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Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

WAYNE INTERIM STORAGE SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1989

Wayne, New Jersey

May 1990

Bechtel National, Inc.

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WAYNE INTERIM STORAGE SITE
ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1989

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Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

Under Contract No. DE-AC05-81OR20722

By

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Oak Ridge, Tennessee

Bechtel Job No. 14501

SUMMARY ASSESSMENT
ENVIRONMENTAL COMPLIANCE ACTIVITY
U.S. DEPARTMENT OF ENERGY
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM
WAYNE INTERIM STORAGE SITE

BACKGROUND AND OVERVIEW

To evaluate the environmental compliance record of the Wayne Interim Storage Site (WISS), managed as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), it is necessary to describe the history of the site.

From 1948 through 1971, Rare Earths, Inc./W.R. Grace and Company processed monazite sand to extract thorium and rare earths. In 1954, after the Atomic Energy Act was passed, Rare Earths received a U.S. Atomic Energy Commission (AEC) license to conduct these operations. The Davison Chemical Division of W.R. Grace acquired the facility in 1957, and processing activities continued until July 1971. During this time, some process wastes from the thorium operations were buried on site, and some were neutralized before being released to a local storm drain as liquid effluent. The storm drain emptied into Sheffield Brook, which overflowed its banks during periods of heavy rainfall. This resulted in contamination from thorium processing operations being spread to nearby low-lying properties.

Thorium and rare earths were extracted by dissolving monazite sand in a strong acid and, at the proper pH, adding a reagent to selectively precipitate the thorium/rare earth mixture, which was in turn separated by further selective precipitation. Wastes and residues from the processing operations typically contained less than 5 percent of the original thorium concentration. These residues included ore tailings, yttrium sludges, and sulfate precipitates.

When processing ceased in 1971, the facility was licensed for storage only. The site was partially decontaminated by W.R. Grace in 1974. Some buildings were razed; the rubble and processing equipment were buried on the property. Remaining buildings were decontaminated and disposal areas were covered with clean fill to reduce radiation levels to below 0.2 mR/h.

In 1974, the U.S. Nuclear Regulatory Commission assumed licensing responsibilities formerly held by AEC. The storage license for the W.R. Grace plant was terminated in 1975 following site decommissioning.

In 1984, the site was assigned to the U.S. Department of Energy (DOE) as part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Appropriations Act. DOE placed responsibility for the site under its existing program, FUSRAP. WISS is currently used by DOE as an interim storage area for contaminated materials removed during cleanup of the site and vicinity properties. In June 1986, WISS was placed on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL).

During its history, WISS has been subject to evolving federal and state environmental regulations. The following summary describes compliance requirements as they currently exist.

Clean Air Act (CAA) and National Emission Standards for Hazardous Air Pollutants (NESHAPs)

WISS does not have any state or federal air permits. As a non-operating facility, only Subpart H of NESHAPs is applicable. Subpart Q of NESHAPs does not apply to WISS, because calculations show that the waste material does not contain radium-226 of sufficient concentration to emit radon-222 in excess of the standard prior to remedial action. Compliance with the non-radon radionuclide standard in Subpart H will be determined by evaluating the site using a computer model (e.g., AIRDOS-PC) approved by EPA.

DOE Orders for Radionuclide Releases

Site releases must comply with specific DOE orders that place quantitative limits, called derived concentration guides (DCGs), and dose limits for radiological releases from DOE facilities. Results of environmental monitoring conducted in 1989 show that WISS is in compliance with applicable DOE orders.

Clean Water Act (CWA)

WISS does not have any state or federal water permits and has only stormwater discharge. An environmental compliance assessment conducted by Oak Ridge National Laboratory (ORNL) in October 1989 did not find any deficiencies under the CWA. The amendments to the CWA in 1987 required EPA to promulgate regulations requiring permits for stormwater discharges from industrial facilities; therefore, a stormwater discharge permit may be required in the future.

Resource Conservation and Recovery Act (RCRA)

As stated in CERCLA 121, Superfund remedial actions must comply with substantive requirements of RCRA and other environmental laws when they are applicable or relevant and appropriate. RCRA permits are not required for on-site actions. RCRA-regulated waste is not known to be present at WISS. Additionally, an environmental compliance assessment conducted by ORNL in October 1989 did not find any deficiencies under RCRA.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Because WISS is on the NPL, a Federal Facilities Agreement (FFA) is required for site remedial action. EPA and DOE have negotiated an FFA that is awaiting signature.

Toxic Substances Control Act (TSCA)

As stated in CERCLA 121, Superfund remedial actions must comply with substantive requirements of TSCA and other environmental laws when they are applicable or relevant and appropriate. TSCA-regulated waste is not known to be present at WISS. The environmental compliance assessment of the site by ORNL did not find any deficiencies under TSCA.

National Environmental Policy Act (NEPA)

In the past, compliance with NEPA has been accomplished through the use of action description memoranda and corresponding memoranda-to-file. Actions taken to date have been determined to have no significant impact on the environment. Henceforth, compliance with NEPA for WISS remedial actions will be accomplished by incorporating those elements required by an environmental impact study into the format of the CERCLA remedial investigation/feasibility study.

ABSTRACT

The environmental monitoring program, begun in 1984, was continued in 1989 at the Wayne Interim Storage Site (WISS), a U.S. Department of Energy (DOE) facility located in Wayne Township, New Jersey. The WISS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to decontaminate or otherwise control sites where residual radioactive material remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. As part of the decontamination research and development program authorized by Congress under the 1984 Energy and Water Appropriations Act, remedial action was conducted at the site and at vicinity properties by Bechtel National, Inc. (BNI), project management contractor for FUSRAP. The environmental monitoring program is also carried out by BNI.

The monitoring program at WISS measures radon and thoron concentrations in air; external gamma radiation levels; and uranium, radium, and thorium concentrations in surface water, groundwater, and sediment. Additionally, several nonradiological parameters are measured in groundwater. The radiation dose was calculated for a hypothetical maximally exposed individual to verify that the site is in compliance with the DOE radiation protection standard (100 mrem/yr) and to assess its potential effects on public health. Based on the conservative scenario described in the report, this hypothetical individual receives an annual external exposure approximately equivalent to 2.7 percent of the DOE radiation protection standard. By comparison, this exposure is approximately the same as a person receives during a flight from New York City to Los Angeles as a result of greater amounts of cosmic radiation at higher altitudes. The cumulative dose to the population within an 80-km (50-mi) radius of WISS that results from radioactive materials present at the site is indistinguishable from the dose that the same population receives from naturally occurring radioactive sources. Results of the 1989 monitoring show that WISS is in compliance with the DOE radiation protection standard.

CONTENTS

FIGURES

TABLES

TABLES

(continued)

1.0 INTRODUCTION

This report presents the findings of the environmental monitoring program conducted at the Wayne Interim Storage Site (WISS) during calendar year 1989. Environmental monitoring has been conducted at WISS since 1984 as part of the decontamination research and development program authorized by Congress under the 1984 Energy and Water Appropriations Act. The work is being performed as part of the U.S. Department of Energy (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP); Bechtel National, Inc. (BNI) is conducting remedial action at the site and at vicinity properties.

1.1 LOCATION AND DESCRIPTION

WISS is located at 868 Black Oak Ridge Road in Wayne Township, Passaic County, New Jersey, approximately 1.6 km (1 mi) east of Pompton Plains in Pequannock Township (Figure 1-1). WISS is situated on a 2.6-ha (6.5-acre) parcel that includes an office building and an interim waste storage area, as shown in Figure 1-2. The office building is a two-story masonry structure, about 44 m (145 ft) long and 14 m (45 ft) wide. The site is accessible from Black Oak Ridge Road, which runs along the western boundary of the property. Figure 1-3 is an aerial photograph of the site and its vicinity.

WISS is located within the glaciated section of the Piedmont Plateau of north-central New Jersey. The ground surface at WISS rises from 60 m (197 ft) above mean sea level (msl) near the northwestern corner to 69.5 m (228 ft) above msl at the eastern side. The site is underlain by glacial deposits consisting of boulders, gravel, sand, silt, and clay. Based on observations made during the installation of six shallow observation wells in December 1982, it was concluded that the materials underlying the site are unstratified till deposits (Ref. 1). Available data (Ref. 1) and well logs for the area indicate that the thickness of

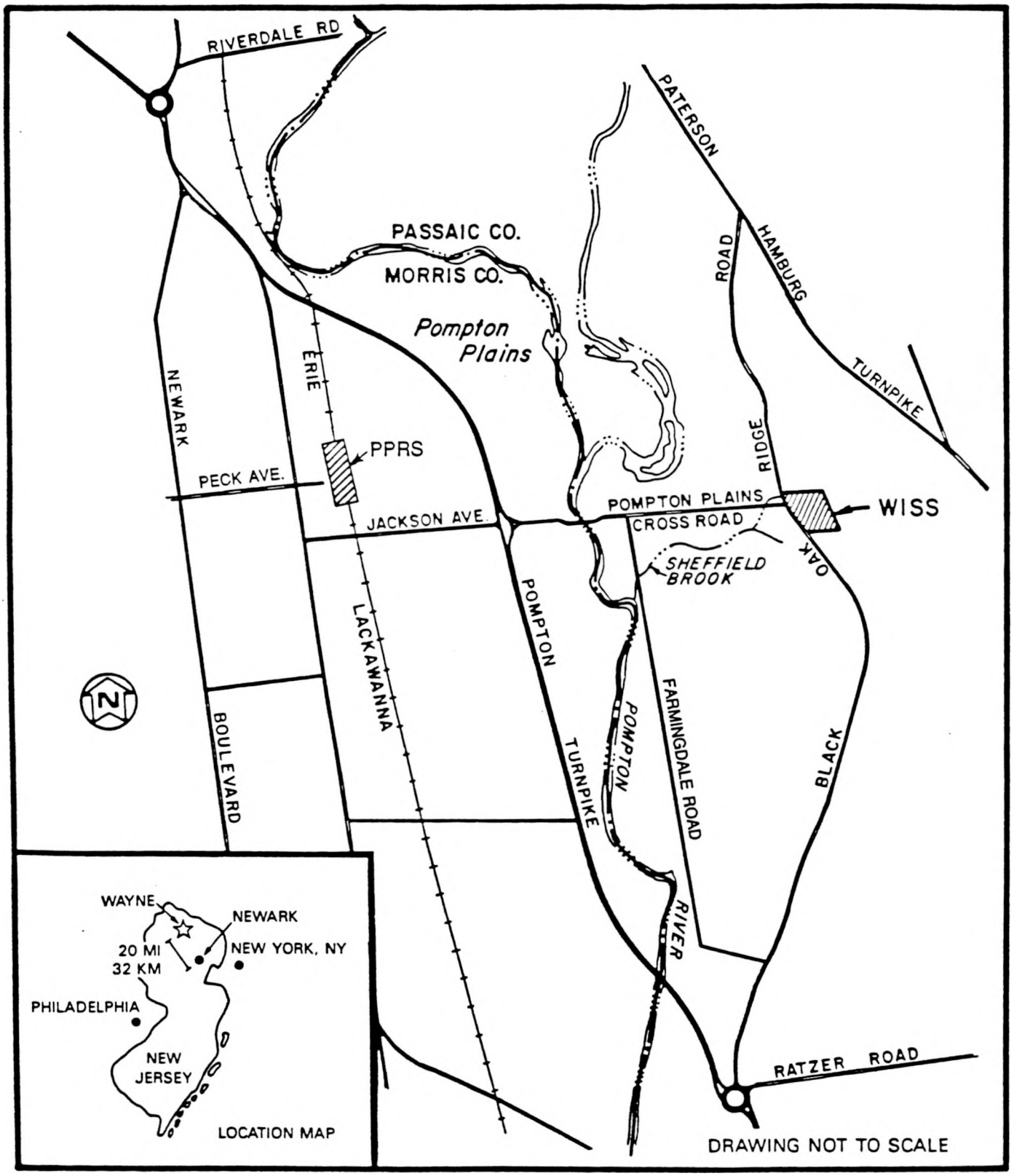

FIGURE 1-1 LOCATION OF WISS

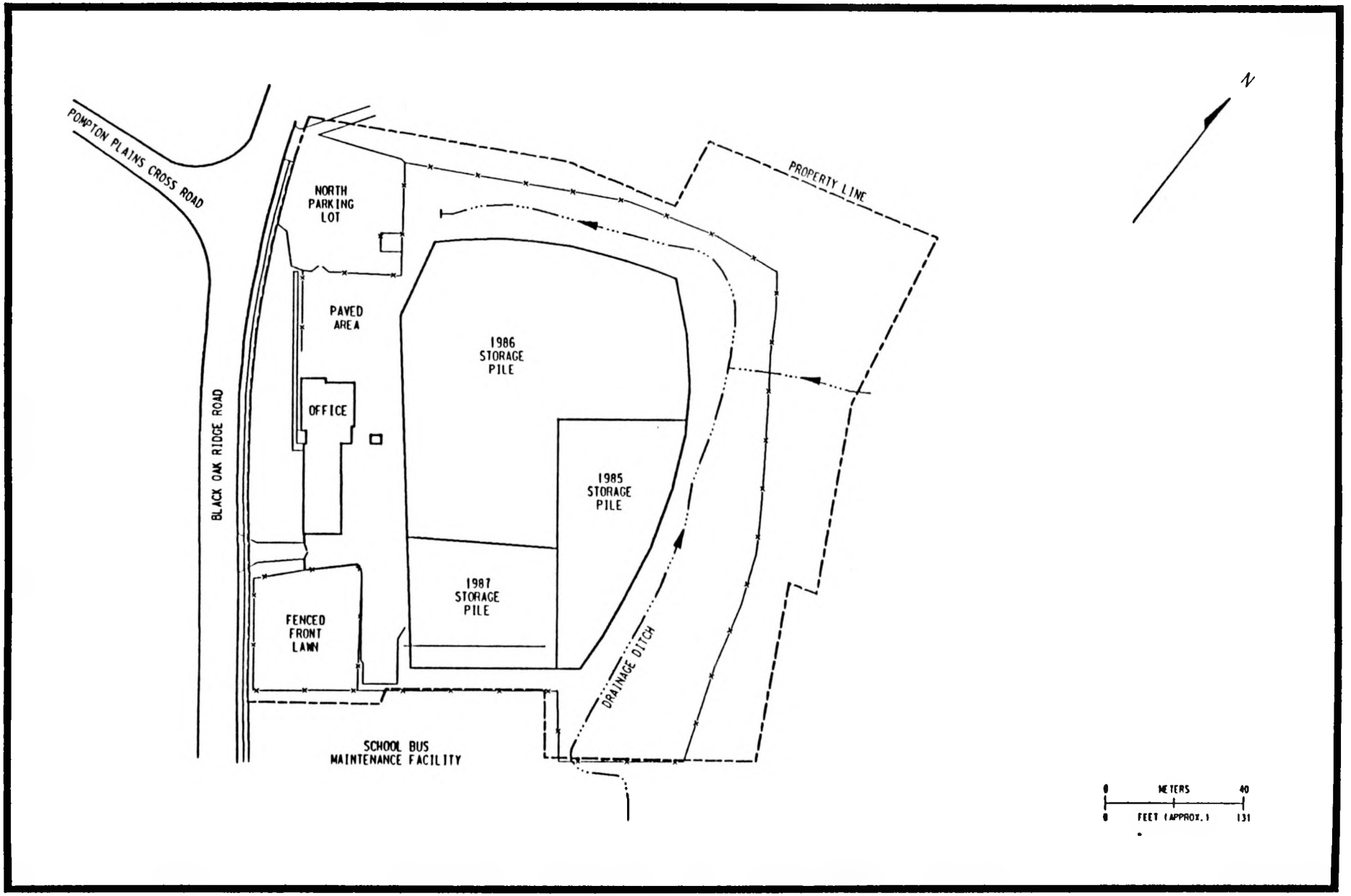

FIGURE 1-2 SITE PLAN OF WISS

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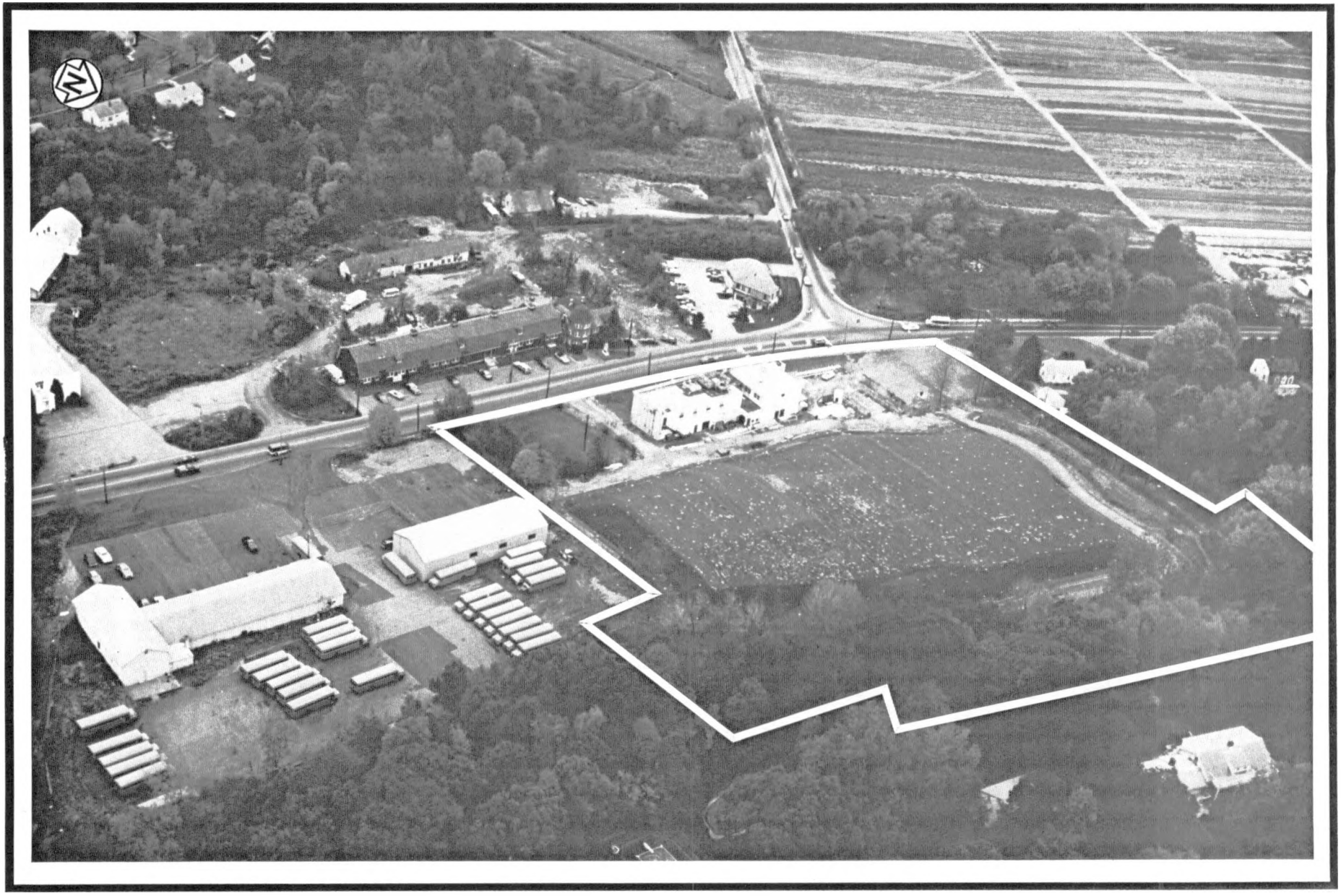


FIGURE 1-3 AERIAL VIEW OF WISS

the unconsolidated glacial deposits beneath the site ranges from 6.1 to 15 m (20 to 50 ft). The drilling log for an on-site bedrock well shows 11 m (37 ft) of unconsolidated deposits at the site. The Brunswick formation underlies the unconsolidated glacial deposits. This bedrock formation typically consists of alternating beds of reddish-brown sandstone and mudstone. Unconsolidated surface materials from the northern and eastern portions of the site were used by the previous owner to cover waste disposal pits containing processing residues (Ref. 2).

