DAMES & MOORE

Task Order No. 16
Verification Investigation Work Plan for Radford Army Ammunition Plant, Virginia
Volume 1: Part A
(Draft Final)

Prepared for:
Commander, U.S. Army Toxic and Hazardous Materials Agency
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CONTENTS

CONTENTS (cont'd)

CONTENTS (cont'd)

CONTENTS (cont'd)

CONTENTS (cont'd)

CONTENTS (cont'd)

TABLES

FIGURES

FIGURES (cont'd)

FIGURES (cont'd)

LIST OF ACRONYMS AND ABBREVIATIONS

ACO	Administrative Contracting Officer
AOP	Ammonia oxidation process
ASTM	American Society for Testing and Materials
BNA	Base neutral/acid extractable organic compound
CAMBL	Continuous Automated Multi-Base Line
CEC	Cation-exchange capacity
CIL	Canadian Industries, Limited
CLP	Contract Laboratory Program
cm/sec	Centimeters per second
CRL	Certified Reporting Limit
CVAA	Cold vapor atomic absorption
DNT	Dinitrotoluene
EM	Electromagnetic
EP	Extraction procedure
ESE	Environmental Science and Engineering, Inc.
FAL	Fly ash landfill
GC/MS	Gas chromatography/mass spectroscopy
GFAA	Graphite furnace atomic absorption
GOCO	Government-owned, Contractor-operated
HPLC	High performance liquid chromatography
ICAP	Inductively coupled plasma-emission spectroscopy
ICP	Inductively coupled plasma
IRDMS	Installation Restoration Data Management System
KCl	Potassium chloride
lb/ft^3	Pounds per cubic foot
meq	Millequivalent
mg/l	Milligrams per liter
mgd	Million gallons per day
mph	Miles per hour
msl	Mean sea level
NAC	Nitric acid concentration

NC	Nitrocellulose
NG	Nitroglycerin
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NROW	New River Ordnance Works
PC	Personal computer
PID	Photoionization detector
POL	Petroleum, oil, and lubricant
ppm	Parts per million
PQL	Practical Quantitation Limit
psi	Pounds per square inch
QA	Quality assurance
QAC	Quality assurance coordinator
QC	Quality control
RAAP	Radford Army Ammunition Plant
RBCs	Rotating biological contactors
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
ROW	Radford Ordnance Works
SAC	Sulfuric acid concentration
SAR	Sulfur acid regeneration
SNARLS	Suggested no adverse response levels
SOP	Standard operating procedure
SWMU	Solid waste management unit
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
TNT	Trinitrotoluene
TOC	Total organic carbon
TOX	Total organic halogen
USACE	U.S. Army Corps of Engineers
USAEHA	U.S. Army Environmental Hygiene Agency

USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
UST	Underground storage tank
VI	Verification investigation
VOC	Volatile organic compound
VPI&SU	Virginia Polytechnic Institute and State University

PART A--SAMPLING AND ANALYSIS PLAN

1.0 PROJECT DESCRIPTION

1.1 INTRODUCTION

This document is the draft Work Plan for Task Order 16, Verification Investigation (VI) at Radford Army Ammunition Plant (RAAP), Radford, Virginia. This Work Plan has been prepared for the U. S. Army Toxic and Hazardous Materials Agency (USATHAMA) and is being submitted under the requirements of Contract No. DAAA15-88-D-0008.

This report, identified as the VI Work Plan, consists of five parts as follows:

- Part A--Sampling and Analysis Plan
- Part B--Acid/Industrial Sewer Survey Plan
- Part C--Health and Safety Plan
- Part D--Community Relations Fact Sheet
- Part E--Quality Assurance Project Plan.

RAAP was issued a Permit for Corrective Action and Incinerator Operation by the U.S. Environmental Protection Agency (EPA), effective December 13, 1989. The permit (No. VA-21-002-0730), under the criteria of Section 3004(u) of the Resource Conservation and Recovery Act (RCRA), requires RAAP to conduct a VI and, if necessary, a RCRA Facility Investigation (RFI) for suspected releases from select solid waste management units (SWMUs).

The objective of this Work Plan is to provide a basis for performing a VI at RAAP. The objectives of the VI are to:

- Identify releases or suspected releases of hazardous waste or hazardous constituents into soil, sediment, surface water, and groundwater that need further investigation and/or implementation of interim measures at the facility.
- Screen from further investigation those SWMUs that do not pose a threat to human health or the environment.

- As an option, characterize the waste contained in selected SWMUs to determine whether it is hazardous waste or contains hazardous constituents.

To develop this Work Plan, Dames & Moore conducted a review of pertinent documents and maps obtained from USATHAMA and RAAP. Sampling data from previous investigations were reviewed, as were topographic and geologic maps, aerial photographs, site utility maps, and existing boring and well logs.

Dames & Moore conducted facility visits in February, March, and May 1990. Representatives of Dames & Moore met with representatives of RAAP and USATHAMA to identify SWMUs and their locations, to obtain additional pertinent data, and to discuss proposed investigative strategies. During the visits, photographs of SWMUs were taken for future reference. The relationships among factors such as physical facilities, topography, vegetation, existing monitoring wells, and surface water bodies were observed and recorded. Proposed monitoring well locations were considered as well as potential drilling rig and heavy equipment entry/access problems. Potential soil, surface water, and sediment sampling locations were also reviewed.

Information obtained during the facility visits and from previous reports, as well as from conversations and meetings with RAAP personnel, was used to develop a Work Plan that considers SWMU histories, operations, and current conditions, and is responsive to the requirements of the permit.

This Work Plan presents a technical approach to performance of the VI. Part A includes methodologies and procedures for well drilling and well installation, geophysical surveying, sample collection and preservation, and chemical analysis.

References used in preparation of the Work Plan are provided in the Bibliography. Appendix A provides well construction details for existing wells to be sampled during the VI. Analytical parameter lists are included in Appendix B.

1.2 SCOPE OF WORK

The VI program proposed to fulfill the objectives and requirements of the permit is as follows:

- Investigating a total of 36 SWMUs.
- Drilling exploratory boreholes and installing groundwater monitoring wells.
- Collecting groundwater, soil, surface water, sediment, and waste samples from specified SWMUs and submitting the samples for chemical analysis.
- Collecting soil samples during drilling for physical testing.
- Comparing contaminant levels in the samples to health-based limits specified in the permit.
- Collecting groundwater elevation data from existing and newly installed wells and reviewing slug test results to assess site-specific hydrogeology.
- Collecting background soil samples for comparison and evaluation of SWMU-specific chemical data.
- Collecting and analyzing quality control (QC) samples for data evaluation.
- Initiating an acid/industrial sewer integrity testing program.

Data derived from the above effort will be used to screen from further investigation those SWMUs that do not pose a threat to human health or the environment, and to identify suspected releases of hazardous waste or hazardous constituents from SWMUs that require further investigation and/or implementation of interim corrective measures.

1.3 SWMUs FOR INVESTIGATION

The RCRA permit for RAAP has identified the following 36 SWMUs for VI efforts:

- SWMU 6: Acidic Wastewater Lagoon
- SWMU 8: Calcium Sulfate Settling Lagoons (A-B Line)
- SWMU 9: Calcium Sulfate Settling Lagoons (C-Line)
- SWMU 10: Biological Treatment Plant Equalization Basin
- SWMU 26: Fly Ash Landfill No. 1
- SWMU 27: Calcium Sulfate Landfill
- SWMU 29: Fly Ash Landfill No. 2
- SWMU 31: Coal Ash Settling Lagoons
- SWMU 32: Inert Waste Landfill No. 1
- SWMU 35: Calcium Sulfate Drying Bed (NE Section)
- SWMU 36: Calcium Sulfate Drying Bed (NE Section)
- SWMU 37: Calcium Sulfate Drying Bed (NW Section)
- SWMU 38: Calcium Sulfate Drying Bed (NW Section)
- SWMU 39: Incinerator Wastewater Ponds
- SWMU 40: Sanitary Landfill (NG Area)
- SWMU 41: Red Water Ash Landfill
- SWMU 43: Sanitary Landfill (Adjacent to New River)
- SWMU 45: Sanitary Landfill (West of Main Bridge)
- SWMU 46: Waste Propellant Disposal Area
- SWMU 48: Oily Wastewater Disposal Area
- SWMU 50: Calcium Sulfate Disposal Area
- SWMU 53: Activated Carbon Disposal Area
- SWMU 54: Disposal Area for Ash from Burning of Propellants
- SWMU 57: Pond by Buildings No. 4931 and 4928
- SWMU 58: Rubble Pile
- SWMU 59: Bottom Ash Pile
- SWMU 61: Mobil Waste Oil Tanks
- SWMU 68: Chromic Acid Treatment Tanks

- SWMU 69: Pond by Chromic Acid Treatment Tanks
- SWMU 71: Flash Burn Parts Area
- SWMU 74: Inert Landfill No. 3
- SWMU 75: Waste Oil Underground Storage Tank (UST)
- SWMU 76: Waste Oil USTs (South of Oleum Plant)
- SWMU F: Drum Storage Area (Near Building No. 9387-2)
- SWMU P: Spent Battery Storage Area (Scrap Metal Salvage Yard)
- SWMU Q: Calcium Sulfate Drying Bed

In addition, SWMU 49 was identified in the permit for investigation. However, as a result of the data collection and evaluation efforts for completion of this Work Plan, it was concluded that SWMU 49 does not exist.

An additional six SWMUs were identified for RFI efforts; they are addressed in a separate Work Plan prepared under the permit requirements.

2.0 DESCRIPTION OF CURRENT CONDITIONS

2.1 FACILITY BACKGROUND

2.1.1 Location and History

RAAP is a Government-owned, contractor-operated (GOCO) military industrial installation supplying solvent and solventless propellant grains and TNT explosives. The present contractor-operator is Hercules Incorporated (formerly Hercules Powder Company).

RAAP is located in the mountains of southwest Virginia (Figure 2-1) in Pulaski and Montgomery Counties. The installation consists of two noncontiguous areas--the Radford Unit (or Main Section) and the New River Ammunition Storage Area Unit. The Main Section is located approximately 5 miles northeast of the city of Radford, Virginia, approximately 10 miles west of Blacksburg and 47 miles southwest of Roanoke. The New River Unit is located about 6 miles west of the Main Section, near the town of Dublin (Figure 2-2). The Main Section of RAAP (Figure 2-3) is the focus of this report; all uses of the terms "RAAP" or "the installation" in this report refer to the Main Section only.

Montgomery County, with an area of 394 square miles and an estimated 1988 population of 67,000, is bordered by mountains to the east, north, and south and by the New River on the west. The primary roads in the county are US Route 11, Interstate 81, and US Route 460. The county seat is Christiansburg.

Pulaski County, to the west of Montgomery County, is 328 square miles in size and had an estimated 1988 population of 34,000. The county is bounded by mountains to the north, west, and south and by the New River on the east. The primary roads are US Route 11 and Interstate 81, which run east-west through the center of the county. Pulaski County is generally mountainous except in the central portion, where the hills are gently rolling. The town of Pulaski is the county seat.

RAAP lies in one of a series of narrow valleys typical of the eastern range of the Appalachian Mountains. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long, with a width of 8 miles at the southwest end,

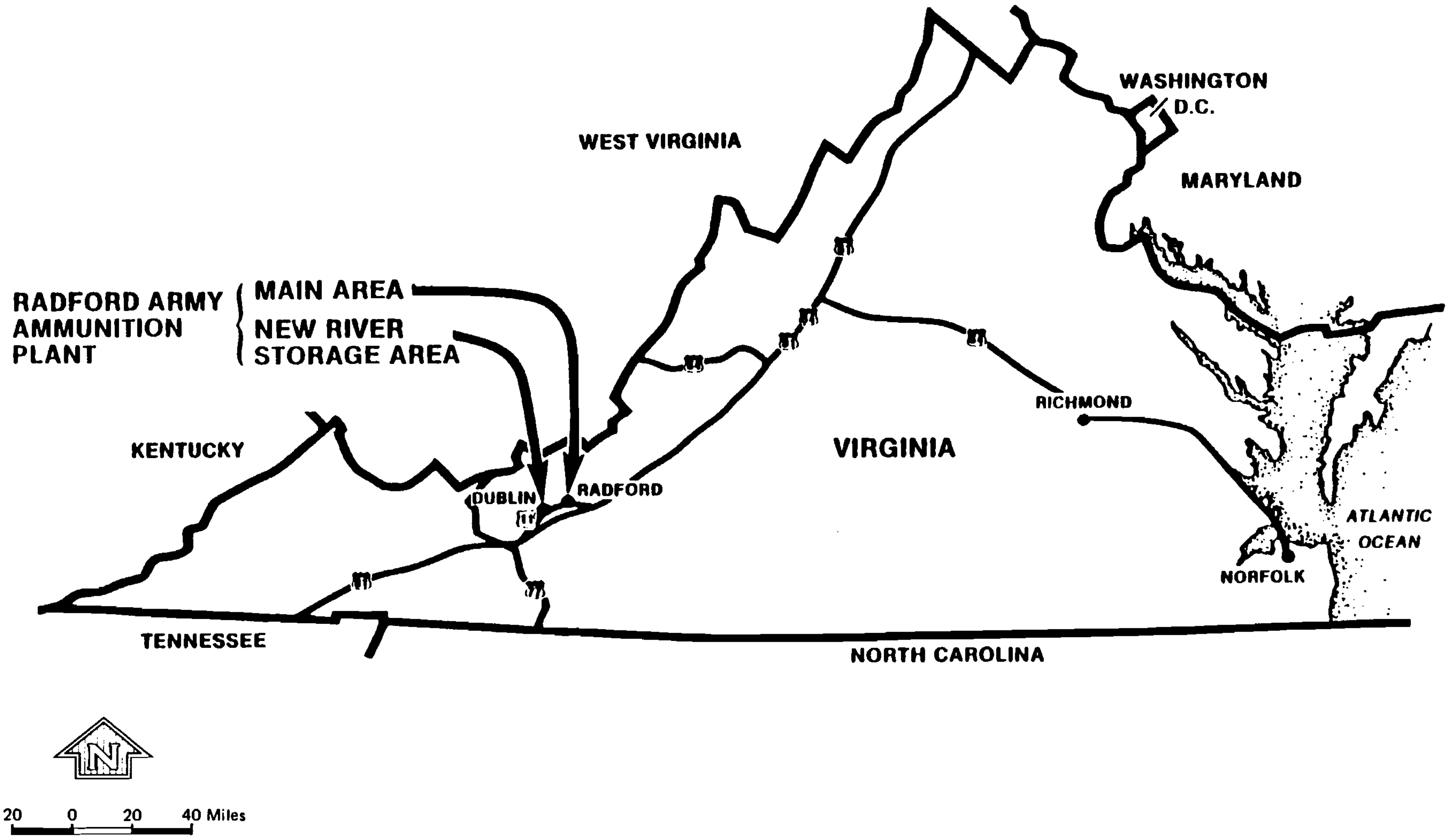

FIGURE 2-1
LOCATION MAP,
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SOURCE: USAEHA,1980b.

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23

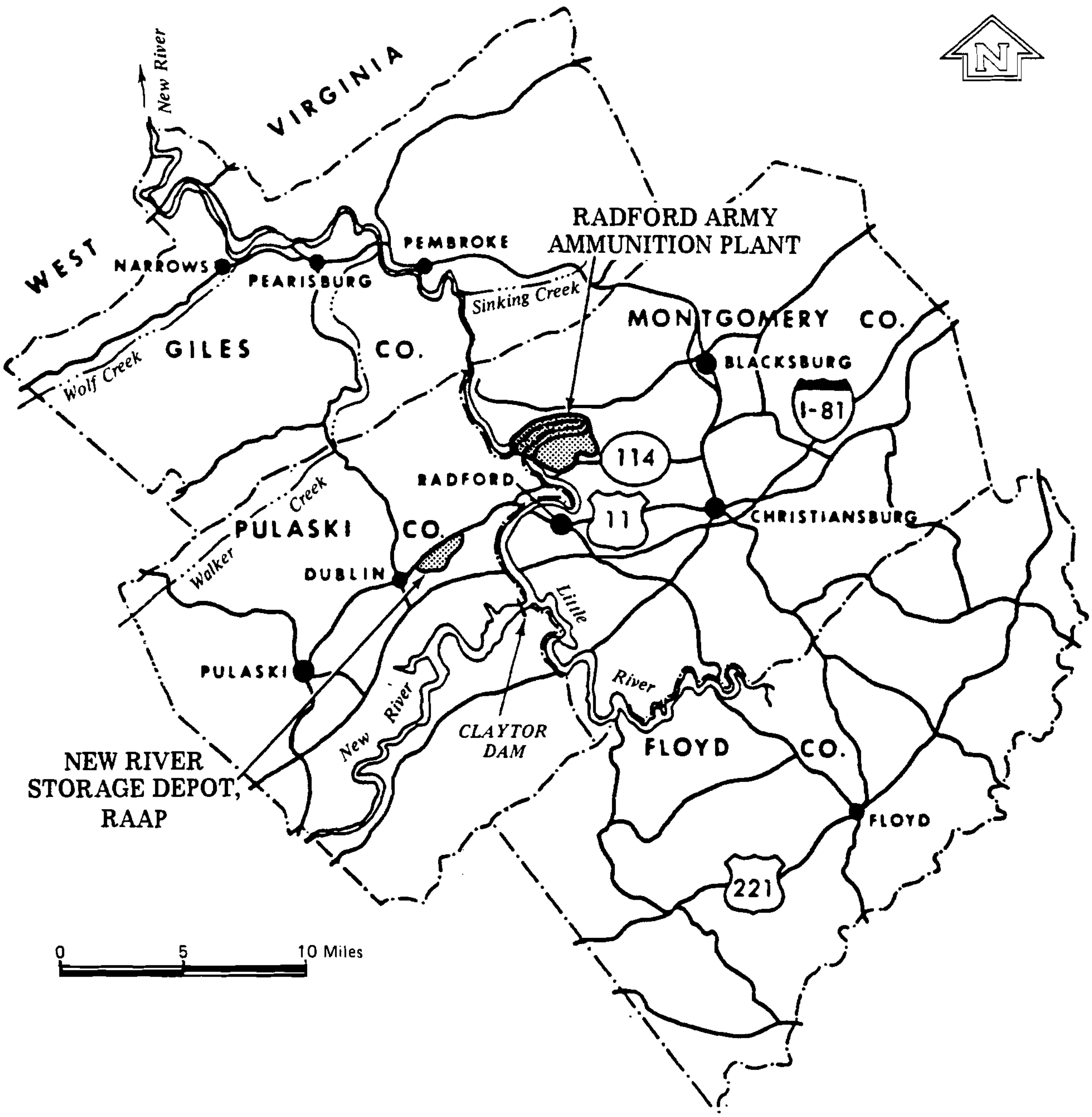

FIGURE 2-2
RAAP AND VICINITY MAP
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SOURCE: USAEHA, 1980b.

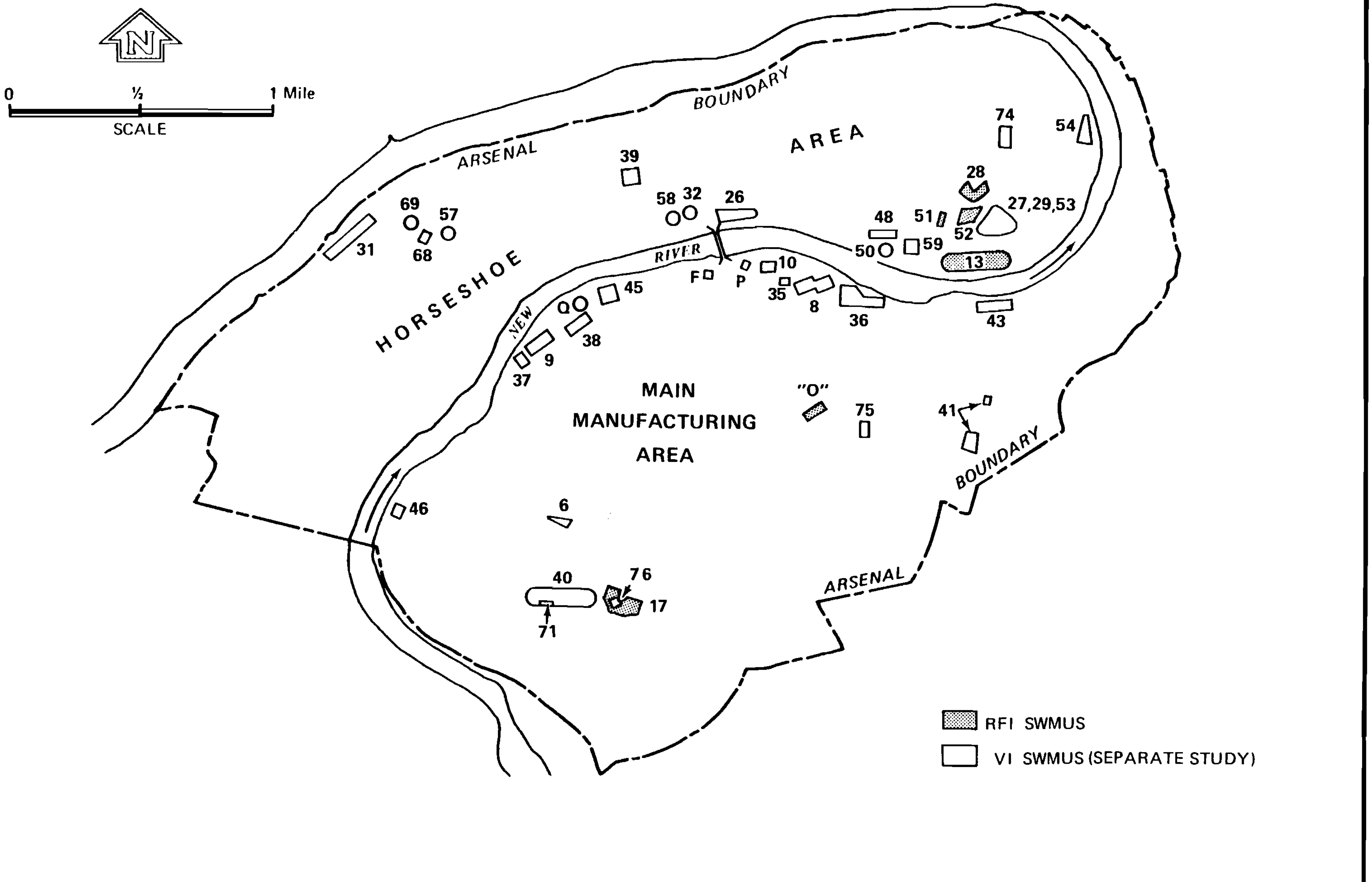

FIGURE 2-3
LAYOUT AND SWMU LOCATION MAP
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

BASE MAP SOURCE: USATHAMA, 1976

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narrowing to 2 miles at its northeast end. The plant lies along the New River in the relatively narrow northeast corner of the valley.

The New River divides the Main Section of RAAP into two areas. Within the New River meander is the "Horseshoe Area." Located in the Horseshoe Area are the Nitroglycerin (NG) No. 2 Area, the Cast Propellant Area, and the Continuous Solvent Propellant Area. Many of the former landfills at RAAP are located in this area, as are the Hazardous Waste Landfill, the currently active Sanitary Landfill, and the Waste Propellant Burning Ground. South of the New River is the "Main Manufacturing Area," which includes the Finishing Area; the Trinitrotoluene (TNT) Area; the NG, Nitrocellulose (NC), and Acid Areas; the Automated Propellant Area; and the Administration Area.

RAAP is assigned the following general responsibilities (USATHAMA, 1976):

- Manufacture of explosives and propellants.
- Handling and storage of strategic and critical materials as directed for other government agencies.
- Operation and maintenance, as directed, of active facilities in support of current operations. Maintenance and/or lay-away, in accordance with Ammunition Procurement and Supply Agency instructions, of standby facilities, including any machinery and packaged lines received from industry, in such conditions as will permit rehabilitation and resumption of production within the time limitations prescribed.
- Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service Stock and industrial stock as required or directed.
- Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials.
- Mobilization planning, including review and revision of plant as required.

- Custodial maintenance and administrative functions of subinstallations.
- Support services for tenants.

This mission is accomplished through the efforts of the operating contractor, Hercules Inc. The Administrative Contracting Officer (ACO) and his staff provide technical assistance and administer the contracts with the civilian operating contractors. RAAP provides logistics support for tenant activities such as the U.S. Army Research, Development and Acquisition Information Systems Agency, which is charged with performing data processing activities during peacetime and mobilization.

Construction of the current RAAP production facility began in 1940 with the impending participation of the United States in World War II, and the determination by Congress of a need for increased ammunition production facilities. Initially, RAAP consisted of two distinct areas--a smokeless-powder plant [Radford Ordnance Works (ROW)] and a bag-manufacturing-and-loading plant for artillery, cannon, and mortar projectiles [New River Ordnance Works (NROW)]. These two production facilities continued to be operated separately from 1940 to 1945. Late in 1945, ROW was designated Radford Arsenal, and NROW was a subpost. By January 1950, NROW was made an integral part of Radford Arsenal and no longer considered a subpost. The arsenal was renamed Radford Ordnance Plant in 1961 and was finally redesignated RAAP in August 1963 (USATHAMA, 1984).

Since its inception as a GOCO facility in 1940, RAAP has been operated by Hercules. Expansion of both ROW and NROW continued throughout World War II. Late in 1945, the Radford Unit was placed on standby status. The following year, the nitric acid area of the plant was reactivated to produce ammonium nitrate fertilizer, an activity that continued until 1949 under contract with Hercules Powder Company (now Hercules Inc.). In September 1945, the New River Unit was declared surplus; but in April 1946, the magazine areas were changed from surplus status to standby. Between December 1946 and January 1948, large parcels of the New River plant manufacturing area were sold (USATHAMA, 1984).

Powder production was begun on a limited scale in 1949. The Radford Unit underwent rehabilitation and expansion throughout the 1950s in support of the Korean Conflict. At the same time as the new construction, surplus buildings--including the entire pentolite and TNT manufacturing areas--were demolished.

Between 1952 and 1958, Goodyear Aircraft Corp., of Akron, Ohio, contracted to manufacture component parts used in missile production at RAAP. The close coordination required between Goodyear and Hercules led to Goodyear moving its assembly and coating operations to RAAP. In 1958, Hercules took over the Goodyear operations at this plant (USATHAMA, 1984).

Activities at RAAP decreased significantly in the mid-1950s. The remaining manufacturing areas at the New River Unit were sold by 1962-1963, reducing the area to its current size of 2,839 acres.

Activities again increased during the Vietnam Conflict, peaking in 1968, though no significant changes were required in production facilities or techniques. Following the decline in the United States' involvement in Vietnam and a subsequent production decline at RAAP, the post underwent a modernization program.

The continuous TNT plant was put into production in mid-1968 and remained in operation until destroyed by an explosion in May 1974. This plant had five main operational areas--the nitration lines, the finishing buildings, the red water concentration facility, the acid neutralization facility, and the spent acid recovery plant. C-line in the TNT area ran from 1983 to 1986, when the TNT plant was placed on standby. Later, in December 1988, a facility cleanup was conducted and the plant was prepared for long-term standby status.

A chronological listing of major RAAP facilities and activities is presented in Table 2-1.

2.1.2 Industrial Operations

The principal end products produced at RAAP since 1941 are TNT, single and multibase propellant, and cast and solventless propellant. Intermediate products produced are oleum (concentrated sulfuric acid), nitric acid, NG, and NC.

TABLE 2-1

Chronological List of Major Activities at RAAP

Date	Activity
August 1940	Contract signed with Hercules Powder Company for construction and operation of smokeless powder plant
September 1940	Construction of Radford Plant
April 1941	Production started at Radford Plant
1941	Separate New River bag loading plant constructed
1941/45	Construction of various facilities continued
1945	Consolidation of Radford and New River plants
1945	Production stopped--plant in standby
1946/49	Ammonium nitrate produced in Acid Area
1949	Limited resumption of powder production
1950	Plant reactivated for Korean Conflict
1950/51	Large areas of plant rehabilitated
1951	Multibase propellant and cast rocket grain facilities constructed
1967/68	Continuous TNT lines constructed
1970/72	New acid plants constructed
1971/	Preproduction project work on Continuous Automated Multibase Line (CAMBL) started
1972/	Continuous Automated Single-Base Line (CASBL) construction started
1972/	Continuous nitrocellulose nitration construction started
1973/	Military Construction, Army (MCA) pollution abatement facilities construction started
May 1974	TNT plant explosion
1976/	Continuous Automated Single-Base Line M6/M1 conversion started
1978	Construction started on biological wastewater treatment plant
1980	C-line Nitrocellulose Manufacturing Area closed
1983	TNT plant reopened
1986	TNT plant placed on standby
1987	C-line Nitrocellulose Manufacturing Area reopened
December 1988	TNT plant cleanup, preparation for long-term standby

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SOURCE: Modified from USATHAMA, 1976.

The production mission of RAAP is accomplished at the primary and secondary manufacturing areas. The production activities of these areas are described below.

The primary manufacturing processes are the production of single-base and multibase solvent propellants, cast and solventless propellants, and TNT. Separate process areas are provided for the production of solvent-type propellant, referred to as rolled powder. The process steps are essentially the same in the production of solvent-type single-, double-, and triple-base propellants. Major differences are in the specific chemicals and explosives ingredients added, as outlined below:

Propellant	Chemicals
Single base and double base	Barium nitrate, potassium nitrate, ethyl centralite, graphite, carbon black, potassium sulfate, lead carbonate, dibutylphthalate, diphenylamine
Triple base	Ethyl centralite, potassium sulfate cryolite
Special high energy propellants	HMX

The production of solventless propellants involves similar process steps, but without the addition of solvents in the mixing step. After the addition of NG, the propellant is air dried and temporarily stored before it is processed through a blender. From the blender, the "powder" is transported to the preroll building and then to the final roll process. The sheets produced from the rolling operations are cut and made into "carpet rolls" or otherwise shaped as desired. These products then proceed for final processing and preparation for shipment.

The separate processes used in the production of the various propellants are discussed below.

- Single-base solvent propellant--In this batch process, nitrocellulose is dehydrated and mixed with appropriate chemicals and solvents for the desired blend. The mixture then undergoes a series of operations where it is shaped into a cylindrical block, extruded into strands, and cut to desired size. The solvents ethyl alcohol and ethyl ether are recovered, and the grains are water and air dried. The last major operation includes glazing, blending, and packaging.

- <u>Multibase solvent propellant</u>--The manufacture of the multibase solvent propellant is similar to the single base except for the addition of nitroglycerin, nitroguanidine, and other chemicals for the formulation desired. The ethyl alcohol and acetone solvents are recovered, and the mix is forced-air dried.
- <u>Cast propellant</u>--The manufacturing of cast propellants for rocket grains requires the mixing of nitroglycerin with triacetin, diethyl phthalate, ethyl centralite and 2-NDPA (depending on formulation), and a casting solvent, followed by the addition of the base grain. The rocket grain is then cast, cured, machined, assembled, and packaged.
- <u>Solventless propellant (rolled powder)</u>--The solventless propellant is prepared by a batch process in which nitrocellulose, nitroglycerin, and other chemicals are slurried in water, wrung to a wet cake, and dried to a paste. After the paste is blended, the mixture is rolled into sheets. The propellant is then wound into a carpet roll for extrusion into small rocket grains. The propellant is also rolled and finished for mortar increments.

The TNT plant, before its destruction in May 1974, consisted of three manufacturing lines, each with a rated capacity of 50 tons/day using the modern Canadian Industries, Limited (CIL), continuous nitration and purification process and an advanced drying, solidifying, and packaging operation. When the TNT plant reopened in 1983, the B and C lines were restored, and improved safety equipment, process equipment, and a TNT wastewater treatment facility were added. In addition, the overall volume of TNT production was reduced. In direct support of TNT manufacture and located in the TNT plant area were operations for fume recovery, red water concentration and destruction, waste neutralization, and spent acid recovery.

In the nitration process, a toluene feed stock was reacted with a mixture of nitric acid and oleum (strong sulfuric acid) to yield a crude trinitrotoluene by using eight nitrators and eight separators connected in series for the three nitrating steps (mono, di, and tri).

The crude TNT then flowed to adjacent, series-connected tanks located in the same building. The steps in the purification process involved an acid wash and two sellite (sodium sulfite) wash operations. A yellow water produced in the acid wash step was normally fed back into the No. 2 (di-) nitrator in the nitration process. The unwanted isomers removed in sellite washing produced a red water waste.

After purification, the molten TNT was mixed with water and the slurry was pumped to the finishing building. The water was then separated from the TNT and recycled to the purification process. The TNT was passed through a hold tank, then dried and flaked for packaging into cardboard cartons to a net weight of 50 pounds.

Nitrogen oxide fumes generated during nitration were exhausted and scrubbed in the fume recovery towers for recovery of the oxides as nitric acid for reuse in the process.

The red water generated in the sellite TNT purification process has been disposed of by various means, including incineration in rotary kilns or sale to the paper industry. Incineration ash has been landfilled in various RAAP locations.

Acid waste was processed through three tanks wherein the pH level was adjusted by the addition of soda ash (sodium carbonate). The treated effluent was then diluted with TNT Area cooling water and released to Stroubles Creek.

The spent acid from the nitration process was separated by distillation into nitric acid, which was reused, and into sulfuric acid, which was concentrated at another part of the plant and sold.

The secondary manufacturing operations at RAAP are the production of oleum, sulfuric and nitric acids, nitroglycerin, and nitrocellulose, as described below:

- Oleum 40 percent is manufactured by absorbing sulfur trioxide (SO_3) in 100 percent sulfuric acid. A new plant, constructed in 1970, uses a sulfur acid regeneration (SAR) process.
- The ammonia oxidation process (AOP) is used to make weak 60 percent nitric acid. A new plant was constructed in 1970.
- The sulfuric acid concentration (SAC) process produces 93 percent sulfuric acid, and concentrates the sulfuric acid residue from the nitric acid concentration (NAC) and TNT processes. This process was replaced by the SAR process in 1970.
- The NAC process is used to concentrate the weak nitric acid produced in the AOP plant and to recover the spent acids from NC and NG manufacture. This was replaced by a new facility constructed in 1970.

These are major ingredients for the manufacture of the primary products.

NG was manufactured at RAAP by both the batch and continuous (Biazzi) processes. The batch process employs three steps--nitration of glycerin to produce NG, separation, and neutralization of the NG charge. The continuous process is a fully automated controlled method in which the NG is produced by reactions similar to the batch process. In 1984, the batch process became inoperative and was replaced by a continuous process. Since 1984, only the continuous process has been operating.

The manufacture of NC starts with the preparation and air drying of cotton linters and wood pulp fibers and the preparation of the mixed acid (nitric/sulfuric acid). The remaining major steps consist of nitration and purification. A dry charge of cotton linters or wood pulp fibers, depending on the type and grade of NC desired, is agitated with the mixed acid in a dipping pot. After nitration, the spent acid is separated from the NC. The raw NC from the nitration operation is stabilized by a stabilization acid boil and two neutral boils in the boiling tub house. It is then transferred to the beater house, where it is cut to suitable size and partially neutralized. Next, in the poacher house, a series of NC boils are performed; first, a soda boil neutralizes any remaining acid, then neutral boils and washes are performed to remove the soda. The NC is then screened, filtered, and washed. In the blender house, NC of various analyses is mixed to produce the mixture or blend desired. The mixture is then wrung through centrifugal wringers in the final wringer house to obtain a product containing a small and uniform amount of moisture. The NC is then shipped to the green powder lines for processing into single-base solvent propellant and to the NG premix area for processing into multibase solvent and solventless propellant.

2.1.3 Climate

The climate of the area encompassing Montgomery and Pulaski Counties is classified as "moderate continental" and is characterized by moderately mild winters and warm summers. The climate is determined, for the most part, by the prevailing westerly wind, with a southerly component in the warm season and a northerly component during the cold season. The year-round average surface-air velocity is 8 miles per hour (mph).

The mean annual precipitation in the two-county area is about 39 inches. Tables 2-2 and 2-3 list the average monthly precipitation and temperature for several stations in and around each county. Snowfall in the same area averages 17 inches annually.

Both counties lie in one of the areas of highest occurrence of dense fog in the United States. Dense fog can be expected to occur between 20 and 45 days per year.

2.1.4 General Topography

RAAP lies within the Valley and Ridge Province of the Appalachian Physiographic Division. The Valley and Ridge Province is characterized by a series of long, narrow, flat-topped mountain ridges separated by valleys of varying widths. Either of these landforms may predominate; the mountains may be widely spaced and isolated or so closely spaced that the lowlands are disconnected or absent. A distinctive feature of the installation area is the absence of mountain ridges.

TABLE 2-2

Average Monthly Precipitation for Locations Near RAAP

Station	Annual Precipitation (inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Years of Record
Allisonia	36.14	2.50	3.04	4.03	3.74	3.21	2.86	3.96	3.44	2.96	2.13	1.60	2.58	9
Blacksburg	40.73	3.18	3.08	3.61	3.17	3.73	4.21	4.70	3.90	3.03	2.77	2.35	3.03	70
Floyd	44.73	3.40	3.36	3.64	3.59	3.97	4.25	4.86	4.31	4.56	2.96	2.66	3.17	28
Glen Lyn	37.38	3.10	2.97	3.38	2.90	3.23	3.50	4.17	3.92	2.54	2.61	2.27	2.79	47
Pulaski	38.23	2.86	2.84	3.72	2.98	3.44	3.72	4.40	4.42	2.70	2.02	2.39	2.79	18
Claytor Dam	36.53	2.96	2.67	3.26	2.81	3.31	3.49	4.25	3.34	2.78	2.74	2.13	2.79	55

SOURCE: NOAA, 1973.

TABLE 2-3

Average Monthly Temperatures (°F), 1931-1960, for Locations Near RAAP

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Period of Record High	Period of Record Low
Blacksburg	35.3	36.5	42.5	53.0	62.0	69.4	72.5	71.4	65.4	55.0	43.6	35.6	100	-27
Floyd	35.3	37.8	42.7	53.2	61.9	69.2	72.0	71.1	64.8	55.1	43.9	36.9	103	-8
Glen Lyn	36.6	38.0	44.3	55.2	64.5	71.7	74.6	73.6	67.5	56.9	45.0	36.5	102	-9

SOURCE: NOAA, 1973.

The topography within the installation (Insert 1) varies from a relatively flat flood plain to elevated uplands in the extreme southeast section. The New River forms the RAAP boundary on the north, with the elevation approximately 1,675 feet above mean sea level (msl). The eastern boundary represents a transition from flood plain elevations (1,680 feet msl) to elevations of 1,900 feet msl in the upland. The southern boundary traverses terrain consisting of creek bottoms and sharply rising summits. The western boundary follows the bluff line overlooking the New River to the point where the Norfolk and Western Railroad crosses the lower arm of the Horseshoe. In the Horseshoe Area to the north and east, the New River has a narrow flood plain. Just west of the Waste Propellant Burning Ground, the flood plain is terminated by steep bluffs that extend westward to the plant boundary.

The Horseshoe Area exhibits rolling karst terrain, with three prominent terraces and escarpments that are remnants of ancient New River flood plains.

2.1.5 General Geology and Soils

2.1.5.1 Soils. The near-surface soil at RAAP is divided into three general soil associations identified as "Map Units" by the Soil Conservation Service (SCS, 1985a; SCS, 1985b). One unit covers the higher elevation areas below the south and southeast sections of RAAP, with two very similar associations found beneath the relatively flat-lying portions of the Manufacturing Area and the Horseshoe Area. The following paragraphs describe the characteristics of these three soil map units.

The Groseclose-Poplimento-Duffield association consists of deep, well-drained, gently sloping-to-steep soils that have a clayey subsoil and have formed in limestone, shale, and sandstone residuum and colluvium or moderately dissected uplands.

The soils are on broad, moderately dissected uplands. Sinkholes are common in some areas. Slopes are dominantly 0 to 25 percent, but steeper slopes are apparent near the New River and other streams.

This map unit covers the uplands on the southern and southeastern areas of RAAP. Usually this association is about 21 percent Groseclose soils, 15 percent

Poplimento soils, and 9 percent Duffield soils. The remaining 55 percent is minor soils.

The Groseclose, Poplimento, and Duffield soils are found on broad ridgetops and side slopes. They have a loam or silt loam surface layer and a clay subsoil. In some areas, the surface layer is cherty.

The minor soils in this map unit are in the Berks, Caneyville, Lowell, Opequon, Rayne, Vertrees, Ernest, McGary, Ross, and Weaver series. The well-drained Berks, Caneyville, Lowell, Opequon, Rayne, and Vertrees soils and the moderately well drained Ernest soils are on ridgetops and side slopes; and the somewhat poorly drained McGary, the well-drained Ross, and the moderately well-drained Weaver soils are on flood plains.

The soils on the broad, gently sloping ridges are suited to cultivated crops--such as corn, small grains, and alfalfa--while the steeper soils are suited to pasture. The major limitations for farming are the low natural fertility and acidity of the soils. The erosion hazard is severe in steep areas. Scattered areas of stony and rocky soils are poorly suited to cultivation.

The clayey subsoil, slow permeability, low strength, high shrink-swell potential, and slope limit the nonfarm uses of the soils. The high slope limits urban development.

The Unison-Braddock association consists of deep, well-drained, gently sloping-to-moderately steep soils that have a clayey subsoil. These soils have formed in old alluvium and on stream terraces and alluvium fans. This map unit is found on the level ground of the RAAP Manufacturing Area between the uplands and the New River.

These soils are found on remnants of old stream terraces and on alluvial fans. Most surfaces are broad and gently sloping and have common sinkholes where the old alluvium is underlain by limestone. Small areas of residual soils are on the steep side slopes created by stream downcutting. A few areas of moderately steep terrace soils occur where material from the original surface layer has been beveled or reworked. Slopes are dominantly 0 to 25 percent, but areas of steeper slopes are included.

This map unit is made up of about 34 percent Unison soils, 15 percent Braddock soils, and 51 percent minor soils. The surface layer of the Unison and Braddock soils is fine, sandy loam or loam, and the subsoil is clay. Rounded pebbles and cobblestones are on the surface and throughout the soil in some areas.

The minor soils in this map unit are in the Berks, Caneyville, Groseclose, Opequon, Weikert, Duffield, Hayter, Guernsey, McGary, Ross, and Weaver series. The well-drained Berks, Caneyville, Groseclose, Opequon, and Weikert soils are on side slopes and ridgetops; the well-drained Duffield soils are on foot slopes, in upland depressions, and along drainageways; the well-drained Hayter soils and moderately well-drained Guernsey soils are on terraces; and the somewhat poorly drained McGary soils, well-drained Ross soils, and moderately well-drained Weaver soils are on flood plains.

The soils in the broad, gently sloping areas are suited to corn, small grains, and alfalfa, while the steeper areas are suited to pasture. The major limitations for farming are the acidity of the soil, the low natural fertility, and--in some areas--the high content of coarse fragments. The erosion hazard is severe on side slopes. The clayey subsoil, moderate permeability, low strength, and slope limit nonfarm uses of these soils.

The Braddock-Wheeling association consists of deep, nearly level-to-hilly soils that have a clayey or loamy subsoil formed in alluvium. These soils are found throughout the horseshoe area of RAAP and are very similar to the Unison-Braddock unit. The unit consists of high and low terraces. Slopes range from 0 to 30 percent. This unit is made up of about 40 percent Braddock soils, 12 percent Wheeling soils, and 48 percent other soils.

The Braddock soils are on undulating-to-hilly, high terraces. The soils have a surface layer of dark yellowish brown loam and a subsoil of yellowish red and red clay.

The Wheeling soils are on nearly level, low terraces near streams. The soils have a surface layer of dark brown, sandy loam and a subsoil of dark brown, sandy clay loam.

The dominant minor soils are Carbo soils on convex side slopes and along small streams, Cotaco soils on low terraces, and Fluvaquents soils on long, narrow flood plains adjacent to streams.

Most of the acreage of this unit is used for cultivated crops, pasture, hay, and a few types of community development. Some of the steeper areas are wooded. The soils are suited to all of the crops grown in the county and support many dairy and beef cattle operations. The hazard of erosion is a major farming concern. The major trees are upland oaks, eastern white pine, Virginia pine, hickory, and black locust. The potential productivity for trees is high.

Permeability, a clayey subsoil, and slope are the main limitations of the unit, especially the Braddock soils, for community development.

2.1.5.2 Structural Geology. The Valley and Ridge Province is characterized by folded and thrust-faulted strata of mostly sedimentary rocks formed between 600 and 300 million years ago. The thrust faults and folds indicate that the rocks were much compressed in the horizontal direction. Strike of bedding planes is north to south and dips to the southeast. RAAP occupies the Blacksburg-Pulaski Synclinorium and rests on the Pulaski Fault thrust sheet. The rocks have been thrust approximately 8 miles west-southwest. The thrust plate has been breached by erosion, exposing Mississippian sandstones and shales of the McCrady/Price Formation in a fenster (window) east of the main plant area along Stroubles Creek. The fault trace is exposed above the computer complex bunker where the Mississippian McCrady/Price Formation can be seen underlying the Cambrian Elbrook Formation. There is no evidence of recent faulting. However, the Radford area has experienced seven earth tremors in the last 200 years that recorded an intensity of VI or higher on the Modified Mercalli Scale (USAEHA, 1980).

2.1.5.3 Stratigraphy. RAAP is underlain by four major rock units and one unconsolidated sedimentary unit that range in geologic age from Cambrian to Quaternary. The rock units are as follows--Cambrian Formations (Rome, Elbrook, and Conococheaque) and Mississippian Formations (McCrady/Price). Dip of the rock units varies over RAAP from nearly horizontal to 50 degrees. The unconsolidated sediments are Quaternary in age and include alluvial, residual, and colluvial deposits. Figure 2-4 is a general geologic map of the major consolidated rock formations at RAAP. The following paragraphs describe the consolidated and unconsolidated formations at RAAP (USAEHA, 1980).

The Elbrook Formation is the major rock unit cropping out at RAAP. This formation is composed of thickly bedded, blue-gray dolomite interspersed with blue-gray to white limestones; brown, green, and red shales; argillaceous limestones; and brecciated limestones (colors of which range from mottled light to dark gray and yellow brown). Sinkholes, solution channels, pinnacled surfaces, and vugs are common to the Elbrook. This formation ranges from 1,400 to 2,000 feet in thickness.

The Rome formation underlies the Elbrook Formation, but it is not known if the Rome crops out at RAAP due to the complex tilted and fractured structure of the overlying Elbrook. The Rome is composed of red and green shales, sandstone, dolomite, and limestone. The red shales commonly mark the basal unit. Thickness ranges from 1,000 to 2,000 feet.

Mississippian rocks of the McCrady/Price Formation outcrop in a fenster east of the main plant area along and south of Stroubles Creek. This formation consists of mottled red and green shale and mudstone interspersed with brownish-green siltstone and sandstone. The formation ranges upwards to 1,500 feet in thickness.

Unconsolidated sediments (overburden) mantle the major portion of RAAP. These sediments include alluvial plain sediments deposited by the New River prior to entrenchment; residual deposits from in-place weathering of parent bedrock; and colluvial deposits developed by residual slope wash. Alluvial plain deposits commonly line the New River and Stroubles Creek as recent flood-plain material or as geologically older terraces. On the horseshoe loop, three terraces are in evidence. In general, there is a textural fining upwards, with gravels and silty, clayey sands forming the basal unit followed by finer micaceous silts and clays. Sporadic cobbles and boulders (known as river jack) occur as lenses throughout the alluvial strata. Thickness of the alluvial deposits varies from a few feet to 50 feet, with an average of 20 feet.

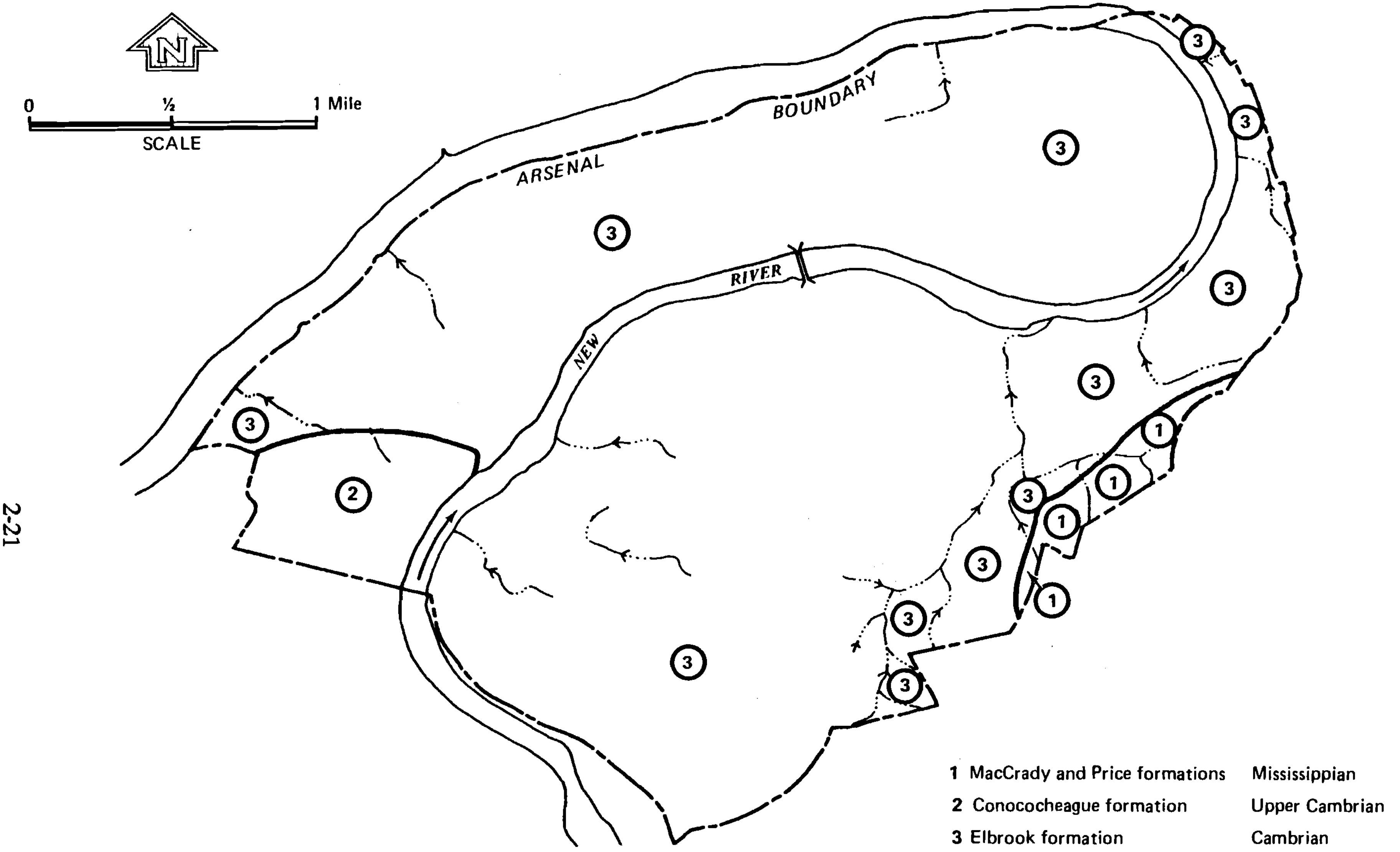

FIGURE 2-4
GENERAL GEOLOGIC MAP
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SOURCE: USATHAMA, 1976

Dames & Moore

Residual deposits (clay and silts) are a result of the mechanical, physical, and chemical weathering of the parent bedrock (primarily Elbrook Dolomite at RAAP). Most of RAAP is covered by residual deposits. In most cases along the New River and in the Horseshoe Area, these residual deposits underlie the alluvium, except where the residuum has been eroded to bedrock and replaced by alluvium. The depth of the residium varies from a few feet to 40 feet.

Colluvial deposits are generally formed from mass-wasting of slopes and escarpments. In general these deposits are a heterogeneous mixture of alluvium, residuum, and rock debris that has migrated from the original position. These deposits are generally interbedded between the strata of alluvium and residuum; thickness is variable.

2.1.6 Groundwater Conditions

The conditions at RAAP are complexed in terms of defining the water table and the available supply of groundwater. Several borings within the Horseshoe Area of RAAP indicate that the water table within the flood plain is approximately at the same elevation as the surface water of the river. These conditions would exist in the flood plain across the river in the main plant area of RAAP (USATHAMA, 1976).

In areas of high elevations within the Horseshoe and south of the river within the Manufacturing Area, the water table is extremely variable. Because of impervious layers, solution cavities, and the thickness of overburden, extreme caution must be exercised in projecting water table data from existing borings into a new area (USATHAMA, 1976).

Groundwater beneath RAAP is mainly derived from the infiltration of surface water through the unsaturated soil mantle into the saturated zone of the soil or bedrock. Groundwater fills the interconnected primary and secondary pore spaces in the bedrock, with the vast majority of available water occurring within the secondary pore spaces. The secondary pore spaces include fractures, open bedding planes, open foliation surfaces, and solution cavities. The limestone and dolomite underlying RAAP is severely fractured, foliated, and faulted as a result of movement along the Pulaski Fault System. The topographic maps clearly show evidence of solution cavities and collapse structures within the less competent limestone units.

Groundwater levels in the bedrock or soil aquifers generally respond immediately to heavy precipitation and may rise several feet in a short time. This illustrates the direct connection between the groundwater and surface water that could compromise the quality of groundwater for domestic use. This condition exists throughout RAAP and especially in areas where surface water has been intentionally routed into the sinkholes. Stormwater flows to the bottom of the sinkholes and percolates downward into the unconfined aquifer. The New River is the discharge for groundwater at RAAP as it is for regional groundwater flow. The saturated zone at RAAP can be generally in either the soil or bedrock. Open fractures and karst structures beneath the soil mantle, coupled with the relatively low elevation of the New River (1,680 feet msl), provide accessible conduits for groundwater flow, thereby rapidly draining the overlying, less permeable soils (CTM, 1988).

Groundwater supplies in the Valley and Ridge province are presently of good or superior quality compared to surface water supplies. However, due to extended contact with minerals, many groundwater supplies contain higher levels of dissolved solids than the streams into which they discharge. Because of the sinkholes and underground caverns in the karst aquifers, there is a threat to the groundwater due to direct infiltration of contaminated surface water, where present.

2.1.7 Surface Water Drainage

The New River is the major drainage within RAAP. The river varies from 200 to 1,000 feet in width, but averages about 410 feet. Generally, the depth is about 4 to 6 feet; however, pools may be 10 feet deep between rock outcrops in the river bed. The flow through RAAP is regulated by a control structure located approximately 7 miles south of the installation. There are 13 miles of river shoreline within the RAAP boundaries.

Stroubles Creek is the largest tributary of the New River and originates in the southeast sector of RAAP. This creek is fed by several branches that originate on and off post. The larger surface drainageways within the installation and their direction of flow are shown in Figure 2-5. Manmade surface drainageways at RAAP also influence local drainage. Regardless of location, the direction of surface drainage flow is ultimately to the New River.

Subsurface drainage is present in RAAP through the sinks or solution cavities formed by percolating waters within the underlying limestone. These cavities vary in size and shape and may be interconnected, forming underground drainageways. Groundwater flow at RAAP is discussed in detail in Section 2.1.6.

Stroubles Creek consists primarily of stormwater runoff and effluent from the Blacksburg, Virginia, Municipal Wastewater Treatment Plant. The creek empties into the New River on the RAAP installation and contributes significant loadings of domestic and industrial wastewater (USATHAMA, 1976).

Both industrial and domestic wastewaters are being discharged into the New River from the city of Radford, upstream from RAAP. Previously, Radford provided only primary sewage treatment before discharging 2.5 million gallons per day (mgd) into the New River (USATHAMA, 1976); secondary treatment is now provided at the Peppers Ferry Regional Wastewater Treatment Plant.

Twenty-eight industrial wastewater outfalls were designated by RAAP on an application for a discharge permit filed pursuant to the Federal Water Pollution Control Act (Permit No. VA0000248). In addition to these, there are a large number of surface streams not identified as industrial outfalls that convey surface drainage from various industrial or service facilities. For internal use and reference, RAAP has identified a total of 40 outfalls to either the New River or Stroubles Creek from the main production and Horseshoe Areas. The age and condition of the facilities at RAAP, as well as the dispersion and topography of the production areas, have resulted in many instances of combined drainage for surface runoff, cooling waters, and industrial discharges.

The New River itself has experienced few major problems from the discharge of either treated or untreated effluent. The ability of the New River to recover from organic loading is generally high because of the river's natural reaeration characteristics, high base flow, and the present quality and quantity of waste discharge. With few exceptions, the quality of surface water obtained from various

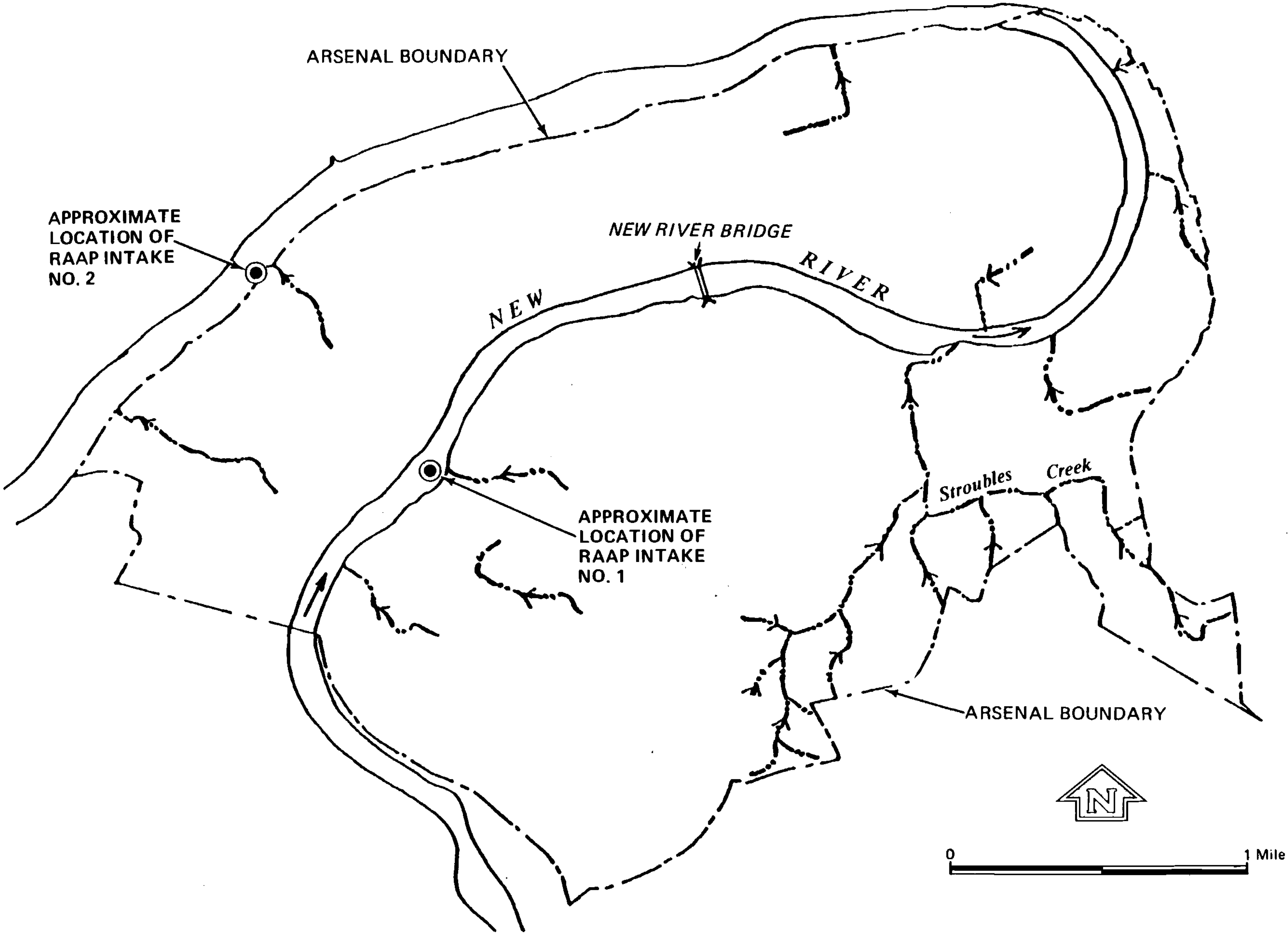

FIGURE 2-5
SURFACE WATER DRAINAGE,
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SOURCE: USAEHA, 1980b.

Dames & Moore

sources within Pulaski and Montgomery Counties can generally be described as good (USATHAMA, 1976).

The upper reaches of the New River and its tributaries have water of excellent quality. These streams have less than 50 parts per million (ppm) of dissolved solids due to the underlying metamorphic rocks, which contribute very little to natural pollution. In the balance of the region, dissolved solids increase the 50- to 199-ppm range as water drains from areas underlain by shale, sandstone, and limestone formations. Where carbonate rocks occur, the bicarbonate content of the water is particularly high, resulting in 100 to 199 ppm of calcium carbonate ($CaCO_3$) found in the waters of Walker Creek, Sinking Creek, Wolf Creek, and the New River below RAAP (Figure 2-2).

The Commonwealth of Virginia has classified Stroubles Creek and the stretch of New River passing through the confines of RAAP as water generally satisfactory for beneficial uses, which include public or municipal water supply, secondary contact recreation, and propagation of fish and aquatic life (USATHAMA, 1976).

All water used at RAAP is taken from the New River. The river flow varies due to water management at Claytor Dam, approximately 9 miles upgradient from RAAP (Figure 2-2). Typical flows are about 3,800 mgd. Separate water systems are provided for the main plant and the Horseshoe Area. Intake No. 1 is located approximately 2 miles upstream of the mouth of Stroubles Creek. Intake No. 2 is located approximately 6 miles downstream of the mouth of Stroubles Creek (Figure 2-5). Upstream of RAAP, the New River serves as a source of drinking water for the towns of Blacksburg and Christiansburg.

In 1976, water quality analysis of the New River was conducted both where the river enters the RAAP installation and where it exits the installation. The analysis indicated that the quality of the water when it leaves the installation was essentially the same as when it enters. Table 2-4 provides a summary of the general water quality of the New River, determined in 1976.

The National Pollutant Discharge Elimination System (NPDES) permit issued to RAAP in June 1986 required semiannual biomonitoring (toxicity testing) and an annual qualitative benthic macroinvertebrate study on the New River. Results have

TABLE 2-4

Analyses of the New River Entering and Leaving Radford Army Ammunition Plant, Virginia

PARAMETER	CONCENTRATION [a]	
	ENTERING	LEAVING
Alkalinity (as $CaCO_3$)	45	45
BOD	2	2
COD	10	10
Total Solids	66	66
Total Dissolved Solids	61	61
Total Suspended Solids	5	5
Total Volatile Solids	29	29
Ammonia	0	0
Kjeldahl Nitrogen	0.4	0.4
Nitrate (as Nitrogen)	0.4	0.7
Phosphorus Total	< 0.3	< 0.3
Color (Color Units)	16	15
Nitrite	< 0.01	< 0.01
Sulfate	4	10
Sulfide	< 0.1	< 0.1
Bromide	0.59	0.59
Aluminum	< 0.10	< 0.10
Cadmium	< 0.005	< 0.005
Chloride	5.2	5.7
Copper	< 0.010	< 0.010
Iron	0.35	0.33
Lead	< 0.010	< 0.010
Magnesium	5	4
Mercury	< 0.002	< 0.002
Beryllium	0	0
Boron	0	0

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[a] All results are in milligrams per liter (mg/l), except as noted.
SOURCE: USATHAMA, 1976.

indicated that three of RAAP's outfalls were often toxic and were having a localized impact on the New River biota. RAAP is currently conducting a toxicity reduction evaluation at two of the outfalls to determine the cause of the toxicity and what treatment would be effective (USAEHA, 1989).

In recent years, especially during extended low flow conditions, there has been a severe impact on biota in the vicinity of the combined outfalls. In addition, a *Sphaerotilus*-like growth has blanketed the New River substrate. Effluent plumes reportedly do not mix well with the New River until directed into the main flow at the confluence of Stroubles Creek.

2.1.8 Biological Resources

Lists of the mammals, birds, reptiles, amphibians, aquatic invertebrates, trees, and plants found on the installation and of the fish inhabiting the New River where it flows through the installation are presented in earlier environmental assessments of RAAP and are not included herein. These lists were compiled by combining data from the RAAP Woodland Management Plan, the RAAP Fish and Wildlife Management Plan, the 1973 RAAP declaration of timber available for harvest, the RAAP Land Management Plan, and verbal information from the forester at RAAP (USATHAMA, 1976).

Several studies of fish and aquatic invertebrates, deer populations, and growth rates of tree rings at RAAP were conducted by several departments of the Virginia Polytechnic Institute and State University (VPI&SU) in Blacksburg, Virginia. For most of the installation's life forms, there is little information available about the occurrence, abundance, breeding areas, and distributions.

It is probable that all of the reptiles, all of the mammals (except the bobcat), and most of the birds (except migratory waterfowl) listed in the 1976 Installation Assessment (USATHAMA, 1976) breed on the installation. Foxes periodically build up large populations, and the Virginia Commission of Game and Inland Fisheries cooperates in trapping them to prevent rabies outbreaks. The last trapping program for foxes was conducted in 1966. Deer also become overabundant and are sometimes significant road hazards. A deer capture program conducted annually by personnel from VPI&SU has attempted to maintain a constant population.

Because the installation is on the Atlantic Flyway, the New River is a haven for many species of migratory waterfowl throughout the spring and winter.

No threatened or endangered species are suspected of dwelling at RAAP, nor are there any known species with unusual aesthetic value. There are no species known to occur exclusively at RAAP or to be absent from the rest of the counties or State; there are no species known for which the installation lies at the limit of their ranges. Indications are that some species, including ruffed grouse and upland plovers, have decreased in number or have disappeared from RAAP (USATHAMA, 1976).

No hunting or fishing is permitted within RAAP because of the many buildings used for the manufacture and storage of explosives. Public fishing is permitted from boats in the New River. Although no hunting is permitted, deer are trapped by the Virginia Department of Conservation for restocking in neighboring counties.

A survey made of the fish population in the New River by VPI&SU determined that there was an adequate stock of native species for sportfishing. Salt blocks, grain fields, and grain-stocked shelters have been provided on RAAP for game species. There is no other active management of the wildlife.

Wildlife is not intentionally propagated on RAAP, but the sanction against hunting provides a sheltered area where deer and other wildlife can flourish.

According to the most recent Woodland Management Plan, the forest area of RAAP is essentially the same as when originally acquired. All hardwood of merchandisable size inside the security fence at the New River was removed because of damage by 2,4-D, which was sprayed to eliminate musk thistle in 1971. Musk thistle was declared a noxious weed by the Virginia General Assembly, and its control is required by law. In the 1950s approximately 3,000 acres were reforested with shortleaf pine (Pinus echinata), loblolly pine (Pinus taeda), eastern white pine (Pinus strobus), yellow poplar (Liriodendron tulipfera), and black walnut (Juglans nigra). Heavy timbering occurred prior to Government acquisition. There are no records of forest fires.

There are 2,537 acres of managed woodlands. The rolling areas and one flat bottom have been reforested. No reforestation has occurred in the main Manufacturing Area. In 1964, 922 acres of the Horseshoe Area were reforested. Primary species (white pine, poplar, and walnut) are grown because of their adaptability to the site, their value as a timber crop, and the need for a mobile reserve; secondary species (shortleaf and loblolly pine) are planted when primary species are not present in sufficient quantity to ensure a maximum yield. A 50-year planting rotation is practiced for shortleaf and loblolly pine sites, a 70-year rotation is practiced for eastern white pine sites, and an 85-year rotation is planned for hardwood vegetation sites.

The cutting cycle on existing forest lands is 7 years; the first cutting took place in 1966. Reforestation and forest improvement were in effect from 1955 to 1973 at suitable sites. Black walnut and white oak will be retained on the stump, if they are in good condition, to provide a mobile reserve. Unsuitable or diseased trees are removed.

As recommended by the Virginia Forestry Department, timber stands have been improved in all areas through selective cutting of mature trees with mechanized equipment when possible. Weed trees have been sprayed with ammonium sulfamate. Controlled burning is not practiced because of the fire hazard.

2.1.9 Land Use

Land in the vicinity of RAAP is mostly rural. Development has been kept to a minimum in much of the area due to the steep terrain. Much of the area surrounding RAAP that is less rugged is agricultural. Although there are private residences immediately adjacent to the installation, the nearest substantial residential area is Fairlawn, located approximately 3 miles to the southwest. Located approximately 5 miles to the southwest is Radford (estimated 1988 population of 12,000). To the north of RAAP is the Jefferson National Forest. The population densities of Montgomery and Pulaski Counties are 173.1 and 106.9 persons per square mile, respectively.

Since 1960, Montgomery and Pulaski Counties have experienced strong population growth. Montgomery County consistently exhibits the strongest population growth in the New River Valley Region (comprised of Giles, Floyd, Pulaski, and Montgomery Counties and the City of Radford), posting increases far in excess of regional trends. Projections are for populations to grow at similar rates through the year 2000 (Table 2-5).

Table 2-6 presents data on employment characteristics in the vicinity of RAAP. Statistics were collected with regard to place of employment rather than place of residence. Manufacturing is the largest individual employment sector in the area, with 17,282 employees in the second quarter of 1988 accounting for 33.8 percent of the area's total employment. Hercules Incorporated employees involved in the manufacture of explosives and propellants are included in these figures.

2.2 SWMU DESCRIPTIONS

2.2.1 Acidic Wastewater Lagoon--SWMU 6

This unit was an unlined surface impoundment located approximately 2,000 feet northwest of the Administration Area (Figure 2-3). The lagoon, described in previous investigation reports as "tear-dropped" or "triangular" in shape, was approximately 80 feet long by 30 feet wide at its widest point (Figure 2-6). From 1974 to 1980, the lagoon received overflows and rinse waters from an acid storage tank area in the C-Line NC manufacturing area. During its active life, SWMU 6 received wastewaters that typically exhibited the characteristic of a corrosive liquid (D002). There were no overflow controls at the lagoon.

Between 1980 and 1987, the C-Line NC manufacturing area was shut down; therefore, no wastewaters were introduced to the lagoon during this period. In 1987, the lagoon was filled with soil and replaced by a holding tank, from which water flows to the Biological Treatment Plant (SWMU 10). No RCRA closure activities have occurred at SWMU 6 (EPA, 1987).

SWMU 6 is suspected to occupy a collapsed sinkhole, as supported by the following evidence:

- The topography of the unit is typical of a sinkhole.

TABLE 2-5

Population in Vicinity of RAAP

Jurisdiction	1970	Percent Change (1960-1970)	1980	Percent Change (1970-1980)	1988(a)	Percent Change (1980-1988)	2000(b)	Percent Change(b) (1988-2000)
Montgomery Co.	47,157	43.2	63,516	34.7	67,000	5.5	78,030	16.4
Pulaski Co.	29,564	8.5	35,229	19.2	34,000	-0.3	37,890	11.4
City of Radford	11,596	23.7	13,225	14.0	13,700	3.6	14,810	8.1
City of Blacksburg	--	--	--	--	23,000 (year-round) 37,000 (incl. students)	--	--	--
New River Valley	114,833	18.1	141,343	11.6	--	--	162,940	--

(a) Estimated.
(b) Projected.
SOURCE: NRVPDC, 1989.

