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Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for Maywood, New Jersey

U.S. Department of Energy

0489-0613.1

(10-84)

United States Government

072713

Department of Energy

Oak Ridge Operations

memorandum

DATE: November 8, 1990

REPLY TO ATTN OF: EW-93:Oldham

SUBJECT: ANNUAL SITE ENVIRONMENTAL REPORT - MAYWOOD INTERIM STORAGE SITE

TO: Those on the Attached List

Attached for your information is the 1989 Annual Site Environmental Report for the Maywood Interim Storage Site.

The usual distribution of these reports is being made to interested local, state, and federal agencies, members of the public, and the news media.

If you have any questions regarding the content of this attachment, please contact Steven Oldham of my staff at (FTS) 626-7070. If you require additional copies of the attachment, please contact Ms. Robin Evans of my staff at (FTS) 626-4452.

Lester K. Price, Director
Former Sites Restoration Division

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DOE/OR/20722-267

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

MAYWOOD INTERIM STORAGE SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1989

Maywood, New Jersey

May 1990

Bechtel National, Inc.

0189-0260.3

DOE/OR/20722-267

MAYWOOD INTERIM STORAGE SITE
ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1989

MAY 1990

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.

P. O. Box 350

Oak Ridge, Tennessee

Bechtel Job No. 14501

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

BACKGROUND AND OVERVIEW

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

From 1916 through 1956, Maywood Chemical Works processed monazite sand for use in manufacturing industrial products such as mantles for gas lanterns. During that time, slurry containing process wastes from the thorium operations was pumped to diked areas west of the plant. In 1932, New Jersey Route 17 was built through this disposal area. Some of these process wastes were removed from Maywood Chemical Works and used as mulch and fill on nearby properties, thereby contaminating them. Some of the material migrated off site via natural drainage formerly provided by Lodi Brook.

In 1954, the U.S. Atomic Energy Commission (AEC) issued License R-103 to Maywood Chemical Works, thereby allowing it to continue to possess, process, manufacture, and distribute radioactive materials under the auspices of the Atomic Energy Act of 1954. Maywood Chemical Works was sold to the Stepan Company in 1959.

In 1961, the Stepan Company was issued an AEC radioactive materials license (STC-130). Based on AEC inspections and information related to the property on the west side of Route 17, Stepan Company agreed to perform remedial actions in the general area. The cleanup was begun in 1963. In 1966, approximately

6,400 m^3 (8,400 yd^3) of waste was removed from the area east of Route 17 and buried on site at Burial Site No. 1, which is now overlain by grass. In 1967, approximately 1,600 m^3 (2,100 yd^3) of waste was removed from the same general area and buried on site at Burial Site No. 2, which is now a parking lot. In 1968, the Stepan Company obtained permission from AEC to transfer an additional 6,600 m^3 (8,600 yd^3) of waste from the south end of the property and bury it on site at Burial Site No. 3, an area where a warehouse was later built.

At the request of the Stepan Company, a radiological survey of the property west of Route 17 was conducted by AEC in 1968. Based on the findings of that survey, clearance was granted for release of the property for use without radiological restrictions. At the time of the survey, AEC was not aware that unexcavated waste materials were present in the northeast corner of the property. In 1968, the Stepan Company sold the property west of Route 17 to a private citizen, who later sold it to the current owners, Ballod and Associates.

In 1980, the U.S. Nuclear Regulatory Commission (NRC) was notified that elevated readings were obtained on the Ballod property. This information prompted NRC to request a comprehensive survey to assess the radiological condition of the property. This was the first of many surveys of the area.

In September 1983, the U.S. Environmental Protection Agency (EPA) added the Maywood site to the National Priorities List (NPL).

The Maywood site was assigned to the U.S. Department of Energy (DOE) as part of the decontamination research and development project initially authorized by Congress under the 1984 Energy and Water Appropriations Act.

An interim storage pile was created in 1984 to store contaminated materials removed from the vicinity properties. The storage pile currently contains approximately 26,700 m^3 (34,900 yd^3) of radioactively contaminated materials.

During its history, MISS 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)

MISS does not have any state or federal air permits. As a non-operating facility, only Subparts H and Q of NESHAPs are applicable. 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. A strategy for determining compliance with the radon flux standard in Subpart Q was submitted to EPA. Comments were received from EPA on the proposed compliance strategy on April 19, 1990. The comments require minor modifications to the compliance strategy. Radon flux measurements of the pile will begin by July 18, 1990, absent further comments from 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 MISS exceeded the DOE guideline for thoron (Rn-220) (3.0 pCi/L) at one location. The average for the site is below this guideline. All other measurements indicate that the site is in compliance with DOE orders.

Clean Water Act (CWA)

MISS 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. EPA has not yet promulgated regulations; however, 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 waste was present at MISS, and an environmental compliance assessment conducted by ORNL in October 1989 found 12 deficiencies under RCRA. Eight of the deficiencies have been addressed; the remainder, which involve waste management documentation, will be addressed by June 1990.

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

MISS is on the NPL; therefore, a Federal Facilities Agreement (FFA) is required for site remedial action. EPA and DOE have developed 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 present at MISS. 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 had no significant impact on the environment. A formal NEPA determination has been made for final cleanup of the site, and completion of an environmental impact study (EIS) is required.

Compliance with NEPA for site remedial actions will be accomplished by incorporating those elements required by an EIS into the format of the CERCLA remedial investigation/feasibility study.

ABSTRACT

The environmental monitoring program, which began in 1984, was continued in 1989 at the Maywood Interim Storage Site (MISS), a U.S. Department of Energy (DOE) facility located in the Borough of Maywood and the Township of Rochelle Park, New Jersey. MISS is currently used for storage of soils contaminated with low-level radioactivity.

MISS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to identify and decontaminate or otherwise control sites where residual radioactive materials (exceeding current guidelines) remain 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 project authorized by Congress under the 1984 Energy and Water Development Appropriations Act, remedial action is being conducted at this 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 MISS measures thoron and radon concentrations in air; external gamma radiation levels; and thorium, uranium, and radium 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 this report, this hypothetical individual receives an annual external exposure approximately equivalent to 1 percent of the DOE radiation protection standard. This exposure is less than a person receives during a round-trip flight from New York to Los Angeles (because of the greater amounts of cosmic radiation present at higher altitudes). The cumulative dose to the population within an 80-km (50-mi) radius of MISS that results

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

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FIGURES

FIGURES
(continued)

TABLES

1.0 INTRODUCTION

This report presents the results of the environmental monitoring program conducted at the U.S. Department of Energy's (DOE) Maywood Interim Storage Site (MISS) during calendar year 1989. Environmental monitoring began at MISS in 1984. The research and development decontamination program authorized by Congress under the 1984 Energy and Water Development Appropriations Act assigned MISS to the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP). Bechtel National, Inc. (BNI) serves as the project management contractor for conducting remedial action at the site and at vicinity properties.

1.1 LOCATION AND DESCRIPTION

MISS is located in the Borough of Maywood and the Township of Rochelle Park, in Bergen County, New Jersey, approximately 19 km (12 mi) north-northwest of downtown Manhattan (New York City) and 21 km (13 mi) northeast of Newark, New Jersey (Figures 1-1 and 1-2). Figure 1-3 is an aerial photograph of the site. MISS is bounded by New Jersey Route 17 on the west, a railroad line on the northeast, and commercial/industrial areas on the south and east. The site occupies 4.73 ha (11.7 acres) and is fenced. The adjacent Stepan Company (former Maywood Chemical Works) property is also enclosed by a fence and is currently used for chemical processing activities.

MISS is located within the glaciated section of the Piedmont Plateau of north-central New Jersey (Ref. 1). The terrain is generally level but includes intermittent shallow ditches and slight mounds (Ref. 2). MISS slopes gently toward the Saddle River, which is west of the site (Figure 1-2). The site is underlain by sedimentary rocks (sandstone, mudstone, and siltstone) of the Brunswick formation (Refs. 3 and 4). Bedrock lies close to the surface and is overlain by 0.9 to 4.6 m (3 to 15 ft) of weathered bedrock debris and unconsolidated glacial deposits of clay, silt, sand, and gravel. The depth of the glacial deposits