Groundwater in the vicinity of WISS is found in both the unconsolidated glacial deposits and the underlying bedrock. The occurrence and movement of groundwater in the unconsolidated deposits are controlled by intergranular openings in the deposits, whereas groundwater in the consolidated bedrock occurs in and moves through cleavage planes, joints, and fractures. These secondary openings in the bedrock form a relatively small volume in comparison with the total volume of rock. These openings also become fewer and narrower with increasing depth.

Groundwater in the unconsolidated material in the stratified glacial deposits is an important source of water for public supply and industrial use in Wanaque, Pompton Lakes, and along the western side of Wayne Township. These residential areas are approximately 6, 3, and 6 km (4, 2, and 4 mi), respectively, from the site. However, for the most part, these unconsolidated deposits have not been extensively explored and represent a potentially important source of groundwater for future development (Ref. 3). Currently, the Brunswick formation is the major source of groundwater for public supply and industrial use in Passaic County.

Groundwater flow in the unconsolidated deposits beneath the site is to the west-northwest (Ref. 1). Measured groundwater levels in on-site wells, however, indicated a highly variable groundwater surface. This may be due to the heterogeneous nature of the underlying deposits as well as to disturbance caused by on-site waste disposal areas. The direction of groundwater flow in the bedrock near the site has not yet been determined, but is

probably to the west-southwest. According to the United States Geological Survey (Ref. 3), groundwater flow in the Brunswick formation is generally along strike formations within tabular aquifers separated by zones that inhibit the flow of water.

The site is situated along the base of a northeast-trending ridge with a total relief across the site of approximately 15 m (50 ft). Surface water drainage on the site is controlled by a system of drainage ditches. The water flows into an on-site catch basin before being discharged into an off-site storm sewer (Ref. 4) and then into Sheffield Brook, which flows into the Pompton River.

The average frequency of precipitation in the area is 120 days per year, and the mean annual precipitation is approximately 122 cm (48 in.). The average annual snowfall is 73.9 cm (29.1 in.). The prevailing winds are from the northwest from October through April and from the southwest during the summer months (Ref. 5). Figure 1-4 is an annual wind rose for the WISS area (Ref. 6).

The population of Passaic County in 1980 was 447,585; the 1980 populations of Wayne and Pequannock townships were 46,474 and 13,776, respectively. The population of Passaic County has continued to increase over the last 50 years; over the next 20 years it is expected to grow by 16 percent (Ref. 7).

WISS is surrounded by commercial and residential properties. Residential properties border WISS on the north, northeast, and east, while commercial properties form the southern and southwestern boundaries. The commercial property on the south is a school bus maintenance facility, where remedial action activities began in 1985 and were completed in 1986. A large truck garden farm lies approximately 91 m (300 ft) northwest of the site. Figure 1-5 shows the generalized land uses in the vicinity of WISS. Future land use in the site vicinity is expected to remain primarily residential but will probably also include public, quasipublic, and industrial park use. Residential development is expected to occur along the Pompton River.

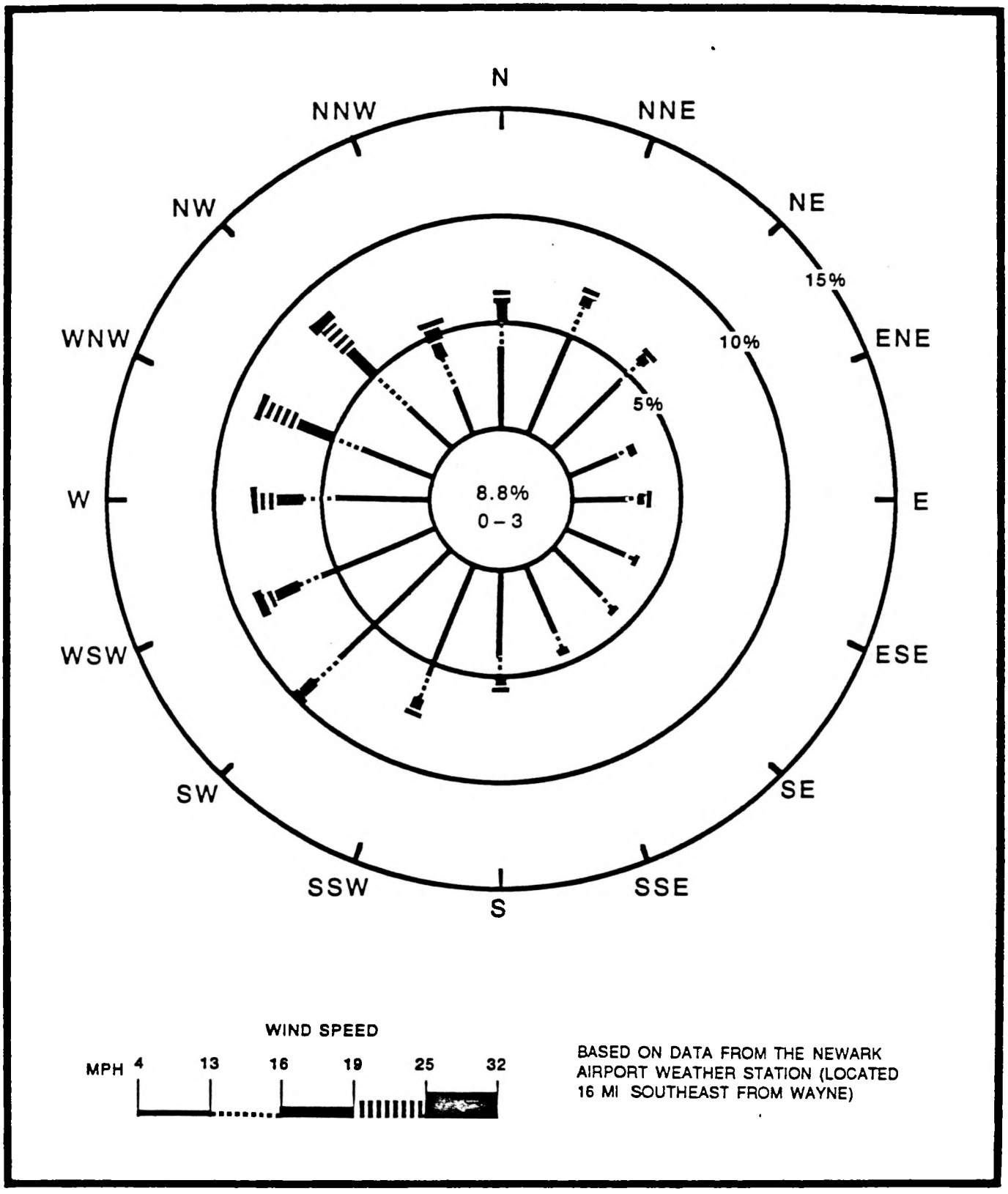
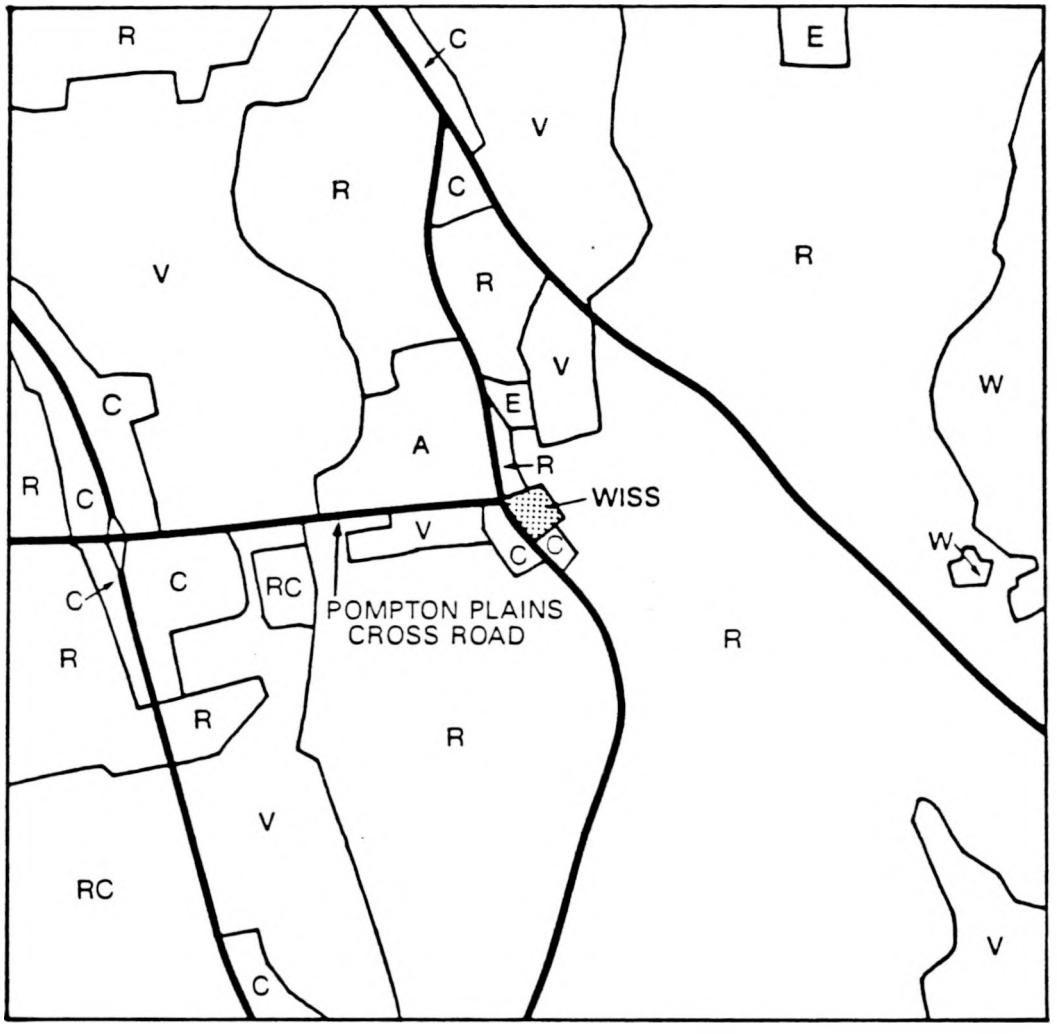


FIGURE 1-4 ANNUAL WIND ROSE FOR WISS



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

A	AGRICULTURAL	RC	RECREATIONAL
C	COMMERCIAL	V	VACANT
E	EDUCATIONAL	W	RESERVOIR
R	RESIDENTIAL		

0 0.5 MI
0 0.8 KM

N

FIGURE 1-5 GENERALIZED LAND USE IN THE VICINITY OF WISS

1.2 SITE HISTORY

From 1948 through 1971, Rare Earths, Inc./W.R. Grace processed monazite sand at the site to extract thorium and rare earths. In 1954, after the Atomic Energy Act was passed, Rare Earths received an Atomic Energy Commission (AEC) license to conduct these operations. The Davison Chemical Division of W.R. Grace acquired the facility in 1957, and processing activities continued until July 1971. During this time, some process wastes from the thorium operations were buried on site, and some were released to local storm drains as liquid effluent. The storm drains emptied into Sheffield Brook, which overflows its banks during periods of heavy rainfall. This caused contamination resulting from thorium processing operations to spread to nearby low-lying properties.

The monazite sand handled by Rare Earths/W.R. Grace came from both domestic and foreign sources, including Idaho, Brazil, India, and Australia. The sand typically included 60 percent rare earth oxides and from 3 to 10 percent thorium oxide. Some of the sand was shipped to the W.R. Grace site by rail and was unloaded at a railroad siding near the east end of Peck Avenue in Pequannock Township, New Jersey (Figure 1-1).

The process used to extract the rare earths and thorium from the monazite in solution involved controlling the pH and selectively precipitating and separating desired products. Wastes and residues from the processing operations typically contained less than 5 percent of the original thorium concentration. These residues included ore tailings, yttrium sludges, and sulfate precipitates. Liquid effluent streams were treated in an on-site waste treatment plant, neutralized, and discharged into Sheffield Brook (Figure 1-1). Residues were disposed of in an on-site sludge dump (Ref. 2).

After processing ceased in 1971, the facility was licensed for storage only. The site was partially decontaminated by W.R. Grace in 1974. Some buildings were razed; the rubble and processing equipment were buried on the property. The remaining buildings

were decontaminated. The disposal areas on the site were covered with clean fill to reduce radiation levels to below 0.2 mrem/h (Ref. 8).

In 1974, the U.S. Nuclear Regulatory Commission assumed licensing responsibilities formerly held by AEC. The storage license for the W.R. Grace plant was terminated in 1975 following site decommissioning.

Since 1984, following assignment of the site to DOE by Congress, WISS has served as an interim storage area for contaminated material removed during cleanup of the site and several vicinity properties. As part of the decontamination research and development program authorized by Congress under the 1984 Energy and Water Appropriations Act, BNI conducted remedial action at the site and at vicinity properties.

An evaluation of previous radiological survey data collected by EG&G (Refs. 9 and 10), Oak Ridge Associated Universities (Refs. 11, 12, and 13), and the New Jersey Department of Environmental Protection (NJDEP) Bureau of Radiation Protection (Refs. 2 and 14) indicated radioactive contamination at four off-site areas:

- Wayne Township Park -- Two small areas at the recreational field bordering Sheffield Brook between Farmingdale Road and the Pompton River (remedial action completed in 1986)

- School bus maintenance facility -- Property immediately south of WISS on Black Oak Ridge Road (remedial action completed in 1986)

- Sheffield Brook area -- From Pompton Plains Cross Road southwest to the Pompton River [approximately 670 m (2200 ft)], including approximately 15 properties along the brook, ditch, and drainage pipe (remedial action completed in 1987)

- Railroad area -- Adjacent to 17 Peck Avenue within the city limits of Pompton Plains [approximately 30 m (100 ft) by 12 m (40 ft)], including the unused railroad siding lying parallel to the Erie Lackawanna Railroad

In 1985, BNI collected additional characterization data from Sheffield Brook (Ref. 15) and WISS (Ref. 16) to supplement previous survey data. These combined data formed the basis for design engineering for the remedial action completed in 1985, the development of the former W.R. Grace property as an interim storage site, and the remedial action to be conducted along Sheffield Brook and on contiguous properties.

In the fall of 1986, a small area at Wayne Township Park and a small area along the fence between WISS and the school bus maintenance facility were both decontaminated, completing the remedial action at these two properties. The yard in front of the office building at the WISS was also decontaminated and restored, and a small quantity of contaminated material was removed from the right-of-way of Pompton Plains Cross Road across the street from WISS.

Also in 1986, the Pompton River was characterized at its confluence with Sheffield Brook. Assessments of characterization data indicated that the contamination was confined to the mouth of the brook and did not extend into the river or downstream. During 1986, contaminated soil in the floodplain of Sheffield Brook and in the stream channel itself was removed between Pompton Plains Cross Road and Farmingdale Road. The work was conducted in accordance with terms specified by an NJDEP stream encroachment permit and a Department of the Army wetlands restoration permit.