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TABLE 2-6

Average Employment Near RAAP
Second Quarter 1987 and 1988

Classification	Montgomery Co.		Pulaski Co.		City of Radford		Totals	
	1987	1988	1987	1988	1987	1988	1987	1988
Agriculture, forestry	190	222	248	179	0	0	438	401
Construction	1,253	1,283	436	457	244	216	1,933	1,956
Manufacturing	8,136	8,491	6,419	6,610	2,221	2,181	16,776	17,282
Transportation/communication/ utilities	204	265	660	683	155	163	1,019	1,111
Wholesale	223	282	238	299	93	83	554	664
Retail trade	5,907	6,193	1,742	1,782	835	852	8,484	8,827
Financial/insurance/ real estate	955	1,070	274	245	255	297	1,484	1,612
Services	3,137	3,478	1,724	1,843	1,088	1,216	5,949	6,537
Government	8,558	8,952	1,722	1,764	1,891	1,890	12,171	12,606
TOTAL	28,579	30,256	13,476	13,897	6,784	6,905	48,839	51,058

SOURCE: NRVPDC, 1989.

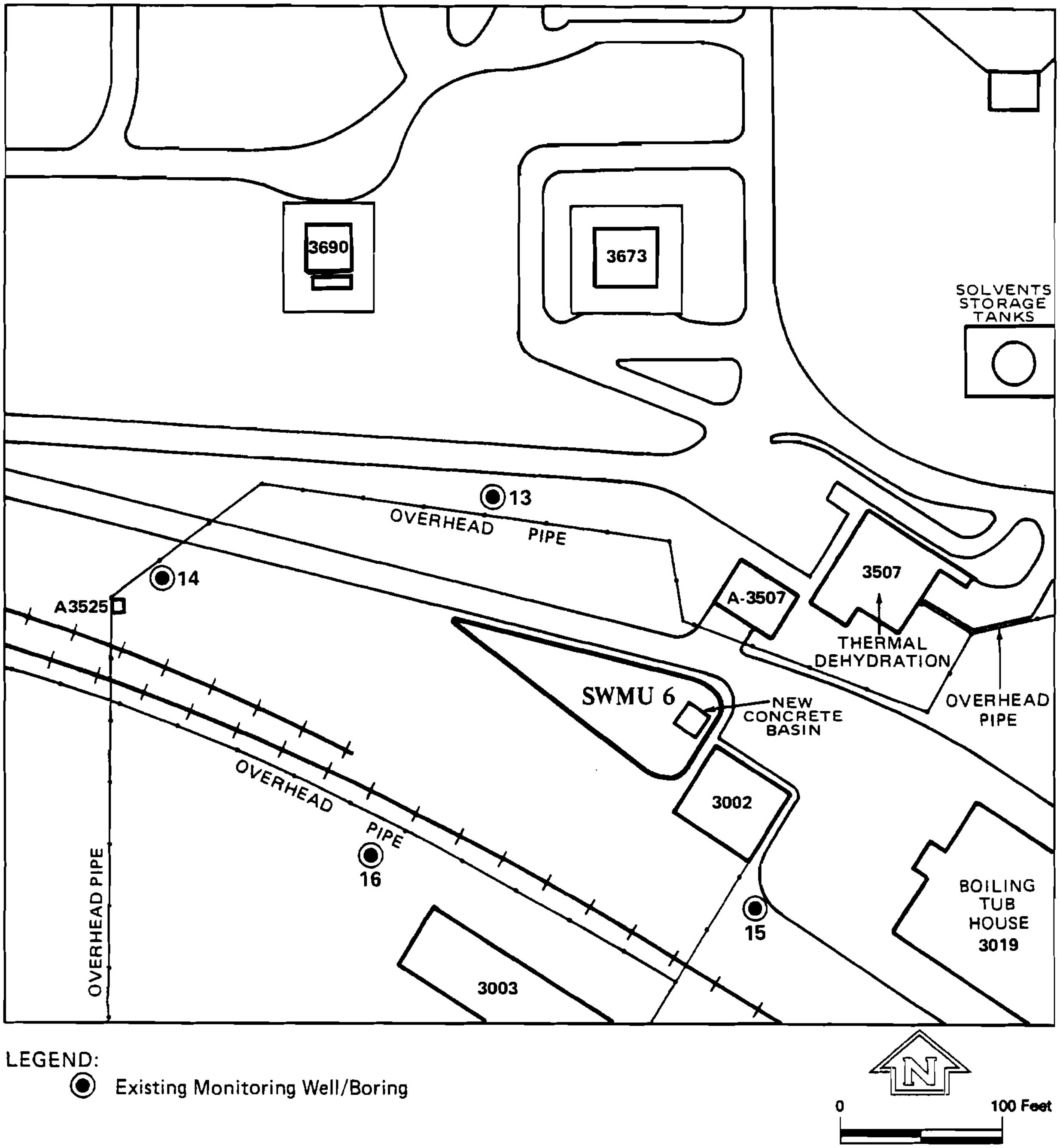

FIGURE 2-6
SWMU 6 – ACIDIC WASTEWATER LAGOON
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

- RAAP personnel indicate a history of collapses and subsidences of roads and foundations near the former lagoon.
- Well logs for monitoring wells installed at the lagoon in 1981 indicate that no dolomite was encountered near the center of the depression, while dolomite was encountered in surrounding wells.
- During development of three of the four monitoring wells, all fluid was lost due to subsurface cavities.
- 300 pounds of sand pack were lost to a subsurface cavity during the grouting of one well (USAEHA, 1981).

These factors indicate that a direct route exists for wastes disposed of in the lagoon to have entered the groundwater. Reddish-brown silty clay was encountered in each boring from the ground surface (excluding road materials) to bedrock or borehole termination. Depth to the Elbrook Formation bedrock ranged from 21 feet to greater than 45 feet. Groundwater encountered in these borings probably reflects perched water within the clay and not the unconfined water table aquifer.

A geophysical survey investigation conducted at SWMU 6 in 1984 indicated the presence of a soil horizon at 17.6 feet below the ground surface. This horizon was interpreted as a lithologic change in the overburden. A break in the profile was interpreted as a possible collapsed sinkhole (USACE, 1984). If seepage into this assumed sinkhole has occurred, the rapid groundwater flow through the karst aquifer would likely have carried it away from the SWMU and into the New River within days of the seepage.

In 1981, four monitoring wells (MW13, MW14, MW15, and MW16) were installed at the unit as part of an Army Pollution Abatement Study at SWMUs 4, 5, 6, and 7 (USAEHA, 1981). Well locations are shown in Figure 2-6. Three of these wells (MW14, MW15, and MW16) could not be sampled after installation, because no groundwater was present after well development. Sampling of MW13 indicated detectable groundwater concentrations of sulfate, sodium, manganese, zinc, nitrate (as N), and total dissolved solids (TDS). The high conductivity of the sample from MW13 indicated potential groundwater contamination. Later sampling of MW14 and MW15 indicated the presence of acetone at concentrations of 7 and 27 mg/1 respectively (USATHAMA, 1984). However, acetone is a typical laboratory cleaning agent. The groundwater table apparently rose to intersect the well screens of MW14 and MW15. Well MW16 was terminated at a very shallow depth and may have been installed permanently above the unconfined water table.

Soil samples collected at the lagoon showed trace concentrations of nitrocellulose in three of six samples (USEPA, 1987), indicating that surface water runoff in the area may have contained NC.

The concern at SWMU 6 is potential soil and groundwater contamination.

2.2.2 Calcium Sulfate Areas

These areas include SWMUs 8 and 9; 35, 36, 37, 38, and Q; 50; and the disposal area near SWMU 38.

2.2.2.1 Calcium Sulfate Settling Lagoons--SWMUs 8 and 9. SWMU 8, Calcium Sulfate Settling Lagoons (A-B Line Acidic Wastewater), consists of two unlined, below-grade earthen lagoons located in the northeast section of the main manufacturing area along the south bank of the New River (Figures 2-3 and 2-7). Each rectangular lagoon is approximately 200 feet long, 150 feet wide, and 10 feet deep. It is estimated that these currently active lagoons began operation in the early 1950s during the Korean War (USACE, 1981). The lagoons are operated on an alternating basis to accommodate maintenance and dredging. The adjacent sludge drying beds are SWMU 35 and SWMU 36.

SWMU 8 manages neutralized, formerly acidic wastewater from the A-B Line Acidic Wastewater Treatment Plant (SWMU 19). The neutralization process that takes place at the treatment plant is as follows:

$$\underset{\substack{\text{(Hydrated}\\\text{lime)}}}{\mathrm{Ca(OH)2}} \quad + \quad \underset{\substack{\text{(Sulfuric}\\\text{acid)}}}{\mathrm{H2SO4}} \quad ==> \quad \underset{\substack{\text{(Calcium}\\\text{sulfate)}}}{\mathrm{CaSO4}} \quad + \quad \underset{\text{(Water)}}{\mathrm{2H2O}}$$

The wastewater containing the calcium sulfate flows through a series of weir gates in the lagoons, causing the calcium sulfate to precipitate out and settle to the

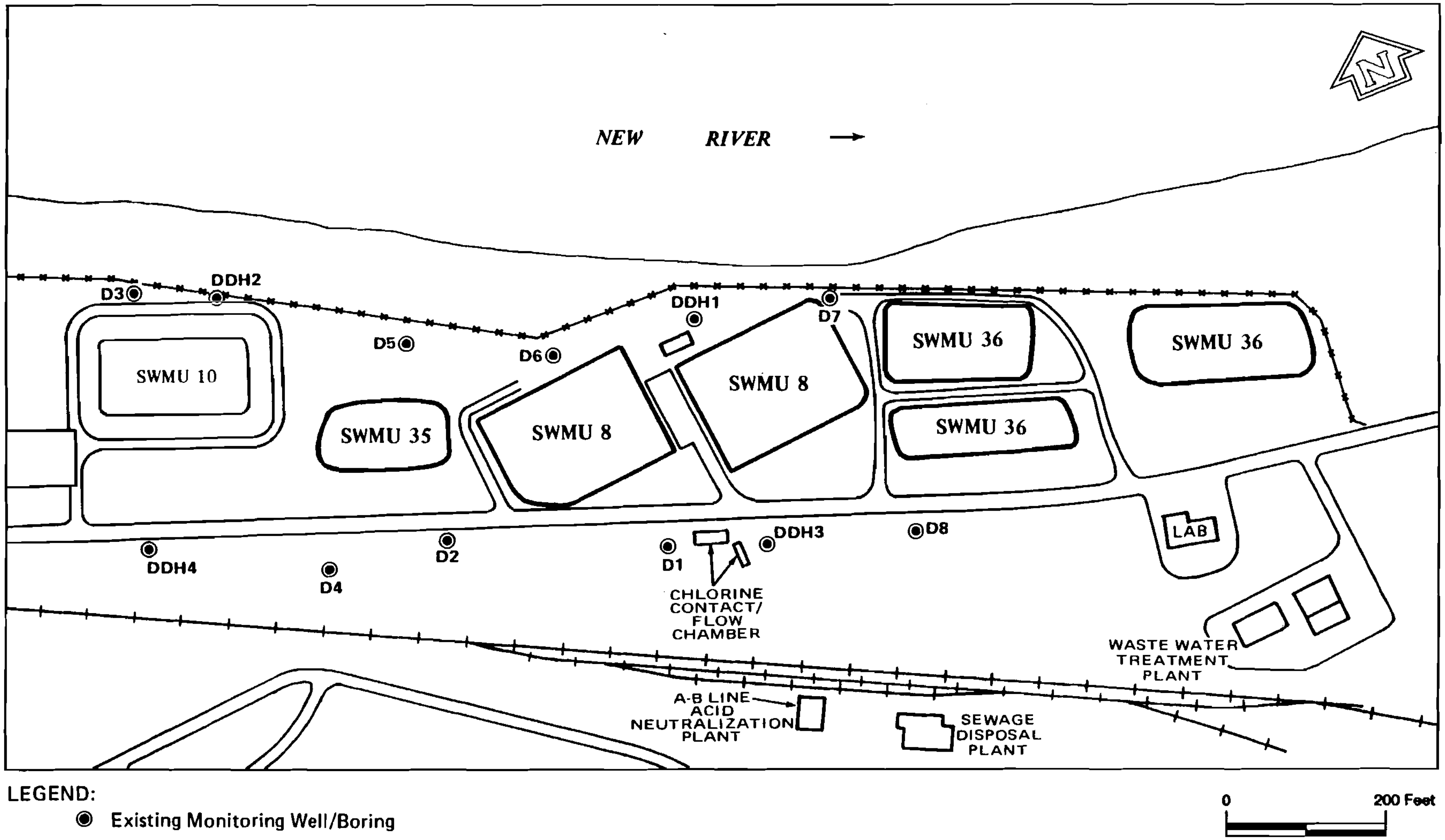

FIGURE 2-7
SWMU 8 – CALCIUM SULFATE SETTLING LAGOONS
SWMUs 35 AND 36 – CALCIUM SULFATE DRYING BEDS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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bottom of the lagoons as a sludge. The supernatant is discharged to the New River via NPDES Outfall 007 (Permit No. VA 0000248), adjacent to the unit (USATHAMA, 1976). The calcium sulfate sludge is dredged from the lagoons on a periodic basis (approximately once every 5 to 7 months) and placed in adjacent drying beds (SWMUs 35 and 36). After drying, the sludge is removed from the beds; since 1982, it has been disposed of in Fly Ash Landfill No. 2 (SWMU 29). Prior to 1982, the sludge was disposed of in Fly Ash Landfill No. 1 (SWMU 26), the Calcium Sulfate Landfill (SWMU 27), and the locations described in Section 2.2.2.3.

Analyses performed on sludge samples collected from SWMU 8 indicate that the sludge does not exhibit any of the four hazardous waste characteristics as outlined in 40 CFR 261.34. However, there is concern that the sludge contains some organic compounds used in manufacturing activities at RAAP (USEPA, 1987; USACE, 1981). Analyses performed on sludge samples in 1989 indicated the following results, with concentrations shown for a range of three samples (Olver, 1989):

Analyte	Concentration (mg/kg)*
Alkalinity as $CaCO_3$	9,900 - 123,000
pH	8.07 - 9.88
Chloride	6 - 20
NH_3-N	5 - 16
NO_2-N	0.48 - 978
NO_3-N	62 - 5,250
Total P	418 - 890
Cadmium	1.9 - 3.5
Calcium	66,500 - 133,000
Chromium	80.8 - 976
Copper	36 - 624
Lead	95 - 112
Magnesium	5,520 - 15,300
Manganese	134 - 215
Mercury	0.633 - 0.44
Nickel	37 - 281
Potassium	421 - 1,410
Zinc	83.8 - 844

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*Milligrams per kilogram for all analytes except pH.

Soil and rock borings completed in the vicinity of the SWMU 8 area as part of a hydrogeologic investigation (USACE, 1981) indicated the presence of two major lithologic units--unconsolidated sand with some gravel and clay lenses overlying limestone/dolostone bedrock.

The consolidated deposits, which thicken away from the river, consist primarily of fine- to coarse-grained, yellowish-brown sand varying in thickness between 14 and 30 feet. Zones of large cobbles (river jack) are present, but are not as common as found at other sites at RAAP. Silty brown clay lenses found at the land surface may represent recent deposition during flood events.

Underlying the sand unit is the gray limestone/dolostone of the Elbrook Formation. At SWMU 8, the gray limestone/dolostone is highly argillaceous. An extensive bed of mudstone appears to run between borings D-1 and D-6. The limestone/dolostone itself is highly fractured and fragmented. Up to 21 feet of material of the Elbrook Formation was penetrated during the 1980 boring program. A total of 29 field and laboratory permeability tests were performed during the investigation. The reported permeability for the unconsolidated material ranges from less than 3.28 x 10^{-6} centimeters per second (cm/sec) to 1.37 x 10^{-2} cm/sec. The lowest permeabilities are found in clay and silt lenses of the unit, and the highest permeabilities are found in the gravel. Seven in situ permeability tests were conducted on material of the Elbrook Formation. The average permeability of the limestone/dolostone is 8.42 x 10^{-3} cm/sec with a range from 1.73 x 10^{-4} to 2.08 x 10^{-2} cm/sec. These data support the observation that the formation is highly fractured, and it is likely that groundwater flows through these channels with virtually no restriction.

The water table at this unit is found at a depth ranging from 10 to 23 feet below ground surface. Groundwater flow is essentially toward the New River. The available data indicate that the water table may also slope toward Stroubles Creek on the east side of SWMU 36 (USACE, 1981). Eight monitoring wells were installed in the vicinity of SWMU 8 as part of the 1980 hydrogeologic evaluation (USACE, 1981). Well locations are shown in Figure 2-7. Analyses on samples collected from these wells indicated that groundwater quality at the unit was potentially degraded, though a direct attribution to the two settling basins was not made. Analyses for inorganic constituents indicated that three of the four background wells (D-1, D-2, D-3) produced water exhibiting concentrations above recommended drinking water standards for at least one of the following parameters--nitrates, iron, manganese, fluoride, or TDS (USACE, 1981). Likewise, monitoring wells placed between the impoundments and the New River (D-3, D-5, D-6, and D-7) exceeded drinking water standards for at least one of the following--nitrate, sulfate, fluoride, iron, manganese, or TDS. TDS and sulfate levels were generally higher in the downgradient wells, which may reflect the calcium sulfate drying beds to the east and west of the lagoons, but iron concentrations decreased as the groundwater moved beneath the impoundments.

Although organic constituents detected in groundwater samples collected from SWMU 8 wells have included chlorinated solvents such as 1,1-dichloroethane, methylene chloride, l,l,l-trichloroethane, chloroform, l,l-dichloroethylene, and trichloroethylene; plasticizers such as bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate; and volatile organics such as benzene and toluene, all organics except methylene chloride were detected at concentrations near or below the available recommended drinking water and ambient water quality standards, or Suggested No Adverse Response Levels (SNARLS) (USACE, 1981).

A 1984 investigation was conducted at SWMU 8 as part of a groundwater quality and unit assessment study of six SWMUs and a petroleum, oil, and lubricant (POL) spill area at RAAP (USACE, 1984). Groundwater monitoring data from the existing wells indicated that the concentrations of nitrate plus nitrite and sulfate, and specific conductivity levels varied over a considerable range between the wells. Concentrations of these constituents were generally lower in samples collected from two of the three upgradient wells than in the downgradient well samples. The third upgradient well showed concentrations similar to those found in the three downgradient wells.

SWMU 9, Calcium Sulfate Settling Lagoons (C-Line Nitrocellulose Wastewater), consists of two below-grade, unlined earthen lagoons located in the northwest area of the manufacturing facility (Figures 2-3 and 2-8). Each rectangular lagoon is approximately 150 feet long by 75 feet wide, and 8 to 10 feet deep. Operation of these currently active lagoons began in 1950-1953 during the Korean War (USACE, 1981). The lagoons are operated on an alternating basis to accommodate maintenance and dredging activities. The sludge drying beds adjacent to SWMU 9 are SWMU 37, SWMU 38, and SWMU Q.

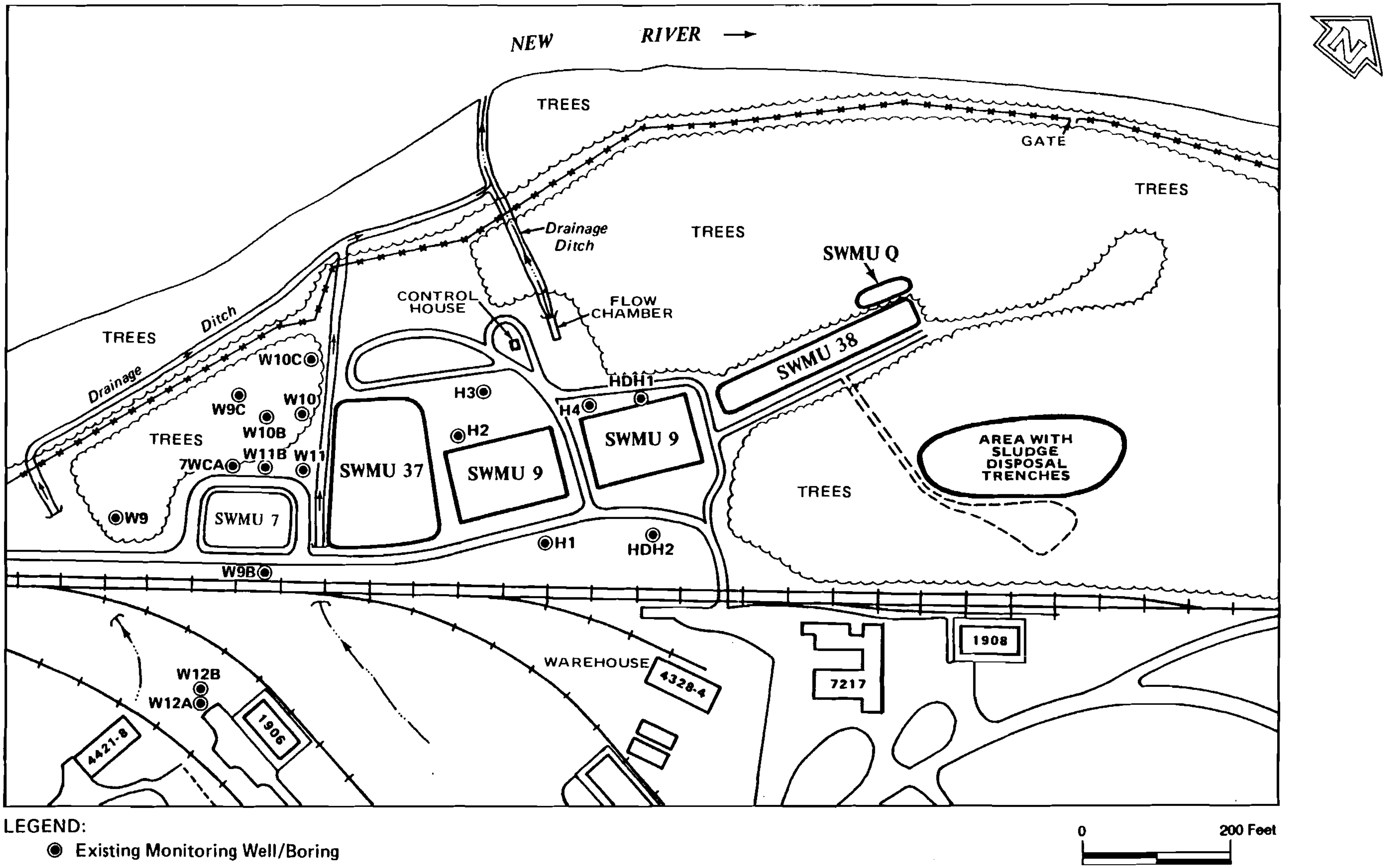
SWMU 9 receives neutralized, formerly acidic wastewater from the C-Line Acidic Wastewater Treatment Plant (SWMU 20). The neutralization process that takes place at the treatment plant is similar to the process occurring for A-B Line Wastewater prior to entering SWMU 8.

The wastewater containing the calcium sulfate is gravity-fed into SWMU 9 via an underground process sewer pipe. The wastewater then flows through a series of weir gates in the lagoons, causing the calcium sulfate to precipitate out and settle to the bottom of the lagoons as a sludge. The water is discharged to the New River via NPDES Outfall 005 (Permit No. VA 0000248), adjacent to the unit. Similar to SWMU 8, the calcium sulfate sludge is dredged from the lagoons on a periodic basis (approximately once every 5 to 7 months) and placed in adjacent drying beds (SWMUs 37, 38, and Q). After drying, the sludge is removed from the beds; since 1982, it has been disposed of in Fly Ash Landfill No. 2 (SWMU 29). Prior to 1982, the sludge was disposed of in Fly Ash Landfill No. 1 (SWMU 26) and the Calcium Sulfate Landfill (SWMU 27), as well as in the locations described in Section 2.2.2.3.

Soil and rock borings completed at the SWMU 9 Area during a hydrogeologic investigation conducted in 1980 (USACE, 1981) indicated the presence of two major lithologic units--unconsolidated sand and gravel with clay lenses overlying limestone/dolostone bedrock.

The unconsolidated deposits consist primarily of fine- to coarse-grained, yellowish-brown sand that is approximately 30 feet thick. With depth, large cobbles (river jack) become more dominant in the unit, and lenses of brown, silty clay are more dominant in the upper part of the unit.

Underlying the sand and gravel unit is the gray limestone/dolostone of the Elbrook Formation. The bedrock is highly argillaceous, and a large mudstone unit--



LEGEND:

● Existing Monitoring Well/Boring

FIGURE 2-8
SWMU 9 – CALCIUM SULFATE SETTLING LAGOONS
SWMUs 37 AND 38 – CALCIUM SULFATE DRYING BEDS
SWMU Q – CALCIUM SULFATE DRYING BED
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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which generally trends between borings H-1 and H-3--is present. The limestone/dolostone is moderately weathered and fractured. Up to 17 feet of bedrock was penetrated during the boring program.

A total of 16 field and laboratory permeability tests were performed by the USACE to determine the ability of the earth material at SWMU 9 to transmit fluids. The unconsolidated material exhibited a permeability ranging from 1.5 x 10^{-5} to 7.8 x 10^{-3} cm/sec, with an average of 6.45 x 10^{-4} cm/sec. Although the permeability appears to be low considering the prevalence of sand and gravel beneath the SWMU 9 Area, the unit is poorly sorted, which may result in filling of the large pore spaces by fine-grained silt and clay, thus decreasing permeability.

Only three permeability tests were performed for limestone/dolostone material. Permeabilities range from 1.85 x 10^{-3} to 8.05 x 10^{-3} cm/sec, with an average value of 5.90 x 10^{-3} cm/sec. Two cation-exchange capacity (CEC) tests were performed by the USACE on unconsolidated sediments at the SWMU 9 Area. The samples tested were silty sand and clayey silt, with CEC values of 8.3 millequivalents (meq)/100 grams (gm) and 9.0 meq/100 gm of soil, respectively.

The water table at the SWMU 9 Area is found generally along the bedrock surface, at a depth of 26 to 29 feet below ground surface. The water table, as indicated by the limited data available, appears to be virtually flat. Although it appears that the water table may be about 0.5 foot higher immediately beneath the impoundments in comparison with other monitor wells, the presence of a water table mound cannot be confirmed. The water table elevation is highest at H-4, which is immediately adjacent to the discharge line from the impoundments (which could be leaking).

Available water level data indicate that when water levels in the New River are altered by releases from the dam upstream of RAAP, the water table fluctuates accordingly. The groundwater flow in the vicinity of the SWMU 9 Area would be toward the New River, because there is no major point of groundwater discharge inland from the river that would reverse hydraulic gradients (USACE, 1981).

In 1980, six monitoring wells were installed at the SWMU 9 Area as part of the hydrogeologic evaluation (USACE, 1981). Well locations are shown in

Figure 2-8. Analyses on samples collected from these wells indicated that groundwater quality at the unit was potentially degraded, though a direct attribution to the two settling basins was not made. Analyses for inorganic constituents indicated that downgradient monitoring wells H-2, H-3, and H-4 yielded water that exceeded drinking water standards for at least four of the following parameters--fluoride, nitrate, lead, manganese, sulfate, or TDS. H-1, an upgradient well, exceeded the standards for both fluoride and TDS. Water collected from wells between the impoundments and the river showed higher concentrations of manganese, sulfate, and dissolved solids in comparison with water in the well (H-1) that is located inland from the impoundments. The fluoride concentrations decreased in downgradient wells. Nitrate levels were higher in the wells closest to the lagoons. It is possible that the high TDS and sulfate concentrations reflected the past disposal of calcium sulfate to the northeast.

The samples collected from monitoring wells in the vicinity of SWMU 9 included chlorinated solvents such as chloroform and methylene chloride; plasticizers such as bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate; the wood preservative pentachlorophenol; volatile organics such as benzene and toluene; and heavy organics such as anthracene and phenanthrene. The monitoring well inland from the impoundments (H-1) showed the highest number of organic constituents.

A 1984 investigation was conducted at the SWMU 9 Area as part of a groundwater quality and unit assessment study of six SWMUs and a POL spill area at RAAP (USACE, 1984). The investigation used existing wells for collection of samples and groundwater data.

Groundwater monitoring data from the SWMU 9 Area wells indicated the potential for groundwater contamination. Elevated concentrations of nitrate, sulfate, chlorides, sodium, total organic carbon, specific conductance, and chlorinated hydrocarbons were detected in all downgradient wells and in wells intended to be upgradient. It was not clear whether the higher concentrations detected in the upgradient wells were due to a local reversal in the gradient (away from the river and toward the upgradient wells) as a result of mounding or to sources located further upgradient. One report (USACE, 1981) also stated that past waste disposal practices at the SWMU may be the source of the higher concentrations.

2.2.2.2 Calcium Sulfate Drying Beds--SWMUs 35, 36, 37, 38, and Q. SWMUs 35 and 36, Calcium Sulfate Drying Beds (Northeast Section), are located along the New River in the northeast section of the Main Manufacturing Area (Figure 2-3). SWMU 35 is located immediately west of and adjacent to SWMU 8 (Calcium Sulfate Settling Lagoons); this drying bed has been previously described as "an abandoned lagoon (mud)" (USACE, 1981). SWMU 36 is located immediately east of and adjacent to SWMU 8. The drying beds were excavated into the natural grade and are unlined. Approximately once every 5 to 7 months, calcium sulfate sludge is dredged from SWMU 8 and pumped into one of the drying beds to dehydrate. After drying, the sludge is removed for disposal. Since 1982, the sludge has been disposed of in FAL No. 2 (SWMU 29). Prior to 1982, the sludge was disposed of in various locations at RAAP, as described in Section 2.2.2.3.

SWMU 36 consists of three separate drying beds (Figure 2-7), apparently of different ages. Based on a review of aerial photography and the February 1990 initial facility visit, the northernmost bed (closest to the New River) appears to be the original drying bed. To the south of this bed is apparently the second oldest bed. These two beds are approximately 40 to 50 feet wide, 200 feet long, and 10 to 15 feet deep. At the time of the February 1990 facility visit, sludges were being excavated from these two beds for disposal in FAL No. 2 (SWMU 29). The easternmost bed is the drying bed in current use. It is about 60 feet wide by 200 feet long. At the time of the February 1990 facility visit, this bed was filled with liquid that had been pumped from the Calcium Sulfate Settling Lagoons.

Analysis performed on a sludge sample collected from the Calcium Sulfate Settling Lagoons (SWMU 8) indicated that the sludge does not meet any of the four hazardous waste characteristics as outlined in 40 CFR 261.34. However, there is concern that the sludge contains some organic compounds used in manufacturing activities at RAAP (USACE, 1981). The potential, therefore, exists for contamination of groundwater and soil (beneath the beds) by volatiles and semivolatiles.

SWMUs 37 and 38, Calcium Sulfate Drying Beds (Northwest Section), are located along the New River in the northwest section of the RAAP Main Manufacturing Area (Figure 2-7). SWMU 37, about 80 feet wide by 100 feet long, is located immediately southwest of and adjacent to SWMU 9 (Calcium Sulfate Settling Lagoons). SWMU 38, about 40 feet wide by 225 feet long, is located immediately northeast of and adjacent to SWMU 9 (Figure 2-8). The units are excavated into the natural grade and are unlined. The depth of each unit is assumed to be 6 to 8 feet (USACE, 1987). Immediately northwest of and adjacent to SWMU 38 is SWMU "Q" (Figure 2-8). This abandoned lagoon was reported to be another sludge drying bed that was used when SWMU 38 was full. Sludge was pumped from SWMU 38 to "Q" via pipes that ran through a depression in the berm surrounding the drying bed.

As with SWMUs 8, 35, and 36, calcium sulfate sludge is dredged from SWMU 9 on a periodic basis and pumped into one of the drying beds to dehydrate. After drying, the sludge is removed for disposal. Since 1982, the sludge has been disposed of in FAL No. 2 (SWMU 29). Prior to 1982, the sludge was disposed of at various locations at RAAP, as described in Section 2.2.2.3.

The sludge present in these units is assumed to have the same characteristics as that in SWMU 8, the Calcium Sulfate Settling Lagoons, as described in Section 2.2.2.1.

2.2.2.3 Calcium Sulfate Sludge Disposal Areas--SWMU 50 and Trench Area Near SWMU 38. As discussed previously, calcium sulfate sludge has been disposed of in various locations throughout RAAP, including Fly Ash Landfills Nos. 1 and 2 (SWMUs 32 and 29) and the Calcium Sulfate Landfill (SWMU 27). Another disposal area, SWMU 50 (Calcium Sulfate Disposal Area), was reported by USEPA to be located in the Horseshoe Area approximately 3,400 feet east of the main New River bridge. The unit was reported to be contiguous to SWMU 48 (Oily Wastewater Disposal Area) and SWMU 49 (Red Water Ash Disposal Area), with no distinction possible by visual observation (USEPA, 1987). However, based on a review of historical aerial photographs and an interview with plant personnel, it has been determined that sludge disposal occurred in an open area south of SWMU 48 (see Section 2.2.1.5, Figure 2-20). The unit is approximately 300 feet by 300 feet in size. Until 1982, this was the major disposal area at RAAP for calcium sulfate sludge removed from the calcium sulfate drying beds (SWMUs 35, 36, 37, 38, and Q). An estimated 60 tons of sludge were reportedly disposed of in this unit.

In addition to SWMU 50, another sludge disposal area was identified during the March 1990 facility visit. In a wooded area located west of and adjacent to SWMU 38 (Figure 2-8), trenches were used for the disposal of an unknown quantity of sludge. This area was previously identified as the location of SWMU 45. There is evidence that indicates SWMU 45 is located 800 feet northeast of this area, as discussed in Section 2.2.1.2.

Of concern at SWMU 50 and the two additional sludge disposal areas is potential groundwater contamination.

2.2.3 Biological Treatment Plant Equalization Basin--SWMU 10

This unit, located along the New River in the north-central part of the main plant area (Figure 2-3), is the first of nine components that make up the biological treatment system at RAAP. This system treats wastewaters of widely varying characteristics, including nonacidic wastewaters from propellant manufacturing (on both a batch and continuous basis), pretreated wastewaters from nitroglycerine manufacturing and alcohol rectification, and wastes from the recovery of ethyl ether (USEPA, 1987). The biological treatment system was built in 1978/1979 and became operational in 1980. Prior to 1980, these wastewaters were discharged directly to the New River.

This unit was reportedly constructed on top of an NC fines settling lagoon (USACE, 1981). The lagoon was approximately 200 feet by 100 feet in size and surrounded by a 7-foot-high dike. The lagoon was filled with very soft, wet NC fines. According to construction plans for the equalization basin, the fines were removed prior to construction of the basin.

The equalization basin is approximately 160 feet wide by 255 feet long, located adjacent to and east of SWMU 35 (Figure 2-9). Based on the design capacity of 1,350,000 gallons, the depth of the basin is calculated to be approximately

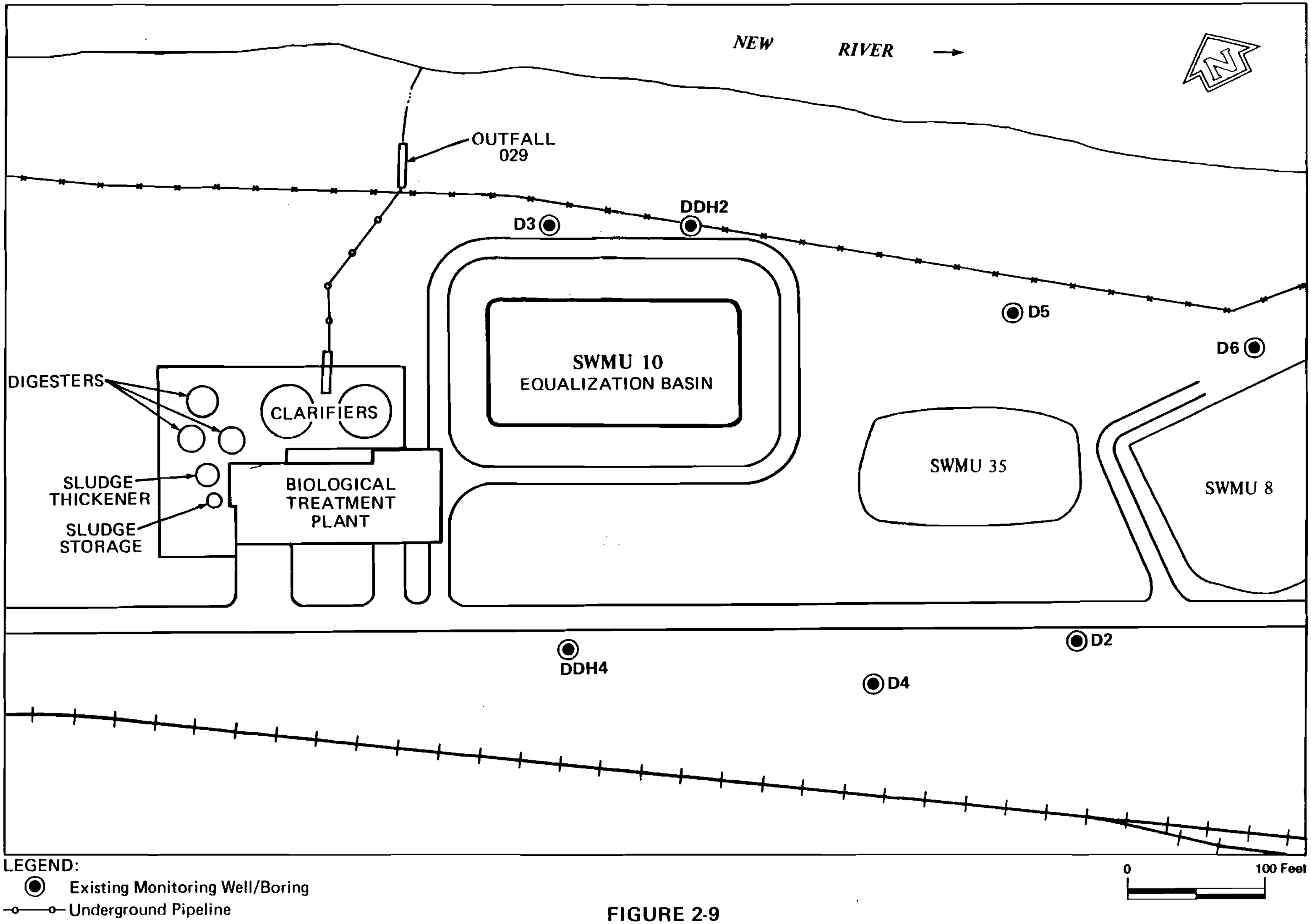

FIGURE 2-9
SWMU 10 – BIOLOGICAL TREATMENT PLANT EQUALIZATION BASIN
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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15 feet. The containment walls are constructed of concrete, and the basin is lined with a soil/cement/clay liner. The unit was expanded to its current dimensions since original construction. The basin's northern and eastern outside embankments are reinforced with rip-rap. Suspended polymeric dividers accommodate aeration/equalization and divide the basin into three compartments. According to the plant operator interviewed during the March 1990 facility visit, the basin has never overflowed. Operating procedures are such that influent flows are cut off if the basin capacity is reached.

The eastern and central compartments of the basin are each equipped with two surface aerators. The western compartment is equipped with a subsurface jet injection-type aerator. From the equalization basin, the wastewater is pumped at a constant rate to the biological treatment system. As originally designed, the biological treatment system consisted of two parallel trains of six rotating biological contactors (RBCs). The first two RBCs in each train were designed to operate anaerobically; the remaining four units were to operate aerobically. Following startup, it was discovered that the anaerobic RBCs were hindering plant performance, and they were subsequently converted to aerobic RBCs. At present, the plant is operating with 12 aerobic RBCs on-line. These units have a total surface area of 611,200 square feet. The RBCs are run as three-stage systems, with the first two RBCs in each train operated as a single stage (USEPA, 1987).

From the RBC trains the wastewater flows to two circular, center-feed, peripheral weir clarifiers. Clarified effluent is discharged to the New River at NPDES Outfall No. 029.

Sludge handling consists of aerobic digestion, chemical conditioning, and belt press dewatering. The three digesters (83,000 gallons each) are maintained at about 75 percent of capacity to prevent overflows. The sludge from the digesters is a listed hazardous waste (K044, sludge from the treatment of wastewater from explosives manufacturing) (USAEHA, 1980). Prior to February 1990, the sludge was landfilled in Fly Ash Landfill No. 2 (SWMU 29); at present, it is containerized and shipped to an off-post hazardous waste landfill.

Sludge samples from the treatment plant were analyzed on at least two occasions. In 1982, it was determined that the sludge was nonexplosive and relatively inert (USEPA, 1987) In addition, NG concentrations were below detection, and nitrocotton was less than 0.05 percent. Following digestion, the sludge contained 90 percent organic material in the ratio 5C:7H:2O:1N. The remaining 10 percent consisted of inorganic oxides of phosphorus, sulfur, sodium, calcium, magnesium, potassium, and iron.

In 1983, laboratory results indicated that a sample of basin sludge contained 0.01 percent NG, 69.0 percent silicon dioxide, 6.3 percent moisture, 1.3 percent iron oxide, 0.03 percent lead, and 0.01 percent copper. Test results for hazardous waste characteristics on a sludge sample collected from the plant are as follows (USEPA, 1987):

- EP Toxicity (mg/l):
    - Silver <0.1
    - Arsenic 0.008
    - Barium 0.9
    - Cadmium <0.1
    - Chromium <0.1
    - Mercury 0.0009
    - Lead 0.1
    - Selenium 0.010
- Ignitability: Not ignitable at 60°C
- Corrosivity: Not corrosive
- Reactivity: Not reactive.

In 1989, sludge samples were analyzed, with the following results (Olver, 1989):

- pH 7.18
- Total solids 7.5%
- Organic matter 76% of total solids
- Alkalinity as $CaCO_3$ 7,740 mg/kg
- Chloride 26 mg/kg

NH_3-N	1,180 mg/kg
NO_3	2.8 mg/kg
NO_2	0.30 mg/kg
TKN-N	6,580 mg/kg
Total P	524 mg/kg
Boron	15 mg/kg
Cadmium	5.1 mg/kg
Calcium	14,300 mg/kg
Chromium	160 mg/kg
Copper	1,535 mg/kg
Lead	8,100 mg/kg
Magnesium	7,270 mg/kg
Manganese	280 mg/kg
Mercury	0.75 mg/kg
Nickel	61 mg/kg
Potassium	1,350 mg/kg
Zinc	1,280 mg/kg.

Due to the proximity of SWMU 10 to the Calcium Sulfate Settling Lagoons directly to the east (SWMU 8), both units were investigated as one site (Site "D") in 1980 (USACE, 1981). The geology described for the SWMU 8 Area in Section 2.2.2.1 applies to SWMU 10 because of the proximity of the two areas. Likewise, monitoring wells installed by USACE in 1980 at Site "D" provide groundwater data representative of both SWMUs 8 and 10. Samples collected from these wells indicated elevated levels of sulfate (as SO_4) and nitrate (as N) in downgradient wells (USACE, 1981).

The equalization basin is of concern due to the possibility of leakage of hazardous constituents through the soil/cement/clay liner.

2.2.4 Fly Ash Landfill No. 1 (FAL No. 1)--SWMU 26

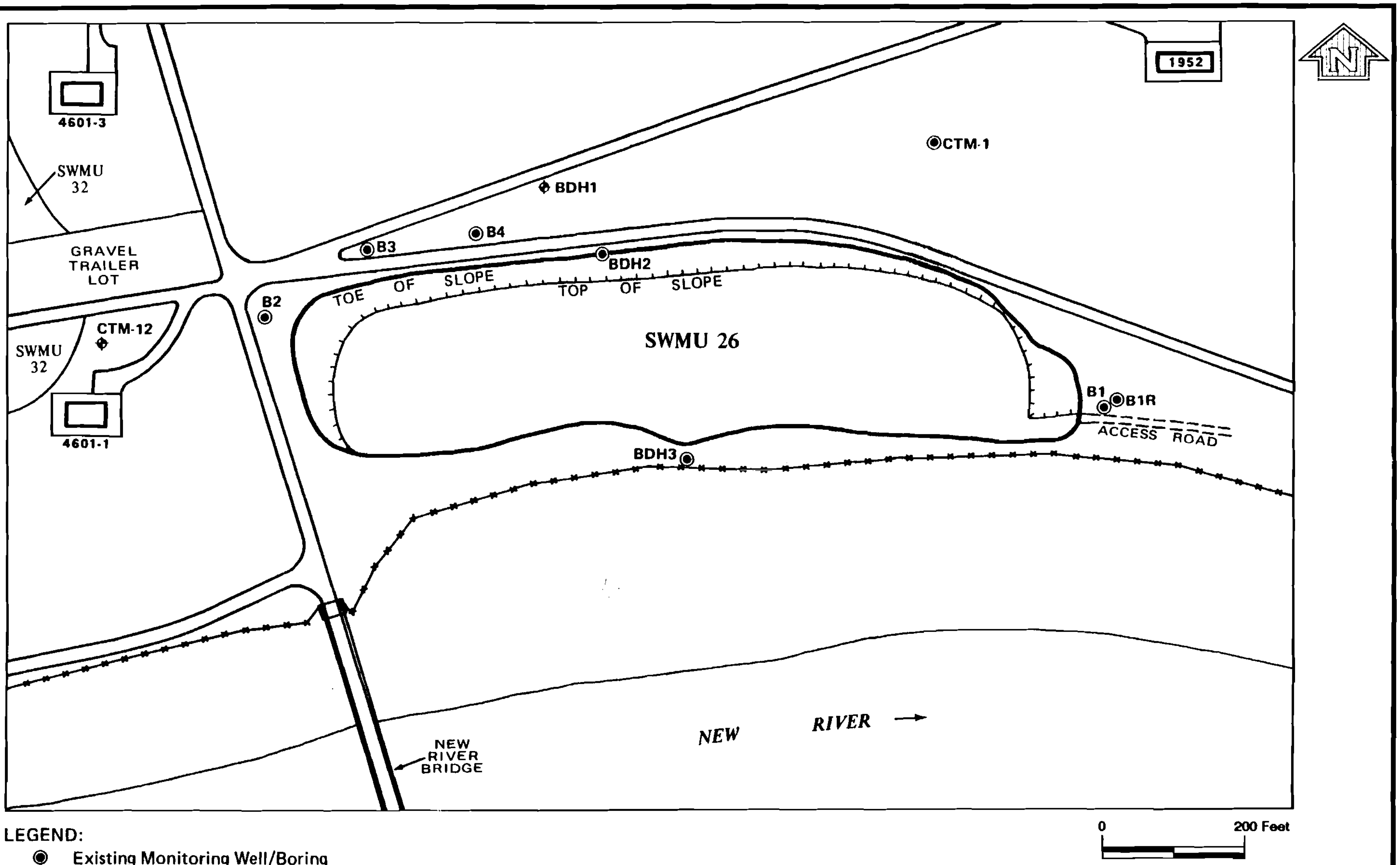
This unit is a closed, unlined landfill located in the south-central section of the Horseshoe Area, about 600 feet east of the main bridge over the New River (Figure 2-3). It is situated on the north slope of an east-west trending ridge that rises more than 700 feet above the river. The highest point on the landfill has an elevation of more than 1,850 feet msl, from which the land surface naturally slopes north and south. The landfill was formed by excavating a deep, flat-bottomed pit, primarily into the north sloping portion of the ridge (USACE, 1981). The unit is approximately 1,100 feet long and 200 to 250 feet wide (Figure 2-10).

Fly ash disposal at SWMU 26 began in 1971 (USATHAMA, 1984). Prior to 1971, fly ash was discharged directly to the New River. The Virginia Department of Health granted a solid waste management permit (Permit No. 399) to operate the landfill in April 1983. The permit specified that the landfill could receive "fly ash and bottom ash wastes from powerhouses 1 and 2 on the plant premises." The permit did not allow the disposal of asbestos or hazardous waste at the landfill. However, in addition to fly ash, unknown quantities of calcium sulfate sludge (from SWMUs 35, 36, 37, and 38) and asbestos were reportedly disposed of in the landfill (USEPA, 1987). During the active life of the unit, 60 to 100 tons/day of fly ash were reportedly disposed of in the landfill (USATHAMA, 1984). The landfill reached capacity and was closed in mid-1985.

In 1980, seven monitoring wells and one boring were completed around SWMU 26 as part of a hydrogeologic evaluation of four SWMUs at RAAP (USACE, 1981). In 1988, one well (CTM-1) and one boring (CTM-12) were completed near SWMU 26 as part of a landfill siting investigation (CTM, 1988). Well and boring locations are presented on Figure 2-10.

Soil and rock borings completed at SWMU 26 indicated the presence of two major lithologic units--unconsolidated sand and gravel with some clay lenses overlying limestone/dolostone bedrock.

The unconsolidated deposits consist primarily of fine- to coarse-grained, yellowish-brown sand that varies between 30 to 86 feet in thickness at borings B-4 and B-1-R, respectively. Several major lenses of large cobbles (river jack) are found throughout the unit. An areally extensive clay unit was encountered above the sand in borings completed to the north of the landfill. The material is characterized as a silty-to-gravelly, red-brown, plastic clay that may represent a talus-type deposit



LEGEND:

- ◉ Existing Monitoring Well/Boring
- ⊕ Existing Boring

FIGURE 2-10
SWMU 26 – FLY ASH LANDFILL No. 1
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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from the highland area to the south. The clay unit appears to have been removed from the landfill during construction.

Underlying the sand and gravel unit is the gray limestone/dolostone of the Elbrook Formation. The unit is highly fractured and fragmented with breccia, vugs, and solution channels, but may be massive for short intervals. Many of the fractures have been totally or partially filled with calcite, and many others have been filled with clay and fine sand. Borings were completed as much as 62 feet into the limestone/dolostone bedrock.

A total of 34 field and laboratory permeability tests were conducted by USACE to determine the ability of the earth material at FAL No. 1 to transmit fluids. The unconsolidated material exhibits an average permeability of 4.06×10^{-3} cm/sec, with a range between 2.8×10^{-6} and 1.09×10^{-2} cm/sec. The lower permeabilities (2.8×10^{-6} cm/sec and 1.3×10^{-5} cm/sec) were found in the clay lenses of the unit. Average permeability of the sand and gravel sections of the unit is 6.62×10^{-3} cm/sec, with a range between 3.00×10^{-4} and 1.09×10^{-2} cm/sec. The results of in situ permeability tests performed on the limestone/dolostone indicated an average permeability of 2.85×10^{-5} cm/sec.

Considering the high level of fracturing encountered in the limestone beneath SWMU 26, it can likely be assumed that there are open channels in the rock through which fluids flow with virtually no restrictions. In these flow channels, permeability could be considered to be almost limitless.

Three CEC tests were performed by USACE on selected samples of the unconsolidated material at FAL No. 1. All samples tested were silty-to-sandy in nature and exhibited a CEC between 6.1 and 10.7 meq/100 gm of soil.

The water table at the SWMU 26 Area is found within the limestone/dolostone bedrock from 73 to 81 feet below land surface (except at well B-1-R, where the depth to water is 132 feet). The water table should slope both north and south away from the east-west ridge immediately south of SWMU 26, but available data are sufficient to describe only the northward flow system.

Analyses on samples collected from four monitoring wells indicated that groundwater quality at the landfill, as indicated by TDS, was below the Secondary Drinking Water Standard of 500 mg/l. TDS ranged from 265 to 480 mg/l in the four samples collected from wells at the SWMU.

Review of the analyses performed for characterizing inorganic constituent concentrations suggested that water quality impacts from the landfill were minimal. Samples from one downgradient well (B-4) exhibited fluoride levels above the recommended drinking water standards. However, samples from the upgradient well (B-1-R) showed both fluoride and iron concentrations to be above these same standards.

The organics detected during 1981 sampling include 4-nitrophenol; chlorinated solvents such as chloroform and methylene chloride; plasticizers such as bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, and butyl benzyl phthalate; and volatile organics including benzene and toluene. All organics, except methylene chloride (a typical laboratory artifact), were found at levels near or below the available accepted drinking water and ambient water quality standards, and SNARLS. The data were determined to be inadequate to determine whether a direct relationship existed between the source of these organic contaminants and the landfill.

The environmental concern at FAL No. 1 is the potential for groundwater contamination by metals, volatiles, and semivolatiles.

2.2.5 Calcium Sulfate Landfill, Fly Ash Landfill No. 2, and Activated Carbon Disposal Area--SWMUs 27, 29, and 53

2.2.5.1 Calcium Sulfate Landfill--SWMU 27. The Calcium Sulfate Landfill is a closed, unlined earthen landfill located in the southeastern section of the Horseshoe Area (Figure 2-3). It is located within the boundary of Fly Ash Landfill No. 2 (SWMU 29) (Figure 2-11). The landfill was used for disposal of calcium sulfate sludge during 1981 and 1982. The landfill has been described as triangular-shaped and is approximately 150 feet long. Since disposal operations ceased, the unit has been completely covered by ash.

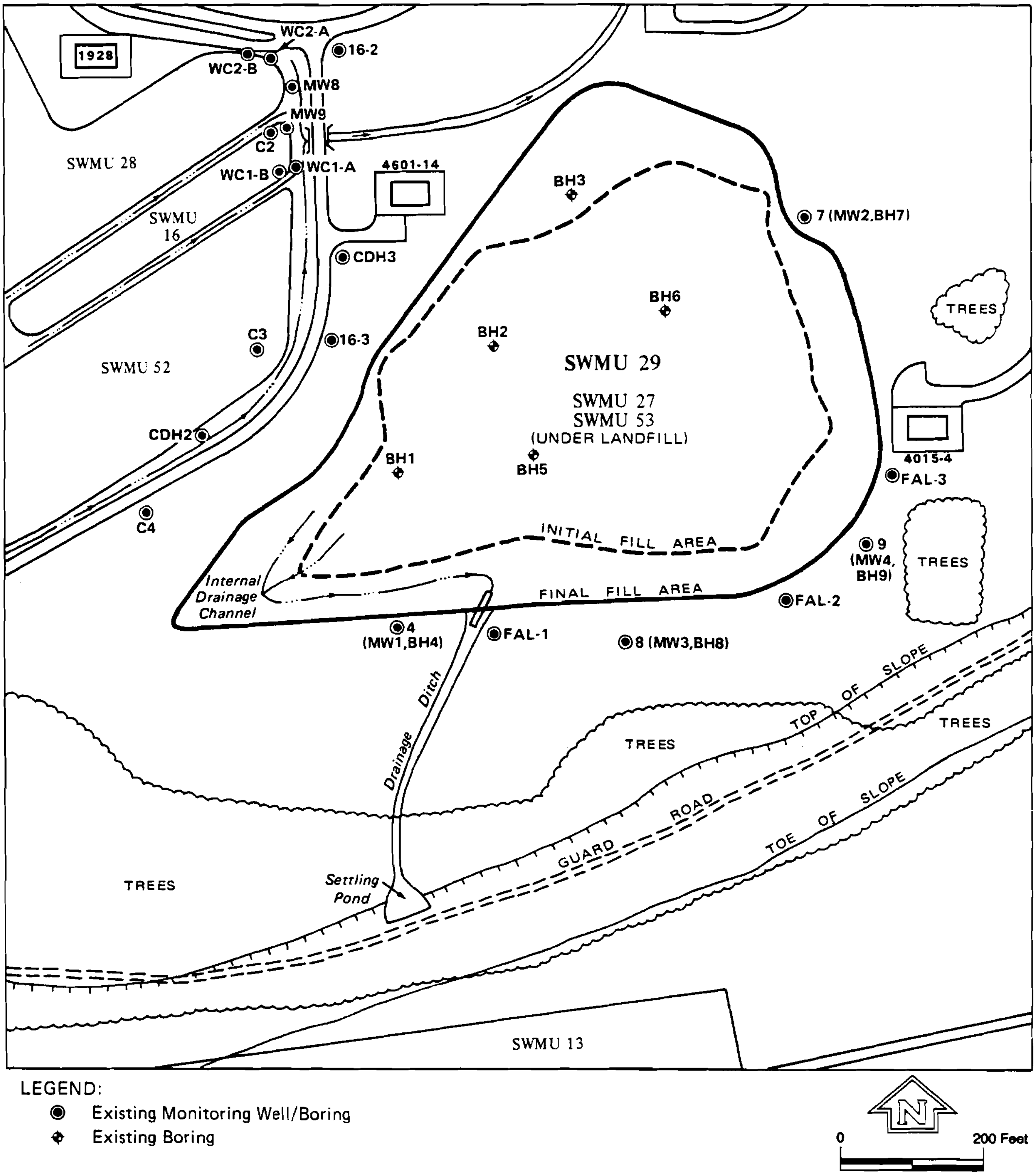

FIGURE 2-11
SWMU 29 – FLY ASH LANDFILL No. 2
SWMU 27 – CALCIUM SULFATE LANDFILL
SWMU 53 – ACTIVATED CARBON DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

The sludge disposed of in this unit was generated from the neutralization of sulfuric acid at the A-B Line and C-Line acidic wastewater treatment plants (Section 2.2.2). Analyses of sludges from these plants (not collected from the landfill itself) indicated that they did not meet any of the four hazardous waste characteristics as outlined in 40 CFR 261.34. However, there is concern that such sludges contain some hazardous constituents used in the manufacturing activities at RAAP (USEPA, 1987; USACE, 1981).

The 1987 RCRA Facility Assessment (USEPA, 1987) states that results of groundwater samples from the monitoring wells installed in the vicinity of the Calcium Sulfate Landfill were indicative of groundwater contamination. The locations and specific analytes and concentrations of samples from these wells were not detailed in this report. Due to the contiguous location of the Calcium Sulfate Landfill (SWMU 27) and both the Activated Carbon Disposal Area (SWMU 53) and the Closed Sanitary Landfill (SWMU 52), this reported groundwater contamination cannot be directly attributed to SWMU 27.

2.2.5.2 Fly Ash Landfill No. 2--SWMU 29. Fly Ash Landfill No. 2 (FAL No. 2) is an active, unlined earthen landfill located in the southeast section of the Horseshoe Area. It is approximately 200 feet east of the Closed Sanitary Landfill (SWMU 52) (Figures 2-3 and 2-11).

A land disposal study was conducted in 1980 to determine the suitability of the site for the landfill (USAEHA, 1980b). Nine boreholes were drilled and four monitoring wells were installed; these locations are shown on Figure 2-11. A hydrogeologic interpretation of subsurface data, taken from published sources, onsite drilling and soil sampling, and subsequent laboratory analysis of soil samples, indicated that the site was geologically viable for ash landfill operations. The Fly Ash Landfill No. 2 was constructed in October and November 1981. The 10-acre unit was permitted by the Virginia Department of Health in May 1982 (Permit No. 353) as an industrial waste landfill that could receive "fly ash, calcium sulfate sludge, and sludge from water treatment plants" (Va DOH, 1982).

The topography of the Horseshoe Area is characterized by three prominent terraces and escarpments that are remnants of ancient New River flood plains.

FAL No. 2 occupies the eastern middle terrace flat and the escarpment face of the upper terrace in the horseshoe meander loop. Surface drainage of FAL No. 2 is to the east and then south via a small gully that flows to the Waste Propellant Burning Ground (SWMU 13). A settling pond was constructed upgradient of SWMU 13 so that runoff should not enter the unit.

The geology of SWMU 29 is represented primarily by an overburden of New River alluvium composed of reddish-brown, micaceous clays and silts, with lenses of sandy silts interspersed about the perimeter of the unit. Also evident are some thin lenses of river jack (sporadic cobbles and boulders) (USAEHA, 1980b). Boring logs indicate that the depth of overburden ranges from 17 to 49 feet.

Drilling revealed that a low-yield groundwater table is present beneath the landfill near the interface of the overburden and the weathered Elbrook Formation. The groundwater table is recharged by local precipitation percolating through the unconsolidated overburden.

The monitoring wells were not properly developed or were completed above the water table, resulting in two wells (MW1 and MW4) being dry after installation. Samples were collected from MW2 and MW3 for laboratory analysis. The specific conductance measured in MW2 was 847 umhos/cm, slightly above the USEPA-recommended concentration limit of 800 umhos/cm for drinking water. TDS for MW2 was 522 mg/l, slightly above the USEPA-recommended concentration of 500 mg/l. The pH of samples from both wells was 8.45, attributed to the carbonate bedrock. Both samples showed cadmium concentrations (0.022 mg/l and 0.005 mg/l) that exceeded Virginia standards of 0.0004 mg/l for groundwater. Other metals detected were zinc, copper, lead, sodium, magnesium, calcium, and potassium, all of which were below Virginia and USEPA standards (USAEHA, 1980b).

The quantity and source of refuse disposed of at the landfill (on a daily basis at full plant operation) was estimated as follows in the permit application (Webb, 1982):

Source	Quantity	
	(lb/day)	(yd^3/day)
Bottom ash and fly ash from Powerhouse No. 1	200,000	185
Calcium sulfate from the sulfuric acid regeneration (SAR) treatment plant	150,000	68
Sludge from water treatment plant, Building 409 (SWMU 16)	8,825	4
Sludge from water treatment plant, Building 407 (SWMU 19)	4,928	2.2
Fly ash from Powerhouse No. 2	7,000	6.5

The volumes listed above were based on the bottom ash and fly ash having a density of 40 pounds per cubic foot (lb/ft^3); calcium sulfate having a density of 82 lb/ft^3 at 20 percent solids; and the water treatment plant sludge having a density of 82 lb/ft^3 at 35 percent solids. The quantity of ash may vary depending on the ash content of coal. Theoretically, 6,239 pounds of the ash are used at the water treatment plants for precoating the pressure filters and conditioning the sludge. The remainder is landfilled. Lime can also be used as a precoating and conditioning material at the water treatment plants. When lime is used, the entire amount of ash from Powerhouse No. 2 is landfilled.

The bottom ash from Boiler House No. 2 is not landfilled, but is used as an aggregate on plant roads during icy or snowy weather and for the stabilization of a temporary road at the landfill. The sludge from the water filter plants contains alum and solids that are filtered out of the raw water from the river, and either the lime or ash that is used for precoating and conditioning. All of the above materials are inert and compatible.

Sample analyses of materials landfilled at FAL No. 2 are outlined in Table 2-7 (Olver, 1980).

The permit application presented the operation of the landfill as taking place in two stages of both trench fill and area fill methods. Stage 1 was to consist of the excavation and filling of seven trenches, about 50 feet long and averaging 25 feet deep, and ranging in length from 280 to 720 feet. The direction of fill was to be from east to west. The unit is currently operating in Stage 2, which consists of area filling, in five lifts, of 10-foot layers on top of the previously filled trenches. The direction of fill for Stage 2 is from east to west. During area filling, berms are constructed to control blowing ash. The fourth of the five lifts is currently being filled. A site for a third fly ash landfill is currently being investigated by RAAP to replace this unit, which is nearing capacity.

Daily cover is not required at FAL No. 2 because of the inert characteristics of the wastes being landfilled. The permit requires 2 feet of cover to be placed on each trench or fill area as it is filled. Final cover will consist of at least 2 feet of compacted natural soil, graded to slopes of 3:1 and seeded with grass to retard erosion and minimize rainwater percolation. Runoff will be directed south to a central drainage ditch that coincides with and is effluent to the natural topographic ravine (USAEHA, 1980b).

A pipe, located about 30 feet above the lowest grade of the landfill, extends through the earthen berm and apparently drains surface water from the landfill to a drainage ditch. This ditch drains runoff to a retention pond located approximately 300 feet south of the landfill and north of SWMU 13 (Figure 2-11). Of concern at the drainage ditch and the settling basin is potential soil contamination by metals.

2.2.5.3 Activated Carbon Disposal Area--SWMU 53. The Activated Carbon Disposal Area is located within Fly Ash Landfill No. 2 (SWMU 29) (Figure 2-11). When observed in 1986, the disposal area was described as a 500-foot-long by 50-foot-wide plateau of an unknown height (USEPA, 1987). The date of disposal is unknown; however, based on the operating procedures and age of FAL No. 2, it can be assumed that disposal occurred before October 1981 when SWMU 29 was

TABLE 2-7

Analyses of Samples Landfilled at SWMU 29, Fly Ash Landfill No. 2[a]

Analyte	SAR Treatment Plant Sludge	Water Treatment Plant Sludge	Power House No. 1 Fly Ash	Power House No. 2 Fly Ash
pH	6.5	10.1	5.0	2.6
Total solids	99.7%	60.1%	82.9%	96.7%
Organic matter	16.2%	17.1%	5.8%	2.7%
Chloride	179	1,430	1,400	1,970
Alkalinity as $CaCO_3$	1,900	134,000	3	<1
TKN-N	397	4,450	117	64
NH_3-N	231	383	48	23
Cadmium	6.0	10.0	2.4	8.2
Calcium	140,000	216,000	3,510	9,680
Chromium	10	50	37	66
Copper	4.0	1,280	72.6	185
Lead	16	47	19	119
Magnesium	4,500	4,980	2,420	1,850
Manganese	22	598	54	36
Mercury	0.4	<0.1	1.0	0.8
Nickel	10.0	30.0	60.5	144
Potassium	50	747	3,030	1,030
Zinc	6.8	136	34	309

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[a] With the exception of pH (which has no units), concentrations are in milligrams per kilogram unless otherwise noted.

constructed. Since 1986, the disposal area has been completely covered by subsequent fly ash landfilling operations.

Activated carbon is used in two manufacturing operations at RAAP. In propellant manufacturing operations, activated carbon is used to recover solvents, ethyl alcohol, and ethyl ether. It was reported, but not confirmed, that the activated carbon disposed of at SWMU 53 was from these alcohol recovery units at the propellant manufacturing area (USEPA, 1987).

In TNT manufacturing operations, activated carbon columns in the TNT wastewater treatment plant are used to treat "pink water" (a waste product that is essentially dilute TNT). Spent filter cartridges and carbon from the treatment plant are reportedly burned at the Waste Propellant Burning Ground (SWMU 13) (USATHAMA, 1984).

2.2.6 Coal Ash Settling Lagoons--SWMU 31

This unit is located in the northwest section of the Horseshoe Area (Figure 2-3). The unit has previously been referred to as both the "fly ash settling lagoon" and the "bottom ash settling lagoon." As referenced in the permit (USEPA, 1989), this unit will be referred to as the Coal Ash Settling Lagoons throughout this report, reflecting the probability that both fly ash and bottom ash have been discharged into it. In addition, the flocculating basin underdrainage and filter backwash water from Water Plant 4330 reportedly flowed to this unit (USATHAMA, 1976; Appendix G).

SWMU 31 (Figure 2-12) is associated with Power House No. 2, which burns low sulfur coal to supply steam at 150 pounds per square inch (psi) to the buildings in the Horseshoe Area. No electrical power is generated at this power plant, which is scheduled to be closed according to RAAP representatives. Prior to 1971, when electrostatic precipitators were installed at the power house, fly ash-contaminated wastewater was discharged directly to the New River (USATHAMA, 1984).

SWMU 31 consists of three unlined settling lagoons. Water carrying fly ash from the power house flows down a below-grade, concrete-lined sluice waterway to the primary settling lagoon, which was constructed in about 1962. At one time, the

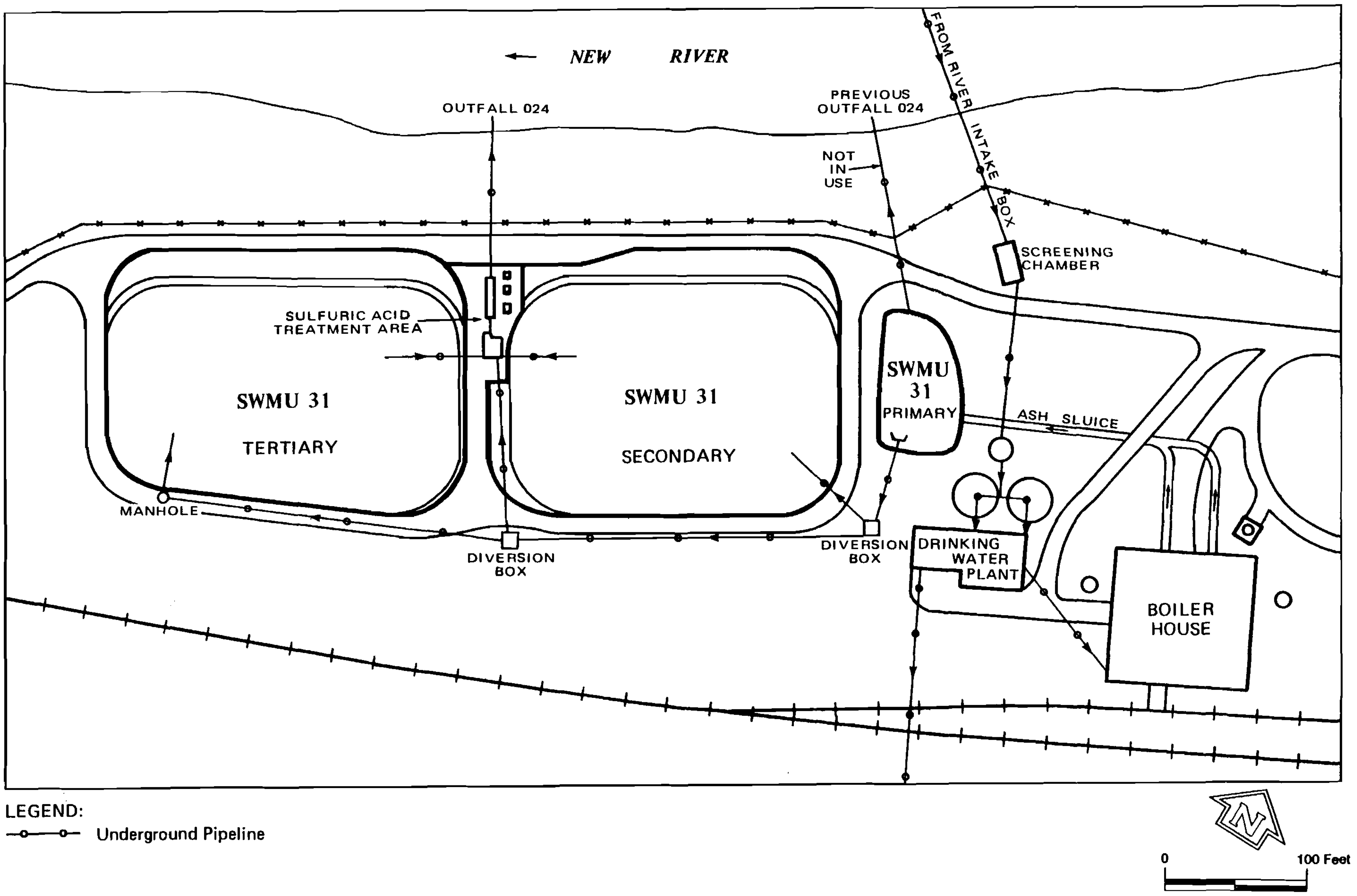

FIGURE 2-12
SWMU 31 – COAL ASH SETTLING LAGOONS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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supernatant from the primary settling lagoon was emptied directly into the New River via Outfall 024 (Permit No. VA 0000248). In 1978 or 1979, additional components were added to the unit; wastewater now flows from the primary settling lagoon through a below-ground pipe to a concrete sump. The sump is 18 to 20 feet deep, 2 feet of which is abovegrade. From the concrete sump, water is discharged to the secondary settling lagoon, which is approximately 150 feet wide by 200 feet long and of an unknown depth. From the secondary settling lagoon, water is discharged to the tertiary settling lagoon.