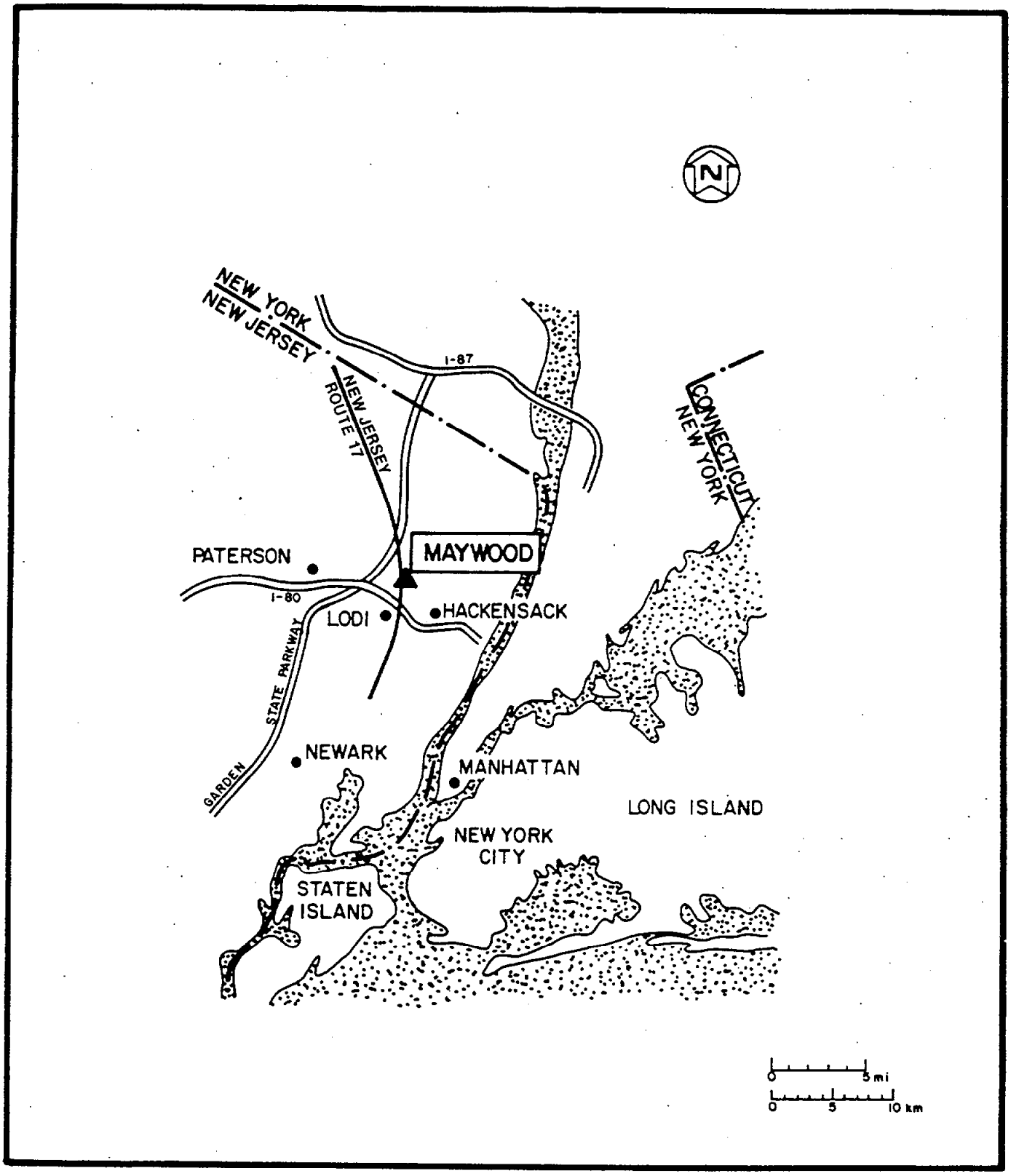

FIGURE 1-1 LOCATION OF MAYWOOD, NEW JERSEY

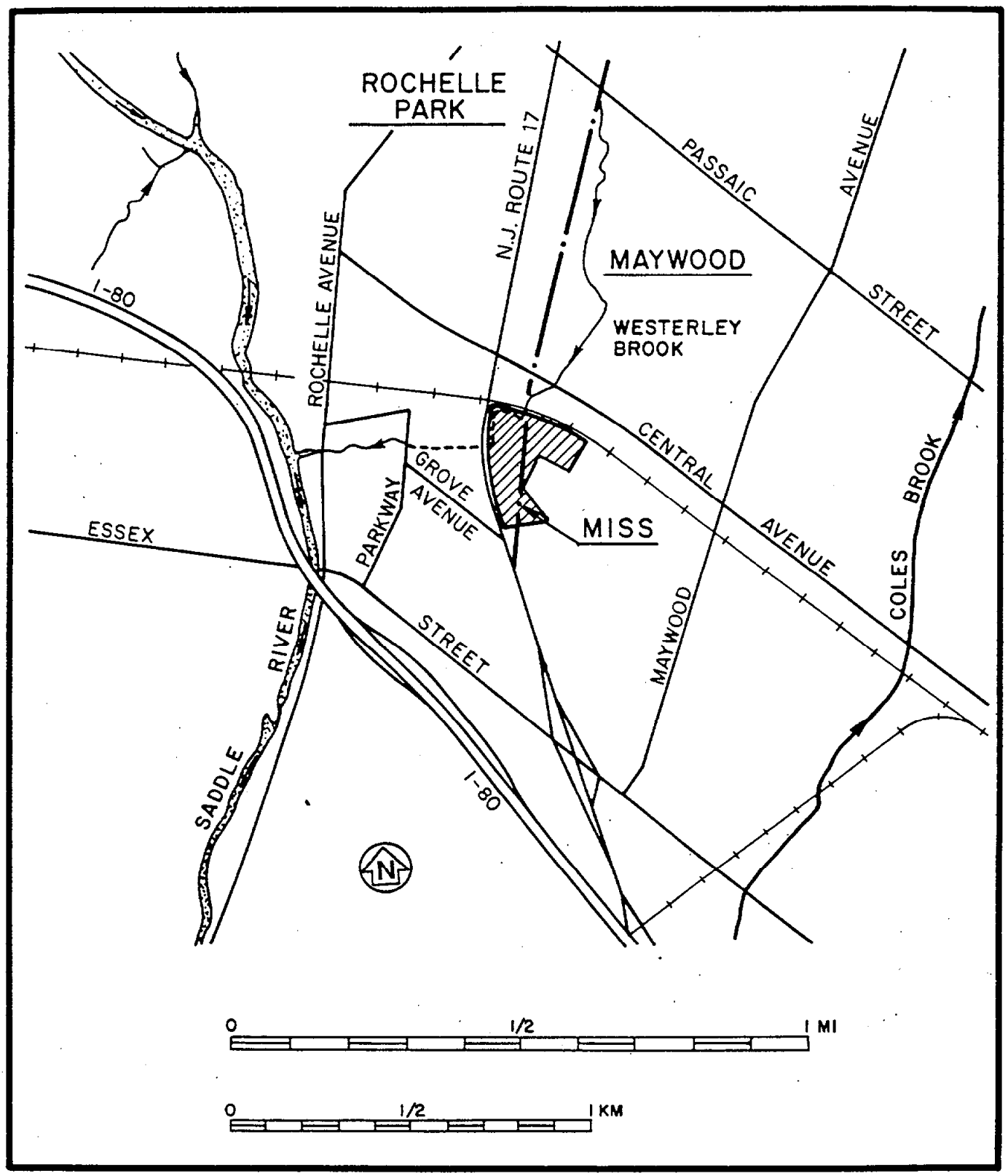

FIGURE 1-2 LOCATION OF MISS

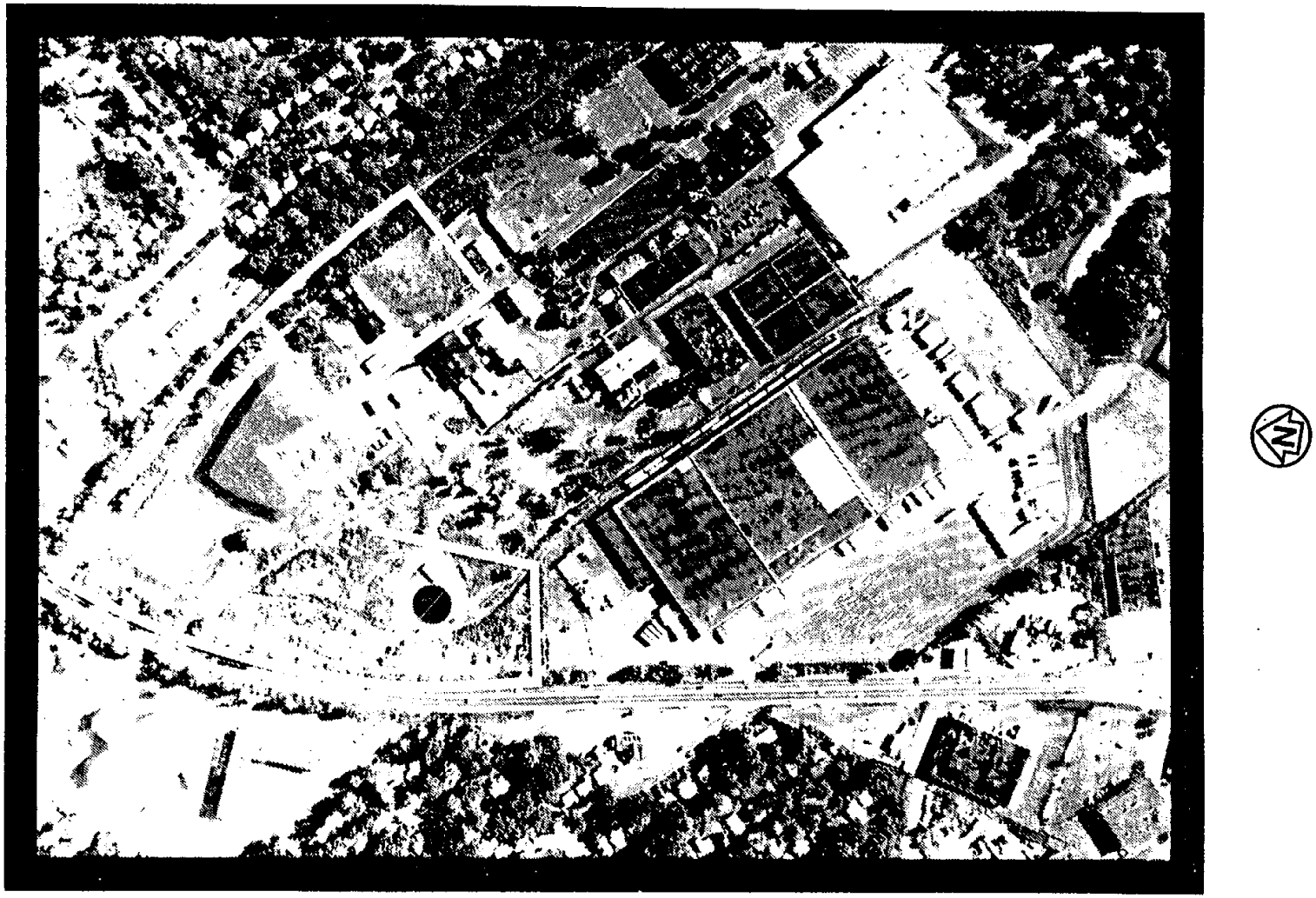

FIGURE 1-3 AERIAL VIEW OF MISS AND VICINITY

varies considerably in the vicinity of the site. In addition, fill materials consisting primarily of soil and building rubble were placed on the site during its many years of industrial use (Ref. 3).

MISS is located within the Saddle River drainage basin (Figure 1-2), approximately 0.7 km (0.4 mi) east of the Saddle River (a tributary of the Passaic River) and approximately 1.6 km (1 mi) west of the drainage divide lying between the Hackensack River and the Saddle River (Ref. 4). MISS is poorly drained. Rainwater runoff from MISS empties into the Saddle River via Westerley Brook. The brook flows under the site through a concrete storm drain, passes under New Jersey Route 17, and eventually empties into the Saddle River. Neither the Saddle River nor Westerley Brook is used as a source of drinking water (Ref. 5).

The groundwater table is generally shallow, lying 1.2 to 3.7 m (4 to 12 ft) below the ground surface. Groundwater in the Maywood area is available primarily from a bedrock aquifer and from unconsolidated surficial deposits; the former is generally considered to be the more significant groundwater resource. Wells that draw from the unconsolidated surficial deposits generally have low yields and are used for domestic purposes. However, some wells located in areas with thicker surficial deposits of stratified glacial drift have high yields and have been developed for industrial and public uses.

The average frequency of precipitation in New Jersey is 120 days/yr; the mean annual precipitation is approximately 122 cm (48.0 in.), with an average annual snowfall of 74 cm (29 in.) As shown in Figure 1-4, winds in the area blow predominantly from the west at a mean speed of 17.2 km/h (10.2 mph) (Refs. 6 and 7).

Populations of Maywood and Rochelle Park in 1980 were approximately 9,900 and 5,600, respectively, a decline from 11,000 and 6,400 in 1970. The 1970 and 1980 populations of Bergen County were approximately 898,000 and 845,000, respectively. The population of Bergen County is expected to increase over the next 20 years (Ref. 1).

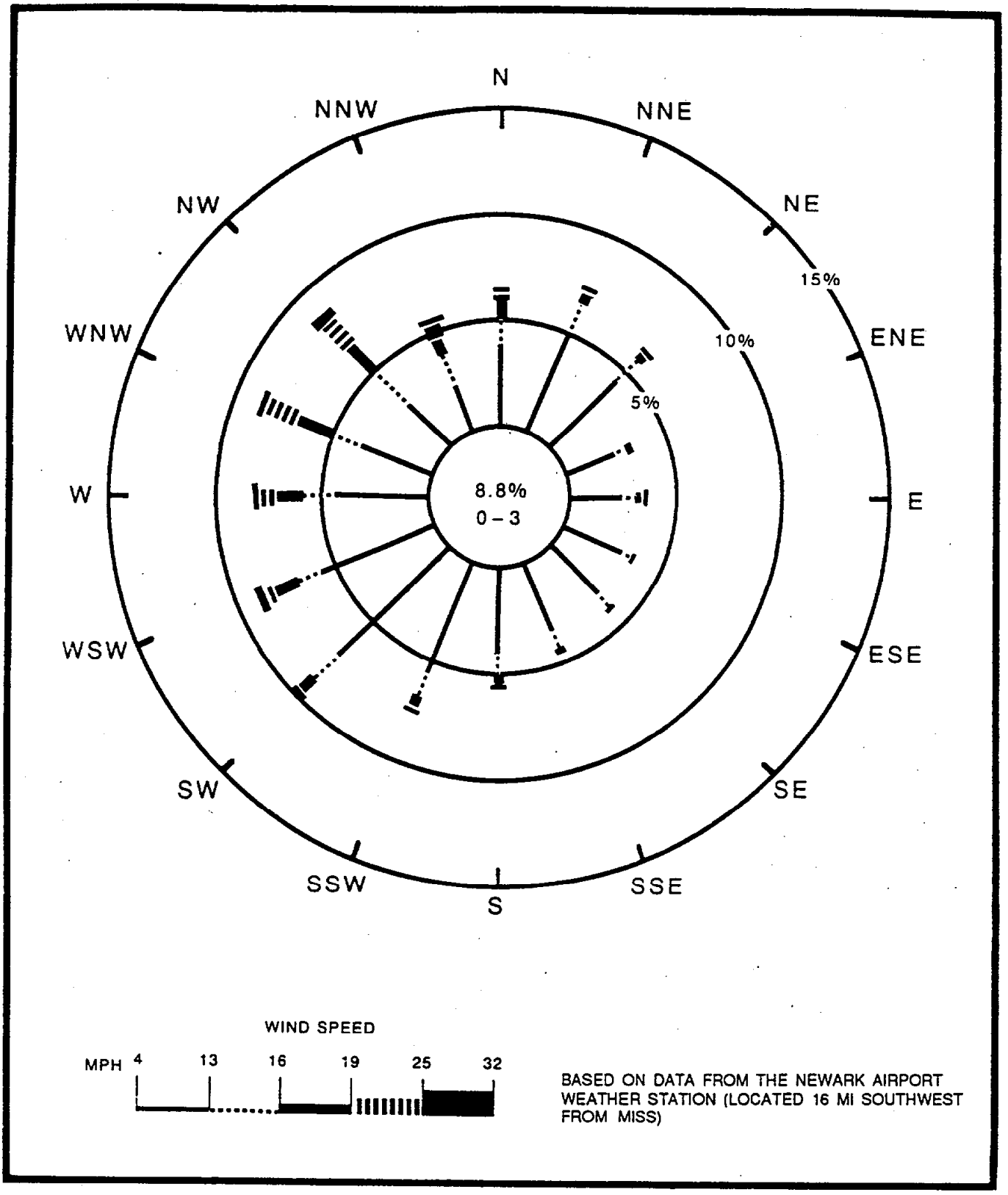

FIGURE 1-4 ANNUAL WIND ROSE FOR MISS

Generalized land uses in the vicinity of MISS are shown in Figure 1-5. The areas adjacent to the site are zoned primarily for commercial, commercial/industrial, or residential use. Except for one house on the eastern border of the Stepan Company property, areas east and south of the site are used for industrial and restricted commercial purposes. The New York, Susquehanna and Western Railroad runs along the northern border of MISS.

