potassium	14,000 (400 - 30,000)
Radium	8×10^{-7} ($3 - 20 \times 10^{-7}$)
Rubidium	100 (20 - 600)
Scandium	7 (10 -25)
Selenium	0.2 (0.01 - 2)
Silicon	330,000 (250,000 - 350,000)
Silver	0.1 (0.01 - 5)
Sodium	6,300 (750 - 7,500)
Strontium	300 (50 - 1,000)
Sulfur	700 (30 - 900)

Composition of Soils[a]

(continued)

Element	Mean (Range) in Dry Soil (mg/kg)
Thallium	0.1
Thorium	5 (0.1 - 12)
Tin	10 (2 - 200)
Titanium	5,000 (1,000 - 10,000)
Uranium	1 (0.9 - 9)
Vanadium	100 (20 - 500)
Yttrium	50 (25 - 250)
Zinc	50 (10 - 300)
Zirconium	300 (60 - 2,000)

[a]The figures refer to oven-dried soils. Soils near mineral deposits have been omitted in computing ranges. Insufficient data are available for Ag, Be, Cd, Ce, Cs, Ge, Hf, Hg, La, Sb, Sn, Tl, and U, and the values quoted for these elements may require revision.

[b]The range shown is an estimate.

Source: Bowen, H. J. M., 1966. Trace Elements in Biochemistry, Academic Press, London.

APPENDIX C

RESULTS OF MEASUREMENTS TAKEN ALONG ROADSIDES IN HAZELWOOD, MISSOURI

Appendix C
Results of Measurements Taken Along Roadsides in Hazelwood, Missouri

Anomaly	Description	Approximate Location[a]	Range of gamma exposure rates (mR/h)
1	South side of Pershall Road	Ford Motor Co. 6250 Pershall Rd. Hazelwood, MO (new car parking lot)	15-40
2	South side of Pershall Road	Ford Motor Co. 6250 Pershall Rd. Hazelwood, MO (new car parking lot)	20
3	South side of Pershall Road	No address	20
4	North and south side of Pershall Road at west side of Coldwater Creek	No address	12-18
5	North and south side of Pershall Road at east side of Coldwater Creek	Sears warehouse 8950 Pershall Road Hazelwood, MO	8-51
6	North side of Pershall Road (spotty)	Sears warehouse 8950 Pershall Road Hazelwood, MO	20
7	South side of Pershall Road at entrance to Sears warehouse	Sears warehouse 8950 Pershall Road Hazelwood, MO	12-22
8	South side of Pershall Road	Sears warehouse 8950 Pershall Road Hazelwood, MO	12-41
9	West side of Hazelwood Avenue (spotty)	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	10-40
10	West side of Hazelwood Avenue ~220 ft south from railroad	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	60
11	West side of Hazelwood Avenue (spotty)	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	10-40
12	West side of Hazelwood Avenue ~75 ft south from railroad ($15 m^2$)	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	30
13	East side of Hazelwood near gravel road ($2 m^2$)	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	15-20

Appendix C
(continued)

Anomaly	Description	Approximate Location[a]	Range of gamma exposure rates (mR/h)
14	West side of Hazelwood Avenue (spotty)	Wetterau 7101 Hazelwood Avenue Hazelwood, MO	10-20
15	East side of McDonnell Blvd.	No address	15
16	East side of McDonnell Blvd.	No address	20-93
17	East side of McDonnell Blvd.	No address	20-82
18	East side of McDonnell Blvd.	No address	82

Source: ORNL 1986a.

[a]Approximate address for location purposes only. All anomalies are on the state highway right-of-way.