The effluent from the tertiary settling basin is designed to discharge to the New River via Outfall 024 following pH adjustment with sulfuric acid. However, facility representatives indicate that there has never been a discharge. All water discharged to the basin apparently percolates through the basin into the surrounding soils.

Coal ash that has settled out in the three lagoons is periodically dredged and disposed of in FAL No. 2 (SWMU 29). Previously, it was disposed of in FAL No. 1 (SWMU 26).

Of concern at SWMU 31 is potential soil and groundwater contamination from metals and semivolatiles.

No borings or monitoring wells have been completed in the vicinity of SWMU 31. Based on the location of this unit--adjacent to the New River and on a terrace--the hydrogeology can be inferred using data from similarly located SWMUs. Approximately 20 to 30 feet of unconsolidated sediments--mostly sand, clay, and silt--can be expected. Occasional seams of gravels or cobbles (river jack) would also be expected. Bedrock would likely consist of fractured limestone/dolostone of the Elbrook Formation. The water table should be encountered at an elevation similar to the nearby New River. If the water table is within the bedrock, the aquifer would be karstic with high velocity and very high porosity and permeability. Flow would be toward the river.

2.2.7 Inert Landfill No. 1--SWMU 32

This unit is a closed, unlined landfill located in the Horseshoe Area of RAAP, approximately 600 feet north of the main bridge over the New River and 100 feet east of the Rubble Pile (SWMU 58) (Figure 2-3). Although the 8-acre landfill was permitted by the Virginia Department of Health (Permit No. 400) in April 1983, the unit reportedly began receiving wastes in 1978. The permit allowed SWMU 32 to receive construction waste, demolition waste, plastics, dirt, and inert wastes. Approximately 50 to 100 tons/day of debris wastes were to be disposed of in the landfill, according to the permit.

The unit reached capacity and was closed sometime between July 1986 and April 1987 (USEPA, 1987). The closed landfill is approximately 600 feet by 600 feet in area (Figure 2-13), and 30 feet high. Indications are that wastes were deposited on the original ground surface with no excavation and periodically covered with soil. It has been reported that in addition to inert materials such as soil, concrete, and fiberglass, the following materials were disposed of in the landfill--asphalt, cardboard boxes, fluorescent lamp tubes, bottom ash, wet coal, and empty lab containers (including some labelled sulfuric acid, sec-butyl alcohol, and lead salicylate (USEPA, 1987; USATHAMA, 1984).

The unit was closed with a 2-foot clay cap and topsoil, and then seeded. One area is covered with gravel and used for trailer parking. During the February and March 1990 facility visits, erosional gullies were noted in the unit's cover materials.

Although no sampling has been conducted at SWMU 32, there is concern that the potential exists for groundwater contamination. The hydrogeologic conditions at this SWMU would be very similar to those at SWMU 26 (Section 2.2.4). Groundwater in the unconsolidated soil would probably flow northward following topography, but the karstic nature of the bedrock can orient groundwater in various directions.

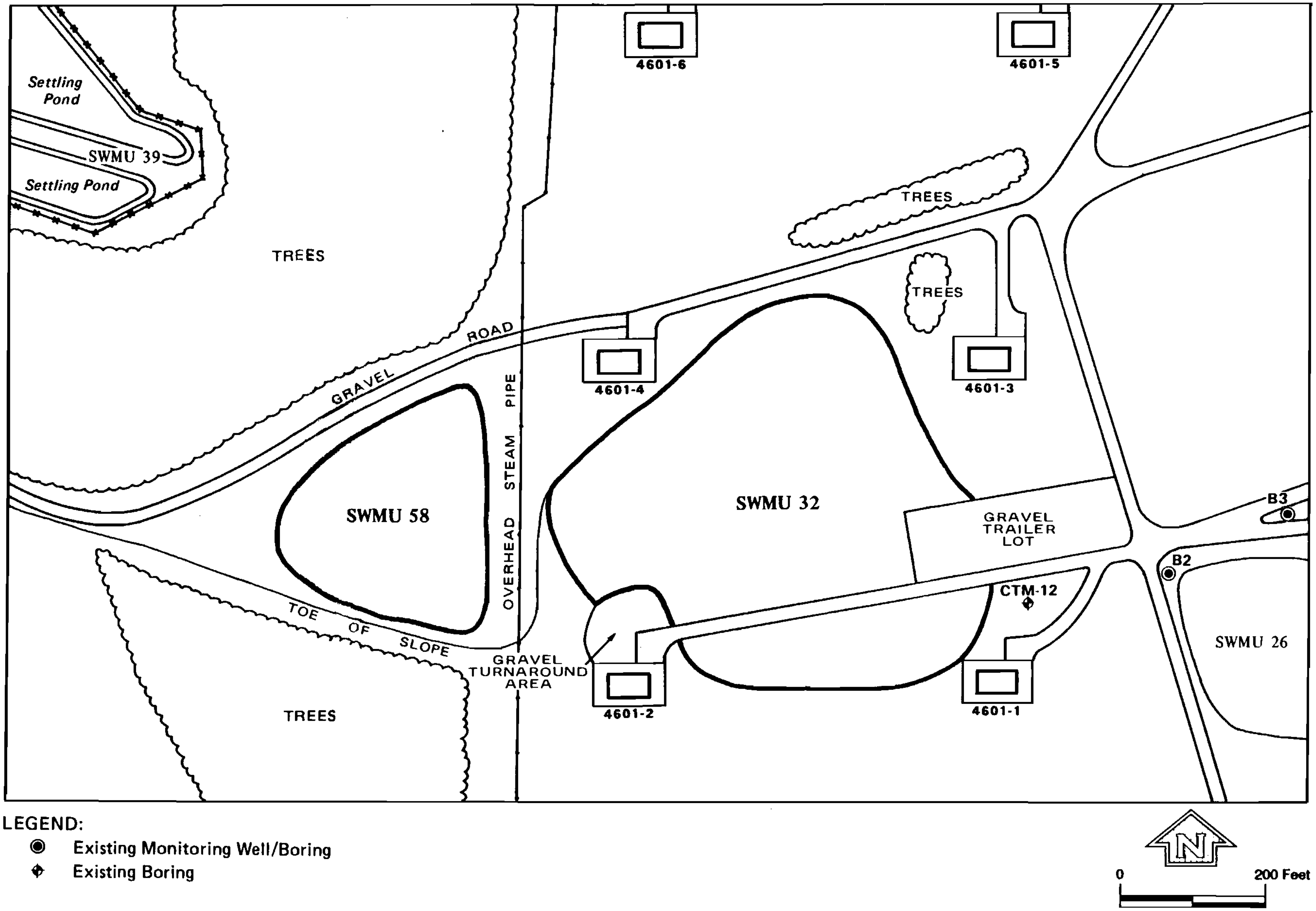

FIGURE 2-13
SWMU 32 – INERT WASTE LANDFILL No. 1
SWMU 58 – RUBBLE PILE
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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2.2.8 Incinerator Wastewater Ponds--SWMU 39

This unit is located in the north-central section of the Horseshoe Area (Figure 2-3). It is located adjacent to and associated with the Hazardous Waste Incinerator (SWMU 14).

SWMU 39 (Figure 2-14) consists of a concrete-lined aeration pond and two unlined earthen ponds. The aeration pond serves as a cooling pond for incinerator scrubber and cooling water, which has been described as either contact or noncontact cooling water. The gas cooler uses water to cool the exhaust gas from the afterburner to 160° F. The scrubber system is designed to cool the exhaust gases to 140° F. The wastewater from the cooler and scrubber is pumped to the spray pond, with the supernatant recycled and reused in the cooler and scrubber. According to a facility representative, caustic is periodically added to the water to neutralize it, and the water is pumped to the Biological Treatment Plant (SWMU 10). Sludges have reportedly never been removed from the pond for disposal. During spray aeration, water is usually windblown from the pond to settle onto the surrounding ground surface. Therefore, there is the potential for contamination of surface soils by the wastewaters.

The settling ponds are excavated an estimated 6 to 8 feet into the natural grade. These ponds receive overflow from the aeration pond, though overflow is reportedly rare. Both are evaporation ponds, with no outlet from either pond.

Analysis of a sludge sample dredged from the spray pond in 1983 (Olver, 1983) indicated that the sludge did not exhibit any of the four hazardous waste characteristics as outlined in 40 CFR 261.34. Analytical results were as follows:

- EP Toxicity (mg/l):

-	Silver	<0.1
-	Arsenic	0.010
-	Barium	1.1
-	Cadmium	<0.1
-	Chromium	0.3

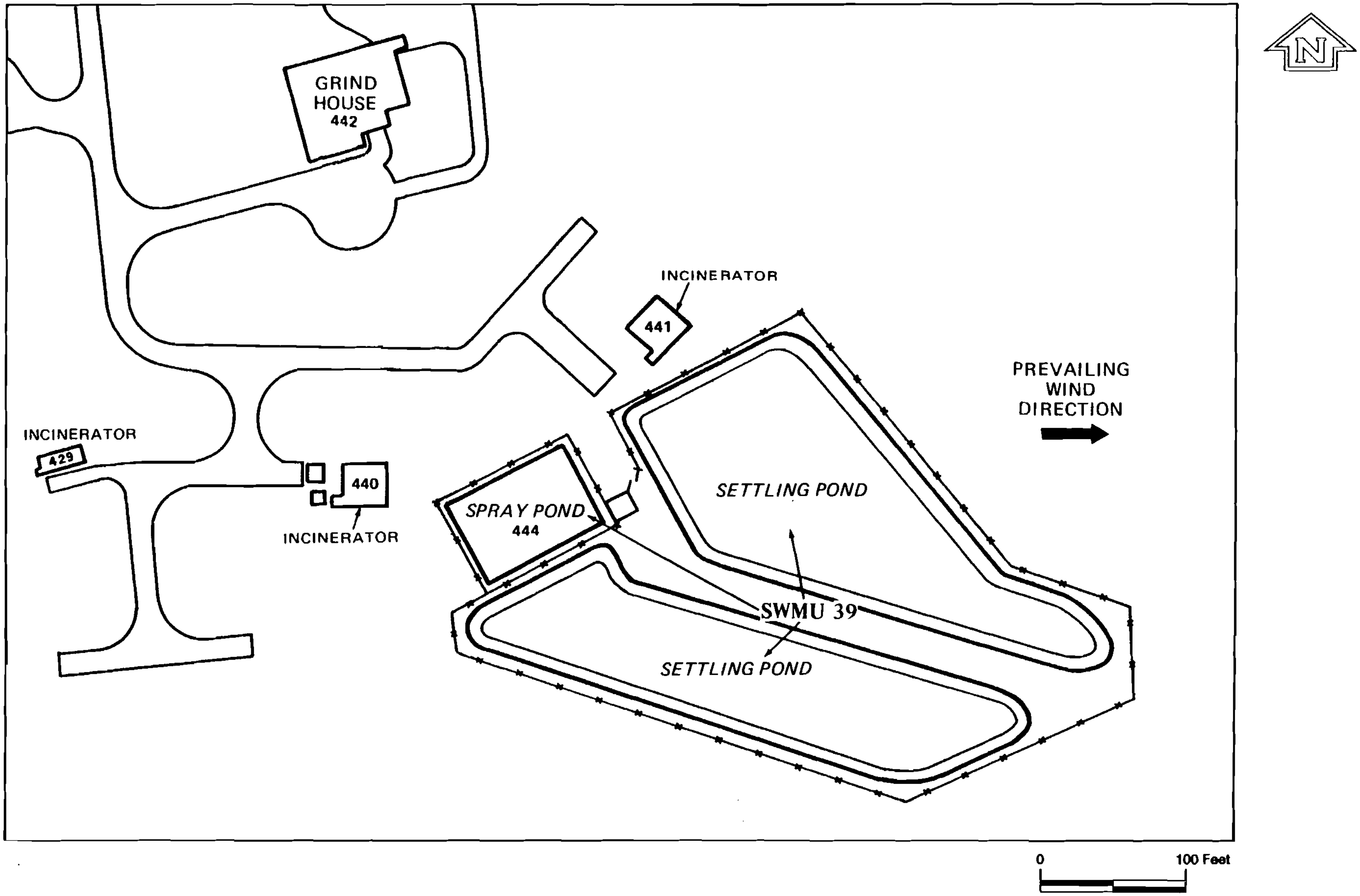

FIGURE 2-14
SWMU 39 – INCINERATOR WASTEWATER PONDS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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-	Mercury	0.0010
-	Lead	0.2
-	Selenium	0.012

- Ignitability: Not ignitable at 60° C
- Corrosivity: Not corrosive
- Reactivity: Not reactive.

No site-specific hydrogeologic studies have been performed at SWMU 39, but the subsurface conditions can be inferred from similar areas. Approximately 20 to 30 feet of unconsolidated sand, clay, and silt, with seams of gravels or cobbles, should overlie fractured limestone or dolostone of the Elbrook Formation. Groundwater probably flows northward toward the New River, approximately 1,200 feet away. Flow velocity through the bedrock would be very high due to the karstic nature of the bedrock.

2.2.9 Sanitary Landfill (Nitroglycerine Area)--SWMU 40

This unit is located approximately 1,000 feet southeast of NG Area No. 1, in the south-central section of the RAAP Main Manufacturing Area (Figure 2-3). It is situated about 400 feet west-northwest of the Contaminated Waste Stage and Burn Area (SWMU 17A) (Figure 2-15). This landfill was never permitted, and was used in the 1970s and early 1980s (following closure of SWMU 43) for the disposal of uncontaminated paper, municipal refuse, cement, and rubber tires (USEPA, 1987; USATHAMA, 1976). It is not known whether hazardous wastes or wastes containing hazardous constituents were ever disposed of in the landfill.

The landfill is approximately 430 feet by 100 feet in size (about 1 acre). The unit was an area fill; no trenches were excavated. The unit was closed with a soil cap and moderate grass cover. Since closure, excavated "clean" soils have been stockpiled on top of the unit by the USACE.

This landfill was apparently constructed on a natural depression in the escarpment that runs generally east to west in this part of RAAP. The pre-existing topography suggests that the depression is a solution feature of the underlying bedrock. No site-specific study has been performed that would define the subsurface

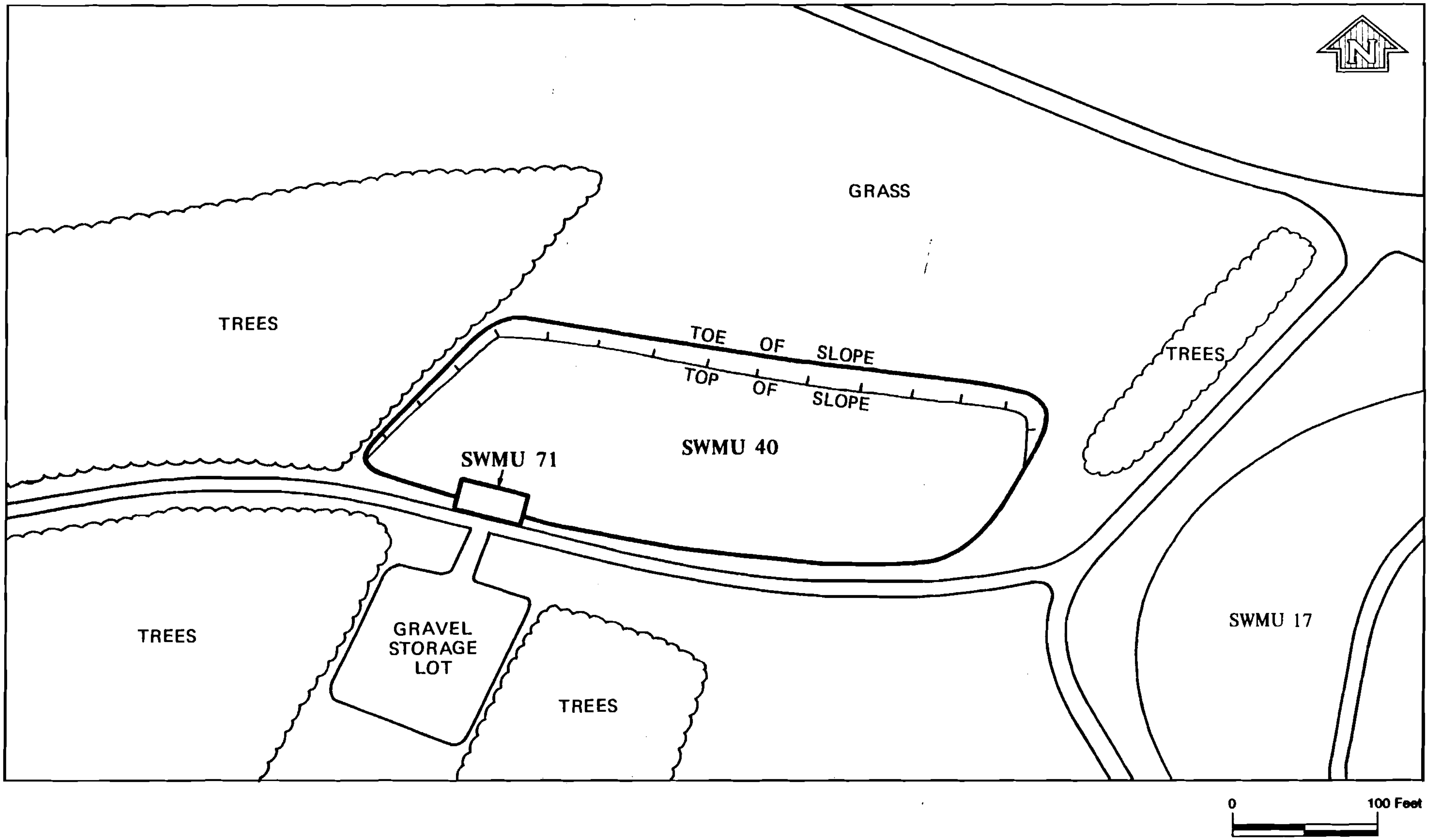

FIGURE 2-15
SWMU 40 – SANITARY LANDFILL (NITROGLYCERINE AREA)
SWMU 71 – FLASH BURN PARTS AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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conditions. Based on morphologic conditions and the general geology of RAAP, site hydrogeologic conditions can be inferred. Because of the escarpment, unconsolidated soil is probably less than 20 feet thick, except where solutioning has removed the underlying bedrock--resulting in thicker sequences. Soil would probably consist of mostly silty clay derived from weathering of the carbonate rocks of the Elbrook Formation. Groundwater is probably controlled by the karstic nature of the Elbrook, with discharge generally westward to northward into the New River.

If hazardous constituents were disposed of in the landfill during fill operations, the potential exists for groundwater contamination by metals, volatiles, and semivolatiles. No sampling has been conducted to date at SWMU 40.

2.2.10 Red Water Ash Landfill (Southeast of Barracks)--SWMU 41

This unit is located in the southeast section of the Main Manufacturing Area at RAAP, northwest of the barracks and adjacent to the TNT wastewater treatment unit (Figure 2-3). SWMU 41 consists of two noncontiguous disposal areas (Figure 2-16).

Red water is a waste product generated during the production of TNT. Its name is derived from its characteristically intense red color. Red water contains numerous TNT byproducts, including alpha, beta, and gamma TNT isomers and TNT sodium disulfates. It characteristically has a pH of approximately 8, and consists of approximately 30 percent solids. Red water is a listed hazardous waste (K047).

From 1968 to 1972, prior to construction of the red water treatment plant, red water was concentrated by evaporation and burned in four rotary kilns located in the TNT manufacturing area (USATHAMA, 1976). The ash produced from these kilns was disposed of in SWMU 41 and SWMU 51 (TNT Neutralization Sludge Disposal Area). From 1972 to 1974, the red water was sold to the paper industry.

Red water ash has been described as yellowish-tan in color when dry. When wet, it turns a dark red and generates a dark red leachate. It is corrosive and fine-grained, though it may contain large clinkers.

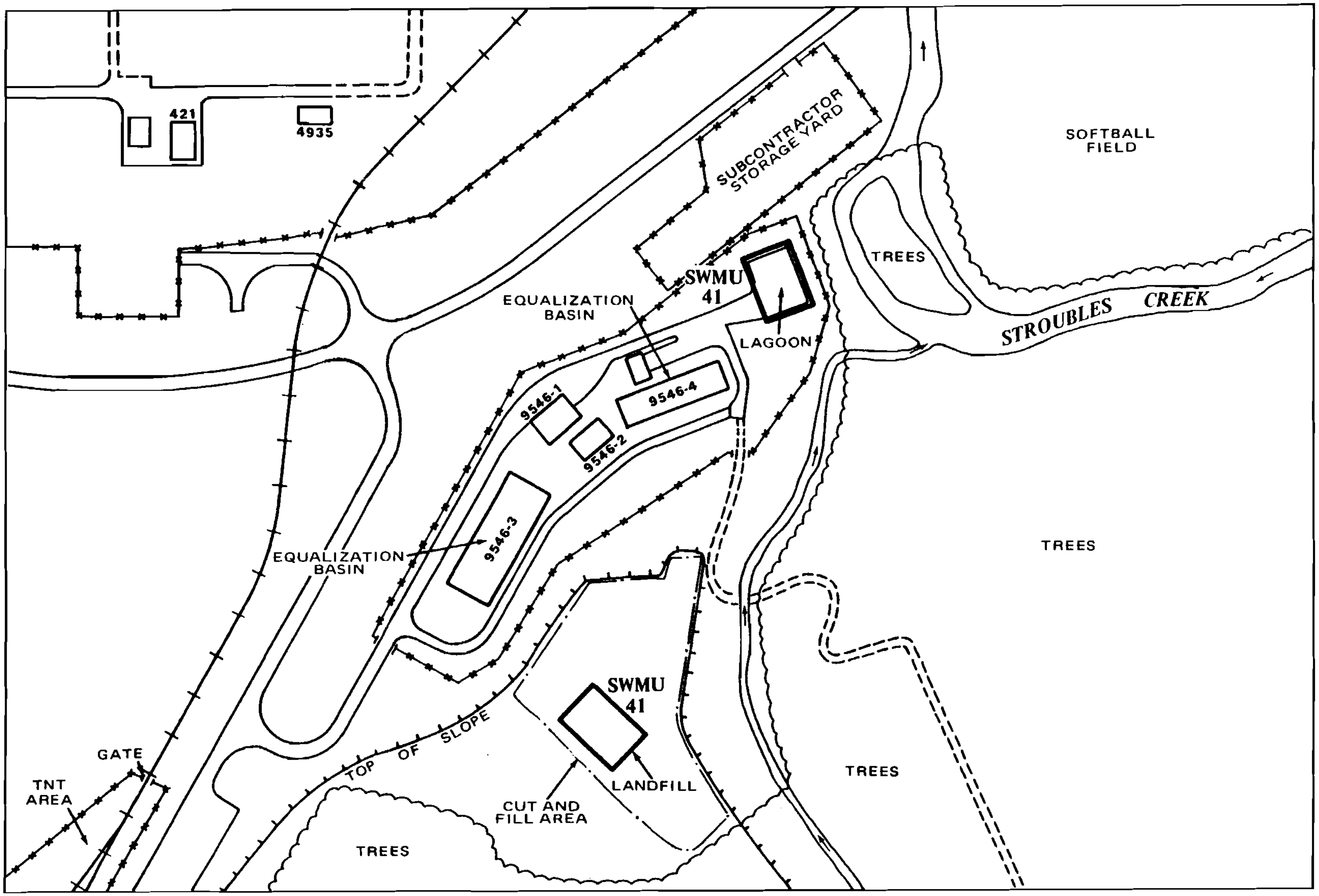

FIGURE 2-16
SWMU 41 – RED WATER ASH LANDFILL
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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The larger of the two disposal areas at SWMU 41 was a landfill that was never permitted and did not undergo formal closure. The unit was used for red water ash disposal from approximately 1967 to 1971. The approximate size of the unit is 100 feet by 150 feet, and it is located within a larger, relatively flat fill area. RAAP personnel have described the landfill as an excavated bowl that was lined with clay soils prior to ash disposal. The ash may be approximately 20 feet deep in places. Following disposal, the USACE used this area for the disposal of "clean" soil excavated for nearby building construction. The ash may be buried with up to 30 feet of this soil.

A second ash disposal area (Figure 2-16) is located approximately 600 feet to the northeast. This area consisted of an unlined lagoon that received runoff from the washing of trucks used to haul red water ash. Ash was also disposed of in the lagoon, which was eventually covered with 4 to 6 feet of soil. Potential leachate from the lagoon has reportedly been observed downslope from the disposal area, in the vicinity of Stroubles Creek.

The geology of this area is probably more complex than at other areas of RAAP. Just east of SWMU 41, the geologic fenster of Mississippian aged formations is present. The SWMU is probably located on very broken Elbrook Formation bedrock because the thrust fault below the sheet containing the Elbrook is exposed around the fenster. Thickness of the Elbrook is not known, but it is probably less than 200 feet until the underlying thrust fault is encountered. The rocks on each side of the fault would be very disturbed, resulting in irregular groundwater flow patterns at that depth. The SWMU 41 landfill was built above the level of the nearby tributary at Stroubles Creek, and shallow groundwater would probably flow toward this tributary. The reported seepage from the SWMU 41 lagoon would support this interpretation.

It is not known if hazardous constituents are present in the red water ash. If present, the potential exists for hazardous constituents to contaminate groundwater in the vicinity of SWMU 41.

2.2.11 Sanitary Landfill (Adjacent to New River)--SWMU 43

This unit is a closed, unlined landfill located adjacent to the New River in the northeast section of the RAAP Main Manufacturing Area (Figure 2-3). The unit was never permitted. Although the exact boundaries of the unit have not been determined, the landfill apparently extends approximately 600 feet on either side of a drainage ditch that divides the area (Figure 2-17). The landfill was a trench-fill operation. Subsidence of the soil cover has been noted during facility inspections. The landfill reportedly received 300 tons of paper and refuse over its active life; however, based on the estimated size of the landfill the quantities were probably larger.

It was reported by RAAP personnel that this landfill was operated from about 1967 through the early 1970s. Another report (USATHAMA, 1984) described a sanitary landfill in the same location as having operated from 1958 to 1969. Aerial photographs indicate possible landfill operations at the unit prior to 1962. It seems likely, but is not certain, that landfilling occurred at SWMU 43 from the late 1950s to the early 1970s.

This landfill is situated adjacent to the New River, and groundwater would probably flow northward to the river. Subsurface conditions at this SWMU have not been investigated, but the conditions would be expected to be very similar to those present at the SWMU 8 Area (Section 2.2.2.1) located 1,500 feet to the west.

It is not known whether any hazardous wastes or wastes containing hazardous constituents were disposed of in SWMU 43. If so, the potential exists for groundwater contamination. No sampling has yet been conducted at this unit.

2.2.12 Sanitary Landfill (West of Main Bridge)--SWMU 45

This unit, an inactive landfill, was reportedly located approximately 3,000 feet west of the main bridge over the New River, in the north-central section of the Main Manufacturing Area (Figures 2-3 and 2-18). The unit was never permitted. The exact boundaries of the unit cannot be determined, because the area is overgrown with pine trees that were reportedly planted after the landfill operations ceased. Soil

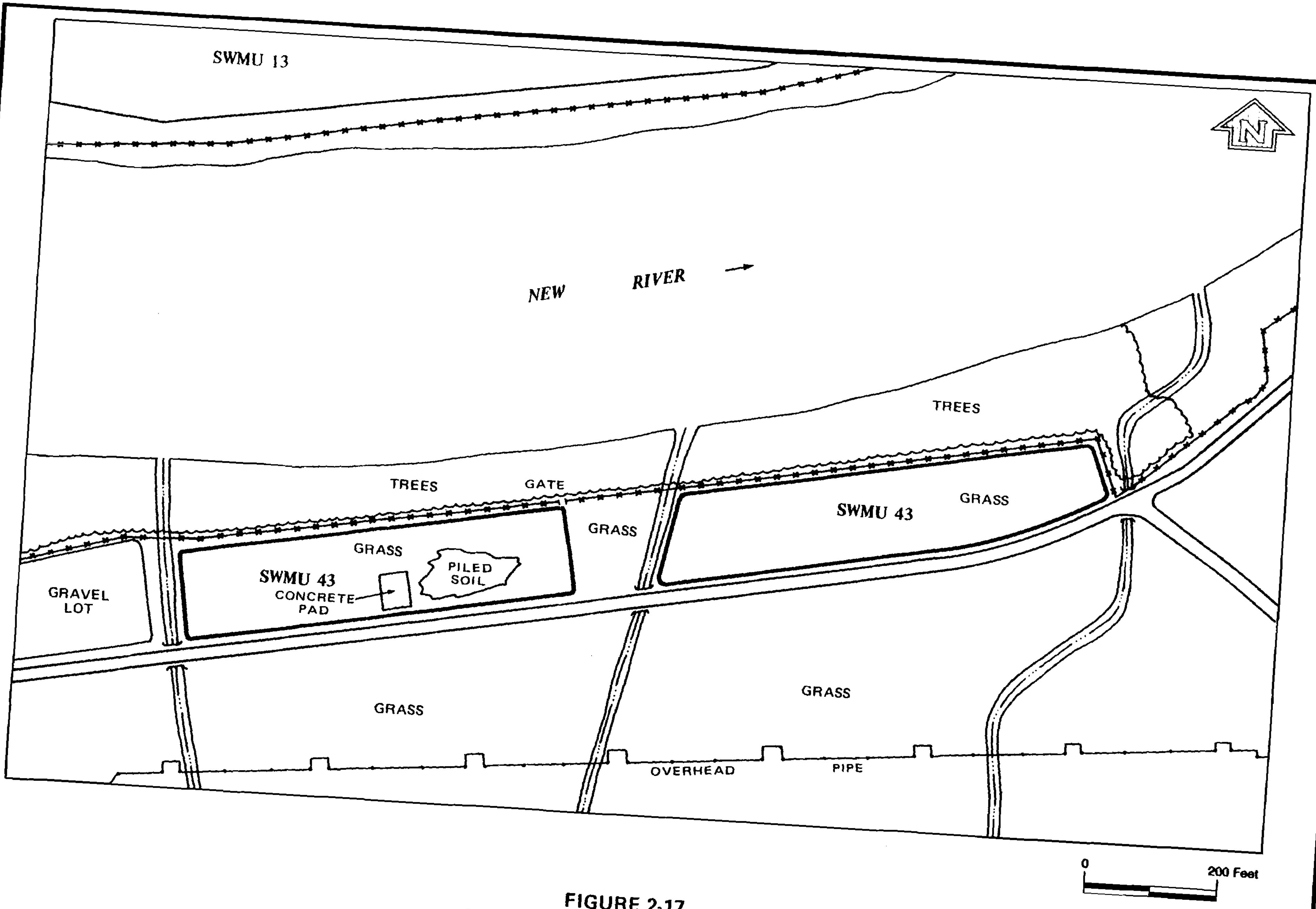

FIGURE 2-17
SWMU 43 – SANITARY LANDFILL
(ADJACENT TO NEW RIVER)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

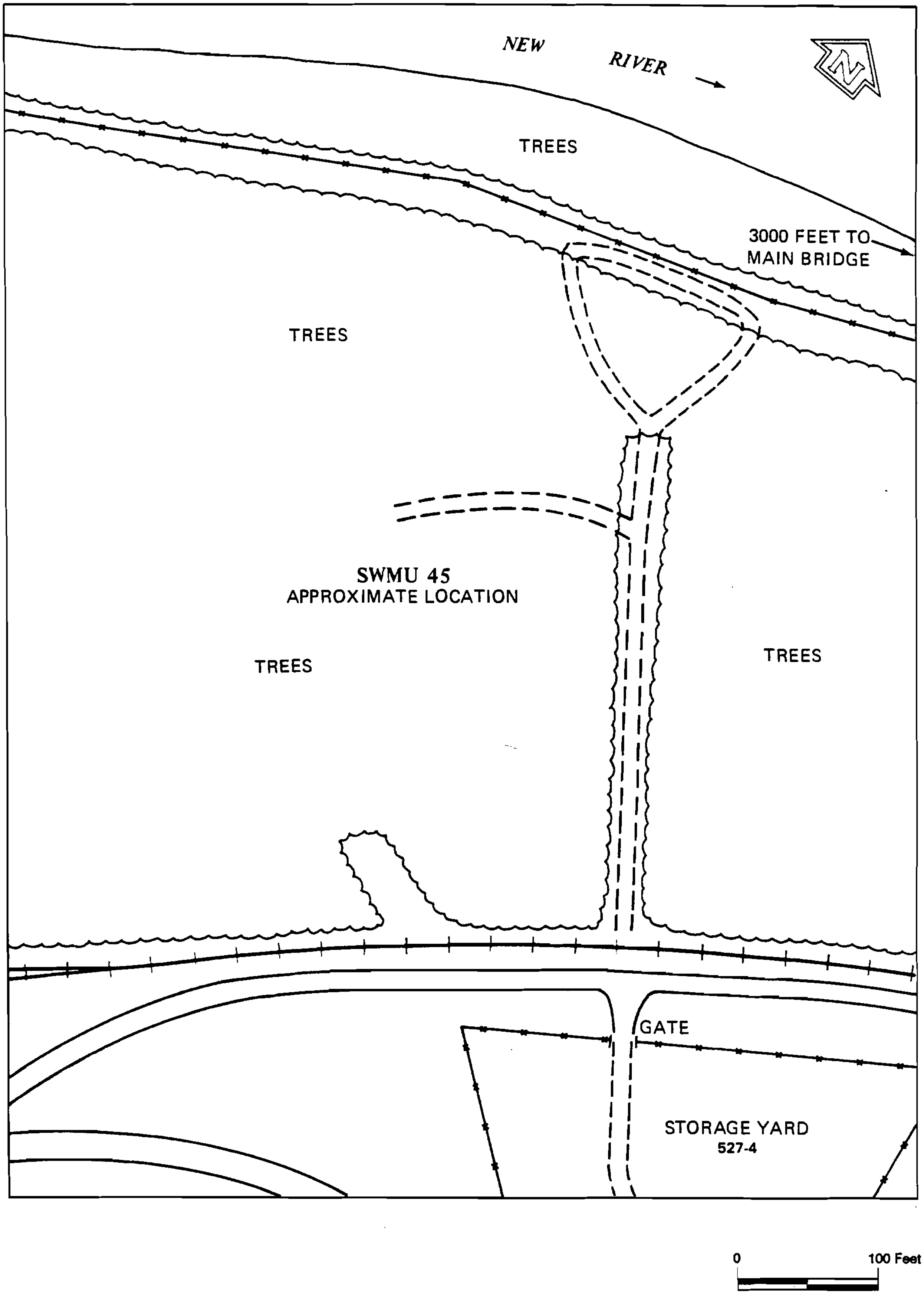

FIGURE 2-18
SWMU 45 – SANITARY LANDFILL
(WEST OF MAIN BRIDGE)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

mounds and excavations are visible. This unit may be as large as 2 acres (USATHAMA, 1976).

The RCRA Facility Assessment (RFA) (USEPA, 1987) described this landfill as having operated during the 1970s. Another report (USATHAMA, 1984) describes this landfill as the first known landfill at RAAP, operated between 1957 and 1961. The latter dates appear to be more reliable based on recollections of plant personnel and the apparent ages of the pine trees. Paper and municipal refuse were the only materials reportedly disposed of in SWMU 45. It was also reported that wastes were placed in trenches and burned prior to burial. Evidence of burning has been observed in the area. If hazardous constituents were disposed of in this landfill, the potential exists for groundwater contamination.

This SWMU is located approximately 1,500 feet northeast of the SWMU 9 Area, and subsurface hydrogeologic conditions would be similar (Section 2.2.2.2). Groundwater would be expected to flow northward toward the New River.

2.2.13 Waste Propellant Disposal Area--SWMU 46

This unit lies along the New River, in the northwest section of the Main Manufacturing Area (Figure 2-3). Approximately 1 ton of earth and propellants were reportedly disposed of at this location as a one-time occurrence because of a railroad derailment in the 1950s (USATHAMA, 1976). USEPA identified the location of this unit as a 0.5-acre hummocky area 50 to 100 feet southeast of the bank of the New River. However, during the March 1990 facility visit, a broken-off sign identifying "BURIED EXPLOSIVE WASTE" was found in a low area between the railroad tracks and the driveway leading to Building 456 (Figure 2-19). RAAP personnel verified that the sign was originally placed in the area where it was found. RAAP personnel also identified the hummocky area identified by USEPA as the location of septic tank sludge burial in the 1970s.

The actual size of the Waste Propellant Disposal Area is not known. However, based on the quantity reportedly disposed of, it is probably quite small. There is the potential for soil contamination by metals and explosives at SWMU 46.

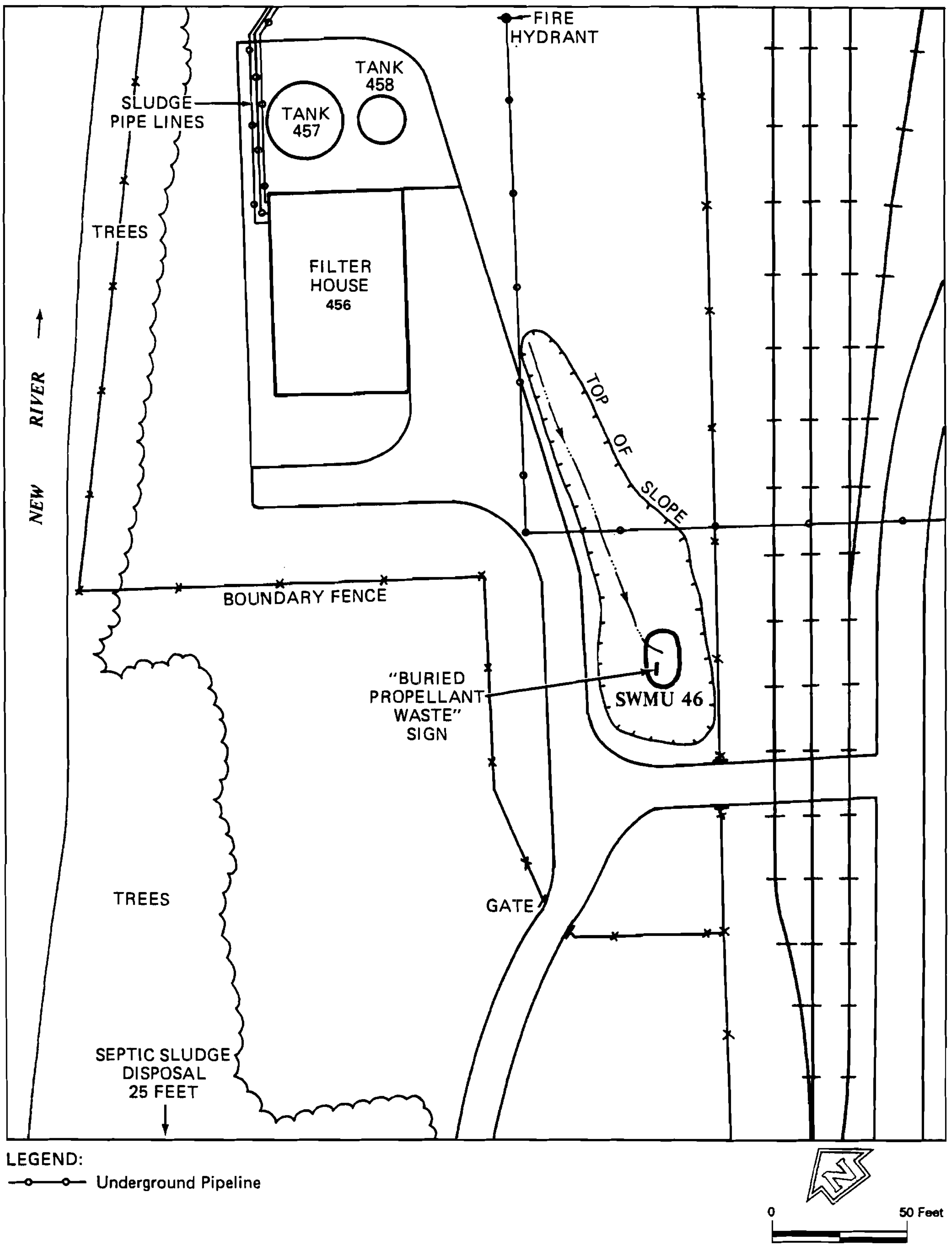

FIGURE 2-19
SWMU 46 – WASTE PROPELLANT DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

The reported location of SWMU 46 is a small depression with no drainage outward. This shape suggests that run-on would percolate into the subsurface and enter the water table. The New River, located only 200 feet to the northwest, is probably the discharge zone for the groundwater. Approximately 20 to 30 feet of sand, silt, clay, and gravel overlies Elbrook bedrock below the area.

2.2.14 Oily Wastewater Disposal Area--SWMU 48

This unit is located in the RAAP Horseshoe Area, approximately 3,400 feet east of the main bridge over the New River (Figure 2-3). USEPA reported this unit as contiguous to SWMU 49 (Red Water Ash Disposal Area) and SWMU 50 (Calcium Sulfate Disposal Area), with no distinction possible by visual observation (USEPA, 1987). However, based on a review of historical aerial photographs and discussions with plant personnel, it has been determined that the unit consists of two separate disposal areas, as shown in Figure 2-20.

Prior to the start of off-post waste oil reclamation, oily wastewaters removed from oil/water separators throughout RAAP were disposed of at SWMU 48. It is estimated that 200,000 gallons or more of oil-contaminated wastewater were disposed of in unlined trenches at this unit. The potential exists for groundwater contamination from past disposal activities at SWMU 48.

The SWMU 48 Area has not been directly investigated, but the landfill area 500 feet to the northeast (SWMU 52) was the subject of a 1981 study (USACE, 1981).

Based on investigations at SWMU 52, the groundwater below SWMU 48 is expected to flow southward, following topography, with discharge into the New River. This flow direction may be altered by drainage into the underlying bedrock in the vicinity of sinkholes or solution features.

Four CEC tests were performed by the USACE on selected samples of unconsolidated material at SWMU 52. All samples tested were silty sand or clay exhibiting a CEC between 2.5 and 8.5 meq/100 gm of soil.

The depth to the water table is quite variable. Northwest of the landfill, the depth to water is approximately 46 feet, but immediately south of the landfill the

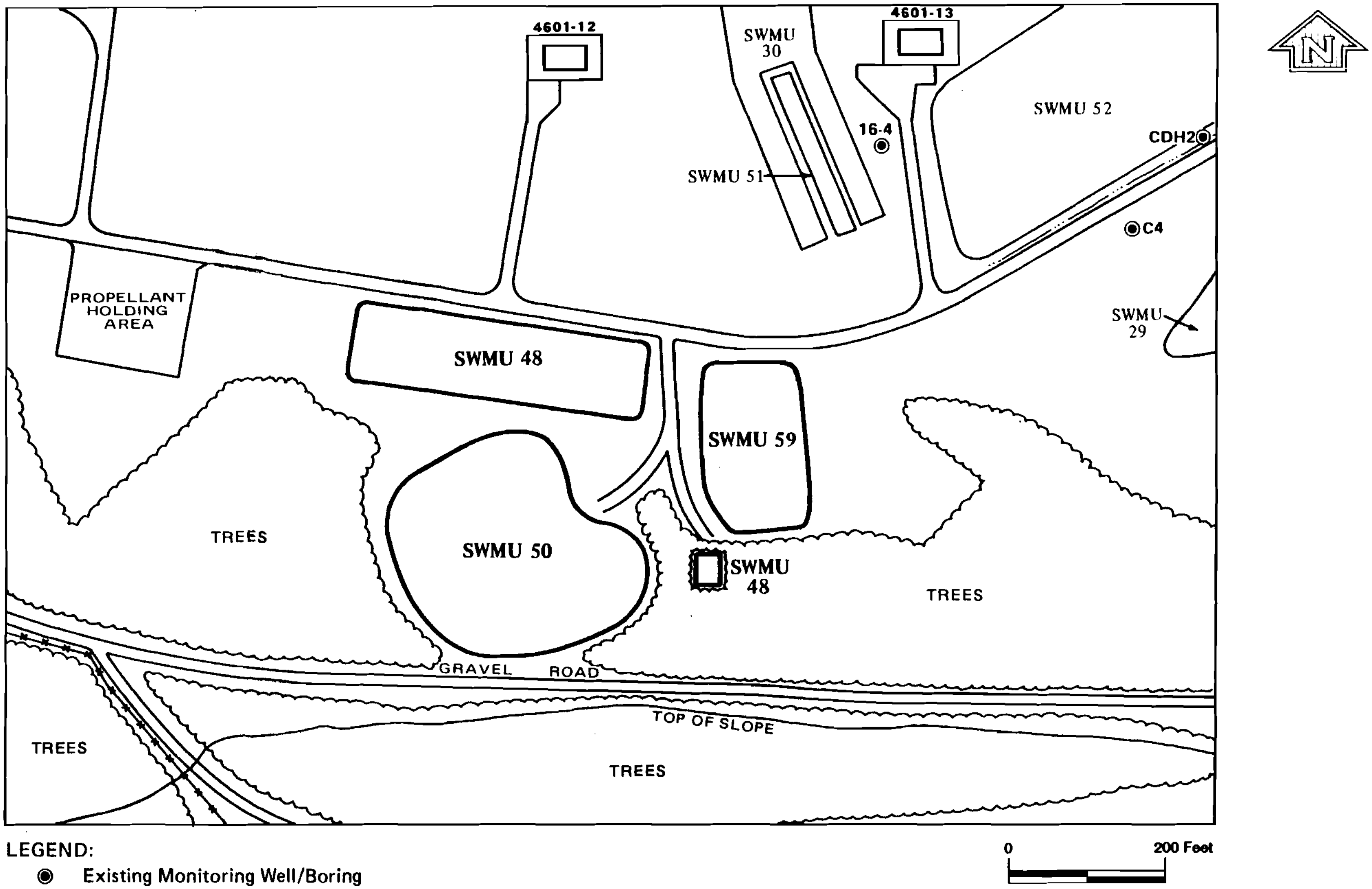

FIGURE 2-20
SWMU 48 – OILY WASTEWATER DISPOSAL AREA
SWMU 50 – CALCIUM SULFATE SLUDGE DISPOSAL AREA
SWMU 59 – BOTTOM ASH PILE
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

water table was not encountered until 70 feet below land surface where a soil boring was terminated.

Soil and rock borings completed at SWMU 52 indicate the presence of three major lithologic units--clay and silt overlying sand and gravel, which in turn overlies limestone/dolostone bedrock.

The clay and silt unit mantles the surface at the site to a depth of as much as 38 feet. The reddish-brown clay, which is plastic and occasionally moist, is very silty and contains lenses of fine sand. Underlying the clay are Quaternary terrace deposits of fine- to coarse-grained, yellowish-brown sand. Lenses of large cobbles (river jack) are found throughout.

Underlying the sand and gravel unit is the gray limestone/dolostone of the Elbrook Formation. The top of bedrock is 50 to 60 feet below land surface west of the landfill (nearest to SWMU 48), but was not encountered at a total drilling depth of over 70 feet in two borings located south and east of the landfill. The unit is highly fractured and fragmented with breccia, vugs, and solution channels.

The clay material exhibits a permeability ranging from less than 3.28 x 10^{-6} to 1.31 x 10^{-4} cm/sec. Average permeability for the sand and gravel unit is 2.31 x 10^{-3} cm/sec, with a range between 2.0 x 10^{-5} and 5.72 x 10^{-3} cm/sec (USACE, 1981).

2.2.15 Red Water Ash Disposal Area--SWMU 49

EPA reported this unit as contiguous to SWMU 48 (Oily Wastewater Disposal Area) and SWMU 50 (Calcium Sulfate Disposal Area), with no distinction possible by visual observation (USEPA, 1987). Ten tons of red water ash were reportedly disposed of in SWMU 49 in the 1970s. However, based on interviews with plant personnel, it has been determined that no red water ash was disposed of at this location. Rather, red water ash was disposed of in SWMU 51 (TNT Neutralization Sludge Disposal Area), which is located approximately 400 feet to the northeast, as well as in SWMU 41 and SWMU 42 (on off-post property). SWMU 51 is being separately investigated as part of the RFI and is not addressed further in this report.

2.2.16 Disposal Area for Ash From Burning Propellants--SWMU 54

This unit is located in the easternmost section of the Horseshoe Area, just outside Gate 19-D of the RAAP fence (Figures 2-3 and 2-21). The disposal area is visible as an elongated triangular area of hummocky grass-covered soil, with some 2- to 4-foot-high piles and several 3- to 5-foot-deep pits. The disposal area extends east-west along the fence (Figure 2-2). The total area of the unit is estimated to be less than 1 acre.

Prior to startup of the Hazardous Waste Landfill (SWMU 16) in 1980, ash from propellant burning operations at the Waste Propellant Burning Ground (SWMU 13) were reportedly disposed of at this unit during the late 1970s. The quantity of ash disposed of in this unit is estimated to be 10 tons (USATHAMA, 1976). According to plant personnel, disposal occurred on the surface, with no routine disposal in pits or trenches. Ash residue is visible where surface soils have been disturbed.

Located to the northwest of the ash disposal area is another large clearing in the woods, approximately 300 feet by 300 feet in size. Although historical aerial photographs indicate some disturbance or earthmoving activities taking place here, plant personnel could recall no ash disposal in this area. Some evidence of inert waste disposal (concrete, brick) was observed.

A sample of the ash disposed of in the Hazardous Waste Landfill was analyzed for RCRA metals (EP toxicity leachate procedure). Results indicated that the ash exceeded the Virginia maximum allowable concentration for lead (51 mg/l, compared to the maximum allowable concentration of 5 mg/l) (USEPA, 1987). It may be assumed that ash disposed of in SWMU 54 exhibited similar characteristics. Therefore, the potential exists for groundwater contamination in the vicinity of SWMU 54.

Subsurface conditions have not been investigated in the SWMU 54 area, but the topographic and morphologic setting of this area is similar to the lower areas of SWMU 29 (Section 2.2.5). Unconsolidated soils should consist of approximately 20 to 30 feet of reddish-brown clays and silts, with sand and river jack (cobbles and

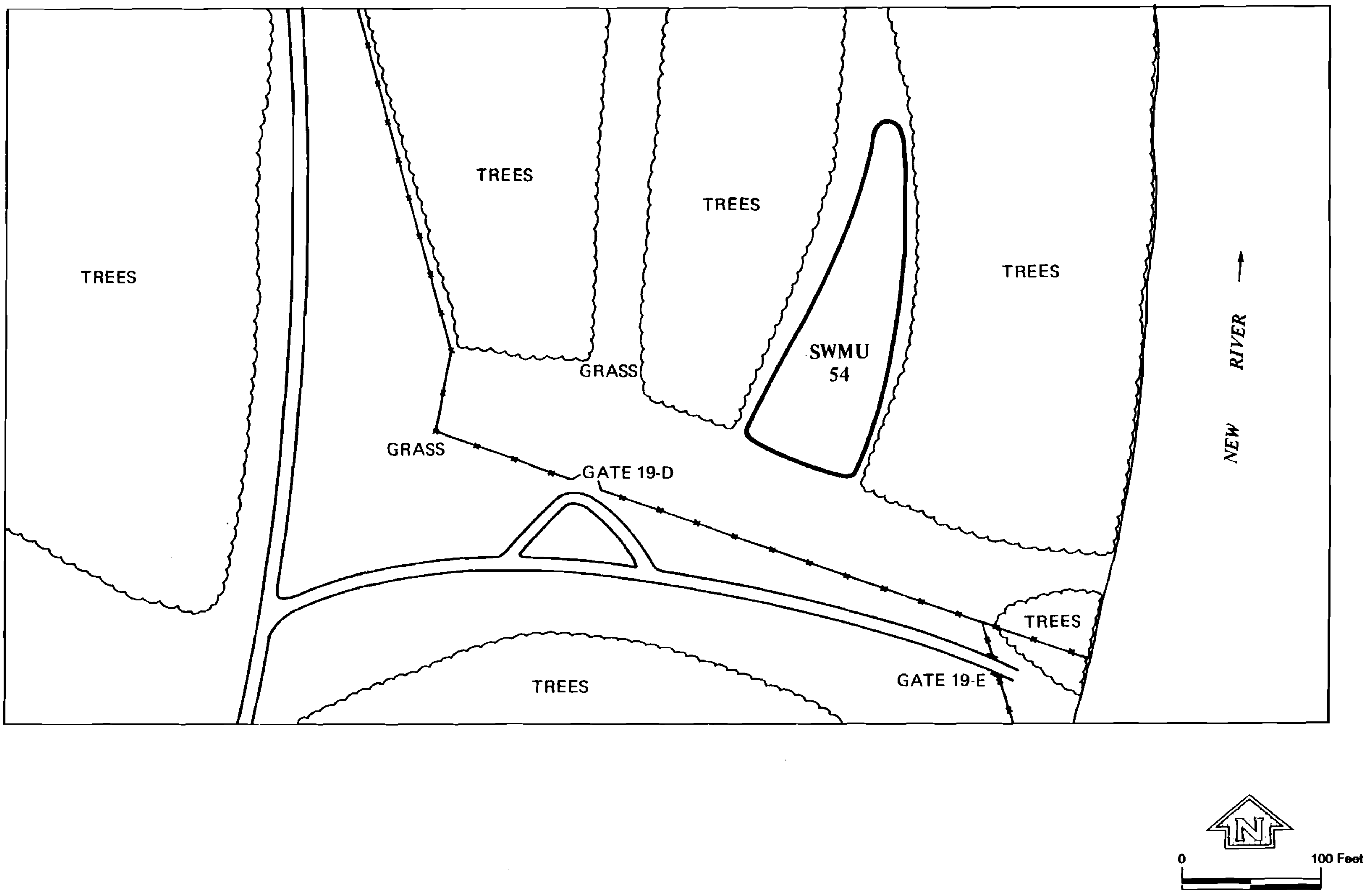

FIGURE 2-21
SWMU 54 – PROPELLANT BURNING ASH DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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boulders) seams. Bedrock consists of the limestone/dolomite of the Elbrook Formation. An unknown thickness of very weathered material is present above the unweathered karstic bedrock. Groundwater should flow eastward and discharge into the New River.

2.2.17 Pond by Building Nos. 4931 and 4328--SWMU 57

This unit is located in the western section of the Horseshoe Area, east of the Cast Propellant Area (Figure 2-3), north of Building 4931, and northeast of Building 4928 (Figure 2-22). An underground pipe connects Building 4931 to the pond. RAAP facility drawings label this pond as an "acid settling pond." However, construction plans for the chromic acid treatment plant do not show this pond.

The pond measures approximately 30 feet in diameter and is surrounded by a gravel berm and a 5-foot chain-link fence. There is no apparent outlet from the pond, and the berm extends several feet above the natural ground surface. The origin of the liquid currently in the pond is uncertain, though precipitation is a likely source. If hazardous constituents have been piped to the pond via inflows, the potential exists for soil and groundwater contamination.

No site-specific subsurface investigations have been conducted in this area. The SWMU is located on a plateau area above a hillside that slopes northwestward to the New River. Soils underlying the SWMU should consist of approximately 20 feet of clay, silt, and sand, with occasional seams of cobbles and boulders. This would overlie the karstic limestone/dolomite of the Elbrook Formation. Groundwater should follow topography and flow northwestward, discharging into the New River.

2.2.18 Rubble Pile--SWMU 58

This unit is located in the south-central portion of the Horseshoe Area, approximately 2,600 feet east of the main bridge over the New River and directly west of the Inert Waste Landfill No. 1 (SWMU 32) (Figures 2-3 and 2-13). The rubble pile is approximately 400 feet by 200 feet in area and 50 feet high. Erosion of the soil cover is evident. According to facility representatives interviewed during the March 1990 facility visit, SWMU 58 was used as a one-time disposal site in approximately 1979. During clearing activities, prior to construction of the

105

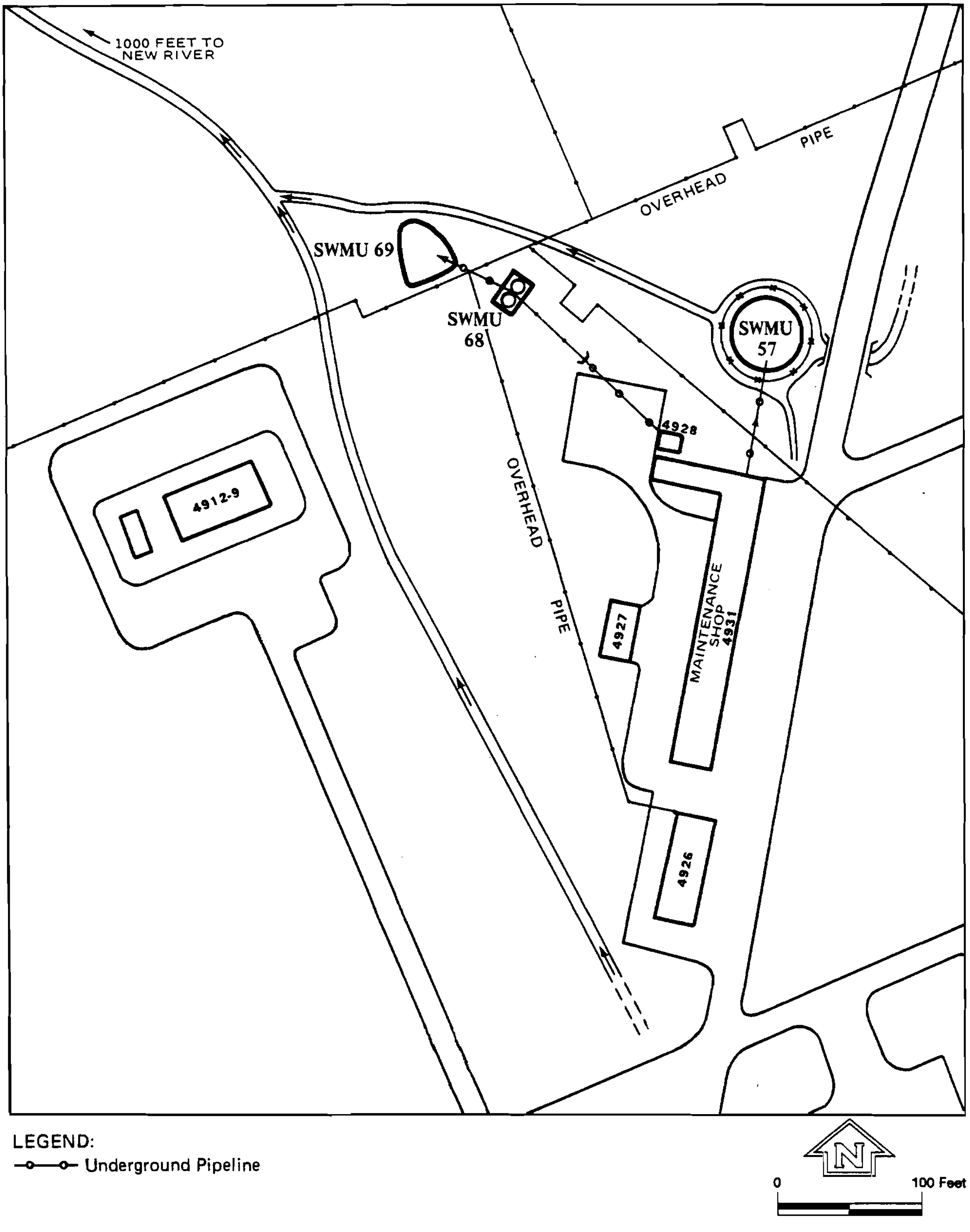

FIGURE 2-22
SWMU 57 – POND BY BUILDINGS 4928 AND 4931
SWMU 68 – CHROMIC ACID TREATMENT TANKS
SWMU 69 – POND BY CHROMIC ACID TREATMENT TANKS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Continuous Automated Multibase Line (CAMBL), pine trees and surface debris were pushed into a pile and then covered with dirt and fill material. It is believed that no other materials were disposed of at SWMU 58.

This SWMU is located immediately west of SWMU 32 (Section 2.2.7) and 800 feet west of SWMU 26 (Section 2.2.4). Subsurface conditions would be similar to conditions at these two SWMUs. Groundwater should flow northward.

2.2.19 Bottom Ash Pile--SWMU 59

SWMU 59 is located near SWMUs 48 and 50 in the Horseshoe Area of RAAP, approximately 3,400 feet east of the main bridge over the New River (Figures 2-3 and 2-20). The pile is currently approximately 100 feet by 50 feet in area and 20 feet high. The source of the bottom ash is one or both of the power plants at RAAP. Power Plant No. 1 (Building 400) is a coal-fired plant that uses pulverized coal to produce electricity for the main plant and Horseshoe Area. Power Plant No. 2 is also coal-fired and supplies steam at 150 psi to buildings in the Horseshoe Area. Both plants use low sulfur coal.

Bottom ash is permitted to be buried in landfills on the installation (in particular FAL No. 1). Some bottom ash is apparently stored in piles around RAAP for use on roadbeds and as landfill cover material (USEPA, 1987). It can be assumed that this pile or similar piles have existed at RAAP since operation of the power plants began in the mid-1940s.

Because studies have shown that coal bottom ash can release hazardous constituents to the environment, sampling will be conducted to evaluate whether soil contamination exists at this unit.

SWMU 59 is located 200 feet east of SWMU 48 (Section 2.2.14). Subsurface hydrogeologic conditions would be similar to conditions at that unit.

2.2.20 Mobile Waste Oil Tanks--SWMU 61

A number of oil/water separators and waste oil storage tanks located throughout RAAP are used for the collection of waste oil generated primarily from machinery and vehicle engines. On a regular basis, oil from these locations is collected in the mobile waste oil tanks and transported to the Waste Oil

Underground Storage Tanks (USTs) south of the oleum plant (SWMU 76). Insert 2 shows the locations where the mobile waste oil tanks are temporarily parked for collection of the waste oil. Of concern at these locations is potential surface soil contamination from leaks and spills of waste oil during handling and collection.

2.2.21 Chromic Acid Treatment Tanks and Pond by Chromic Acid Treatment Tanks--SWMUs 68 and 69

The Chromic Acid Treatment Tanks (SWMU 68) are located in the western section of the Horseshoe Area in the vicinity of Building 4931 (Figure 2-3). SWMU 68 consists of two 4,000-gallon aboveground, open-top reactor vessels and associated aboveground piping (Figure 2-22). The tanks are 9 feet tall and 8.5 feet in diameter and are supported by steel legs. There is no secondary containment. A sign posted on the unit describes the tanks as the "Chromic Acid Treatment Plant."

The tanks were used prior to 1974 to treat spent chromic acid generated from the cleaning of rocket encasements (USEPA, 1987). Hexavalent chromic acid was batch treated using hydroxide precipitation. Spent hexavalent chromic acid (Cr^{+6}) was first pH adjusted to approximately 1.5 using sulfuric acid, and then reduced to the trivalent state (Cr^{+3}) using sodium metabisulfate as the reducer. High calcium lime was added to the solution to adjust the pH to approximately 8.6. The treated wastewater was discharged to a shallow settling pond (SWMU 69) where chromium hydroxide sludge would settle out. The pond is bermed and about 1 to 2 feet deep. It is not known whether chromium hydroxide sludge has ever been dredged from the pond. The supernatant was discharged to the New River via Outfall No. 17.

Since 1974, "Oakite 33"--an acidic rust stripper consisting of phosphoric acid and butyl cellosolve mixture--has been used instead of chromic acid to clean rocket encasements (USEPA, 1987). Spent Oakite 33 is pH adjusted to 5.0 with soda ash prior to discharge to SWMU 69.

Because of the lack of secondary containment, there is the potential for contamination of surface soils surrounding the tanks as a result of past spills and overflows of chromic acid. The potential also exists for soil and surface water contamination at the pond from past chromic acid treatment practices.

These SWMUs are located 100 feet northwest of SWMU 57 (Section 2.2.17) and almost at the point where the plateau of the Horseshoe Area starts sloping to the New River. Subsurface conditions at SWMUs 68 and 69 would be similar to those encountered at SWMU 57.

2.2.22 Flash Burn Parts Area--SWMU 71

This inactive unit is located in the south-central portion of the Main Manufacturing Area, in the southwest corner of the Sanitary Landfill (NG Area) (SWMU 40) (Figures 2-3 and 2-15). It consists of an open gravel area, about 25 feet by 50 feet in size, where metal process pipes potentially contaminated with propellant were flash burned from about 1962 to 1982. The pipes were then reused or sold for scrap. The potential exists for surface soil contamination by metals and explosives. Because fuel was used for the flash burn ignition, there is also the potential for hydrocarbons to exist in the surface soils. Hydrogeologic conditions at this unit would be similar to those at SWMU 40 (Section 2.2.9).

2.2.23 Inert Landfill No. 3--SWMU 74

This active landfill is located in the central portion of the Horseshoe Area, approximately 800 feet north of the Active Sanitary Landfill (SWMU 28) (Figure 2-3). This unlined unit was permitted by the Virginia Department of Health in May 1984 (Permit No. 433) as "Debris Landfill No. 2" to receive construction waste, demolition waste, wood, tree trimmings, stumps, and inert waste materials. The landfill is being area-filled in two lifts, with wastes pushed off the edge of existing fill from west to east (Figure 2-23). The fill is currently about 300 feet by 400 feet in size; future filling will continue eastward to the road. The estimated remaining life in the landfill is 3 to 4 years.

In addition to the above specific inert wastes, the following materials have been observed as being disposed of in the landfill--cardboard, fluorescent light bulbs, wet coal or asphalt, and laboratory chemical and reagent 5-gallon cans (empty). If chemical wastes were disposed of in the landfill, the potential exists for contamination of groundwater.

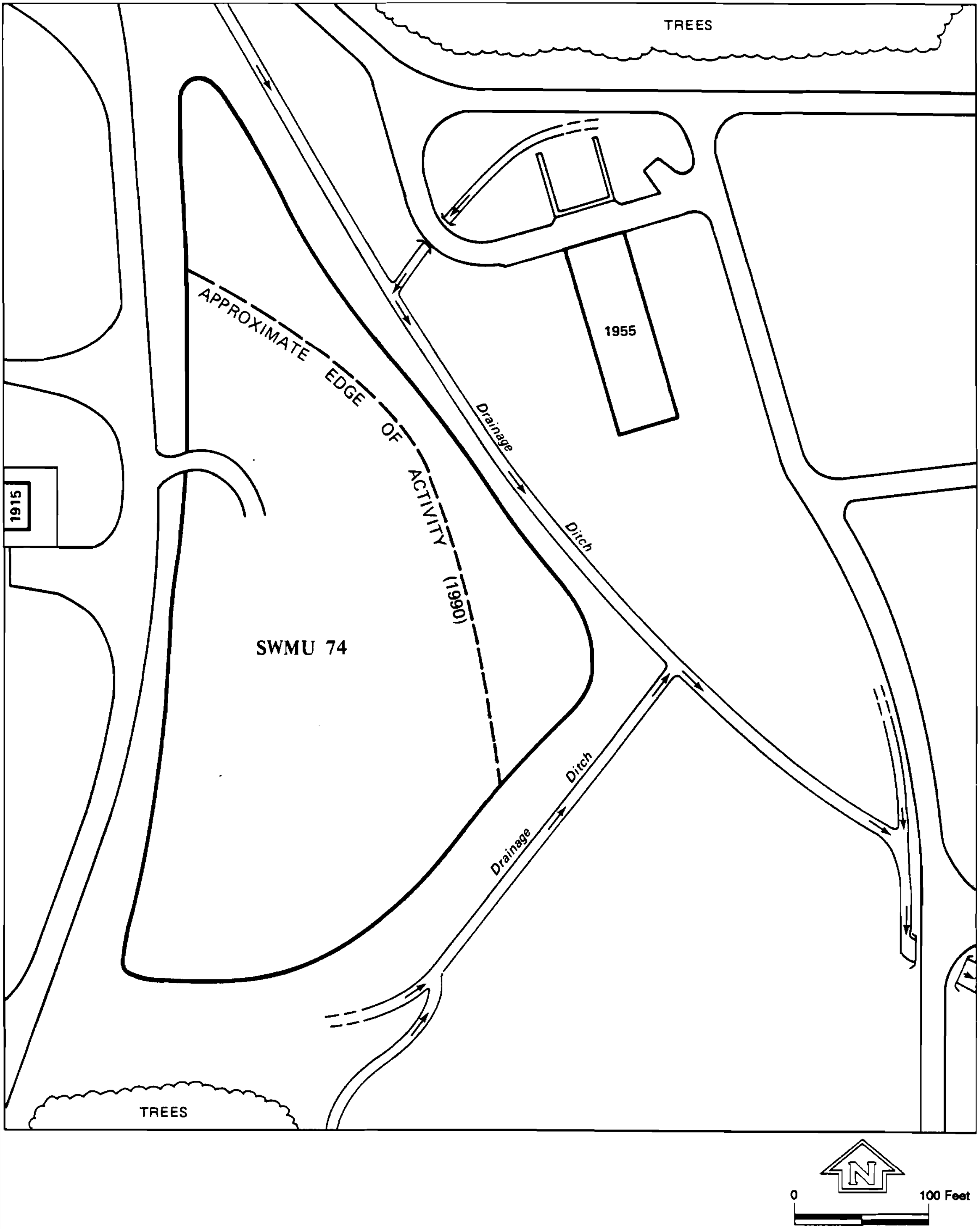

FIGURE 2-23
SWMU 74 – INERT LANDFILL No. 3
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

This SWMU is located 800 feet north of SWMU 29 (Section 2.2.5), in a topographically similar area, and subsurface hydrogeologic conditions would likely also be similar.

2.2.24 Waste Oil Underground Storage Tank (Inert Gas Plant)--SWMU 75

This UST is located in the Main Manufacturing Area, due south of the Acidic Wastewater Lagoon (SWMU 4) (Figures 2-3 and 2-24). The UST is reportedly a single-walled tank with a capacity of 600 to 700 gallons. It is currently used to store waste oil and hydraulic fluids that are generated in the inert gas plant compressor house. The contents of the UST are periodically pumped out into 55-gallon drums for use as fuel at the Hazardous Waste Incinerator (SWMU 14) (USEPA, 1987).

The concern at SWMU 75 is an accumulation of drips and spills around the tank access port. Surface soils may be contaminated with metals or semivolatile compounds.

There have been no subsurface investigations at this SWMU to define hydrogeologic conditions, but several investigations have been performed for the SWMU 4 lagoon located 300 feet to the northwest, and conditions should be similar. SWMU 4 is underlain by approximately 20 feet of yellowish-brown to dark grayish-brown silty clay overlying several feet of silty sand, with gravel or large cobbles upon weathered bedrock. Bedrock is limestone/dolomite of the Elbrook Formation that is very weathered at the soil contact. Groundwater is present within the unconsolidated soils, with flow generally northeastward. The gravelly seams probably control flow. Evidence of sinkholes has also been reported in the vicinity (BCM, 1984).