1.2 SITE HISTORY

From 1916 through 1956, Maywood Chemical Works processed monazite sand (thorium ore) for use in manufacturing industrial products such as mantles for gas lanterns. During that time, slurry containing process wastes from the thorium operations was pumped to diked areas west of the plant. Some of these process wastes were removed from Maywood Chemical Works and used as mulch and fill on nearby properties, thereby contaminating them. Some of the material migrated off site via natural drainage formerly provided by Lodi Brook. In 1932, New Jersey Route 17 was built through this disposal area (Figure 1-2).

In 1954, the Atomic Energy Commission (AEC) issued License R-103 to Maywood Chemical Works, thereby allowing it to continue to possess, process, manufacture, and distribute radioactive materials under the auspices of the Atomic Energy Act of 1954 (Ref. 8). Maywood Chemical Works was sold to the Stepan Company in 1959.

In 1961, the Stepan Company was issued an AEC radioactive materials license (STC-130) (Ref. 8). Based on AEC inspections and information related to the Ballod property on the west side of Route 17, the Stepan Company agreed to take remedial action. The cleanup was begun in 1963. In 1966, 6,392 m^3 (8,360 yd^3) of waste was removed from the area east of Route 17 and buried on site at Burial Site No. 1, which is now overlain by grass. In 1967, 1,570 m^3 (2,053 yd^3) of waste was removed from the same general area and buried on site at Burial Site No. 2, which is now a parking lot. In 1968, the Stepan Company obtained permission from

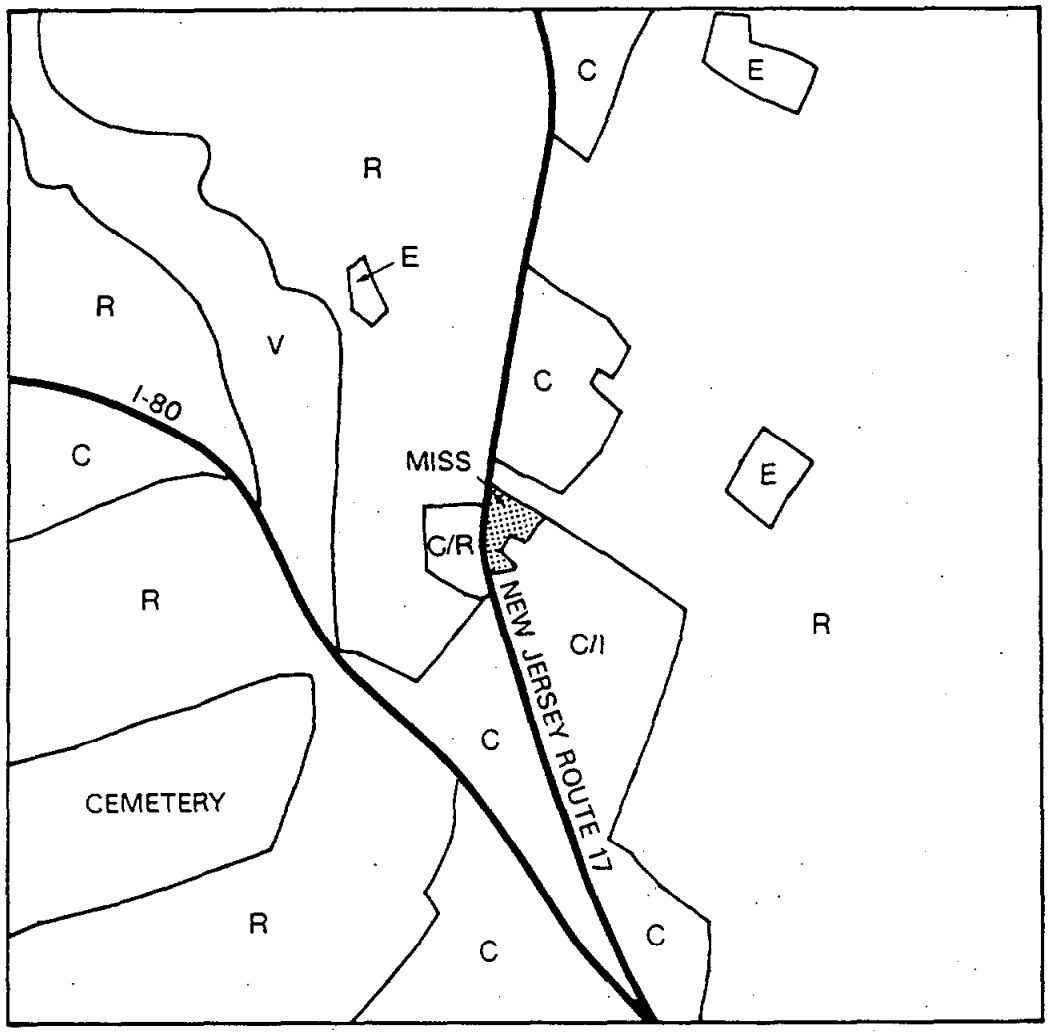

FIGURE 1-5 GENERALIZED LAND USE IN THE VICINITY OF MISS

AEC to transfer an additional 6,576 m^3 (8,600 yd^3) of waste from the south end of the Ballod property and bury it on site at Burial Site No. 3, an area where a warehouse was later built (Ref. 8). Figure 1-6 shows the approximate locations of these burial sites.

At the request of the Stepan Company, a radiological survey of the south end of the Ballod property west of Route 17 was conducted by the AEC in 1968. Based on the findings of that survey, clearance was granted for release of the property (Ref. 8). At the time of the survey, AEC was not aware that unexcavated waste materials were present in the northeast corner of the property. In 1968 this portion of the Stepan Company property was sold to a private citizen, who later sold it to the current owners, Ballod and Associates (Ref. 8).

In 1980 the U.S. Nuclear Regulatory Commission (NRC) was notified that elevated gamma radiation readings were obtained on the Ballod and Associates property (Ref. 8). This information prompted NRC to request a comprehensive survey to assess the radiological condition of the property. The survey was performed by Oak Ridge Associated Universities (ORAU) with the assistance of a representative from the Region I office of NRC in February 1981 (Ref. 2).

NRC also requested that an aerial radiological survey of the Stepan Company site, the Ballod and Associates property, and the surrounding area be conducted. This survey, which was conducted by EG&G in January 1981, resulted in the discovery of other anomalies (readings distinctly higher than those of surrounding areas) (Ref. 9). Elevated gamma readings (greater than the local background level) were detected directly over the Stepan Company chemical plant, as well as immediately to the west and south of the plant. Two other points of elevated background gamma radiation were detected approximately 0.8 km (0.5 mi) from the center of the plant: one to the northeast and the other to the south. Follow-up ground surveys were performed to determine the nature of these anomalies. These surveys identified contaminated residential properties on Davison and Latham streets.

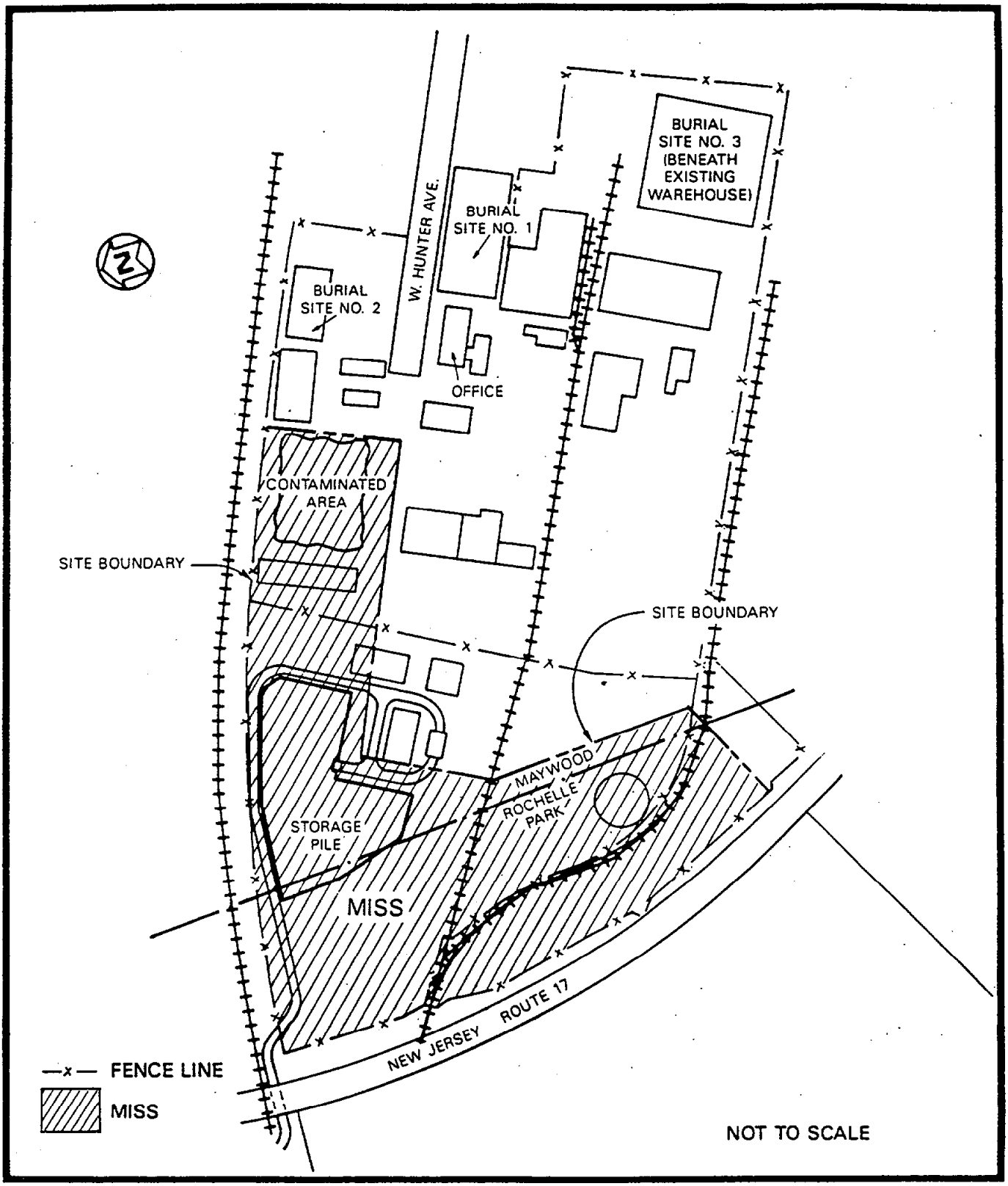

FIGURE 1-6 BURIAL SITE LOCATIONS ON THE STEPAN COMPANY PROPERTY

In 1984, DOE had Oak Ridge National Laboratory (ORNL) survey the Lodi area with a mobile van (Ref. 10). Eight residential properties were found to be contaminated with thorium-232; additional properties were found to be contaminated with radium-226 and uranium. The presence of radium-226 and uranium appears to be associated with the presence of natural uranium.

In 1984, DOE negotiated an agreement with the Stepan Company for access to a 4.73-ha (11.7-acre) portion of the Stepan Company property on which to establish MISS, pending execution of an agreement to transfer ownership of the site to DOE. Development of the storage site commenced, and contaminated materials removed from 17 vicinity properties in Maywood and Rochelle Park were brought to the site in 1984. In 1985, remedial action was conducted at eight residential properties in the Borough of Lodi and at the Ballod property in Rochelle Park. In September 1985, ownership of the MISS property was transferred to DOE.

Radiological characterization surveys were conducted in 1986 on the Sears property and adjoining commercial properties southeast of MISS; on the New York, Susquehanna and Western Railroad property adjoining the northern boundary of MISS; on a portion of Route 17; and on the north Ballod property. Radiological surveys of the following Lodi properties were also conducted in 1986: 1 commercial, 1 state-owned, 26 residential, and 1 municipal. Remedial action is planned for certain of these properties.

In 1987, several radiological surveys were conducted at residential, commercial, and municipal properties in Lodi. In addition, in late 1987, a layer of clean fill material was placed along the MISS boundary to reduce elevated levels of radon and external gamma radiation. Also in 1987, several groundwater monitoring wells were installed on the Stepan property and adjacent properties to monitor the shallow groundwater system and deep aquifer. These wells, along with those added in the summer of 1988 on the MISS, railroad, and Grove Street properties, are used to provide data on groundwater flow and quality. Data from the 1988 wells are presented in this report.