In 1987 excavation along the brook was completed in the area between Farmingdale Road and the Pompton River. To perform this work, it was necessary to excavate through the roadbed at Farmingdale Road. Cleanup of the mouth of the brook involved construction of a cofferdam to permit excavation into the backwaters of the Pompton River. Remedial action at the railroad area and the site will be completed when a permanent disposal site is established.

There are no continuing commercial, industrial, or remedial activities at WISS; therefore, there are no radioactive effluents from the site, and waterborne radioactive effluents are limited to extremely low concentrations in surface drainage.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

Hydrogeologic characteristics of the site did not change from those reported in previous years. The unconfined upper system continues to flow from east to west at a gradient of about 0.06. The confined lower groundwater system exhibits artesian characteristics but is presumed to flow from east to west. The data and interpretations presented in this section are based on groundwater levels measured in calendar year 1989. The two groundwater systems monitored were designated "upper" and "lower" in the well installation report (Ref. 17). Groundwater monitoring wells (Figure 1-6) were installed at WISS in late 1984 and early 1985. Five additional wells (two in the lower groundwater system and three in the upper system) were installed in late 1989 but are not yet included as an active part of the monitoring program. A summary of well construction information for active wells included in the monitoring program is shown in Table 1-1. Further background information on site geology, hydrogeology, and well installation methods can be found in Ref. 17. An example of well construction details from Ref. 17 is shown in Appendix E. Groundwater levels at the WISS site were measured weekly with an electric downhole probe water level indicator.

1.3.1 Upper Groundwater System

The unconfined water table in the upper groundwater system occurs approximately 0.3 to 2.1 m (1 to 7 ft) below ground surface. (The water table, or potentiometric surface, is defined as the level to which water will rise in tightly cased wells. The potentiometric surface of an aquifer delineates groundwater slope and flow direction.) Wells in the upper groundwater system are

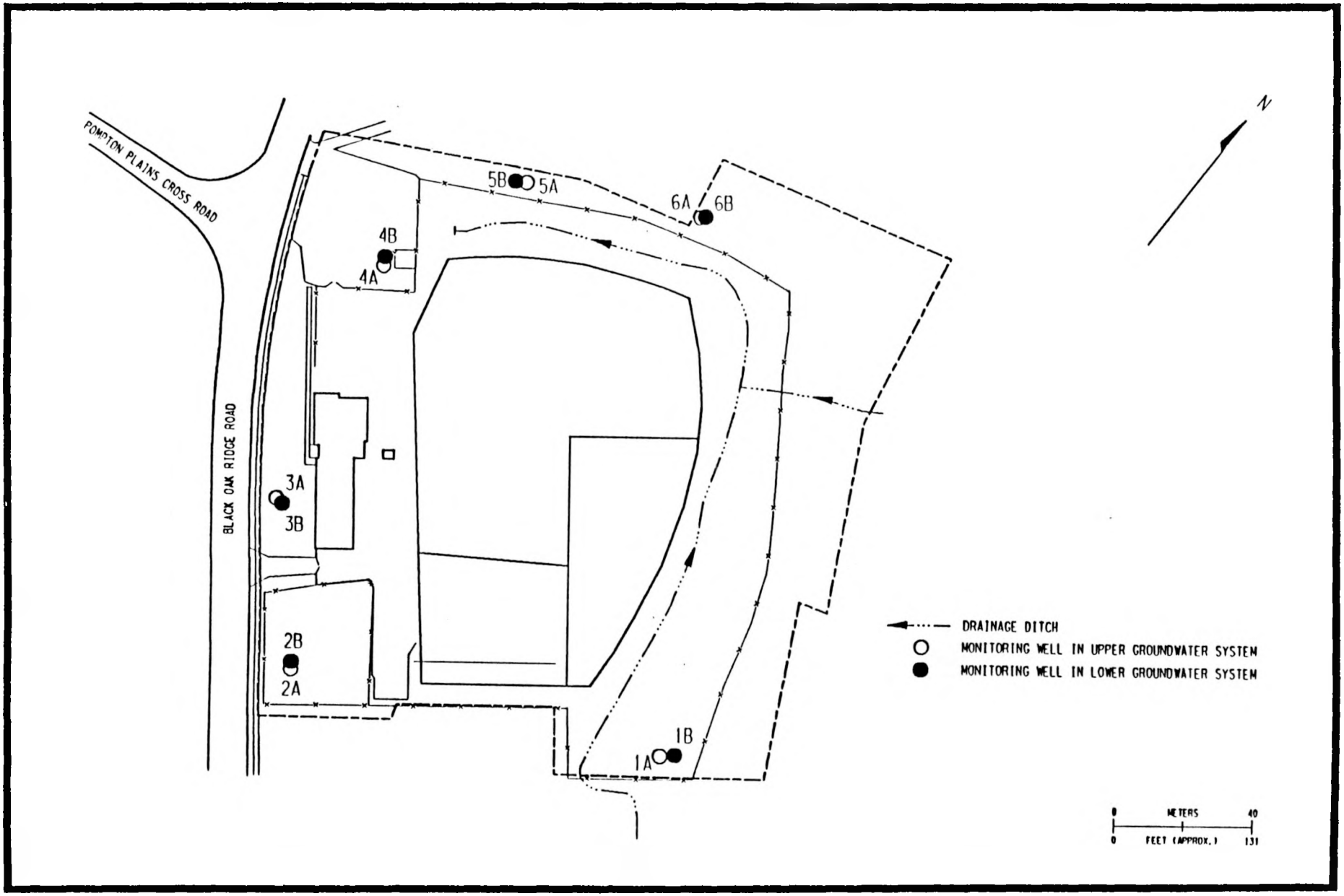


FIGURE 1-6 ACTIVE GROUNDWATER MONITORING LOCATIONS AT WISS

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TABLE 1-1

WISS MONITORING WELL CONSTRUCTION SUMMARY

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitored or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
1A	Nov. 1984	9.8 (32.0)	1.2-9.8 (4.0-32.0)	PVC[b]
1B	Dec. 1984	22.3 (73.0)	13.1-22.3 (43.0-73.0);[c] Open	Steel
2A[d]	Dec. 1982	6.1 (20.0)	4.6-6.1 (15.0-20.0)	PVC
2B	Dec. 1984	23.2 (76.0)	14.0-23.2 (46.0-76.0);[c] Open	Steel
3A	Dec. 1984	5.6 (18.5)	1.4-5.3 (4.5-17.5)	PVC
3B	Jan. 1985	24.1 (79.0)	14.9-24.1 (49.0-79.0);[c] Open	Steel
4A	Dec. 1984	6.1 (20.0)	1.5-6.1 (5.0-20.0)	PVC
4B	Jan. 1985	18.3 (60.0)	9.2-18.3 (30.0-60.0);[c] Open	Steel
5A	Dec. 1984	7.3 (24.0)	1.2-7.3 (4.0-24.0)	PVC
5B	Jan. 1985	18.6 (61.0)	9.5-18.6 (31.0-61.0);[c] Open	Steel
6A	Dec. 1984	5.5 (18.0)	1.5-5.5 (5.0-18.0)	PVC
6B	Jan. 1985	17.1 (56.0)	7.9-17.1 (26.0-56.0);[c] Open	Steel

[a]"A" designates wells installed in upper groundwater system; "B" designates wells in lower system.

[b]PVC - polyvinyl chloride.

[c]Carbon steel casing extends through overburden and 0.6 m (2 ft) into bedrock; monitored interval is a 7.6-cm- (3-in.-) diameter open hole in bedrock.

[d]Formerly designated EN-4.

screened in unconsolidated sands at depths of 1.5 to 9.8 m (5 to 32 ft). Groundwater level elevations measured in 1989 for each well in this system are shown as hydrographs (Figure 1-7). Precipitation records were not available for WISS, but those from the Middlesex Sampling Plant (MSP), a FUSRAP site located approximately 64 km (40 mi) southwest of WISS, are presented (for reference only) beneath the hydrographs in Figure 1-7.

The hydrographs for the upper groundwater system show a slight seasonal fluctuation in groundwater levels; the highest levels were measured in the summer.

The slope and flow direction of the upper groundwater system were calculated from potentiometric surface maps. Two of these maps (Figure 1-8 for May 22 and 1-9 for October 22) are presented to document the minimal seasonal variation in the upper groundwater system. The direction of flow is from east to west on both maps. The slope of the potentiometric surface is approximately parallel to the slope of site topography (Ref. 17). The slope of both potentiometric surfaces is on the order of 0.065.

1.3.2 Lower Groundwater System

Artesian conditions encountered in most of the lower groundwater system wells indicate that the system is confined. These wells are open holes (no screen or filter pack) below a surface casing grouted into the Brunswick formation from depths of 7.9 to 24 m (26 to 79 ft). All of these wells flow at top of casing except well 1B, which is installed near the highest ground surface elevation on the site.

The hydrograph of WISS-1B (Figure 1-10) shows the only lower groundwater system where water level measurements were recorded. The hydrograph compares WISS-1B levels with those of WISS-1A, indicating that general levels are similar but, because of the artesian nature of the lower system, they behave independently. The precipitation records for the MSP site are shown on Figure 1-10 for reference only.

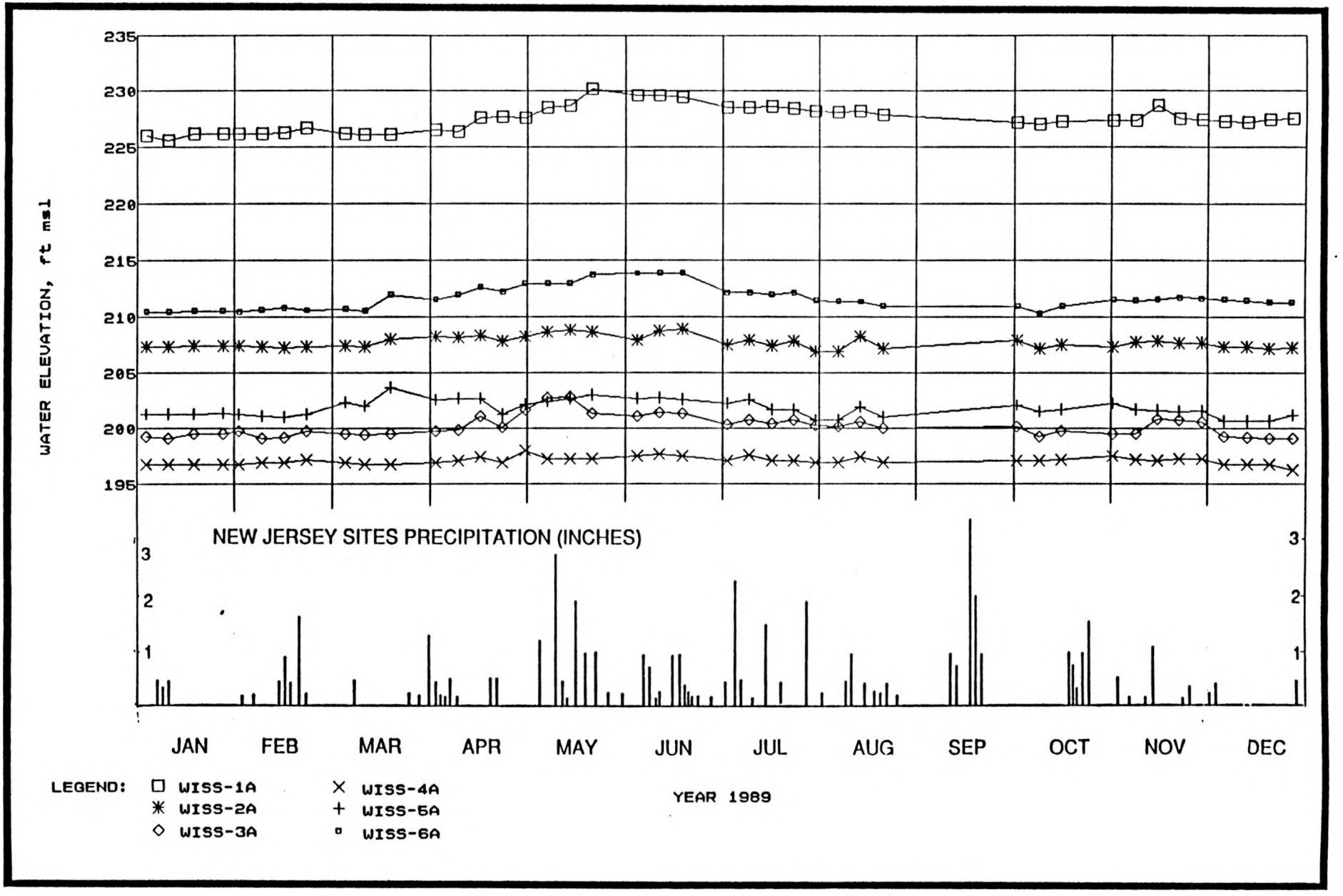

FIGURE 1-7 HYDROGRAPHS OF SHALLOW GROUNDWATER MONITORING WELLS IN THE UPPER GROUNDWATER SYSTEM AT WISS

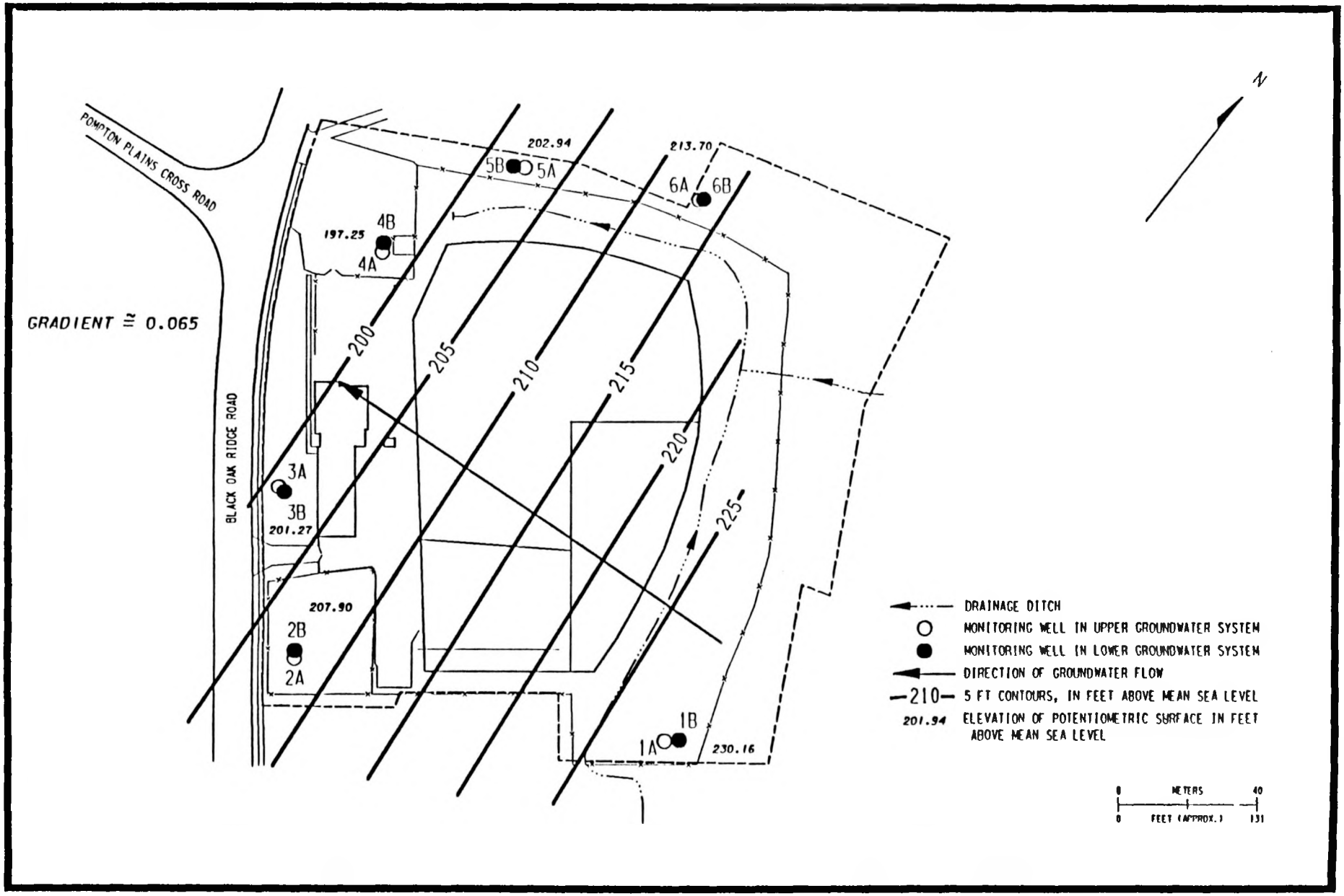

FIGURE 1-8 POTENTIOMETRIC SURFACE MAP OF UPPER GROUNDWATER SYSTEM AT WISS (5/22/89)