2.2.25 Waste Oil Underground Storage Tanks (South of Oleum Plant)--SWMU 76

This unit consists of two waste oil USTs located within the Contaminated Waste Stage and Burn Area (SWMU 17A) in the south-central part of the Main Manufacturing Area (Figures 2-3 and 2-25). The capacity of Tank No. 1 is 5,050 gallons; the capacity of Tank No. 2 is 2,640 gallons. Waste oil from machinery and vehicle engines throughout RAAP is collected in the Mobile Waste Oil Tanks (SWMU 61) and then stored in the SWMU 76 tanks. The waste oil is then sold to

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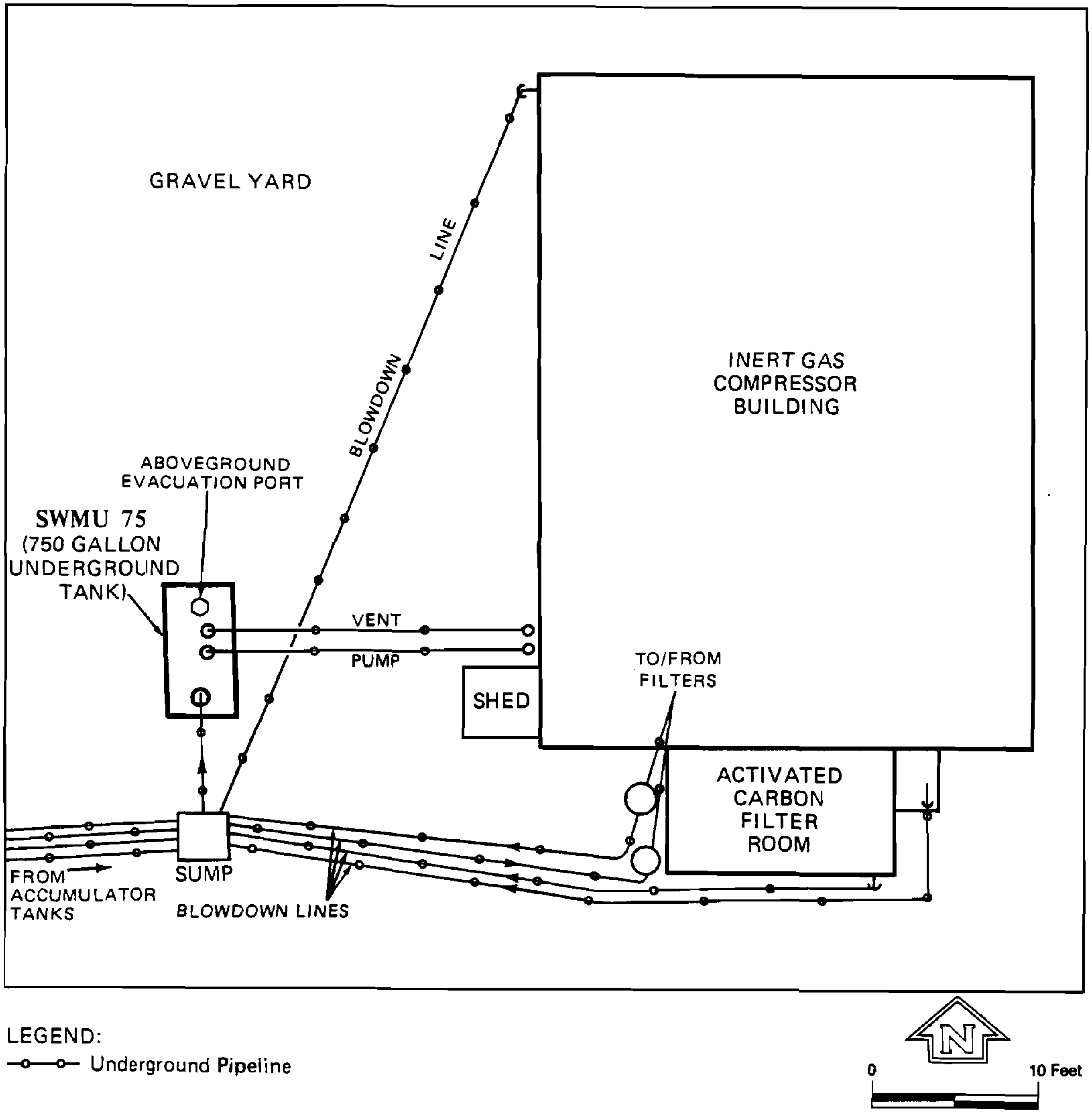


FIGURE 2-24
SWMU 75 – WASTE OIL UST (INERT GAS PLANT)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

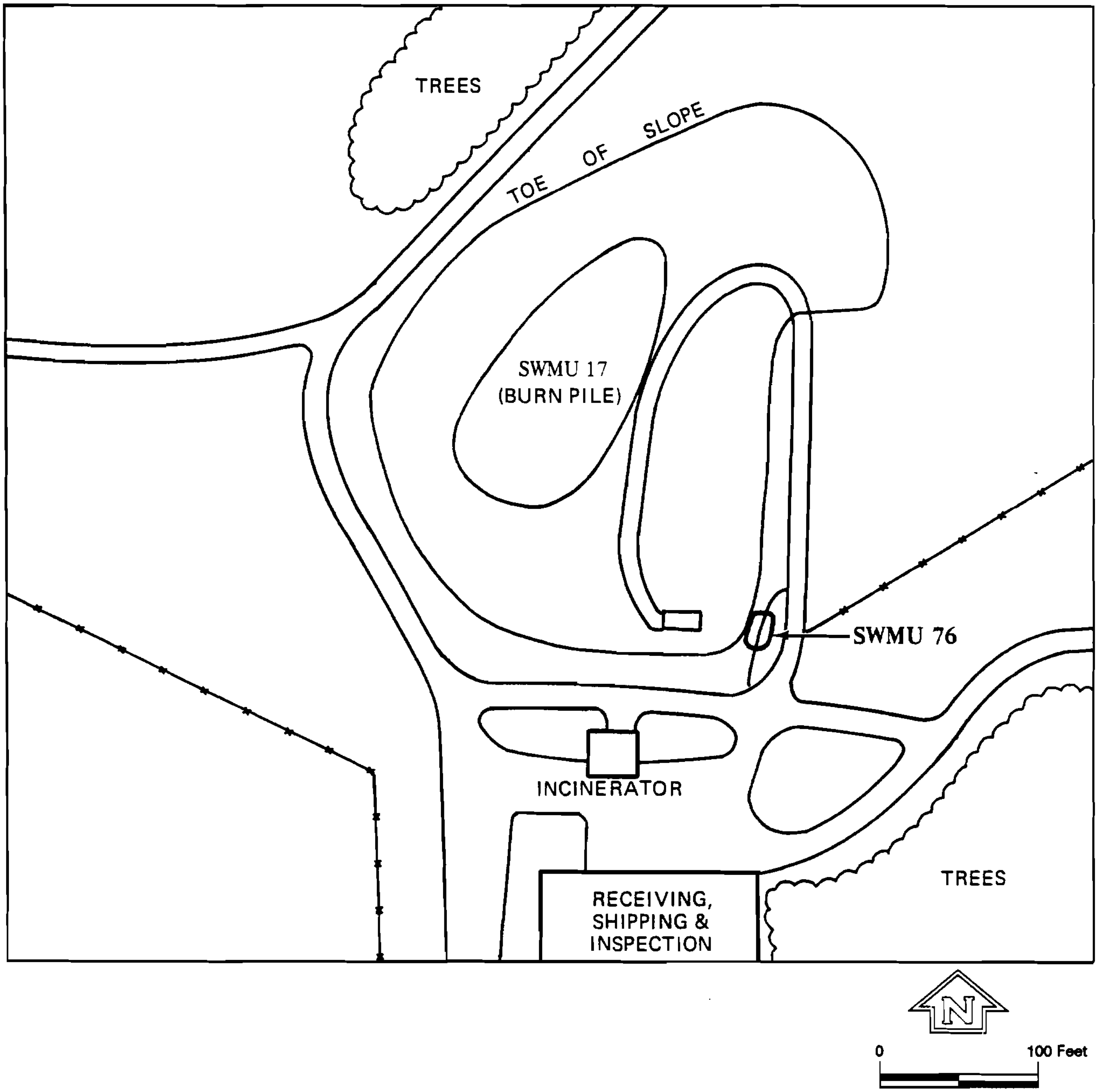


FIGURE 2-25
SWMU 76 – WASTE OIL USTs (SOUTH OF OLEUM PLANT)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

an off-post firm for reclamation. Waste oil is also reportedly used to fuel fires in the Contaminated Waste Stage and Burn Area (SWMU 17A).

The concern at SWMU 76 is an accumulation of drips and spills around the tank access ports. Surface soils may be contaminated with metals or semivolatile compounds.

2.2.26 Drum Storage Area--SWMU F

This area is located by Warehouse No. 2 (9387-2), approximately 3,000 feet from the New River (Figures 2-3 and 2-26). The area is a gravel lot, about 50 feet by 50 feet in size. Empty drums from throughout RAAP are stacked on their sides in SWMU F prior to being sold. The drums are reportedly rinsed out before being stored. Of concern at this area is visible staining of the gravel and surface soils. Approximately 20 to 30 feet of unconsolidated soil (clay, silt, and sand with gravel seams) should be present on the Elbrook Formation bedrock at SWMU F. Groundwater should flow northward and discharge into the New River.

2.2.27 Spent Battery Storage Area--SWMU P

This area is located along the New River, just west of the Biological Treatment Plant (SWMU 10) (Figures 2-3 and 2-27). The entire storage area, an open lot several acres in size, is used for the storage of shredded scrap metal and decommissioned tanks. Associated with the scrap metal yard is a spent battery storage area, about 50 feet wide and 200 feet long. An estimated 20 to 30 spent batteries are generated at RAAP each month. Battery electrolyte is drained and disposed of into the RAAP acid sewer. The cleaned batteries are accumulated in this storage area prior to shipment off post. Batteries are sold when 40,000 pounds are accumulated (approximately once every 1 to 1.5 years (Pieper, 1989).

The potential exists for contamination of surface soils by heavy metals from the spent batteries.

Alluvial deposits consisting of clay, silt, and sand, with seams of river jack, should underlie SWMU P. Bedrock consists of limestone/dolomite at the Elbrook Formation. Groundwater should flow northward and discharge into the New River, which is only 200 feet from the storage area.

1.4

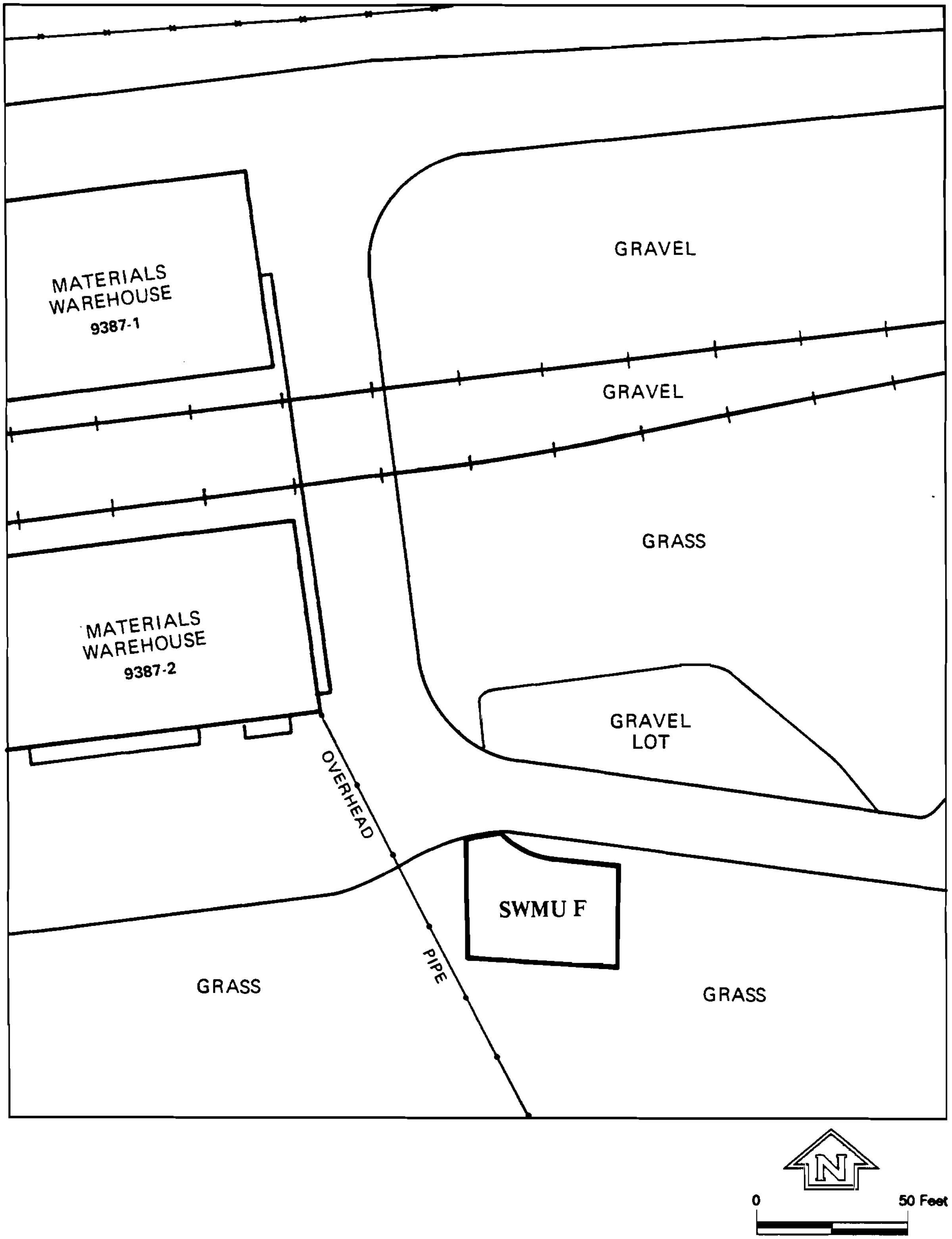


FIGURE 2-26
SWMU F – DRUM STORAGE AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

116

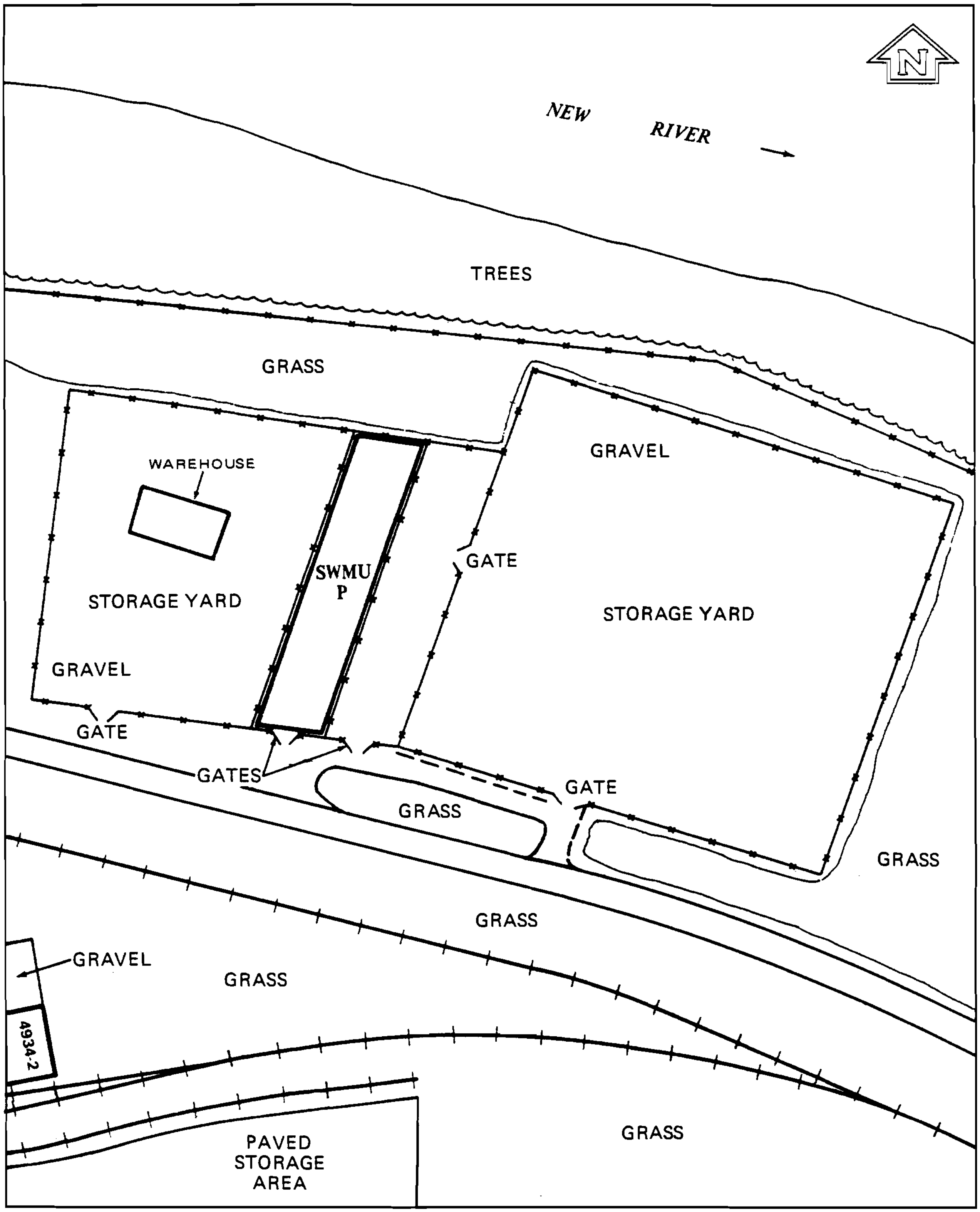


FIGURE 2-27
SWMU P – SPENT BATTERY STORAGE AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

3.0 IDENTIFICATION OF POTENTIAL RECEPTORS

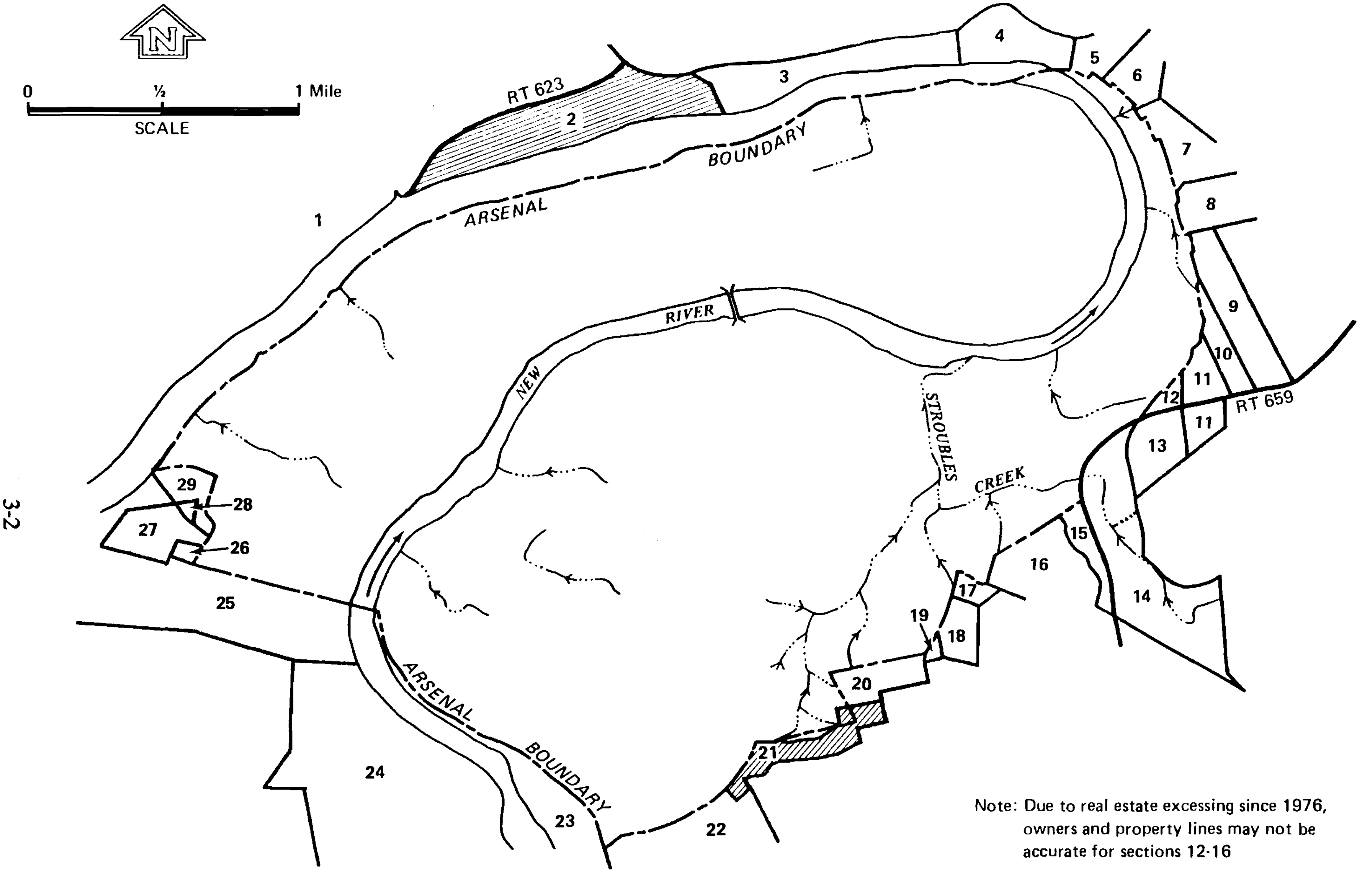
The RCRA permit issued to RAAP requires that data be collected to identify human populations and environmental systems that are susceptible to exposure from contamination at the subject SWMUs. Demographics, groundwater and surface water use, and ecological characteristics data are necessary to identify potential receptors and pathways of contamination exposure. These issues are discussed in the following sections.

3.1 LOCAL DEMOGRAPHICS

As described in Section 2.1.9 of this Work Plan, the area surrounding RAAP is mostly rural, with minimal development. The estimated 1988 populations of Montgomery and Pulaski Counties was 101,000 combined, with an approximate overall population density of 143 persons per square mile. The closest residential community is Fairlawn, approximately 3 miles to the southwest. Figure 3-1 and Table 3-1 identify the owners and locations of properties bordering RAAP.

In 1980, the median age of persons in Montgomery and Pulaski Counties was 23.7 and 31.3, respectively. Population characteristics of the two counties are shown in Table 3-2.

The 36 SWMUs being investigated under this VI are located well within the installation boundaries. Due to the military nature of activities at RAAP, access to the installation is limited to official visitors. However, the general public does have access to the New River, which flows through RAAP and near several SWMUs, but a security fence separates the river from RAAP. Of concern in the VI are SWMUs 8, 10, 31, 35, 36, 43, 45, and 54, which are located adjacent to the New River (Figure 2-3). Persons boating, fishing, or swimming in the river could potentially be exposed to contaminants migrating from these SWMUs via shallow groundwater. However, due to the significant dilution capacity of this river, potential exposure from any individual SWMU is considered minimal. Of particular concern is SWMU 13, located on the banks of the New River; however, this SWMU is addressed in the separate RFI document.



Note: Due to real estate excessing since 1976, owners and property lines may not be accurate for sections 12-16

▨ Numerous owners of small parcels

FIGURE 3-1
ADJACENT PROPERTY OWNERS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

BASE MAP SOURCE: USATHAMA, 1976

Dames & Moore

TABLE 3-1

Property Owners Adjacent to RAAP
(May 1990)

1. Virginia Polytechnic Institute
2. H. M. Albert Estate (26 individual lots)
3. Albert, M. L. et al. and Albert, Genoa T. Graves
4. Price, H. L.
5. Shaver, J. L.
6. Trower, W. P.
7. Humphrey, L. P.
8. Gallimore, E. A.
9. Nuckols, R. D.
10. Gallimore, C. R.
11. Cadle, R. Y.
12. Johnson, D., Mr. and Mrs.
13. Akers, James, Mr. and Mrs.
14. Blacksburg, Christiansburg, VPI Water Authority
15. Belvins, C. E.
16. Blacksburg, Christiansburg, VPI Water Authority
17. Howard, R. N.
18. Blacksburg, Christiansburg, VPI Water Authority
19. U.S.A.
20. Blacksburg, Christiansburg, VPI Water Authority
21. R.D. Stafford Lots (142 individual lots)
22. Hampton, Dr. C. L.
23. Oak Manor Farms
24. Ratcliffe, V. D. & Mason, L. D.
25. Stanley, R., Jr. and Nadine S.
26. McGraw, W. T., Mr. and Mrs.
27. Robertson, J. M.
28. Smith, S. J., Smith, V. & White, A. S.
29. Smart, J. H.

TABLE 3-2

Population Characteristics (1989)
Montgomery and Pulaski Counties

	Male	Female	White	Nonwhite	19 and Under	20-64 Yr	Over 65 Yr
Montgomery County	52.4%	47.6%	96.3%	3.7%	26.0%	66.7%	7.3%
Pulaski County	48.5%	51.5%	94.3%	5.7%	26.9%	60.0%	13.1%

SOURCE: NRVDPC, 1989.

Hunting is not permitted on RAAP property, and recreation by RAAP employees is limited to activities such as softball, jogging, etc.

3.2 GROUNDWATER RECEPTORS

There are two known supply wells at RAAP (Insert 1)--well No. 1 is not currently used; well No. 2 is used as a backup potable supply for a tenant activity, the U.S. Army Research, Development and Acquisition Information Systems Agency. Potential contamination of groundwater is a concern at many of the SWMUs being investigated under this VI. However, neither of these two RAAP supply wells are located in the immediate vicinity of any of the SWMUs.

Groundwater is a source of water supply to some residents in the Town of Blacksburg, but the supply wells are located more than 5 miles east of RAAP. In addition, shallow groundwater for many of the SWMUs flows toward the New River and would not likely migrate toward any groundwater users in the vicinity of RAAP.

Groundwater usage in the vicinity of RAAP has not been directly characterized. An off-post well inventory to identify potential receptors is proposed as an RFI activity. The survey will involve a records search of well logs maintained by the Virginia State Water Control Board and/or the Pulaski and Montgomery County Health Departments. The well inventory will be conducted to collect pertinent data such as well locations, depths, production rates, and uses.

This information will be available during assessment of the VI SWMUs.

3.3 SURFACE WATER RECEPTORS

Most water used at RAAP is taken from the New River via two intakes--one located approximately 2 miles upstream of the mouth of Stroubles Creek and the other located approximately 6 miles downstream of the mouth of Stroubles Creek (Figure 2-5). Upstream of RAAP, the New River serves as a source of water supply for the cities of Blacksburg and Christiansburg.

The Commonwealth of Virginia has classified the stretch of the New River that passes through RAAP as water generally satisfactory for public or municipal water supplies, secondary contact recreation, and propagation of fish and aquatic life.

Stroubles Creek, which drains approximately one-third of the RAAP Main Manufacturing Area, enters the New River approximately 1 mile east of the New River Bridge (Figure 2-5). A large portion of the flow in Stroubles Creek is attributable to effluent from the Blacksburg municipal sewage treatment plant. There are no known domestic or recreational uses of this stream.

3.4 AIR QUALITY

Much of the two-county area is susceptible to inversion layers in the fall, causing entrapment of particulate matter as well as gases from manufacturing processes and auto exhaust.

Air emissions from SWMUs at RAAP are of concern primarily at the two SWMUs where burning operations take place--SWMU 13 and SWMU 17. These burning areas, permitted by the Virginia Air Pollution Control Board, are a subject of the separate RFI.

3.5 THREATENED AND ENDANGERED SPECIES

Available data indicate that no threatened or endangered species are suspected of inhabiting RAAP, nor are there any known species with unusual aesthetic value. No species are known to occur exclusively at RAAP or to be absent from the rest of the two counties or the State. There are no species known for which the installation lies at the limit of their ranges. Indications are that the numbers of some species, including the ruffed grouse and upland plovers, have become depleted or have disappeared from RAAP (USATHAMA, 1976).

4.0 RECOMMENDATIONS FOR SWMU INVESTIGATIONS

4.1 INTRODUCTION

The overall objective of this Work Plan is to obtain representative samples of soil, sediment, surface water, and groundwater at the subject SWMUs, as well as to characterize hydrogeologic conditions in the vicinity of the SWMUs. Following Dames & Moore's facility visits in February and March 1990, and discussions with representatives of USATHAMA and RAAP, investigative strategies were developed for each SWMU to supplement existing data and to meet the data needs outlined in the permit. These recommended strategies have been designed to meet the VI objective of identifying releases or suspected releases of hazardous waste constituents into groundwater, surface water, soil, or sediments. Recommended activities for SWMU investigations include geophysical surveys, development of standard operating procedures (SOPs), drilling, monitoring well installation, physical soil testing, collection of groundwater elevations, and sample collection and analysis. Methodologies for these activities are provided in Sections 5.0 and 6.0.

Data obtained from the proposed sampling activities will be used to screen from further investigation those SWMUs that do not pose a threat to human health and the environment, and to characterize whether wastes in selected SWMUs are hazardous wastes or contain hazardous constituents.

SWMU descriptions are found in Section 2.0. A summary of the recommended investigation activities for each SWMU is provided in Table 4-1. At SWMUs undergoing waste analysis, followup investigations may be required, as discussed in Section 4.2. Proposed activity and sampling locations are shown in Figures 4-1 through 4-24 (cited later in this section).

The analytical parameters discussed in this section refer to the metals, explosives, volatile organic compounds (VOCs), and base neutral/acid (semivolatile) compounds (BNAs) that were specifically identified in Attachment A of the permit and included in Appendix B. VOCs and BNAs will be analyzed for constituents identified in "List 1" or "List 2" of Attachment A of the permit. It is proposed that some samples also be analyzed for total petroleum hydrocarbons (TPHs) and have

TABLE 4-1

Summary of Proposed SWMU Investigations
Radford Army Ammunition Plant, Virginia

SWMU	Geophysical Survey	SOPs	Backhoe/ Borings	Install Monitor Wells	Physical Soil Testing	Surveying	Water Levels	Sampling				
								GW	SW	SO	SE	W
6--Acidic Wastewater Lagoon	--	--	--/2	--	--	--	4	4	--	4	--	--
8--Calcium Sulfate Settling Lagoons	--	--	--	--	--	--	--	--	--	--	--	2
35/36--Calcium Sulfate Drying Beds	--	--	--/4	--	--	--	--	--	--	--	--	4
9--Calcium Sulfate Settling Lagoons	--	--	--	--	--	--	--	--	--	--	--	2
37/38/Q--Calcium Sulfate Drying Beds/Abandoned Lagoon/Trenches	X	--	--/3	--	--	--	--	--	--	--	--	3
10--Biological Treatment Equalization Basin	--	--	--	--	--	--	3	3	--	--	--	--
26--FAL No. 1	--	--	--	--	--	--	4	4	--	--	--	--
27/29/53--Calcium Sulfate LF/FAL No. 2/Activated Carbon Disposal Area	--	--	--	--	--	--	5	5	1	--	3	--
31--Coal Ash Settling Lagoons	--	--	--	--	--	--	--	--	--	--	--	3
32--Inert Waste LF No. 1	--	--	--	2	2	2	2	2	--	--	--	--
39--Incinerator Wastewater Ponds	--	--	--	--	--	--	--	--	--	3	--	3
40--Sanitary Landfill (NG Area)	--	--	--	4	4	4	4	4	--	--	--	--
41--Red Water Ash Landfill	--	--	--/1	3	4	3	3	3	1	2	--	--
43--Sanitary Landfill (adjacent to New River)	--	--	--	6	6	6	6	6	--	--	--	--
45--Sanitary Landfill (west of main bridge)	X	--	--	3	3	3	3	3	--	--	--	--
46--Waste Propellant Disposal Area	--	--	8/--	--	--	--	--	--	--	2	--	--
48--Oily Wastewater Disposal Area	--	--	--/3	--	--	--	--	--	--	6	--	--
50--Calcium Sulfate Disposal Area	--	--	--/2	--	--	--	--	--	--	--	--	2

TABLE 4-1 (cont'd)

SWMU	Geophysical Survey	SOPs	Backhoe/ Borings	Install Monitor Wells	Physical Soil Testing	Surveying	Water Levels	Sampling				
								GW	SW	SO	SE	W
54--Propellant Ash Disposal Area	X	--	--	3	3	3	3	3	--	--	--	--
57--Pond by Buildings 4931 and 4928	--	--	--	--	--	--	--	--	1	--	1	--
58--Rubble Pile	--	--	--	--	--	--	--	--	--	3	--	--
59--Bottom Ash Pile	--	--	--	--	--	--	--	--	--	2	--	--
61--Mobile Oil Tanks	--	X	--	--	--	--	--	--	--	--	--	--
68--Chromic Acid Treatment Tanks	--	--	--	--	--	--	--	--	--	2	--	--
69--Pond by SWMU 68	--	--	--	--	--	--	--	--	1	2	1	--
71--Flash Burn Parts Area	--	--	--	--	--	--	--	--	--	3	--	--
74--Inert LF No. 3	--	--	--	1	1	1	1	1	--	--	--	--
75--Waste Oil UST (Inert Gas Plant)	--	X	--	--	--	--	--	--	--	--	--	--
76--Waste Oil UST (Oleum Plant)	--	X	--	--	--	--	--	--	--	--	--	--
F--Drum Storage Area	--	--	--	--	--	--	--	--	--	4	--	--
P--Spent Battery Storage Area	--	--	--/5	--	--	--	--	--	--	10	--	--
QC Samples												
Drilling/Rinse water	--	--	--	--	--	--	--	--	3	--	--	--
Equipment blank	--	--	--	--	--	--	--	--	4	--	--	--
Field blank	--	--	--	--	--	--	--	--	6	--	--	--
Trip blank	--	--	--	--	--	--	--	--	4	--	--	--
Replicate	--	--	--	--	--	--	--	2	1	3	1	1
TOTAL	3	3	8/20	22	23	22	38	40	22	46	6	20

~~54~~ 52

Abbreviations:
SOPs - Standard Operating Procedures
GW - Groundwater
SW - Surface Water
SO - Soil
SE - Sediment
W - Waste

Note: Drilling/rinse water, equipment blank, and field blank assumed to come from a surface water source.

the Toxicity Characteristic Leaching Procedure testing for metals (TCLP metals). Note that while the permit lists 12 metals for total analyses, TCLP metals refers to the eight RCRA metals identified in 40 CFR Part 261.24. In addition to these parameters, all aqueous samples will be analyzed for total organic carbon (TOC) and total organic halogen (TOX) and will be field-tested for pH, specific conductance, and temperature. A summary of the proposed analytical program is provided in Table 4-2.

4.2 RATIONALE FOR STUDY AREAS

As provided for in the permit, several SWMUs to be investigated under this VI are proposed to be combined into study areas. Based on SWMU proximity and/or similarity of wastes disposed of in the units, the following study areas are proposed:

- Calcium Sulfate Areas--Calcium sulfate sludge from the neutralization of acidic wastewaters has been or is currently managed in several units. SWMUs 8 and 9 are sludge settling lagoons; SWMUs 35, 36, 37, 38, and Q are sludge drying beds; and SWMU 50 and the area near SWMU 38 were used for sludge disposal. As discussed in Section 4.2.2, waste analysis will be performed on the calcium sulfate sludge from these units to determine whether hazardous constituent concentrations in the sludge exceed maximum allowable permit limits.

  SWMU 27, an additional calcium sulfate sludge disposal area, is not included within this study area. Because this unit is buried within another landfill (SWMU 29), waste analysis of the sludge is inappropriate.

- Calcium Sulfate Landfill, Fly Ash Landfill No. 2, and Activated Carbon Disposal Area (SWMUs 27, 29, and 53)--These three units are grouped into one study area because SWMUs 27 and 53 are buried beneath SWMU 29.

- Chromic Acid Treatment Tanks and Pond (SWMUs 68 and 69)--These units are two separate components of a chromic acid treatment system.

TABLE 4-2

Summary of Proposed VI Analytical Program
Radford Army Ammunition Plant, Virginia

			Analytical Parameters[a]										
						List 1		List 2					
SWMU[b]	Samples[c]	Media[d]	Metals	TPH	Explosives	VOCs	BNAs	VOCs	BNAs	TOC	TOX	pH	TCLP Metals
6--Acidic Wastewater Lagoon	6SB1A, 6SB1B	SO	X										
	6SB2A, 6SB2B	SO	X										
	13, 14, 15, 16	GW	X							X	X	X	
8--Calcium Sulfate Settling Lagoons	8SL1, 8SL2	SL				X	X						X
9--Calcium Sulfate Settling Lagoons	9SL1, 9SL2	SL				X	X						X
10--Biological Treatment Equalization Basin	D3, DDH2, DDH4	GW	X		X	X	X			X	X	X	
26--FAL No. 1	B3, BDH2, BDH3, CTM-1	GW	X					X	X	X	X	X	
27/29/53--Calcium Sulfate LF/FAL No. 2/Activated Carbon Disposal Area	FAL-1, FAL-2, FAL-3, 7,16-3	GW	X		X			X	X	X	X	X	
	29SE1, 29SE2, 29SE3	SE	X		X			X	X				
	29SW1	SW	X		X			X	X	X	X	X	
31--Coal Ash Settling Lagoons	31SL1, 31SL2, 31SL3 (composites)	SL	X				X						
32--Inert Waste LF No. 1	32MW1, 32MW2	GW	X			X	X			X	X	X	
35--Calcium Sulfate Drying Bed	35SL1	SL				X	X						X
36--Calcium Sulfate Drying Beds	36SL1, 36SL2, 36SL3	SL				X	X						X
37--Calcium Sulfate Drying Bed	37SL1	SL				X	X						X
38--Calcium Sulfate Drying Bed	38SL1	SL				X	X						X
39--Incinerator Wastewater Ponds	39SL1, 39SL2, 39SL3 (composites)	SL	X		X		X						
	39SS1, 39SS2, 39SS3	SO	X		X		X						

TABLE 4-2 (cont'd)

			Analytical Parameters[a]										
						List 1		List 2					
SWMU[b]	Samples[c]	Media[d]	Metals	TPH	Explosives	VOCs	BNAs	VOCs	BNAs	TOC	TOX	pH	TCLP Metals
40--SLF (NG Area)	40MW1, 40MW2, 40MW3, 40MW4	GW	X			X	X			X	X	X	
41--Red Water Ash Landfill	41MW1, 41MW2, 41MW3	GW	X		X		X			X	X	X	
	41SB1A, 41SB1B	SO	X		X		X						
	41SW1	SW	X		X		X			X	X	X	
43--SLF (adjacent to New River)	43MW1, 43MW2, 43MW3, 43MW4, 43MW5, 43MW6	GW	X			X	X			X	X	X	
45--SLF (west of main bridge)	45MW1, 45MW2, 45MW3	GW	X		X	X	X			X	X	X	
46--Waste Propellant Disposal Area	46SS1, 46SS2	SO	X		X								
48--Oily Wastewater Disposal Area	48SB1A, 48SB1B, 48SB2A, 48SB2B, 48SB3A, 48SB3B	SO	X			X	X						X
50--Calcium Sulfate Disposal Area	50SL1, 50SL2					X	X						X
54--Propellant Ash Disposal Area	54MW1, 54MW2, 54MW3	GW	X		X	X	X			X	X	X	
57--Pond by Buildings 4931 and 4928	57SW1	SW	X			X	X			X	X	X	
	57SE1	SE	X			X	X						
58--Rubble Pile	58SS1, 58SS2, 58SS3	SO	X			X	X						
59--Bottom Ash Pile	59SS1, 59SS2	SO	X				X						
68--Chromic Acid Treatment Tanks	68SS1, 68SS2	SO	X									X	

			Analytical Parameters[a]										
						List 1		List 2					
SWMU[b]	Samples[c]	Media[d]	Metals	TPH	Explosives	VOCs	BNAs	VOCs	BNAs	TOC	TOX	pH	TCLP Metals
69--Pond by SWMU 68	69SW1	SW	X							X	X	X	
	69SE1	SE	X									X	
	69SS1, 69SS2	SO	X									X	
71--Flash Burn Parts Area	71SS1, 71SS2, 71SS3	SO	X	X	X								
74--Inert LF No. 3	74MW1	GW	X			X	X			X	X	X	
F--Drum Storage Area	FSS1, FSS2, FSS3, FSS4	SO				X	X						
P--Spent Battery Storage Area	PSB1A/B through PSB5A/B	SO	X									X	
Q--Calcium Sulfate Drying Bed	QSL1	SL				X	X						X
Drilling/Rinse Water	RAAP-1(3)	RW	X		X	X	X	X	X	X	X	X	

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[a] Metals: as described in Attachment A of permit
TPH: total petroleum hydrocarbons
Explosives: as described in Attachment A of permit
VOCs: volatile organic compounds
BNAs: base neutral/acid extractables (semivolatiles)
TOC: total organic carbon
TOX: total organic halogen
TCLP metals: leaching procedure analysis for As, Ba, Cd, Cr, Hg, Pb, Se, Ag.

[b] Other codes:
FAL: fly ash landfill
SLF: sanitary landfill
LF: landfill
UST: underground storage tank
NG: nitroglycerin.

[c] Sample designation codes assigned as described in Section 4.0:
MW: groundwater from monitoring well
RW: drilling/rinse water
SB: soil boring
SE: sediment
SL: sludge
SS: surface soil
SW: surface water
Other codes derived from existing well identification numbers.

[d] Media to be sampled:
GW: groundwater
SE: sediment
SL: sludge
SO: soil
SW: surface water

Treated chromic acid wastewater was discharged from the tanks to the adjacent settling pond. Sampling is proposed to evaluate potential soil, surface water, and sediment contamination resulting from this process.

4.3 RECOMMENDED SWMU INVESTIGATIONS

4.3.1 Acidic Wastewater Lagoon--SWMU 6

Sampling will be conducted at SWMU 6 to determine whether soil contamination exists from acidic wastewater that was formerly discharged to the lagoon. It is proposed that two boreholes (6SB1 and 6SB2) be drilled at this SWMU (Figure 4-1). One boring will be drilled in what was likely the deepest part of the lagoon, which would have contained wastewater over the longest period. A second boring will be drilled in the northwest portion of the filled lagoon, where wastewater most likely would have been present only during high influent/low effluent periods. It is anticipated that these two borings will not exceed 20 feet in depth.

Two soil samples will be collected from each boring. One sample will be collected from any sludge or visibly contaminated soil horizon, and one sample will be collected beneath this zone from visibly "clean" soil. The four samples (6SB1A, 6SB1B, 6SB2A, and 6SB2B) will be analyzed for metals and pH.

There are currently four existing wells (13, 14, 15, and 16) at SWMU 6. To determine whether groundwater quality in the vicinity of the unit has been impacted, these wells will be inspected and sampled if possible. As discussed in Section 2.2.1, these wells could not be sampled at times due to loss of fluid attributed to an underlying sinkhole. If the wells contain liquid, groundwater samples will be collected and analyzed for metals.

No new monitoring wells are proposed to be installed at SWMU 6 due to the karst terrain. The suspected sinkhole occupied by the lagoon makes the investigation of groundwater extremely difficult. Installation of additional wells at this location is not considered to be appropriate.

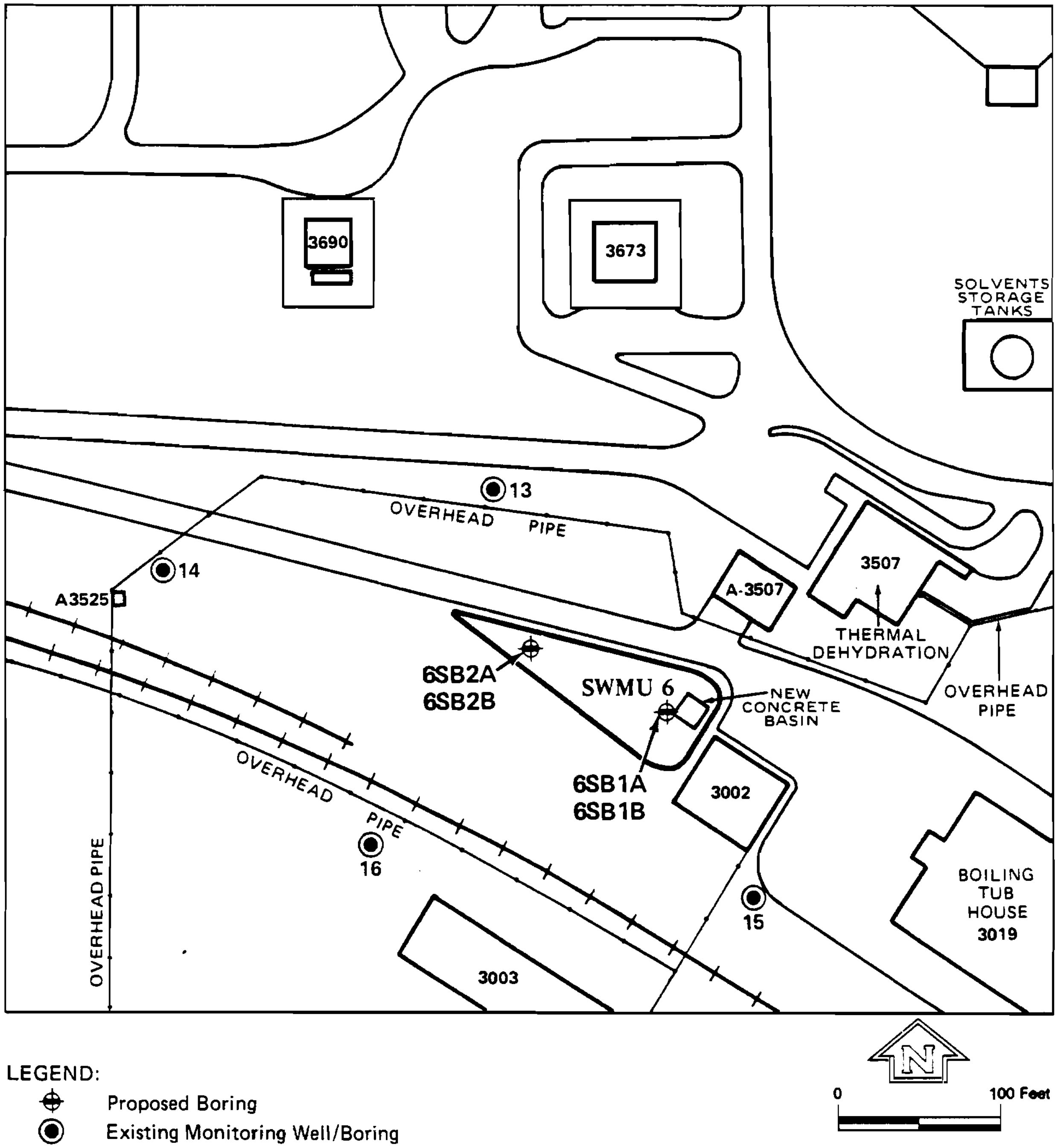


FIGURE 4-1
RECOMMENDED INVESTIGATION
SWMU 6 – ACIDIC WASTEWATER LAGOON
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

4.3.2 Calcium Sulfate Areas--SWMUs 8, 9, 35, 36, 37, 38, Q, and 50, and Sludge Disposal Area Near SWMU 38

Wastes at these units were generated from similar processes and are considered to be relatively homogenous in character. As provided for in the permit, wastes from these units will be sampled and analyzed to evaluate whether any hazardous constituent concentrations exceed the maximum allowable permit limits. In the event that the wastes are determined to contain hazardous constituents in excess of allowable limits, investigative strategies will be developed to address potential contamination of soils and groundwater. If the wastes are reported to be below the maximum allowable permit limits in the hazardous constituents concentrations, no further action will be considered necessary at these units.

4.3.2.1 Calcium Sulfate Settling Lagoons--SWMUs 8 and 9. These units consist of liquid-filled sludge settling lagoons. Sludges present in the lagoons will be sampled (Figures 4-2 and 4-3). One sample will be collected from each of the two lagoons (8SL1 and 8SL2) at SWMU 8, and one sample will be collected from each of the two lagoons (9SL1 and 9SL2) at SWMU 9 (for a total of four sludge samples). Sample locations will be along the edges of the lagoons if possible, or in a central location if a boat is used. The top 1 foot of sludge will be sampled. The four sludge samples will be analyzed for VOCs and BNAs (List 1) and TCLP metals.

If analytical results indicate that hazardous constituent concentrations in the sludge are above maximum allowable permit limits, a groundwater monitoring well installation and sampling program will be developed to determine whether these constituents are migrating from SWMUs 8 and 9.

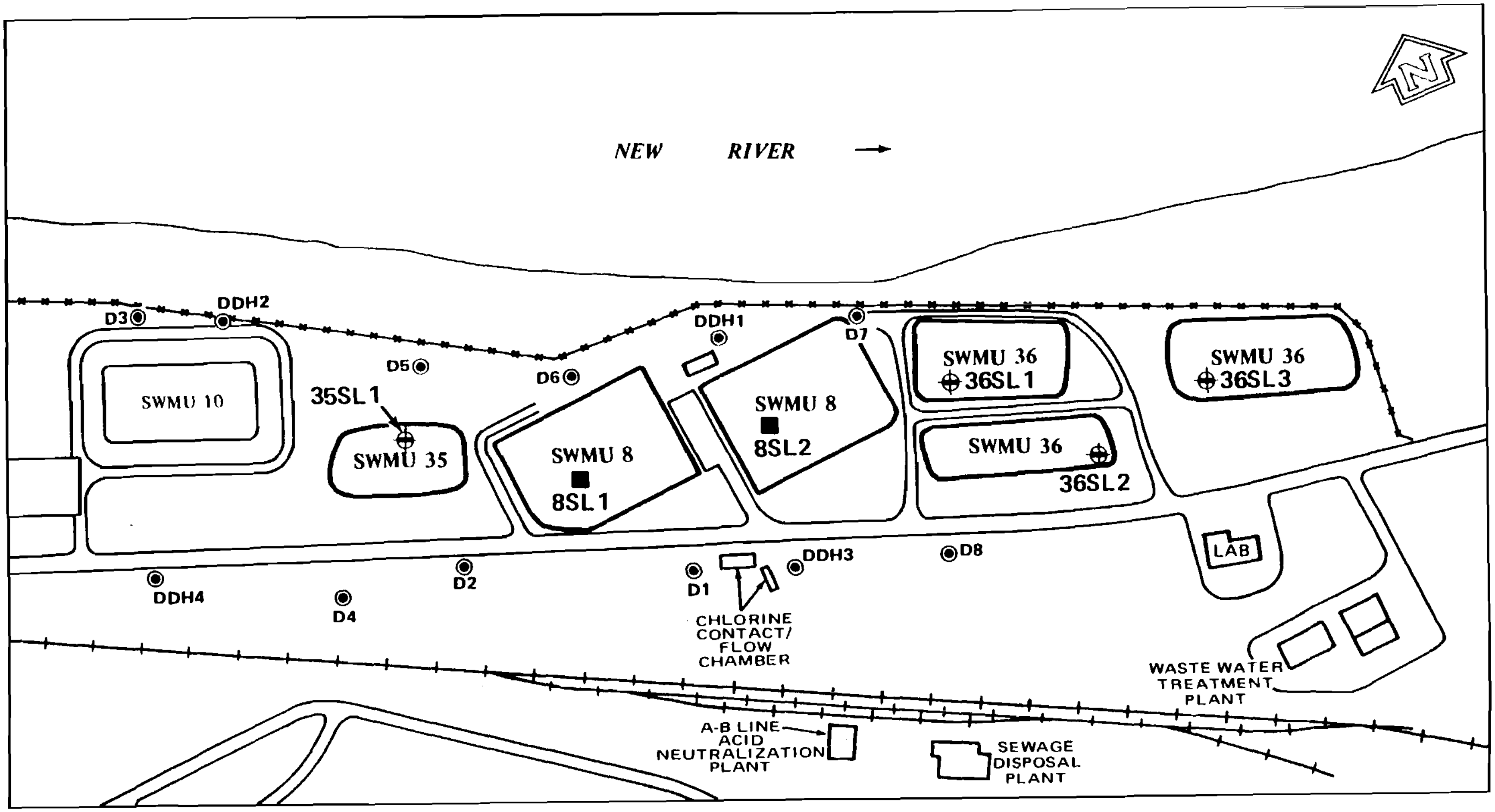
4.3.2.2 Calcium Sulfate Drying Beds--SWMUs 35, 36, 37, 38, and Q. There are a total of seven drying beds within these five units (Figures 4-2 and 4-3). In drying beds that contain liquids, one sample will be collected from the top 1 foot of sludge present in the bed. Sample locations will be along the edges of the bed where sampling from the edge is possible. In drying beds that contain only dried, solidified sludge, a 5-foot boring will be drilled in the central part of the units. One sample will be collected from each 5-foot core to ensure a representative sample of sludge drying episodes. All samples collected from the drying beds will be analyzed for

VOCs, BNAs, and TCLP metals. Tentatively, samples 35SL1, 36SL1, 36SL2, 36SL3, 37SL1, 38SL1, and QSL1 will be collected, as shown in Figures 4-2 and 4-3.

If analytical results indicate that hazardous constituent concentrations in the sludge are above maximum allowable permit limits, a groundwater monitoring well installation and sampling program will be proposed to determine whether these constituents are migrating from SWMUs 35, 36, 37, 38, and Q.

4.3.2.3 Calcium Sulfate Disposal Areas--SWMU 50 and Sludge Disposal Area Near SWMU 38. The specific locations of sludge disposal at SWMU 50 have been identified through a review of aerial photographs and onsite inspections. However, in the Sludge Disposal Area Near SWMU 38, specific sludge disposal locations and boundaries have not been appropriately determined. Therefore, a geophysical survey is proposed to delineate trench locations. Details of the geophysical techniques to be used are discussed in Section 5.2. A series of lines spaced approximately 15 feet apart will be traversed, with magnetic and electromagnetic readings taken at 15-foot intervals. The geophysical survey will cover an area of less than 1 acre, as shown in Figure 4-3.

Two soil borings are proposed at SWMU 50 (Figure 4-4) to collect two sludge samples (50SLI, 50SL2) for waste characterization. Five-foot borings will be drilled into the central unit, and a 5-foot core will be collected for chemical analysis. The samples will be analyzed for VOCs, BNAs, and TCLP metals. No sampling activities are proposed at the Sludge Disposal Area Near SWMU 38. Because sludge disposed of in this area was generated in the settling lagoons and drying beds, described above, the analytical results from the samples collected from those units will indicate whether the sludge disposal area contains hazardous constituents at concentrations potentially above maximum allowable permit limits. If analyses performed on the settling lagoon and drying bed sludge samples indicate that the sludge contains hazardous constituents, a groundwater monitoring well installation and sampling program will be proposed to address potential soil and groundwater contamination.

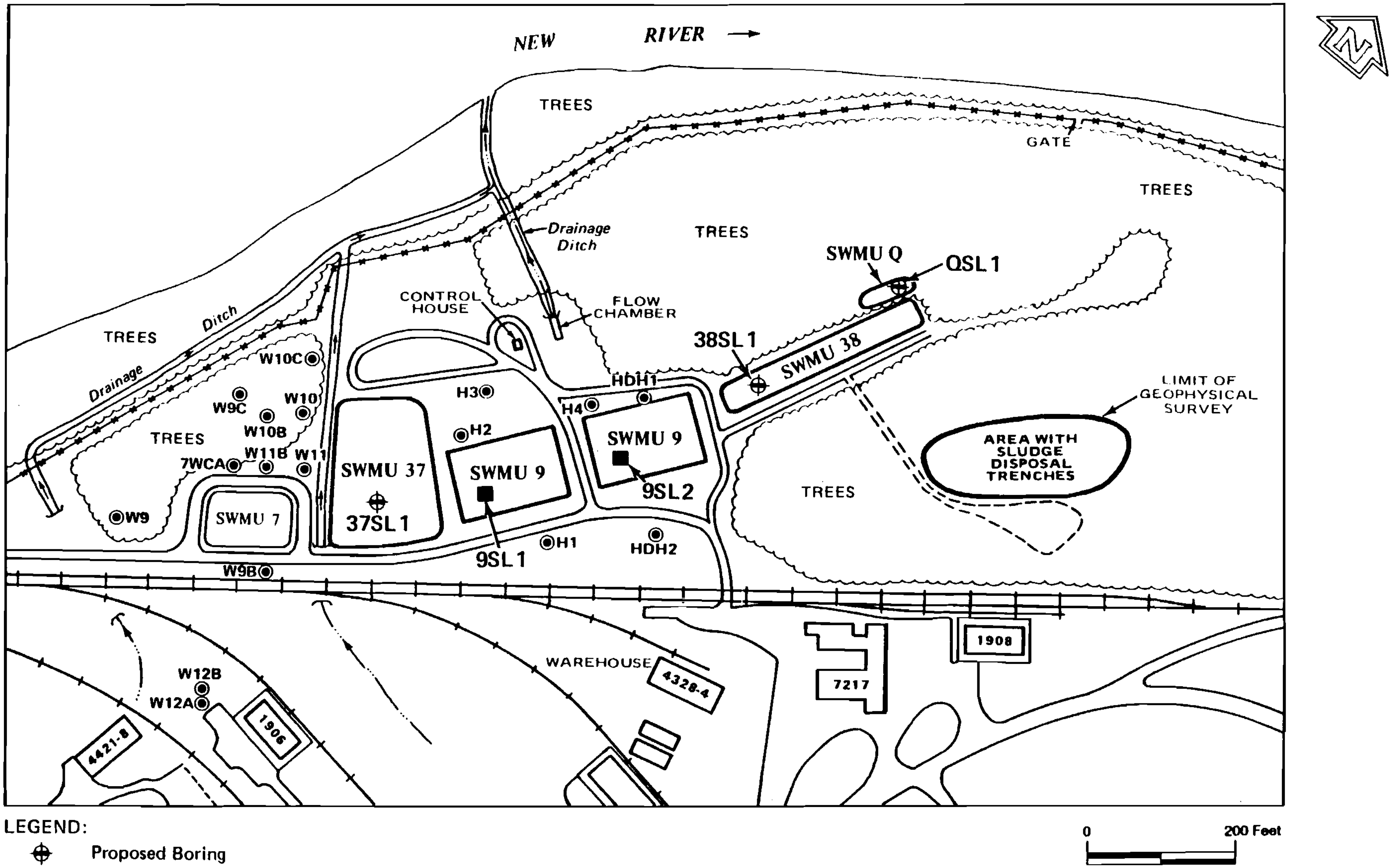


LEGEND:

- ⊕ Proposed Boring
- ◉ Existing Monitoring Well/Boring
- ■ Proposed Soil/Waste Sample

FIGURE 4-2
RECOMMENDED INVESTIGATIONS
SWMU 8 – CALCIUM SULFATE SETTLING LAGOONS
SWMUs 35 AND 36 – CALCIUM SULFATE DRYING BEDS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

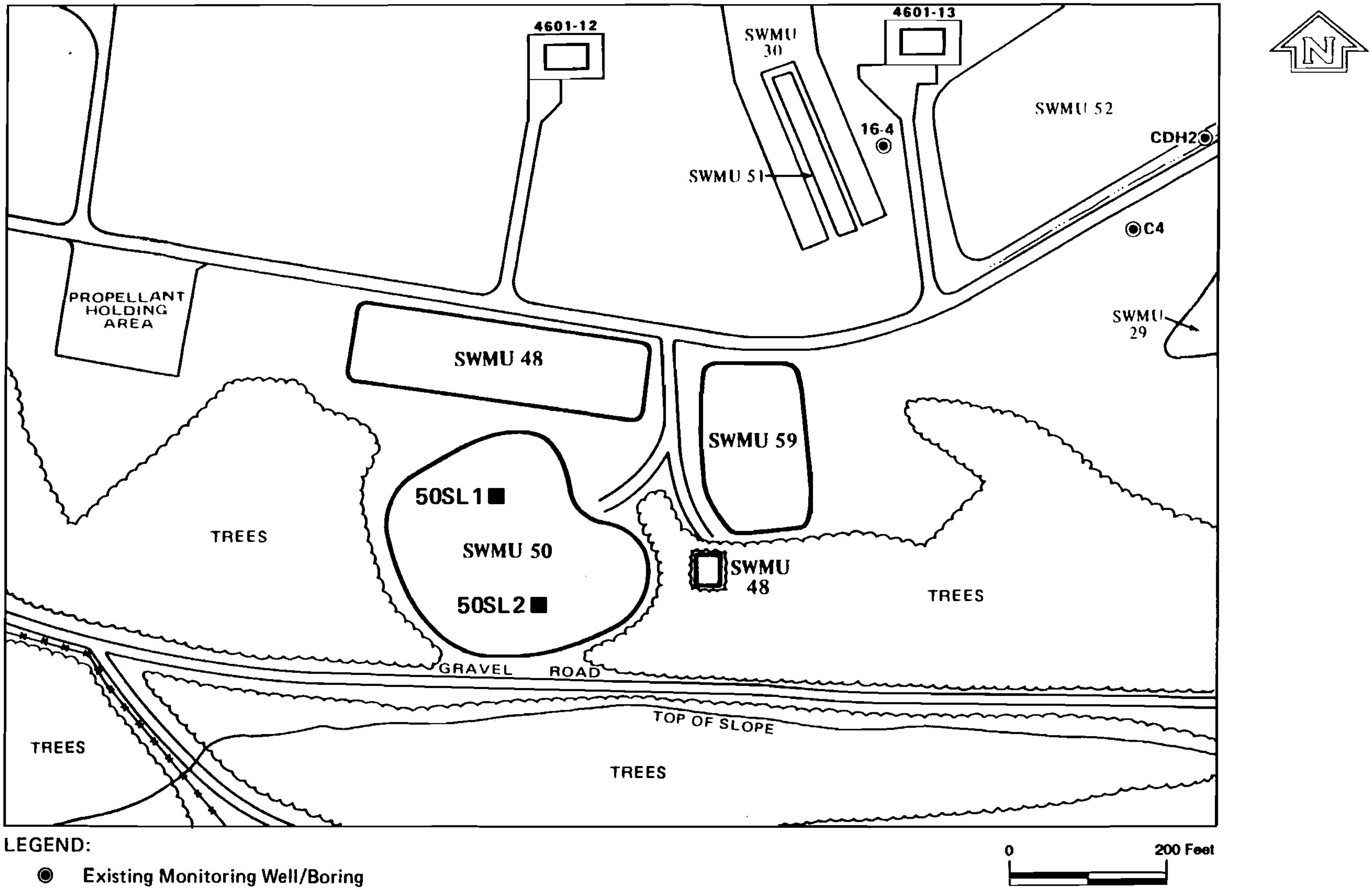


LEGEND:

- ⊕ Proposed Boring
- ◉ Existing Monitoring Well/Boring
- ■ Proposed Soil/Waste Sample

FIGURE 4-3
RECOMMENDED INVESTIGATIONS
SWMU 9 – CALCIUM SULFATE SETTLING LAGOONS
SWMUs 37 AND 38 – CALCIUM SULFATE DRYING BEDS
SWMU Q – CALCIUM SULFATE DRYING BEDS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore



LEGEND:

- ◉ Existing Monitoring Well/Boring
- ■ Proposed Soil/Waste Sample

FIGURE 4-4
RECOMMENDED INVESTIGATION
SWMU 50 – CALCIUM SULFATE DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

4.3.3 Biological Treatment Equalization Basin--SWMU 10

At present, there are seven monitoring wells in the vicinity of SWMU 10 (Figure 4-5). These wells were installed during the 1980 investigation of SWMU 10 and SWMU 8, to the east. Available well construction details for existing wells are provided in Appendix A.

The concern at this unit is potential leakage of hazardous constituents through the basin's soil/cement/clay liner and degradation of groundwater quality. It is proposed that three of the existing wells--D3 and DDH2 (downgradient) and DDH4 (upgradient)--be inspected to determine whether they are suitable for sampling. If a well is not suitable for any reason, USATHAMA will be notified and it will be determined whether another well can be substituted for sampling or if a new well should be installed. Because the biological treatment plant reportedly receives a variety of wastewaters, it is proposed that groundwater samples collected from the three wells be analyzed for metals and explosives in addition to the VOCs and BNAs specified in the permit.

4.3.4 Fly Ash Landfill No. 1--SWMU 26

There are currently eight monitoring wells in the vicinity of SWMU 26 (Figure 4-6). These wells were installed during the 1980 and 1988 investigations of the unit. Available well construction details for existing wells are provided in Appendix A. It is proposed that four of these wells--B2, CTM-1, and BDH1 (downgradient) and BDH3 (upgradient)--be inspected to determine whether they are suitable for sampling. If a well is not suitable for any reason, another well will be substituted (if appropriate) with USATHAMA approval. The four selected wells will be sampled and analyzed for metals, VOCs, and BNAs (List 2).

4.3.5 Calcium Sulfate Landfill, Fly Ash Landfill No. 2, and Activated Carbon Disposal Area--SWMUs 27, 29, and 53

Because SWMUs 27 and 53 have been covered by fly ash landfilling operations at SWMU 29, the three units have been combined into one study area. A groundwater monitoring program that includes collection of water levels and

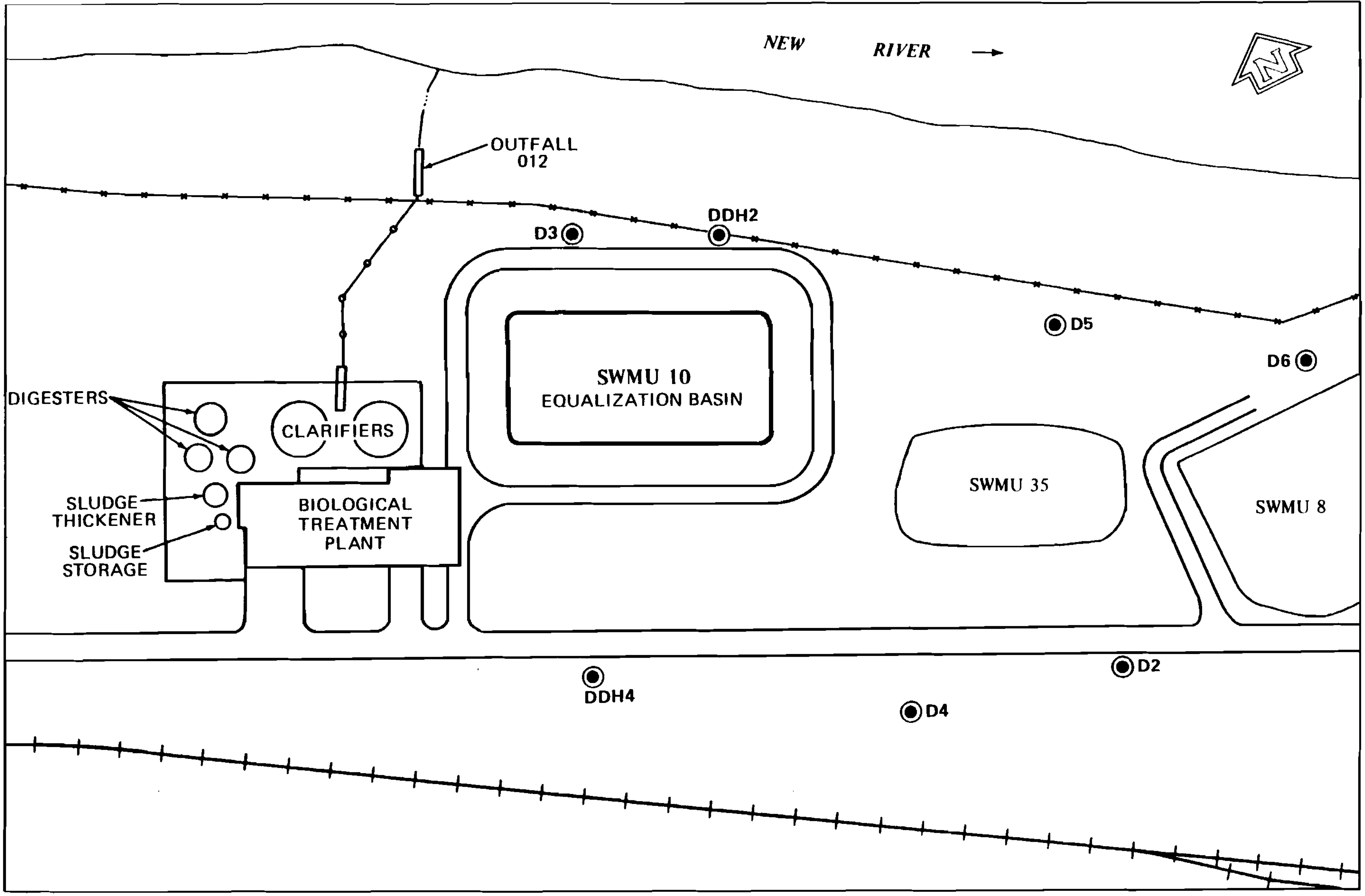
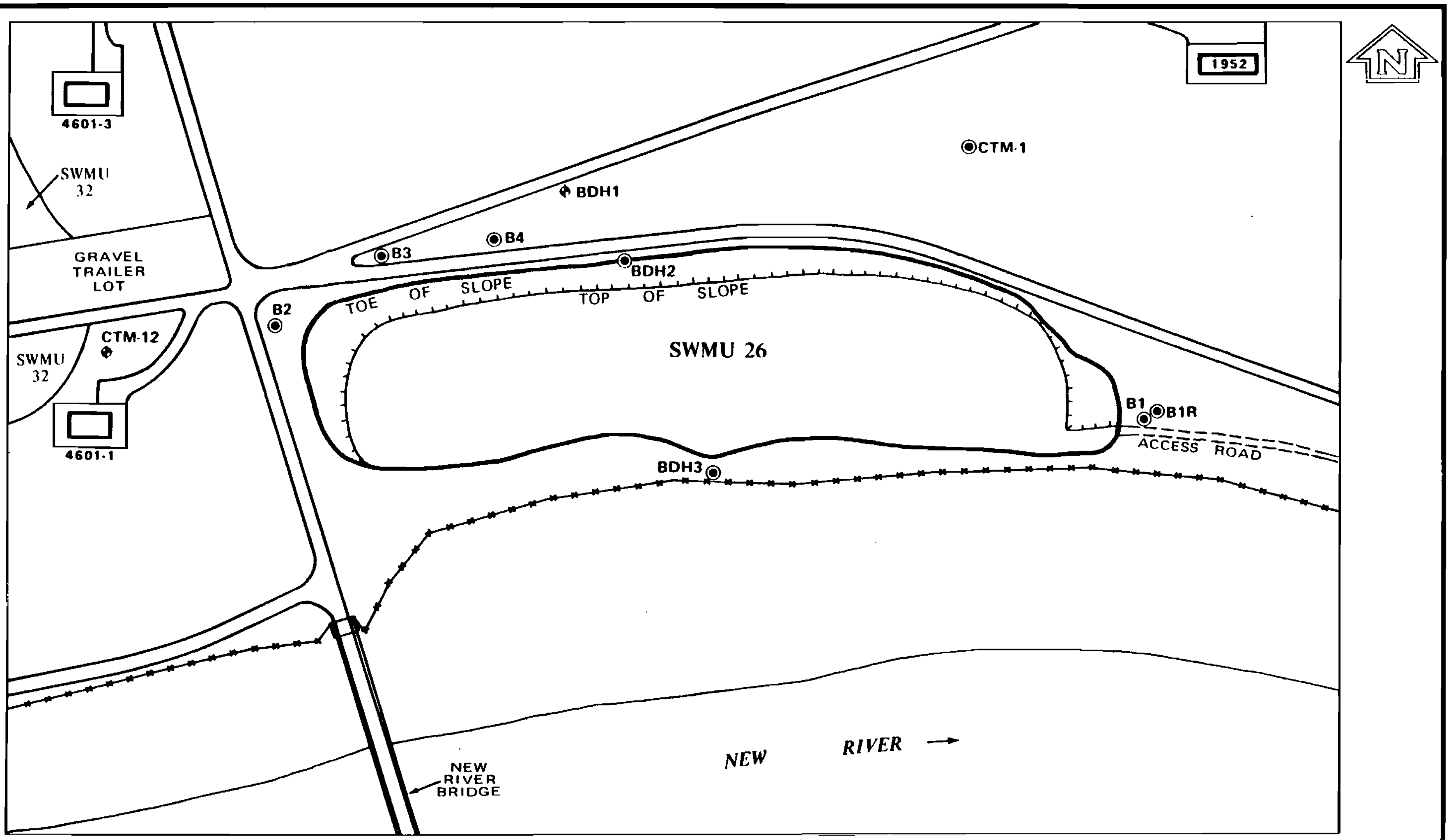


FIGURE 4-5
RECOMMENDED INVESTIGATION
SWMU 10 – BIOLOGICAL TREATMENT PLANT EQUALIZATION BASIN
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

137



LEGEND:

- ◈ Existing Boring
- ◉ Existing Monitoring Well/Boring

FIGURE 4-6
RECOMMENDED INVESTIGATION
SWMU 26 – FLY ASH LANDFILL No. 1
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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samples from five existing wells is proposed to identify potential contaminant migration from any of the three units in the study area.