There were no commercial, industrial, or remedial activities at MISS in 1989. Radioactive effluents were limited to radon and thoron, which were barely detectable above background at the site perimeter.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

The hydrogeological characteristics of the site observed in 1989 are the same as those reported in previous environmental reports. The data and interpretations are based on groundwater levels measured in calendar year 1989. Groundwater monitoring wells (Figure 1-7) were first installed at MISS in late 1984 through early 1985 (Ref. 11). Additional monitoring wells were installed during 1987 and 1988 in the properties surrounding MISS. A summary of construction information for wells sampled for this report is shown in Table 1-1. An example of well construction details is included as Appendix E.

The two groundwater systems monitored have previously been designated "shallow" and "bedrock" (Ref. 11). This report uses "upper" instead of "shallow." Monitoring wells installed in the upper groundwater system are designated with an "A" or "S" suffix, and wells installed in the bedrock system are designated with a "B" or "D" suffix. Further background information on site geology, hydrogeology, and well installation methods can be found in Ref. 11.

1.3.1 Upper Groundwater System

The water table of the upper groundwater system is approximately 1.2 to 3.7 m (4 to 12 ft) below ground surface. (The water table, or potentiometric surface, is defined as the level to which water will rise in tightly cased wells. Delineation of the potentiometric surface of an aquifer indicates groundwater gradient and flow direction.) Wells in this zone are screened in

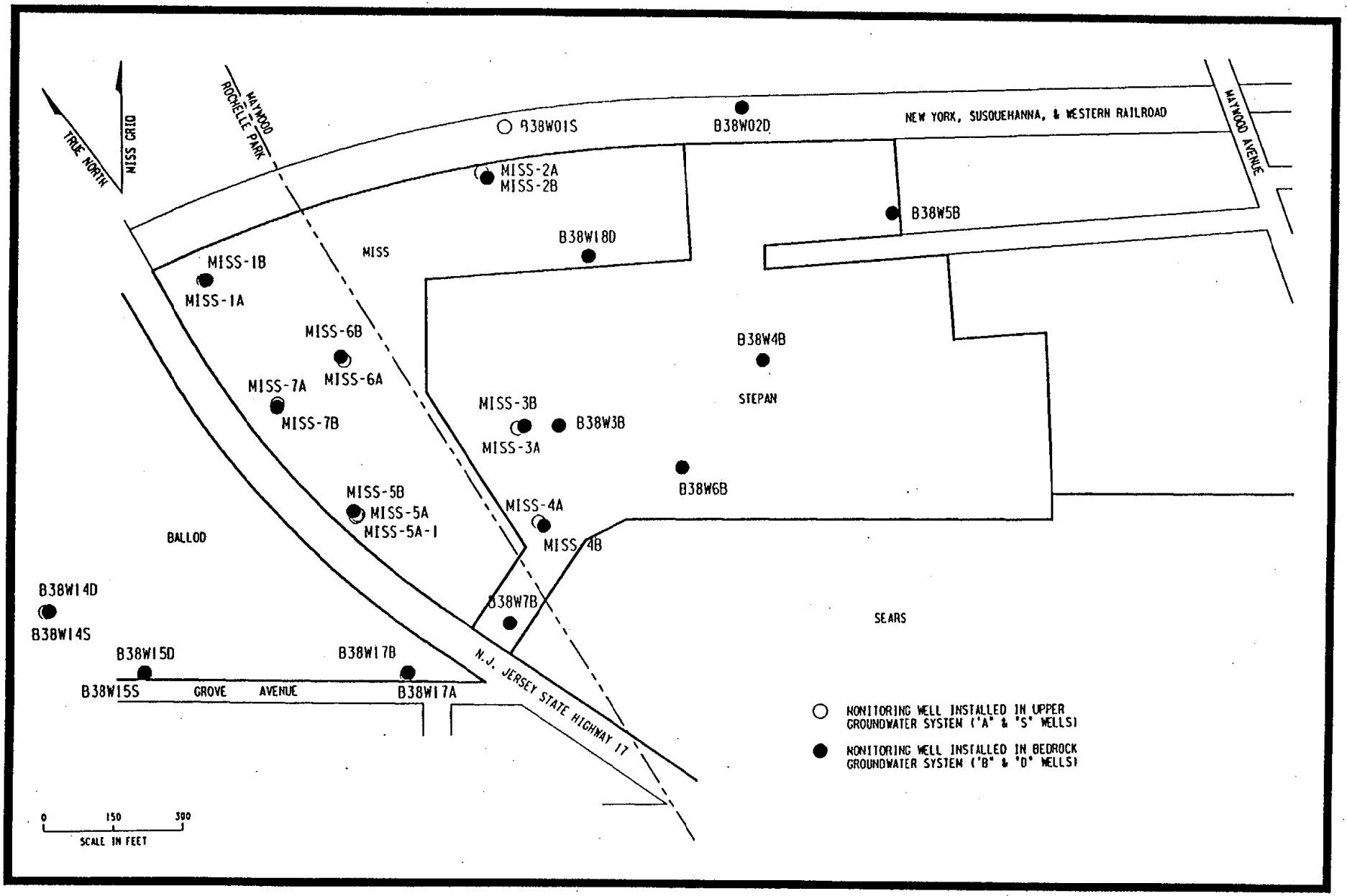

FIGURE 1-7 LOCATIONS OF GROUNDWATER MONITORING WELLS AT MISS AND VICINITY

TABLE 1-1

MONITORING WELL CONSTRUCTION SUMMARY FOR MISS

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitored Interval Below Ground [m-m (ft-ft)]	Construction Material[b]
MISS-1A	Nov. 1984	3.66 (12.0)	1.2-3.47 (4.0-11.4)	PVC
MISS-1B	Nov. 1984	16.3 (53.5)	7.01-16.3 (23.0-53.5);[c] Open hole	Steel
MISS-2A	Oct. 1984	6.10 (20.0)	1.5-5.8 (5.0-18.9)	PVC
MISS-2B	Nov. 1984	17.8 (58.5)	8.7-17.8 (28.5-58.5);[c] Open hole	Steel
MISS-3A	Oct. 1984	4.57 (15.0)	1.5-3.87 (5.0-12.7)	PVC
MISS-3B	Nov. 1984	15.2 (50.0)	6.10-15.2 (20.0-50.0);[c] Open hole	Steel
MISS-4A	Oct. 1984	3.05 (10.0)	1.2-3.0 (3.8-9.7)	PVC
MISS-4B	Nov. 1984	14.3 (47.0)	5.19-14.3 (17.0-47.0);[c] Open hole	Steel
MISS-5A	Nov. 1984	4.58 (15.0)	3.1-4.5 (10.0-14.6)	PVC
MISS-5A1	Nov. 1984	2.4 (8.0)	0.8-2.4 (2.5-8.0)	PVC
MISS-5B	Nov. 1984	16.8 (55.0)	7.6-16.8 (25.0-55.0);[c] Open hole	Steel
MISS-6A	Oct. 1984	4.88 (16.0)	1.5-4.64 (5.0-15.2)	PVC
MISS-6B	Nov. 1984	16.2 (53.0)	7.02-16.2 (23.0-53.0);[c] Open hole	Steel
MISS-7A	Nov. 1984	3.51 (11.5)	0.8-2.9 (2.5-9.6)	PVC
MISS-7B	Nov. 1984	15.0 (49.0)	5.79-15.0 (19.0-49.0);[c] Open hole	Steel
B38W01S	Nov. 1988	7.02 (23.0)	5.20-6.7 (17.0-22.0)	SS
B38W02D	Nov. 1988	13.1 (43.0)	11.3-12.8 (37.0-42.0)	SS
B38W03B	Aug. 1987	12.3 (40.5)	9.09-12.1 (29.8-39.5)	SS
B38W04B	Sept. 1987	11.1 (36.3)	4.03-8.5 (13.2-27.7)	SS
B38W05B	Sept. 1987	13.6 (44.5)	6.92-10.1 (22.7-33.0)	SS
B38W06B	Sept. 1987	11.1 (36.4)	4.85-6.4 (15.9-20.9)	SS
B38W07B	Sept. 1987	12.0 (39.2)	5.64-8.8 (18.5-28.8)	SS

TABLE 1-1

(continued)

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitored Interval Below Ground [m-m (ft-ft)]	Construction Material[b]
B38W14S	Nov. 1988	3.97 (13.0)	2.4-3.96 (8.0-13.0)	SS
B38W14D	Nov. 1988	15.6 (51.0)	14.0-15.4 (46.0-50.5)	SS
B38W15S	Oct. 1988	5.03 (16.5)	3.20-4.73 (10.5-15.5)	SS
B38W15D	Oct. 1988	14.0 (46.0)	12.2-13.7 (40.0-45.0)	SS
B38W17A	Oct. 1987	4.30 (14.1)	2.4-3.87 (7.7-12.7)	SS
B38W17B	Oct. 1987	13.5 (44.4)	5.67-8.81 (18.6-28.9)	SS
B38W18D	Oct. 1988	12.5 (41.0)	10.7-12.2 (35.0-40.0)	SS

[a] Wells installed in the upper groundwater system are designated with an "A" or "S"; wells installed in the bedrock system are designated with a "B" or "D".

[b] PVC - polyvinyl chloride; SS - stainless steel.

[c] Carbon steel casing extends through overburden and 0.6 m (2 ft) into bedrock; monitored interval is a 7.6-cm- (3.0-in.-) diameter open hole in bedrock.

unconsolidated materials at depths of 0.76 to 6.71 m (2.5 to 22.0 ft). Groundwater level measurements taken in 1989 with an electric downhole probe water level indicator are shown as hydrographs (Figures 1-8 through 1-11). No hydrographs are given for wells 1A and 5A1 because they were dry throughout 1989.

Precipitation records were not available for MISS. Records of precipitation collected at the Middlesex Sampling Plant (MSP), which is approximately 48 km (30 mi) southwest, are presented with the hydrographs (for reference only) in Figures 1-8 through 1-10.

The hydrographs for the upper groundwater system show slight seasonal fluctuations in groundwater levels. Generally, the highest levels tend to be in the spring, and the lowest in the fall and winter.

The gradient and flow direction of the upper groundwater system were determined from two potentiometric surface maps (Figure 1-12 for August 1 and Figure 1-13 for December 6), which show the minimal seasonal variation in this system. The gradient of the potentiometric surface on both days is on the order of 0.01. The general flow direction is from east to west. The contours suggest that the potentiometric surface is approximately parallel to the regional surface topography.

1.3.2 Bedrock Groundwater System

The potentiometric surface of the semiconfined bedrock groundwater system is from 2.1 to 5.2 m (7 to 17 ft) below the ground surface. The 1984 bedrock wells are open holes (no screen or filter pack), below a steel surface casing set through the overburden, emplaced with a cement grout seal in the top of the Brunswick formation. These wells range in depth from 11.1 to 18.0 m (36.3 to 58.9 ft). The newer (1987-1988) bedrock wells have stainless steel screens and sand filter packs installed in the bedrock and bentonite seals isolating the screened section from the upper groundwater system.