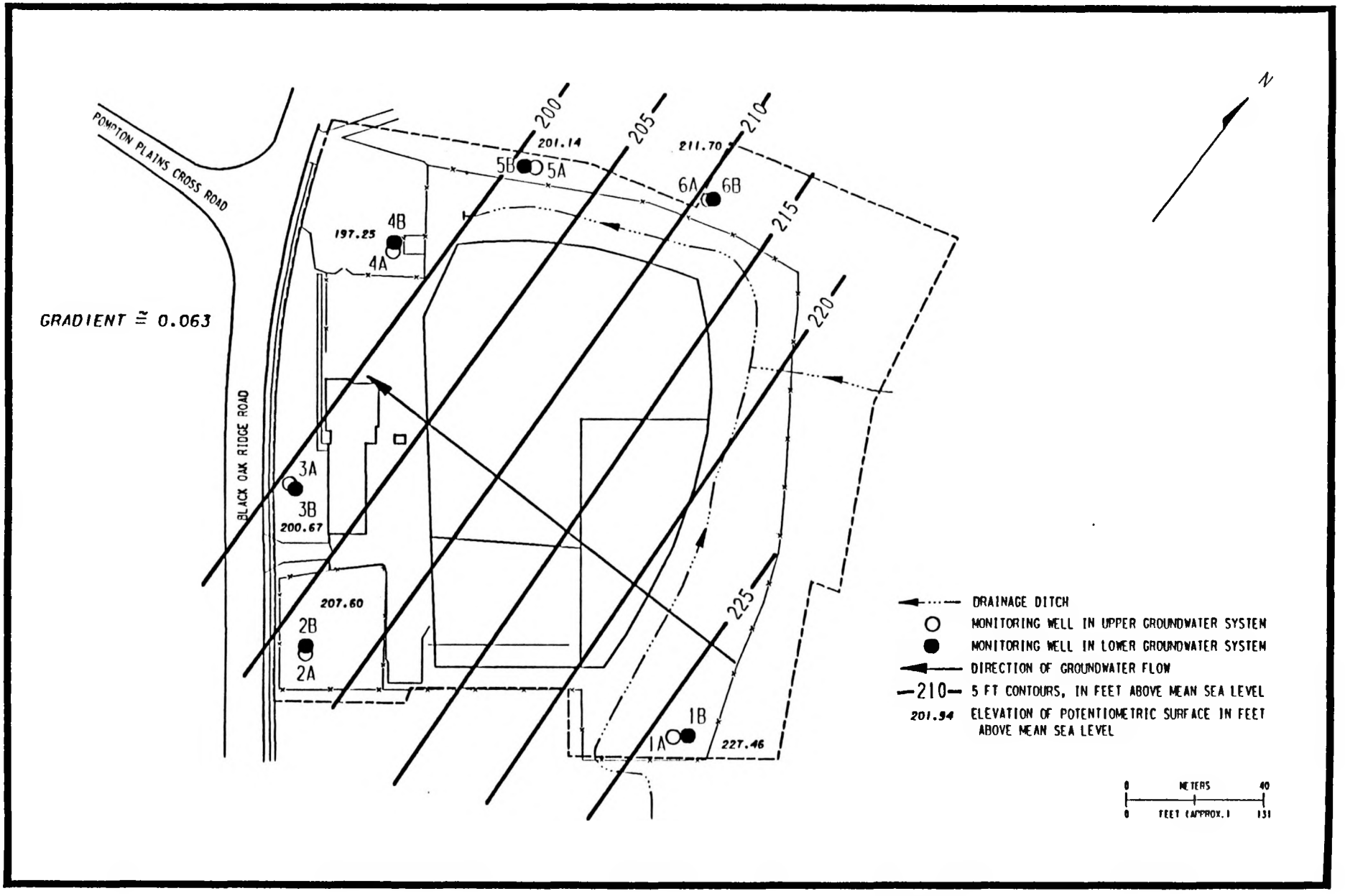

FIGURE 1-9 POTENTIOMETRIC SURFACE MAP OF UPPER GROUNDWATER SYSTEM AT WISS (11/22/89)

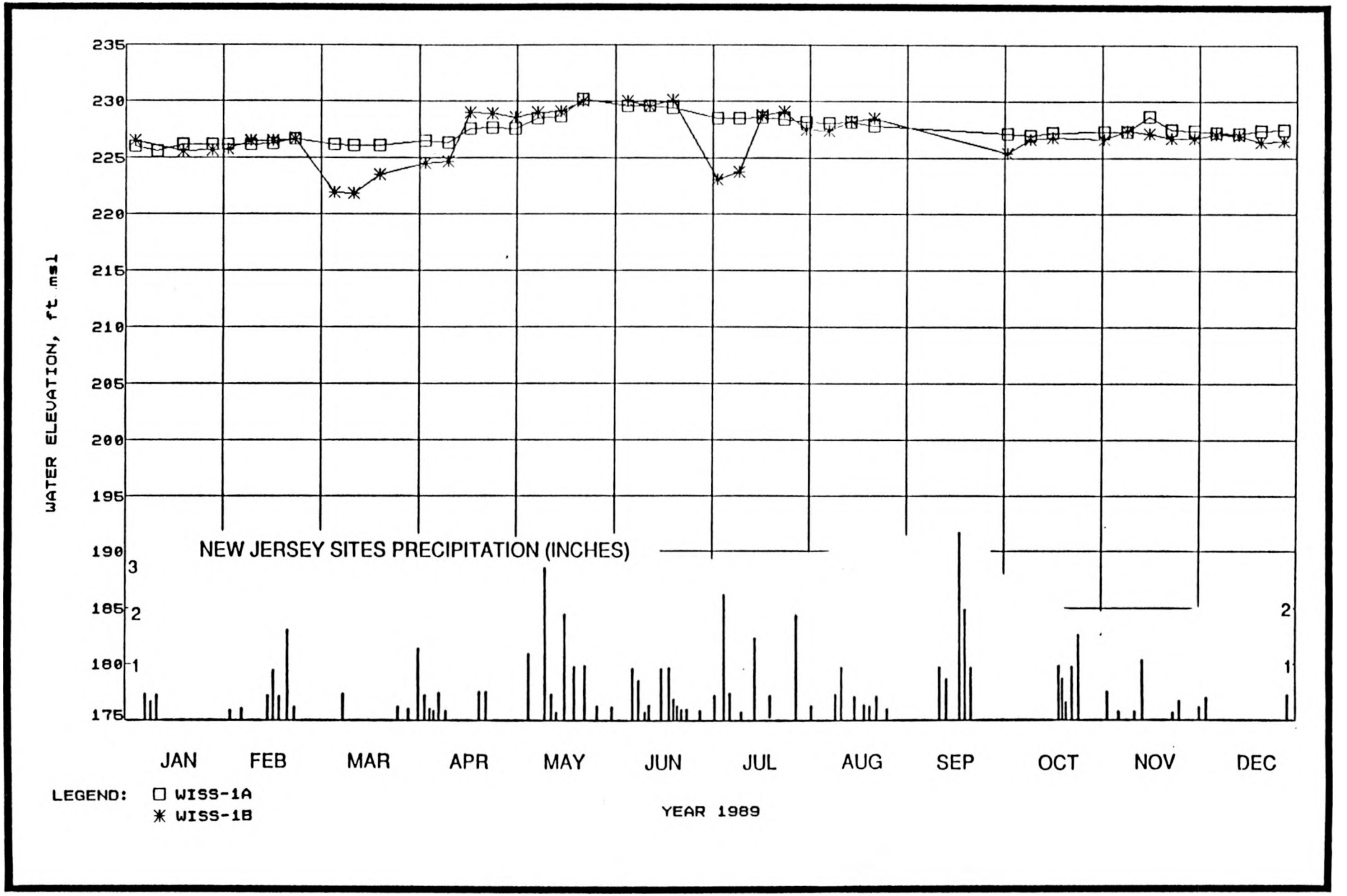

FIGURE 1-10 HYDROGRAPHS OF WELL PAIR 1A/1B

Slope and flow direction for the lower groundwater system could not be determined for 1989. Data for 1985 (Ref. 17) show a flow direction from east to west and a slope on the order of 0.01, which represents a lower gradient than that reported for the upper system. Because artesian conditions are still occurring, the slope is probably still on the order of 0.01.

1.3.3 Conclusions

- The water table for the unconfined upper groundwater system is consistently 0.3 to 2.1 m (1 to 7 ft) below ground surface. Groundwater flows from east to west at a slope on the order of 0.065. Potentiometric surfaces and slopes are consistent throughout the year and are equivalent to those observed in 1988.

- The lower groundwater system is a confined system; this conclusion is based on its artesian behavior. Slope and flow direction for 1989 were not determined.

2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program at WISS, begun in 1984, continued during 1989; air, water, and sediment samples were taken, and radon levels and external gamma radiation levels were monitored to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 18). The potential dose that might be received by the maximally exposed individual was calculated to determine the degree of compliance with the radiation protection standard.

Annual average concentrations of radon (including background) ranged from 4 to 7 x 10^{-10} μCi/ml (0.4 to 0.7 pCi/L). The average background radon-222 (radon) concentration for WISS was 6 x 10^{-10} μCi/ml (0.6 pCi/L). Thoron (radon-220) concentrations (including background) ranged from <1.0 x 10^{-10} to 3 x 10^{-9} μCi/ml (<0.1 to 3.0 pCi/L). The average background thoron concentration for WISS was <1.0 to 10^{-10} μCi/ml (<0.1 pCi/L). Radon and thoron concentrations (including background) at all monitoring locations were approximately equal to the background concentration (Refs. 19-23).

Annual average external radiation levels measured at WISS in 1989 ranged from background to 8 mrem/yr above background. During 1986, the area along the fence adjacent to the school bus maintenance facility was covered with plastic and then with sandbags to reduce the external radiation in the area. These radiation levels may be compared with the external radiation level from naturally occurring background radiation in the WISS area, which averaged 86 mrem/yr. External radiation levels are discussed in Subsection 3.2. External gamma radiation levels have fallen over the 5-year monitoring period (see Subsection 3.7.2) (Refs. 20-23).

In surface waters (Subsection 3.3), the annual average concentration of uranium was <5.0 x 10^{-9} μCi/ml (<5.0 pCi/L) at all locations; for radium-226 it was 5 x 10^{-10} μCi/ml (0.5 pCi/L); for radium-228 it was <1.8 x 10^{-9} μCi/ml (<1.8 pCi/L); and for thorium-232 it was 2.0 x 10^{-10} μCi/ml (0.2 pCi/L). Concentrations

of radionuclides in surface water over the 1985-1989 monitoring period have approximated the upstream background concentrations (see Subsection 3.7.3) (Refs. 20-23).

In groundwater (Subsection 3.4), the highest annual average concentration of uranium was 6.3×10^{-9} μCi/ml (6.3 pCi/L). The highest annual average concentrations of thorium-232 and radium-226 were 5.0×10^{-10} μCi/ml (0.5 pCi/L) and 1.7×10^{-9} μCi/ml (1.7 pCi/L), respectively; the highest annual average for radium-228 was $<8.0 \times 10^{-9}$ μCi/ml (<8.0 pCi/L). Over the 1985-1989 monitoring period, there has been some fluctuation in the concentrations of radionuclides in groundwater, but concentrations have remained basically stable (see Subsection 3.7.4) (Refs. 20-23).

Analyses of well water for several water quality indicator parameters and chemicals on the New Jersey priority pollutants list indicated that WISS groundwater is of relatively good quality. The indicator results were within normal range, and none of the priority pollutants was detected.

In stream sediments (Subsection 3.5), the highest annual average concentration of total uranium was 1.2 pCi/g; the highest average concentrations of thorium-232, radium-226, and radium-228 were 0.8, 0.9, and <2.0 pCi/g, respectively. These concentrations have remained at essentially background levels.

Calculations were made of the radiological dose received by a hypothetical maximally exposed individual. This individual is one who is assumed to be adjacent to the site and who, when all routes of exposure are considered, receives the greatest dose. Exposure to external gamma radiation was the exposure pathway quantified. The exposure to the hypothetical maximally exposed individual from external gamma radiation is 2.7 mrem/yr above background. This exposure is approximately equivalent to 2.7 percent of the DOE radiation protection standard (100 mrem/yr). By comparison, exposure to the measured background level of external gamma radiation results in an annual dose of approximately 86 mrem. The cumulative dose to the population within an 80-km (50-mi) radius of

the WISS that results from radioactive materials present at the site is indistinguishable from the dose that the same population receives from naturally occurring radioactive sources.

Results of the 1989 monitoring show that WISS is in compliance with the DOE radiation protection standard of 100 mrem/yr.

On December 30, 1989, NJDEP sent notification to DOE that the New Jersey Pollutant Discharge Elimination System permit for groundwater discharge (permit No. NJ0055051) was no longer in effect. NJDEP stated that the permit was issued primarily for the construction of the interim storage piles. Because construction had been accomplished to the satisfaction of NJDEP, the permit was no longer required. As a result, the sampling and analysis parameters previously followed to comply with the specific permit conditions could be modified at the discretion of DOE.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1989 environmental monitoring at WISS. A description is also given of the sampling, monitoring, and analytical procedures used. Calculations were made to determine the estimated maximum possible radiation dose based on environmental conditions, measurements recorded, and evaluation of potential exposure pathways.

Data are presented in summary tables that include number of data points collected, and minimum, maximum, and average values. Individual sources of error (e.g., analytical error or sampling error) were not estimated. The "less than" notation (<) is used to denote specific sample analysis results that are below the limit of sensitivity of the analytical method, based on a statistical analysis of parameters. When computing annual averages, quarterly values reported as less than a given limit of sensitivity (detection limit) are considered equal to that limit of sensitivity. In previous environmental monitoring reports, when two or more such values were involved in calculating an annual average, the reported value carried the "less than" notation. This year, because limits of sensitivity varied from quarter to quarter, an increasing number of results are at or below the limit of sensitivity, and because data error terms are not reported, a more conservative method of computing annual averages is being employed. Annual averages carry the "less than" notation only if all of the quarterly values involved in the calculation were less than the limit of sensitivity.

During 1989, the routine environmental monitoring program for WISS included monitoring for radon and thoron, measuring external gamma radiation, sampling surface water and sediment, and monitoring groundwater wells within the site boundary (which is a fenced and posted area).

Trend tables are provided for radon, thoron, and external gamma radiation levels and for radionuclides measured in surface water and groundwater. These tables list annual averages for each

monitoring location for the years 1985 through 1989 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.7).

3.1 RADON AND THORON MONITORING

Two forms of radon are present at WISS. The more common form, radon-222, is the daughter product of radium-226 decay and is part of the natural uranium decay chain. The other form, radon-220, is part of the natural thorium decay chain. To distinguish between the two forms of radon, the term thoron (the common name for radon-220) is used in this report to refer to radon-220, while the term radon refers only to radon-222.

Nine pairs of radon and thoron detectors are maintained on fenceline locations, with one pair designated for quality control. Another pair of detectors is located at the Department of Health in Paterson, New Jersey, to measure background levels. A new pair of detectors was installed in January 1989 at the Wayne Water Treatment Plant to measure background radon and thoron levels.

The locations of the site radon monitors are shown in Figure 3-1. Radon and thoron concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F and Type M Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which gas can diffuse. Radon and thoron will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, they will equilibrate with radon and thoron in the outside air. Alpha particles from the radioactive decay of radon and thoron and their daughters in the cup create tiny tracks when they collide with the film. When returned to Terradex for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm^2) is related through calibration to the concentration of thoron and/or radon. Although this technique is

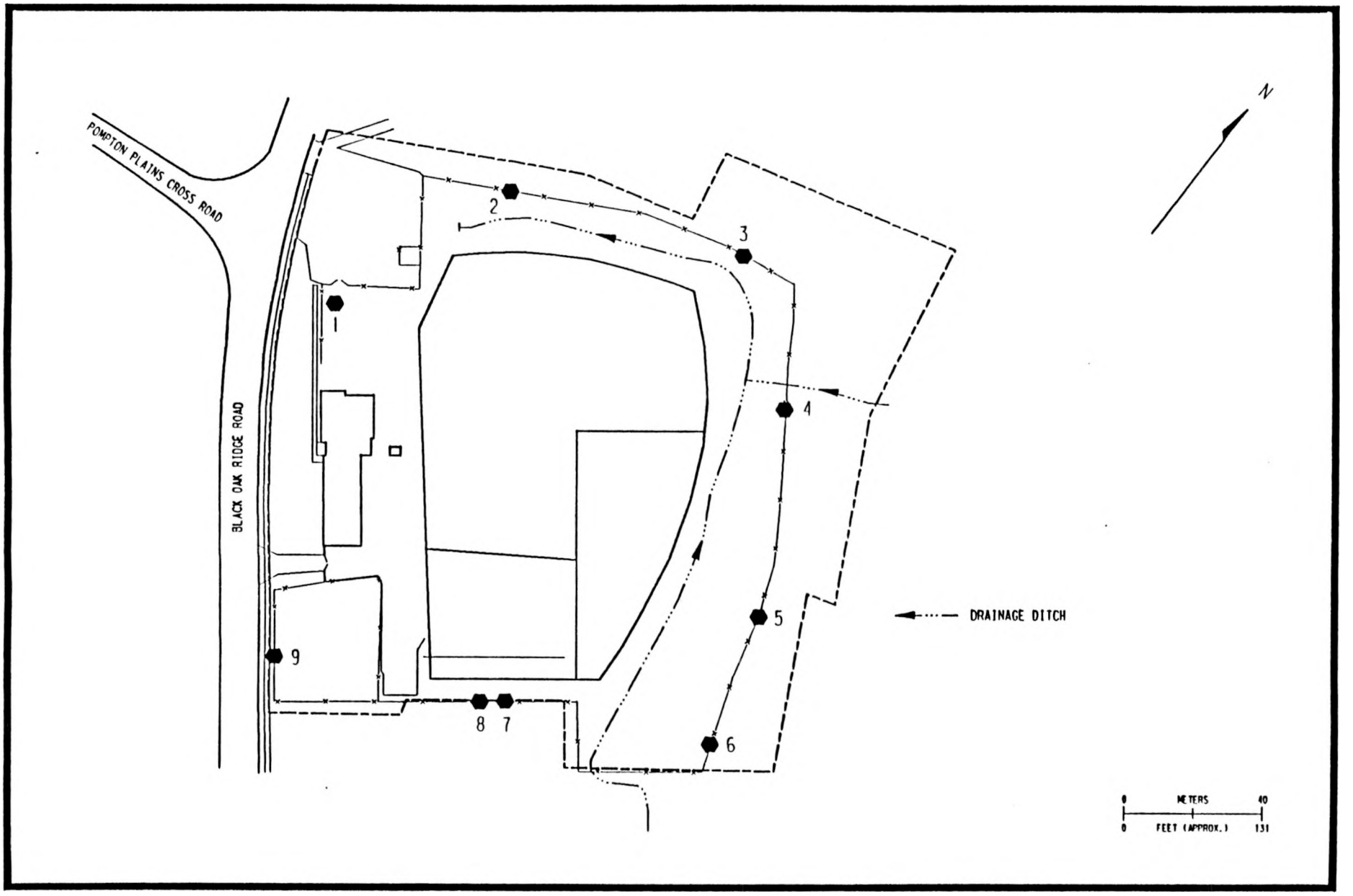

FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT WISS

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experimental, it is the only one commercially available for detecting thoron at environmental levels. The Type F detectors measure both radon and thoron. The Type M detector is designed to measure only radon. The thoron concentration is obtained by subtracting the Type M reading from the Type F reading (Ref. 24). A negative or zero value indicates a thoron level that is below the minimum detectable limit for the detector. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling location and return the exposed monitors to Terradex for analysis.