There are four existing monitoring wells located downgradient of the study area--FAL-1, FAL-2, FAL-3, and 7 (Figure 4-7). These wells will be inspected to determine whether they are suitable for sampling. If a well is not suitable for any reason, another well will be substituted, if appropriate, with USATHAMA approval.

Upgradient of the study area are a number of monitoring wells that were installed to investigate SWMUs 16, 28, and 52, as shown in Figure 4-7. Only two of these wells--16-3 and CDH3--are located downgradient of units 16, 28, and 52 and upgradient of units 27, 29, and 53. Well 16-3 has been included in the proposed sampling program for the RFI at SWMUs 28, 51, and 52. The groundwater sample collected from this well is to be analyzed for metals, explosives, VOCs, and BNAs (List 2) and will provide pertinent data for the VI at this study area. Samples collected from wells FAL-1, FAL-2, FAL-3, and 7 will be analyzed for metals, explosives, VOCs, and BNAs (List 2).

To evaluate whether contaminants are migrating via surface water/sediment runoff, one sediment sample (29SE3) will be collected from the drainage ditch that flows south from the study area. This sample will be collected from 0 to 6 inches below the water/sediment interface. Two sediment samples (29SE1 and 29SE2) will also be collected from the runoff settling pond at a depth of 0 to 12 inches below the water/sediment interface. These three sediment samples will be analyzed for metals, explosives, VOCs, and BNAs (List 2). If standing water exists in the settling pond at the time of sampling, a surface water sample (29SW1) will also be collected and analyzed for the same constitutents as the sediment samples, as well as for TOC and TOX.

4.3.6 Coal Ash Settling Lagoons--SWMU 31

The coal ash that is discharged to this unit is considered to be relatively homogenous in character. As provided in the permit, a waste sample from this unit will be collected and analyzed to determine whether it contains hazardous constituents at concentrations exceeding the maximum allowable permit limits. If the waste hazardous constituent concentrations exceed these limits, a groundwater

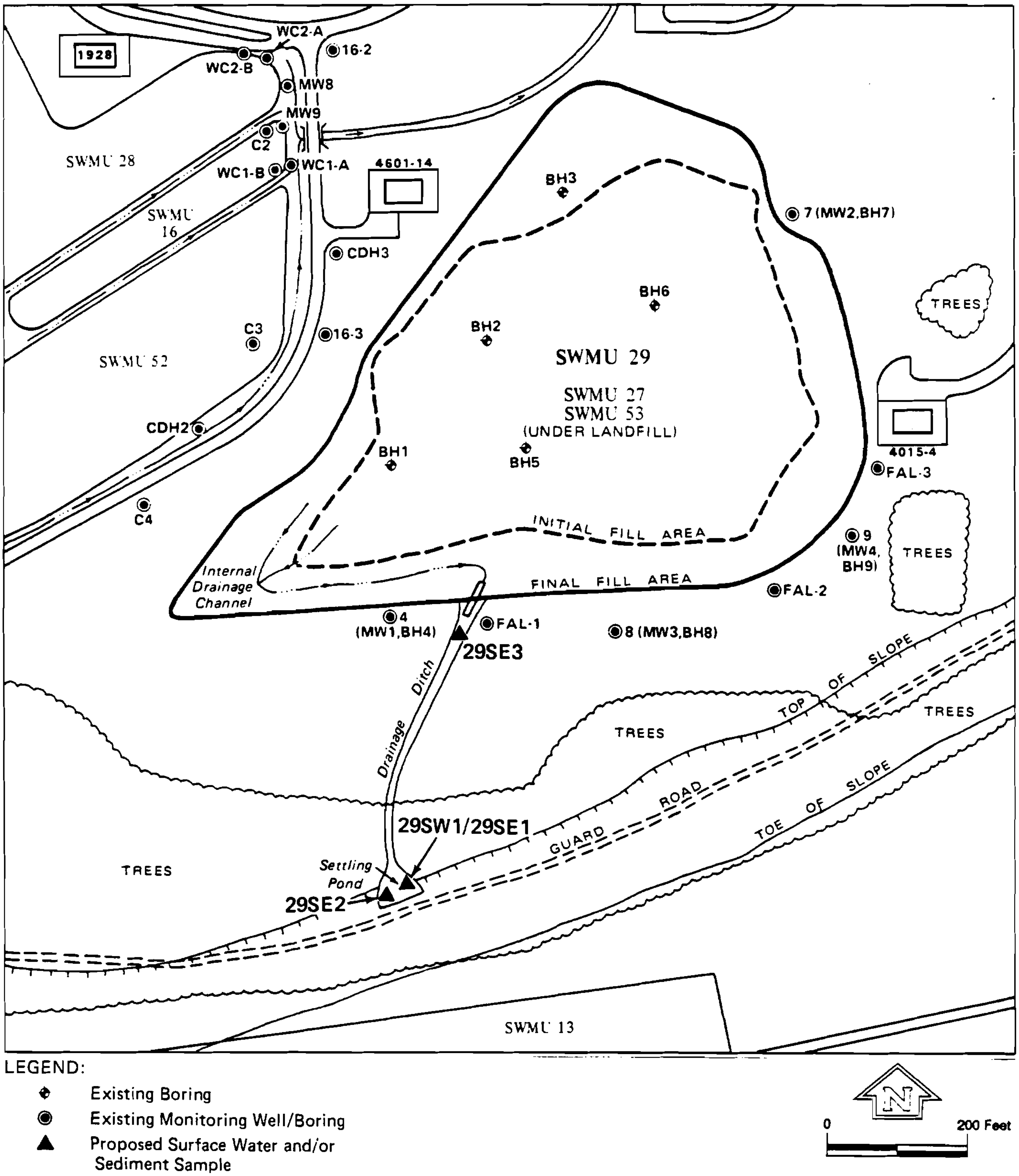

FIGURE 4-7
RECOMMENDED INVESTIGATIONS
SWMU 29 – FLY ASH LANDFILL No. 2
SWMU 27 – CALCIUM SULFATE LANDFILL
SWMU 53 – ACTIVATED CARBON DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

monitoring well installation and sampling program will be proposed to address potential contamination of soils and groundwater. If the hazardous constituent is below the permit maximum allowable limits, no further action will be considered necessary at this unit.

Two to three sludge samples will be collected from each of the three lagoons at SWMU 31 (Figure 4-8). Sample locations will be selected along the edges of the lagoons, if possible, or in a central location if a boat is used. The top 1 foot of sludge beneath the water/sludge interface will be sampled. The samples from each lagoon will be composited, resulting in a total of three samples (31SL1, 31SL2, 31SL3) to be submitted for chemical analysis. These samples will be analyzed for metals and BNAs (List 1).

4.3.7 Inert Waste Landfill No. 1--SWMU 32

There are currently no monitoring wells located in the immediate vicinity of this unit. Because SWMU 32 was operated as an inert landfill under a Virginia Solid Waste Permit according to permit requirements (Section 2.2.7), it is unlikely that hazardous constituents are associated with it. However, to evaluate whether groundwater quality has been impacted by wastes disposed of in this landfill, it is proposed that one well be installed upgradient (40MW1) and one well be installed downgradient (40MW2) of the landfill. Based on the local topography and hydrogeologic conditions, the inferred direction of groundwater flow is northward from the unit to the New River. Thus, the proposed locations for the wells are as indicated in Figure 4-9. The estimated maximum depth of these wells is 100 feet.

Following well installation and development, a sample will be collected from each well and analyzed for metals, VOCs, and BNAs (List 1).

4.3.8 Incinerator Wastewater Ponds--SWMU 39

There are two identified concerns at this unit--potential contamination of surface soils adjacent to the aeration pond from windblown spray, and potential groundwater contamination from hazardous constituent releases from the aeration pond and the two unlined settling basins. To address the potential soil contamination, it is proposed that three surface soil samples (39SS1, 39SS2, and

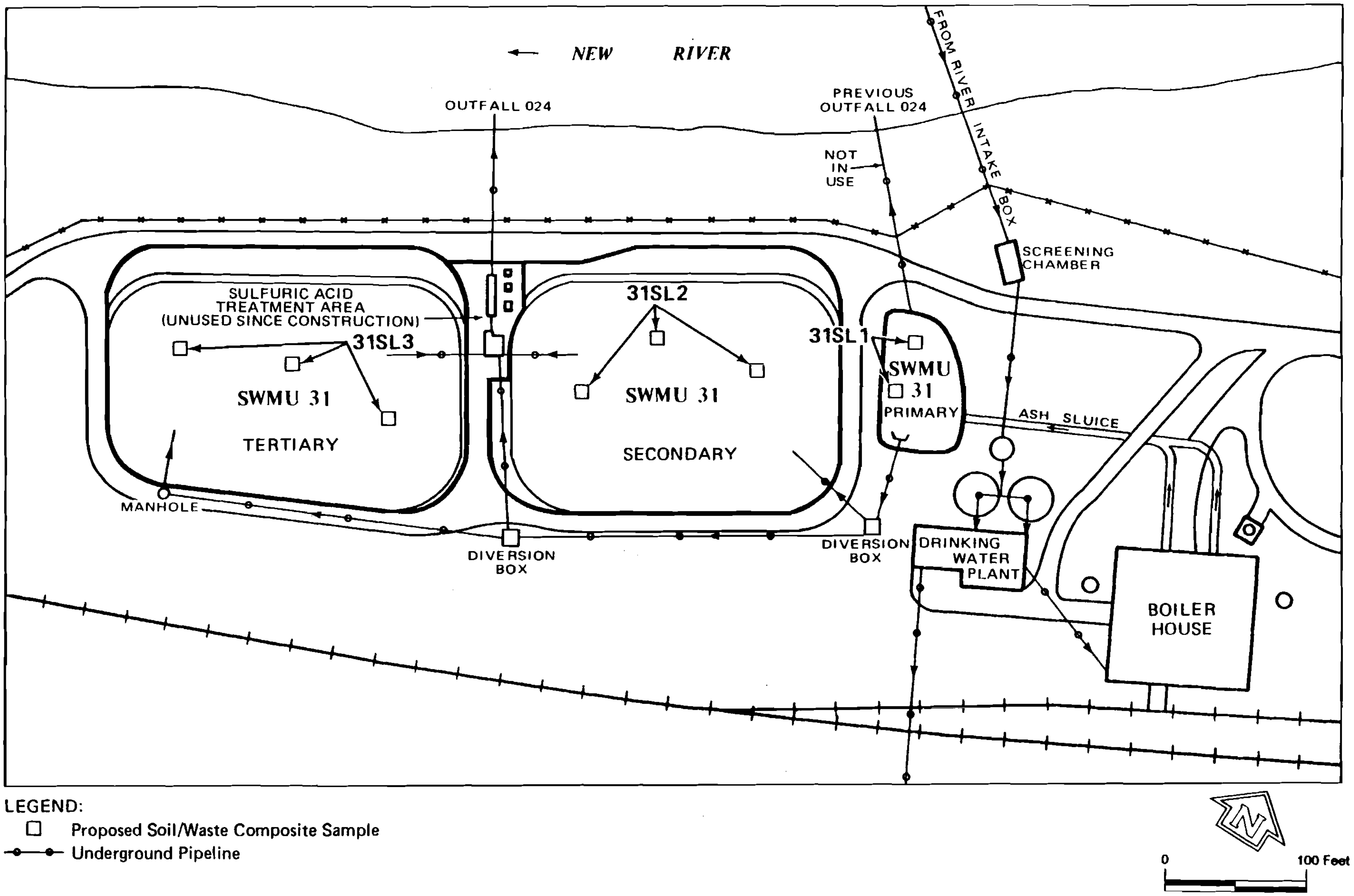

FIGURE 4-8
RECOMMENDED INVESTIGATION
SWMU 31 – COAL ASH SETTLING LAGOONS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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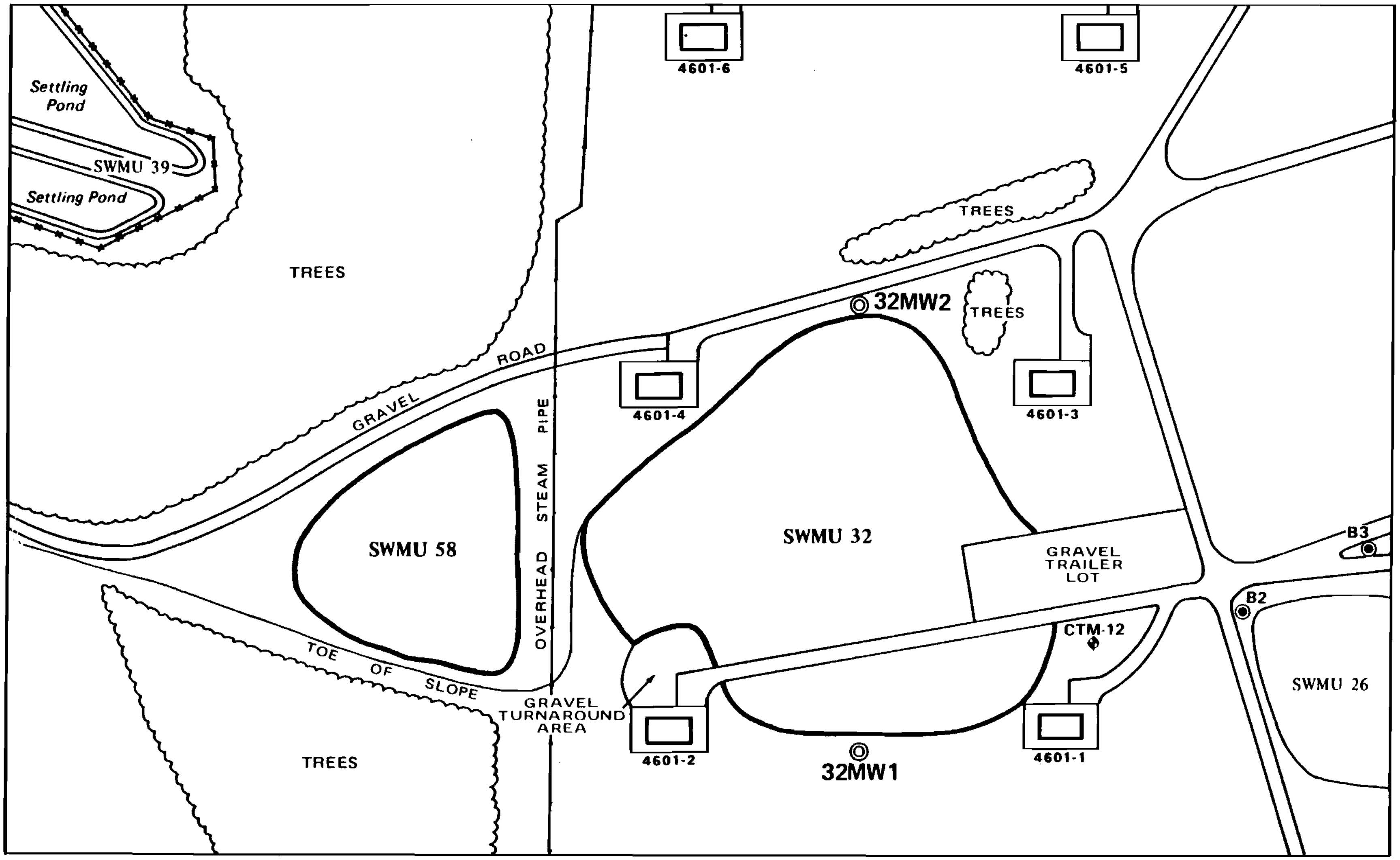

LEGEND:

- ◆ Existing Boring
- ● Existing Monitoring Well/Boring
- ◎ Proposed Monitoring Well/Boring

FIGURE 4-9
RECOMMENDED INVESTIGATION
SWMU32 – INERT WASTE LANDFILL No. 1
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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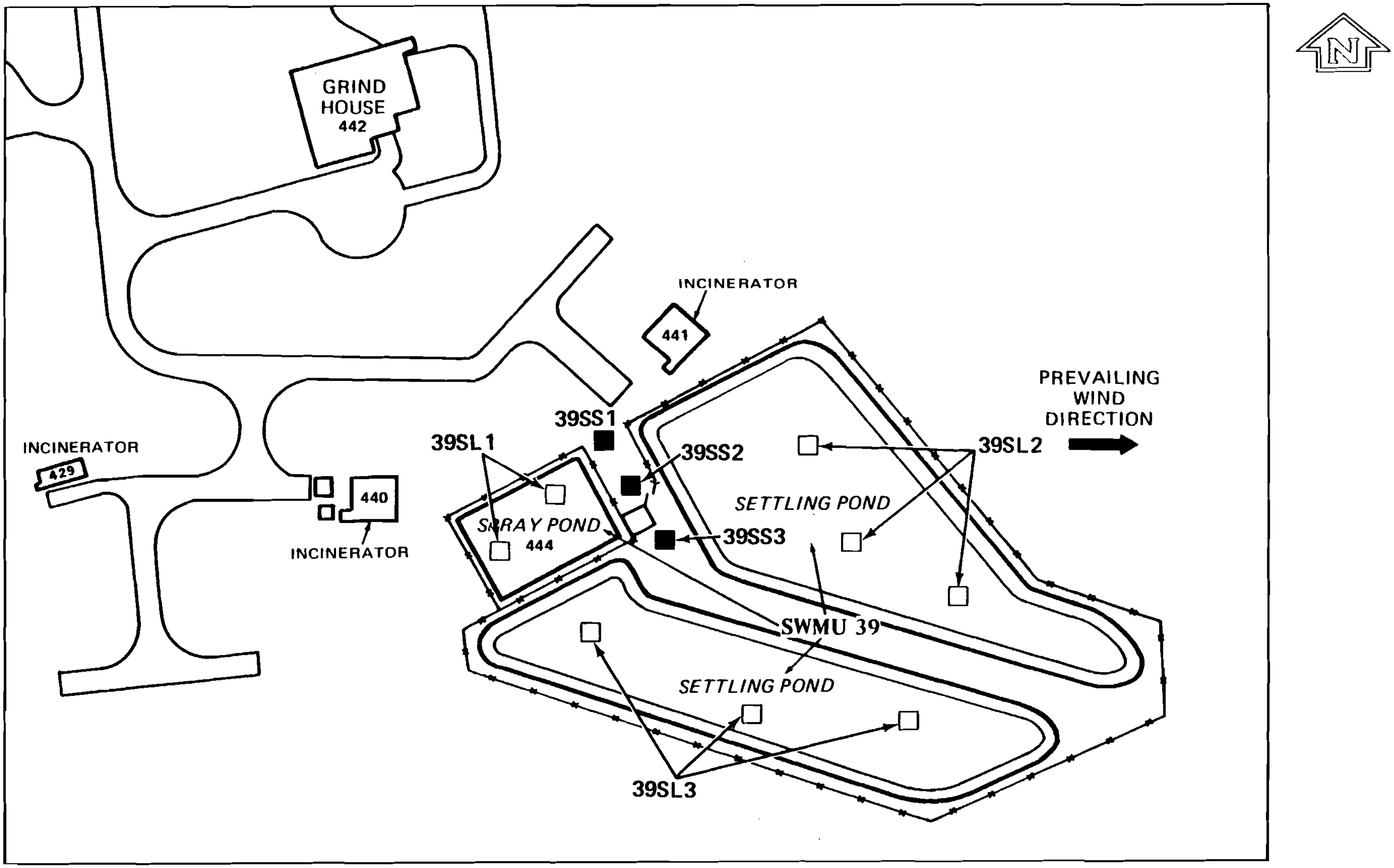
39SS3) be collected on the side of the aeration pond that is most likely to receive windblown spray. One sample will be collected on the eastern side of the spray pond in the prevailing wind direction (east), and one sample will be collected at a 45° angle on either side of this direction (Figure 4-10). Samples will be collected from a depth of 0 to 6 inches below any surface gravel or organic root zone and analyzed for metals, BNAs (List 1), and explosives.

To address the potential for groundwater contamination in the vicinity of the ponds, it is proposed that waste characterization be performed on sludge samples collected from the ponds rather than installing and sampling monitoring wells. Two sludge samples will be collected from the aeration pond, and three samples will be collected from each of the settling ponds. Sample depths will be 0 to 1 foot below the water/sludge interface. The samples from each lagoon will be composited, resulting in a total of three sludge samples (39SL1, 39SL2, and 39SL3) submitted for analysis. These samples will be analyzed for metals, explosives, and BNAs (List 1).

If the waste is determined to contain hazardous constituents at concentrations exceeding the maximum allowable permit limits, it is proposed that a groundwater investigation be conducted to address potential contamination of underlying soils and groundwater. If hazardous constituent concentrations are determined to be below maximum allowable permit limits, no further action will be considered necessary at this unit.

4.3.9 Sanitary Landfill (Nitroglycerine Area)--SWMU 40

Currently, no monitoring wells are located in the vicinity of this unit. To evaluate whether groundwater quality has been impacted by wastes disposed of in this landfill, it is proposed that four wells be installed--two along bedrock strike (40MW2 and 40MW4) and two along bedrock dip (40MW1 and 40MW3). Tentative locations for these wells are shown in Figure 4-11. It is proposed that these well borings be drilled to a maximum depth of 100 feet. The additional hydrogeologic information will also be useful for evaluation of SWMU 17, located to the east of SWMU 40. SWMU 17 is included in the separate RFI Work Plan document.



LEGEND:

■ Proposed Soil/Waste Sample

☐ Proposed Soil/Waste Composite Sample

FIGURE 4-10

RECOMMENDED INVESTIGATION
SWMU 39 – INCINERATOR WASTEWATER PONDS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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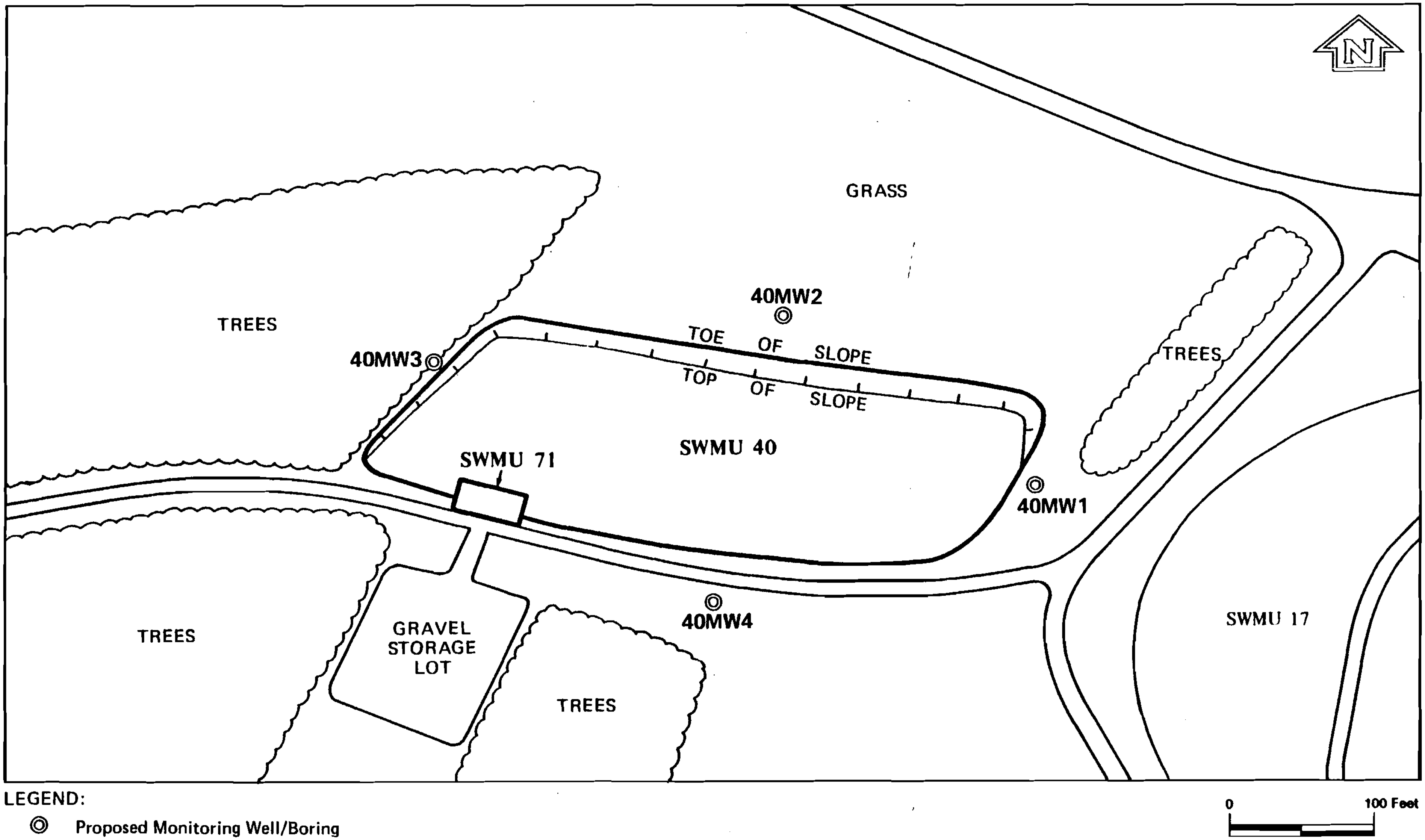

FIGURE 4-11
RECOMMENDED INVESTIGATION
SWMU 40 – SANITARY LANDFILL (NITROGLYCERINE AREA)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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/88

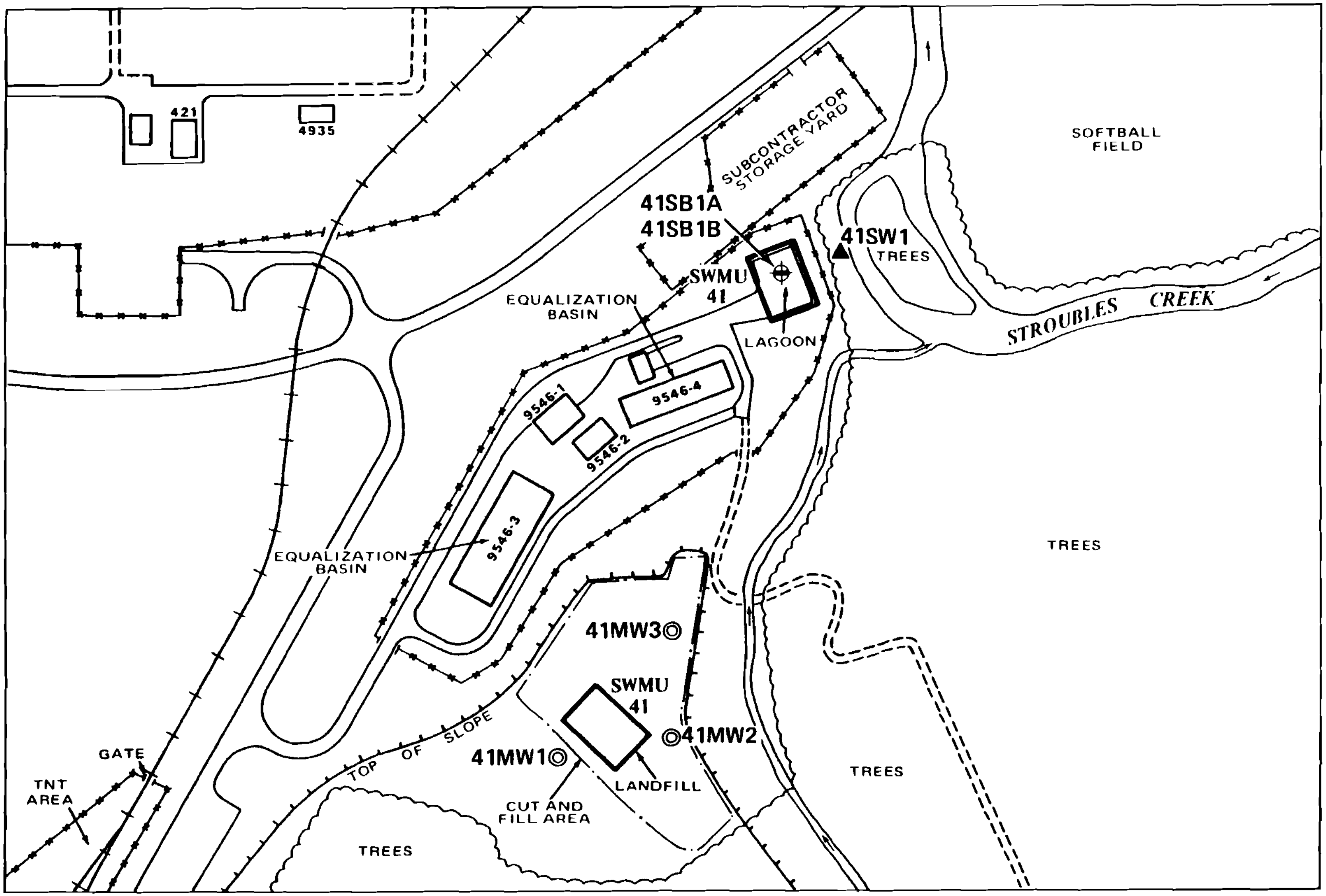
Following well installation and development, groundwater levels will be recorded, and samples will be collected and analyzed for metals, VOCs, and BNAs (List 1).

4.3.10 Red Water Ash Landfill--SWMU 41

The two noncontiguous disposal areas that make up this unit--the landfill and a lagoon area--will require separate sampling strategies. At the landfill, the red water ash has been covered with up to 30 feet of excavated (clean) soil (Section 2.2.10). Because the location of ash disposal within the cut and fill area is not accurately known, sampling of the ash for waste characteristics is not considered appropriate. Instead, it is proposed that three wells be installed to evaluate whether groundwater quality in the vicinity of the unit is being impacted by the buried red water ash. Based on the local topography, the inferred direction of groundwater flow is eastward from the landfill to the tributary of Stroubles Creek (Figure 4-12). One well will be installed upgradient of the landfill (41MW1), and two wells (41MW2 and 41MW3) will be installed downgradient of the disposal area, but within the cut and fill area. It is estimated that the maximum depth of the upgradient and downgradient wells will be 70 to 90 feet and 50 to 70 feet, respectively.

Following well installation, these wells will be developed as discussed in Section 5.4. Groundwater samples will be collected and analyzed for metals, explosives, and BNAs (List 1).

At the lagoon area located north of the landfill (Figure 4-12), the relatively thin cover material (in comparison to more than 30 feet at the landfill) will allow for sampling of the red water ash. It is proposed that one boring (41SB1) be drilled in the center of the lagoon, to a maximum depth of 15 feet. Two soil samples will be collected from the boring (41SB1A and 41SB1B) for chemical analysis. One sample will be collected from any ash layer encountered. To evaluate whether hazardous constituents are leaching from the ash, one sample will be collected from the soil underlying the ash. These two samples will be analyzed for metals, explosives, and BNAs (List 1). If the ash is determined to contain hazardous constituents at concentrations exceeding the maximum allowable permit limits, a



LEGEND:

- ⊕ Proposed Boring
- ◎ Proposed Monitoring Well/Boring
- ▲ Proposed Seep Sample

FIGURE 4-12
RECOMMENDED INVESTIGATION
SWMU 41 – RED WATER ASH LANDFILL
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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followup investigation will be proposed to address potential groundwater contamination.

One surface water sample (41SW1) will be taken of seepage from the eastern bank of the small filled ash lagoon prior to the seepage entering Stroubles Creek. The seepage has been reported at various times by RAAP personnel, but it does not appear to be perennial. The bank will be visited at various times throughout the VI field program and will be sampled when the seep is active. This sample will be analyzed for metals, explosives, and BNAs (List 1).

4.3.11 Sanitary Landfill (Adjacent to New River)--SWMU 43

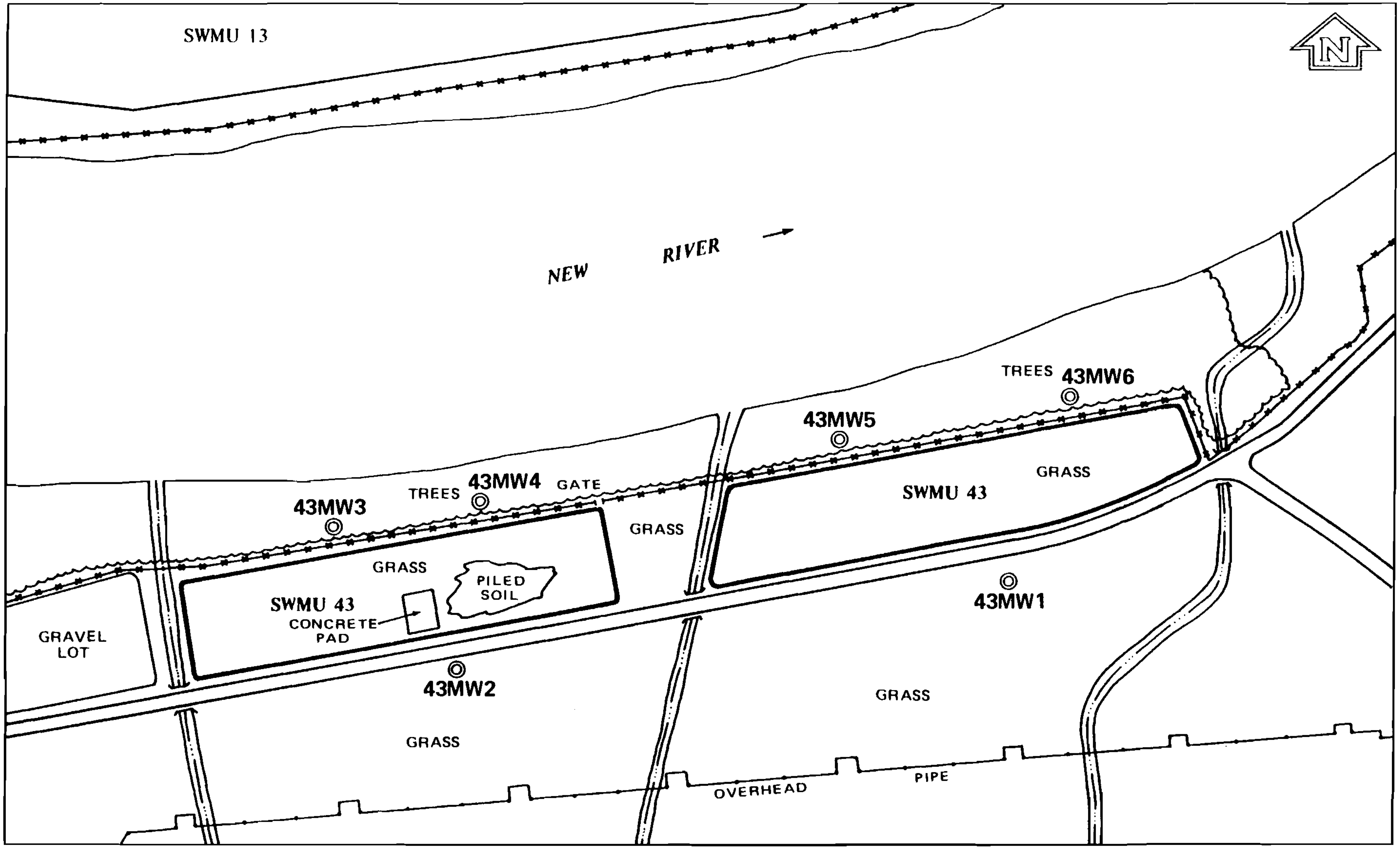
To evaluate whether groundwater quality in the vicinity of this unit has been impacted by landfilled wastes, it is proposed that six monitoring wells be installed. Currently, there are no existing wells in the vicinity of this landfill. One well will be installed upgradient of each section of the landfill (43MW1 and 43MW2), and two wells will be installed downgradient of each section (43MW3, 43MW4, 43MW5, and 43MW6) (Figure 4-13). The inferred direction of groundwater flow is northward from the landfill to the New River. It is estimated that the maximum depth of these six wells will be 30 feet.

Following well installation, the wells will be developed as described in Section 5.4. In addition to measuring water levels in these wells, groundwater samples will be collected from the six wells and analyzed for metals, VOCs, and BNAs (List 1).

4.3.12 Sanitary Landfill (West of Main Bridge)--SWMU 45

The boundaries and specific disposal area locations at this unit cannot be determined from available information. Therefore, to delineate the landfill boundaries and trench locations, it is proposed that a geophysical survey be conducted over the approximate 5-acre area identified in Figure 4-14. Details of the geophysical investigative techniques are discussed in Section 5.2.

A series of transects located approximately 100 feet apart will be traversed, with magnetic and electromagnetic readings recorded at 15-foot intervals. The exact placement of these lines will depend on accessibility and maneuverability through the



LEGEND:

◎ Proposed Monitoring Well/Boring

0 200 Feet

FIGURE 4-13
RECOMMENDED INVESTIGATION
SWMU 43 – SANITARY LANDFILL
(ADJACENT TO NEW RIVER)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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147

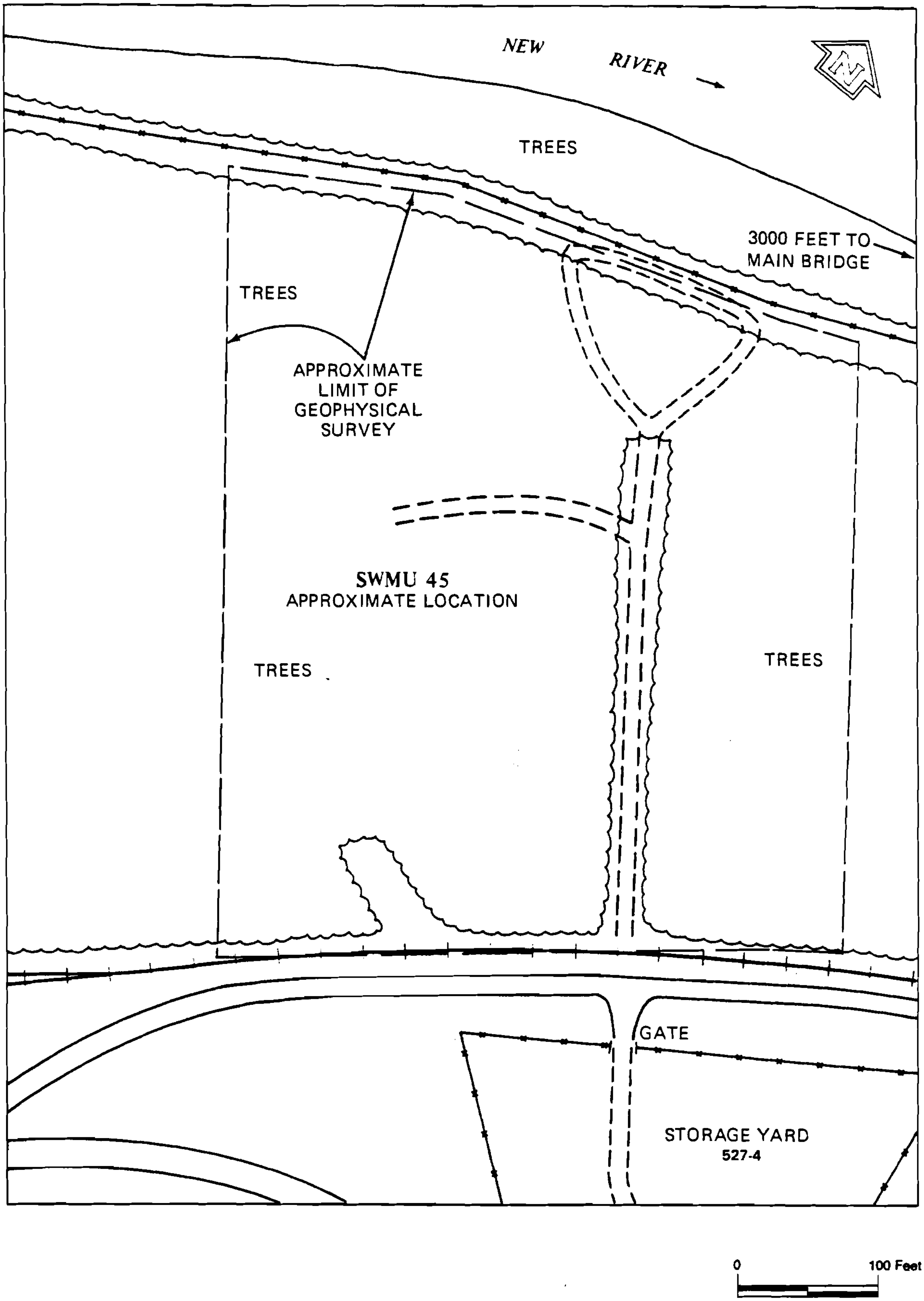

FIGURE 4-14
RECOMMENDED INVESTIGATION
SWMU 45 – SANITARY LANDFILL
(WEST OF MAIN BRIDGE)
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

wooded site. Based on the results of this preliminary survey, lines will be set closer (15 feet apart) and additional readings will be obtained. More detailed (closely spaced) readings will allow for better definition of boundaries and possible delineation of landfill trenches.

Results of the geophysical survey will enable the appropriate placement of three monitoring wells--one upgradient (45MW1) and two downgradient (45MW2 and 45MW3) of the landfill area. Following installation, the wells will be developed as described in Section 5.4. In addition to the collection of groundwater levels from each well, groundwater samples will be collected and analyzed for metals, VOCs, BNAs (List 1), and explosives. Explosives may be a concern because of the age of the unit and poor historical documentation.

4.3.13 Waste Propellant Disposal Area--SWMU 46

Soil sampling is proposed at SWMU 46 to evaluate whether soil contamination exists from the one-time disposal of waste propellants. Before sampling begins, a metal detection sweep will be conducted to locate the base of the "BURIED EXPLOSIVE WASTE" sign. If located, eight shallow borings will be drilled around the sign. If not located, the borings will be drilled in the area identified as the disposal location during the March 1990 facility visit (Figure 4-15). Due to the unknown explosion hazard associated with disturbance by hand augering or digging into this material, a backhoe or "bobcat"-mounted auger will be used for remote augering. Appropriate safety precautions approved by USATHAMA and RAAP will be implemented prior to any surface disturbance activities in this area. The borings will be drilled to a depth of 0 to 3 feet below the surface organic root zone. Based on visual observation, two soil samples (46SS1 and 46SS2) will be collected and analyzed for metals and explosives.

4.3.14 Oily Wastewater Disposal Area--SWMU 48

To address the potential for groundwater contamination from previous wastewater disposal activities at this unit, it is proposed that waste characterization be performed at this SWMU rather than installing monitoring wells.

153

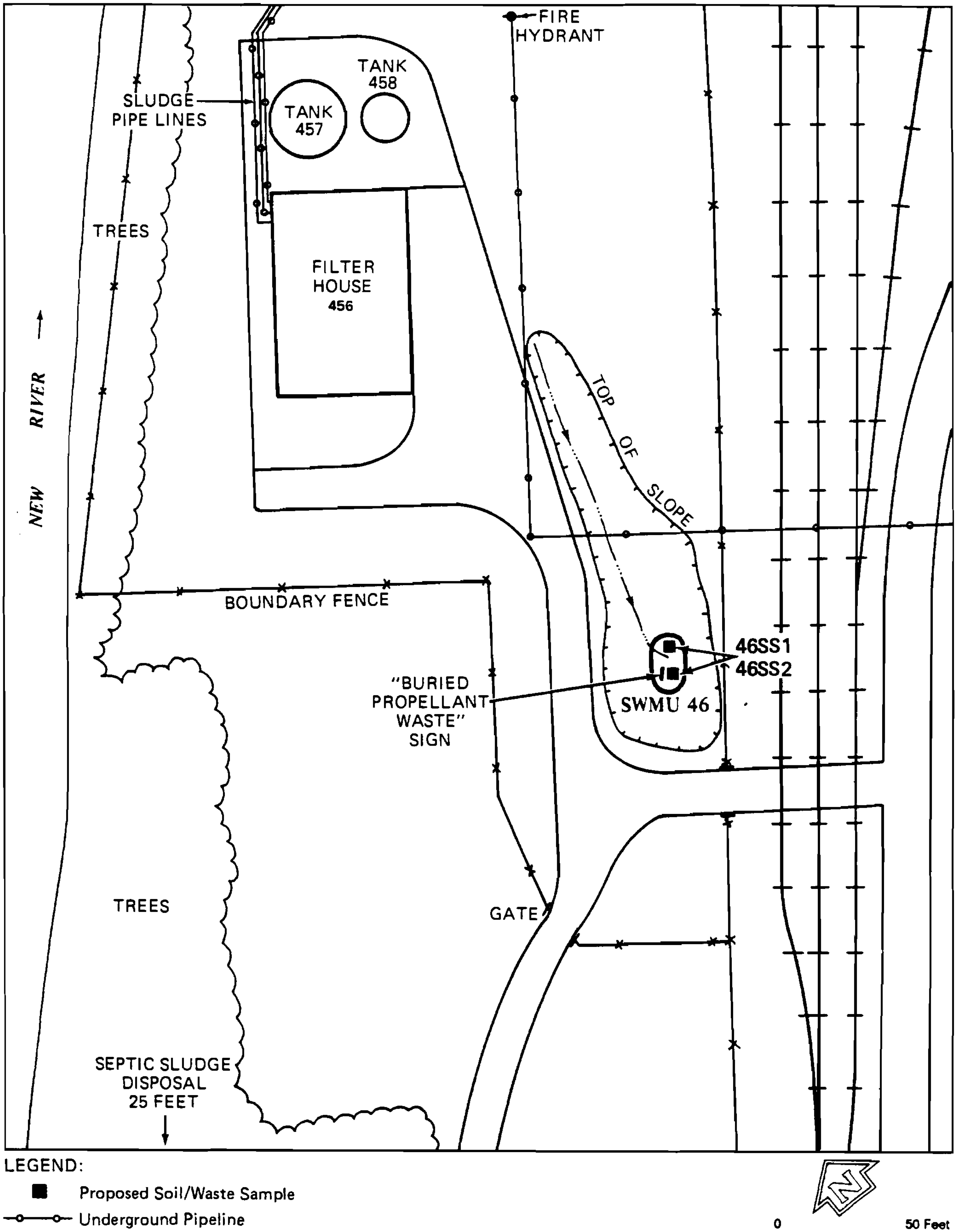

FIGURE 4-15
RECOMMENDED INVESTIGATION
SWMU 46 – WASTE PROPELLANT DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Therefore, it is proposed that a total of three soil borings (48SB1, 48SB2, and 48SB3) be installed in the two disposal areas (Figure 4-16). Two soil samples will be collected from each boring for chemical analysis. One sample in each boring (48SB1A, 48SB2A, and 48SB3A) will be collected from near-surface, visually oil-stained soil, and one sample in each boring (48SB1B, 48SB2B, and 48SB3B) will be collected from visually "clean" soil beneath the upper layer. The estimated maximum depth of these borings is 25 feet. Borings will continue until "clean," undisturbed soil is observed for at least 2 feet below the deepest stained soil.

The six soil samples collected will be analyzed for metals, TCLP metals, VOCs, and BNAs (List 1). If the samples are determined to contain hazardous constituents at concentrations exceeding the maximum allowable permit limits, a followup investigation will be proposed to address potential groundwater contamination. If hazardous constituent concentrations are found to be below the maximum allowable permit limits, no further action will be considered necessary at this unit.

4.3.15 Disposal Area for Ash From Burning of Propellants--SWMU 54

To confirm the assumed boundaries of ash disposal at this unit, a geophysical survey is proposed for the approximate 5-acre area identifed in Figure 4-17. Details of the geophysical investigative techniques are discussed in Section 5.2.

Magnetic and electromagnetic readings will be obtained at 15-foot intervals along each survey line, with lines spaced 15 feet apart. Results of the geophysical survey will enable the appropriate placement of monitoring wells. There are no existing monitoring wells located in the vicinity of this unit. To evaluate whether groundwater quality has been impacted by ash disposed of in the unit, it is proposed that three wells be installed--one upgradient (54MW1) and two downgradient (54MW2 and 54MW3) of the disposal area. Tentative locations for the three wells are shown in Figure 4-17. Based on the local topography, the inferred direction of groundwater flow is eastward from the unit to the New River. The estimated maximum depth of these wells is 20 feet.

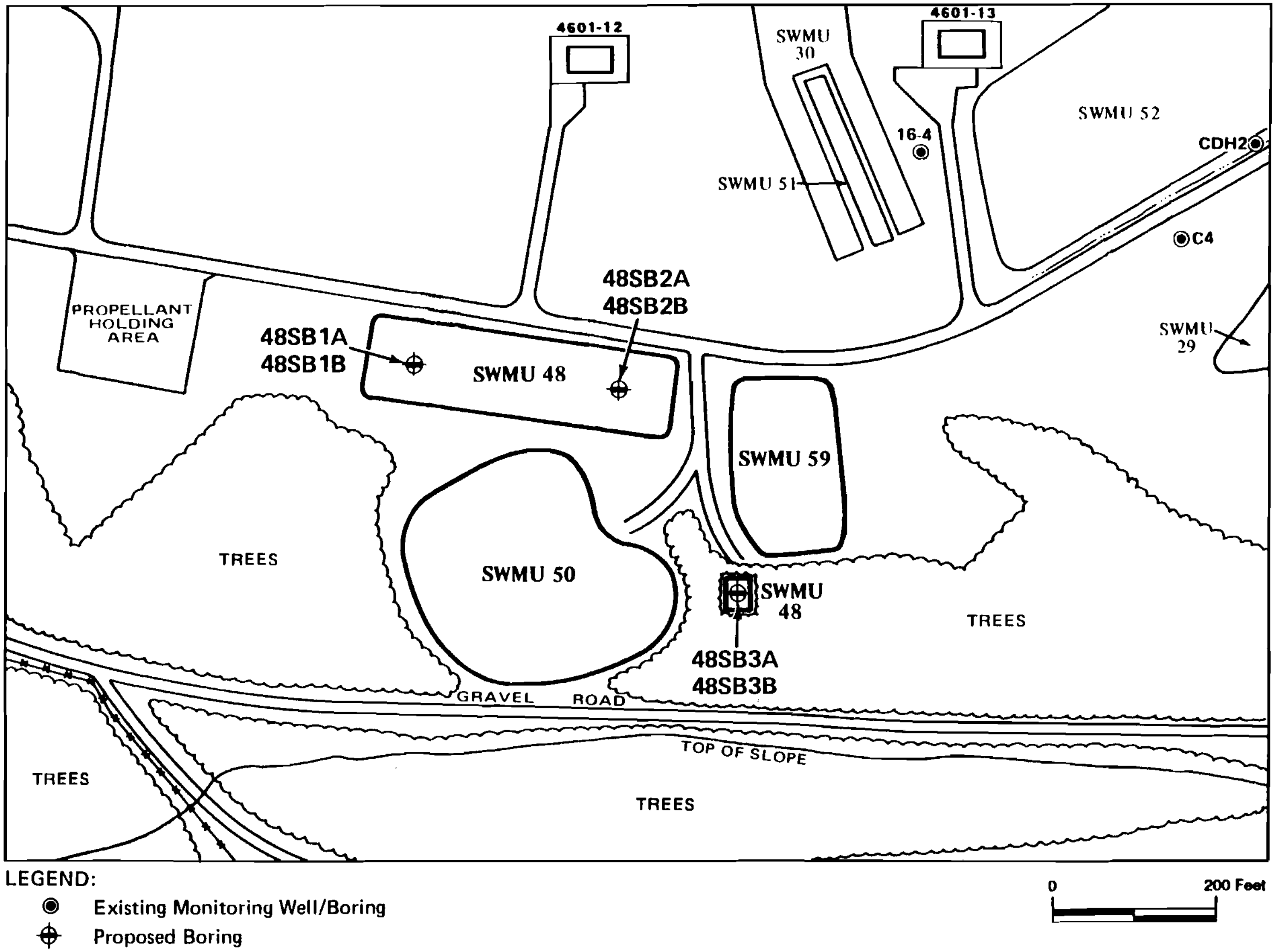

FIGURE 4-16
RECOMMENDED INVESTIGATION
SWMU 48 – OILY WASTEWATER DISPOSAL AREA
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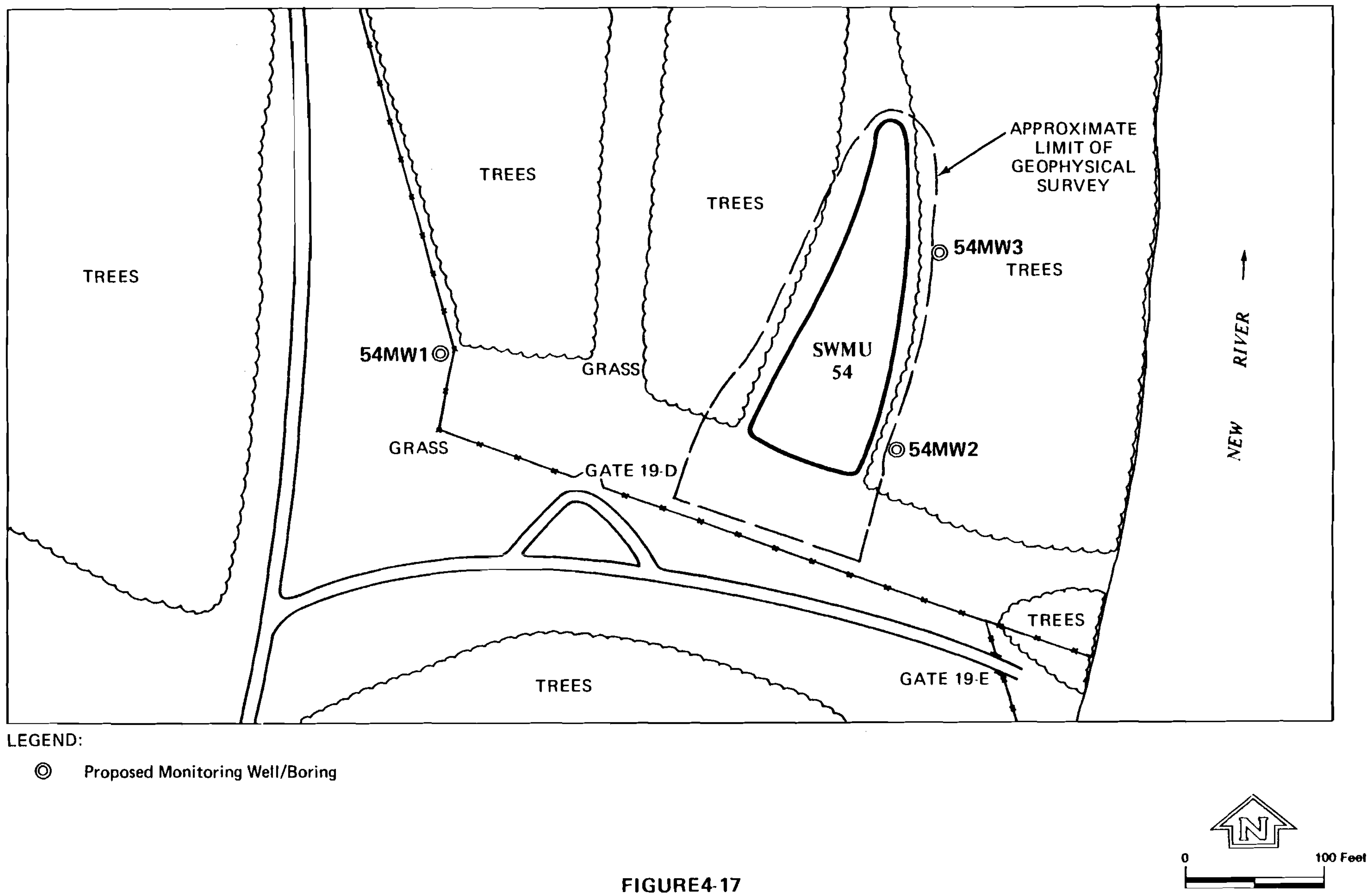

FIGURE4-17
RECOMMENDED INVESTIGATION
SWMU 54 – PROPELLANT BURNING ASH DISPOSAL AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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Following well installation and development, groundwater levels will be recorded and samples will be collected and analyzed for metals, explosives, VOCs, and BNAs (List 1).

4.3.16 Pond by Buildings 4931 and 4928--SWMU 57

As shown in Figure 4-18, a surface water sample will be collected from SWMU 57 to evaluate the characteristics of the liquid in the pond. The sample will be analyzed for metals, VOCs, and BNAs (List 1). To evaluate the characteristics of the sediment in the pond, one sediment sample will be collected from a depth of 0 to 12 inches below the water/sediment interface. The sample will be analyzed for metals, VOCs, and BNAs (List 1).

4.3.17 Rubble Pile--SWMU 58

Available information indicates that this pile (Figure 4-19) consists only of brush and trees covered with excavated "clean" soil. Reportedly, no hazardous materials or other wastes were disposed of at SWMU 58. However, to evaluate the potential soil contamination in accordance with the permit requirements, three soil samples (58SS1, 58SS2, and 58SS3) will be collected from beneath the cover material at the edges of the base of the rubble pile. A hand-auger sample will be collected at each location from 0 to 1 foot beneath the piled materials. These samples will be analyzed for metals, VOCs, and BNAs (List 1).

4.3.18 Bottom Ash Pile--SWMU 59

Because studies have shown that coal bottom ash can leach hazardous constituents to the environment, sampling will be conducted at this unit to evaluate whether soil contamination exists beneath the ash pile. It is proposed that a backhoe be used to clear the ash away from two areas near the edge of the pile to expose the underlying soils (Figure 4-20). One soil sample will be collected from each of the areas (59SS1 and 59SS2) at a depth of 0 to 1 foot. Each sample will be analyzed for metals and BNAs (List 1).

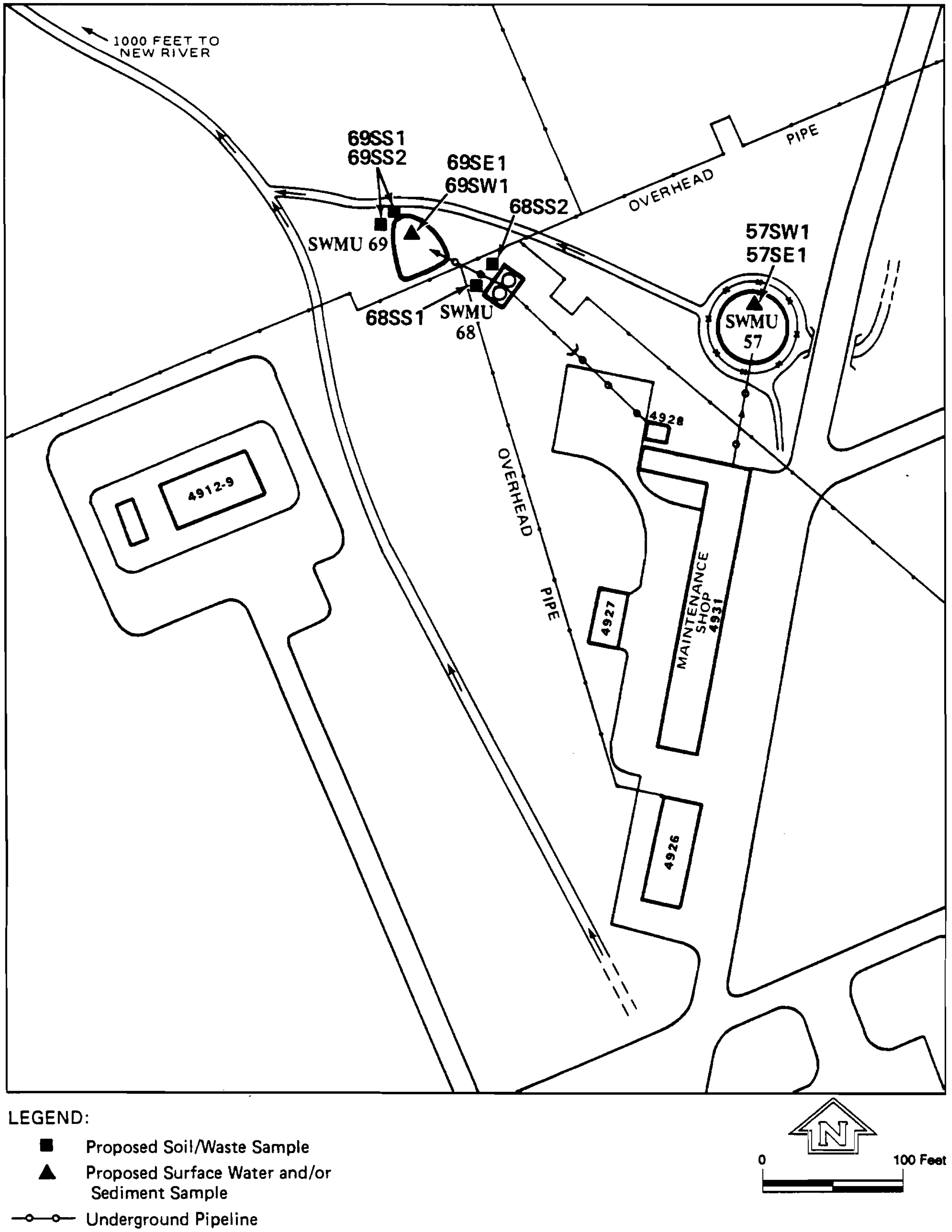


FIGURE 4-18
RECOMMENDED INVESTIGATIONS
SWMU 57 – POND BY BUILDINGS 4928 AND 4931
SWMU 68 – CHROMIC ACID TREATMENT TANKS
SWMU 69 – POND BY CHROMIC ACID TREATMENT TANKS
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

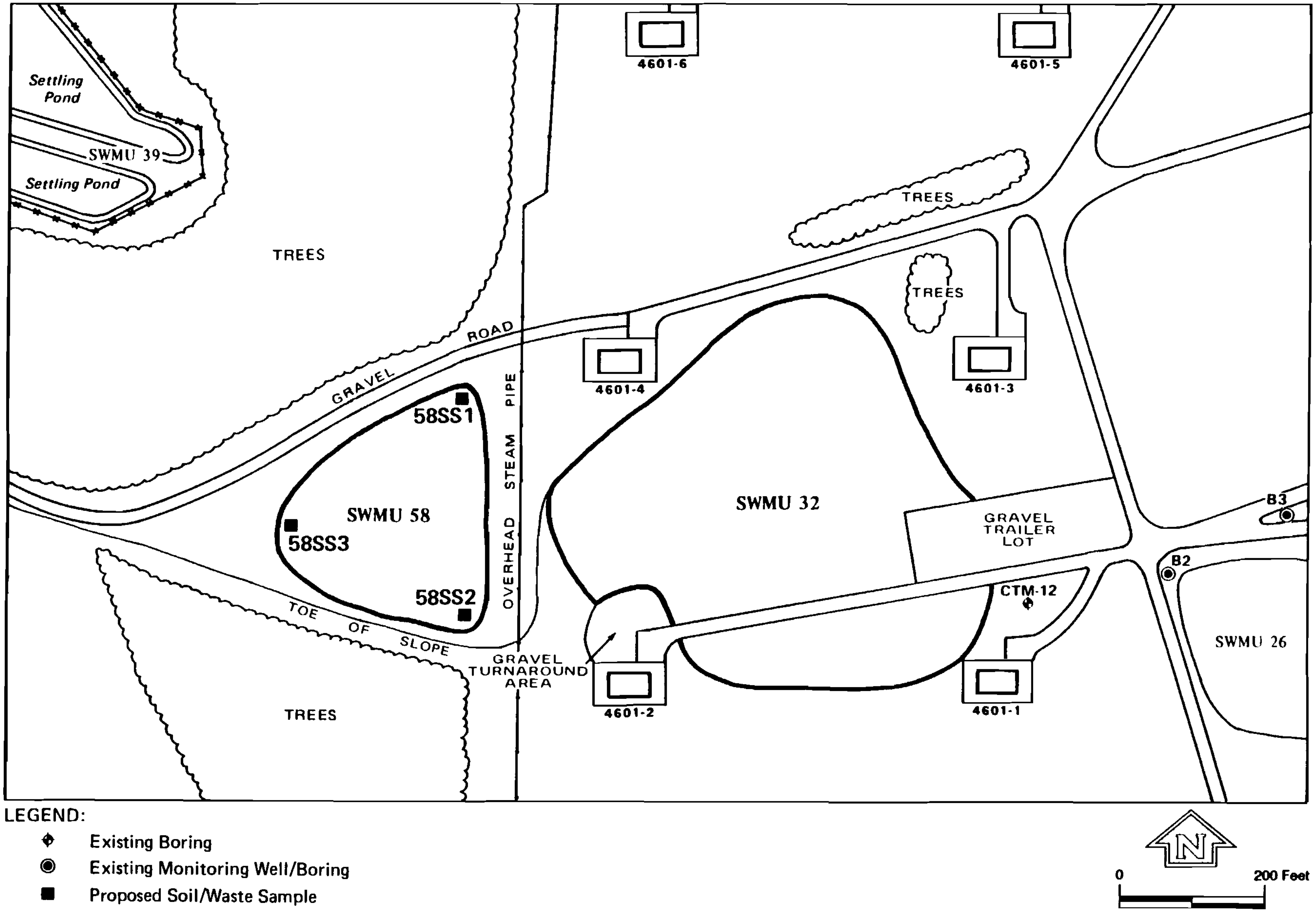
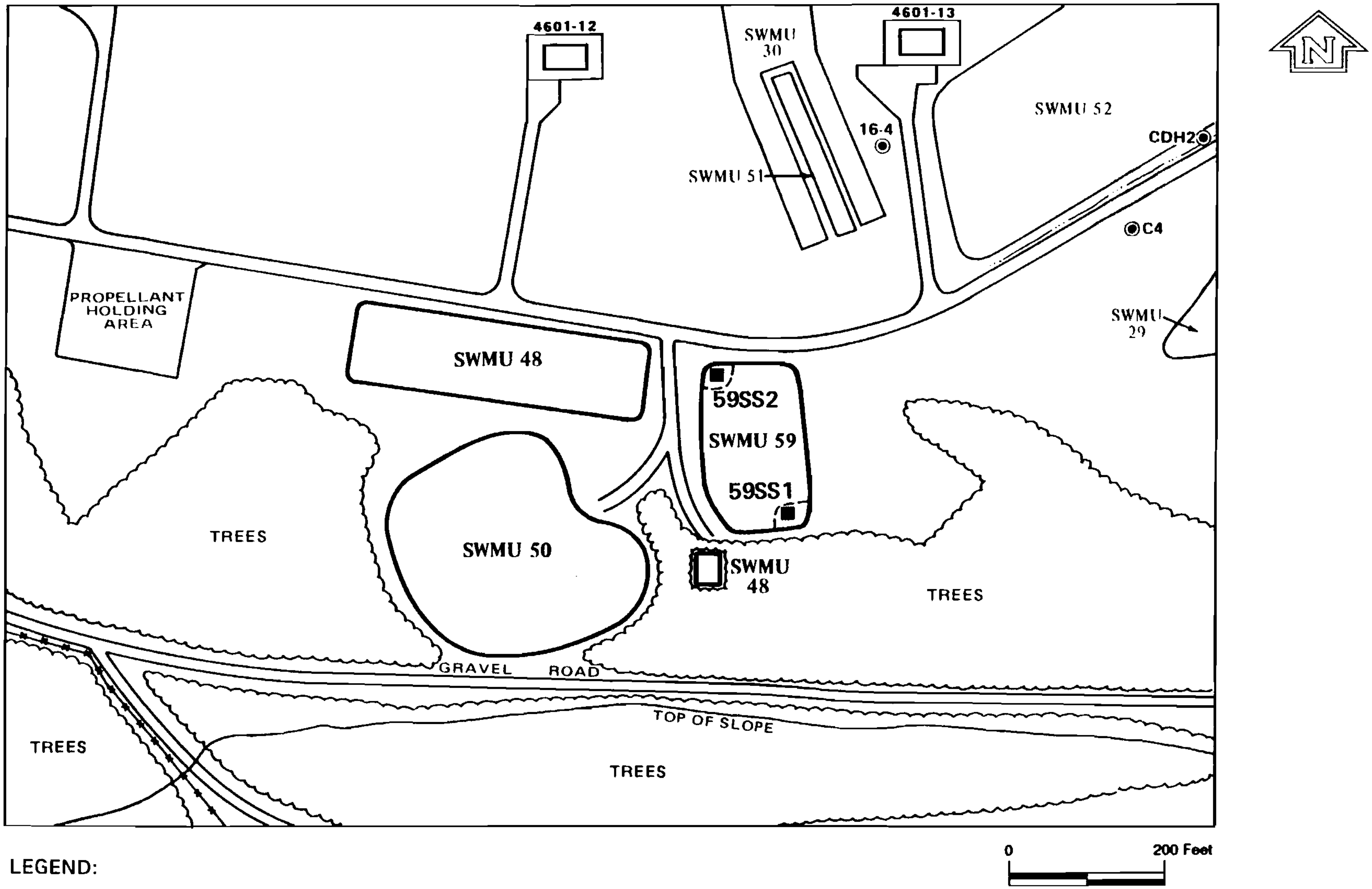


FIGURE 4-19
RECOMMENDED INVESTIGATION
SWMU 58 – RUBBLE PILE
RADFORD ARMY AMMUNITION PLANT, VIRGINIA



LEGEND:

◉ Existing Monitoring Well/Boring

■ Proposed Soil/Waste Sample

FIGURE 4-20
RECOMMENDED INVESTIGATION
SWMU 59 – BOTTOM ASH PILE
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4.3.19 Mobile Waste Oil Tanks--SWMU 61

The handling and temporary storage of waste oil in the mobil tanks provides the potential for spillage of waste oil onto surface soils at the waste oil collection and storage points. To mitigate the potential for contaminant migration from these areas, SOPs have been developed to routinely inspect these locations, to remove any surface soils that appear to be visually stained from routine waste handling, and to replace with clean fill. The SOPs developed by RAAP for pumping of underground condensation catch tanks and oil separators, including routine inspection, replacement, and disposal of stained surface soils, are provided in Procedure 4-27-120 (Rev. 4).