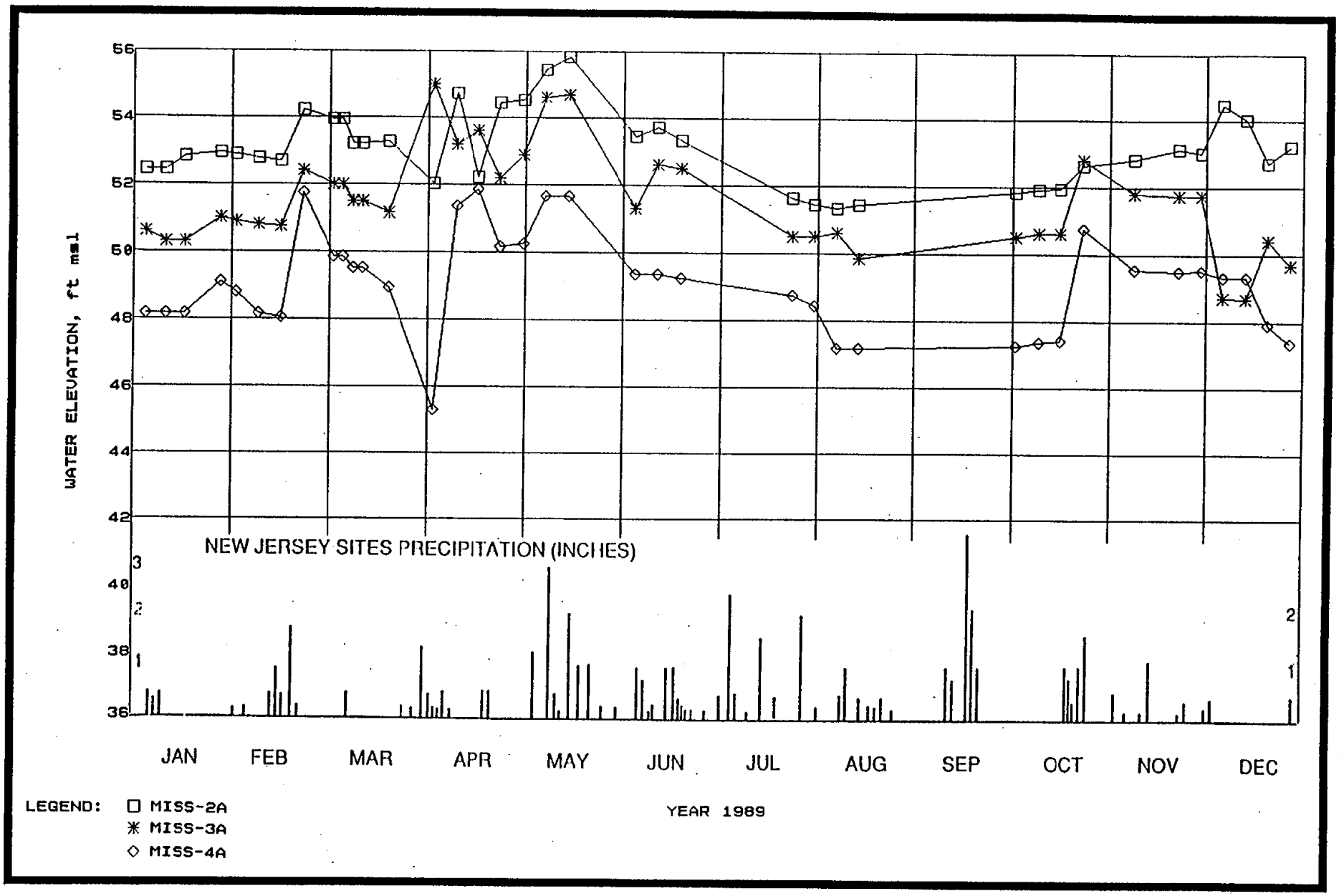

FIGURE 1-8 HYDROGRAPHS OF WELLS 2A, 3A, AND 4A IN THE UPPER GROUNDWATER SYSTEM AT MISS

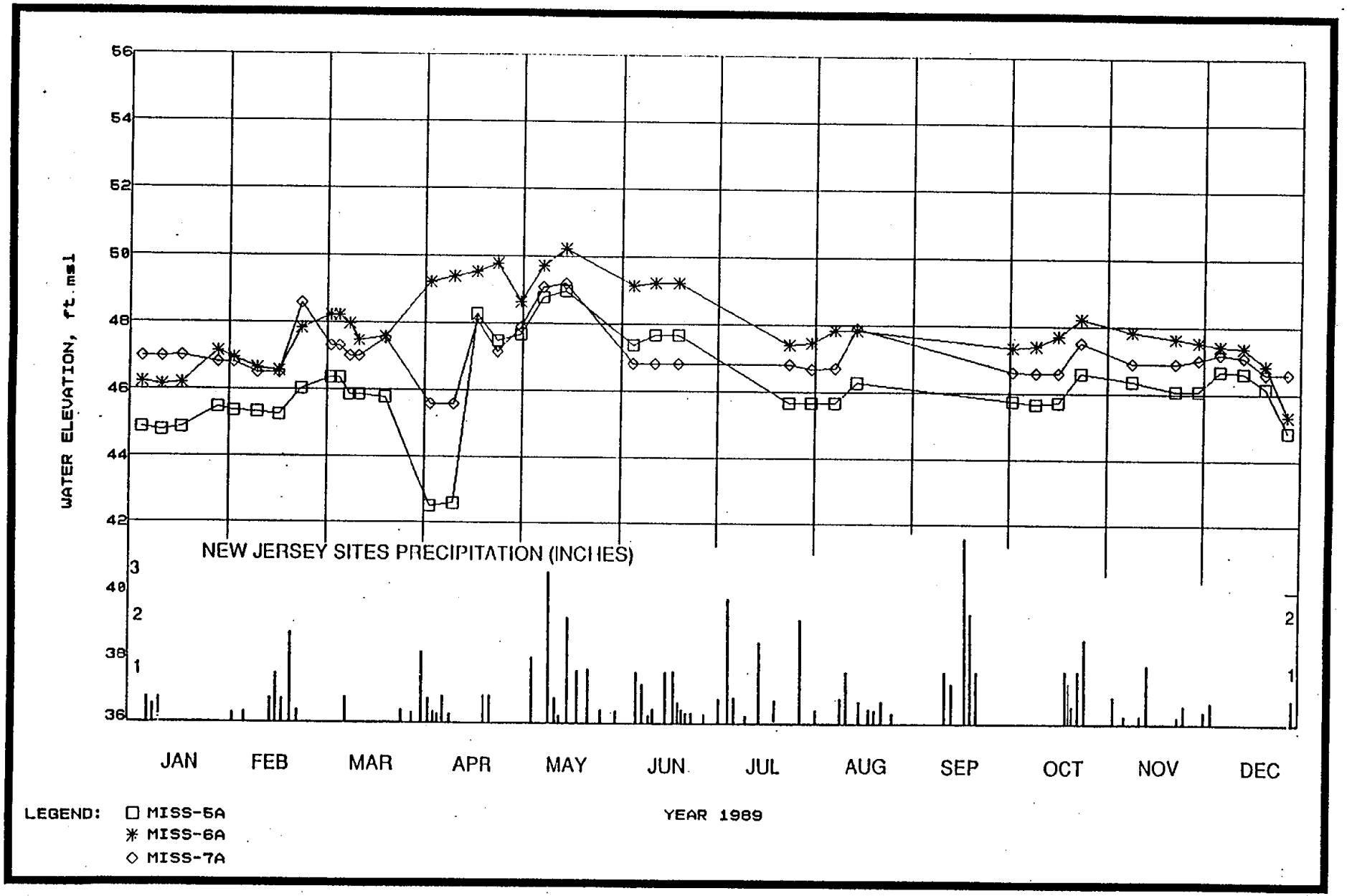

FIGURE 1-9 HYDROGRAPHS OF WELLS 5A, 6A, AND 7A IN THE UPPER GROUNDWATER SYSTEM AT MISS

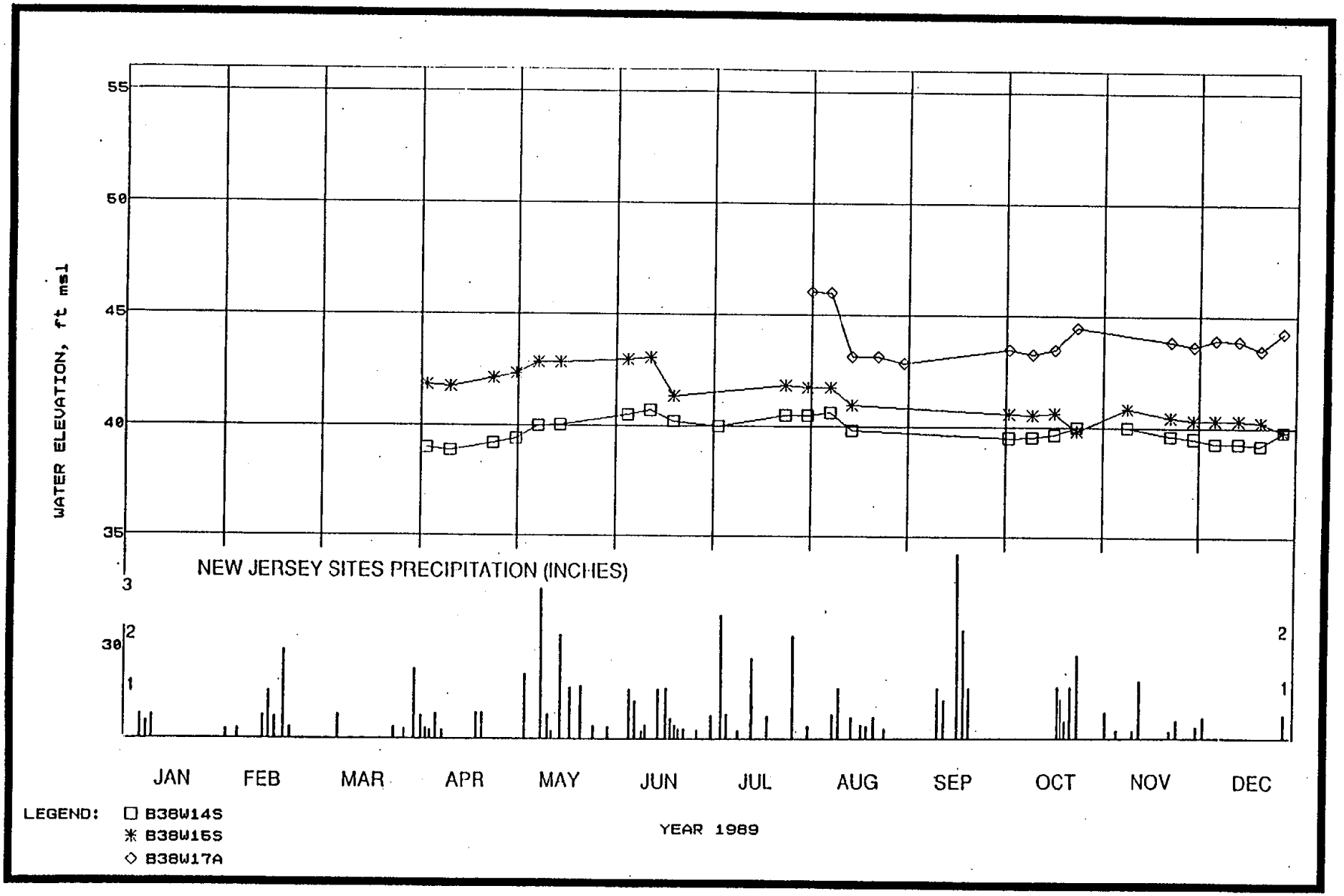

FIGURE 1-10 HYDROGRAPHS OF WELLS B38W14S, B38W15S, AND B38W17A IN THE UPPER GROUNDWATER SYSTEM AT MISS

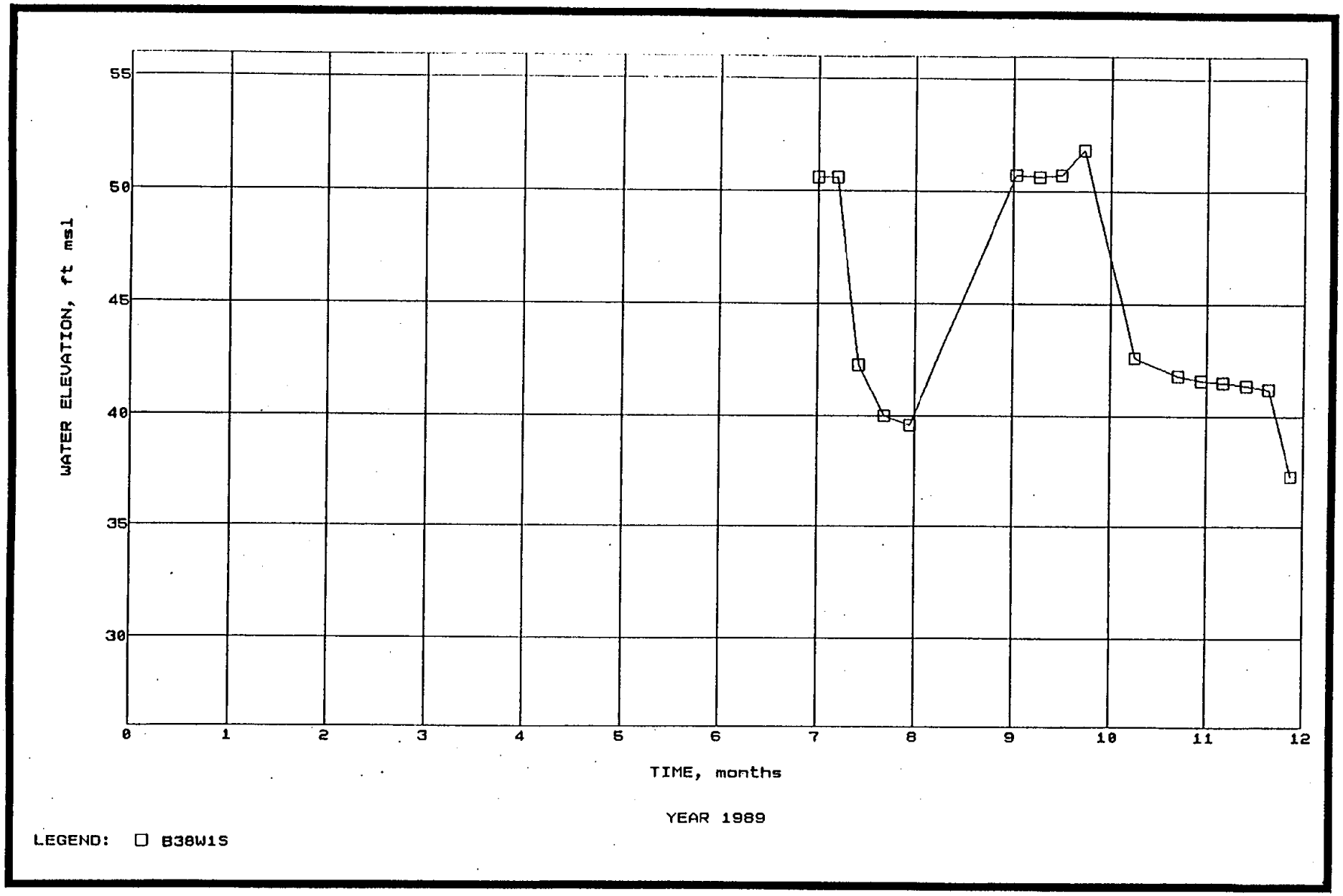

FIGURE 1-11 HYDROGRAPH OF WELL B38W10S IN THE UPPER GROUNDWATER SYSTEM AT MISS

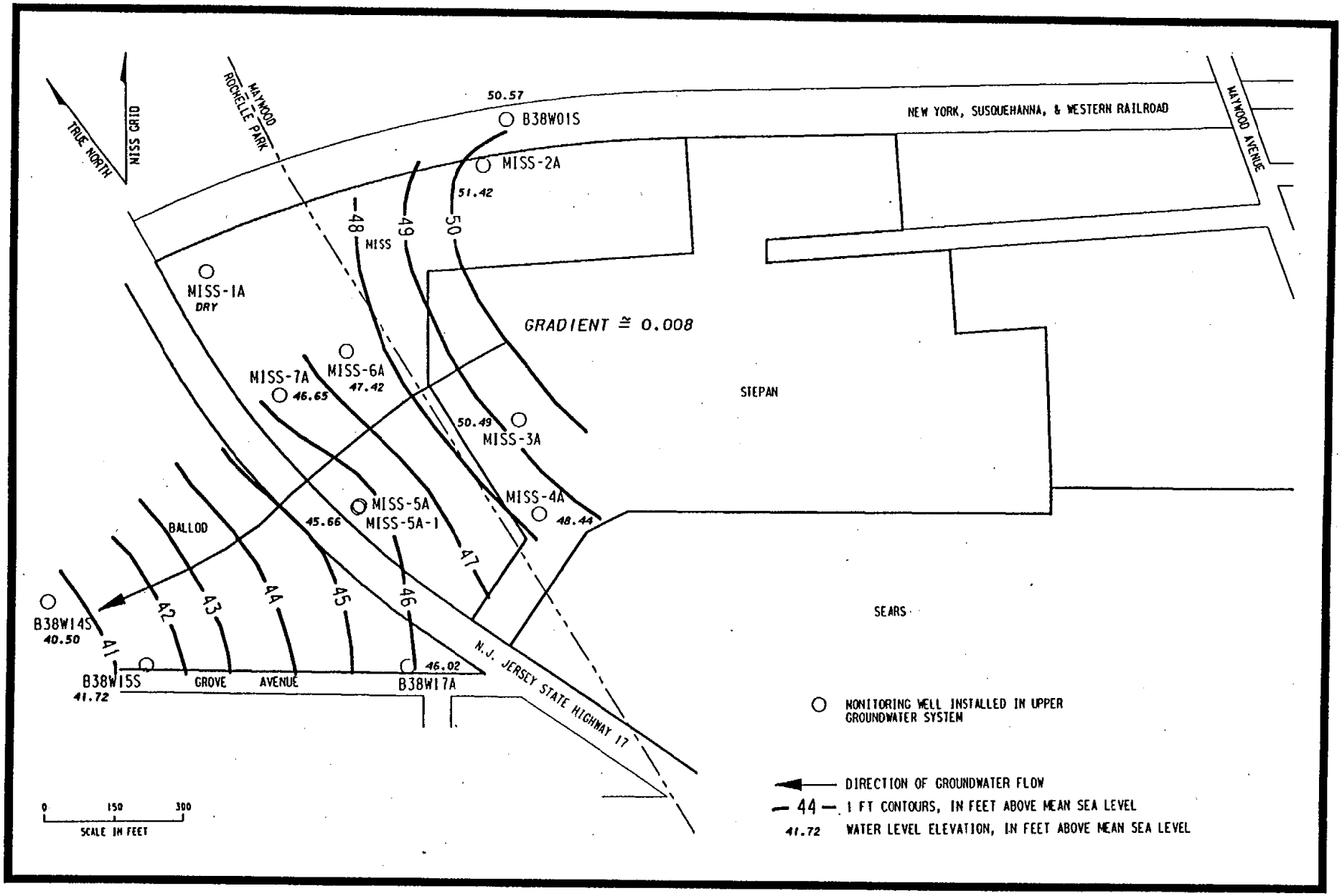

FIGURE 1-12 POTENTIOMETRIC SURFACE MAP OF THE UPPER GROUNDWATER SYSTEM AT MISS (8/1/89)

138F045.DGN GIG02

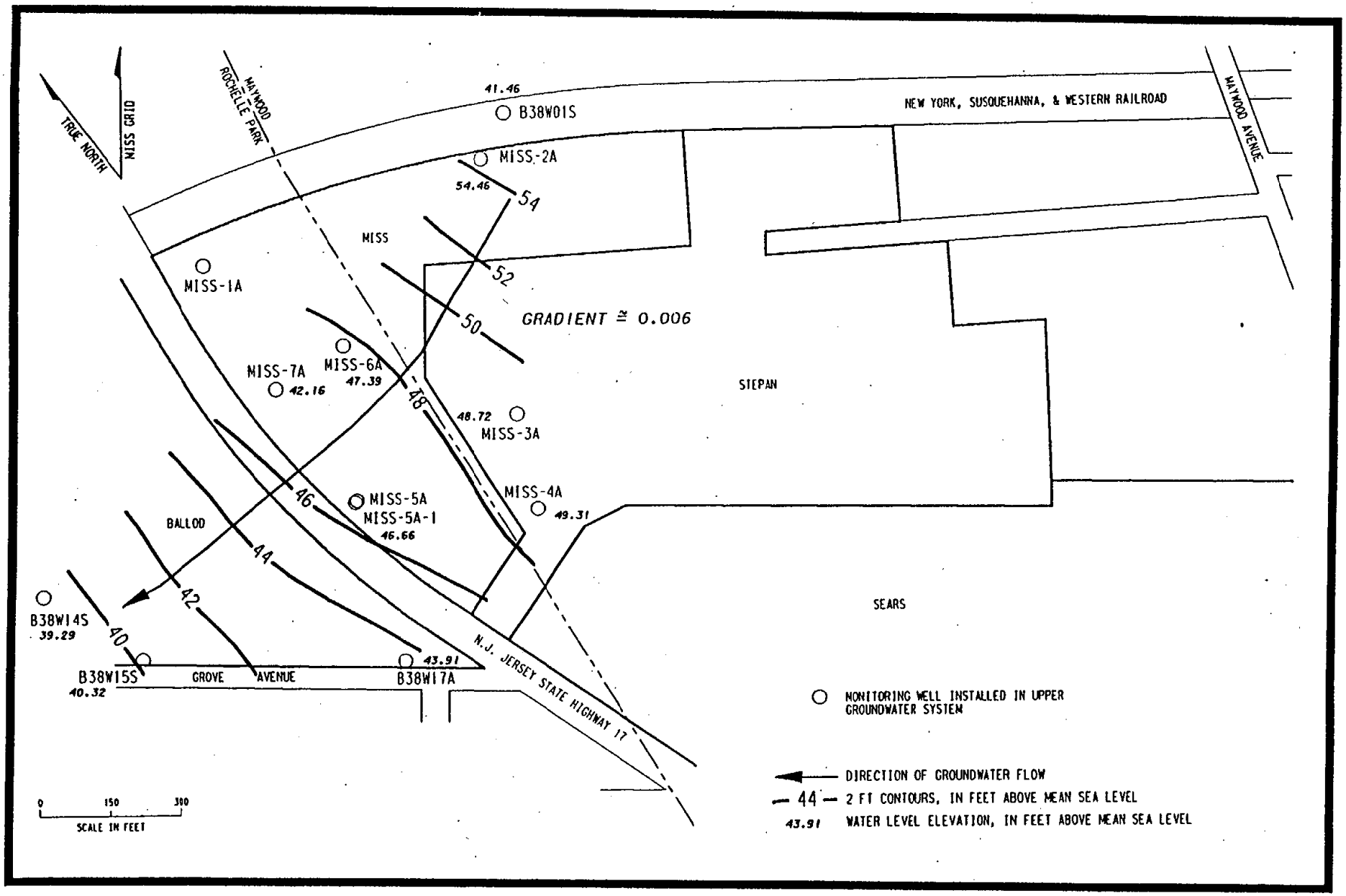

FIGURE 1-13 POTENTIOMETRIC SURFACE MAP OF THE UPPER GROUNDWATER SYSTEM AT MISS (12/6/89)

138F045.DGN GIG03

Hydrographs of the bedrock groundwater system (Figures 1-14 through 1-19) show a seasonal variation similar to that of the upper groundwater system, and there is better correlation of water levels from well to well. Precipitation records for the MSP site are also shown beneath the hydrographs (for reference only) in Figures 1-14 through 1-17.