Table 3-1 lists thoron and radon concentrations (including background) recorded at WISS in 1989. The site locations where thoron was measured had maximum annual average concentrations of 3.0×10^{-9} μCi/ml (3.0 pCi/L). The average background concentrations measured at the Wayne Water Treatment Plant and the Department of Health in Paterson, New Jersey, were less than the minimum detectable limit of 1.0×10^{-10} μCi/ml (0.1 pCi/L).

Annual average concentrations of radon-222 ranged from 4.0 to 7.0×10^{-10} μCi/ml (0.4 to 0.7 pCi/L). The average of the background radon concentrations measured at the Department of Health in Paterson and the Wayne Water Treatment Plant was 6.0×10^{-10} μCi/ml (0.6 pCi/L).

Radon-222 and thoron levels at WISS are well within DOE derived concentrations guidelines. For a comparison of radon and thoron concentrations measured at WISS from 1985 through 1989, see Subsection 3.7.1.

3.2 EXTERNAL GAMMA RADIATION

External gamma radiation levels were measured at nine site boundary locations. All locations correspond to radon (Terradex) detector locations (Figure 3-1). Monitoring stations to measure background radiation are located at the Department of Health in Paterson and the Wayne Water Treatment Plant.

TABLE 3-1

THORON AND RADON-222 CONCENTRATIONS AT WISS, 1989

Sampling Station[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Thoron				
1	4	<0.1	11.3	3.0
2	4	<0.1	0.3	<0.1
3	4	<0.1	<0.1	<0.1
4	4	<0.1	0.1	<0.1
5	4	<0.1	1.0	0.3
6	4	<0.1	0.9	0.3
7	4	<0.1	1.0	0.1
8[d]	4	<0.1	0.2	0.1
9	4	<0.1	<0.1	<0.1
Background				
14[e]	4	<0.1	<0.1	<0.1
15[f]	2[g]	<0.1	<0.1	<0.1
Radon-222				
1	4	0.3	0.8	0.5
2	4	0.3	0.5	0.4
3	4	0.4	0.8	0.6
4	4	0.4	1.0	0.7
5	4	0.3	1.0	0.6
6	4	0.4	0.7	0.5
7	4	0.3	1.3	0.7
8[d]	4	0.3	0.7	0.4
9	4	0.3	0.5	0.4
Background				
14[e]	4	0.4	0.5	0.5
15[f]	2[g]	0.5	0.8	0.7

[a] Locations of sampling stations are shown in Figure 3-1 (see also footnotes f and g).

[b] 1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[c] Background levels have not been subtracted.

[d] Station 8 is the quality control detector for station 7.

[e] Located at the Department of Health, Paterson, NJ, approximately 5 km (3 mi) east of WISS.

[f] Located at the Wayne Water Treatment Plant, Wayne, NJ, approximately 1.6 km (1 mi) west of WISS; established in January 1989.

[g] No data available for the first two quarters.

External gamma radiation levels are measured using lithium fluoride thermoluminescent dosimeters (TLDs). Beginning in 1988, the system of measurement utilizes tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to the tissues of the body at a depth of 1 cm. Each dosimetry station contains a minimum of four dosimeters, which are exchanged after approximately one year of accumulated exposure. For example, a dosimeter placed in the station in October 1988 would be removed in October 1989 and replaced with a new dosimeter. Each dosimeter contains five individual lithium fluoride chips (each group of five chips was preselected on the basis of having a reproducibility of ±3 percent across a series of laboratory exposures), the responses of which are averaged.

Analysis is performed by Thermo Analytical/Eberline (TMA/E). The average value is then corrected for the shielding effect of the shelter housing (approximately 8 percent). The corrected value is then converted to millirem per year by dividing by the number of days of exposure and subsequently multiplying by 365 days.

Because the current measurement system allows for dosimeter detection intervals of approximately a year versus the 3-month interval previously used, the current system is more sensitive to low radiation levels than the system used previously. Although the tissue-equivalent TLDs used are "state-of-the-art," one should keep in mind when examining the external gamma radiation results that the dosimeter accuracy is approximately ±10 percent at levels from 100 mrem/yr to 1 rem/yr and ±25 percent at radiation levels around 70 mrem/yr.

Monitoring results for external gamma radiation are presented in Table 3-2. For each quarter, an average of the background levels measured was subtracted from the site boundary measurements to provide an estimate of radiation levels resulting from residual materials. Annual average external gamma radiation levels ranged from less than average background to 8 mrem/yr above background at the monitoring locations.

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT WISS, 1989

Sampling Station[a]	Number of Measurements	Radiation Level (mrem/yr)[b] Minimum	Maximum	Average
1	4	--[c]	22	8
2	4	--[c]	15	6
3	4	--[c]	<1	--[c]
4	4	--[c]	--[c]	--[c]
5	4	--[c]	--[c]	--[c]
6	4	--[c]	5	1
7	4	--[c]	3	1
8[d]	4	--[c]	6	1
9	4	--[c]	8	2
Background				
14[e]	4	59	100	77
15[f]	3[g]	86	105	94

[a]Locations of sampling stations are shown in Figure 3-1 (see also footnotes e and f).

[b]Measured background has been subtracted from the readings obtained at the nine sampling locations shown in Figure 3-1.

[c]Measurement was less than or equal to the average background value.

[d]Station 8 is the quality control detector for station 7.

[e]Located at the Department of Health, Paterson, NJ, approximately 5 km (3 mi) east of WISS.

[f]Located at the Wayne Water Treatment Plant, Wayne, NJ, approximately 1.6 km (1 mi) west of WISS.

[g]Detector not established at sampling location in first quarter.

The background external gamma radiation value for a given location is not constant. Because the background radiation value is determined by combining radiation from both natural terrestrial and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil can affect the value measured. Independent of the placement of the detector at the site are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 25).

Because of these factors, the background radiation level is not constant from one location to another even over a short time. Thus it is not abnormal for some stations at the boundary of a site to have external gamma radiation values less than the background level measured some distance from the site. For comparisons of external gamma radiation levels measured from 1985 through 1989, see Subsection 3.7.2.

3.3 SURFACE WATER SAMPLING

During 1989, sampling was performed to determine the concentrations of thorium-232, total uranium, radium-226, and radium-228 in on-site and off-site surface water locations. Surface water sampling locations are shown in Figure 3-2.

Surface water samples were collected quarterly from locations 1, 5, and 6. As part of the on-site remedial action work in 1985, riprap was placed in the drainage ditch passing through the site to minimize erosion of the sides and bottom of the ditch during periods of heavy runoff. This activity made locations 2, 3, and 4 impossible to sample. Location 6 is in Sheffield Brook and is upstream of the intersection of the drainage ditch and Sheffield Brook. Collection locations were selected based on migration potential and discharge routes from the site.

Nominal 1-L (0.26-gal) grab samples were collected to fill a 3.8-L (1.0-gal) container. The samples were analyzed by TMA/E for total uranium, thorium-232, radium-228, and radium-226. Total uranium was determined by a fluorometric method. Radium-226

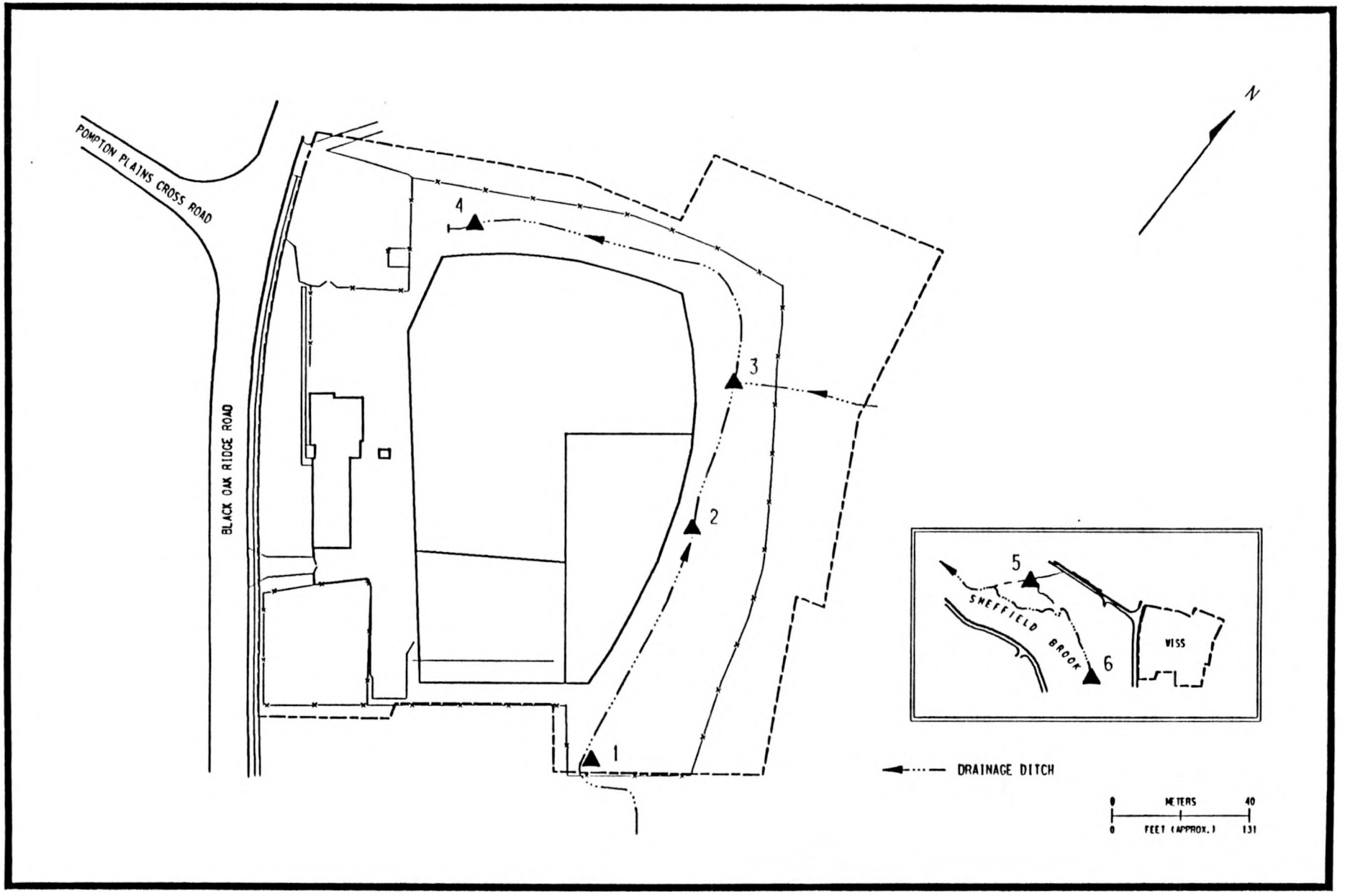

FIGURE 3-2 SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS AT WISS

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concentrations in water were determined by radon emanation. (This method consists of precipitating radium as sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.) The concentrations of thorium-232 and radium-228 were determined by eluting the thorium-232 or radium-228 in solution, electrodepositing it on stainless steel discs, and counting it by alpha spectrometry.

Analytical results for thorium-232 and total uranium are presented in Table 3-3. Results for radium-226 and radium-228 are given in Table 3-4. The maximum annual average thorium-232 concentration was 2.0×10^{-10} μCi/ml (0.2 pCi/L) at location 1. The maximum annual average uranium value was $<5.0 \times 10^{-9}$ μCi/ml (<5.0 pCi/L) at all locations. For radium-226 and radium-228, the maximum average concentrations were 5×10^{-10} μCi/ml (0.5 pCi/L) and $<1.8 \times 10^{-9}$ μCi/ml (<1.8 pCi/L), respectively. These levels are essentially equivalent to background levels and are within DOE derived concentration guidelines. For a comparison of radionuclide concentrations measured in surface water from 1985 through 1989, see Subsection 3.7.3.

3.4 GROUNDWATER SAMPLING

During 1989, groundwater samples were collected quarterly from 12 on-site wells at 6 locations (see Figure 1-6).

Groundwater is assumed to flow from east to west in the bedrock; therefore, well 1B is the upgradient well for groundwater in bedrock. The direction of flow in the unconsolidated deposits is also east to west; therefore, wells 1 and 6 are upgradient for the upper groundwater system. Wells 2, 3, 4, and 5 are generally downgradient monitoring locations.

TABLE 3-3

CONCENTRATIONS OF THORIUM-232 AND TOTAL URANIUM IN SURFACE WATER AT WISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
Thorium-232				
1	4	<0.1	0.4	0.2
5	4	<0.1	0.2	0.1
6[c]	4	<0.1	<0.1	<0.1
Total Uranium				
1	4	<5.0	5.0	<5.0
5	4	<5.0	<5.0	<5.0
6[c]	4	<5.0	<5.0	<5.0

[a] Sampling locations are shown in Figure 3-2. Locations 2, 3, and 4 were inaccessible during 1989 because of riprap placed in the on-site drainage ditch to minimize erosion.

[b] 1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[c] Location 6 is in Sheffield Brook, upstream of where the site drainage ditch enters the brook. It also serves as a background location.

TABLE 3-4

CONCENTRATIONS OF RADIUM-226 AND RADIUM-228

IN SURFACE WATER AT WISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
Radium-226				
1	4	0.2	1.1	0.5
5	4	0.3	0.6	0.4
6[c]	4	0.2	0.5	0.4
Radium-228				
1	4	<1.0	<3.0	<1.8
5	4	<1.0	<3.0	<1.8
6[c]	4	<1.0	<2.0	<1.5

[a] Sampling locations are shown in Figure 3-2. Locations 2, 3, and 4 were inaccessible during 1989 because of riprap placed in the on-site drainage ditch to minimize erosion.

[b] 1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[c] Location 6 is in Sheffield Brook, upstream of where the site drainage ditch enters the brook. It also serves as a background location.

Samples were collected with a hand bailer after the wells had been bailed dry and allowed to recover or after three casing volumes had been removed; nominal 1-L (0.26-gal) grab samples were collected to fill a 3.8-L (1.0-gal) container. Samples were analyzed by TMA/E using the same methods used for surface water analyses, with one exception. In 1986, the use of alpha spectrometry to determine total uranium concentration was initiated as required under NJDEP groundwater permit No. NJ0055051. As an analytical method, alpha spectrometry is more precise than the fluorometric method, and it has the additional advantage that it provides information about the individual isotopes as well as about total uranium. Weston Analytical Laboratory analyzed samples for several chemical parameters.

3.4.1 Radiological

Analytical results for thorium-232 and total uranium in groundwater are presented in Table 3-5; results for radium-226 and radium-228 are presented in Table 3-6. The maximum annual average uranium value was 6.3×10^{-9} μCi/ml (6.3 pCi/L). The maximum annual average concentration of thorium-232 was 5×10^{-10} μCi/ml (0.5 pCi/L). The maximum annual average concentration of radium-226 was 1.7×10^{-9} μCi/ml (1.7 pCi/L). For radium-228, the maximum annual average concentration was $<8.0 \times 10^{-9}$ μCi/ml (<8.0 pCi/L). All of these levels are well within the respective DOE derived concentration guidelines. For comparisons of radionuclide concentrations measured in groundwater from 1985 through 1989, see Subsection 3.7.4.

3.4.2 Chemical

Several water quality indicator parameters were measured quarterly at WISS. The parameters were pH, total organic carbon (TOC), total organic halides (TOX), and specific conductivity.

Results are presented in Table 3-7. Additionally, one-time analyses for compounds on the New Jersey priority pollutants list were performed (Table 3-8).

Specific conductance and pH measure changes in the inorganic composition of the groundwater. Acidity or basicity of water is expressed as pH. A change in pH affects the solubility and mobility of chemical contaminants in groundwater. Specific conductance measures the capacity of water to conduct an electrical current. Generally, conductivity increases with an elevated concentration of dissolved solids. Waters with high salinities or high total dissolved solids exhibit high conductivities.

Groundwater is analyzed for TOC and TOX to determine organic content. TOC measures the total organic carbon content of water but is not specific to a given contaminant. TOX measures organic compounds containing halogens; many pollutants contain halogenated hydrocarbons, which are organic compounds containing fluorine, chlorine, bromine, and iodine.