These procedures require inspection and cleanup of the work area before leaving the job site. For oil spillage during transfer, absorbent material will be used as follows by RAAP personnel:

- Sprinkle a generous amount of absorbent material on spilled oil. Allow material at least 10 minutes to absorb oil and water.
- Use a broom and a shovel to place spent absorbent material in a plastic bag.
- Notify supervisor for correct method of disposal.
- Remove surface soil and/or gravel that is oil-stained from the work area, and notify supervisor for correct method of disposal.
- If necessary, replace removed soil with clean fill material.

4.3.20 Chromic Acid Treatment Tanks and Pond--SWMUs 68 and 69

To evaluate whether surface soils in the vicinity of the treatment tanks (SWMU 68) are contaminated as a result of past spills, leaks, or overflows of waste chromic acid, it is proposed that surface soil samples (68SS1 and 68SS2) be collected from two locations downgradient of the tanks (Figure 4-18). The two samples will be collected from a depth of 0 to 6 inches below the surface organic root zone and will be analyzed for pH and metals.

In addition, to evaluate whether the pond (SWMU 69) has received hazardous constituents from past discharges from the tanks, it is proposed that one surface water sample (69SW1) and one sediment sample (69SE1) be collected from the pond. The sediment sample will be collected from a depth of 0 to 1 foot below the water/sediment interface. Both the surface water and sediment sample will be analyzed for pH and metals.

Two soil samples will also be collected downgradient of the pond to evaluate whether past overflows transported potentially hazardous constituents from the pond to the surrounding soils. The samples will be collected from a depth of 0 to 6 inches below any surface organic root zone and analyzed for pH and metals.

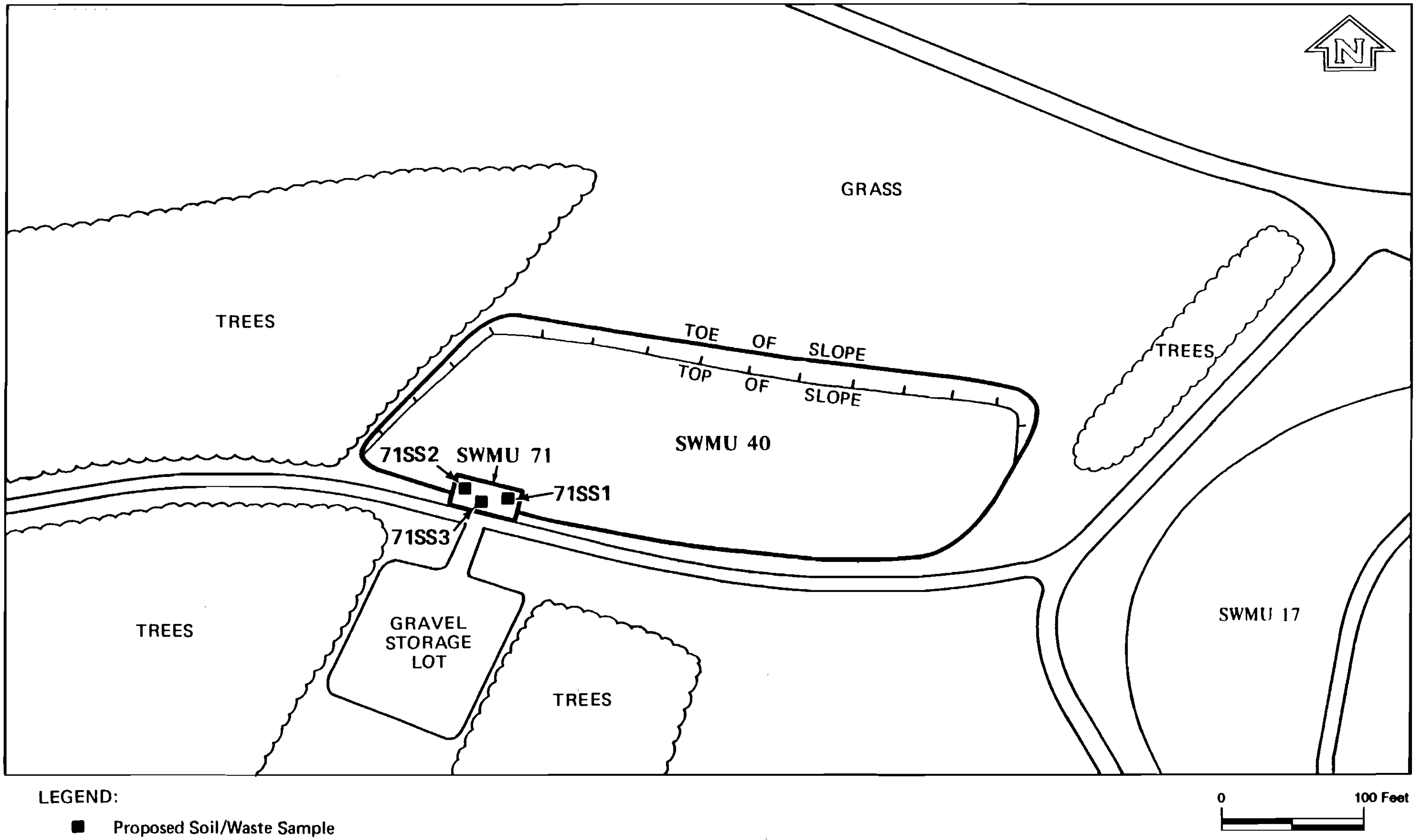
4.3.21 Flash Burn Parts Area--SWMU 71

It is proposed that three surface soil samples be collected within this unit (Figure 4-21) to determine whether surface soils have been impacted through the release of hazardous constituents during flashing operations. Each sample will be collected from a depth of 0 to 6 inches below any gravel or surface organic root zone and analyzed for metals, explosives, and TPHs. (TPH analysis, though not required by the permit, is recommended due to the use of fuel oil in the flashing operations.)

4.3.22 Inert Landfill No. 3--SWMU 74

Currently, there are no monitoring wells located in the immediate vicinity of this unit. Because this landfill is operated as an inert landfill under an existing Virginia Solid Waste Permit, it is unlikely that hazardous constituents are associated with this SWMU. However, to evaluate whether groundwater quality has been impacted by waste disposed of in this unit, it is proposed that one well (74MW1) be installed downgradient of the landfill as shown in Figure 4-22. Based on local topography, the inferred direction of groundwater flow is eastward from the unit to the New River. The estimated maximum depth of this downgradient well is 20 to 30 feet.

Following well installation and development, groundwater level in the well will be recorded and a sample will be collected and analyzed for metals, VOCs, and BNAs (List 1).



LEGEND:

■ Proposed Soil/Waste Sample

FIGURE 4-21
RECOMMENDED INVESTIGATION
SWMU 71 – FLASH BURN PARTS AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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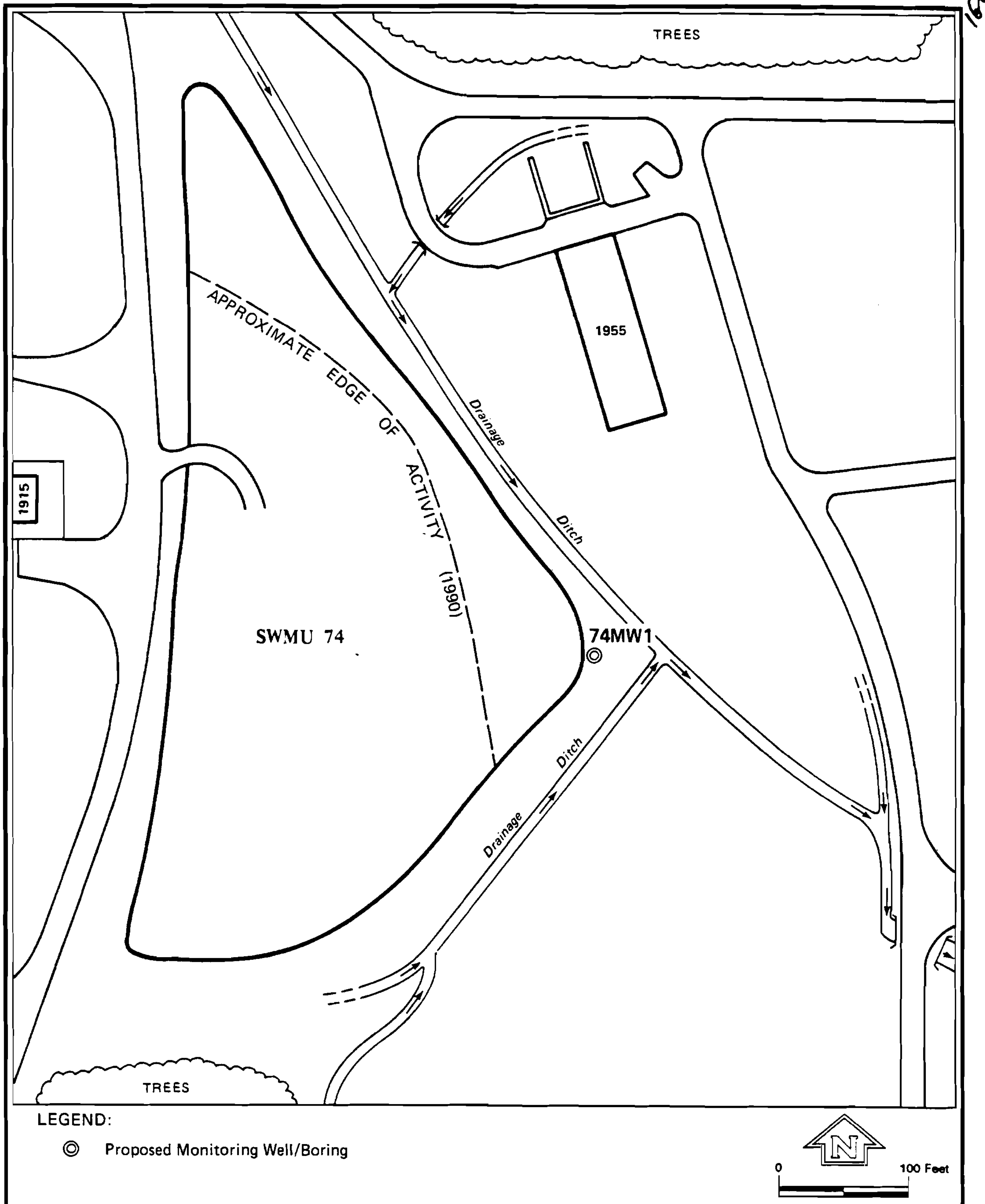

FIGURE 4-22
RECOMMENDED INVESTIGATION
SWMU 74 – INERT LANDFILL No. 3
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

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4.3.23 Waste Oil UST (Inert Gas Plant)--SWMU 75

Because this unit is a waste oil storage area, the SOPs provided in Section 4.2.19 for SWMU 61 will be implemented in this area in lieu of a proposed analytical and sampling program.

4.3.24 Waste Oil USTs (South of Oleum Plant)--SWMU 76

The SOPs provided in Section 4.2.19 for SWMU 61 will be implemented in this area in lieu of a proposed analytical and sampling program, because this unit is a waste oil storage area.

4.3.25 Drum Storage Area--SWMU F

Although only empty, rinsed drums are reportedly stored in this unit, visible staining of the gravel surface suggests the possibility that hazardous constituents have been released to surface soils as a result of the spillage of drum residues. To address this concern, it is proposed that four surface soil samples (FSS1, FSS2, FSS3, and FSS4), as shown in Figure 4-23, be collected for chemical analysis. Based on visible staining, four specific sample locations will be selected during sampling activities. Within each stained area, the gravel will be cleared to expose underlying soils. Soil samples will then be collected at a depth of 0 to 6 inches. Each sample will be analyzed for VOCs and BNAs (List 1).

4.3.26 Spent Battery Storage Area--SWMU P

To evaluate whether soils at SWMU P have been impacted from the possible spillage of spent battery electrolyte, it is proposed that 10 soil samples be collected within the fenced area. At each of five locations (Figure 4-24), the gravel will be cleared to expose underlying soils. Soil samples (PSB1A, PSB2A, PSB3A, PSB4A, and PSB5A) will then be collected using a hand shovel at a depth of 0 to 6 inches. A second sample from each location will be collected from a depth of 4 to 5 feet using a hand auger. Results from these samples (PSB1B, PSB2B, PSB3B, PSB4B, and PSB5B) will be used to evaluate the potential for vertical migration of contaminants through the underlying soils. Each sample will be analyzed for metals and pH.

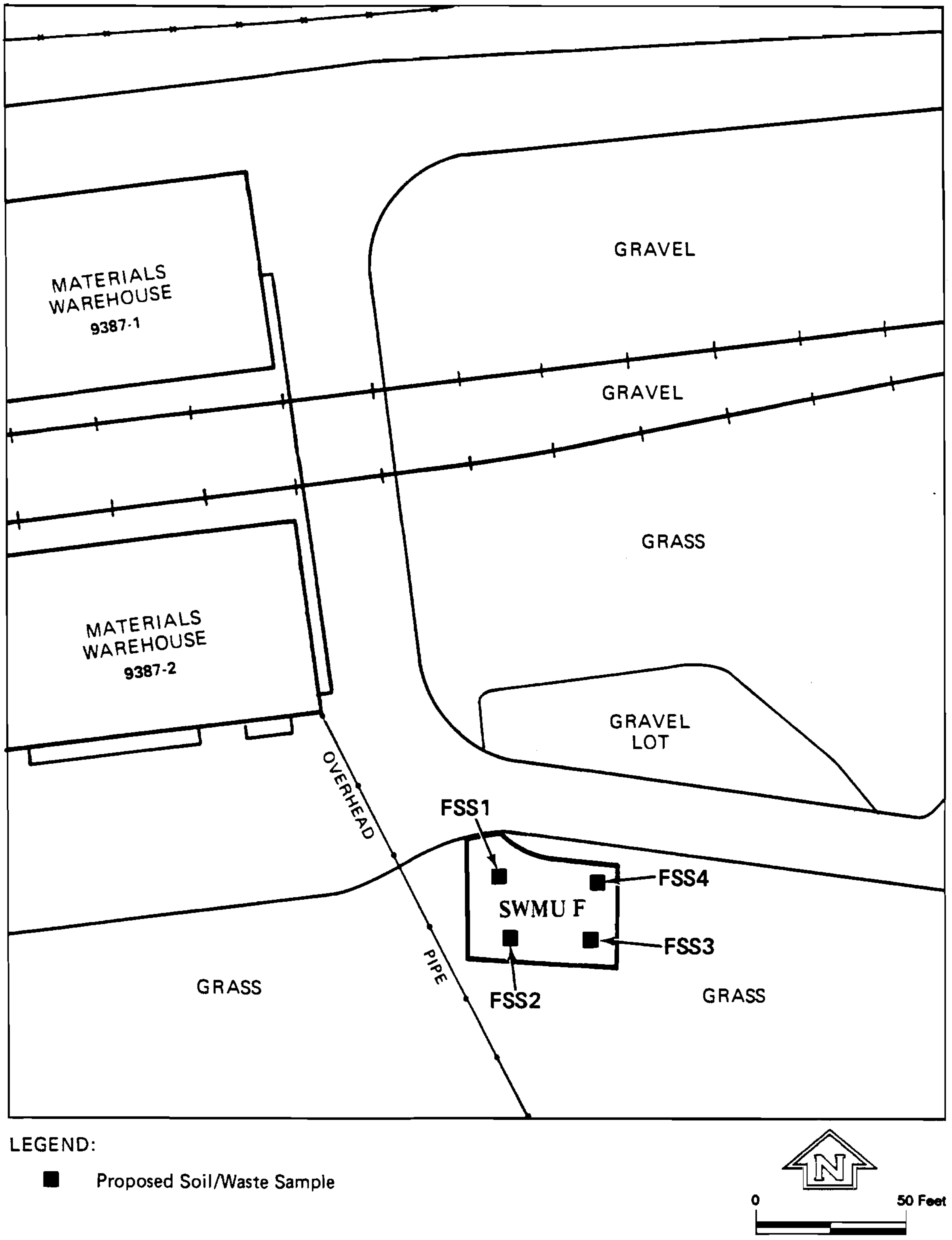
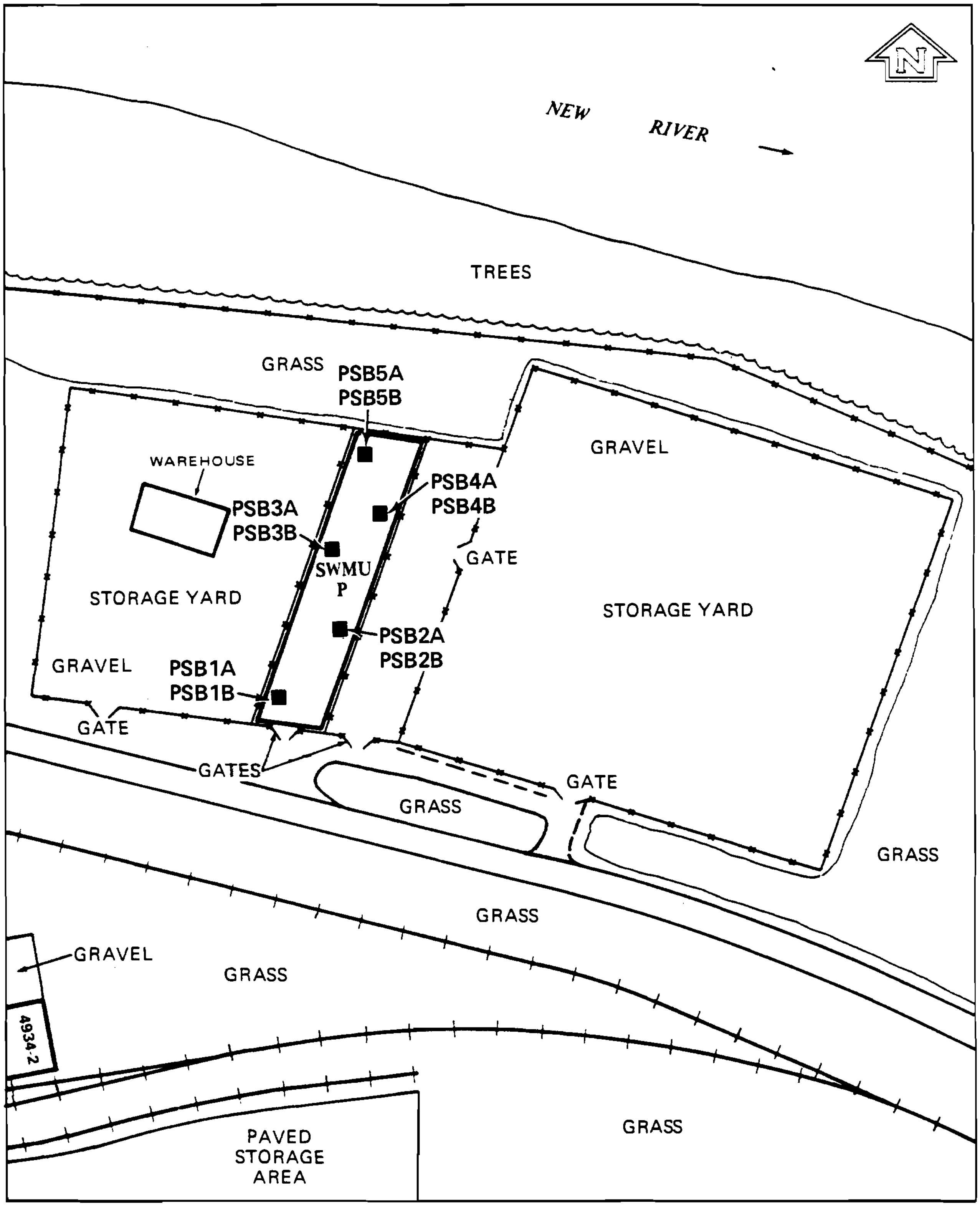


FIGURE 4-23
RECOMMENDED INVESTIGATION
SWMU F – DRUM STORAGE AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

167



LEGEND:

■ Proposed Soil/Waste Sample

FIGURE 4-24
RECOMMENDED INVESTIGATION
SWMU P – SPENT BATTERY STORAGE AREA
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

5.0 GEOTECHNICAL INVESTIGATION

5.1 INTRODUCTION

The following sections describe the proposed geotechnical investigation at RAAP for the VI SWMUs. Data gained through this investigation will supplement existing data, thus enabling better characterization of hydrogeologic conditions and determination of contaminant migration potential and extent. Exploratory borings, installation of monitoring wells, collection of water level measurements, and inspection of existing on-post wells to be sampled as part of the VI are proposed to fill the identified data gaps. Geophysical surveys will also be conducted at several SWMUs. The analysis of information gathered from the field investigations will help define local lithology, aquifer characteristics, depth of potentiometric surfaces, hydraulic gradients, localized direction of groundwater flow, locations and/or areal extent of subsurface contaminant sources, and possible contaminant plumes. This information will be useful to evaluate the need for any followup investigations, RFI activities, remediation, or monitoring.

5.2 WELL INSPECTION

The existing monitoring wells at RAAP, to be included in the VI sampling program, will be inspected in detail at the time of sampling. Available construction details (i.e., materials, diameter, etc.) will be verified. Water level and total depth will be measured at each well, and mapped locations will be verified. This information will be used to determine groundwater flow directions (if possible), to determine the usefulness of each well relative to the designed SWMU, and to ensure their integrity for use in the VI. Headspace vapors in the wells will be monitored with a photoionization detector (PID) to detect any volatile constituents indicative of groundwater contamination. Some wells may require re-development if inactivity has resulted in excessive sediment deposition. Boring logs, well construction diagrams, survey data, and other pertinent information will be compiled from other sources and ultimately included in the VI report.

Existing wells to be sampled at each SWMU include:

- 13, 14, 15, and 16 (SWMU 6)
- D3, DDH2, and DDH4 (SWMU 10)
- B3, BDH2, BDH3, and CTM-1 (SWMU 26)
- FAL-1, FAL-2, FAL-3, 7, and 16-3 (SWMU 27/29/53).

Well installation details for the existing pertinent wells at RAAP are provided in Appendix A. Upon inspection, if any of these wells are not usable for this investigation, a determination will be made as to whether another existing well can be substituted or whether a new well should be installed during the VI field program. Problems associated with the use of any well and/or the necessity of installing additional wells will be discussed with USATHAMA prior to final action.

5.3 GEOPHYSICAL SURVEY

To definitively identify SWMU boundaries and specific areas of disposal (trenches, pits, etc.) and to assist in well placement, geophysical surveys will be conducted at the following SWMUs:

- Trenches near SWMU 38
- SWMU 45--Sanitary Landfill (West of Main Bridge)
- SWMU 54--Propellant Ash Disposal Area.

The areas of coverage, survey grid-spacings, and SWMU-specific details of the surveys are provided in Section 4.2.

The investigations will consist of both magnetic and electromagnetic (EM) conductivity surveys to confirm and locate areas of possible buried metallic objects and other conductive materials, and areas of soil disturbance indicative of excavation or earthmoving activities.

The magnetometer survey to identify ferrous metals (iron and steel) will be conducted using an EDA OMNI-IV or GEM tie-line precession magnetometer consisting of a sensor, staff, and control unit. In the configuration used in this survey, the sensor contains two sensing units spaced at a 1-meter vertical separation.

The lower sensor is supported at a height of approximately 2.4 meters above the ground surface by a staff.

Operated in the gradiometer mode, the OMNI-IV will obtain measurements of the total magnetic field intensity from the upper and lower sensors at each survey station. The difference between the lower and upper sensor will be automatically calculated to yield the vertical magnetic gradient. Temporal changes in the earth's normal magnetic field will be corrected using a base station and tie points.

The EM survey will be conducted using a Geonics EM-31 electromagnetic induction meter, which measures the apparent conductivity of the subsurface by using the principles of electromagnetic induction. The EM-31 consists of two horizontal coplanar loops, one acting as a transmitter and the other as a receiver, separated by a rigid boom. The transmitter induces eddy currents in the earth, which, in turn, produce a secondary field. The receiver intercepts the secondary field in which the EM-31 measures the terrain conductivity by comparing the strength of the secondary field to that of the primary.

The depth of investigation by EM is a function of the intercoil spacings and the orientation of the antenna dipoles. The EM-31 has intercoil spacings of 12 feet; used in the horizontal mode, it has an effective depth of analysis of approximately 20 feet. This depth is considered sufficient to locate soil disturbance areas such as landfill trenches, pits, and buried objects at RAAP.

At each measurement station, four readings will be measured with the EM-31. Readings will be obtained with the antenna boom oriented in two compass directions, north-south and east-west. The EM-31 will be connected to an OMNI Polycorder data logger that simultaneously records both the quadrature-phase component and the in-phase component. The quadrature-phase component measures the terrain conductivity of the subsurface and will detect metallic and nonmetallic objects or features with varying conductivity. The in-phase component gives measurements that are proportional to an effective, average magnetic susceptibility of the surrounding earth. The readings do not indicate true magnetic susceptibility, because there is an unknown additive constant and multiplying factor that would be required to convert the measured values to magnetic susceptibility. The in-phase mode is significantly more sensitive to large metallic objects.

The results of the geophysical surveys will be incorporated into the VI report.

5.4 MONITORING WELL INSTALLATION

The following sections describe the borehole drilling and installation methods for the monitoring wells recommended for this VI. The field program for the VI study areas includes the following:

- Twenty-two monitoring well borings and installations at seven SWMUs.
- Physical soil tests performed on 23 soil boring samples.
- Surveying of the new monitoring wells for elevation and state planar coordinates.

All locations for well installations will be marked prior to drilling, and RAAP will clear each location for utilities. If buried or aboveground utility lines interfere with the safe operation of equipment, alternate locations will be selected and approved by USATHAMA.

5.4.1 Well Drilling Methodology

All necessary approvals for equipment, methods, and materials will be obtained from USATHAMA prior to the start of drilling. All geotechnical methods will be performed in accordance with USATHAMA's Geotechnical Requirements (USATHAMA, 1987). Typical methods of drilling in unconsolidated overburden include hollow-stem auger, water/mud rotary, cable tool, and air rotary. Dry hollow-stem auger is the preferred method and is expected to be used for overburden drilling at RAAP. The likely presence of river jack (cobbles and boulders) in some areas may require mud rotary methods for drilling through the overburden. Boreholes into bedrock will be cored using an NX-sized diamond or carbide-studded bit. This method will provide an intact sample of bedrock to evaluate lithology, structure, and physical condition. Every effort will be made to avoid methods that introduce potential cross-contaminants. Use of a hollow-stem auger will facilitate the identification of water-bearing strata via observation of changes in the soil moisture of samples or cuttings.

The drilling subcontractor will comply with all State and local requirements as they pertain to drilling and well installation. This includes procurement of appropriate permits, submission of well logs, samples, etc., and review of drillers' credentials or licenses, as applicable. State license and monitoring well construction permits have not been required at RAAP in the past.

All overburden well borings will be performed using the following procedure when possible. Very coarse sediments may require a mud rotary method for well installation. For all 4-inch monitoring wells installed in unconsolidated soils, a 6.25-inch I.D. dry hollow-stem auger will be used. Split-spoon sampling will be conducted at 5-foot intervals during drilling to allow a detailed log to be developed for each boring. The method used to collect split-spoon samples will be the Standard Penetration Test (ASTM D-1586), in which a 140-pound weight is dropped 30 inches, driving an 18- or 24-inch sampler into the soil. The number of blows needed to drive the sampler at intervals of 6 inches of penetration will be recorded on the boring logs. Hollow-stem augering, as described above, will be performed through the overburden until bedrock is encountered. NX rock coring will then be performed to penetrate to approximately 15 feet below the encountered water table. After completion of the rock coring, a 6-inch roller bit will be used to ream out the hole to place the well. Only USATHAMA-approved water will be used for coring/reaming. Waste drilling water will not be containerized unless contamination is apparent at the time of drilling or existing data prove that significant contamination is present.

The mud rotary method appropriate for drilling through very coarse unconsolidated sediments would use materials unlikely to alter the chemical character of the penetrated soils. The water used for drilling will be from a supply tested and approved by USATHAMA prior to any field efforts. The thickening agent added to the water will be bentonite clay powder. A sample of the bentonite to be used during drilling will be submitted to USATHAMA prior to initiation of field efforts, along with documentation on manufacturing and origin of the material.

Only approved bentonite will be used for drilling and well installation. After penetrating to the required depths, the mud will be flushed from the borehole using USATHAMA-approved water. Volumes of mud and water lost into the formation will be recorded at the time of drilling and flushing.

An experienced geologist will supervise the drilling of each borehole and will maintain continuous detailed subsurface logs by examining drill cuttings, recording samples, and noting first-encountered and static groundwater levels for each borehole. The rock cores will be placed in wooden boxes and photographed with appropriate identification. In addition, a daily field log will be maintained to include such information as the progress of drilling operations, problems encountered, and well installation procedures. All original boring logs, well diagrams, and field notes will be submitted to USATHAMA according to its 1987 Geotechnical Requirements. Copies of all boring logs will also be submitted to RAAP, as required.

The drill rig and all sampling equipment will be decontaminated prior to arrival at RAAP, prior to drilling the first borehole, and after the drilling of each borehole by a portable steam-cleaner provided by the driller at a steam temperature of 220° F and a pressure of 1,000 psi. One or more locations will be designated for steam-cleaning that are as close to the proposed drilling sites as possible to minimize the distance the drill rig must travel for decontamination. A sample from the water source to be used for drilling, rinsing, and steam-cleaning will have been analyzed and the results submitted to USATHAMA for approval before fieldwork initiation.

5.4.2 Well Construction

Monitoring wells will be installed in the newly drilled boreholes using a 6.25-inch I.D. dry hollow-stem auger method whenever possible. Well installations and all geotechnical procedures will be performed according to USATHAMA's 1987 Geotechnical Requirements and the requirements of the Commonwealth of Virginia. All well casing and screening materials will be made of new Schedule 40 PVC. PVC is considered appropriate for the conditions to be encountered and the contaminants of concern. The screen for each well will be approximately 10 feet long with a slot size of 10 (0.010 inch). This screen length will ensure that the screens remain opposite the producing groundwater zone even during drier periods, lessening the chances of a dry well during future groundwater sampling efforts. Only threaded couplings will be used to join sections of PVC casing and screening materials. All well casings and screens will be thoroughly washed with USATHAMA-approved water prior to insertion in the borehole. All water for drilling, well installation, and development will be obtained from the approved water source.

A 4-inch-diameter casing will be installed in the borehole (with a 2.5-foot stickup) per USATHAMA's 1987 Geotechnical Requirements. The casing will have an appropriate screen or slotted casing, will be plugged at the bottom, and will be located no more than 3 feet above the bottom of the borehole and opposite the producing groundwater zone. The top of the screen will be positioned 1 to 2 feet above the stabilized water level encountered, where possible, for all shallow wells to intercept petroleum hydrocarbons or other contaminants that may be floating on the water table, as well as other types of constituents. The screened section will be sand packed, to at least 5 feet above the screen, wherever circumstances permit.

The overriding concern will be to ensure room for a sufficient annulus seal to prevent vertical infiltration of surface water. A 5-foot-thick bentonite seal will be placed above the sand pack, depth permitting, and the remaining annular space between the top of the seal and ground surface will be grouted with a cement and bentonite mixture. The grout will be pumped into the open annulus through a rigid tremie pipe, which will be lowered into the hollow stem of the augers, outside the well casing, to the bottom of the annulus. Grout will be pumped until undiluted grout rises to the surface. Augers will then be removed, allowing the grout to fall into the evacuated hole, but at no time will the grout fall below the bottom of the deepest auger. The grout will again be added to fill the remaining open annulus, and more augers will be removed. This operation will be repeated until all augers have been removed and grout is present at the ground surface. Data concerning screen, filter sand, bentonite seal and grout thickness, and depths will be recorded. An installation diagram will be prepared for each well.

The bedrock wells proposed for the RAAP VI will be placed within the reamed bedrock and consist of a 15-foot screen and sand pack similar to the overburden wells. The bottom of each screen will be placed approximately 12 to 13 feet below the water table, with the sand pack extending up to 5 feet below the soil/bedrock contact. A 5-foot bentonite pellet seal will be placed above the sand pack and terminated at the soil/bedrock contact. Bentonite/cement grout will be placed from above the bentonite seal to the ground surface.

A 5-foot length of protective, clean steel casing--with a diameter of at least 6 inches and with a locking cap--will be installed over the well casing immediately after grouting, to a depth of 2.5 feet below the ground surface. No more than 0.2 foot of height will separate the top of well casing and the top of protective casing. An internal mortar collar will be placed within the steel protective casing and outside the PVC well casing to a height of 0.5 foot above ground surface. An internal drainage hole will be drilled through the steel casing just above the mortar collar. After the grout has thoroughly set, the protective steel casing will be brush painted with orange paint and identified by number in white. Additional protection will be afforded by four steel posts set radially around the well. The posts will be placed 4 feet from the well, and the area between the posts and the well will be covered with 6 inches of gravel.

5.4.3 Well Development

Proper well development will remove water, drilling muds, and other fluids or materials introduced into the aquifer as a result of borehole drilling operations. It also functions to reduce the amount of fine-grained sediment around the sand-packed portions of the annulus, which might otherwise clog the well screen, and to enhance porosity for free flow in the screened zone. Well development techniques that could potentially contaminate or alter the chemistry of the water-producing zones will be avoided. Well development equipment will be decontaminated prior to use and between wells. Prior to development, the static water level will be measured and recorded. Field conductivity, temperature, and pH will also be measured and recorded before, at least twice during, and at completion of development to ensure that the development process is complete.

Dames & Moore will develop each monitoring well no sooner than 48 hours or later than 7 days after the placement of the internal mortar collar around the well. We propose to use a 4-inch submersible pump for development. Water will be removed throughout the water column by periodically changing the position of the pump in the well during development. In addition, the well cap and interior of the well casing will be washed with water withdrawn from the well during development. Surging--the use of a surge block or plunger to create a vacuum on the upstroke and positive pressure on the downstroke--will be used to help loosen and remove fine-grained sediment, if needed. A bottom discharge/filling bailer may also be used to aid in well purging. The well will be developed until it yields water clear to the unaided eye and sediment remaining in the well occupies less than 1 percent of the screen length. At a minimum, the standing water volume in the well and in the saturated annulus will be removed at least five times. In addition, if drilling fluids were introduced and lost into the well, an additional quantity to equal five times the measured volume of lost fluids will be removed. For each well, a l-pint sample of the last water removed during development will be captured and retained for visual inspection prior to submittal of the sample to the RAAP environmental coordinator. The water level in the well will be allowed to fully recover prior to any groundwater sampling. All appropriate data and field measurements will be recorded and submitted as part of the well development report. If problems arise, such as slow recharge, lack of adequate volume, or permanent discoloration of pumped water, field personnel will coordinate with USATHAMA in seeking resolution. Other problems, such as a large fluid loss in the bedrock borehole, will also be resolved in consultation with USATHAMA.

5.5 BORING AND WELL ABANDONMENT

Any soil borings in which wells will not be installed must be sealed upon completion. It is not anticipated that the new monitoring wells being constructed will need to be abandoned. In the event that a well must be abandoned either during installation or upon completion, it will be sealed. The following procedure will pertain to both borings and abandoned wells.

Any boring or well to be abandoned will be sealed by grouting from the bottom of the boring/well to ground surface. This will be accomplished by placing a grout pipe at the bottom of the boring/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through the pipe until undiluted grout flows from the boring/well at ground surface. Any open or ungrouted portion of the annular space between the well casing and borehole will be grouted in the same manner. After grout placement, the drill casing/augers may be removed.

After 24 hours, the abandoned drilling site will be checked for grout settlement. On that day, any settlement depression will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at ground surface.

Grout will be composed by weight of 20 parts cement (Portland cement type II) to one part untreated bentonite powder, with a maximum of 8 gallons of USATHAMA-approved water per 94-pound bag of cement. Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with water. All grout materials will be combined in an aboveground, rigid container and mechanically mixed onsite to produce a thick, lump-free mixture.

5.6 FIELD MEASUREMENT OF CONDUCTIVITY AND pH

Field measurements of conductivity, temperature, and pH will be recorded each time a surface water sample is collected, each time an individual well is purged, and again after it is sampled. Conductivity and pH measurements will also be taken during well development. Conductivity and temperature will be measured using a Fisher-Porter or equivalent field electrical conductivity meter. Measurements will be made in the field according to the instrument manufacturer's recommendations. Each instrument will be checked and calibrated before sampling at each location and at the beginning and end of each day using standard potassium chloride (KCl) solutions with known conductivity.

Field meters to be used during sampling--specifically, the pH and specific conductance meters--will be checked to ensure proper calibration and precision response before initiation of the field program. Thermometers will be checked against a precision thermometer certified by the National Institute of Standards and Technology (NIST; formerly National Bureau of Standards). These activities will be performed by the field supervisor. In addition, buffer solutions and standard KCl solutions to be used to field calibrate the pH and conductivity meters will be laboratory tested to ensure accuracy. The preparation date of standard solutions will be clearly marked on each of the containers to be taken into the field. A log that documents problems experienced with the instrument, corrective measures taken, battery replacement dates, dates of use, and user will be maintained for each meter and thermometer. Appropriate new batteries will be purchased and kept with the meters to facilitate replacement in the field.

All equipment to be used during the field sampling will be examined to certify that it is in operating condition. This includes checking the manufacturer's operating manuals and the instructions with each instrument to ensure that all maintenance items are being observed. Field notes from previous sampling trips will be reviewed so that any prior equipment problems can be remedied. A spare electrode will be sent with each pH meter that is to be used for field measurements. Two thermometers will be sent to sampling locations where temperature measurement is required.

5.7 PHYSICAL SOIL TESTING

As required by USATHAMA, physical testing of at least 10 to 20 percent of the soil samples obtained during the field investigation will be conducted to characterize the encountered soil formations and their hydrogeologic properties. The samples selected for testing will represent the range and frequency of soil types encountered within the study areas. The laboratory tests will include determination of particle-size distribution (ASTM D-422) and Atterberg limits (ASTM D-4318), and assignment of Unified Soil Classification System (USCS) symbols.

Particle-size analyses will be performed to classify the coarser grained soils and to correlate with permeability and other properties. These tests will include washed sieve analyses and percent fines determinations (percent of sample finer than a U.S. No. 200 sieve size). Atterberg limits of representative fine-grained soil samples will be evaluated to aid in classification and correlation to permeability characteristics. Procedures for all tests will be in accordance with those described in the Annual Book of ASTM Standards, Volume 04.08 (formerly Part 19).

Laboratory data sheets will be submitted to USATHAMA within 10 working days of final test completion.

5.8 SURVEYING

After completion of the last well, the newly installed wells will be surveyed to determine location coordinates and vertical elevation. The Virginia State Planar Coordinate System will be referenced, with locations surveyed to ±3 feet. Elevations to the top of the PVC will be reported within ±0.01 foot, using the National Geodetic Vertical Datum of 1929.

5.9 CONTAINERIZATION, STORAGE, AND DISPOSAL OF FIELD-GENERATED WASTES

Completion of the proposed field program will result in the generation of bore soil cuttings, core drilling fluids, well development purge water, and well sampling purge water. It is proposed that purge water generated from developing the new monitoring wells and from sampling new and existing wells not be containerized at the time of removal unless contamination is apparent at the time of removal or existing data prove that significant contamination is present. At the time of purging, the suspected water will be temporarily placed in a portable tanker or 55-gallon drums and then transferred by the drilling subcontractor and Dames & Moore to a designated on-post industrial sewer for disposal. Water from equipment decontamination will not be containerized unless significant contamination is suspected. If containerized, the water will be disposed of in a designated on-post industrial sewer.

Borehole soil cuttings generated during drilling for well installation will remain on the ground surface at the drilling locations and will not be containerized. Because drilling for well installation will occur outside the boundaries of waste disposal areas, contaminant concentrations of soil cuttings are expected to be minimal.

6.0 SAMPLING PROGRAM

6.1 OVERVIEW

The purpose of the VI sampling program is to collect representative samples of groundwater, surface water, soils, sediment, and waste for use in identifying contaminants at RAAP. Figures 4-1 through 4-24 show proposed sampling locations at RAAP. The locations and number of samples have been selected to optimize the identification of sources of contaminants and pathways of contaminant migration. The collection procedures take into account characteristics of known contaminants, as well as the need to identify suspected contaminants and measure a range of standard parameters (e.g., analysis for drinking water standards and parameters that monitor changes in the sample, such as pH and conductivity). A summary of the samples to be collected and the analytical program is provided in Tables 4-1 and 4-2.

All sampling will be accomplished in accordance with USATHAMA's technical requirements for contamination surveys, as specified in paragraph C.3.1.2.3 of the contract (USATHAMA, 1988). In addition, sampling will be accomplished in accordance with USATHAMA's Quality Assurance (QA) Program (USATHAMA, 1990). USATHAMA QA procedures and requirements are discussed in detail in Section 6.0, Section 7.0, and Appendix E. In general, the USATHAMA methods and the standard EPA methods (Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846) are consistent--with only minor differences in the type of QC required, as discussed below. Section 7.0 provides a comparison of inorganic (metals and cyanide) and organic (GCMS) analytical methods.

Correction of final analytical data by certification slope recoveries is optional in the USATHAMA data base, but generally correction has been USATHAMA policy. The rationale for this correction relates to method certification and daily control spikes for analytical runs to prove that the method is valid and being followed. Surrogate recovery data have never been used to correct final data. Surrogate recovery data have been used, however, to monitor possible matrix interferences or random extraction problems.

Matrix spikes have typically not been required by USATHAMA because of the potential error associated with choice of spike level versus background concentration. Although matrix spikes can sometimes provide useful matrix interference information, the cost on return ratio has proven to be prohibitive for USATHAMA. Recently, USATHAMA has been required to perform matrix spikes at some installations by some EPA regions and by states. However, because surrogate information provides a degree of similar matrix spike information, matrix spikes have not been required for methods incorporating surrogates.

Both Environmental Science and Engineering, Inc. (ESE) and USATHAMA have automated data checking procedures at different phases of the data review chain. ESE's computerized data management procedures minimize manual manipulation of data at the bench into the data management system (some instrumentation files are transferred to our data management system). ESE then uses automated procedures to produce transfer files to submit to the USATHAMA IRDMS. IRDMS has several automated data checking routines to ensure conformance of submitted data files with the certified method requirements and verification of map files for site identification. Further discussions are presented in Section 7.0 of the QAPP, Appendix A.

USATHAMA requires contract laboratories to control the data quality they produce through pre-analysis certification and subsequent daily control spikes that produce precision and accuracy data. Precision and accuracy estimates of the generated data can also be produced by replicate or collocated sampling and matrix spikes; however, these are required only on a case-by-case basis.

USATHAMA certification is required to provide initial performance data based on standard matrix control spikes. Daily control spikes are subsequently used to document conformance with certification and to update method precision and accuracy estimates (this is done through a control chart process). Performance data obtained during certification include CRLs; upper CRLs, above which samples require dilution; method precision and accuracy data; and initial control chart limits for the required daily control spike levels. Acceptance criteria for analytical data generated are based on control chart limits, which are a measure of laboratory control for that method. Method performance criteria can be used to help judge acceptance of analytical results. Weekly control chart explanations and corrective actions are supplied to USATHAMA for approval.

Weekly control chart submissions to the USATHAMA Technology Division require continual monitoring of the analytical processes and identification of any corrective actions. Explanations of out-of-control situations or trends must be sufficient enough for USATHAMA to accept the analyses performed. Corrective actions are required to ensure USATHAMA of control data quality.

The following sections describe the field sampling program and sampling procedures to be followed during the investigation. The rationale for this program was discussed in Section 4.0. Requirements for sample containers, preservatives, holding times, lot sizes, etc., are provided in Section 7.0.

6.2 GROUNDWATER SAMPLING

Groundwater samples will be collected from 16 existing wells and 22 wells installed under this VI. Replicate samples from two wells will also be taken for quality control (QC). Proposed locations are shown in figures provided in Section 4.2. These wells, as identified in Tables 4-1 and 4-2, will be sampled as part of the groundwater investigation at the following SWMUs:

- SWMU 6--Acidic Wastewater Lagoon
- SWMU 10--Biological Treatment Plant Equalization Basin
- SWMU 26--FAL No. 1
- SWMUs 27, 29, and 53--Calcium Sulfate Landfill, FAL No. 2, and Activated Carbon Disposal Area
- SWMU 32--Inert Waste Landfill No. 1
- SWMU 40--Sanitary Landfill (NG Area)
- SWMU 41--Red Water Ash Landfill
- SWMU 43--Sanitary Landfill (adjacent to New River)
- SWMU 45--Sanitary Landfill (West of Main Bridge)

- SWMU 54--Propellant Ash Disposal Area
- SWMU 74--Inert Landfill No. 3.

A primary consideration in obtaining a representative groundwater sample is to guard against mixing the sample with standing, stagnant water in the well casing. In a nonpumping well, there will be little or no vertical mixing of the volume of water above the screened interval, and stratification may occur. Such stagnant water may contain foreign or degraded material, resulting in an unrepresentative sample and misleading chemical data. Therefore, purging of wells is necessary prior to sample collection. The following procedures will be followed when collecting groundwater samples from monitoring wells at RAAP:

- Sampling will be conducted no sooner than 14 days after well development has been completed for the newly installed wells. All equipment used to purge wells and collect samples will be protected from ground surface contact and contamination by the use of clean plastic sheeting.
- Groundwater depth will be measured and recorded for each well prior to purging and sampling.
- Where recharge rates permit, the well will be purged by an appropriate pump or bailer to remove five times the volume of the standing water in the well plus annulus. Water levels will be allowed to adequately recover prior to sample withdrawal.
- At the start of purging and after collection of the sample for chemical analysis, a groundwater sample will be collected for field measurement of temperature, pH, and conductivity.
- The sample will be collected with a dedicated PVC bailer that has been cleaned with USATHAMA-approved water between samples. All other sampling equipment will also be rinsed with USATHAMA-approved water between wells to prevent cross contamination. Use of a dedicated PVC bailer rather than reuse and decontamination of Teflon bailers is considered more appropriate for ensuring sample

integrity. The bailer will be cleaned, wrapped, and left at RAAP for possible future use.

- Sample containers and caps will be triple rinsed with the water being sampled; those for filtered samples will be rinsed with filtered sample water, and those for unfiltered samples will be rinsed with unfiltered sample water. The samples will be collected so as to minimize aeration as water enters the bottle. Sample containers of appropriate volume and composition will have been prepared in advance by the certified laboratory to ensure the collection of sufficient volumes for specified analyses.
- Samples for metals analysis will be filtered in the field using a disposable 0.45-micron filter and preserved according to USATHAMA requirements and laboratory instructions. Samples for nonvolatiles will be filtered in the laboratory as specified.
- Samples for volatile analysis will be bailed and collected in screw-cap, septum-top glass vials and filled so that there are no air bubbles present to allow volatilization. These samples will not be filtered.
- Sample containers will be labeled with appropriate identifying information (location, date, time, condition, etc.), and each sample will be logged in a field notebook at the time of collection. Labeling and notebook information requirements specified in the QA Program will be met.
- All sample containers will be transferred to a temperature-controlled chest (cooler kept at a temperature of 4°C with ice packs) and delivered to the laboratory in sufficient time so that specified holding times are not exceeded.
- Appropriate safety precautions will be taken during sampling to guard against the anticipated physical and environmental hazards of toxic materials. Details are presented in the accompanying Site-Specific Health and Safety Plan.

6.3 SURFACE WATER SAMPLING

A total of five surface water samples (four environmental and one replicate QC) will be collected from the following SWMUs:

- SWMU 29--FAL No. 2
- SWMU 41--Red Water Ash Landfill
- SWMU 57--Pond by Buildings 4931 and 4928
- SWMU 69--Pond by SWMU 68.

A representative sample for water quality testing will be collected at each sampling location.

The following sample collection procedures will be followed:

- All sampling equipment (containers, tubing, pumps) will be washed with USATHAMA-approved water prior to use to minimize contamination. All equipment will be protected from ground surface contact and contamination through the use of clean plastic sheeting.
- All sample containers except vials for VOC analyses and sampling equipment will be triple-rinsed with water from the sampling location prior to the collection of a sample.
- Grab samples will be collected at approximately one-half to two-thirds of the water depth for shallow streams, ditches, and ponds, where possible. The mouth of the sample collection device will be maintained completely underwater, when possible, and will face upstream into the current.
- Samples will be collected during dry weather conditions.
- No samples will be filtered in the field.
- All samples will be preserved according to the requirements specified in Section 7.0. Preservatives will be added to the sample until the proper pH is met.

- Sample containers will be completely filled with water, wiped clean and dry, marked on the label with a waterproof marker, and stored for shipment. Identifying information will include the time, date, location, depth, sampler's initials, and identification number. Samples containing anticipated high concentrations will be so marked. Labeling and logbook information recorded will be in accordance with the USATHAMA QA Program.

- Samples will be stored in a temperature-controlled chest, kept on ice at a temperature of 4°C, and shipped to the laboratory in sufficient time so that specified holding times are not exceeded.

- Appropriate safety precautions will be observed during sampling to guard against the anticipated physical and environmental hazards of toxic materials. Details are presented in the Site-Specific Health and Safety Plan.

6.4 SEDIMENT SAMPLING

A total of six sediment samples (five environmental and one replicate QC) will be collected from the following SWMUs:

- SWMUs 27, 29, and 53--Calcium Sulfate Landfill, FAL No. 2, and Activated Carbon Disposal Area
- SWMU 57--Pond by Buildings 4931 and 4928
- SWMU 69--Pond by SWMU 68.

Sediment samples will be collected to a depth of approximately 12 inches beneath the sediment-water interface, whenever possible. Samples will be collected with a shovel or other hand-operated sampler. In sampling, care will be taken to collect and retain the "fines," which often contain the highest concentrations of chemical deposits. Prior to sampling, the chosen sampling device will be rinsed with stream water at a point downstream from the sampling location or with ponded water at a point near the sampling location, as appropriate. Only stainless-steel utensils will be used for the placement of sediment into the sample containers.

The sample containers, liners, and caps will be washed in the laboratory prior to field use. After collection, the sediment sample container will be wiped clean and dry and labeled. The label, written with indelible ink, will include the time, date, location, sampler's initials, and identification number. The same information, along with the sample condition, will be recorded in the field notebook. Labeling and notebook information recorded will be in accordance with the USATHAMA QA Program. The samples will be stored and shipped in the same manner as surface water and well water samples. The maximum storage time for sediment samples is equivalent to that for water samples.

After the samples have been collected at a particular location, the sampling device will be scrubbed as necessary and rinsed with USATHAMA-approved water to prevent cross contamination.

Appropriate safety precautions will be taken by all personnel during sampling. Procedures specified in the Site-Specific Health and Safety Plan address both the physical and environmental hazards of toxic materials.

6.5 SOIL SAMPLING

A soil sampling program consisting of the collection of up to 46 near-surface soil and soil boring samples (43 environmental and three QC) is proposed for the VI at RAAP. The approximate soil sampling locations are shown in figures in Section 4.2. Table 4-2 provides a summary of the sampling points. Section 4.2 also identifies specific sampling locations with respect to the SWMU investigations and provides pertinent information relative to sample collection at each site. Unless indicated otherwise, all soil samples will be from discrete locations. Composite sampling is recommended at some SWMUs to cover a larger geographic area in sampling and simultaneously reduce the analytical program. Similar sample volumes from composite locations will, upon collection, be placed in an appropriately large container. The sample will then be homogenized by mixing with a stainless-steel utensil and submitted for analysis. At soil sampling locations where analysis for VOCs will occur, samples will not be composited. A separate VOC sample will be collected at each composite location.

It is anticipated that near-surface soil samples will be collected from 0 to 1 foot below ground surface (excluding any surface gravel, organic root zone, or other nonsoil cover). Soil samples will be collected at the following SWMUs:

- SWMU 6--Acidic Wastewater Lagoon
- SWMU 39--Incinerator Wastewater Ponds
- SWMU 41--Red Water Ash Landfill
- SWMU 46--Waste Propellant Disposal Area
- SWMU 48--Oily Wastewater Disposal Area
- SWMU 58--Rubble Pile
- SWMU 59--Bottom Ash Pile
- SWMU 68--Chromic Acid Treatment Tanks
- SWMU 69--Pond by SWMU 68
- SWMU 71--Flash Burn Parts Area
- SWMU F--Drum Storage Area
- SWMU P--Spent Battery Storage Area.

The procedures discussed below will be followed when collecting soil samples:

- Surface soils will be sampled with hand augers or hand shovels. Boring samples will be collected with split-spoon samplers during drilling. All sampling equipment will be washed clean with USATHAMA-approved water between samples to prevent cross contamination.
- Only stainless-steel utensils will be used to place soil into the sample jars.
- Samples will be stored and shipped in appropriate containers, as specified in Section 7.0; samples will be stored in a temperature-controlled chest at a temperature of 4°C and shipped to the laboratory in sufficient time so that specified holding times are not exceeded.
- Samples will be marked with identifying information and logged in the field notebook. Data on the labels of all sample bottles will include source/sampling location, date and time sample was taken, identity of sampler, and parameter(s) to be analyzed. Labeling and notebook

information requirements specified by the USATHAMA QA Program will be met.

- Maximum storage times will not exceed those designated for soil samples, as approved by USATHAMA.
- Appropriate precautions, as detailed in the Site-Specific Health and Safety Plan, will be observed during sampling. Specified procedures are used to guard against physical and environmental hazards.

6.6 WASTE SAMPLING

Wastes disposed of at the following Calcium Sulfate Areas were generated as a result of identical or similar manufacturing processes and, therefore, should be homogenous in character--SWMUs 8, 9, 35, 36, 37, 38, Q, 50, and the Sludge Disposal Area Near SWMU 38. Although some of the SWMUs contain dried (dewatered) sludges, and the water content varies from SWMU to SWMU, the hazardous (or nonhazardous) characteristics of the wastes from these units should be similar. Waste analyses will be conducted on sludges collected from each of these SWMUs to determine whether the wastes contain constituents at concentrations exceeding maximum allowable permit limits.

Waste disposed of at SWMU 31 is considered to be homogenous. Waste analysis will be conducted at this SWMU to determine whether the waste contains any hazardous constituents.

SWMUs 8, 9, and 31 consist of liquid-filled settling lagoons. Sludges from these units will be sampled with a hand auger equipped with a sludge sampler, or a bottom dredge. Samples will be collected from the edge of the lagoons, if possible. Otherwise, a small boat or appropriate floating platform will be used to facilitate sampling at other locations.

SWMUs 35, 36, 37, 38, Q, 50, and the Sludge Disposal Area Near SWMU 38 consist of sludge drying beds or sludge disposal areas. In the disposal areas and in drying beds that contain only dried, solidified sludge, the sludge will be sampled with hand augers or hand shovels. In the drying beds that contain liquified or very wet sludge, samples will be collected with a hand auger equipped with a sludge sampler or a bottom dredge.

A total of 19 waste samples and one replicate for QC will be taken at RAAP. The procedures outlined below will be followed when collecting waste samples from any of these SWMUs:

- All sampling equipment will be washed clean with USATHAMA-approved water between samples to prevent cross contamination.
- Only stainless-steel utensils will be used to place soil in the sample jars.
- Samples will be stored and shipped in appropriate containers, as specified in Section 7.0; samples will be stored in a temperature-controlled chest at a temperature of 4° C and shipped to the laboratory in sufficient time so that specified holding times are not exceeded.
- Samples will be marked with identifying information and logged in the field notebook. Data on the labels of all sample bottles will include source/sampling location, date and time sample was taken, identity of sampler, and parameter(s) to be analyzed. Labeling and notebook information requirements specified by the USATHAMA QA Program will be met.
- Maximum storage times will not exceed those designated for soil samples, as approved by USATHAMA.
- Appropriate precautions, as detailed in the Site-Specific Health and Safety Plan, will be observed during sampling. Specified procedures are used to guard against anticipated physical and environmental hazards.

6.7 BACKGROUND SOIL SAMPLING

A total of 10 background soil samples will be collected for the RFI from off-post locations in the immediate vicinity of RAAP to provide data for comparison to SWMU-specific samples collected. These data will be available from the RFI to use in this VI. These samples will be collected by Dames & Moore from areas identified by RAAP personnel. Samples will be collected after any access/permission requirements for sample collection are satisfied by RAAP. Sampling locations will be areas considered to be representative of background conditions and soil types of the SWMUs under investigation; the selection of locations will not be influenced by any activities that would be known to impact the "natural" concentrations of metals. The 10 samples will be tested only for metals, because these are the major constituents of concern known to be naturally occurring. Sample collection procedures outlined in Section 6.5 will be followed.

6.8 QUALITY CONTROL SAMPLES

6.8.1 Drilling and Rinse Water Sampling

The water anticipated for use in decontaminating drilling equipment and rinsing sampling equipment must be analyzed prior to the initiation of field efforts and approved by USATHAMA. Two samples of this water (RAAP-1) will be collected at one time and submitted to the laboratory for analysis in separate lots. The results will then be submitted to USATHAMA for approval. If the source has been determined to be unsuitable, an alternate source will be identified, with two samples once again submitted for analysis and approval.

The approved water will be resampled at the start of the sampling efforts and submitted to the laboratory with or prior to the first shipment of environmental samples. Concentrations and analytes detected in the source water can then be compared to those found in the environmental samples.

6.8.2 Field QC Samples

The QA/QC protocol for the VI field program requires the use of field QA/QC samples to verify the soundness of sample techniques, chain-of-custody, and chemical analysis results. The following types of samples will be prepared/collected:

- Field (trip) blanks--consisting of distilled water in appropriately preserved bottles, to monitor any sample contamination that might occur during handling or shipping.

- Equipment blank samples--consisting of USATHAMA-approved rinse water poured through the cleaned bailer assembly or other sampling equipment into appropriately preserved bottles, to check the effectiveness of sampling equipment decontamination procedures.
- Field blank samples--consisting of USATHAMA-approved water to be used for washing/rinsing equipment and then poured directly into appropriately preserved bottles, to monitor contamination that might occur from the rinse water source or sample containers. These samples would be the same as those to be collected in Section 6.7.1 for evaluation of the drilling/rinse water source.
- Replicate samples (see Section 7.0)--to check laboratory analytical accuracy.

Trip blanks will be analyzed for VOCs only. Equipment blanks, field blanks, and drilling/rinse water samples will be analyzed for VOCs, BNAs, metals, and explosives. Replicate samples will be analyzed for the same analytes to be tested for in the initial sample.

The number of QC samples to be collected during the VI field program is shown in Table 4-1. The approximate frequency of collection is as follows:

- Drilling/wash/rinse water: 2 times per water source prior to field program; 1 time at start of field program.
- Trip blanks: 5 percent of VOC samples.
- Equipment blanks: 5 percent of all surface water, soil, and sediment samples.
- Replicates: 5 percent of all samples per matrix.

6.9 SPLIT SAMPLES

As provided by the permit, EPA and the Virginia Department of Waste Management reserve the right to require split samples. Prior to initiation of any sampling activities, both agencies will be notified in writing of the anticipated startup date. Such notification will be made at least 14 calendar days in advance of that date to provide adequate notice, and will be sent to the following individuals:

Ms. Mary F. Beck (3HW52)
U.S. Environmental Protection Agency
841 Chestnut Building
Philadelphia, PA 19107

and

Mr. William F. Gilley
Director, Division of Regulation
Department of Waste Management
Monroe Building, 11th Floor
101 N. 14th Street
Richmond, VA 23219

If split samples are desired, double (or triple) volumes of each sample will be collected to ensure adequate volume. Sample containers will be provided and filled by the agency requiring the split samples.

7.0 CHEMICAL ANALYSIS PROGRAM

7.1 INTRODUCTION

This section presents the requirements for the chemical analysis of environmental and QA/QC samples collected for the VI at RAAP. Although the RFI activities are outlined in a separate document, the VI and RFI sampling and analysis programs will be conducted concurrently. The successful completion of the analytical program requires the effective integration of several program activities, including proper containerization, preservation, and shipping of samples to ensure chemical integrity. The use of these techniques will significantly reduce the possibility of sample contamination from external sources. The analytical program for the VI was discussed in Section 4.0. Analytes of interest in this program include VOCs, BNAs (semivolatiles), metals, explosives (nitroaromatics), TOX, and TOC. Constituents included in these categories are identified in Section 7.2.4. Also included are comparisons of USATHAMA analytical methods to EPA methods.

7.2 SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

7.2.1 Sample Containers

For water samples, sample containers will be selected that are compatible with the analytes of interest. In general, glass bottles with teflon-lined caps will be used for organics and explosives analyses, and plastic (polyethylene) bottles will be used for metals analyses. For soil, sediment, and waste samples, wide-mouth glass bottles with teflon-lined lids will be used. Specific sample container requirements are summarized in Table 7-1. All sample containers will be appropriately cleaned in the laboratory prior to shipment to the field. All sample containers will be labeled with pertinent information including sample number, date, time, initials of sampler, and pH (for aqueous samples).

7.2.2 Sample Preservation

Water samples for metals analysis will be preserved in the field with nitric acid to a $pH<2$. Groundwater samples for dissolved metals will be filtered prior to preservation. Water samples for VOC analysis will be preserved with hydrochloric

TABLE 7-1

Proposed Methods, Container Types, Volume Requirements, Holding Times, and Lot Sizes for VI Analytical Effort

Method Name	Army Method No.	EPA Method No.	Technique[a]	Container Type	Volume	Preservation Requirement[b]	Holding Time[c]	Lot Size
				WATER SAMPLES				
VOCs	UM20	624	GC/MS	60 ml vials	4 x 60 ml	HCL, pH <2	14D	10
BNAs	UM18	625	GC/MS	Glass	1L	Chill	7D[d]	10
Metals	SS10	200.7	ICAP	Plastic	100 ml	HNO_3, pH <2	6M	25
Hg	SB01	245.1	CVAA	Plastic	250 ml	HNO_3, pH <2	28D	25
Se	SD21	270.2	GFAA	Plastic	100 ml	HNO_3, pH <2	6M	25
Pb	SD20	239.2	GFAA	Plastic	100 ml	HNO_3, pH <2	6M	25
Ag	SD23	272.2	GFAA	Plastic	100 ml	HNO_3, pH <2	6M	25
As	SD22	206.2	GFAA	Plastic	100 ml	HNO_3, pH <2	6M	25
Explosives	UW14	609	HPLC	Glass	1L	Chill, store in dark	7D[d]	15
TOC	--	415.2	--	Plastic	50 ml	H_2SO_4, pH <2	28D	--
TOX	--	9020		Plastic	500 ml	H_2SO_4, pH <2	28D	--
				SOIL, SEDIMENT, AND WASTE SAMPLES				
VOCs	LM19	8240	GC/MS	60 ml vials	50g	Chill	14D	10
BNAs	LM18	8270	GC/MS	Glass	50g	Chill	7D	10
Metals	JS11	6010	ICAP	Glass	10g	Chill	6M	25
Hg	JB01	7471	CVAA	Glass	10g	Chill	28D	25
Se	JD15	7740	GFAA	Glass	10g	Chill	6M	25
Pb	JD17	7421	GFAA	Glass	10g	Chill	6M	25
Ag	JD18	7761	GFAA	Glass	10g	Chill	6M	25
As	JD19	7060	GFAA	Glass	10g	Chill	6M	25
Explosives	LW12	8090	HPLC	Glass	50g	Chill, store in dark	7D[d]	15
TPH	--	9071/9073	--	Glass	50g	Chill	28D	--

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[a] GC/MS-gas chromatography/mass spectroscopy; ICAP-inductively coupled plasma-emission spectroscopy; CVAA-cold vapor atomic absorption; GFAA-graphite furnace atomic absorption; HPLC-high performance liquid chromatography.

[b] Chill to approximately 4°C.

[c] D-day; M-month.

[d] 7 days until extraction; 40 days after extraction.

acid to a pH<2. Water samples for TOC and TOX analyses will be preserved with sulfuric acid to a pH<2. Following necessary preservation, all water samples will be cooled to approximately 4°C in a closed cooler. All soil, sediment, and waste samples will be cooled to approximately 4°C in a closed cooler. Sample preservation requirements are summarized in Table 7-1.

7.2.3 Sample Holding Times and Shipping

The maximum time that a preserved sample may be held between collection and analysis is based on the analyte(s) of interest. Holding time limitations are intended to minimize chemical change in a sample before it is analyzed. Maximum holding times for samples collected at RAAP are summarized in Table 7-1.

To provide for the shortest in-transit storage periods, all environmental samples will be shipped in tightly sealed coolers by priority air express to reach the laboratory in time for analyses within the specified holding times. Most samples will be sent to the laboratory on the day of collection. Sample chain-of-custody procedures, as discussed in Section 4.0 of the QAPP (Part E), will be followed for sample logging. Conformance with all applicable Federal, state, and local regulations regarding sample shipping will be maintained.

7.2.4 Analytical Methods

The analytical parameters discussed in this section refer to the constituents that were specifically identified in Attachment A of the permit and discussed in Section 4.0 of this Work Plan. The proposed analytical parameters for each sample to be collected at RAAP are summarized in Table 4-2. The USATHAMA and laboratory method reference codes and analytical method names are summarized in Table 7-1. The Certified Reporting Limit (CRL) and specific test name and certified method (using USEPA method number if possible) for each analyte of interest are listed in Table 7-2. In addition, the permit Practical Quantitation Limits (PQLs) are also provided. Tables 7-3 and 7-4 provide comparisons of USATHAMA methods to EPA analytical methods for organics and inorganics, respectively.

TABLE 7-2

PROPOSED ANALYTICAL METHODS, PQLS AND HBNs FOR PROPOSED RFI

PROPOSED RFI ANALYTICAL EFFORT FOR WATERS

METHOD UM20 (624); VOLATILE ORGANICS IN WATER BY GC/MS FOR BOTH PRIORITY POLLUTANTS AND HAZARDOUS SUBSTANCE LIST COMPOUNDS (a)

SHORT NAME	STORET	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	CRL	USATHAMA UCL	CLP CRDL	PQL	HBN
111TCE	34506	1,1,1-TRICHLOROETHANE	Y	Y	0.5	200	5	5	200
112TCE	34511	1,1,2-TRICHLOROETHANE	Y	Y	1.2	200	5	5	6
11DCE	34501	1,1-DICHLOROETHENE	Y	Y	0.5	200	5	5	7
11DCLE	34496	1,1-DICHLOROETHANE	Y	Y	0.68	200	5	5	0.4
12DCLE	34531	1,2-DICHLOROETHANE	Y	Y	0.5	50	5	5	5
12DCLP	34541	1,2-DICHLOROPROPANE	Y	Y	0.5	200	5	5	6
2CLEVE	34576	2-CHLOROETHYLVINYL ETHER	Y	N	0.71	200			
BRDCL	32101	BROMODICHLOROMETHANE	Y	Y	0.59	200	5	5	700
C13DCP	34704	CIS-1,3-DICHLOROPROPENE	Y	Y	0.58	230	5	10	0.2
C2H3CL	39175	VINYL CHLORIDE	Y	Y	2.6	200	10	10	2
C2H5CL	34311	CHLOROETHANE	Y	Y	1.9	200	10	10	—
C6H6	34030	BENZENE	Y	Y	0.5	200	5	5	5
CCL3F	34488	TRICHLOROFLUOROMETHANE	Y	N	1.4	50		5	1E+4
CCL4	32102	CARBON TETRACHLORIDE	Y	Y	0.58	200	5	5	5
CH2CL2	34423	METHYLENE CHLORIDE	Y	Y	2.3	100	5	5	5
CH3BR	34413	BROMOMETHANE	Y	Y	5.8	100	10	10	50
CH3CL	34418	CHLOROMETHANE	Y	Y	3.2	200	10	10	30
CHBR3	32104	BROMOFORM	Y	Y	2.6	200	5	5	700
CHCL3	32106	CHLOROFORM	Y	Y	0.5	200	5	5	600
CLC6H5	34301	CHLOROBENZENE	Y	Y	0.5	200	5	5	1000
		DICHLORODIFLUOROMETHANE (c)						5	7000
DBRCL	32105	DIBROMOCHLOROMETHANE	N	Y	0.67	100	5		
ETC6H5	34371	ETHYLBENZENE	Y	Y	0.5	200	5	5	4000
MEC6H5	34010	TOLUENE	Y	Y	0.5	200	5	5	1E+4
		TRANS-1,2-DICHLOROETHYLENE (b)						5	700
T13DCP	34699	TRANS-1,3-DICHLOROPROPENE	N	Y	0.7	280	5	10	0.2
		1,1,1,2-TETRACHLOROETHANE (d)						5	10
TCLEA	34516	1,1,2,2-TETRACHLOROETHANE	Y	Y	0.51	200	5	5	2
TCLEE	34475	TETRACHLOROETHENE	Y	Y	1.6	200	5	5	7
TRCLE	39180	TRICHLOROETHENE	Y	Y	0.5	200	5	5	5
XYLEN	99649	XYLENE	N	Y	0.84	200	5	5	7E+4
ACET	81552	ACETONE	N	Y	13	200	10	100	4000
CS2	77041	CARBON DISULFIDE	N	Y	0.5	200	5	5	4000
12DCE	99642	1,2-DICHLOROETHENE (TOTAL)			0.5	200	5		
MEK	81595	METHYL ETHYL KETONE	N	Y	6.4	200		100	2000
C2AVE	77057	VINYL ACETATE	N	Y	8.3	50	10		
MIBK	81596	METHYL ISOBUTYL KETONE	N	Y	3	200	10	100	2000
MNBK	77103	METHYL-N-BUTYL KETONE	N	Y	3.6	200	10		
STYR	77128	STYRENE	N	Y	0.5	200	5		
		NONCERTIFIED ANALYTES							
CL2BC	81524	DICHLOROBENZENE (TOTAL)							
ACROL	34210	ACROLEIN						5	50
ACRYLO	34215	ACRYLONITRILE						5	0.06

Note: All Units are in microgram/liter (ug/l).