APPENDIX D

SOIL TESTING DATA FOR THE SLAPS/BALL FIELD PROPERTIES

Table D

Soil Testing Data for the SLAPS/Ball Field Properties

Boring	Depth Top (ft)	Depth Bottom (ft)	Unit	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Atterberg Limits Plasticity Index	Dry Density (pcf)	Specific Gravity	Water Content (%)	Void Ratio	Gradation Sand (%)	Gradation Fines (%)	Uranium Distribution Ratio (ml/g)	Effective Cation Exchange Capacity (meq/100 g soil)	Laboratory Vertical Permeability (cm/s)
A-1	20.5		3T												5.0E-06
A-1	27.5		3T	40	21	19									2.0E-08
A-3	15.5		2	32	25	7	84.3	2.63							8.0E-07
A-5	26.5		3T	31	22	9									9.0E-07
B-2	16.5		2				90.7		29.5	0.823					2.0E-04
B-2	29.0		3T				95.6		27.6	0.730					7.0E-05
B-2	41.5		3T				91.2		29.8	0.813					5.0E-05
B-2	49.0		3M				82.5		38.5	1.004					7.0E-07
B-2	66.5		4				88.0		32.4	0.879					2.0E-05
B-2	79.0		4				96.2		24.7	0.719					8.0E-06
P-2	69.5		4	29	24	5									8.0E-07
P-2	83.5		4												2.0E-08
P-4	20.5		2	33	23	10	90.7	2.66							2.0E-07
G10-17	52.0	54.0	3M	70	25	45		2.34	23		15	85	11	223	
G12-12	49.5	51.5	3M	70	26	44		2.38	29		5	95	8.1	214	
G13-10	45.0	47.0	3M	70	28	42		2.35	28		1	99	8	187	
M13.5-8.5D	36.0	38.0	3T	30	21	9		2.31	22		6	94	11	150	
G11-27	31.0	33.0	3T	39	19	20		2.40	25		17	83		144	
M10-15D	80.0	82.0	4	26	NP	NP		2.38	29		20	80			
M13.5-8.5D	52.0	54.0	3M	43	20	23		2.32	32		12	88			
M11-21	10.0	12.0	2	30	25	5		2.33	25		31	69			
M10-8D	53.0	55.0	3B	29	23	6		2.53	27		13	87			
M10-8S	18.0	20.0	2	35	NP	NP		2.34	26		9	91			
G10-21	30.0	32.0	3T	27	NP	NP		2.42	23		3	97			
G10-29	27.0	29.0	3T	37	20	17		2.27	26		10	90			
G10-12	10.0	12.0	2	31	24	7		2.46	26		13	87			
M10-25D	28.5	30.5	3T	38	15	23		2.47	36		7	93			
M11-9	22.5	24.5	2	31	NP	NP		2.36	38		36	64			
G13-10	17.0	19.0	2	27	26	1		2.38	26		6	94			
M13.5-8.5S	22.0	24.0	2	37	NP	NP		2.57	38		19	81			
M10-15S	12.0	17.0	2	32	23	9		2.59	25		19	81			
G12-12	34.0	36.0	2					2.66	24		14	86			
M10-8D	33.1	33.3	3T	37	14	23		2.42	26		5	95			
G10-10	36.5	37.3	3T	29	23	6		2.35	13		6	94			

Table D

(continued)

Boring	Depth Top (ft)	Depth Bottom (ft)	Unit	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Atterberg Limits Plasticity Index	Dry Density (pcf)	Specific Gravity	Water Content (%)	Void Ratio	Gradation Sand (%)	Gradation Fines (%)	Uranium Distribution Ratio (ml/g)	Effective Cation Exchange Capacity (meq/100 g soil)	Laboratory Vertical Permeability (cm/s)
G10-12	32.9	33.6	3T	30	21	9		2.37	19		7	93			
G10-17	20.7	21.0	2	27	24	3		2.41	19		12	88			
M10-25D	48.5	49.2	3T	37	21	16		2.38	29		10	90			
M13.5-8D	61.1	61.8	3B	30	22	8		2.57	22		15	85			
G14-24	33.5	34.0	3M	59	23	36		2.52	12		18	82			
M10-8D	46.0	46.8	3M					2.31	20		6	94			
M10-8D	68.0	70.0	3B					2.60	17		30	70			
M10-15D	86.4	87.1	4					2.21	12		44	56			
G10-17	28.2	28.8	3T					2.46	14		12	88			
G10-21	27.5	27.8	3T	39	19	20		2.31	18		10	90			
G10-21	39.0	39.3	3M					2.26	8		12	88			
G10-21	42.9	43.7	3M					2.27	25		6	94			
M10-25S	20.0	20.3	2					2.29	20		37	53			
M10-25D	37.0	37.5	3M					2.33	21		14	36			
G10-29	20.5	20.8	2	32	22	10		2.41	14		8	92			
M10-25S	13.5	13.8	1					2.33	26		53	48			
G12-8A	26.3	26.5	3T						2.44	10		32	68		
G12-12	39.9	40.4	3M					2.37	14		5	95			
G12-12	43.3	43.6	3M					2.34	26		11	89			
M12.5-8.5D	70.0	71.3	3B					2.35	18		15	85			
M13.5-8.5D	72.4	73.2	3B					2.53	14		31	69			
G14-12	16.4	16.6	1	25	23	1		2.46	21		22	78			
G14-12	21.7	21.9	2					2.36	3		9	91			
B53G18	8.0	13.0	2	36	23	13		2.54	22						
B53G06	0.0	2.5	2	34	20	14			18						
B53G06	2.5	7.5	2	35	22	13			21						
B53G06	13.5	18.5	2	33	21	12			24						
B53G06	18.5	23.5	2	40	28	12			27						
B53G06	28.5	33.5	3T	31	20	11			25						
B53G06	45.5	48.5	3M	77	26	51			37						
B53W02S	0.0	4.0	2	51	23	28			24						
B53W02S	4.8	9.0	2	37	18	19			22						
B53W02S	14.0	19.0	2	33	20	13			22						
B53W02S	19.5	22.0	3T	28	17	11			20						