With the exception of one elevated TOX reading in the upgradient well 1A, indicator parameter measurements for WISS wells can be characterized as falling within normal ranges and are representative of background conditions. No compounds on the New Jersey priority pollutants list were detected.

The potential for groundwater at WISS to become chemically or radioactively contaminated will remain low as long as artesian conditions exist.

3.5 SEDIMENT SAMPLING

Sediment samples were composites of approximately 500 g (1.1 lb) obtained at surface water sampling locations where sediment was present. These samples were analyzed by TMA/E for isotopic uranium, radium-226, radium-228, and thorium-232. The concentration of isotopic uranium was determined by alpha spectrometry after the uranium had been leached, organically

TABLE 3-5

CONCENTRATIONS OF THORIUM-232 AND TOTAL URANIUM IN GROUNDWATER AT WISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
Thorium-232				
1A	4	<0.2	<0.3	<0.2
1B	4	<0.2	<0.2	<0.2
2A	4	<0.2	1.1	0.5
2B	4	<0.2	<0.2	<0.2
3A	4	<0.2	0.6	0.4
3B	4	<0.2	<0.3	<0.2
4A	4	<0.2	0.2	<0.2
4B	4	<0.2	<0.2	<0.2
5A	4	<0.2	0.3	<0.2
5B	4	<0.2	<0.2	<0.2
6A	4	<0.2	0.3	0.2
6B	4	<0.2	<0.4	0.3
Total Uranium				
1A	4	0.9	2.5	1.5
1B	4	0.4	1.4	1.0
2A	4	1.6	3.2	2.3
2B	4	0.6	2.7	1.8
3A	4	2.1	2.9	2.3
3B	4	0.9	3.5	1.9
4A	4	4.3	10.0	6.3
4B	4	0.6	2.9	1.4
5A	4	1.4	2.8	1.9
5B	4	1.0	1.5	1.2
6A	4	0.6	1.9	1.4
6B	4	1.3	2.4	1.8

[a]Sampling locations are shown in Figure 1-6.

[b]1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

TABLE 3-6

CONCENTRATIONS OF RADIUM-226 AND RADIUM-228

IN GROUNDWATER AT WISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
Radium-226				
1A	4	0.7	1.9	1.2
1B	4	0.7	1.9	1.2
2A	4	0.7	3.1	1.7
2B	4	0.7	2.2	1.1
3A	4	0.7	1.3	1.0
3B	4	0.5	1.7	0.9
4A	4	0.6	1.4	0.9
4B	4	0.5	1.3	0.8
5A	4	0.5	1.5	0.8
5B	4	0.4	1.5	1.0
6A	4	0.4	1.5	0.9
6B	4	0.5	1.4	0.9
Radium-228				
1A	4	<5.0	<9.0	<6.0
1B	4	<4.0	<10.0	<6.0
2A	4	<4.0	<10.0	<7.0
2B	4	<5.0	<9.0	<6.0
3A	4	<5.0	<9.0	<6.0
3B	4	<4.0	<8.0	<6.0
4A	4	<5.0	<8.0	<6.0
4B	4	<4.0	<8.0	<6.0
5A	4	<4.0	<8.0	<6.0
5B	4	<4.0	<9.0	<7.0
6A	4	<5.0	<11.0	<8.0
6B	4	<5.0	<10.0	<6.0

[a]Sampling locations are shown in Figure 1-6.

[b]1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

TABLE 3-7

ANALYTICAL RESULTS FOR INDICATOR PARAMETERS AND CHEMICAL CONTAMINANTS IN GROUNDWATER AT WISS, 1989[a]

Parameter (Units)	Sampling Location (Monitoring Well Number)[b,c]											
	1A[d]	1B[d]	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
pH (standard units)	6.9-7.3	8.2-8.4	7.9-8.1	8.0-8.4	7.2-7.6	7.6-8.0	7.2-7.8	7.8-8.1	8.0-8.2	8.1-8.2	6.8-8.1	7.9-8.1
Total organic carbon (mg/L)	1.6-3.2	ND-3.3	ND-5.4	0.5-1.2	0.6-2.2	ND-1.2	0.6-2.1	ND-1.1	ND-2.8	ND-6.6	0.8-1.4	ND-0.7
Total organic halides (µg/L)	11-120	ND-38	ND-42	ND	ND-20	ND-24	ND-54	ND-12	ND-54	ND-20	ND	ND-68
Specific conductance (µmhos/cm)	408-794	238-358	233-360	305-475	376-397	306-514	306-897	326-500	308-564	322-482	351-679	377-548

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

[b] ND - no detectable concentration.

[c] Sampling locations are shown in Figure 1-6.

[d] Upgradient well.

TABLE 3-8

CHEMICAL CONTAMINANTS NOT DETECTED IN GROUNDWATER AT WISS, 1989

Benzene	Benzo(g,h,i)perylene	N-nitroso-di-n-propylamine
Bromodichloromethane	4-bromophenyl-phenylether	Naphthalene
Bromoform	Butylbenzylphthalate	Nitrobenzene
Bromomethane	Di-n-butylphthalate	Pentachlorophenol
Carbon tetrachloride	bis(2-chloroethoxy)methane	Phenanthrene
Chlorobenzene	bis(2-chloroethyl)ether	Phenol
Chloroethane	bis(2-chloroisopropyl)ether	Pyrene
2-chloroethylvinylether	4-chloro-3-methylphenol	1,2,4-trichlorobenzene
Chloroform	2-chloronaphthalene	2,4,6-trichlorophenol
Chloromethane	2-chlorophenol	Aldrin
Dibromochloromethane	4-chlorophenyl-phenylether	BHC, alpha
1,2-dichlorobenzene	Chrysene	BHC, beta
1,3-dichlorobenzene	1,2-dichlorobenzene	BHC, gamma
1,4-dichlorobenzene	1,3-dichlorobenzene	BHC, delta
1,1-dichloroethane	1,4-dichlorobenzene	Chlordane, alpha
1,2-dichloroethane	3,3'-dichlorobenzidine	Chlordane, gamma
1,1-dichloroethene	2,4-dichlorophenol	Dieldrin
Trans-1,2-dichloroethene	Di-n-octyl phthalate	Endosulfan, alpha
1,2-dichloropropane	Dibenzo(a,h)anthracene	Endosulfan, beta
Cis-1,3-dichloropropene	Diethylphthalate	Endosulfan, gamma
Trans-1,3-dichloropropene	2,4-dimethylphenol	Endrin
Ethylbenzene	Dimethylphthalate	Heptachlor
Methylene chloride	4,6-dinitro-2-methylphenol	Heptachlor epoxide
1,1,2,2-tetrachloroethane	2,4-dinitrophenol	Toxaphene
Tetrachloroethene	2,4-dinitrotoluene	4,4'-DDT
Toluene	2,6-dinitrotoluene	4,4'-DDE
1,1,1-trichloroethane	Bis(2-ethylhexyl)phthalate	4,4'-DDD
1,1,2-trichloroethane	Fluoranthene	Aroclor 1016
Trichloroethene	Fluorene	Aroclor 1221
Vinyl chloride	Hexachlorobenzene	Aroclor 1232
Acenaphthene	Hexachlorobutadiene	Aroclor 1242
Acenaphthylene	Hexachlorocyclopentadiene	Aroclor 1248
Anthracene	Hexachloroethane	Aroclor 1254
Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene	Aroclor 1260
Benzo(b)fluoranthene	Isophorone	
Benzo(k)fluoranthene	2-nitrophenol	
Benzo(a)pyrene	4-nitrophenol	

extracted, and electroplated on a metal substrate. Total uranium concentrations were obtained by summing the concentrations of the individual isotopes. Thorium-232, radium-226, and radium-228 concentrations were determined by gamma spectrometry. Sediment sampling locations are shown in Figure 3-2. The concentrations of uranium, radium, and thorium measured downstream are essentially the same as concentrations measured upstream. All levels are below DOE derived concentration guidelines for soils. (Currently DOE does not have guidelines for radioactivity levels in sediments.) Analytical results for total uranium, thorium-232, radium-226, and radium-228 are shown in Table 3-9.

3.6 RADIATION DOSE

To assess the potential health effects of the radioactive materials stored at WISS, radiological exposure pathways were evaluated to calculate the dose to a hypothetical maximally exposed individual. This individual is one who is assumed to be adjacent to the site and who, when all potential routes of exposure are considered, receives the greatest dose. An appraisal of potential pathways (exposure to external gamma radiation, ingestion of water, and inhalation of radon) suggested that external gamma radiation was the only plausibly significant exposure mode.

The dose from ingesting groundwater or surface water from sources on the WISS property was not calculated because it was considered unrealistic to assume that ingestion of this water would occur. WISS is fenced and locked, and security is well maintained. Therefore, a member of the public could only consume water on the site by trespassing on the property.

Radon and thoron concentrations measured at the WISS boundary were within the normal variation and levels associated with background measurements for this area. Consequently, this pathway does not contribute additional exposure to the maximally exposed individual.

TABLE 3-9

CONCENTRATIONS OF THORIUM-232, RADIUM-226,
RADIUM-228, AND TOTAL URANIUM IN SEDIMENTS AT WISS, 1989

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Thorium-232				
1	3[b]	0.4	0.7	0.6
5	4	0.4	1.1	0.8
6	4	0.1	0.5	0.4
Radium-226				
1	3[b]	0.7	1.1	0.9
5	4	0.4	0.6	0.6
6	4	0.3	0.8	0.5
Radium-228				
1	3[b]	<1.0	<3.0	<2.0
5	4	<1.0	<3.0	<1.8
6	4	<1.0	<3.0	<1.8
Total Uranium				
1	3[b]	1.0	1.5	1.2
5	4	1.0	1.3	1.1
6	4	0.9	1.2	1.0

[a]Sampling locations are shown in Figure 3-2. Locations 1 and 6 are upstream of the WISS influence; location 5 is downstream. Sediment samples could not be collected from locations 2, 3, and 4 during 1989 because riprap was placed in the on-site drainage ditch to minimize erosion.

[b]Sampling location was frozen in the first quarter.

3.6.1 Dose to the Maximally Exposed Individual

To identify the individual in the vicinity of WISS who would receive the highest dose from on-site radioactive materials, the dose from exposure to external gamma radiation was calculated at various monitoring locations that could be accessible to the public. Based on these calculations, the highest overall dose would be received by a resident living directly to the northwest of the site.

The annual average radiation level measured by TLDs at monitoring location 1 was 8 mrem/yr above background (Figure 3-1). If it is assumed that a resident might spend 8 hours a day at the property fenceline facing location 1 and received the radiation measured at that location, the individual would receive an annual exposure of less than 2.7 mrem/yr above background. This exposure is equivalent to 2.7 percent of the DOE radiation protection standard of 100 mrem/yr. By comparison, a person receives a similar dose during a flight from New York City to Los Angeles because of the greater amounts of cosmic radiation at higher altitudes (see Appendix D).

The scenario above is highly conservative in that it is very unlikely that any individual would spend this much time at this location, and actual radiation levels at the fence [a distance of approximately 10 m (33 ft) from location 1] would be much lower than 8 mrem/yr (see Subsection 3.5.2).

3.6.2 Dose to the Population in the Vicinity of WISS

The dose to the population represents the conceptual cumulative radiation dose to all residents within an 80-km (50-mi) radius of a given site. This calculated dose includes contributions from all potential pathways. For WISS, these pathways are direct exposure to gamma radiation and inhalation of radon.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be

measured, because gamma radiation levels decrease rapidly as distance from the source of radiation increases. For example, if the gamma exposure rate at a distance of 1 m (3 ft) from a small-area radioactive source were 100 mrem/yr, the exposure rate at a distance of 6.4 m (21 ft) from the source would be indistinguishable from naturally occurring background radiation.

Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 26). Therefore, radon exposure does not contribute significantly to population dose.

On the basis of radionuclide concentrations measured in water leaving the site, it also appears that there is no predictable pathway by which ingestion of water could result in a significant exposure to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, thereby lowering potential exposures to even less significant levels.

The cumulative dose to the population within an 80-km (50-mi) radius of WISS that results from radioactive materials present at the site is indistinguishable from the dose the same population receives from naturally occurring radioactive sources.

3.7 TRENDS

The environmental monitoring program at WISS was established to allow an annual assessment of the environmental conditions at the site, provide a historical record for comparisons from year to year, and permit detection of trends over time. In the following subsections, 1989 annual averages for each monitoring location for radon, external gamma radiation, surface water, and groundwater are compared with results for 1985-1988. As the environmental monitoring program continues at WISS and more data are collected, comparisons and analyses of trends will become more valid.

3.7.1 Radon and Thoron

There have been no identifiable trends in either radon or thoron concentrations at WISS since 1985. As shown in Table 3-10,

TABLE 3-10

ANNUAL AVERAGE THORON AND RADON-222 CONCENTRATIONS AT WISS, 1985-1989[a]

Sampling Station[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Thoron					
1	0.4	0.1	0.3	0.1	3.0
2	0.2	<0.1	0.3	<0.1	0.1
3	0.5	<0.1	0.7	0.1	<0.1
4	0.1	<0.1	0.5	0.1	<0.1
5	0.1	<0.1	<0.1	0.2	0.3
6	0.1	0.3	<0.1	0.2	0.3
7	1.0	<0.1	<0.1	0.2	0.3
8	0.7	<0.1	<0.1	<0.1	0.1
9	0.2	<0.1	<0.1	0.1	<0.1
Background					
14[d]	0.1	0.4	0.3	<0.1	<0.1
15[e]	--	--	--	--	<0.1
Radon-222					
1	0.7	1.0	0.6	0.3	0.5
2	0.7	1.0	0.9	0.3	0.4
3	0.7	0.4	0.4	0.3	0.6
4	0.7	0.5	0.5	0.4	0.7
5	0.6	0.8	0.8	0.5	0.6
6	0.6	0.9	0.5	0.5	0.5
7	0.4	0.6	0.5	0.5	0.7
8	0.6	0.8	0.5	0.3	0.4
9	0.8	0.9	1.3	0.3	0.4
Background					
14[d]	0.4	1.0	0.8	0.3	0.6
15[e]	--	--	--	--	0.7

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

[b]Locations of sampling stations are shown in Figure 3-1 (see also footnotes e and f).

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/L.

[d]Located at the Department of Health, Paterson, NJ, approximately 5 km (3 mi) east of the WISS.

[e]Located at the Wayne Water Treatment Plant, approximately 1.6 km (1 mi) west of WISS; established in January 1989.

though there are some variations from year to year, radon-222 and thoron levels at WISS remain quite stable at concentrations approximating background levels.

3.7.2 External Gamma Radiation

As shown in Table 3-11, external gamma radiation levels at WISS have decreased since 1985. Levels measured in 1989 were essentially equivalent to background.

3.7.3 Surface Water

As shown in Tables 3-12 and 3-13, radionuclide concentrations have remained at essentially background levels over the past five years.

3.7.4 Groundwater

As shown in Tables 3-14 and 3-15, the average concentrations of total uranium, thorium-232, radium-226, and radium-228 in groundwater from most wells monitored at WISS have remained very low since the monitoring program was initiated. All measurements are less than 10 percent of the applicable DOE derived concentration guidelines.

TABLE 3-11

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT WISS, 1985-1989[a]

Sampling Station[b]	Radiation Level (mrem/yr)[c]				
	1985	1986	1987	1988	1989
1	69	48	28	28	8
2	36	26	27	23	6
3	9	20	29	13	--[d]
4	17	18	18	10	--[d]
5	10	15	18	5	--[d]
6	5	22	22	10	1
7	606	77	45	15	1
8	507	82	40	19	1
9	12	21	38	22	2
Background					
14[e]	108	63	61	78	77
15[f]	--	--	--	--	94

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

[b]Locations of sampling stations are shown in Figure 3-1 (see also footnotes e and f).

[c]Measured background has been subtracted from the readings obtained at the nine sampling locations shown in Figure 3-1.

[d]Value is equal to or less than average background.

[e]Located at the Department of Health, Paterson, NJ, approximately 5 km (3 mi) east of WISS.

[f]Located at the Wayne Water Treatment Plant, approximately 1.6 km (1 mi) west of WISS; established in January 1989.

TABLE 3-12

ANNUAL AVERAGE CONCENTRATIONS OF THORIUM-232 AND TOTAL URANIUM IN SURFACE WATER AT WISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Thorium-232					
1	0.2	0.2	<0.1	2.6	0.2
2[d]	0.3	--	--	--	--
3[d]	0.1	--	--	--	--
4[d]	1.1	--	--	--	--
5	0.2	0.3	<0.2	<0.1	0.1
6[e]	0.2	0.3	<0.1	<0.1	<0.1
Total Uranium					
1	<3.0	<3.0	3.4	3.2	<5.0
2[d]	<3.0	--	--	--	--
3[d]	<3.0	--	--	--	--
4[d]	<3.0	--	--	--	--
5	<3.2	<3.0	<3.4	4.0	<5.0
6[e]	<3.0	<3.0	<3.4	5.0	<5.0

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

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

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/L.

[d]Locations 2, 3, and 4 have been inaccessible since 1986 because riprap was placed in the drainage ditch to minimize erosion.

[e]Background location.