TABLE 7–2 (cont'd)

METHOD UM18 (625); EXTRACTABLE ORGANICS (BNAs) IN WATER BY GC/MS FOR BOTH PRIORITY POLLUTANTS AND HAZARDOUS SUBSTANCE LIST COMPOUNDS (a)

SHORT NAME	STORET	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	CRL	USATHAMA UCL	CLP CRDL	PQL	HBN
124TCB	34551	1,2,4–TRICHLOROBENZENE	Y	Y	1.8	50	10	10	700
12DCLB	34536	1,2–DICHLOROBENZENE	Y	Y	1.7	50	10	10	3000
13DCLB	34566	1,3–DICHLOROBENZENE	Y	Y	1.7	200	10	5	3000
14DCLB	34571	1,4–DICHLOROBENZENE	Y	Y	1.7	200	10	5	75
245TCP	77687	2,4,5–TRICHLOROPHENOL	N	Y	5.2	200	50	50	4000
24DCLP	34601	2,4–DICHLOROPHENOL	Y	Y	2.9	200	10	10	100
24DMPN	34606	2,4–DIMETHYLPHENOL	Y	Y	5.8	100	10	10	20
24DNP	34616	2,4–DINITROPHENOL	Y	Y	21	100	50	50	70
24DNT	34611	2,4–DINITROTOLUENE	Y	Y	4.5	200	10	10	0.05
2CLP	34586	2–CHLOROPHENOL	Y	Y	0.99	200	10	10	200
2CNAP	34581	2–CHLORONAPHTHALENE	Y	Y	0.5	200	10	10	—
2MNAP	77416	2–METHYLNAPHTHLENE	N	Y	1.7	50	10		
2MP	99073	2–METHYLPHENOL	N	Y	3.9	200	10	10	2000
2NANIL	99077	2–NITROANILINE	N	Y	4.3	100	50		
2NP	34591	2–NITROPHENOL	Y	Y	3.7	100	10		
33DCBD	34631	3,3–DICHLOROBENZIDINE	Y	Y	12	100	20	20	0.08
		3–METHYLPHENOL (e)							
3NANIL	99078	3–NITROANILINE	N	Y	4.9	100	50		
46DN2C	34657	2–METHYL–4,6–DINITROPHENOL	Y	Y	17	100	50	50	40
4BRPPE	34636	4–BROMOPHENYLPHENYL ETHER	Y	Y	4.2	100	10	10	—
4CL3C	34452	3–METHYL–4–CHLOROPHENOL	Y	Y	4	200	10	10	200
4CLPPE	34641	4–CHLOROPHENYLPHENYL ETHER	Y	Y	5.1	100	10		
4MP	99074	4–METHYLPHENOL	N	Y	0.52	200	10	10	2000
4NANIL	99079	4–NITROANALINE	N	Y	5.2	100	50	20	—
4NP	34646	4–NITROPHENOL	Y	Y	12	100	50	50	—
ANAPNE	34205	ACENAPHTHENE	Y	Y	1.7	50	10		
ANAPYL	34200	ACENAPHTHYLENE	Y	Y	0.5	50	10		
ANTRC	34220	ANTHRACENE	Y	Y	0.5	100	10	2	2
B2CEXM	34278	BIS(2–CHLOROETHOXY) METHANE	Y	Y	1.5	50	10	10	—
B2CIPE	34283	BIS(2–CHLOROISOPROPYL) ETHER	Y	Y	5.3	200	10	10	40
B2CLEE	34273	BIS(2–CHLOROETHYL) ETHER	Y	Y	1.9	50	10	10	0.03
B2EHP	39100	BIS(2–EHTYLHEXYL) PHTHALATE	Y	Y	4.8	100	10	10	3
BAANTR	34526	BENZO [A] ANTHRACENE	Y	Y	1.6	100	10	0.1	0.01
BAPYR	34247	BENZO [A] PYRENE	Y	Y	4.7	100	10	0.2	0.003
BBFANT	34230	BENZO [B] FLUORANTHENE	Y	Y	5.4	50	10	0.2	0.02
BBZP	34292	BUTYLBENZYL PHTHALATE	Y	Y	3.4	100	50	10	9000
BENZOA	77247	BENZOIC ACID	N	Y	13	100	10		
BGHIPY	34521	BENZO [G,H,I] PERYLENE	Y	Y	6.1	50	10		
BKFANT	34242	BENZO [K] FLUORANTHENE	Y	Y	0.87	100	10	0.4	4
BZALC	77147	BENZYL ALCOHOL	N	Y	0.72	100	10		
CHRY	34320	CHRYSENE	Y	Y	2.4	100	10	2	0.2
CL6BZ	39700	HEXACHLOROBENZENE	Y	Y	1.6	100	10	0.5	0.02
CL6CP	34386	HEXACHLOROCYCLOPENTADIENE	Y	Y	8.6	100	10	10	200
CL6ET	34396	HEXACHLOROETHANE	Y	Y	1.5	50	10	10	300
DBAHA	34556	DIBENZ [A,H] ANTHRACENE	Y	Y	6.5	50	10	0.3	0.0007
DBZFUR	81302	DIBENZOFURAN	N	Y	1.7	50	10		
DEP	34336	DIETHYL PHTHALATE	Y	Y	2	200	10	10	30000
DMP	34341	DIMETHYL PHTHALATE	Y	Y	1.5	100	10	10	400000
DNBP	39110	DI–N–BUTYL PHTHALATE	Y	Y	3.7	200	10	10	4000
FANT	34376	FLUORANTHENE	Y	Y	3.3	100	10	10	200
FLRENE	34381	FLUORENE	Y	Y	3.7	50	10		
HCBD	34391	HEXACHLOROBUTADIENE	Y	Y	3.4	100	10	5	5
ICDPYR	34403	INDENO [1,2,3–CD] PYRENE	Y	Y	8.6	100	10	0.4	2

Note: All units are in ug/l.

TABLE 7-2 (cont'd)

SHORT			PRIORITY	HAZARDOUS	USATHAMA		CLP		
NAME	STORET	LONG NAME	POLL.	SUBST. LIST	CRL	UCL	CRDL	PQL	HBN
ISOPHR	34408	ISOPHORONE	Y	Y	4.8	50	10		
NAP	34696	NAPHTHALENE	Y	Y	0.5	20	10	5	10000
NB	34447	NITROBENZENE	Y	Y	0.5	50	10	10	20
NNDNP	34428	N-NITROSO, DI-N-PROPYLAMINE	Y	Y	4.4	50	10	10	0.005
NNDPA	34433	N-NITROSODIPHENYLAMINE	Y	Y	3	200	10	10	7
PCP	39032	PENTACHLOROPHENOL	Y	Y	18	100	50	50	1000
PHANTR	34461	PHENANTHRENE	Y	Y	0.5	100	10	7	2
PHENO	34694	PHENOL	Y	Y	9.2	200	10	10	20000
PYR	34469	PYRENE	Y	Y	2.8	100	10	10	4000
246TCP	34621	2,4,6-TRICHLOROPHENOL	Y	Y	4.2	100	10	10	2
26DNT	34626	2,6-DINITROTOLUENE	Y	Y	0.79	200	10	10	—
4CANIL	99075	4-CHLOROANALINE	N	Y	7.3	100	10	10	100
DNOP	34596	DI-N-OCTYL PHTHALATE	Y	Y	15	100	10	10	—
NONCERTIFIED ANALYTES									
MEXCL	39480	METHOXYCHLOR	N	Y	5.1		0.5		
CLDANA	39348	CHLORDANE, ALPHA	Y	Y	5.1		0.5		
CLDAN	39810	CHLORDANE, GAMMA	Y	Y	5.1		0.5		
ALDRN	39330	ALDRIN	Y	Y	4.7		0.05		
ABHC	39337	BHC, A	Y	Y	4		0.05		
BBHC	39338	BHC, B	Y	Y	4		0.05		
DBHC	34259	BHC, D	Y	Y	4		0.05		
PPDDD	39310	DDD, PP	Y	Y	4		0.1		
PPDDE	39320	DDE, PP	Y	Y	4.7		0.1		
PPDDT	39300	DDT, PP	Y	Y	9.2		0.1		
DLDRN	39380	DDIELDRIN	Y	Y	4.7		0.1		
AENSLF	34361	ENDOSULFAN A	Y	Y	9.2		0.05		
BENSLF	34356	ENDOSULFAN B	Y	Y	9.2		0.1		
ESFSO4	34351	ENDOSULFAN SULFATE	Y	Y	9.2		0.1		
ENDRIN	39390	ENDRIN	Y	Y	7.6		0.1		
HPCL	39410	HEPTACHLOR	Y	Y	2		0.05		
HPCLE	39420	HEPTACHLOR EPOXIDE	Y	Y	5		0.05		
GBHC	34340	BHC, G (LINDANE)	Y	Y	4		0.05		
PCB016	34671	PCB-1016	Y	Y	21		0.5		
PCB221	39488	PCB-1221	Y	Y	21		0.5		
PCB232	39492	PCB-1232	Y	Y	21		0.5		
PCB242	39496	PCB-1242	Y	Y	30		0.5		
PCB248	39500	PCB-1248	Y	Y	30		0.5		
PCB254	39504	PCB-1254	Y	Y	36		1		
PCB260	39508	PCB-1260	Y	Y	36		1		
TXPHEN	39400	TOXAPHENE	Y	Y	36		1		
BENZID	39120	BENZIDINE	Y	N	10				
ENDRN	34366	ENDRIN ALDEHYDE	Y	N	8				
NNDME	34438	N-NITROSODIMETHYLAMINE	Y	N	2				
KEND	78008	ENDRIN KETONE	N	Y	8		0.1		
12DPH	34346	1,2-DIPHENYL HYDRAZINE	Y	N	2				

Note: All units are in ug/l.

TABLE 7-2 (cont'd)

SHORT			PRIORITY	HAZARDOUS		USATHAMA	CLP		
NAME	STORET	LONG NAME	POLL	SUBST. LIST	CRL	UCL	CRDL	PQL	HBN
SB	(200.7)	ANTIMONY	Y	Y	38	6000	60	30	10
BA		BARIUM	N	Y	5	10000	200	20	1000
BE		BERYLLIUM	Y	Y	5	1000	5	3	0.007
CD		CADMIUM	Y	Y	4	5000	5	1	10
CR		CHROMIUM	Y	Y	6	50000	10	10	50
NI		NICKEL	Y	Y	34.3	12500	40	50	700
PB	SD20 (239.2)	LEAD	Y	Y	1.26	100	5	10	50
AG	SD23 (272.2)	SILVER	Y	Y	0.25	10	10	2	50
AS	SD22 (206.2)	ARSENIC	Y	Y	2.54	100	10	10	500
SE	SD21 (270.2)	SELENIUM	Y	Y	3.02	100	5	20	10
HG	SB01 (245.1)	MERCURY	N	Y	0.234	10	0.2	2	2
METHOD UW14 (609); NITROAROMATICS (EXPLOSIVES) IN WATER BY HPLC									
HMX		CYCLOTETRAMETHYLENETETRANITRAMINE			1.65	28.9			
RDX		CYCLONITE			2.11	43.9			
TETRYL		NITRAMINE			0.556	44.5			
246TNT		2,4,6-TRINITROTOLUENE			0.588	40.2			
26DNT		2,6-DINITROTOLUENE			1.15	52.4			
24DNT		2,4-DINITROTOLUENE			0.612	40.2			
CLASSICAL CHEMISTRY									
TOC	(415.2)	TOTAL ORGANIC CARBON	N	N	1 mg/L				
TOX	(9020)	TOTAL ORGANIC HALOGENS	N	N	5 ug/L				
TSS	(160.2)	TOTAL SUSPENDED SOLIDS	N	N	2 mg/L				
TDS	(160.1)	TOTAL DISSOLVED SOLIDS	N	N	5 mg/L				
COD	(410.4)	CHEMICAL OXYGEN DEMAND	N	N	20 mg/L				

CRL: CERTIFIED REPORTING LIMIT
UCL: UPPER CERTIFIED LIMIT
CRDL: CLP CONTACT REQUIRED DETECTION LIMIT
PQL: PRACTICAL QUANTITATION LIMIT
HBN: HEALTH BASE NUMBER
CLP: CONTACT LABORATORY PROGRAM

SYNONYMS

p-CHLOROANALINE = 4-CHLOROANALINE
p-CHLORO-m-CRESOL = 3-METHYL-4-CHLOROPHENOL
m-CRESOL = 3-METHYLPHENOL
o-CRESOL = 2-METHYLPHENOL
p-CRESOL = 4-METHYLPHENOL
o-DICHLORBENZENE = 1,2-DICHLOROBENZENE
m-DICHLORBENZENE = 1,3-DICHLOROBENZENE
p-DICHLORBENZENE = 1,4-DICHLOROBENZENE
4,6-DINITRO-o-CRESOL = 2-METHYL-4,6-DINITROPHENOL
2-NITROANALINE AVAILABLE USING CLP METHOD
p-NITROANALINE = 4-NITROANALINE
p-NITROPHENOL = 4-NITROPHENOL

Note: All units are in ug/l.

TABLE 7.2. (cont'd)

PROPOSED RFI ANALYTICAL PROGRAM FOR SOILS

METHOD LM19 (8240); VOLATILE ORGANICS IN SOIL BY GC/MS FOR BOTH PRIORITY POLLUTANTS AND HAZARDOUS SUBSTANCE LIST COMPOUNDS (a)

SHORT NAME	STORET	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	USATHAMA		CLP CRDL	PQL	HBN
					CRL	UCL			
					UNITS ARE IN UG/KG				
111TCE	98692	1,1,1-TRICHLOROETHANE	Y	Y	4.4	200	5	5	1E+6
112TCE	98693	1,1,2-TRICHLOROETHANE	Y	Y	5.4	200	5	5	1E+5
11DCE	98789	1,1-DICHLOROETHENE	Y	Y	3.9	100	5	5	1E+4
11DCLE	98683	1,1-DICHLOROETHANE	Y	Y	2.3	200	5	5	8000
12DCE	97721	1,2-DICHLOROETHENE			3	100	5		
12DCLE	98684	1,2-DICHLOROETHANE	Y	Y	1.7	200	5	5	8000
12DCLP	98790	1,2-DICHLOROPROPANE	Y	Y	2.9	200	5		
ACET	97020	ACETONE	N	Y	17	100	10	100	1E+6
BRDCL	98783	BROMODICHLOROMETHANE	Y	Y	2.9	200	5	5	1E+6
C13DCP	98791	CIS-1,3-DICHLOROPROPENE	Y	Y	3.2	248	5	10	4000
C2AVE	97723	VINYL ACETATE	N	Y	3.2	100	10		
C2H3CL	98795	VINYL CHLORIDE	Y	Y	6.2	200	10	10	300
C2H5CL	98786	CHLOROETHANE	Y	Y	12	200	10	10	——
C6H6	98699	BENZENE	Y	Y	1.5	200	5	5	2E+4
CCL3F	98794	TRICHLOROFLUOROMETHANE	Y	N	5.9	100		5	1E+6
CCL4	98680	CARBON TETRACHLORIDE	Y	Y	7	200	5	5	5E+4
CH2CL2	98689	METHYLENE CHLORIDE	Y	Y	12	200	5	5	9E+4
CH3BR	98785	BROMOMETHANE	Y	Y	5.7	200	10	10	1E+5
CH3CL	98787	CHLOROMETHANE	Y	Y	8.8	100	10	10	5E+5
CHBR3	98784	BROMOFORM	Y	Y	6.9	200	5	5	1E+6
CHCL3	98682	CHLOROFORM	Y	Y	0.87	200	5	5	1E+5
CLC6H5	98681	CHLOROBENZENE	Y	Y	0.86	200	5	5	3E+4
CS2	97472	CARBON DISULFIDE	N	Y	4.4	100	5	5	1E+6
		DICHLORODIFLUOROMETHANE (c)						5	1E+6
DBRCL	98788	DIBROMOCHLOROMETHANE	N	Y	3.1	200	5		
ETC6H5	98688	ETHYLBENZENE	Y	Y	1.7	200	5	5	1E+6
MEC6H5	98691	TOLUENE	Y	Y	0.78	200	5	5	1E+6
MEK	98801	METHYL ETHYL KETONE	N	Y	70	200	10	100	1E+6
MIBK	98696	METHYL ISOBUTYL KETONE	N	Y	27	100	10	100	1E+6
MNBK	97722	METHYL-N-BUTYL KETONE	N	Y	32	100	10		
STYR	97734	STYRENE	N	Y	2.6	200	5		
		TRANS-1,2-DICHLOROETHYLENE (b)						5	1E+6
T13DCP	98792	TRANS-1,3-DICHLOROPROPENE	N	Y	2.8	152	5	10	4000
		1,1,1,2-TETRACHLOROETHANE (d)						0.1	3E+5
TCLEA	98793	1,1,2,2-TETRACHLOROETHANE	Y	Y	2.4	200	5	5	4E+4
TCLEE	98690	TETRACHLOROETHENE	Y	Y	0.81	200	5	5	1E+5
TRCLE	98694	TRICHLOROETHENE	Y	Y	2.8	200	5	5	6E+4
XYLEN	97724	XYLENE	N	Y	1.5	200	5	5	1E+6
NONCERTIFIED ANALYTES									
CL2BC	98803	DICHLOROBENZENE (TOTAL)							
ACROL	97028	ACROLEIN						5	1E+6
ACRYLO	97029	ACRYLONITRILE						5	1000
2CLEVE	98796	2-CHLOROETHYLVINYL ETHER							

Note: All units are in microgram/kilogram (ug/kg).

TABLE 7-2 (cont'd)

METHOD LM18 (8270); EXTRACTABLE ORGANICS (BNAs) IN SOIL BY GC/MS FOR BOTH PRIORITY POLLUTANTS AND HAZARDOUS SUBSTANCE LIST COMPOUNDS

SHORT NAME	STORET	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	USATHAMA		CLP CRDL	PQL	HBN
					CRL	UCL			
					UNITS ARE IN UG/G				
124TCB	99492	1,2,4-TRICHLOROBENZENE	Y	Y	0.04	13	0.3	0.01	1000
12DCLB	99470	1,2-DICHLOROBENZENE	Y	Y	0.11	13	0.3	0.01	1000
13DCLB	99472	1,3-DICHLOROBENZENE	Y	Y	0.13	13	0.3	0.005	1000
14DCLB	99469	1,4-DICHLOROBENZENE	Y	Y	0.098	13	0.3	0.005	400
245TCP	97732	2,4,5-TRICHLOROPHENOL	N	Y	0.10	13	2	2	1000
24DCLP	99498	2,4-DICHLOROPHENOL	Y	Y	0.18	13	0.3	0.3	200
24DMPN	99499	2,4-DIMETHYLPHENOL	Y	Y	0.69	1.3	0.3	0.3	400
24DNP	99495	2,4-DINITROPHENOL	Y	Y	2.1	6.7	2	2	200
24DNT	99474	2,4-DINITROTOLUENE	Y	Y	0.14	13	0.3	0.3	1
2CLP	99497	2-CHLOROPHENOL	Y	Y	0.06	13	0.3	0.3	400
2CNAP	99464	2-CHLORONAPHTHALENE	Y	Y	0.036	13	0.3	0.3	—
2MNAP	97733	2-METHYLNAPHTHLENE	N	Y	0.049	6.7	0.3		
2MP	97461	2-METHYLPHENOL	N	Y	0.029	1.3	0.3	0.3	1000
2NANIL	97728	2-NITROANILINE	N	Y	0.062	13	2		
2NP	99495	2-NITROPHENOL	Y	Y	0.14	13	0.3		
33DCBD	99471	3,3-DICHLOROBENZIDINE	Y	Y	6.3	13	0.7	1	2
		3-METHYLPHENOL (e)						0.3	1000
3NANIL	9772	3-NITROANILINE	N	Y	0.45	13	2		
46DN2C	99686	2-METHYL-4,6-DINITROPHENOL	Y	Y	0.55	13	2	5	80
4BRPPE	99462	4-BROMOPHENYLPHENYL ETHER	Y	Y	0.033	6.7	0.3	0.3	—
4CL3C	99683	3-METHYL-4-CHLOROPHENOL	Y	Y	0.095	13	0.3	0.3	1000
4CLPPE	99465	4-CHLOROPHENYLPHENYL ETHER	Y	Y	0.033	13	0.3		
4MP	97460	4-METHYLPHENOL	N	Y	0.24	1.3	0.3	0.3	1000
4NANIL	97730	4-NITROANALINE	N	Y	0.41	13	2	1	—
4NP	99496	4-NITROPHENOL	Y	Y	1.4	33	2	3	—
ANAPNE	99450	ACENAPHTHENE	Y	Y	0.036	13	0.3		
ANAPYL	99451	ACENAPHTHYLENE	Y	Y	0.033	6.7	0.3		
ANTRC	99452	ANTHRACENE	Y	Y	0.033	13	0.3	0.1	40
B2CEXM	99459	BIS(2-CHLOROETHOXY) METHANE	Y	Y	0.059	13	0.3	0.3	—
B2CIPE	99461	BIS(2-CHLOROISOPROPYL) ETHER	Y	Y	0.2	13	0.3	0.3	90
B2CLEE	99458	BIS(2-CHLOROETHYL) ETHER	Y	Y	0.033	6.7	0.3	0.3	0.06
B2EHP	99460	BIS(2-EHTYLHEXYL) PHTHALATE	Y	Y	0.62	13	0.3	0.3	50
BAANTR	99453	BENZO [A] ANTHRACENE	Y	Y	0.17	13	0.3	0.009	0.2
BAPYR	99456	BENZO [A] PYRENE	Y	Y	0.25	13	0.3	0.02	0.06
BBFANT	99454	BENZO [B] FLUORANTHENE	Y	Y	0.21	3.3	0.3	0.02	0.4
BBZP	99463	BUTYLBENZYL PHTHALATE	Y	Y	0.17	6.7	0.3	0.3	3000
BENZOA		BENZOIC ACID	N	Y			2		
BGHIPY	99691	BENZO [G,H,I] PERYLENE	Y	Y	0.25	3.3	0.3		
BKFANT	99454	BENZO [K] FLUORANTHENE	Y	Y	0.066	0.67	0.3	0.02	80
BZALC	97731	BENZYL ALCOHOL	N	Y	0.19	1	0.3		
CHRY	99690	CHRYSENE	Y	Y	0.12	36.7	0.3	0.02	4
CL6BZ	99478	HEXACHLOROBENZENE	Y	Y	0.033	6.7	0.3	0.03	0.4
CL6CP	98647	HEXACHLOROCYCLOPENTADIENE	Y	Y	6.2	13	0.3	0.3	600
CL6ET	99480	HEXACHLOROETHANE	Y	Y	0.15	13	0.3	0.3	80
DBAHA	99466	DIBENZ [A,H] ANTHRACENE	Y	Y	0.21	13	0.3	0.02	0.01
DBZFUR	97727	DIBENZOFURAN	N	Y	0.035	6.7	0.3		
DEP	99472	DIETHYL PHTHALATE	Y	Y	0.24	6.7	0.3	0.3	1000
DMP	99473	DIMETHYL PHTHALATE	Y	Y	0.17	13	0.3	0.3	1000
DNBP	99467	DI-N-BUTYL PHTHALATE	Y	Y	0.061	3.3	0.3	0.3	3000
FANT	99689	FLUORANTHENE	Y	Y	0.068	13	0.3	0.3	500
FLRENE	99692	FLUORENE	Y	Y	0.033	13	0.3		
HCBD	99479	HEXACHLOROBUTADIENE	Y	Y	0.23	13	0.3	0.005	90
ICDPYR	99482	INDENO [1,2,3-CD] PYRENE	Y	Y	0.29	13	0.3	0.03	40

Note: All units are in microgram/gram (ug/g).

TABLE 7-2 (cont'd)

SHORT NAME	STORET	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	CRL	USATHAMA UCL	CLP CRDL	PQL	HBN
ISOPHR	99483	ISOPHORONE	Y	Y	0.033	13	0.3		
NAP	99696	NAPHTHALENE	Y	Y	0.037	3.3	0.3	0.005	1000
NB	99485	NITROBENZENE	Y	Y	0.045	13	0.3	0.3	40
NNDNP	99487	N-NITROSO, DI-N-PROPYLAMINE	Y	Y	0.2	13	0.3	0.3	0.1
NNDPA	99488	N-NITROSODIPHENYLAMINE	Y	Y	0.19	13	0.3	0.3	100
PCP	99682	PENTACHLOROPHENOL	Y	Y	1.3	6.7	2	2	1000
PHANTR	99489	PHENANTHRENE	Y	Y	0.033	13	0.3	0.5	40
PHENO	99685	PHENOL	Y	Y	0.11	3.3	0.3	0.3	1000
PYR	99490	PYRENE	Y	Y	0.033	3.3	0.3	0.3	1000
246TCP	99684	2,4,6–TRICHLOROPHENOL	Y	Y	0.17	13	0.3	0.6	40
26DNT	9947	2,6–DINITROTOLUENE	Y	Y	0.085	13	0.3	0.3	—
4CANIL	99726	4–CHLOROANALINE	N	Y	0.81	3.3	0.3	0.3	300
DNOP	99476	DI-N–OCTYL PHTHALATE	Y	Y	0.19	6.7	0.3	0.3	—
NONCERTIFIED ANALYTES									
MEXCL	97569	METHOXYCHLOR	N	Y	0.33		5		
CLDANA	97767	CHLORDANE, ALPHA	Y	Y	0.33		5		
CLDAN	97768	CHLORDANE, GAMMA	Y	Y	0.33		5		
ALDRN	98356	ALDRIN	Y	Y	0.33		0.5		
ABHC	98357	BHC, A	Y	Y	0.27		0.5		
BBHC	98358	BHC, B	Y	Y	0.27		0.5		
DBHC	98359	BHC, D	Y	Y	0.27		0.5		
PPDDD	98362	DDD, PP	Y	Y	0.3		1		
PPDDE	98363	DDE, PP	Y	Y	0.31		1		
PPDDT	98364	DDT, PP	Y	Y	0.31		1		
DLDRN	98365	DDIELDRIN	Y	Y	0.31		1		
AENSLF	98366	ENDOSULFAN A	Y	Y	0.62		0.5		
BENSLF	98367	ENDOSULFAN B	Y	Y	0.62		1		
ESFSO4	98368	ENDOSULFAN SULFATE	Y	Y	0.62		1		
ENDRIN	98369	ENDRIN	Y	Y	0.45		1		
HPCL	98371	HEPTACHLOR	Y	Y	0.13		0.5		
HPCLE	98372	HEPTACHLOR EPOXIDE	Y	Y	0.33		0.5		
GBHC	98360	BHC, G (LINDANE)	Y	Y	0.27		0.5		
PCB016	98140	PCB–1016	Y	Y	1.4		5		
PCB221	98351	PCB–1221	Y	Y	1.4		5		
PCB232	98352	PCB–1232	Y	Y	1.4		5		
PCB242	98353	PCB–1242	Y	Y	1.4		5		
PCB248	98436	PCB–1248	Y	Y	2.0		5		
PCB254	98354	PCB–1254	Y	Y	2.3		10		
PCB260	98139	PCB–1260	Y	Y	2.6		10		
TXPHEN	98373	TOXAPHENE	Y	Y	2.6		10		
BENZID	99457	BENZIDINE	Y	N	0.85				
ENDRN	98370	ENDRIN ALDEHYDE	Y	N	0.53				
NNDME	99486	N-NITROSODIMETHYLAMINE	Y	N	0.14				
KEND	97720	ENDRIN KETONE	N	Y	0.53		1		
12DPH	99477	1,2-DIPHENYL HYDRAZINE	Y	N	0.14				

Note: All units are in ug/g.

TABLE 7-2 (cont'd)

METALS IN SOIL

SHORT			PRIORITY	HAZARDOUS	USATHAMA		CLP		
NAME	METHOD	LONG NAME	POLL.	SUBST. LIST	CRL	UCL	CRDL	PQL	HBN
					UNITS ARE IN UG/G				
SB	JS11	ANTIMONY	Y	Y	3.8	5000	12	20	30
BA	(6010)	BARIUM	N	Y	29.6	200	40	1	1000
BE		BERYLLIUM	Y	Y	1.86	20	1	0.2	0.1
CD		CADMIUM	Y	Y	3.05	20	1	2	40
CR		CHROMIUM	Y	Y	12.7	5000	2	4	400
NI		NICKEL	Y	Y	12.6	5000	8	3	1000
TL		THALLIUM	Y	Y	31.3	5000	2	20	6
PB	JD17 (7421)	LEAD	Y	Y	0.177	10	1	2	—
AG	JD18 (7761)	SILVER	Y	Y	0.025	1	2	4	200
AS	JD19 (7060)	ARSENIC	Y	Y	0.25	10	2	30	0.5
SE	JD15 (7740)	SELENIUM	Y	Y	0.25	10	1	40	200
HG	JB01 (7471)	MERCURY	N	Y	0.05	1	0.04	0.1	20

TCLP METALS

BA	SS10	BARIUM	N	Y	5	10000	200	20	1000
CD	(200.7)	CADMIUM	Y	Y	4	5000	5	1	10
CR		CHROMIUM	Y	Y	6	50000	10	10	50
PB	SD20 (239.2)	LEAD	Y	Y	1.26	100	5	10	50
AG	SD23 (272.2)	SILVER	Y	Y	0.25	10	10	2	50
AS	SD22 (206.2)	ARSENIC	Y	Y	2.54	100	10	10	500
SE	SD21 (270.2)	SELENIUM	Y	Y	3.02	100	5	20	10
HG	SB01 (245.1)	MERCURY	N	Y	0.234	10	0.2	2	2

Note: Units for metals are in ug/g and for TCLP metals leachate test are in ug/l.

TABLE 7-2 (cont'd)

METHOD LW12 (8090): NITROAROMATICS (EXPLOSIVES) IN SOIL BY HPLC

SHORT NAME	LONG NAME	PRIORITY POLL.	HAZARDOUS SUBST. LIST	USATHAMA CRL	USATHAMA UCL	CLP CRDL	PQL	HBN
				UNITS ARE IN UG/G				
24DNT	2,4-DINITROTOLUENE			0.424	21.2	0.938		
26DNT	2,6-DINITROTOLUENE			0.524	26.2	0.977		
HMX	CYCLOTETRAMETHYLENETETRANITRAMINE			0.666	33.3	1.000		
RDX	CYCLONITE			0.587	21.9	0.929		
TETRYL	NITRAMINE			0.731	20.2	1.130		
246TNT	2,4,6-TRINITROTOLUENE			0.456	22.8	1.010		

CLASSICAL CHEMISTRY

TRPH	(9771)	TOTAL PETROLEUM HYDROCARBONS	1
CEC	(f)	CATION EXCHANGE CAPACITY	

CRL: CERTIFIED REPORTING LIMIT
UCL: UPPER CERTIFIED LIMIT
CRDL: CLP CERTITFIED REPORTING DETECTION LIMIT
PQL: PRACTICAL QUANTITATION LIMIT
HBN: HEALTH BASE NUMBER

SYNONYMS

p-CHLOROANALINE = 4-CHLOROANALINE
p-CHLORO-m-CRESOL = 3-METHYL-4-CHLOROPHENOL
m-CRESOL = 3-METHYLPHENOL
o-CRESOL = 2-METHYLPHENOL
p-CRESOL = 4-METHYLPHENOL
o-DICHLORBENZENE = 1,2-DICHLOROBENZENE
m-DICHLORBENZENE = 1,3-DICHLOROBENZENE
p-DICHLORBENZENE = 1,4-DICHLOROBENZENE
4,6-DINITRO-o-CRESOL = 2-METHYL-4,6-DINITROPHENOL
2-NITROANALINE AVAILABLE USING CLP METHOD
p-NITROANALINE = 4-NITROANALINE
p-NITROPHENOL = 4-NITROPHENOL

(a) Non-target compounds are searched
(b) TRANS-1,2-DICHLOROETHYLENE difficult to separate from 1,2-DICHLOROETHENE; method capabilities under review
(c) Method capabilities under review; complete information to be provided
(d) 1,1,1,2 TETRACHLOROETHANE difficult to separate from 1,1,2,2 TETRACHLOROETHANE; method capabilities under review
(e) 3-METHYLPHENOL difficult to separate from 4-METHYLPHENOL; method capabilities under review
(f) Specific method to be determined.

Note: All units are in ug/g.

TABLE 7-3

Methods Comparison for Organic Compounds

Sample Preparation

- BNA in water--In the extraction by USATHAMA certified method UM18, the base fraction is combined with the acid fraction extract before passing through the drying column, and both fractions are concentrated in the same K-d. This should improve the detection limit sensitivity.

- BNA in soil--The EPA-Contract Laboratory Program (CLP) method uses the sonication technique for soil extraction. USATHAMA certified method LM18 prepares BNAs using the continuous sohxlet extraction technique. The techniques are basically equivalent. The continuous (16 to 24 hour) sohxlet extraction is possibly more efficient than a 1- to 2-minute sonication.

- VOA in water and soil--USATHAMA certified methods UM20 and LM19 follow equivalent sample preparation procedures as EPA-CLP methods. Method LM19 is the low-level heated purge and trap method using up to 5 grams of soil.

Detection Limits

Tables in Appendix A.2 to the QAPP (Part E) compare USATHAMA CRLs and EPA-CLP reporting limits.

Analysis Comparison

- EPA-CLP requires instrument tuning with DFTPP or BFB every 12 hours. (No end run standard is required; therefore, if an analytical run is less than 12 hours, no calibration confirmation is required.) USATHAMA requires tuning with DFTPP or BFB every 24 hours, and an end-of-run calibration standard is required. Analytical runs cannot be longer than 24 hours. It is believed that the USATHAMA requirement is more stringent and controls data quality better than the CLP requirement.

- EPA-CLP controls on Continuing Calibration Check (CCC) compounds, which are run at the beginning of a batch, and the 12-hour standards (if the run is longer than 12 hours). Current criteria are ±25 percent difference from initial calibration compared to the average response factors. USATHAMA also controls on the beginning CCC with a ±25 percent difference from initial calibration, but compares to the response factor from the midpoint. Both EPA-CLP and USATHAMA require initial calibrations at five concentration levels with ±30 percent RSD.

TABLE 7-4

USATHAMA and EPA Methods Comparison for Inorganic Analytes

Sample Preparation

- Graphite furnace/atomic absorption (GFAA) water--same as CLP.
- Inductively coupled plasma (ICP) water--same as CLP.
- GFAA soil--same as CLP with one exception; the digestate's final volume is 100 mLs. CLP digestates have a final volume of 200 mLs.
- ICP soil--same as CLP with one exception; the digestate's final volume is 100 mLs. CLP digestates have a final volume of 200 mLs.
- Mercury water--same as CLP.
- Mercury soil--same as CLP with one exception; CLP uses 0.2 g, while USATHAMA requires 1 g.
- Cyanide--same as CLP with one exception; CLP requires 1 to 5 g, while USATHAMA requires 10 g.
- Other inorganic methods certified or used by USATHAMA such as phenols, COD, TOC, TOX, TP, CrIV, etc., follow expected EPA methods.

Detection Limits

Tables in Appendix A.2 of the QAPP (Part 2) present comparisons of reporting limits.

Analysis Comparison

CLP requires matrix spike and matrix duplicates and quarterly detection limit studies to evaluate method performance. USATHAMA requires method certification and daily control spikes to evaluate method performance and validity of certification. Daily control spikes and QC charting include a single low level (two times the CRL) control spike and replicate high level (80 percent of upper certified range). Therefore, matrix spikes are not required except when requested as additional samples to evaluate the applicability of the matrix to the certified method.

7.3 QUALITY ASSURANCE/QUALITY CONTROL

7.3.1 Objectives

The prime objective of the QA/QC program is to ensure the reliability and compatibility of all data generated during the VI at RAAP. The QA/QC program will be coordinated by the Project Manager in conjunction with the Field Activities Group Leader. The organizational structure and relationship between these two components are shown in Figure E-1 of the QAPP (Part E).

Chemical analysis of all environmental samples collected at RAAP will be performed by ESE, under a subcontract to Dames & Moore. A laboratory QA/QC plan has been submitted to USATHAMA to ensure that the quality of new data is compatible with the data generated under other environmental programs conducted by or for USATHAMA. The project QA/QC program will meet or exceed the requirements for QA as described in USATHAMA's Quality Assurance Program (USATHAMA, 1990).

7.3.2 Implementation

The organization team for the VI sampling/analytical program at RAAP includes the following components (as diagrammed in Figure E-1 of this Work Plan):

- USATHAMA Project Officer--The contractor project management will work through the USATHAMA ACO in all matters that require USATHAMA assistance. All documentation of precertification calibration, certification, daily QC, etc., will be supplied to the Project Officer by the laboratory. Decisions made at the laboratory requiring approval from USATHAMA will be cleared through the Project Officer before implementation. Requests for standard analytical reference materials from the Central QA Laboratory will be relayed through the Project Officer.

- Project Manager, Prime Contractor (Dames & Moore)--The contract laboratory (ESE) will work closely with the Project Manager from Dames & Moore to coordinate sample lot sizes, sample collection, sample preservation, and chain-of-custody procedures. The interface between the contractors will be continued through the analysis and data management phases of the work. Scheduled meetings between the project personnel, site visits by the laboratory quality assurance coordinator (QAC), and telephone communication as necessary will ensure the coordination of all contracting efforts.

- Laboratory Project Manager--The ESE Project Manager will serve as the laboratory analytical task manager for the VI tasks. As such, he will submit all method certifications to the specified project team members in a timely fashion. He will oversee the utilization of laboratory facilities and personnel to conduct the analyses, and ensure that schedules are set to implement the USATHAMA QA Program as required. He will also ensure that corrective action is taken when it is recommended by the laboratory QAC.

- Contractor QAC--The laboratory QAC at ESE is responsible only to the vice president/office manager of the Gainesville, Florida, office. This position in the organization does not make the QAC responsible to or for any of the laboratory personnel involved in sampling or analysis. As such, the QAC acts as an independent auditor of the laboratory, responsible for decisions regarding actions to correct out-of-control situations. In all cases, the QAC will ensure that the sampling, analysis, and documentation do not jeopardize the integrity of the VI/RFI analytical data and conform with the scope of work and QA Plan required by USATHAMA.

- Laboratory Data Management Team--The data management team is supervised by the laboratory project management team and consists of an automatic data processing manager, a data program coordinator, and data entry clerks. The data management team is charged with the responsibility of providing reports and control charts using the USATHAMA statistical analysis program. Expeditious production of these data summaries is required by the analysts and the laboratory QAC to allow rapid review by project management, enabling them to take corrective action without compromising sample holding times. The data management group will also assist the laboratory QAC in maintaining all written and printed records in a retrievable fashion.

The project team realizes the importance of maintaining frequent contact with USATHAMA to discuss problems and proposed solutions. This allows USATHAMA the opportunity to provide insight regarding the overall program objectives and requirements that may influence the problem solution. In addition, the project team understands the importance of including QC in all parts of the project.

Calibration procedures and checks, standards preparation, internal quality control checks, sample preparation, and analytical accuracy and precision are discussed in detail in Appendix A of the QAPP (Part E of this Work Plan).

8.0 DATA MANAGEMENT AND REPORTING

8.1 OBJECTIVES

Data management is a key element of this VI program. Effective data management will ensure the orderly transfer of data collected in the field and analyzed in the laboratory, the permanent repositing of that data, and the retrieval of data for analyses and interpretation. The objectives of the data management program for the VI are to provide the following services:

- Data capture and data validation (quality control).
- Data entry to Level 1 files (i.e., files initially created by Dames & Moore or subcontractor) using the Installation Restoration Data Management System (IRDMS) personal computer (PC) chemical and geotechnical acceptance routines to ensure error-free data.
- Transmission of the Level 1 data to the PC host through the IRDMS network for repeated and additional acceptance routines leading to eventual incorporation in the Level 3 IRDMS Ingres data base on the USATHAMA Unisys 5000/95 minicomputer.
- Data retrieval from Level 3 and analysis of the data, for purposes such as assisting technical analyses, presenting data in reports, and assisting in QA/QC.

These objectives will be met through a formal data management program, using IBM PC-AT compatible microcomputers, IRDMS PC software, communications software and hardware, and procedures consistent with the USATHAMA IRDMS.

8.2 DATA MANAGEMENT

Overall data management will be directed by Dames & Moore. However, data activities for the VI will be divided between Dames & Moore and ESE (the subcontractor laboratory). Each firm has the equipment needed to perform the required data management functions. Data processing responsibilities will be assigned in a systematic way. The laboratory will perform all data entry and manipulation operations associated with laboratory certification, analysis of raw analytical data, and provision of chemical analysis results by sampling location. These data will be transmitted to Dames & Moore for interpretation and manipulation during the data analysis phase of the study. Dames & Moore will also code and review geotechnical data (e.g., boring logs, well construction details, and site coordinates) for entry into USATHAMA's computer system. Thus, data obtained from the field will be coded by the person most directly responsible for obtaining them. Dames & Moore will have lead responsibility for producing maps and tables for interpretive and decisionmaking use, and for preparing output for use in reports. Sampling site IDs, media, and sample technique must be added to IRDMS before inputting chemical analysis results from environmental samples. Table C-1, Appendix C, provides information to be input to the system with the analytical results.

8.2.1 Data File System Organization

After initial keying, data files are stored on the microcomputer hard disk, with backups maintained on diskettes. The files are named descriptively, with the name and file extension reflecting the installation, the type of data they contain, and the particular set of data. Because the number of files is relatively small, the creation, checking, and transfer of files is tracked using a normal system of preprinted forms; consequently, the name and contents of a file containing specific data are always readily available. Files created on the microcomputer and transmitted to the IRDMS are designated by a three-letter abbreviation. Based on the VI field program, the following types of files will be created by Dames & Moore and ESE during the completion of the VI for RAAP:

- Dames & Moore:
  - GMA--map location coordinates for boring and sampling sites.
  - GFD--geotechnical field drilling, including boring log and well installation information.
  - GWC--geotechnical well construction data.
  - GGS--geotechnical groundwater stabilized (i.e., groundwater levels).

- ESE:
  - CGW--chemical groundwater data.
  - CSO--chemical soils data.
  - CSW--chemical surface water data.
  - CSE--chemical sediment data.
  - CQC--chemical quality control data.

Files are considered Level 2 files after they have been checked and transmitted from the IRDMS network to the central site processor. Level 2 files exist only until their information can be loaded into the corresponding installation Ingres data base, which is termed Level 3. Data retrievals for producing tables or plots will ordinarily be made from the Level 3 installation data base, using programs supplied by USATHAMA or developed by Dames & Moore. Data generated during the VI will be retrieved, evaluated, and included in the VI report.

8.2.2 Data Flow

Data flow through the system will begin with data generation in the field or laboratory. When necessary, data will be coded onto preprinted forms. Dames & Moore has developed forms for geotechnical data to speed and simplify data coding. Data keyed into the microcomputer are stored as disk files, each containing data of a single type. One type of data may be contained in multiple files; for example, data from 20 borings might be stored in four separate files that provide convenient units for data transmission and editing. After a file is created, it will be kept together as a unit for further processing. It will first be checked using USATHAMA-supplied programs on the microcomputer, and errors will be corrected. When a disk file is free of errors, it will be transmitted to the IRDMS network using 3+Remote network communications software. It will then be checked for errors a second time; if necessary, defective records will be corrected by Dames & Moore. Error-free files will be transmitted by IRDMS staff to the central site processor, where they will be loaded into the installation data base. Data in the installation data base may be tabulated, plotted, or analyzed for reports using USATHAMA programs.

Following transmittal of all chemical data files generated by ESE for RAAP, the laboratory will forward a diskette containing all transfer files to USATHAMA for confirmation and documentation of files previously transmitted. In addition, ESE will provide a hard copy printout of the chemical data to Dames & Moore for its review to ensure that data are complete and accurate with respect to the actual field program.

8.2.3 Problem Resolution

Problems likely to be encountered fall into four categories--equipment, data transmission, software, and coordination. Microcomputer equipment at Dames & Moore and the laboratory is under maintenance service contracts. Equipment malfunctions will be resolved with the service vendor. Data transmission problems will be documented by logging unsuccessful attempts to communicate with the IRDMS network. Recurring problems will be reported to the COR or USATHAMA support personnel. Some communications problems may be circumvented by transmitting at off-peak hours, using alternative long-distance services, or using a 300-baud instead of 1,200-baud communication rate. Problems with USATHAMA-supplied software will be reported to USATHAMA for resolution. Before doing so, Dames & Moore will attempt to reproduce the problem so that the exact circumstances under which it occurs can be described. USATHAMA will be supplied with copies of files being processed when the error occurred. Coordination problems between Dames & Moore and ESE will generally be resolved by direct communication among the data managers involved.

8.3 VI REPORT

8.3.1 SWMU Assessments

All data generated during the VI will be integrated with existing data to assess any releases of hazardous constituents from the SWMUs; to screen from further investigation those SWMUs that do not pose a threat to human health and the environment; and to determine the need for and extent of any RFIs. Data specific to each SWMU, as well as general environmental characterization data available from previous investigations, will be used in the SWMU assessments. The types and quantities of contaminants in and around each SWMU, and the transport mechanisms that are allowing or could allow contaminant migration, will be considered. The locations of suspected contaminant sources will be described and mapped. Contaminants detected during chemical analysis for all samples collected will be compared with the health-based numbers included in the permit to determine the need for and extent of any additional investigations.

Geotechnical data collected during the field investigation and previous studies will be presented and evaluated for the SWMU assessments. SWMU-specific hydrogeology will be described and presented on appropriate maps and cross-sections, where possible. Lithology/stratigraphy will be defined from the descriptions in the existing boring logs and the newly generated boring logs, and from monitoring well installations, geophysical survey results, examination of soil samples, and observations as recorded in the daily field logs. Correlations between borings will be demonstrated on cross-section diagrams, as appropriate. These diagrams will also show boring/well locations, aquifer locations, thickness, and the depth/location of piezometric surfaces derived from lithologic evaluation and records of first-encountered and static water levels.

Groundwater flow direction and velocity will be described, when required. Flow direction will be inferred from maps of groundwater and surface water elevations. Elevation data will be used to evaluate whether contaminants are likely to migrate by way of groundwater and surface water. Available slug test data from selected wells will be used to evaluate aquifer conditions. The evaluation will be presented in the form of maps showing predicted concentrations in groundwater, areas where contaminants may reach surface water, and offsite areas where groundwater and surface water may be affected by contaminants.

Any data gaps or anomalies will be identified, along with any circumstances that arose during the investigation that may have affected the accuracy or validity of the data. Recommendations will be made regarding any additional study effort that may be appropriate to fill data gaps.

Based on the results of the SWMU investigations, conclusions and recommendations will be presented for each SWMU. Recommendations may include, but are not limited to the following:

- No further action required, if the analytical results are below the levels identified in the permit, and those results, together with the physical and operating conditions of the SWMU, indicate no potential threat to human health or the environment.
- Continual monitoring, where analytical results are below the levels identified in the permit, but the presence of hazardous waste or hazardous constituents, together with the physical and operating conditions of the SWMU, indicate that a threat may exist in the future.
- Conduct of an RFI to characterize the rate and extent of releases from an SWMU or group of SWMUs, when the analytical results exceed the levels identified in the permit. An RFI is required if it is likely that a release of a hazardous constituent has occurred.
- Planning interim measures if releases of hazardous constituents are affecting or will affect target populations or sensitive environments.

8.3.2 Report Content and Format

The VI report will contain all data obtained during the investigation, organized in a logical sequence and presented in a technical format. It will include summaries of all findings, problems encountered during the investigation and actions taken to correct those problems, laboratory/monitoring data, well and boring logs, survey data, sampling locations, and identification of potential receptors. All sample locations will be identified on SWMU maps. The report will contain conclusions and recommendations based on the results of the investigation. The selected recommendation(s) for each SWMU will be adequately justified based on those results.

The exact format of the VI report will be determined during data management and reporting. A suggested format would include the following sections:

- Executive summary
- Environmental setting
- SWMU descriptions
- SWMU investigations and results
- Characterization of releases
- Potential receptors
- Evaluation of public health and environmental concerns
- SWMU assessments
- Conclusions and recommendations
- Appendices
  - Boring logs and well construction diagrams
  - Geophysical data
  - Physical testing data
  - Aquifer characterization data
  - Chemical analytical data.

In addition, the VI report will include acid and industrial sewer structural integrity reports according to the approved implementation schedule.

9.0 SCHEDULE FOR VI ACTIVITIES

The proposed schedule, shown in Figure 9-1, corresponds to the permit requirements established by USEPA. Recommended VI activities discussed in Sections 3.0 through 8.0 are identified. Because the VI and RFI activities for RAAP are being conducted simultaneously, the proposed schedule also identifies the proposed schedule for recommended RFI activities that are presented in a separate work plan. The estimated completion time shown for various activities identified in Figure 9-1 incorporates both the VI and RFI efforts.

The proposed schedule indicates that the VI/RFI Work Plans should be completed at the end of 1990, allowing for a regulatory review period of approximately 3-4 months for the final draft VI/RFI Work Plans.

Assuming that final work plan approval is granted by the beginning of 1991 and implementation of these plans is initiated immediately upon plan approval, the estimated completion date of the final draft VI report for regulatory review is December 1991. Allowing for regulatory review as indicated, the final VI report would likely be completed in early to mid-1992.

The VI report will identify additional data requirements, identify SWMUs requiring RFI studies and/or corrective action, and present a proposed schedule for recommended followup activities.

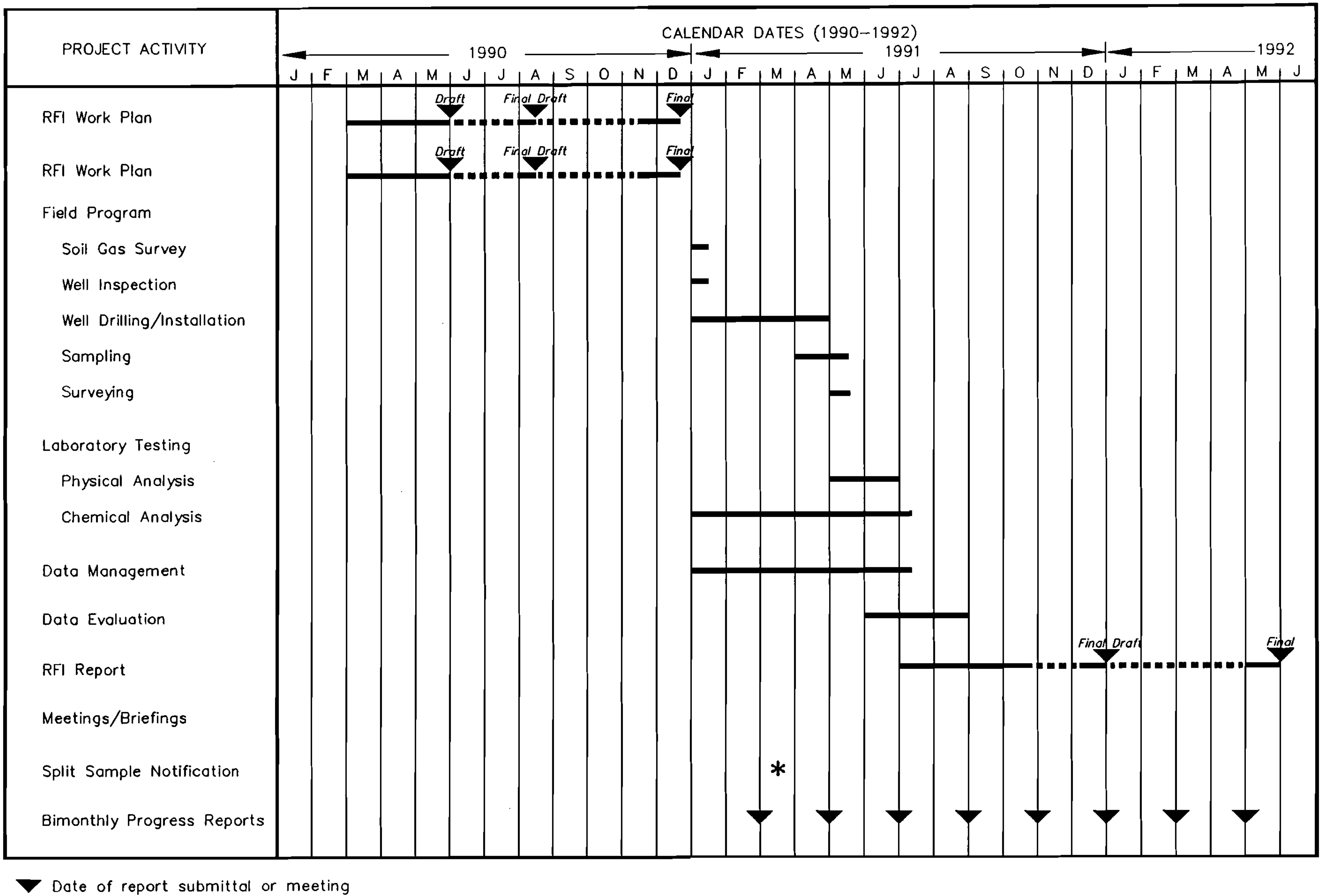

FIGURE 9–1
PROPOSED VI/RFI SCHEDULE
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Dames & Moore

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APPENDIX A: MONITORING WELL CONSTRUCTION DETAILS

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81
DATE 4 Apr 81
LOCATION Site 6, East of lagoon between 2nd road & Steam line (see map)
DRILLERS Smithson, Hoddinott Craig, Gates (logger)
DRILL RIG Acker II w/ 4 in continuous flight auger
BORE HOLE MW 13 (SWMU 6)

TD= 45 feet

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	water level initial 49 ft. 24 hr. 43' 10 " REMARKS	
		fill material for road		31.5 ft. schedule 40 2 in ID PVC casing
			29 ft of concrete grout	
5 ft				
		same material		
10 ft		Reddish brown silty clay, very plastic, damp.		
	MB 10-15			
15 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, east of lagoon between 2nd road & steam line (see map)

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight auger

BORE HOLE MW 13

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
		Easy drilling		
		same material	Concrete grout	PVC casing
20 ft				
25 ft		getting tighter	4 ft of Bentonite	
		same material, easy drilling clay is wetter-very plastic	28 ft of sand pack	
30 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, east of lagoon between 2nd road and steam line (see map)

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight auger

BORE HOLE MW 13

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
		gravel sound-- turnings from auger wet & sticky- near water table		
35 ft		same material	sand pack	12.5 ft of slotted schedule 40, 2 in ID PVC screen (0.008-0.010")
		Change in engine pitch- grinding thumping noise-may be Elbrook FM. Pulled Auger to investigate.		
40 ft		Elbrook Dolomite (last 5 ft of Auger very wet).		
	▼			
45 ft		TD 45 feet	Depth of well 45 feet	

NOTE: Well development loss of +400 gallons of water in 2 min. after pumpimg at 150 psi. Water level fluctuated very little.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, west of apex of lagoon

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II w/ 4 in continuous flight Auger

BORE HOLE MW 14 (SWMU 6)

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	TD= 45 ft water level-dry 48 hr.-dry , loss of fluid REMARKS	
		Red silty clay, very plastic, damp Drilling easy	12 ft of concrete grout	18 ft of schedule 40, 2 in ID PVC casing
		Small pea gravel in red silty clay		
5 ft				
		same material (very Plastic)		
	MB 5-10			
10 ft				
		clay very soft-easy drilling	2 ft of Bentonite	
15 ft			sand	

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, west of apex of Lagoon

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight auger

BORE HOLE MW 14

DEPTH	SAMPLE TYPE	DESCRIPTION	REMARKS	
	BLOWS PER 6 IN			
15				PVC casing
		same material		
			31 ft of sand pack	15 ft of slotted 2 in ID, schedule 40, PVC screen
20 ft				
		same material- getting wetter		
25 ft		Silty clay with gravel (¼-½ in)		
		water table close very easy drilling		
30 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81
DATE 4 April 81
LOCATION Site 6, west of apex of lagoon
DRILLERS Smithson, Hoddinott Craig, Gates (logger)
DRILL RIG Acker II, w/ 4 in continuous flight auger
BORE HOLE MW 14

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
		same material		slotted PVC screen
		wet clay has sealed water lenses		
				add 2 ft of sed trap
35 ft			sand pack	bottom of well 35 ft.
		no returns		
40 ft			sand pack	
		No Elbrook FM encountered,may be a sink hole.	During well development lost 200 gallons of fluid in less than 2 minutes. /there is a void at depth	
45 ft		TD 45 ft		

HSE-ES Form 78, 1 Jun 80

NOTE: fluid loss of 100 gallons water at 100 psi in 2 minutes.

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, next to southwest corner of bldg. 3019 (boiling tub house)

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II w/ 4 in continuous flight Auger

BORE HOLE MW 15 (SWMU 6)

TD=30 ft

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	water level initial=dry 24 hr= dry, loss of fluid REMARKS	
		Fill material red silty clay, saturated (sticky)	4'8" of concrete frout	9 ft of schedule 40, 2 in ID PVC casing
5 ft	MB 5-10		1'8" of Bentonite 22.7 ft of sand pack	
10 ft		same material		18.5 ft of slotted 2 in ID PVC screen (0.008-0.010")
15 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, next to southwest corner of bldg. 3019 (boiling tub house)

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG AckerII w/ 4 in continuous flight Auger

BORE HOLE MW 15

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS
		same material	
20 ft			sand pack
		same material-very sticky water table difficult to locate due to clay plastering the sides of the bore hole	
25 ft		It seems that we have been passing through small perched lenses of water	
		weathered Elbrook FM	2.5 ft of sed. trap
		drilling getting difficult (4700 psi) Refusal - Elbrook FM	
30 ft			Fall back

30 ft TD

NOTE: during well development lost 400 gallons of fluid in 2 min. under 250 psi. There is a void at depth.

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, south of lagoon & rail tracks or a hill next to Blg. 3003 (spent acid storage)

DRILLERS Smithson, Hoddinott, Craig, GAtes (logger)

DRILL RIG Acker II w/ 4 in continuous flight auger

BORE HOLE MW 16 (SWMU 6)

TD= 21 ft

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	water level initial= wet, no yield 24 hr.= dry, loss of fluid REMARKS	
		Red, silty micaceous clay, dry	1 ft of concrete grout	11 ft of schedule 40, 2 in ID PVC casing
			7 ft of Bentonite grout	
5 ft		Reddish brown micaceous sandy silt with ½-1" gravel		
			13 ft of sand pack	
10 ft		same material		
	MB 10-15	Getting more coarse		
		getting wetter		10 ft of screen
15 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 4 April 81

LOCATION Site 6, south of lagoon & RR or by a hill next to bldg. 3003

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II

BORE HOLE MW 16

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
		same material easy drilling	sand pack	Slotted 2 in ID schedule 40, PVC screen (0.008-0.010")
20 ft		Reddish brown/gold silty clay very wet, plastic, sticky		depth of well 21 ft
		Refusal—Elbrook Dolomite	TD 21 ft	
25 ft		NOTE: 300 lb of sand was placed in annular space, until it filled to 8 ft. A small cavern possibly exists at depth which was filled with sand pack.		
30 ft				

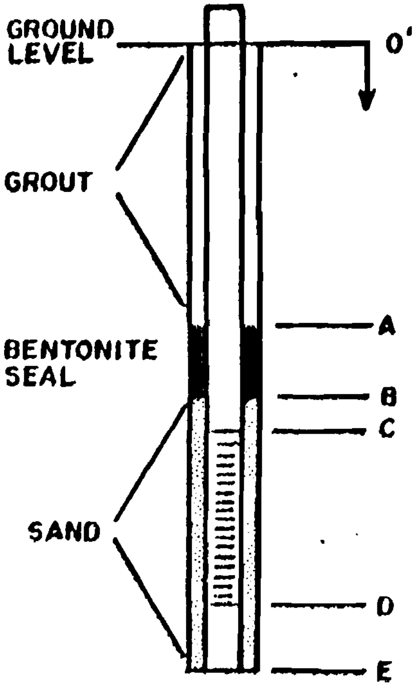
USAEHA Form 95, 12 Aug 74

Army Pollution Abatement Program
Study, Installation of Monitoring
Wells, Radford, VA
RADFORD ARMY AMMUNITION PLANT

US ARMY ENVIRONMENTAL HYGIENE AGENCY
GROUNDWATER MONITOR WELL SUMMARY

2/3

PROJECT 81-26-8251-81 **DATE** 3-9 Apr 81



A - TOP OF BENTONITE SEAL
B - TOP OF SAND
C - TOP OF WELL SCREEN
D - TOP OF SEDIMENT TRAP
E - TOTAL WELL DEPTH

WELL NO.	MW-8	MW-9	MW-10	MW-11	MW-12	MW-13	MW-14
A	8'	15.75'	2,5'	9,5'	10.5'	24'	12'
B	13'	17'	4'	13'	13'	28'	14'
C	29'	20'	7'	16'	14,5'	31,5'	18'
D	0'	30'	17	0	0	0	33'
E	34'	35'	20'	26'	19.5'	44'	35'
GROUT THICKNESS	8'	15.75'	2.5'	9,5'	10.5'	24'	12'
BENTONITE SEAL THICKNESS	5'	1.25'	1,5'	3.5'	2,5'	4'	2'
LENGTH OF PIPE	29'	20'	7'	16'	14,5'	31.5'	18'
LENGTH OF STANDPIPE	2'	2'	2'	2'	2'	2'	2'
LENGTH OF SCREEN	5'	10'	10'	10'	5'	12,5'	15'
LENGTH OF SEDIMENT TRAP	0	5'	3'	0	0	0	2'
SCREEN SLOT SIZE	0.008- 0.010 in --						0,008- 0,010 i
INITIAL WATER LEVEL	24'	22,25'	wet	22'	dry	44'	dry
24 HOUR WATER LEVEL	14.9'	23.5'	15'	23'	dry	44.8'	dry
GROUND LEVEL ELEVATION	*	*	*	*	*	*	*
REMARKS	Exact elevation and locations of wells will be determined by installation survey completed by RAAP personnel.						

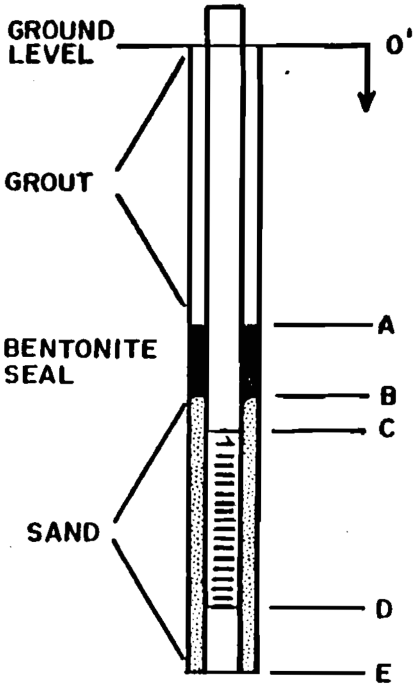
AEHA Form 93, 1 Aug 81 (HSF-FS)

Army Pollution Abatement Program
Study, Installation of Monitoring
Wells, Radford, VA
RADFORD ARMY AMMUNITION PLANT

US ARMY ENVIRONMENTAL HYGIENE AGENCY
GROUNDWATER MONITOR WELL SUMMARY

3/3

PROJECT 81-26-8251-81 **DATE** 3-9 Apr 81



A – TOP OF BENTONITE SEAL
B – TOP OF SAND
C – TOP OF WELL SCREEN
D – TOP OF SEDIMENT TRAP
E – TOTAL WELL DEPTH

WELL NO.	MW-15	MW-16					
A	4.7'	1'					
B	6.4'	8'					
C	9'	11'					
D	27.5'	0					
E	30'	21'					
GROUT THICKNESS	4.7'	1'					
BENTONITE SEAL THICKNESS	1.7'	7'					
LENGTH OF PIPE	9'	11'					
LENGTH OF STANDPIPE	2'	2'					
LENGTH OF SCREEN	18.5'	10'					
LENGTH OF SEDIMENT TRAP	2.5'	0					
SCREEN SLOT SIZE	0.008-0.010 in	0.008-0.010 in					
INITIAL WATER LEVEL	dry	dry					
24 HOUR WATER LEVEL	dry	dry					
GROUND LEVEL ELEVATION	*	*					
REMARKS	Exact location and elevations of wells will be determined by installation survey completed by RAAP personnel.						

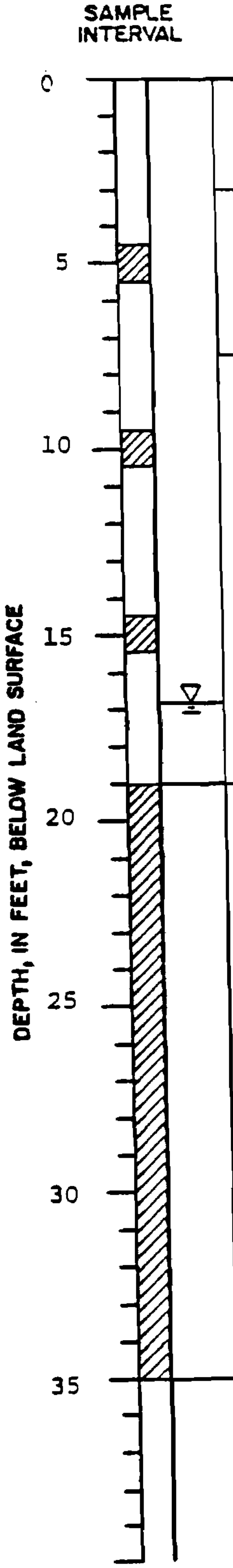
AEHA Form 93, 1 Aug 81 (HSE-ES)

Geraghty & Miller, Inc.

WELL LOG

PROJECT RADFORD
CLIENT NUS
Date Prepared 8/7/80 By G.F.S.