The gradient and flow direction for the bedrock groundwater system were determined from two potentiometric surface maps (Figure 1-20 for August 1 and Figure 1-21 for December), which indicate little seasonal variation. Both maps show the groundwater flow direction to be divergent from east to west, and at a gradient on the order of 0.01.

Water levels from B38W02D are anomalously high and are not included in the contour interpretation. The water levels and well screen are above the elevation of the railroad tracks, yet no water seeps are observed. Well B38W02D was installed in November 1989; therefore, no data exist for comparison with this apparent anomaly.

1.3.3 Discussion

The upper and bedrock groundwater systems at MISS appear to have consistent gradients and flow directions throughout the year, as shown by the hydrographs and potentiometric surface maps. No changes have been observed in basic conditions throughout the monitoring program at MISS.

Potentiometric surface elevations, gradient, and flow directions for the two groundwater systems vary only slightly. Because the bedrock system water levels are above the top of bedrock and because of the differences in hydraulic head between the upper and bedrock system well pairs, the bedrock groundwater system is considered to be a semiconfined system.

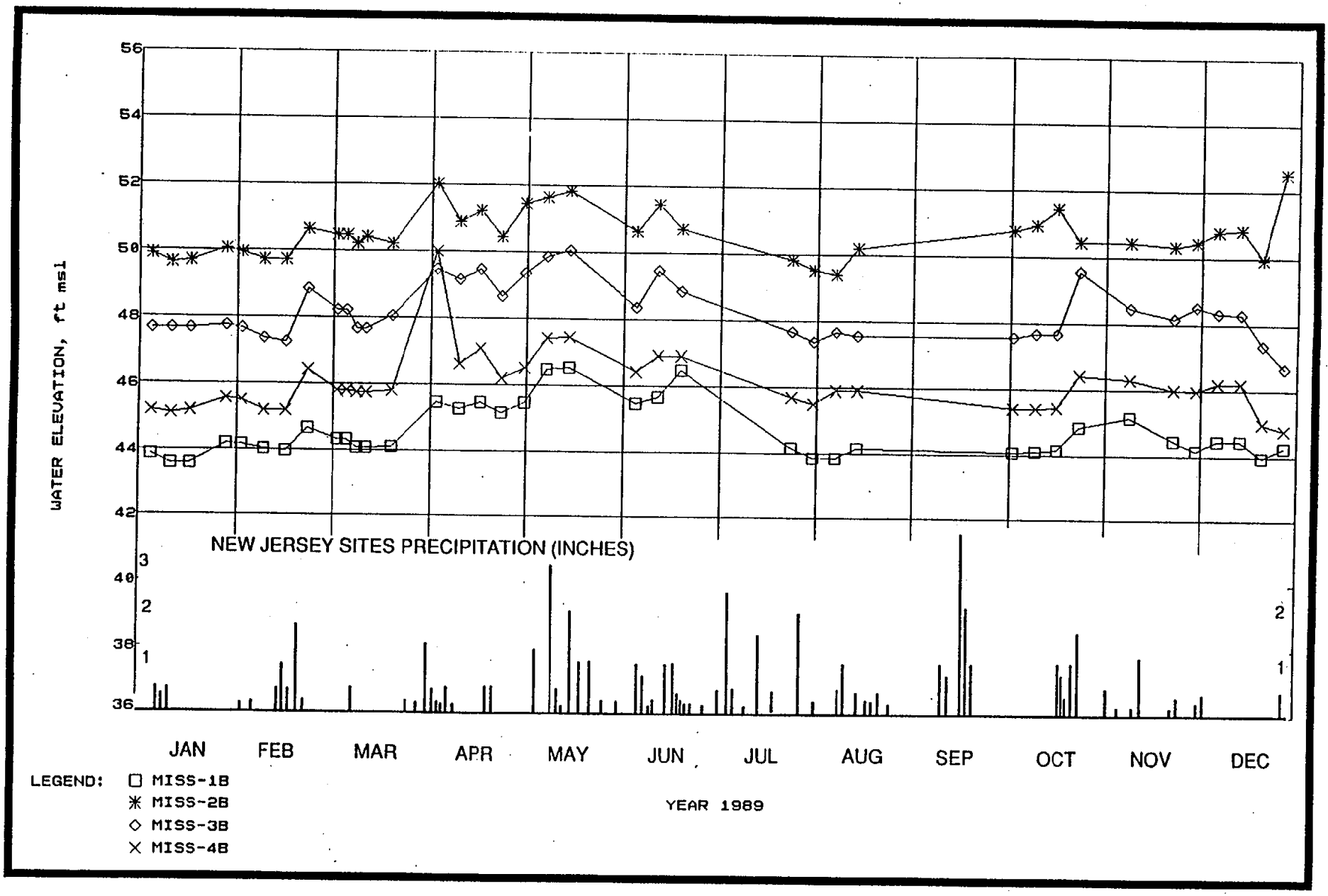

FIGURE 1-14 HYDROGRAPHS OF WELLS 1B, 2B, 3B, AND 4B IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