TABLE 3-13

ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226 AND RADIUM-228 IN SURFACE WATER AT WISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Radium-226					
1	0.2	0.2	0.1	0.8	0.5
2[d]	0.3	--	--	--	--
3[d]	0.1	--	--	--	--
4[d]	0.3	--	--	--	--
5	0.3	0.3	0.2	0.3	0.4
6[e]	0.3	0.2	0.1	0.3	0.4
Radium-228					
1	2.7	2.3	<2.0	<4.5	<1.8
2[d]	<3.0	--	--	--	--
3[d]	<3.0	--	--	--	--
4[d]	<3.0	--	--	--	--
5	2.7	2.5	<2.0	<2.5	<1.8
6[e]	2.7	2.3	<2.0	<3.0	<1.5

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

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

[c]1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[d]Locations 2, 3, and 4 have been inaccessible since 1986 because riprap was placed in the drainage ditch to minimize erosion.

[e]Background location.

TABLE 3-14

ANNUAL AVERAGE CONCENTRATIONS OF THORIUM-232
AND TOTAL URANIUM IN GROUNDWATER
AT WISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Thorium-232					
1A	<0.1	<0.1	<0.1	0.4	<0.2
1B	<0.1	<0.1	0.1	<0.2	<0.2
2A	0.6	<0.1	0.1	1.0	0.5
2B	0.7	<0.1	0.1	<0.2	<0.2
3A	0.1	<0.2	0.1	0.3	0.4
3B	0.2	<0.2	<0.1	<0.2	<0.2
4A	0.1	<0.1	0.1	0.3	<0.2
4B	0.2	<0.1	0.1	<0.2	<0.2
5A	<0.1	<0.1	0.1	0.2	<0.2
5B	0.2	<0.1	0.1	<0.2	<0.2
6A	0.3	<0.1	0.3	0.3	0.2
6B	0.3	<0.2	<0.2	<0.2	0.3
Total Uranium[d]					
1A	<3.0	0.8	1.2	1.6	1.5
1B	<3.0	0.2	0.5	1.1	1.0
2A	<3.0	0.4	1.4	3.3	2.3
2B	<3.0	0.6	1.1	2.0	1.8
3A	<3.0	0.8	1.1	2.1	2.3
3B	<3.0	0.2	0.7	1.7	1.9
4A	14.3	4.7	4.6	8.3	6.3
4B	<3.0	0.4	0.9	1.0	1.4
5A	<3.0	1.1	1.5	2.2	1.9
5B	<3.0	0.5	1.2	1.5	1.2
6A	<3.0	0.6	4.3	1.6	1.4
6B	<3.0	0.7	1.2	2.0	1.8

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

[b]Sampling locations are shown in Figure 1-6.

[c]1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[d]Analytical results for 1986-1989 were obtained using the alpha spectrometry method. The fluorometric method was used in 1985.

TABLE 3-15

ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226 AND RADIUM-228 IN GROUNDWATER AT WISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Radium-226					
1A	0.2	0.7	0.3	1.0	1.2
1B	0.3	0.4	0.4	0.8	1.2
2A	0.3	0.1	0.4	1.3	1.7
2B	0.3	0.5	0.4	1.1	1.1
3A	0.3	0.4	0.4	0.9	1.0
3B	0.3	0.5	0.4	1.0	0.9
4A	0.9	0.4	0.2	0.8	0.9
4B	0.3	0.2	0.3	1.0	0.8
5A	0.3	0.4	0.3	1.0	0.8
5B	0.2	0.4	0.3	0.9	1.0
6A	0.4	0.3	0.4	1.0	0.9
6B	0.3	0.6	0.3	1.0	0.9
Radium-228[d]					
1A	<2.7	<2.3	<2.2	<5.0	<6.0
1B	<2.7	<3.0	<2.2	<4.0	<6.0
2A	2.1	<2.0	<2.5	<4.0	<7.0
2B	2.2	<3.0	<2.2	<5.0	<6.0
3A	<2.7	<2.7	<2.5	<5.0	<6.0
3B	<2.7	<3.0	<2.2	<5.0	<6.0
4A	2.7	<2.3	<2.5	<5.0	<6.0
4B	<2.7	<3.0	<2.8	<5.0	<6.0
5A	<2.7	<3.0	<2.5	<5.0	<6.0
5B	<2.7	<3.0	<3.3	<5.0	<7.0
6A	<2.7	<3.3	<3.0	<5.0	<8.0
6B	<2.7	<3.3	<3.0	<5.0	<6.0

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 20-23).

[b]Sampling locations are shown in Figure 1-6.

[c]1×10^{-9} µCi/ml is equivalent to 1 pCi/L.

[d]Detection limits for radium-228 rose in 1988 and 1989 because of interfering elements in the sample.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

Site maintenance and security were continued in 1989.

4.2 SPECIAL STUDIES

No special studies were performed at WISS in 1989.

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APPENDIX A
QUALITY ASSURANCE

QUALITY ASSURANCE

A comprehensive quality assurance (QA) program involving sampling, data management, and analysis was maintained to ensure that the data reported were representative of actual concentrations in the environment. The QA program meets the requirements of DOE Order 5700.6B and ANSI/ASME NQA-1.

QA sampling requirements were ensured through the following:

- Samples at all locations collected using established procedures
- Sampling program design provided for spikes, trip blanks, field blanks, and quality control (QC) duplicate sampling
- Chain-of-custody procedures implemented to maintain traceability of samples and corresponding analytical results

Data management QA was achieved through:

- Completion and recording of parameter-specific data review checklists for each analysis report
- Use of calculation sheets for constructing data tables and documenting computations
- Double-checking and concurrence on calculations
  - By the originator
  - By an independent, equally qualified second party

System QA audits are conducted by BNI FUSRAP project QA personnel to verify adherence with laboratory procedures and to evaluate the appropriateness and effectiveness of the procedures. Audit team leaders and auditors are trained and certified in accordance with project procedures. Technical specialists participate as auditors under the direction of the audit team leader when warranted by the nature of the activities being audited. Audit reports are prepared for each audit conducted.

Audit findings that require corrective action and followup are documented, tracked, and resolved, as verified by the project QA supervisor.

Routine radioanalyses for the FUSRAP Environmental Monitoring Program were performed under subcontract by TMA/E, Albuquerque, New Mexico. This laboratory maintained an internal quality assurance program that involved routine calibration of counting instruments, source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide determination was determined through the use of standards traceable to the National Institute of Standards and Technology (NIST), when available. When NIST standards were not available, standards from the New Brunswick laboratory were used. The laboratory also participated in the Environmental Protection Agency's (EPA) Laboratory Intercomparison Studies Program. In this program, samples of different environmental media (water, milk, air filters, soil, foodstuffs, and tissue ash) containing one or more radionuclides in known amounts were prepared and distributed to the participating laboratories. After the samples were analyzed, the results were forwarded to EPA for comparison with known values and with the results from other laboratories. This program enabled the laboratory to regularly evaluate the accuracy of its analyses and take corrective action if needed. Table A-1 summarizes results of the EPA comparison studies for water samples. TMA/E has applied and been accepted for readmission into the DOE Laboratory Quality Assessment Program for Radioactive Materials, coordinated by the DOE Environmental Laboratory, New York, New York.

Interlaboratory comparison of the tissue-equivalent TLD results was provided by participation in the International Environmental Dosimeter Project sponsored jointly by DOE, NRC, and EPA.

Chemical analyses were performed under subcontract by Weston Analytical Laboratory, Lionsville, Pennsylvania. Weston's standard practices manual was reviewed and accepted by BNI. The laboratory maintains an internal QA program that involves the following.

TABLE A-1

SUMMARY COMPARISON OF WATER SAMPLE RESULTS

(EPA and TMA/E)

Analysis and Sample Date	Value (pCi/L) EPA	Value (pCi/L) TMA/E	Ratio (TMA/E:EPA)[a]
Alpha			
1/89	41.0 ± 10.0	49.0 ± 1.0	1.20
4/89	8.0 ± 5.0	13.0 ± 1.0	1.63
6/89	30.0 ± 8.0	33.0 ± 2.7	1.10
7/89	29.0 ± 7.0	30.3 ± 2.1	1.04
11/89	4.0 ± 5.0	4.3 ± 0.6	1.08
Beta			
1/89	54.0 ± 5.0	53.0 ± 1.7	0.98
4/89	4.0 ± 5.0	5.3 ± 0.6	1.33
6/89	50.0 ± 5.0	58.3 ± 1.5	1.17
7/89	57.0 ± 5.0	51.0 ± 3.0	0.89
11/89	6.0 ± 5.0	6.7 ± 0.6	1.12
Ra-226			
1/89	5.0 ± 0.8	5.5 ± 0.3	1.10
3/89	3.50 ± 0.50	3.67 ± 0.06	1.05
5/89	4.90 ± 0.7	4.03 ± 0.25	0.82
7/89	3.50 ± 0.50	3.87 ± 0.15	1.11
10/89	17.7 ± 2.7	17.2 ± 0.5	0.97
Ra-228			
1/89	5.2 ± 0.8	6.1 ± 0.2	1.17
3/89	10.3 ± 1.5	11.3 ± 0.7	1.10
5/89	1.70 ± 0.30	1.77 ± 0.30	1.04
7/89	3.60 ± 0.50	5.20 ± 1.04	1.44
10/89	18.3 ± 2.7	24.8 ± 0.3	1.36
U (Natural)			
1/89	5.0 ± 6.0	5.3 ± 0.6	1.06
5/89	5.0 ± 6.0	5.0 ± 0.0	1.00
7/89	3.00 ± 6.00	3.00 ± 0.00	1.00
9/89	41.0 ± 6.0	39.7 ± 1.2	0.97

[a]This ratio can be used to determine the accuracy of TMA/E's analytical procedures.

For inorganic analyses, the program includes:

- Initial calibration and calibration verification
- Continuing calibration verification
- Reagent blank analyses
- Matrix spike analyses
- Duplicate sample analyses
- Laboratory control sample analyses
- Interlaboratory QA/QC

For organic analyses, the program includes:

- Gas chromatography/mass spectrometry instrumentation for both volatile and semivolatile compound analysis
- Initial multilevel calibration for each Hazardous Substances List (HSL) compound
- Matrix spike analyses
- Reagent blank analyses
- Interlaboratory QA/QC
- Continuing calibration for each HSL compound
- Addition of surrogate compounds to each sample and blanks for determining percent recovery information

Weston is currently an EPA-designated Contract Laboratory Program (CLP) laboratory for both organic and inorganic analyses. This requires passing EPA's blind performance evaluation testing each quarter. The technical specifications in BNI's subcontract with Weston specify QA/QC at, and in some cases beyond, the CLP level.

Currently, Weston participates in drinking water, wastewater, and/or hazardous waste certification programs. They are certified (or pending) in 35 such state programs (including New Jersey). Continued certification hinges upon Weston's ability to pass regular performance evaluation testing.

Weston's QA program also includes an independent overview by their project QA coordinator and a corporate vice president who audits their program activities quarterly.

APPENDIX B
ENVIRONMENTAL STANDARDS AND CONVERSION FACTORS

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr above background includes exposure from all pathways except medical treatments (Ref. 18). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represent actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Use of such assumptions will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1
CONVERSION FACTORS

1 yr	=	8,760 h
1 L	=	1,000 ml
1 μCi	=	1,000,000 pCi
1 pCi	=	0.000001 μCi
1 pCi/L	=	10^{-9} μCi/ml
1 pCi/L	=	0.000000001 μCi/ml
1 μCi/ml	=	1,000,000,000 pCi/L
10^{-6}	=	0.000001
10^{-7}	=	0.0000001
10^{-8}	=	0.00000001
10^{-9}	=	0.000000001
10^{-10}	=	0.0000000001
7×10^{-10}	=	0.0000000007
1 gal	=	3.785 L
1 yd^3	=	0.765 m^3
1 ft	=	0.3048 m

APPENDIX C
ABBREVIATIONS AND ACRONYMS

ABBREVIATIONS

cm	centimeter
cm/sec	centimeters per second
ft	foot
ft msl	feet above mean sea level
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
lb	pound
m	meter
m^3	cubic meters
mg	milligram
mg/L	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mrem	millirem
mrem/yr	millirem per year
µCi/ml	microcuries per milliliter
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
yd^3	cubic yards
yr	year

ACRONYMS

AEC	Atomic Energy Commission
BNI	Bechtel National, Inc.
CLP	Contract Laboratory Program
DOE	Department of Energy
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
MSP	Middlesex Sampling Plant
NIST	National Institute of Standards and Technology
NJDEP	New Jersey Department of Environmental Protection
TLD	thermoluminescent dosimeter
TMA/E	Thermo Analytical/Eberline
TOC	total organic carbon
TOX	total organic halides
WISS	Wayne Interim Storage Site

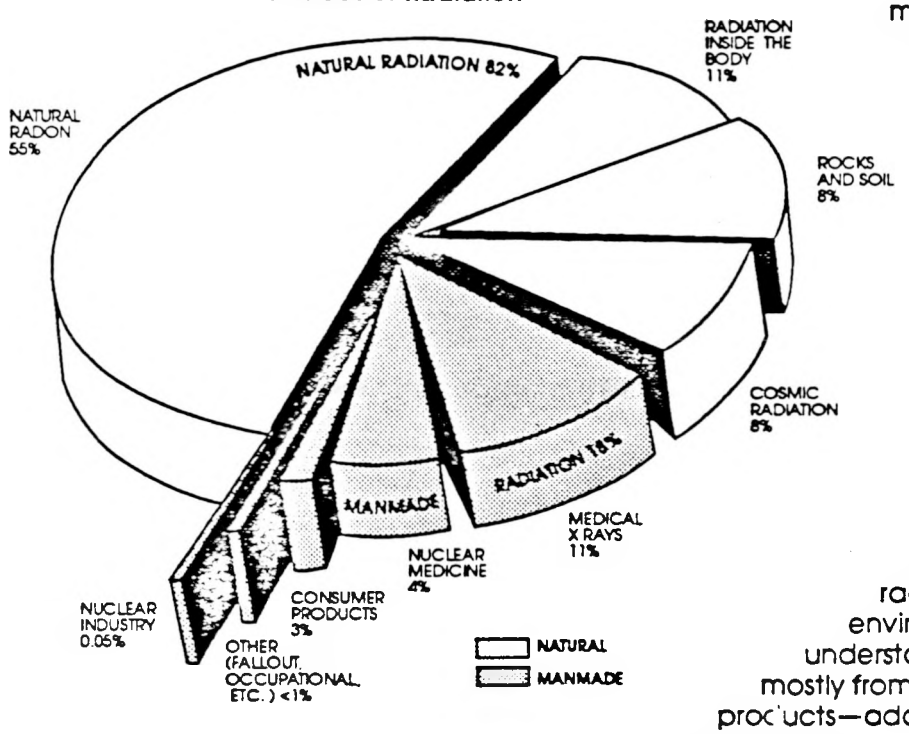
APPENDIX D
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

Radiation is a natural part of our environment. When our planet was formed, radiation was present—and radiation surrounds it still. Natural radiation showers down from the distant reaches of the cosmos and continuously radiates from the rocks, soil, and water on the Earth itself.

During the last century, mankind has discovered radiation, how to use it, and how to control it. As a result, some manmade radiation has been added to the natural amounts present in our environment.

Sources of Radiation



Many materials—both natural and manmade—that we come into contact with in our everyday lives are radioactive. These materials are composed of atoms that release energetic particles or waves as they change into more stable forms. These particles and waves are referred to as *radiation*, and their emission as *radioactivity*.

As the chart on the left shows, most environmental radiation (82%) is from natural sources. By far the largest source is radon, an odorless, colorless gas given off by natural radium in the Earth's crust. While radon has always been present in the environment, its significance is better understood today. Manmade radiation—mostly from medical uses and consumer products—adds about eighteen percent to our total exposure.

TYPES OF IONIZING RADIATION

Radiation that has enough energy to disturb the electrical balance in the atoms of substances it passes through is called *ionizing radiation*. There are three basic forms of ionizing radiation.

Alpha

Alpha particles are the largest and slowest moving type of radiation. They are easily stopped by a sheet of paper or the skin. Alpha particles can move through the air only a few inches before being stopped by air molecules. However, alpha radiation is dangerous to sensitive tissue inside the body.

Beta

Beta particles are much smaller and faster moving than alpha particles. Beta particles pass through paper and can travel in the air for about 10 feet. However, they can be stopped by thin shielding such as a sheet of aluminum foil.

Gamma

Gamma radiation is a type of electromagnetic wave that travels at the speed of light. It takes a thick shield of steel, lead, or concrete to stop gamma rays. X rays and cosmic rays are similar to gamma radiation. X rays are produced by manmade devices; cosmic rays reach Earth from outer space.

Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either 1) the total amount of radioactivity present in a substance, or 2) the level of radiation being given off.

The radioactivity of a substance is measured in terms of the number of transformations (changes into more stable forms) per unit of time. The *curie* is the standard unit for this measurement and is based on the amount of radioactivity contained in 1 gram of radium. Numerically, 1 curie is equal to 37 billion transformations per second. The amounts of radioactivity that people normally work with are in the millicurie (one-thousandth of a curie) or microcurie (one-millionth of a curie) range. Levels of radioactivity in the environment are in the picocurie, or pCi (one-trillionth of a curie) range.

Levels of radiation are measured in various units. The level of gamma radiation in the air is measured by the *roentgen*. This is a relatively large unit, so measurements are often calculated in milliroentgens. Radiation absorbed by humans is measured in either *rad* or *rem*. The rem is the most descriptive because it measures the ability of the specific type of radiation to do damage to biological tissue. Again, typical measurements will often be in the millirem (mrem), or one-thousandth of a rem, range. In the international scientific community, absorbed dose and biological exposure are expressed in *grays* and *seiverts*. 1 gray (Gy) equals 100 rad. 1 seivert (Sv) equals 100 rem. On the average, Americans receive about 360 mrem of radiation a year. Most of this (97%) is from natural radiation and medical exposure. Specific examples of common sources of radiation are shown in the chart below.