SAMPLE INTERVAL **DESCRIPTION**



Clay, silty, dark brown

Silt, clayey, dark brown

Sand, fine, silty, micaceous, brown

Sand grades to medium

Water Table
Change from 5" fishbit to 3"
NX core barrel
Top of Rock
Lost Circulation
Dolostone, calcite crystals and veins, gray

Same as above

Same as above

Bottom of Hole

OWNER Corps of Engineers
WELL No. D-3 (SWM 10)
LOCATION Lagoon D - Settling Ponds

TOPO SETTING
GROUND ELEV. 1699.97

DRILLING STARTED 8/7/80
DRILLING COMPLETED 8/7/80
DRILLER R. A. Monroe
TYPE OF RIG C-40

WELL DATA

HOLE DIAM. 5" to 19 ft; 3" to 35 ft
TOTAL DEPTH 35 ft
CASING DIAM. 2 in Timco PVC
CASING LENGTH 20 ft
SCREEN DIAM. 2 in
SCREEN SETTING 20-35 ft
SCREEN SLOT & TYPE .010 PVC
WELL STATUS Completed

GROUT

TYPE OF GROUT Neat cement
GROUT DEPTH 0-15 ft
VOLUME .6 cu ft
TYPE OF PLUG Bentonite
PLUG DEPTH 14-15 ft
VOLUME 1 lb

DEVELOPMENT

METHOD Air
RATE 0.25 gpm
LENGTH 25 min

TEST DATA

STATIC DEPTH TO WATER 16.74
DATE MEASURED 8/14/80
PUMPING DEPTH TO WATER
DURATION OF TEST
PUMPING RATE
DATE OF TEST
TYPE OF TEST
PUMP SETTING
SPECIFIC CAPACITY

FINAL PUMP CAPACITY
FINAL PUMP SETTING
AVERAGE PUMPAGE

WATER QUALITY

(SWMU 10) **Hole No.** DH-2

DRILLING LOG

DIVISION: NAD

INSTALLATION: NAO

SHEET 1 OF 1 SHEETS

1. PROJECT: RCRA STUDY - LAGOON D
2. LOCATION (Coordinates or Station): N 319,070 E1,407,780
3. DRILLING AGENCY: CUNNINGHAM CORE DRILLING
4. HOLE NO. (As shown on drawing title and file number): DH-2
5. NAME OF DRILLER: BOB MONROE
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 17.5
8. DEPTH DRILLED INTO ROCK: 12.5
9. TOTAL DEPTH OF HOLE: 30.0
10. SIZE AND TYPE OF BIT: 2" O.D. SS; NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SPRAGUE & HENWOOD 40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4 UNDISTURBED 1
14. TOTAL NUMBER CORE BOXES: 1
15. ELEVATION GROUND WATER: 1684.9
16. DATE HOLE: STARTED 16 JULY 80 COMPLETED 16 JULY 80
17. ELEVATION TOP OF HOLE: 1699.0
18. TOTAL CORE RECOVERY FOR BORING: 5.9 34.6 %
19. SIGNATURE OF INSPECTOR: William G. Barker

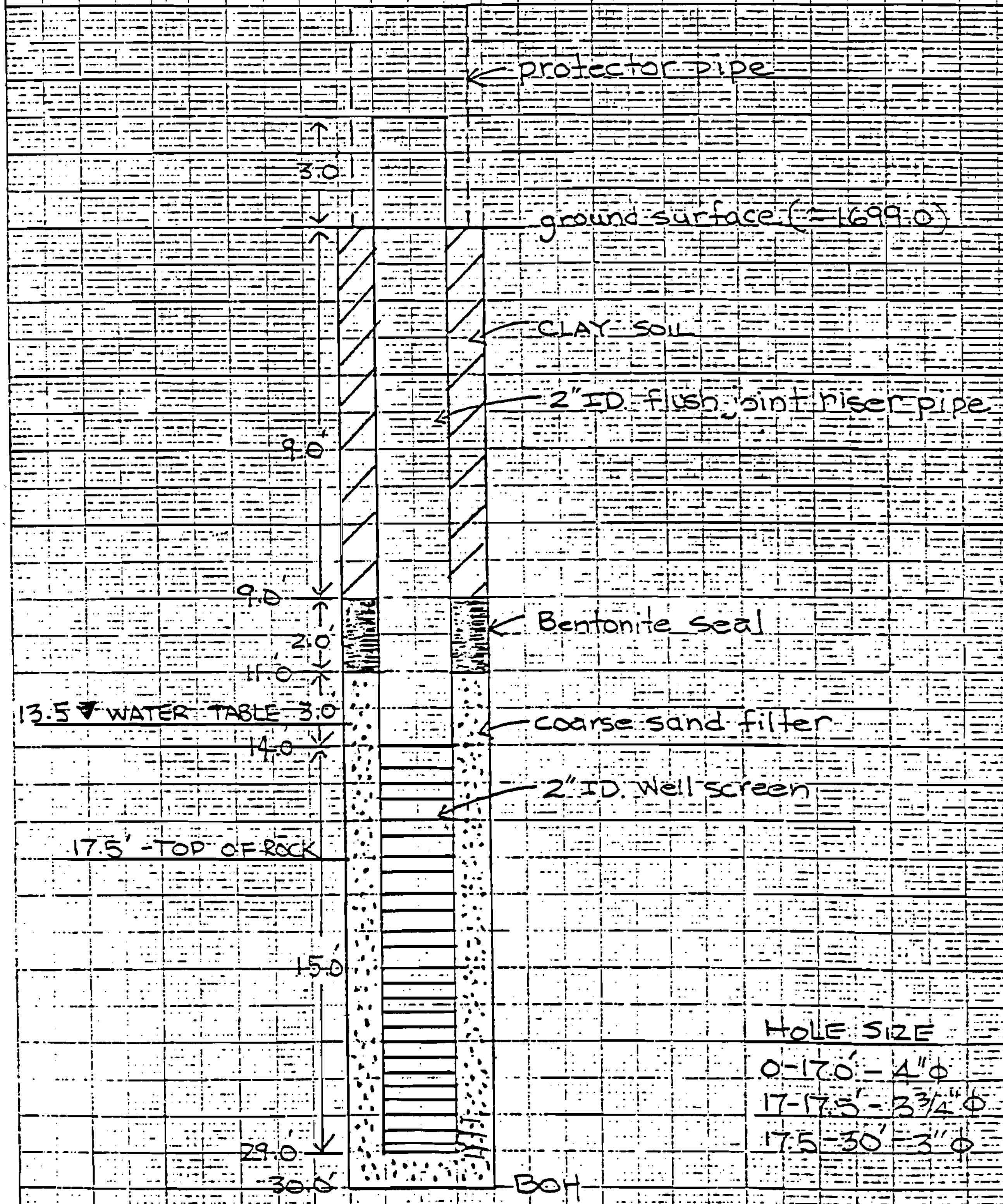
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	
			3" topsoil (ML) SILT, some v. fn sand, brn, slt. plast, moist tr. organics	100	S-1	Split Spoon	2-2-4
						advanced w/4" fishtail k(0-5) = 0	
	4.5		(SM) SAND, v. fn-fn, little silt, brn, NP, v. moist	100	S-2	Split Spoon	1-2-3
						k(0-10) = .1 ft/day	
			same (SM) in shelby tube v. moist	100	UD-1	Shelby tube-push	
			less silt and little med. sand w/depth, saturated			k(0-15) = .49 ft/day k(0-17) = .81 ft/day	
	16.0			100	S-3	Split Spoon	1-1-14
	17.0		(GP) GRAVEL, some fn-crs sand & cobbles, saturated	100	S-4	Split Spoon	17-30/.4
			Top of rock @ 17.5 LIMESTONE BRECCIA, blue gray angular fragments w/clayey silty matrix, badly weathered, soft to mod. hard more fragments than core pieces	35	Run 1 .9	Set casing to 18.0 NX Core: RQD = 0	
				50%	Run 2 Box 1 5.0	k(17.5-30) = .49 ft/day NX Core RQD = 0	
	30.0		BOH - 30.0 Water of completion: Water after 24 hrs:	13.5' 14.1'		Well installation took 2.0 hours	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT: RCRA STUDY - LAGOON D

HOLE NO. DH-2

RCRA STUDY
RADFORD AAP
LAGOON "D"
DH-2



HOLE SIZE
0-17.0' - 4" φ
17-17.5' - 3¾" φ
17.5-30' - 3" φ

NOT TO SCALE

(SWMU 10) **Hole No.** DH-3

DRILLING LOG

DIVISION: NAD
INSTALLATION: NAO
SHEET 1 OF 1 SHEETS

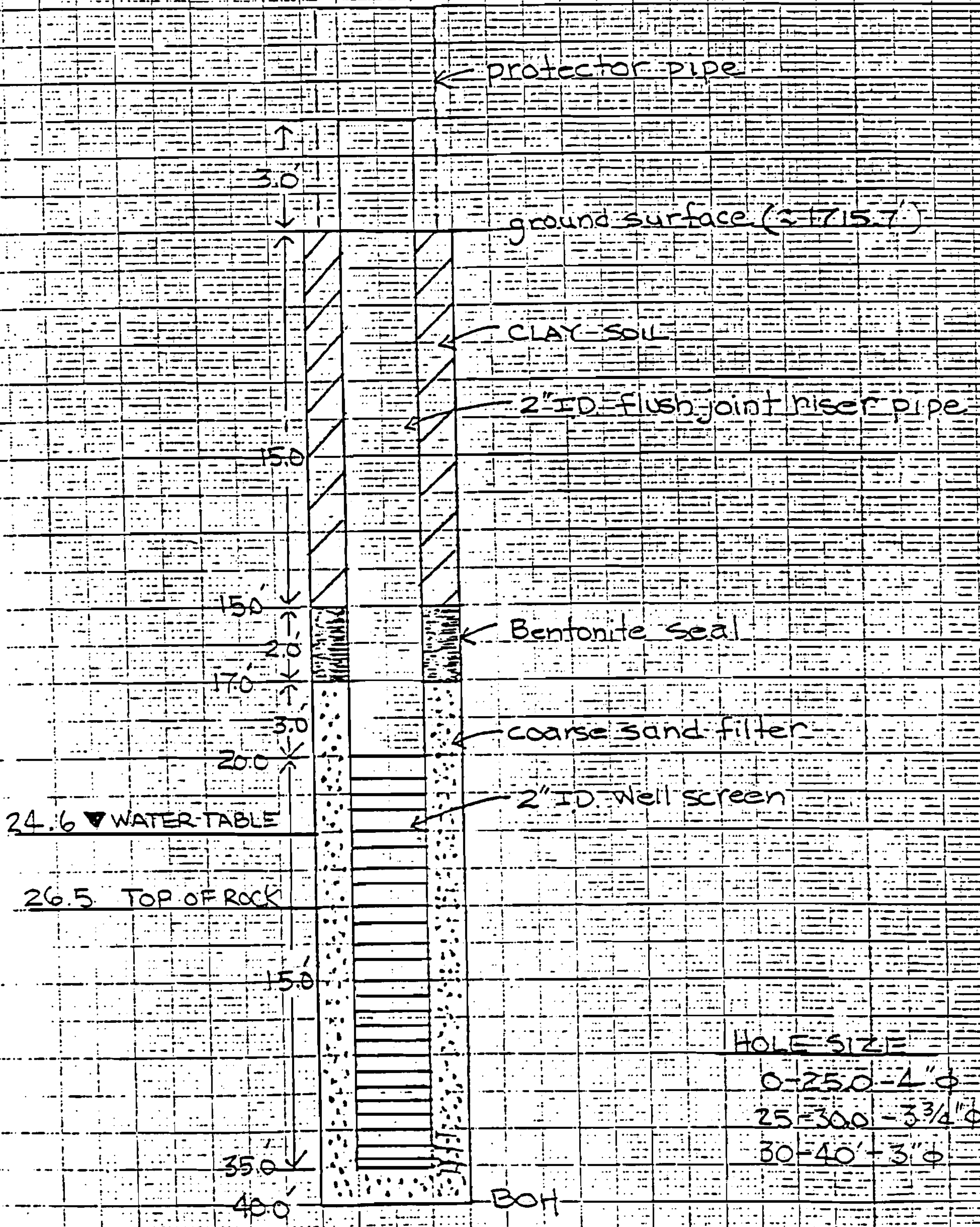
1. PROJECT: RCRA - LAGOON "D"
2. LOCATION (Coordinates or Station): N 318,400 E1. 408,317
3. DRILLING AGENCY: CUNNINGHAM CORE DRILLING
4. HOLE NO. (As shown on drawing title and file number): DH-3
5. NAME OF DRILLER: MARVIN DEAN
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 26.5
8. DEPTH DRILLED INTO ROCK: 13.5
9. TOTAL DEPTH OF HOLE: 40.0
10. SIZE AND TYPE OF BIT: 2" O.D. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME - 75
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 6 UNDISTURBED 2
14. TOTAL NUMBER CORE BOXES: 1
15. ELEVATION GROUND WATER: 1692
16. DATE HOLE: STARTED 16 JULY 80 COMPLETED 17 JULY 80
17. ELEVATION TOP OF HOLE: 1715.7
18. TOTAL CORE RECOVERY FOR BORING: 5.2' 38 %
19. SIGNATURE OF INSPECTOR: William A Barker

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
			3" Topsoil (ML) SILT, little v. fn-fn sand, tr clay, low plast moist, yel. brn	100	S-1	Split Spoon	4-3-3	0
						advanced w/4" fishtail K = (0-5') = 0		
1710.7	5.0		(ML-SM) SILT & SAND, v. fn to fn, micaceous, SH plast. moist, yel. brn	100	S-2	Split Spoon	5-7-11	6.
						K = (0-10') = .32 ft/da		
1706.7	9.0		(SM) SAND, v-fn-fn, little silt, NP, moist, lt brn	160	S-3	Split Spoon	2-3-3	10.
1704.2	11.5		(SP SAND, v. fn-fn, little med sand, tr silt, lt brn moist, NP, becomes fn-med grained w/tr crs sand	75	UD-1	Shelby tube - push		13.
						K = (0-15') = .14 ft/day		
				50	S-4	Split Spoon	2-1-2	16.
						K = (15-20') = .25 ft/da		18.
			same fn-med SAND	50	UD-2	Shelby tube - push		20
1695.7	20		(SP-GP) SAND, fn-crs and gravel, tr silt, NP, v. moist to saturated	30	S-5	Split Spoon	9-6-4	21.
						advanced w/casing K = (20-25) = 38.9 ft/da		25.
1690.7	25.0		(SM-GM) SAND & GRAVEL size LS fragments w/some silt, tr clay badly weathered rock	100	S-6	Split Spoon	5-4-5	26.
1689.2	26.5			14	Run 1 Box 1 .5	advanced to 26.5 RQD = 0 K(25-30) = 40.8 ft/day		30.
			Top of Rock LIMESTONE, blue gray to tan, irregular bedding dipping 10°-50° (tectonic activity apparent) v-fn grd, soft to med. hard, partially fragmented moderately to badly weath. mainly calcite healed fractures and vugs	23	Run 2 Box 1 1.5	advanced casing to 30.0' K(30-36.5) = 19.2 ft/day RQD = 0		36.
				100	Run 3 2.0	RQD = 0		38.
1675.7	40.0			80	Run 4 1.2	RQD = 0 K(30-40) = 12.7 ft/day		40.
			BOH - 40.0'			water at completion = 23.7 water after 24 hrs. = 24.2 time for well installati was 2.5 hrs.		

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.
(TRANSLUCENT)

PROJECT: RCRA - LAGOON "D"
HOLE NO.: DH-3

RCRA STUDY
RADFORD AAP
LAGOON 'D'
DH-3



HOLE SIZE
0-25.0 - 4" ϕ
25-30.0 - 3¾" ϕ
30-40' - 3" ϕ

NOT TO SCALE

(SWMU 10) **Hole No.** DH-4

DRILLING LOG

DIVISION: NAD

INSTALLATION: NAO

SHEET 1 OF 1 SHEETS

1. PROJECT: RCRA STUDY - LAGOON D
2. LOCATION (Coordinates or Station): N 318,740 E1,407,610
3. DRILLING AGENCY: CUNNINGHAM CORE DRILLING
4. HOLE NO. (As shown on drawing title and file number): DH-4
5. NAME OF DRILLER: BOB MONROE
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 25.9
8. DEPTH DRILLED INTO ROCK: 9.4
9. TOTAL DEPTH OF HOLE: 34.3
10. SIZE AND TYPE OF BIT: 2" O.D. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SPRAGUE & HENWOOD 40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 1
15. ELEVATION GROUND WATER: 1690.0
16. DATE HOLE: STARTED 17 JULY 80; COMPLETED 18 JULY 80
17. ELEVATION TOP OF HOLE: 1713.7
18. TOTAL CORE RECOVERY FOR BORING: 8.5 89 %
19. SIGNATURE OF INSPECTOR: William Baker

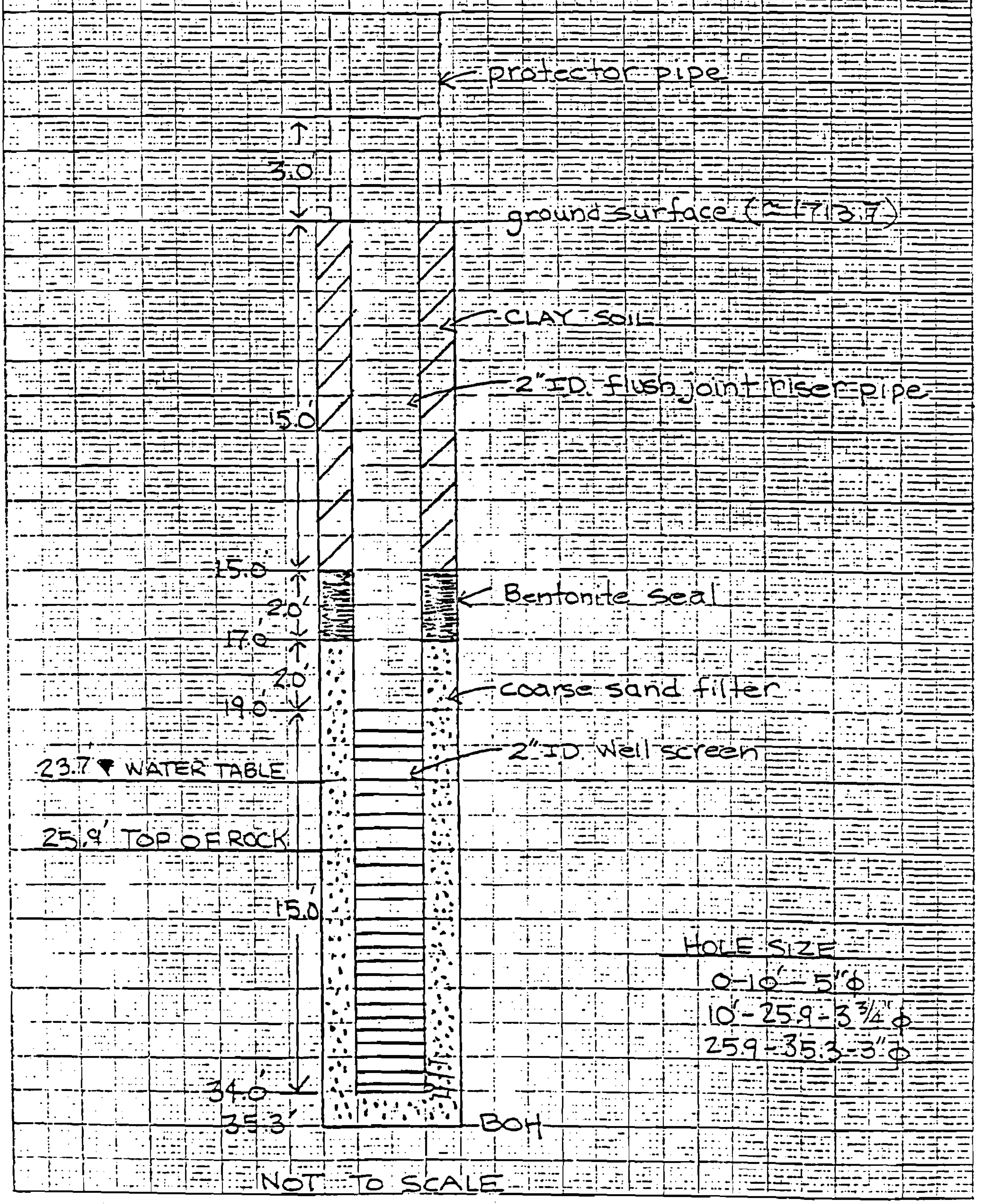
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			2" Topsoil (ML) SILT, little v. fn-fn sand, brn, slt plast. moist to dry	100	S-1	Split Spoon/6-6-5
1710.2	3.5					K (0-5) = 0
			(SM) SAND, fn-fn some mica silt, tr. clay, slt plast moist, yel.brn	100	S-2	Split Spoon 4-6-8
						K (5-10) = .87 ft/day set 4" casing to 10.0
1704.7	9.0		same (SM) w/some gravel and cobbles	100	S-3	Split Spoon 12-25-25
1701.2	12.5		(GP) Gravels & Cobbles, some fn-crs sand, tr silt			K (10-15) = 2.45 ft/day
				0	S-4	Split Spoon 15-30/.4
						no recovery on S-4 advanced casing to 20' K (15-20) = 6.16 ft/day
1693.7	20.0		(GC) Gravels and Sand fn-crs, some silt & clay, yel. brn, low plast saturated, very soft			hole caved below casing K (20-25.9) = 23.6 ft/day Split Spoon - WT of hammer from 20 - 25.9 set casing in rock to 26
1687.8	25.9		Cored river jack 25.9-26.1 Dolomitic limestone, blue gray, thin-med bedded, dipping 25-30° w/zones of irregular bedding dipping up to 70°, v. fn grained, mod hard, SH. weathered, many calcite healed fractures, some calcite filled vugs, largest core piece - 13", average = 5", smallest - 1"	89%	Run 1 Box 1 84	NX Core RQD = 40% K (25.9 - 35.3) = 13.7 ft/day No pressure
1679.4	34.3		BOH - 34.3			Water at completion -23.7 Water after 14hrs. hole size 0 - 10 -5" 10-25.9 -3 3/4" 25.9 - 35.3 -3" time of well installation was 2.75 hrs.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT: RCRA STUDY - LAGOON D

HOLE NO. DH-4

RCRA STUDY
RADFORD AAP
LAGOON "D"
DH-4



HOLE SIZE

0-10' - 5" ϕ

10' - 25.9 - 3 3/4" ϕ

25.9 - 35.3 - 3" ϕ

SWMU 26 **Hole No.** LF-3 DH-2

DRILLING LOG

DIVISION: NAD

INSTALLATION: NAO

SHEET 1 OF 3 SHEETS

1. PROJECT: RCRA - LANDFILL B
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: CUNNINGHAM DRILLING & GROUTING CORP.
4. HOLE NO. (As shown on drawing title and file number): LF-B DH-2
5. NAME OF DRILLER: MARVIN DEAN
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 54.7
8. DEPTH DRILLED INTO ROCK: 50.3
9. TOTAL DEPTH OF HOLE: 105.0'
10. SIZE AND TYPE OF BIT: 2" OD. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-75
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 9 UNDISTURBED 2
14. TOTAL NUMBER CORE BOXES: 3
15. ELEVATION GROUND WATER: (83.0)
16. DATE HOLE: STARTED 1 July 1980 COMPLETED 8 July 1980
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: 40.3' 79%
19. SIGNATURE OF INSPECTOR:

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	
						Fishtail 0.0'-5.0' Perm. test 0.0-5.0 K=0	
	5.0		(CL) CLAY, tr. of silt, tr. of fn. sand med. plast., moist, mottled yellow to orange.	100	S-1	Splitspoon 3-3-5	5. 6.
						Fishtail 6.5'-10.0' Perm. test 5.0'-10.0' K=0.018 ft./day	
	10.0		(ML) SILT, some clay, no plast., dry, mottled lt. brown to dk. brown.	100	S-2	Splitspoon	10 11
						Fishtail 11.5'-15.0 Perm test 10.0-15.0 K=0.019 ft./day	
	15.0		(ML) as above	100	S-3	Splitspoon 8-12-17	15 16
						Fishtail 16.5'-20.0 Perm. test 15.0-20.0 K=0.007 ft./day	
	20.0		(CL) CLAY, some silt, tr. of org., lt. moisture, mottled lt. yellow to orange.	100	S-4	Splitspoon 7-11-13	2 21
				100	UD-1	SHELBY TUBE	23
						Fishtail 23.5-25.0'	
	25.0		(CL) CLAY, as above, milsceous.	100	S-5	Splitspoon 7-10-12	25 2
	29.0					Fishtail 26.5'-30.0' Perm test 25.0-30.0 K=0.04 ft./day	
	29.5		Cobbles, gravel & sand				
	30.0		(CL-SC) CLAY & SAND, fn. - crs., tr. of gravel. med. plast., v. moist, yel.-brown.	100	S-6	Splitspoon 7-12-15	3 3
	32.0		(SM) SAND fn., some mica silt, lt. crs. sand, gravel & cobbles, slt., plast., moist, orange-brn.			Fishtail 31.5'-35.0 Perm. Test 30.0-35.0 K=1.52 ft./day	
	35.0			100	UD-2	SHELBY TUBE	3 3
						Fishtail 37.0-40.0' Perm test 35.0-40.0 K=30.8 ft./day	
	40.0		(SM) as above	100	S-7	Splitspoon 2-2-3	4 4
						Fishtail 41.5-45.0' Perm. test 40.0-45.0' K=22.2 ft./day; cobbles encountered at 41.5'	
	45.0			0	S-8	Splitspoon 2-2-3	45 46
	50.0					Fishtail 45.0-50.0 Perm. test 45.0-50.0 K=17.3 ft./day	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

(TRANSLUCENT)

PROJECT: RCRA - LANDFILL B

HOLE NO.: LF-3 DH-2

SWMU 26 **Hole No.** LF-3 DH-2

DRILLING LOG

DIVISION: NAD

INSTALLATION: NAO

SHEET 2 OF 3 SHEETS

1. PROJECT: RCRA - LANDFILL B
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: CUNNINGHAM DRILLING & GROUTING CORP.
4. HOLE NO. (As shown on drawing title and file number): LF-B DH-2
5. NAME OF DRILLER: MARVIN DEAN
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 54.7
8. DEPTH DRILLED INTO ROCK: 50.3
9. TOTAL DEPTH OF HOLE: 105.0'
10. SIZE AND TYPE OF BIT: 2" OD. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-75
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 9 | UNDISTURBED ~ 2
14. TOTAL NUMBER CORE BOXES: 3
15. ELEVATION GROUND WATER: (83.0)
16. DATE HOLE: STARTED 1 July 1980 | COMPLETED 8 July 1980
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: 40.3' 79 %
19. SIGNATURE OF INSPECTOR:

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	
	50.0					weight of rod drop 50.0 54.0' Perm. test 50.0'-54.0' K=24.0 ft./day	
			LIMESTONE in gravel size.			Splitspoon 18-50/.2	54.
	55.0		Top of weathered rock	0	Run 1	Loss H_2OE 55.2' C. L.-5.0' Perm. test 54.7-59.7 K=18.8 ft./day	54.
	59.7 60.0		Top of hard rock LIMESTONE frangemental, slightly calcareous, moderately hard, dense texture, slightly to unweathered, broken into gravel size fragments. Lt. gray to to dk. grey.	64	Run 2	C. L.-1.9' RQD-0% Perm. test 60.0'-65.0' K=0.28 ft./day	59.
	65.0			100	Run 3	C. L.-0 RQD-0% Perm. test 65.0'-70.0' K=0.02 ft./day	65
	70.0			86	Run 4	C. L. 0.6' RQD-0% Perm. test 70.0' K=0.04 ft./day	68
	75.0		LIMESTONE, fragmental, calcareous, moderately hard dense texture, brecciated, badly weathered, highly vuggy, numerous calcite healed seams, gray-	92	Run 5	C. L. 0.5' RQD 50% Perm. test 75.0'-80.0' K=0.02 ft./day	72
	80.0			T2	Run 6	C. L. 1.2' RQD 63% islolated areas of thin bedding @ 50°. Perm. test 80.0'-85.0' K=0	78
	85.0		BRECCIA, calcareous, moderately hard, coarse, fragmented structure, badly weathered, v. vuggy dk. gray.	100	Run 7	C. L. 0 RQD 61%	83
	90.0			90	Run 8	C. L. 0.8' RQD-71% isolated areas of blue, green, yellow coloring Perm. test 85.0'-90.0' K=0 Perm. test 90.0'-95.0' K=0.02 ft./day Perm. test 93.8-98.8 K=0.06 ft./day	86
	100.0		BRECCIATED LIMESTONE, fragmental slightly calcareous, 1.0 od. hard, ~~coarse~~ texture, brecciated, scattered fractures, slightly to badly weathered. Vuggy, numerous calcite filled seams gray				9 1

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

(TRANSLUCENT)

PROJECT RCRA - LANDFILL B

HOLE NO. LF-B DH-2

Hole No. LF-B DH-2

DRILLING LOG

DIVISION NAD

INSTALLATION NAO

SHEET 3 OF 3 SHEETS

1. PROJECT RCRA - LANDFILL B
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING CORP.
4. HOLE NO. (As shown on drawing title and file number) LF-B DH-2
5. NAME OF DRILLER MARVIN SWEAN
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 54.7
8. DEPTH DRILLED INTO ROCK 50.3
9. TOTAL DEPTH OF HOLE 105.0'
10. SIZE AND TYPE OF BIT 2" OD. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL CME-75
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 9 UNDISTURBED 2
14. TOTAL NUMBER CORE BOXES 3
15. ELEVATION GROUND WATER (83.0)
16. DATE HOLE STARTED 1 July 1980 COMPLETED 8 July 1980
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 40.3' 79 %
19. SIGNATURE OF INSPECTOR

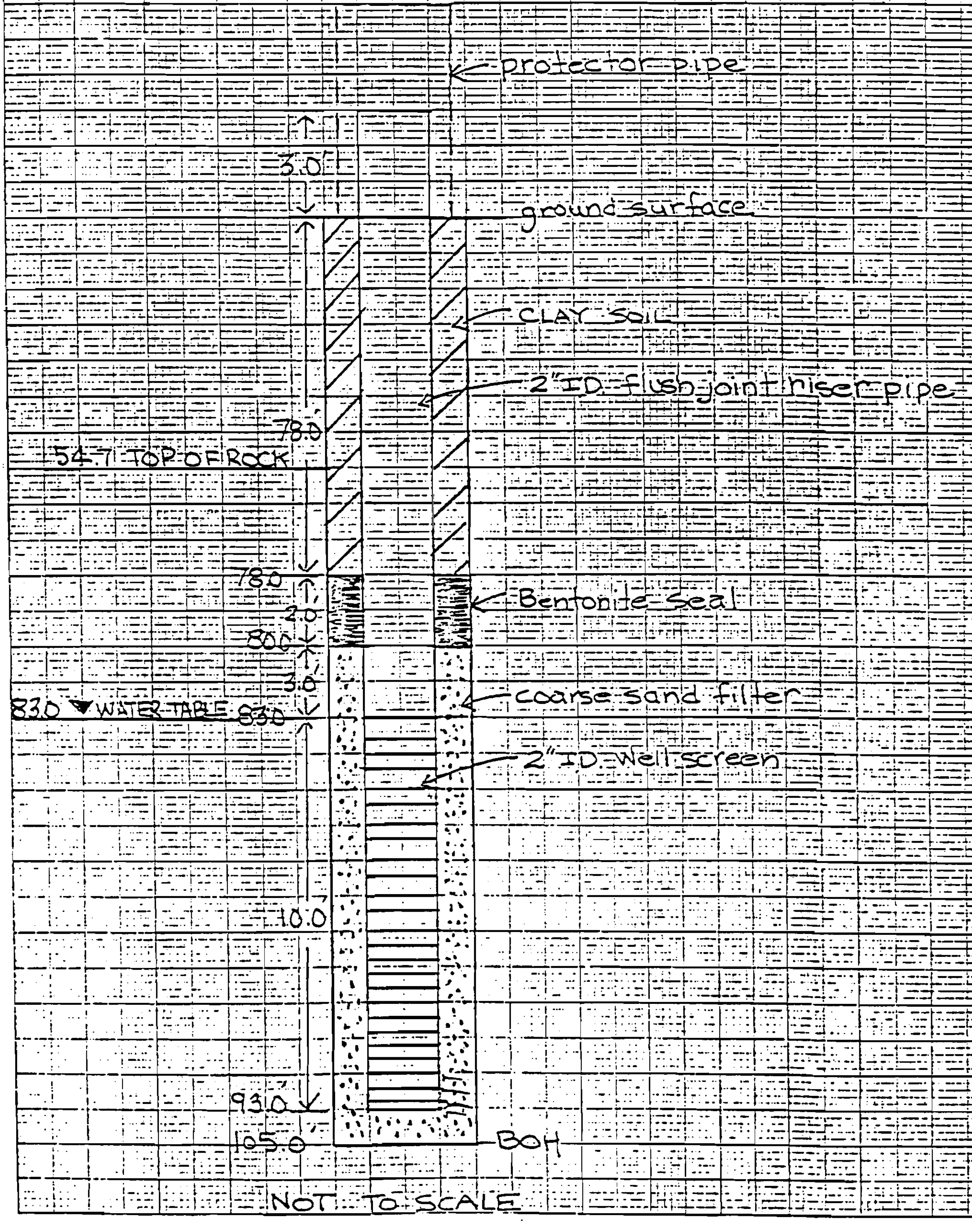
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100.0		BRECCIATED LIMESTONE			
	105.0					105
			BOH 105.0			
			Water at competion=81.5'			
		✓	Water after 24 hrs. = 83.0'			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT RCRA - LANDFILL B

HOLE NO. LF-B DH-2

RCRA STUDY
RADFORD AAP
LANDFILL "B"
DH-2



NOT TO SCALE

SWMU 26 **Hole No.** LF-3-DH-3

DRILLING LOG

DIVISION NAD

INSTALLATION NAO

SHEET 1 OF 3 SHEETS

1. PROJECT RCRA Landfill B
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY CUNNINGHAM DRILLING & CORING CORP
4. HOLE NO. (As shown on drawing title and file number) LF-B DH-3
5. NAME OF DRILLER BOB MONROE
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 52.4
8. DEPTH DRILLED INTO ROCK 60.2
9. TOTAL DEPTH OF HOLE 112.6
10. SIZE AND TYPE OF BIT 2" OD. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL SPRAGUE & HENWOOD 40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8 ; UNDISTURBED 1
14. TOTAL NUMBER CORE BOXES 4
15. ELEVATION GROUND WATER (80.0)
16. DATE HOLE: STARTED 1 JULY 80 ; COMPLETED 12 JULY 80
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 49.8 83%
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	1.0		Topsoil			Fishtail 0.0-4.7'
			(SP) SAND, fn-crs, little gravel, tr of silt, dry, yellow			
	4.7 5.0		Boulder			Core Rock 4.7'-5.0'
			(CL) CLAY, tr of sand, fn-crs, little gravel, med plast, moist, mottled yellow to orange	100	S-1	Split Spoon 10-20-32 Fishtail 6.5-17.3 Boulders Encountered from 7.5-11.3
	10.0 11		(SP) SAND, fn-crs, yellow	0	S-2	Split Spoon 12-13-13 Fishtail 12.8-15.0
	15.0			0	S-3	Split Spoon 5-6-12 Fishtail 16.5'-20.0'
	17.3		(CL) CLAY, tr of weathered rock fragments, low plast, lt moist, yellow			
	20.0			100	S-4	Split Spoon 5-9-11 Fishtail 21.5'-25.0' Perm Test 20.0'-25.0' K=1.0 ft/day
	25.0		(CL) AS ABOVE, with tr of fn sand	100	S-5	Split Spoon 1-1-2 Fishtail 26.5'-30.0' Perm Test 25.0'-30.0' K=28 ft/day Perm Test 28.0-30.0 K=51 ft/day Loss drill water @ 28.7
	30.0		(CL) AS ABOVE, Med Plast	100	UD-1	Shelby Tube Fishtail 33.0'-35.0 Perm Test 30.0'-35.0' K>24 ft/day
	35.0		(CL) AS ABOVE	100	S-6	Split Spoon 1 = 1.5' Fishtail 36.5'-40.0' Perm Test 35.0'-40.0' K 20.9 ft/day
	40.0			0	S-7	Split Spoon 30/.2 Fishtail 40.2'-45.0' Perm Test 40.0'-45.0' K>18.5 ft/day
	45.0		(CL) AS ABOVE	100	S-8	Split Spoon WOH = 1.5' Fishtail 46.5'-50.0'
	50.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT RCRA LANDFILL B

HOLE NO. LF-B-OH-3

Hole No. LF-B-DH-3

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 2 OF 3 SHEETS
1. PROJECT RCRA- LANDFILL B		10. SIZE AND TYPE OF BIT 2" OD. SS: NX DIA	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING CORP		12. MANUFACTURER'S DESIGNATION OF DRILL SPRAGUE & HENWOOD 40C	
4. HOLE NO. (As shown on drawing title and file number)	LFB-DH-3	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 8 | UNDISTURBED 1
5. NAME OF DRILLER BOB MONROE		14. TOTAL NUMBER CORE BOXES 4	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.		15. ELEVATION GROUND WATER (80.0)	
		16. DATE HOLE	STARTED 1 JULY 80 | COMPLETED 12 JULY 80
7. THICKNESS OF OVERBURDEN	52.4	17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK	60.2	18. TOTAL CORE RECOVERY FOR BORING 49.8	83 %
9. TOTAL DEPTH OF HOLE	112.6	19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	50.0		Top of Rock @ 52.4	0	UD-2	Shelby Tube
			DOLOMITE, bedding absent, slightly calcaeous in isolated areas, moderately hard, dense texture, scattered fractures, some clay filled, some calcite healed, slightly weathered, vuggy, broken up into gravel size, lt gray Some iron staining present in fractures		S-9	Split Spoon 30/.3
	55.0			0	Run 1	CL-2.6' RQD-0 Perm Test 50.0'-55.0 K = .85 ft/day
				55	Run 2	CL = 1.0' RQD-0 Perm Test 56.0'-60.0' K = 4.1 ft/day
				100	Run 3	CL = 0 RQD-0
				85	Run 4	CL = 0.3' RQD-0
	60.0			100	Run 5	CL = 0 RQD-0
				100	Run 6	CL-0 RQD -0
				100	Run 7	CL = 0 RQD-0
				100	Run 8	CL = 0 RQD-0
	65.0			100	Run 9	CL = 0 RQD-0
				100	Run 10	CL = 0 RQD-0
				100	Run 11	CL=0 RQD-0
				100	Run 12	CL=0 RQD-0
	70.0			100	Run 13	CL=0 RQD=0 Jointed @ 45° Perm Test 68.0'-70.0' Rock was broken up to seal pack
	75.0 80.0			100	Run 14	CL = 0 RQD-42% Perm Test 70.0'-75.0' K = 0.07 ft/year Water level at 77.3' on 10 July Perm Test 75.0'-80.0' K=0.11 ft/day
				100	Run 15	CL = 0 RQD-0
	85.0			100	Run 16	CL = 0 RQD-0 Perm Test 80.0-85.0 K = 0.1 ft/day Perm Test 83.0-88.0 K = 0.08 ft/day
	90.0		LIMESTONE, thin bedding, calcaeous, moderately hard, dense, scattered fractures, badly weathered, vuggy, dark gray	97	Run 17	CL = 0.2' RQD - 36% Perm Test 88.0-93.0 K = 0.10 ft/day
	95.0 100.0		SILTSTONE, thinly laminated, slightly calcareous, soft, fine texture, bedding gently dipping. Jointed along bedding planes, slightly to badly weath. lt grn to tan	66	Run 18	CL = 1.8' RQD-0 Perm Test 93.0-98.0 K=0

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT RCRA - LANDFILL B

HOLE NO. LF-B-DH-3

Hole No. LF-B-DH-3

DRILLING LOG

DIVISION: NAD

INSTALLATION: NAO

SHEET 3 OF 3 SHEETS

1. PROJECT: RCRA LANDFILL B
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: CUNNINGHAM DRILLING & CORING CORP
4. HOLE NO. (As shown on drawing title and file number): LF-B DH-3
5. NAME OF DRILLER: BOB MONROE
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 52.4
8. DEPTH DRILLED INTO ROCK: 60.2
9. TOTAL DEPTH OF HOLE: 112.6
10. SIZE AND TYPE OF BIT: 2" OD. SS: NX DIA
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SPRAGUE & HENWOOD 40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 9 UNDISTURBED 1
14. TOTAL NUMBER CORE BOXES: 4
15. ELEVATION GROUND WATER: (80.0)
16. DATE HOLE: STARTED 1 JULY 80 COMPLETED 12 JULY 80
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: 49.8 83 %
19. SIGNATURE OF INSPECTOR:

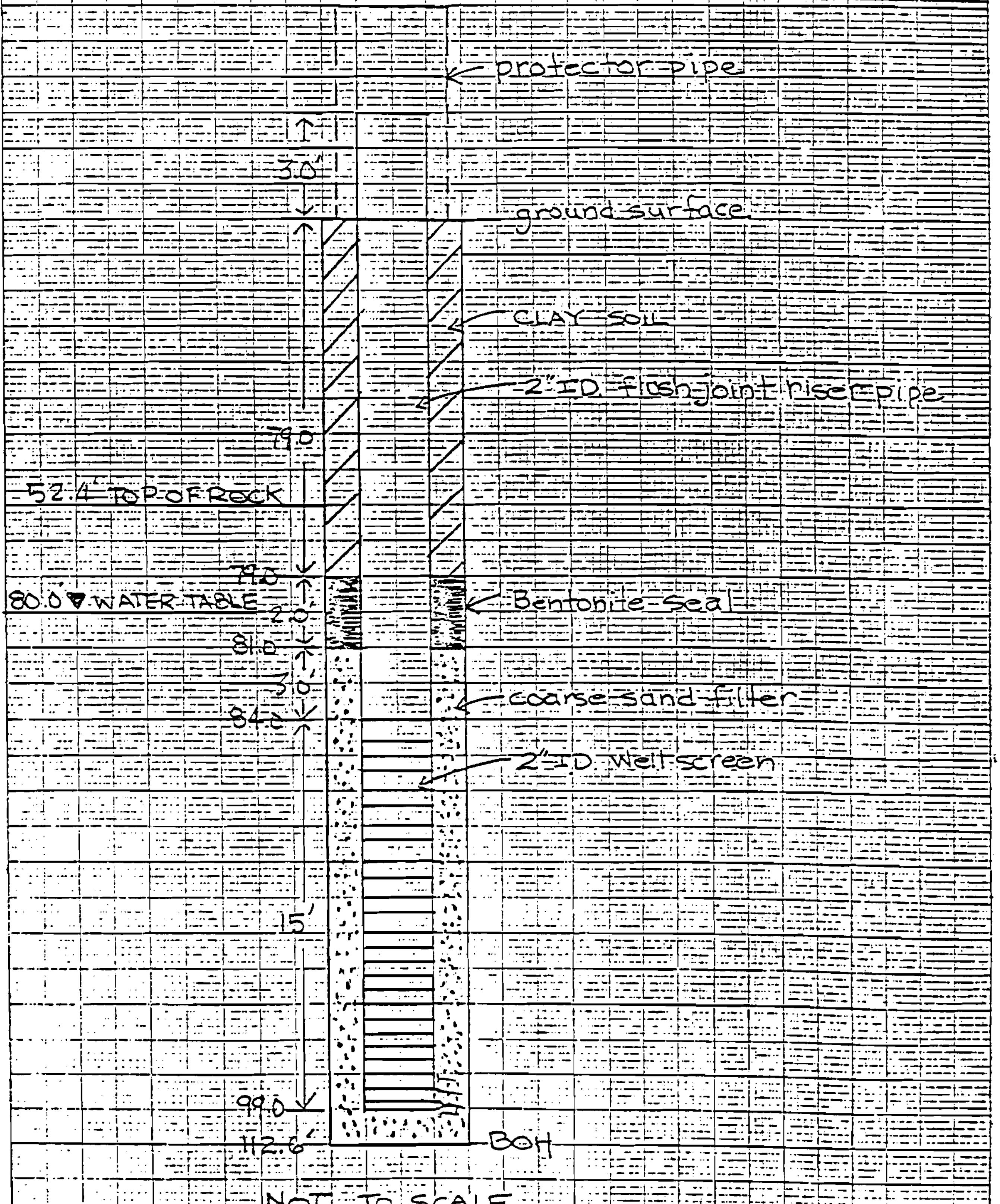
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100.0		BRECCIA, massive bedding, calcareous, moderately hard, coarse texture, brecciated, badly weathered, matrix weathered to clay, blue and green	60	Run 19	CL = 2.0' RQD-0 Perm Test 98-105 K = 0.07 ft/day
	105.0			83	Run 20	CL = 0.5' RQD 21% Thin lense of siltstone in middle of run
	110.0			32	Run 21	CL = 3.3' RQD 9% Perm Test 105-112 K = 0
			BOH @ 112.6' water at completion = 80.0'			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT: RCRA - LANDFILL -B

HOLE NO. LF-B-DH-3

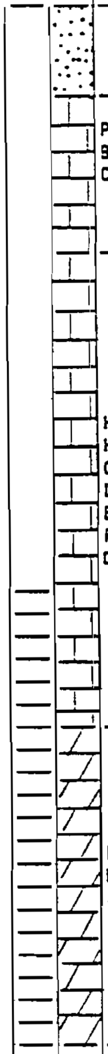
RCRA STUDY
RADFORD AAP
LANDFILL "B"
DH-3



TEST BORING RECORD

SITE: RADFORD AAP
DATE DRILLED: 9-16-88
JOB NUMBER: 1345-80-4100

BORING NO. CTM-1 (SWMU 26)
GROUNDWATER ELEVATION: DRY
DATE MEASURED: 11-17-88



DEPTH (FT.)	UNIFIED CLASSIFICATION	PENETRATION RESISTANCE (BLOWS/FT.) 0 20 40 60 80 100	LITHOLOGY	ELEV.
32.0				1729.65
	GRAY LIMESTONE	50/2	PARTIALLY WEATHERED LIMESTONE; BREAKABLE INTO SANDY-SILTY MATERIAL; COLOR 10YR 5/1	
	AUGER REFUSAL 35.5 FT			1726.15
	FIRST CORE RUN 36.0 - 46.0 FT REC 32% RQD 8%		HARD GRAY THIN BEDDED LIMESTONE HEAVILY FRACTURED, WHITE TO CLEAR CALCITE FRACTURE FILL; VOID SPACES LINED WITH CLEAR CALCITE CRYTALS; EVIDENCE OF DEFORMATION: FOLDING AND FAULTING; PARTIALLY DOLOMITIZED	
43.0	SCREEN INTERVAL 43.0 - 53.0 FT			1718.65
46.0				1715.65
	SECOND CORE RUN 46.0 - 53.0 FT REC 100% RQD 61%		HARD TO MODERATELY HARD GRAY DOLOSTONE; UNIFORMLY BEDDED IN PARTS; FRACTURED AND PARTIALLY WEATHERED IN OTHER AREAS.	
53.0	CORING TERMINATED 53.0 FT			1708.65

REMARKS: COLOR CLASSIFICATION AS PER MUNSELL (1975)

Form No 500

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. R0L-62188

DATE November, 1984

Client: Hercules, Inc.

(SWMU 29)

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL -1
Total Depth: 43.5'
Elevation:
Location: See plan

Type of Boring: Hollow-stem auger
Started: 11-5-84
Completed: 11-6-84
Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	Red brown to brown clayey SILT (ML) roots *				* organics GROUNDWATER DATA
	1.0	Soft red-brown SILT, little fine sand, trace mica (ML) -ALLUVIUM-	3 2 4	4.5 6.0		
	6.5	Red and yellow mottled clayey SILT, trace fine sand, occasional relict structure (ML) -RESIDUUM-	4 5 6	9.5 11.0		
			4 4 3	14.5 16.0		
			1 2 1	19.5 20.0		
			2 3 4	24.5 26.0		
		Auger refusal @ 28.5' Light gray to dove and blue thinly laminated argillaceous LIMESTONE with vugs and numerous calcite-healed fractures. Laminae display much contortion. Trace of algal structure at about 30.0'	*		90%	* Sampler bouncing, not driven 28.5' 33.5' Water level measured @ 33.5'

*No of blows req d. for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in increments The sum of the last two increments of penetration is termed the standard penetration resistance. N

Scale 1"=5' unless otherwise noted

Form No 300

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. R0L-62188 DATE November, 1984

Client: Hercules, Inc.

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-1 cont. Total Depth: Elevation: Location: See plan

Type of Boring: Hollow-stem auger Started: 11-5-84 Completed: 11-6-84 Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	35.0	See description on previous page			95+ %	GROUNDWATER DATA
						38.5'
					> 95%	
	43.5	Boring terminated @ 43.5'				43.5' 20' screen set from bottom

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in increments. The sum of the last two increments of penetration is termed the standard penetration resistance. N.

Scale 1"=5' unless otherwise noted

Form No. 500

BORING LOG

10

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188

DATE November, 1984

(SWMU-29)

Client: Hercules, Inc.

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-2

Total Depth: 44.1

Elevation:

Location: See plan

Type of Boring: Hollow-stem auger

Started: 10-18-84

Completed: 10-19-84

Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	Brown sandy SILT, roots, organics				**GROUNDWATER DATA**
	1.0	Yellow brown silty fine SAND trace fine gravel slightly micaceous -ALLUVIUM-				
			4 5 7	4.5 6.0		
		grades to	4 5 6	9.5 11.0		
		Yellow brown silty medium to fine sand, slightly micaceous (Driftwood)				
		grades to	6 10 8	14.5 16.0		
		Yellow tan coarse to fine sandy coarse to fine GRAVEL, slightly micaceous				
		grading back to	7 8 7	19.5 21.0		
		Brown coarse to fine sandy SILT, little clay, slightly micaceous	WOR	24.5 26.0		
	29.9	Gray brown shaley LIMESTONE, badly weathered to clayey SILT -RESIDUUM-	1 1 *	29.5 30.5	∇	* 30/0.0' Water level measured @ 31.4' on 11-1-84
	34.5 35.0	Auger & spoon refusal; begin coring	*	34.5		* 40/0.0' Began coring @ 34.5'

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance. N.

Scale 1"=5' unless otherwise noted

Form No. 500

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188

DATE November, 1984

Client: Hercules, Inc.

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-2 cont.

Total Depth:

Elevation:

Location: See plan

Type of Boring: Hollow-stem auger

Started: 10-18-84

Completed: 10-19-84

Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	35.0	Dark to medium gray vuggy, saccharoidal thin bedded LIMESTONE with numerous calcite-healed fractures, several shale partings			30% 20%	GROUNDWATER DATA Drill water lost @ 36.0'
	44.1	Boring terminated @ 44.1'				20' screen set from botton of hole

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No 500

BORING LOG

SINCE 1881
FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188 DATE November, 1984

Client: Hercules, Inc. (SWMU 29)

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-3 Total Depth: 90.0' Elevation: Location: See plan

Type of Boring: Hollow-stem auger Started: 10-19-84 Completed: 10-23-84 Driller: W. Simmons, Sr.

Elevation	Depth 0.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	1.0	Black & red CINDER and red brown sandy SILT				GROUNDWATER DATA
	3.0	Brown silty fine SAND, trace clay slightly micaceous -ALLUVIUM- (SM)				
		Light tan fine sandy SILT trace to little clay (slightly micaceous) (ML)	4 4 6	4.5 6.0		
			8 8 10	9.5 11.0		
	13.5	Loose red tan fine sandy SILT, slightly micaceous (ML)	3 3 4	14.5 16.0		
			1 2 4	19.5 21.0		
			3 4 6	24.5 26.0		
			3 5 6	29.5 31.0		
	35.0	Dense red brown silty fine SAND occasional rounded quartz gravels (SM)	4	34.5		

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No 500

BORING LOG

SINCE 1881
FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188

DATE November, 1984

Client: Hercules, Inc.

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-3 cont.

Total Depth:

Elevation:

Location: See plan

Type of Boring: Hollow-stem auger

Started: 10-19-84

Completed: 10-23-84

Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	35.0		11 18			GROUNDWATER DATA
	36.0	Grading to Orange-tan and white coarse to fine sandy GRAVEL, some silt (GM)				
			6 11 5	39.5 41.0		
		Soft yellow-tan clayey SILT some fine sand, slightly micaceous (ML)	1 1 2	44.0 46.0		
		Stiff gray & brown clayey SILT some coarse to fine sand, slightly micaceous (ML)	15 14 9	49.5 51.0		
	53.0	Soft brown clayey SILT, trace fine sand, relict structure (ML) -RESIDUUM-	1 2 2	54.5 56.0		
			5 11 7	59.5 61.0		
			25 31 19	64.5 66.0		
			*	69.5		* Sample not driven
	70.0					

*No. of blows req'd. for a 140 lb hammer dropping 30 in to drive 2 in O.D., 1.375 in I.D. samplers total of 18 inches in three 6 in increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 500

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188

DATE November, 1984

Client: Hercules, Inc.

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: FAL-3 cont. Total Depth: Elevation: Location: See plan

Type of Boring: Hollow-stem auger Started: 10-19-84 Completed: 10-23-84 Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	70.0	Yellow tan clayey SILT, trace fine sand -RESIDUUM-				**GROUNDWATER DATA** Water level measured at 74.0'
					∇	
	75.0		ND	74.5 76.0		
	80.0		ND	79.5 81.0		Pump clean water into hole to clean out augers
	85.0		ND	84.5 86.0		
	90.0	Boring terminated at 90.0'				25' screen set from botton

*No of blows req'd for a 140 lb. hammer dropping 30 in to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in increments The sum of the last two increments of penetration is termed the standard penetration resistance. N

Scale 1"=5' unless otherwise noted

APPENDIX B: ANALYTICAL PARAMETERS LISTS

VOLATILES & SEMIVOLATILES, LIST 1

HAZARDOUS CONSTITUENT	CAS NO.	HBN SOIL mg/kg	HBN WATER mg/l	PQL SOIL mg/kg	PQL WATER mg/l	SUGGESTED METHOD
Acetone	67-64-1	1E+3	4E0	1E-1	1E-1	8240
Acrolein	107-02-8	1E+3	5E-2	5E-3	5E-3	8240
Acrylonitrile	107-13-1	1E0	6E-5	5E-3	5E-3	8240
Benzene	71-43-2	2E+1	5E-3	5E-3	5E-3	8260 (8240)
Bis(2-chloroethoxy) methane *syn.* Dichloromethoxy ethane	111-91-1			3E-1	1E-2	8270
Bis(2-chloroethyl) ether *syn.* Dichloroethyl ether	111-44-4	6E-1	3E-5	3E-1	1E-2	8270
Bis(2-chloroisopropyl) ether *syn.* Dichloroisopropyl ether	108-60-1	9E+1	4E-2	3E-1	1E-2	8270
Bis(2-ethylhexyl) phthalate *syn.* Diethylhexyl phthalate	117-81-7	5E+1	3E-3	3E-1	1E-2	8270
Bromodichloromethane	75-27-4	1E+3	7E-1	5E-3	5E-3	8260 (8240)
Bromoform *syn.* Tribromomethane	75-25-2	1E-3	7E-1	5E-3	5E-3	8260 (8240)
4-Bromophenyl phenyl ether	101-55-3			3E-1	1E-2	8270
Butyl benzyl phthalate	85-68-7	1E+3	9E0	3E-1	1E-2	8270
Carbon disulfide	75-15-0	1E+3	4E0	5E-3	5E-3	8240
Carbon tetrachloride	56-23-5	5E+1	5E-3	5E-3	5E-3	8240
p-Chloroaniline	106-47-8	3E+2	1E-1	3E-1	1E-2	8270
Chlorobenzene	108-90-7	1E+3	1E0	5E-3	5E-3	8260 (8240)
p-Chloro-m-cresol	59-50-7	1E+3	2E-1	3E-1	1E-2	8270
Chloroethane *syn.* Ethyl chloride	75-00-3			1E-2	1E-2	8240
Chloroform	67-66-3	1E+2	6E-1	5E-3	5E-3	8260
2-Chloronaphthalene	91-58-7			3E-1	1E-2	8270
2-Chlorophenol	95-57-8	4E+2	2E-1	3E-1	1E-2	8270
m-Cresol	108-39-4	1E+3	2E0	3E-1	1E-2	8270
o-Cresol	95-48-7	1E+3	2E0	3E-1	1E-2	8270
p-Cresol	106-44-5	1E+3	2E0	3E-1	1E-2	8270
Di-n-butyl phthalate	84-74-2	1E+3	4E0	3E-1	1E-2	8270
o-Dichlorobenzene	95-50-1	1E+3	3E0	1E-2	1E-2	8260 (8270)
m-Dichlorobenzene	541-73-1	1E+3	3E0	5E-3	5E-3	8260 (8270)
p-Dichlorobenzene	106-46-7	4E+2	7.5E-2	5E-3	5E-3	8260 (8270)
3,3'-Dichlorobenzidine	91-94-1	2E0	8E-5	1E0	2E-2	8270
Dichlorodifluoromethane	75-71-8	1E+3	7E0	5E-3	5E-3	8260 (8240)
1,1-Dichloroethane	75-34-3	8E0	4E-4	5E-3	5E-3	8260 (8240)
1,2-Dichloroethane	107-06-2	8E0	5E-3	5E-3	5E-3	8260 (8240)
1,1-Dichloroethylene	75-35-4	1E+1	7E-3	5E-3	5E-3	8260 (8240)
trans-1,2-Dichloroethylene	156-60-5	1E+3	7E-1	5E-3	5E-3	8260 (8240)
2,4-Dichlorophenol	120-83-2	2E+2	1E-1	3E-1	1E-2	8270
1,2-Dichloropropane	78-87-5	1E+2	6E-3	5E-3	5E-3	8260 (8240)
cis-1,3-Dichloropropene	10061-01-5	4E0	2E-4	1E-2	1E-2	8240
trans-1,3-Dichloropropene	10061-02-6	4E0	2E-4	1E-2	1E-2	8240
Diethyl phthalate	84-66-2	1E+3	3E+1	3E-1	1E-2	8270
2,4-Dimethylphenol	105-67-9	4E+2	2E-2	3E-1	1E-2	8270
Dimethyl phthalate	131-11-3	1E+3	4E+2	3E-1	1E-2	8270
4,6-Dinitro-o-cresol	534-52-1	8E+1	4E-2	5E0	5E-2	8270
2,4-Dinitrophenol	51-28-5	2E+2	7E-2	2E0	5E-2	8270
2,4-Dinitrotoluene	121-14-2	1E0	5E-5	3E-1	1E-2	8270
2,6-Dinitrotoluene	606-20-2			3E-1	1E-2	8270
Di-n-octyl phthalate	117-84-0			3E-1	1E-2	8270
Ethylbenzene	100-41-4	1E+3	4E0	5E-3	5E-3	8260 (8240)
Hexachlorobenzene	118-74-1	4E-1	2E-5	3E-1	1E-2	8270
Hexachlorobutadiene	87-68-3	9E+1	5E-3	5E-3	5E-3	8260 (8120)

HBN = Health Based Number
PQL = Practical Quantitation Limit

VOLATILES & SEMIVOLATILES (Continued) LIST 1

HAZARDOUS CONSTITUENT	CAS NO.	HBN SOIL mg/kg	HBN WATER mg/l	PQL SOIL mg/kg	PQL WATER mg/l	SUGGESTED METHOD
Hexachlorocyclopentadiene.	77-47-4	6E+2	2E-1	3E-1	1E-2	8270
Hexachloroethane	67-72-1	8E+1	3E-1	3E-1	1E-2	8270
Methyl bromide *syn.* Bromomethane	74-83-9	1E+2	5E-2	1E-2	1E-2	8260 (8240)
Methyl chloride *syn.* Chloromethane	74-87-3	5E+2	3E-2	1E-2	1E-2	8260 (8240)
Methylene chloride *syn.* Dichloromethane	75-09-2	9E+1	5E-3	5E-3	5E-3	8240
Methyl ethyl ketone *syn.* 2-Butanone	78-93-3	1E+3	2E0	1E-1	1E-1	8240
Methyl isobutyl ketone *syn.* 4-Methyl-2-pentanone	108-10-1	1E+3	2E0	1E-1	1E-1	8240
Naphthalene	91-20-3	1E+3	1E+1	3E-1	1E-2	8270
p-Nitroaniline	100-01-6			1E0	2E-2	8270
Nitrobenzene	98-95-3	4E+1	2E-2	3E-1	1E-2	8270
p-Nitrophenol	100-02-7			3E0	5E-2	8270
N-Nitrosodiphenylamine	86-30-6	1E+2	7E-3	3E-1	1E-2	8270
N-Nitrosodi-n-propylamine	621-64-7	1E-1	5E-6	3E-1	1E-2	8270
Pentachlorophenol	87-86-5	1E+3	1E0	2E0	5E-2	8270
Phenol	108-95-2	1E+3	2E+1	3E-1	1E-2	8270
Pyrene	129-00-0	1E+3	4E0	3E-1	1E-2	8270
1,1,1,2-Tetrachloroethane	630-20-6	3E+2	1E-2	5E-3	5E-3	8260 (8240)
1,1,2,2-Tetrachloroethane	79-34-5	4E+1	2E-3	5E-3	5E-3	8260 (8240)
Tetrachloroethylene	127-18-4	1E+2	7E-3	5E-3	5E-3	8260 (8240)
Toluene	108-88-3	1E+3	1E+1	5E-3	5E-3	8260 (8240)
1,2,4-Trichlorobenzene	120-82-1	1E+3	7E-1	1E-2	1E-2	8260 (8270)
1,1,1-Trichloroethane	71-55-6	1E+3	2E-1	5E-3	5E-3	8260 (8240)
1,1,2-Trichloroethane	79-00-5	1E+2	6E-3	5E-3	5E-3	8260 (8240)
Trichloroethylene	79-01-6	6E+1	5E-3	5E-3	5E-3	8260 (8240)
Trichlorofluoromethane	75-69-4	1E+3	1E+1	5E-3	5E-3	8260 (8240)
2,4,5-Trichlorophenol	95-95-4	1E+3	4E0	2E0	5E-2	8270
2,4,6-Trichlorophenol	88-06-2	4E+1	2E-3	6E-1	1E-2	8270
Vinyl chloride	75-01-4	3E-1	2E-3	1E-2	1E-2	8240
Xylene (total)	1330-20-7	1E+3	7E+1	5E-3	5E-3	8260 (8240)

SEMIVOLATILES

HAZARDOUS CONSTITUENT	CAS NO.	HBN SOIL mg/kg	HBN WATER mg/l	PQL SOIL mg/kg	PQL WATER mg/l	SUGGESTED METHOD
Anthracene	120-12-7	4E+1	2E-3	1E-1	2E-3	8310
Benzo[a]anthracene	56-55-3	2E-1	1E-5	9E-3	1E-4	8310
Benzo[b]fluoranthene	205-99-2	4E-1	2E-5	2E-2	2E-4	8310
Benzo[k]fluoranthene	207-08-9	8E+1	4E-3	2E-2	2E-4	8310
Benzo[a]pyrene	50-32-8	6E-2	3E-6	2E-2	2E-4	8310
Bis(2-chloroethoxy) methane *syn.* Dichloromethoxy ethane	111-91-1			3E-1	1E-2	8270
Bis(2-chloroethyl) ether *syn.* Dichloroethyl ether	111-44-4	6E-1	3E-5	3E-1	1E-2	8270
Bis(2-chloroisopropyl) ether *syn.* Dichloroisopropyl ether	108-60-1	9E+1	4E-2	3E-1	1E-2	8270
Bis(2-ethylhexyl) phthalate *syn.* Diethylhexyl phthalate	117-81-7	5E+1	3E-3	3E-1	1E-2	8270
4-Bromophenyl phenyl ether	101-55-3			3E-1	1E-2	8270
Butyl benzyl phthalate	85-68-7	1E+3	9E0	3E-1	1E-2	8270
p-Chloroaniline	106-47-8	3E+2	1E-1	3E-1	1E-2	8270
p-Chloro-m-cresol	59-50-7	1E+3	2E-1	3E-1	1E-2	8270
2-Chloronaphthalene	91-58-7			3E-1	1E-2	8270
2-Chlorophenol	95-57-8	4E+2	2E-1	3E-1	1E-2	8270
Chrysene	218-01-9	4E0	2E-4	2E-2	2E-3	8310
m-Cresol	108-39-4	1E+3	2E0	3E-1	1E-2	8270
o-Cresol	95-48-7	1E+3	2E0	3E-1	1E-2	8270
p-Cresol	106-44-5	1E+3	2E0	3E-1	1E-2	8270
Dibenz[a,h]anthracene	53-70-3	1E-2	7E-7	2E-2	3E-4	8310
Di-n-butyl phthalate	84-74-2	1E+3	4E0	3E-1	1E-2	8270
o-Dichlorobenzene	95-50-1	1E+3	3E0	1E-2	1E-2	8260 (8270)
m-Dichlorobenzene	541-73-1	1E+3	3E0	5E-3	5E-3	8260 (8270)
p-Dichlorobenzene	106-46-7	4E+2	7.5E-2	5E-3	5E-3	8260 (8270)
3,3'-Dichlorobenzidine	91-94-1	2E0	8E-5	1E0	2E-2	8270
2,4-Dichlorophenol	120-83-2	2E+2	1E-1	3E-1	1E-2	8270
Diethyl phthalate	84-66-2	1E+3	3E+1	3E-1	1E-2	8270
2,4-Dimethylphenol	105-67-9	4E+2	2E-2	3E-1	1E-2	8270
Dimethyl phthalate	131-11-3	1E+3	4E+2	3E-1	1E-2	8270
4,6-Dinitro-o-cresol	534-52-1	8E+1	4E-2	5E0	5E-2	8270
2,4-Dinitrophenol	51-28-5	2E+2	7E-2	2E0	5E-2	8270
2,4-Dinitrotoluene	121-14-2	1E0	5E-5	3E-1	1E-2	8270
2,6-Dinitrotoluene	606-20-2			3E-1	1E-2	8270
Di-n-octyl phthalate	117-84-0			3E-1	1E-2	8270
Fluoranthene	206-44-0	5E+2	2E-1	3E-1	1E-2	8270
Hexachlorobenzene	118-74-1	4E-1	2E-5	3E-2	5E-4	8120
Hexachlorobutadiene	87-68-3	9E+1	5E-3	5E-3	5E-3	8260 (8120)
Hexachlorocyclopentadiene	77-47-4	6E+2	2E-1	3E-1	1E-2	8270
Hexachloroethane	67-72-1	8E+1	3E-1	3E-1	1E-2	8270
Indeno[1,2,3-cd]pyrene	193-39-5	4E+1	2E-3	3E-2	4E-4	8310
Naphthalene	91-20-3	1E+3	1E+1	5E-3	5E-3	8260
p-Nitroaniline	100-01-6			1E0	2E-2	8270
Nitrobenzene	98-95-3	4E+1	2E-2	3E-1	1E-2	8270
p-Nitrophenol	100-02-7			3E0	5E-2	8270
N-Nitrosodiphenylamine	86-30-6	1E+2	7E-3	3E-1	1E-2	8270
N-Nitrosodi-n-propylamine	621-64-7	1E-1	5E-6	3E-1	1E-2	8270
Pentachlorophenol	87-86-5	1E+3	1E0	2E0	5E-2	8270
Phenanthrene	85-01-8	4E+1	2E-3	5E-1	7E-3	8310
Phenol	108-95-2	1E+3	2E+1	3E-1	1E-2	8270

SEMIVOLATILES (Continued)

HAZARDOUS CONSTITUENT	CAS NO.	HBN SOIL mg/kg	HBN WATER mg/l	PQL SOIL mg/kg	PQL WATER mg/l	SUGGESTED METHOD
Pyrene	129-00-0	1E+3	4E0	3E-1	1E-2	8270
1,2,4-Trichlorobenzene	120-82-1	1E+3	7E-1	1E-2	1E-2	8260 (8270)
2,4,5-Trichlorophenol	95-95-4	1E+3	4E0	2E0	5E-2	8270
2,4,6-Trichlorophenol	88-06-2	4E+1	2E-3	6E-1	1E-2	8270

METALS

HAZARDOUS CONSTITUENT	CAS NO.	HBN SOIL mg/kg	HBN WATER mg/l	PQL SOIL mg/kg	PQL WATER mg/l	SUGGESTED METHOD
Antimony	7440-36-0	3E+1	1E-2	2E+1	3E-2	6010(s) 7041(w)
Arsenic	7440-38-2	5E-1	5E-2	3E+1	1E-2	6010(s) 7060(w)
Barium	7440-39-3	1E+3	1E0	1E0	2E-2	6010
Beryllium	7440-41-7	1E-1	7E-6	2E-1	3E-3	6010
Cadmium	7440-43-9	4E+1	1E-2	2E0	1E-3	6010(s) 7131(w)
Chromium	7440-47-3	4E+2	5E-2	4E0	1E-2	6010(s) 7191(w)
Lead	7439-92-1		5E-2	2E0	1E-2	6010(s) 7421(w)
Mercury	7439-97-6	2E+1	2E-3	1E-1	2E-3	7470
Nickel	7440-02-0	1E+3	7E-1	3E0	5E-2	6010
Selenium	7782-49-2	2E+2	1E-2	4E+1	2E-2	6010(s) 7740(w)
Silver	7440-22-4	2E+2	5E-2	4E0	2E-3	6010(s) 7761(w)
Thallium	7440-28-0	6E0	3E-3	2E+1	1E-2	6010(s) 7870(w)

EXPLOSIVES

Cyclotrimethylenetrinitramine - RDX
1,3,5,7-tetranitro-1,3,5,7-tetraazacyclooctane - HMX
Trinitrotoluene - TNT
2,4,6-Trinitrophenol-methylnitramine - Tetryl
2,6-Dinitrotoluene
2,4-Dinitrotoluene

In the submitted work plans, the Permittee shall identify the Health Based Number and Method Detection Limits to be used for the above consitituents.

APPENDIX C: DATA MANAGEMENT TRACKING FORM

TABLE C-1

Data Management and Sample Tracking
Radford Army Ammunition Plant, Virginia

Site	Sample ID[a]	Sample Matrix[b]	Site Type[c]	IRDMS File[d]	Sample Technique[e]	Sample Date	Sample Depth
SWMU 13	13SB1A	SO	BORE	CSO	G		
	13SB1B	SO	BORE	CSO	G		
	13SB1C	SO	BORE	CSO	G		
	13SB2A	SO	BORE	CSO	G		
	13SB2B	SO	BORE	CSO	G		
	13SB2C	SO	BORE	CSO	G		
	13SB3A	SO	BORE	CSO	G		
	13SB3B	SO	BORE	CSO	G		
	13SB3C	SO	BORE	CSO	G		
	13SB4A	SO	BORE	CSO	G		
	13SB4B	SO	BORE	CSO	G		
	13SB4C	SO	BORE	CSO	G		
	13SB5A	SO	BORE	CSO	G		
	13SB5B	SO	BORE	CSO	G		
	13SB5C	SO	BORE	CSO	G		
	13SB6A	SO	BORE	CSO	G		
	13SB6B	SO	BORE	CSO	G		
	13SB6C	SO	BORE	CSO	G		
	13SC1A	SO	BORE	CSO	C		
	13SC1B	SO	BORE	CSO	C		
	13SC1C	SO	BORE	CSO	C		
	13SC2A	SO	BORE	CSO	C		
	13SC2B	SO	BORE	CSO	C		
	13SC2C	SO	BORE	CSO	C		
	13SC3A	SO	BORE	CSO	C		
	13SC3B	SO	BORE	CSO	C		
	13SC3C	SO	BORE	CSO	C		
	13SC4A	SO	BORE	CSO	C		
	13SC4B	SO	BORE	CSO	C		
	13SC4C	SO	BORE	CSO	C		
	13SC5A	SO	BORE	CSO	C		
	13SC5B	SO	BORE	CSO	C		
	13SC5C	SO	BORE	CSO	C		
	13SC6A	SO	BORE	CSO	C		
	13SC6B	SO	BORE	CSO	C		
	13SC6C	SO	BORE	CSO	C		
	13SC7A	SO	BORE	CSO	C		

TABLE C-1 (cont'd)

Site	Sample ID[a]	Sample Matrix[b]	Site Type[c]	IRDMS File[d]	Sample Technique[e]	Sample Date	Sample Depth
SWMU 13 (cont'd)	13SC7B	SO	BORE	CSO	C		
	13SC7C	SO	BORE	CSO	C		
	13SC8A	SO	BORE	CSO	C		
	13SC8B	SO	BORE	CSO	C		
	13SC8C	SO	BORE	CSO	C		
	13SS1	SO	PIT	CSO	G		
	13SS2	SO	PIT	CSO	G		
	13SS3	SO	PIT	CSO	G		
	13SS4	SO	PIT	CSO	G		
	13SE1	SE	POND	CSE	G		
	13SE2	SE	POND	CSE	G		
	13SW1	SW	POND	CSW	G		
	13MW1	GW	WELL	CGW	B		
	13MW2	GW	WELL	CGW	B		
	13MW3	GW	WELL	CGW	B		
	13MW4	GW	WELL	CGW	B		
	13MW5	GW	WELL	CGW	B		
	13MW6	GW	WELL	CGW	B		
	13MW7	GW	WELL	CGW	B		
SWMU 17	17ASS1A	SO	PIT	CSO	G		
	17ASS1B	SO	PIT	CSO	G		
	17ASS2A	SO	PIT	CSO	G		
	17ASS2B	SO	PIT	CSO	G		
	17ASW1	SW	PIT	CSW	G		
	17BSE1	SE	BASN	CSE	G		
	17CSS1A	SO	PIT	CSO	G		
	17CSS1B	SO	PIT	CSO	G		
	17CSS2A	SO	PIT	CSO	G		
	17CSS2B	SO	PIT	CSO	G		
	17DSS1A	SO	PIT	CSO	G		
	17DSS1B	SO	PIT	CSO	G		
	17DSS2A	SO	PIT	CSO	G		
	17DSS2B	SO	PIT	CSO	G		
	17ESW1	SW	POND	CSW	G		
	17ESE2	SE	POND	CSE	G		

TABLE C-1 (cont'd)

Site	Sample ID[a]	Sample Matrix[b]	Site Type[c]	IRDMS File[d]	Sample Technique[e]	Sample Date	Sample Depth
SWMUs 28/51/52	28MW1	GW	WELL	CGW	B		
	28MW2	GW	WELL	CGW	B		
	28MW3	GW	WELL	CGW	B		
	51MW1	GW	WELL	CGW	B		
	51MW2	GW	WELL	CGW	B		
	WC2-A	GW	WELL	CGW	B		
	16-1	GW	WELL	CGW	B		
	16-3	GW	WELL	CGW	B		
	16-4	GW	WELL	CGW	B		
	MW9	GW	WELL	CGW	B		
	C3	GW	WELL	CGW	B		
	C4	GW	WELL	CGW	B		
	CDH2	GW	WELL	CGW	B		
	WC1-A	GW	WELL	CGW	B		
SWMU O	OSB1A	SO	BORE	CSO	S		
	OSB1B	SO	BORE	CSO	S		
	OSB2A	SO	BORE	CSO	S		
	OSB2B	SO	BORE	CSO	S		
	OSB3A	SO	BORE	CSO	S		
	OSB3B	SO	BORE	CSO	S		
	OSB4A	SO	BORE	CSO	S		
	OSB4B	SO	BORE	CSO	S		
	OSB5A	SO	BORE	CSO	S		
	OSB5B	SO	BORE	CSO	S		
	OSB6A	SO	BORE	CSO	S		
	OSB6B	SO	BORE	CSO	S		
	OSB7	SO	BORE	CSO	S		
	OSB8	SO	BORE	CSO	S		
	OSB9	SO	BORE	CSO	S		
	OSB10	SO	BORE	CSO	S		
	OSB11	SO	BORE	CSO	S		
	OSB12	SO	BORE	CSO	S		
	P1	GW	WELL	CGW	B		
	P2	GW	WELL	CGW	B		
	P3	GW	WELL	CGW	B		
	P4	GW	WELL	CGW	B		
	S4W1	GW	WELL	CGW	B		
	S4W4	GW	WELL	CGW	B		
	8B	GW	WELL	CGW	B		

TABLE C-1 (cont'd)

Site	Sample ID[a]	Sample Matrix[b]	Site Type[c]	IRDMS File[d]	Sample Technique[e]	Sample Date	Sample Depth
SWMU O (cont'd)	WC1-1	GW	WELL	CGW	B		
	OMW1	GW	WELL	CGW	B		
	OMW2	GW	WELL	CGW	B		
	OSE1	SE	DTCH	CSE	G		
	OSE2	SE	DTCH	CSE	G		
TRIP BLNK	TB1	SW	QCBL	CQC	G		
	TB2	SW	QCBL	CQC	G		
	TB3	SW	QCBL	CQC	G		
EQO BLNK	EQB1	SW	QCBL	CQC	G		
	EQB2	SW	QCBL	CQC	G		
	EQB3	SW	QCBL	CQC	G		
FLD BLNK	FB1	SW	QCFB	CQC	G		
	FB2	SW	QCFB	CQC	G		
	FB3	SW	QCFB	CQC	G		

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[a] Sample IDs:

MW - groundwater from monitoring well
SB - soil boring
SE - sediment
SS - surface soil
SW - surface water
Other codes derived from existing well identification numbers.

[b] Sample matrix:

GW - groundwater
SO - soil
SE - sediment
SW - surface water

[c] Site types:

BORE - boring
WELL - well
BASN - basin
DTCH - ditch or drainage
PIT - shovel or hand auger sample
POND - pond

TABLE C-1 (cont'd)

QCBL - blank
QCFS - field blank

[d]IRDMS file:
CGW - groundwater
CQC - chemical quality control
CSE - sediment
CSO - soil
CSW - surface water

[e]Sample technique:
B - bail
C - composite grab
G - grab or discreet sample
S - split-spoon core sample