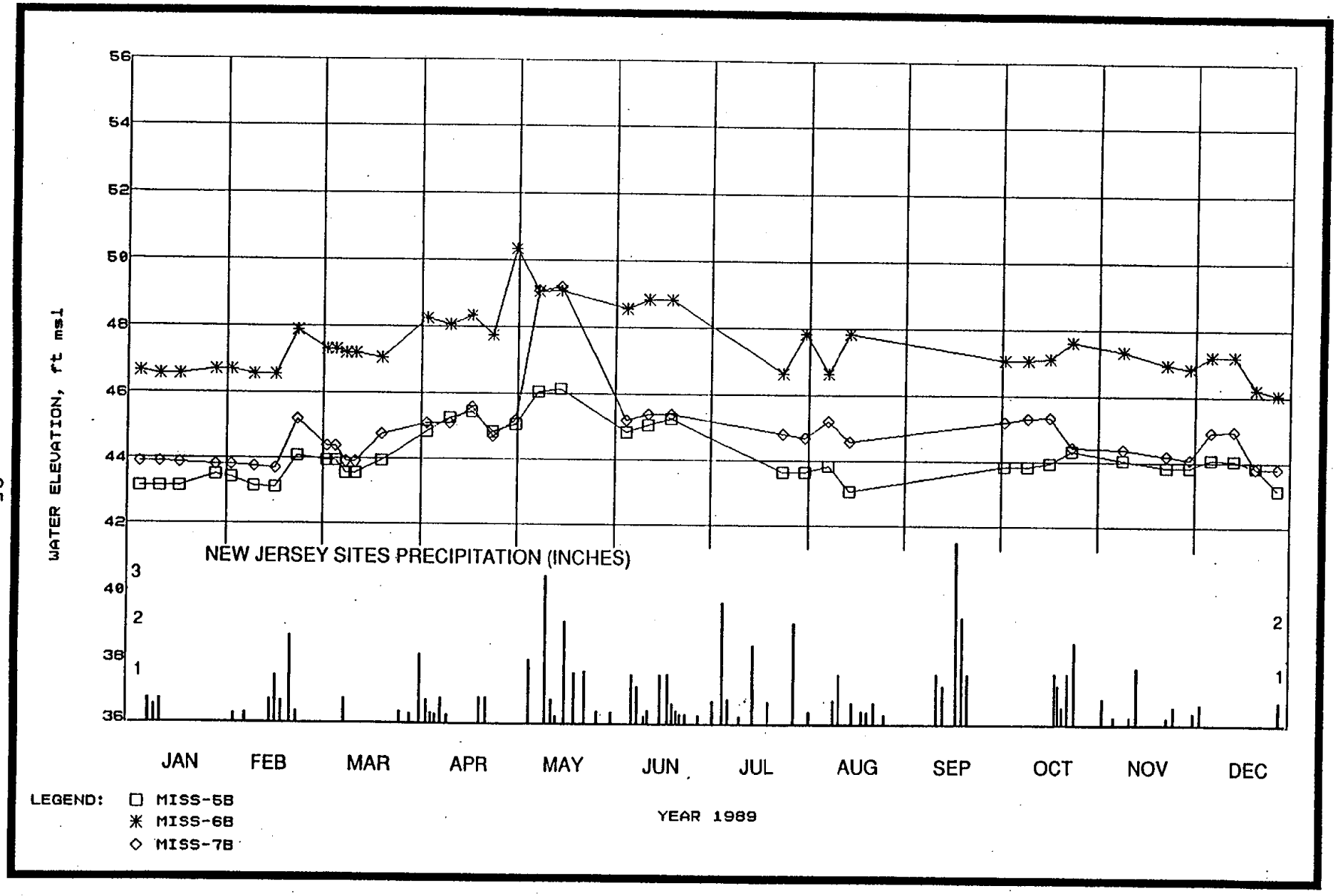

FIGURE 1-15 HYDROGRAPHS OF WELLS 5B, 6B, AND 7B IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

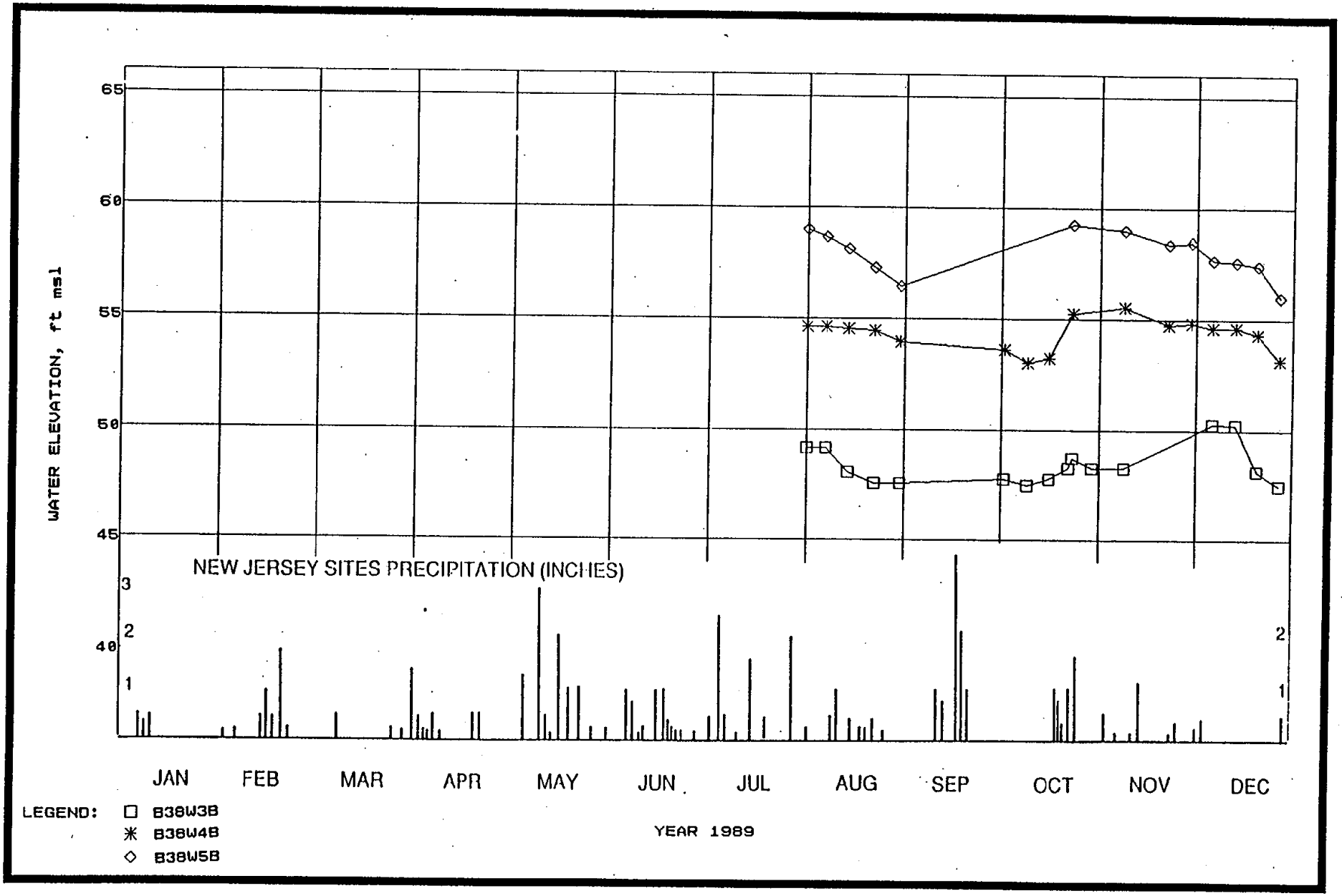

FIGURE 1-16 HYDROGRAPHS OF WELLS B38W03B, B38W04B, AND B38W05B IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

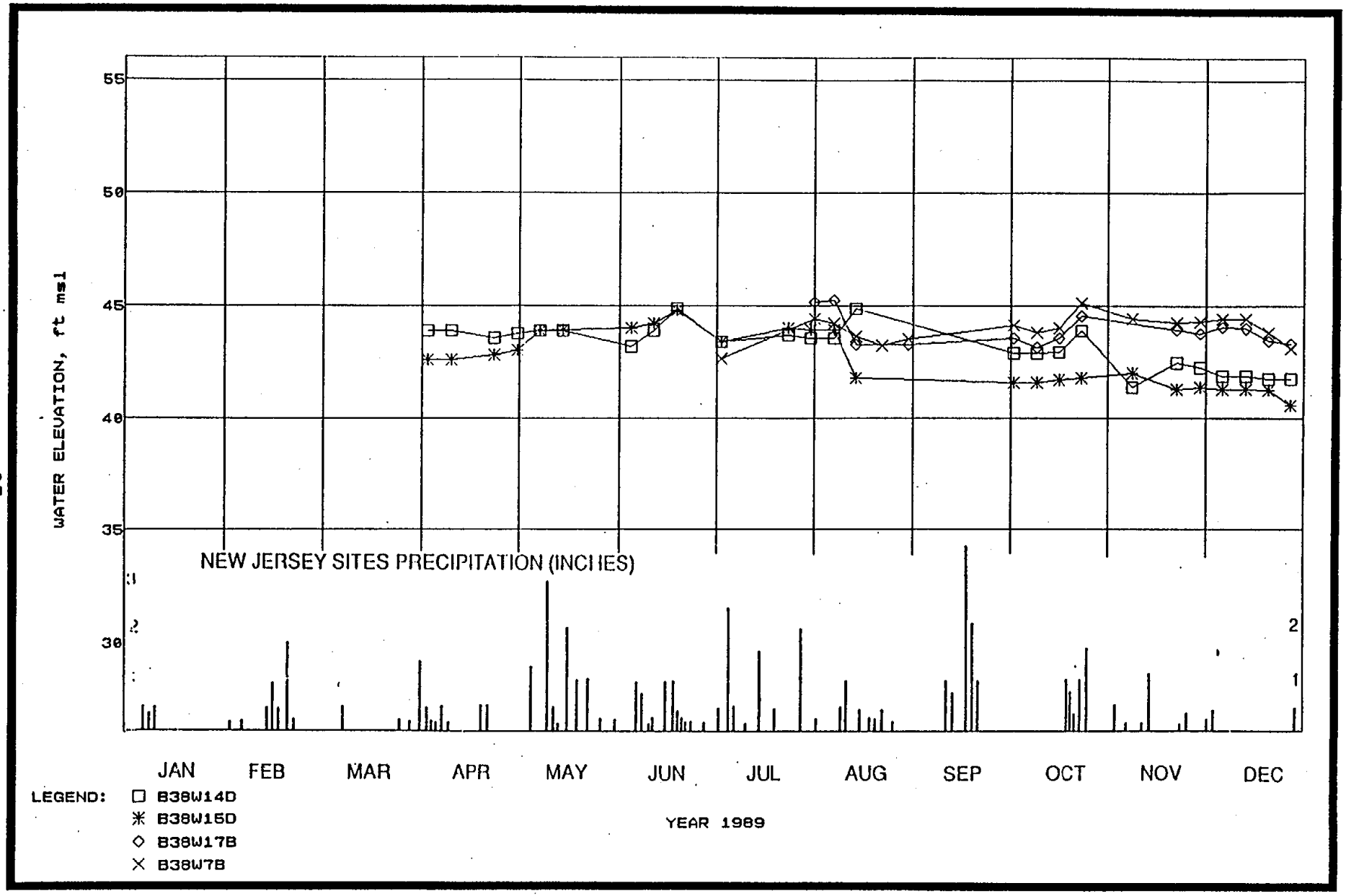

FIGURE 1-17 HYDROGRAPHS OF WELLS B38W14D, B38W15D, B38W17B, AND B38W07B IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