RADIATION IN THE ENVIRONMENT

Because the radioactivity of individual samples varies, the numbers given here are approximate or represent an average. They are shown to provide a perspective for concentrations and levels of radioactivity rather than dose.

mrem = millirem
pCi = picocurie

Cosmic Radiation

Cosmic radiation is high-energy gamma radiation that originates in outer space and filters through our atmosphere.

Sea Level ..... 26 mrem/year
(Increases about 1/2 mrem for each additional 100 feet in elevation)
Atlanta, Georgia (1,050 feet) ..... 31 mrem/year
Denver, Colorado (5,300 feet) ..... 50 mrem/year
Minneapolis, Minnesota (815 feet) ..... 30 mrem/year
Salt Lake City, Utah (4,400 feet) ..... 46 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as uranium, radium, and thorium. Average levels of these elements are 1 pCi/gram of soil.

United States (average) ..... 26 mrem/year
Denver, Colorado ..... 63 mrem/year
Nile Delta, Egypt ..... 350 mrem/year
Paris, France ..... 350 mrem/year
Coast of Kerala, India ..... 400 mrem/year
McAipe, Brazil ..... 2,558 mrem/year
Pocos De Caldas, Brazil ..... 7,000 mrem/year

Buildings

Many building materials, especially granite, contain naturally radioactive elements.

U.S. Capitol Building ..... 85 mrem/year
Base of Statue of Liberty ..... 325 mrem/year
Grand Central Station ..... 525 mrem/year
The Vatican ..... 800 mrem/year

Radon

Radon levels in buildings vary, depending on geographic location, from 0.1 to 200 pCi/liter.

Average Indoor Radon Level ..... 1.5 pCi/liter
Occupational Working Limit ..... 100.0 pCi/liter

Food

Food contributes an average of 20 mrem/year, mostly from potassium-40, carbon-14, hydrogen-3, radium-226, and thorium-232.

Beer ..... 390 pCi/liter
Tap Water ..... 20 pCi/liter
Milk ..... 1,400 pCi/liter
Salad Oil ..... 4,900 pCi/liter
Whiskey ..... 1,200 pCi/liter
Brazil Nuts ..... 14 pCi/g
Bananas ..... 3 pCi/g
Flour ..... 0.14 pCi/g
Peanuts & Peanut Butter ..... 0.12 pCi/g
Tea ..... 0.40 pCi/g

Medical Treatment

The exposures from medical diagnosis vary widely according to the required procedure, the equipment and film used for x rays, and the skill of the operator.

Chest X Ray ..... 10 mrem
Dental X Ray,Each ..... 100 mrem

Consumer Goods

Cigarettes–two packs/day (polonium-210) ..... 8,000 mrem/year
Color Television ..... <1 mrem/year
Gas Lantern Mantle (thorium-232) ..... 2 mrem/year
Highway Construction ..... 4 mrem/year
Airplane Travel at 39,000 feet (cosmic) ..... 0.5 mrem/hour
Natural Gas Heating and Cooking (radon-222) ..... 2 mrem/year
Phosphate Fertilizers ..... 4 mrem/year

Natural Radioactivity in Florida Phosphate Fertilizers (in pCi/gram)

	Normal Superphosphate	Concentrated Superphosphate	Gypsum
Ra-226	21.3	21.0	33.0
U-238	20.1	58.0	6.0
Th-230	18.9	48.0	13.0
Th-232	0.6	1.3	0.3

Porcelain Dentures (uranium) ..... 1,500 mrem/year
Radioluminescent Clock (promethium-147) ..... <1 mrem/year
Smoke Detector (americium-241) ..... 0.01 mrem/year

International Nuclear Weapons Test Fallout from pre–1980 atmospheric tests (average for a U.S. citizen) ..... 1 mrem/year

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PERSPECTIVE: How Big is a Picocurie?

The *curie* is a standard measure for the intensity of radioactivity contained in a sample of radioactive material. It was named after French scientists Marie and Pierre Curie for their landmark research into the nature of radioactivity.

The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations ($2.2X10^{12}$) per minute. A *picocurie* is one trillionth of a curie. Thus, a picocurie represents 2.2 disintegrations per minute.

To put the relative size of one *trillionth* into perspective, consider that if the Earth were reduced to one trillionth of its diameter, the "pico earth" would be smaller in diameter than a speck of dust. In fact, it would be six times smaller than the thickness of a human hair.

The difference between the curie and the picocurie is so vast that other metric units are used between them. These are as follows:

Millicurie = $\frac{1}{1,000}$ (one thousandth) of a curie

Microcurie = $\frac{1}{1,000,000}$ (one millionth) of a curie

Nanocurie = $\frac{1}{1,000,000,000}$ (one billionth) of a curie

Picocurie = $\frac{1}{1,000,000,000,000}$ (one trillionth) of a curie

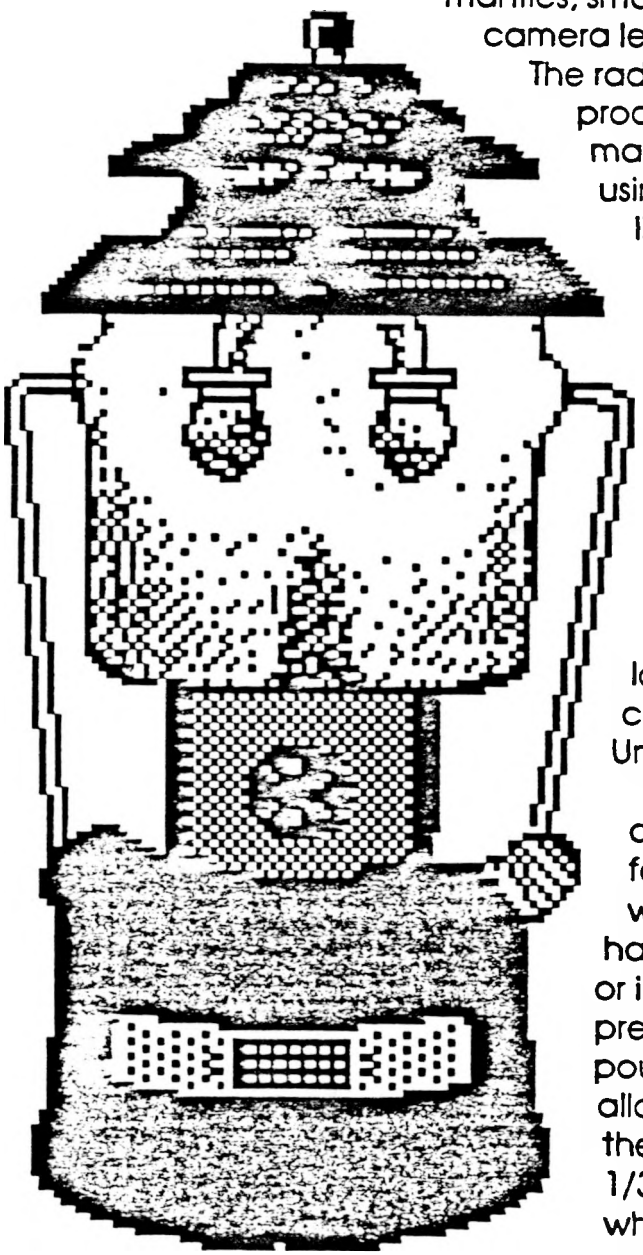
The following chart shows the relative differences between the units and gives analogies in dollars. It also gives examples of where these various amounts of radioactivity could typically be found. The number of disintegrations per minute has been rounded off for the chart.

UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	$2x10^{12}$ or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	$2x10^{9}$ or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	µCi	$2x10^{6}$ or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	$2x10^{3}$ or 2 Thousand	Annual Home Energy Costs	Consumer Products
1 Picocurie	pCi	2	Cost of a Hamburger and Coke	Background Environmental Levels

PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

Many household products contain a small amount of radioactivity. Examples include gas lantern mantles, smoke detectors, dentures, camera lenses, and anti-static brushes. The radioactivity is added to the products either specifically to make them work, or as a result of using compounds of elements like thorium and uranium in producing them. The amount of radiation the products gives off is not considered significant. But with today's sensitive equipment, it can be detected.



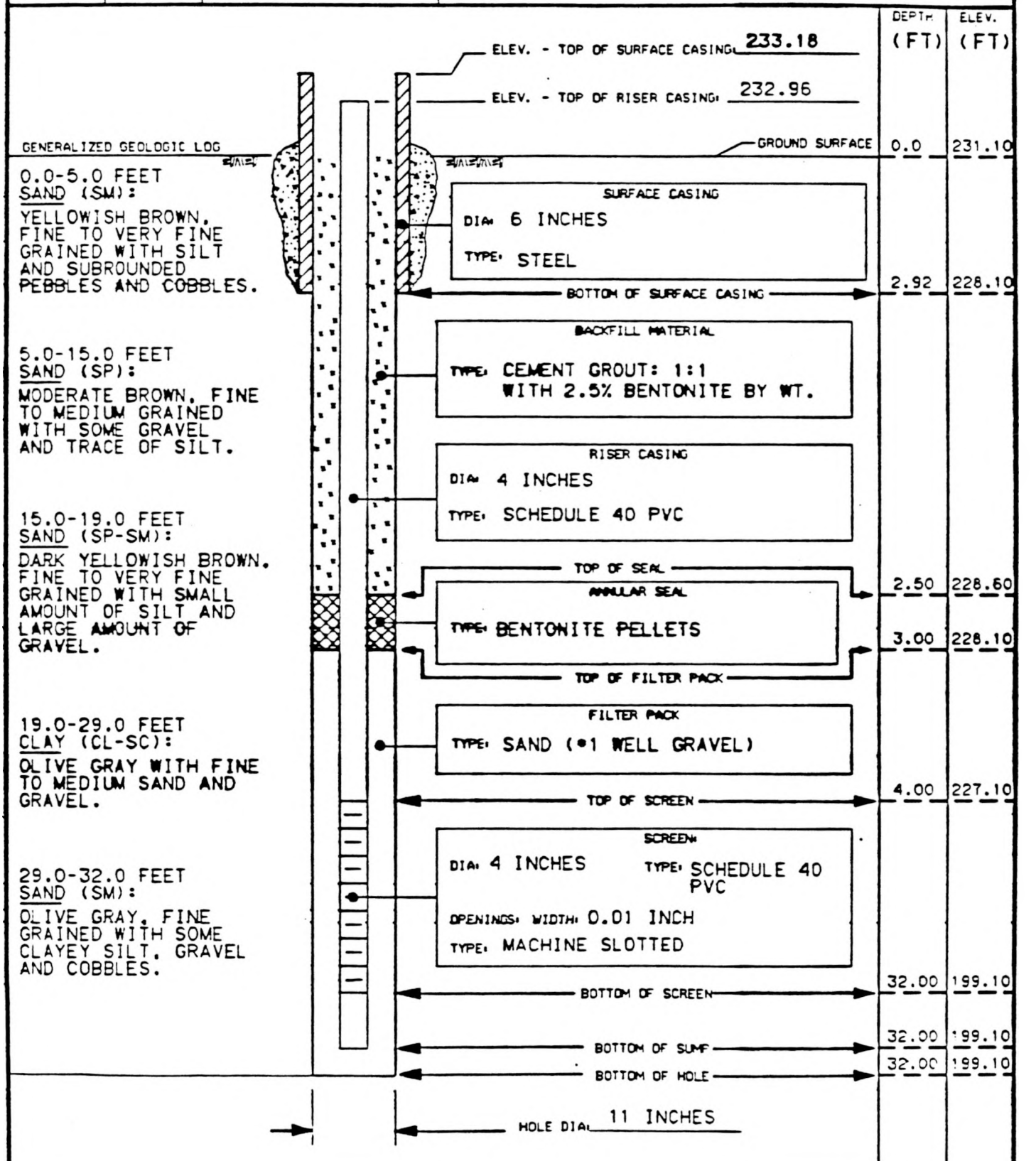
Lanterns: In a New Light

About 20 million gas lantern mantles are used by campers each year in the United States.

Under today's standards, the amount of natural radioactivity found in a lantern mantle would require precautions in handling it at many Government or industry sites. The radioactivity present would contaminate 15 pounds of dirt to above allowable levels. This is because the average mantle contains 1/3 of a gram of thorium oxide, which has a specific activity (a measure of radioactivity) of approximately 100,000 picocuries per gram. The approximately 35,000 picocuries of radioactivity in the mantle would, if thrown onto the ground, be considered low-level radioactive contamination.

APPENDIX E
SAMPLE WELL CONSTRUCTION LOG

MONITORING WELL	PROJECT FUSRAP	WELL NO. WISS-1A
JOB NO. 14501	SITE WAYNE I.S.S.	COORDINATES (JOB-METERS) N 4986.612 E 10,116.432
BEGUN 11-29-84	COMPLETED 11-30-84	PREPARED BY R. H. NELSON
REFERENCE POINT FOR MEASUREMENTS TOP OF RISER CASING		



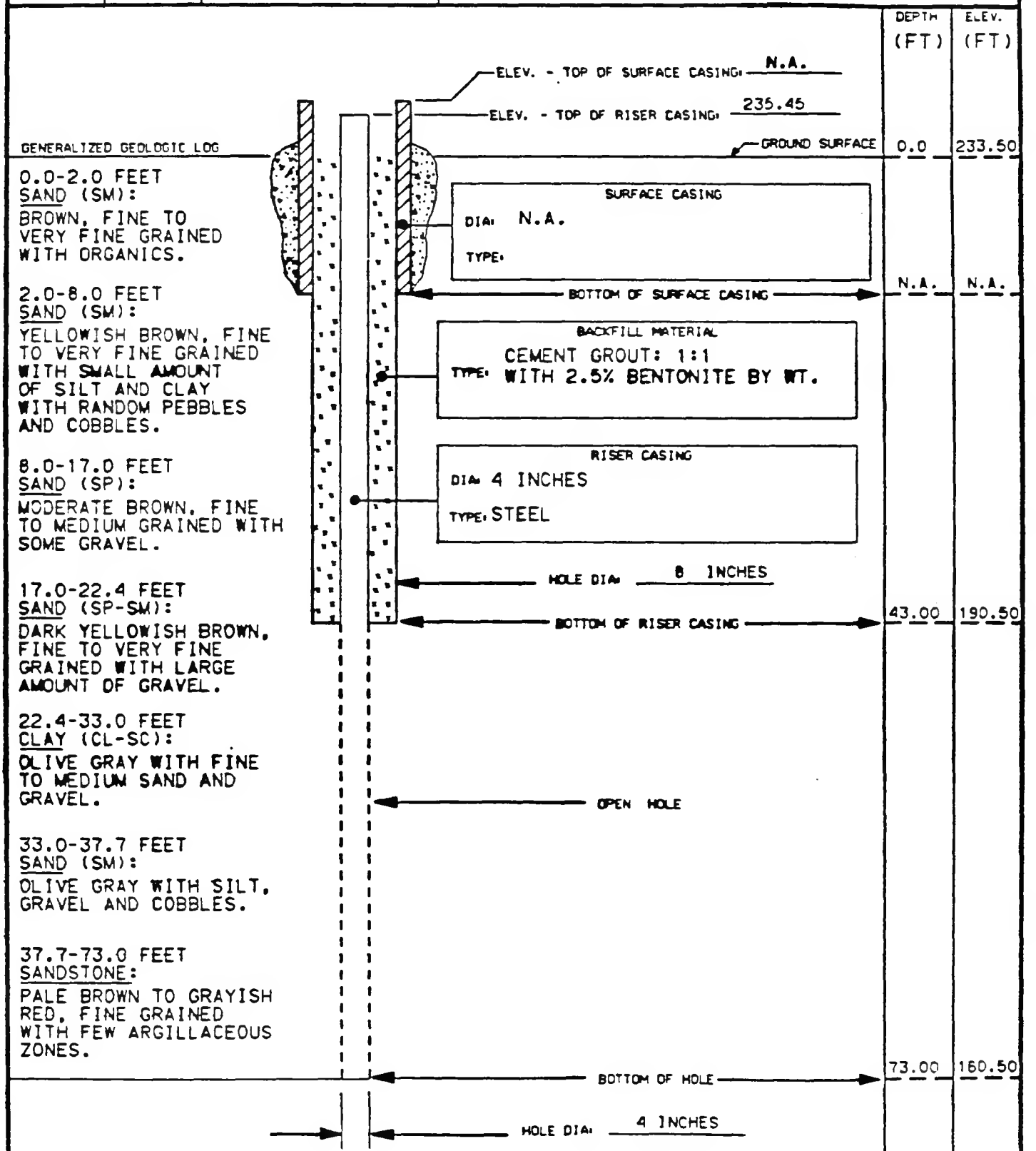
	DEPTH (FT)	ELEV. (FT)
GROUND SURFACE	0.0	231.10
BOTTOM OF SURFACE CASING	2.92	228.10
TOP OF SEAL	2.50	228.60
TOP OF FILTER PACK	3.00	228.10
TOP OF SCREEN	4.00	227.10
BOTTOM OF SCREEN	32.00	199.10
BOTTOM OF SUMP	32.00	199.10
BOTTOM OF HOLE	32.00	199.10

MONITORING WELL

PROJECT	WELL NO.
FUSRAP	WISS-1B

JOB NO.	SITE	COORDINATES (JOB-METERS)
14501	WAYNE I.S.S.	N 4986.890 E 10,120.719

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
12-3 -84	12-18-84	R. H. NELSON	TOP OF RISER CASING



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ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1989

DISTRIBUTION LIST FOR WAYNE INTERIM STORAGE SITE

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