Table D

(continued)

Boring	Depth Top (ft)	Depth Bottom (ft)	Unit	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Atterberg Limits Plasticity Index	Dry Density (pcf)	Specific Gravity	Water Content (%)	Void Ratio	Gradation Sand (%)	Gradation Fines (%)	Uranium Distribution Ratio (ml/g)	Effective Cation Exchange Capacity (meq/100 g soil)	Laboratory Vertical Permeability (cm/s)
B53W02D	44.0	49.0	3M	78	26	52			29						
B53W02D	59.0	64.0	3B	32	20	12			25						
B53G01	18.0	20.0	2				102.9		26	0.528					8.8E-07
B53G02	54.0	56.0	3M				97.3		28	0.501					5.9E-08
B53G03	28.0	30.0	3T				102.4		24	0.475					1.6E-06
B53G04	29.0	31.0	3T				83.2		31	0.815					2.7E-07
B53G05	49.0	51.0	3M				70.5		50	1.071					1.4E-08
B53G06	43.5	45.5	3M				79.0		39	0.848					1.6E-08
B53G07	10.0	13.5	2										35.2	122	
B53G10	9.5	14.0	2										329.3	184	
B53W10S	8.5	13.5	2										126.7	200	
B53W10D	9.5	14.0	2										329.3	142	
B53G12	38.5	40.5	3T				94.4		26	0.600					1.8E-06
B53G13	29.0	31.0	2				102.5		24	0.534					1.4E-08
B53G13	49.0	51.0	3T				95.7		31	0.578					9.0E-07
B53W14S	14.5	18.5	2										19.1	98	
B53G18	58.0	68.0	3B				99.5		29	0.518					1.7E-07
B53G15	13.5	18.5	2	33	23	10		2.63	24		2	98			
B53G18	8.0	13.0	2	36	23	13		2.54	22		1	99			
B53W13S	9.5	14.5	2	39	24	15		2.59	28		5	95			
B53W11D	15.5	18.5	3T	36	22	14			23		5	95			
B53W11D	4.5	9.5	2	36	23	13		2.63	25		3	97			
B53G18	43.0	48.0	3M	78	28	50			32		0	100			
B53G18	25.0	28.0	3T	37	19	18			25		1	99			
B53G18	13.0	18.0	2	33	23	10		2.58	21		0	100			
B53G17	36.0	38.0	3B	29	25	4			19		1	99			
B53G17	19.5	23.0	3T	42	19	23			28		0	100			
B53G17	13.0	18.0	2	39	22	17		2.56	27		0	100			
B53G16	13.5	18.5	2	32	25	7		2.57	27		0	100			
B53G11	34.5	39.5	3T	29	21	8			22		0	100			
B53G11	19.5	24.5	2	34	23	11		2.61	23		0	100			
B53G09	53.0	58.0	3B	53	20	33			27		1	99			
B53G08	14.5	17.0	2	32	24	8		2.51	23		2	98			
B53G14	28.5	32.0	3T	46	81	25			26		3	97			

Table D

(continued)

Boring	Depth Top (ft)	Depth Bottom (ft)	Unit	Atterberg Limits Liquid Limit	Atterberg Limits Plastic Limit	Atterberg Limits Plasticity Index	Dry Density (pcf)	Specific Gravity	Water Content (%)	Void Ratio	Gradation Sand (%)	Gradation Fines (%)	Uranium Distribution Ratio (ml/g)	Effective Cation Exchange Capacity (meq/100 g soil)	Laboratory Vertical Permeability (cm/s)
B53G14	23.5	28.5	3T	35	22	13			25		0	100			
B53G14	8.5	13.5	2	36	24	12		2.44	22		0	100			
B53G13	89.0	94.0	4						16		77	23			
B53G13	9.0	13.5	2	32	22	10		2.53	24		14	86			
B53G12	40.5	43.5	3B	31	19	12			25		25	75			
B53G03	49.0	54.0	3M	71	26	45			21		0	100			
B53G03	64.0	69.0	3B	33	20	13			20		7	93			
B53G12	23.5	28.5	3T	40	18	22			28		5	95			
B53G12	8.5	13.5	2	33	23	10		2.62	26		4	96			
B53G03	23.0	28.0	3T	29	21	8			20		7	93			
B53G03	3.0	8.0	2	34	24	11		2.73	24		2	98			

NOTES: Blank spaces indicate no data or data not available
NP = non-plastic
pcf = pounds per cubic foot
Fines = percent of sample finer than the no. 200 sieve (0.074 mm)

DOE/OR/21949-280

Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-91OR21949

REMEDIAL INVESTIGATION REPORT FOR THE ST. LOUIS SITE

St. Louis, Missouri

January 1994