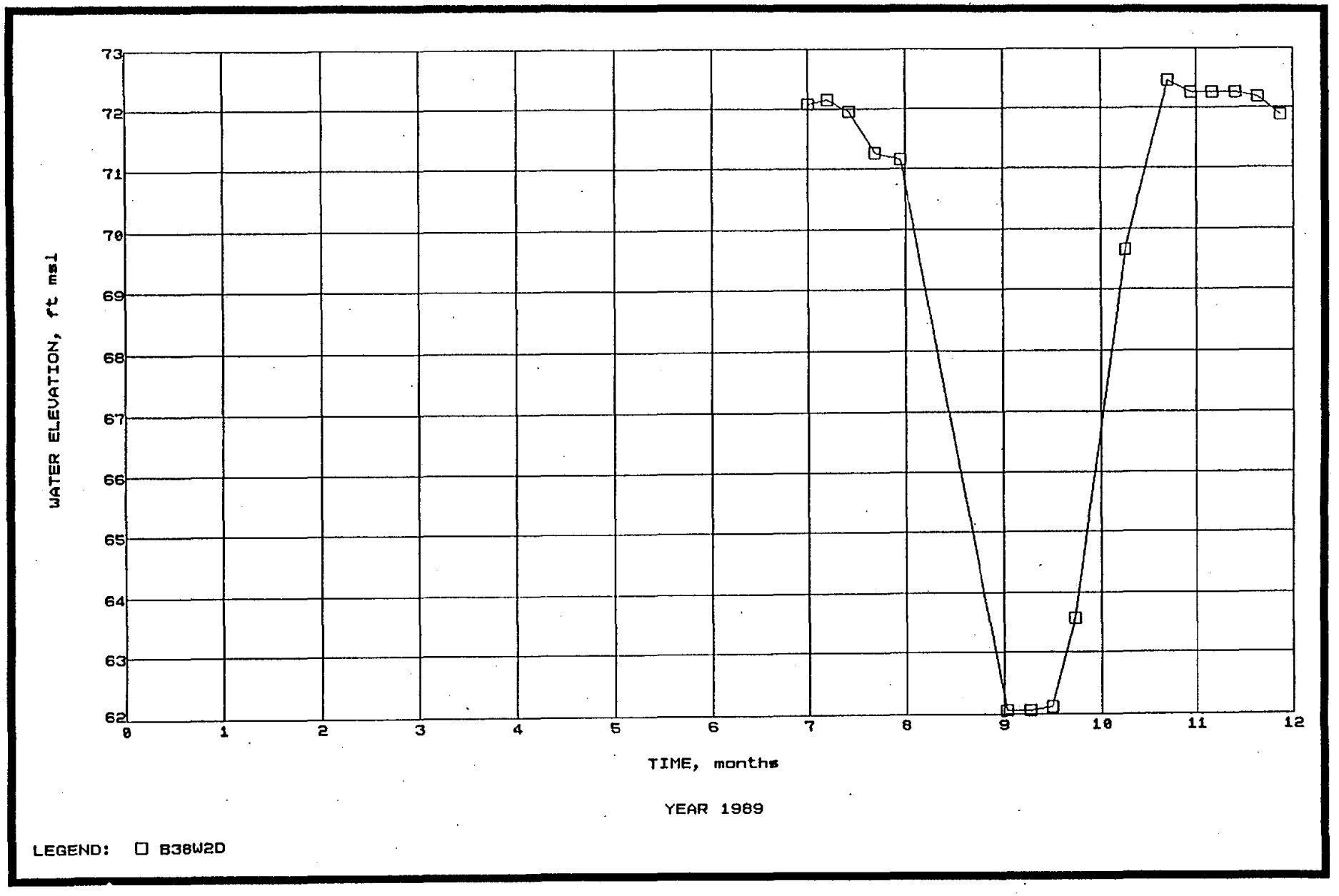

FIGURE 1-18 HYDROGRAPH OF WELL B38W02D IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

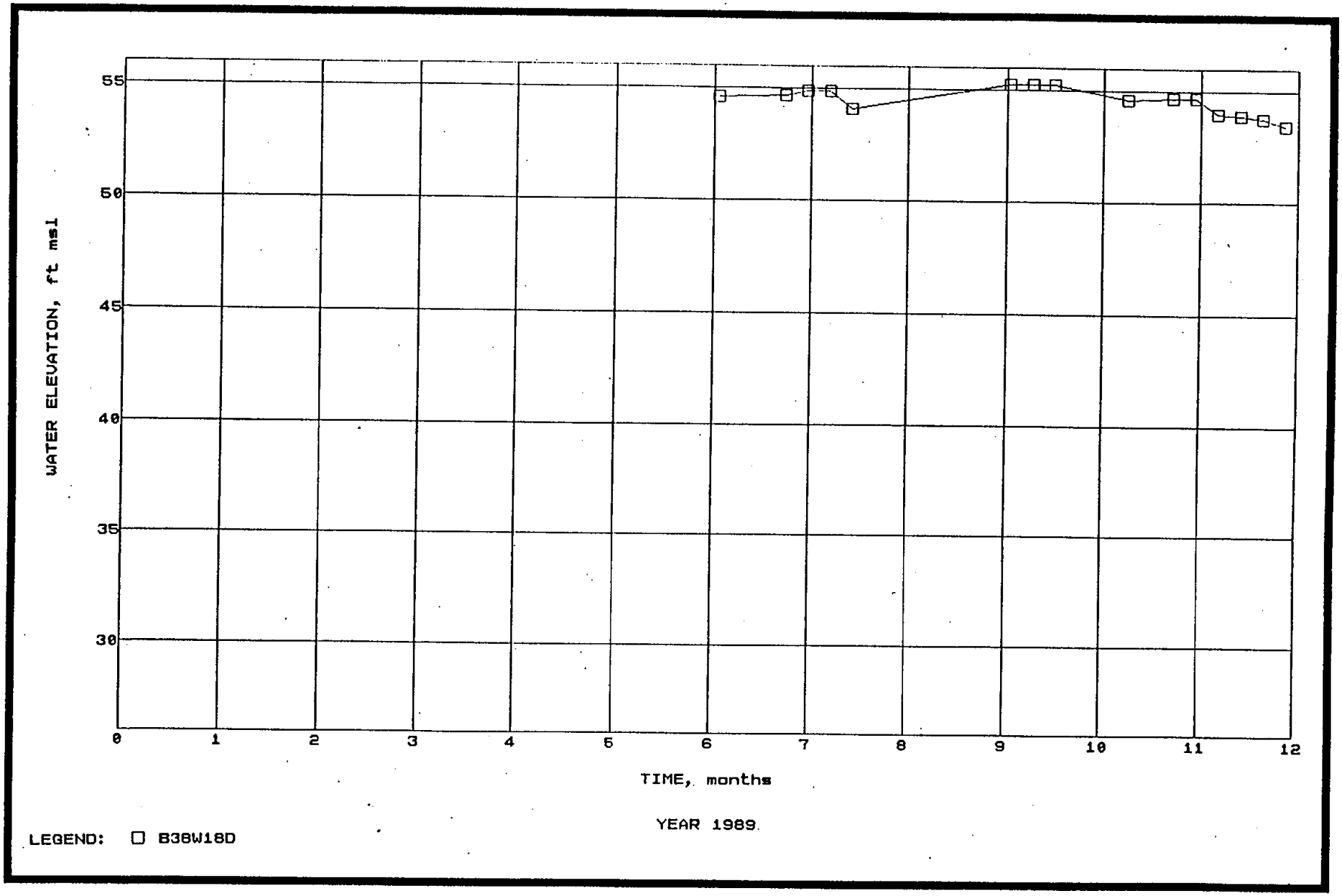

FIGURE 1-19 HYDROGRAPH OF WELL B38W18D IN THE BEDROCK GROUNDWATER SYSTEM AT MISS

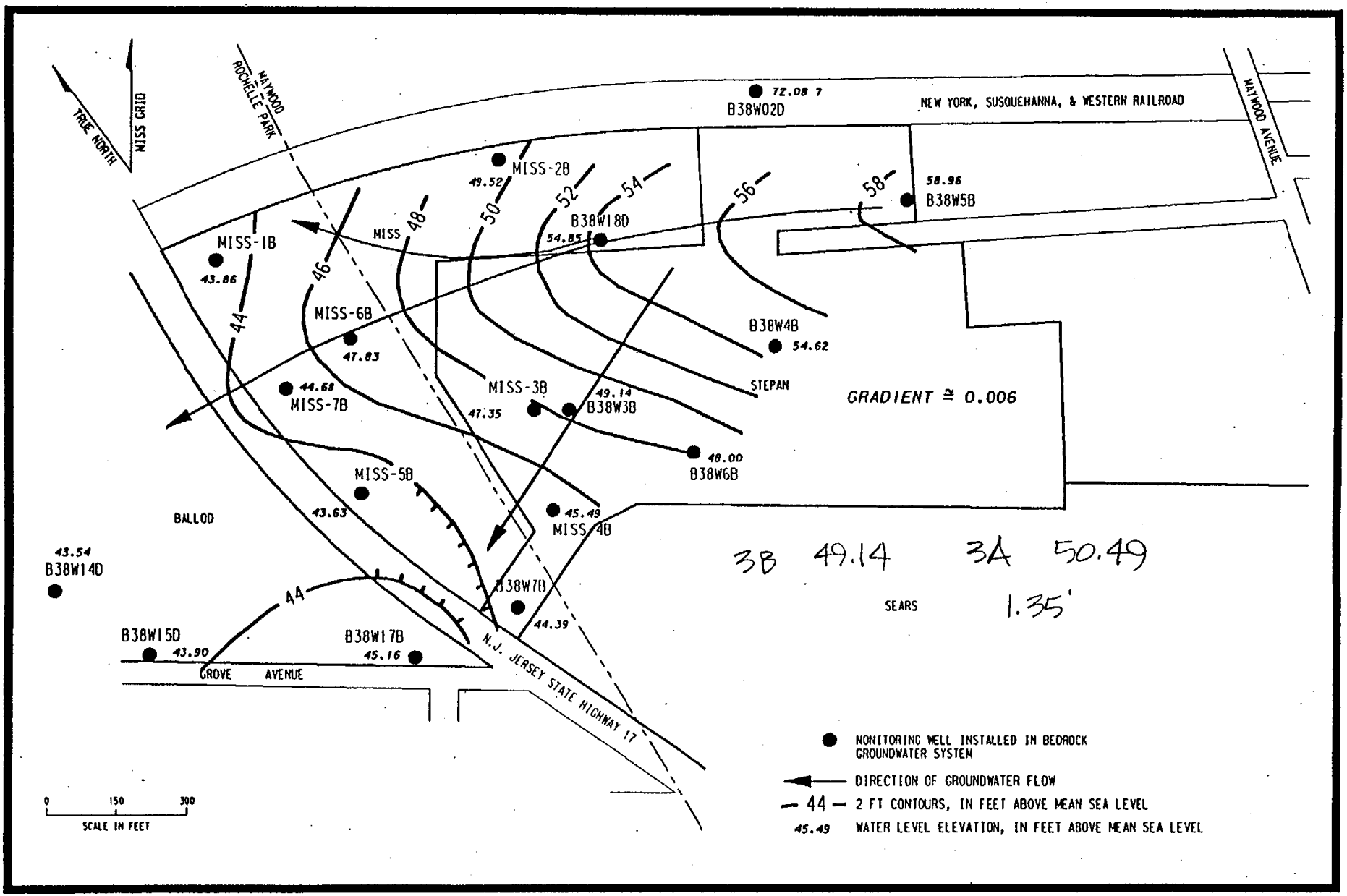

FIGURE 1-20 POTENTIOMETRIC SURFACE MAP OF THE BEDROCK GROUNDWATER SYSTEM AT MISS (8/1/89)

138F045.DGN GIC04

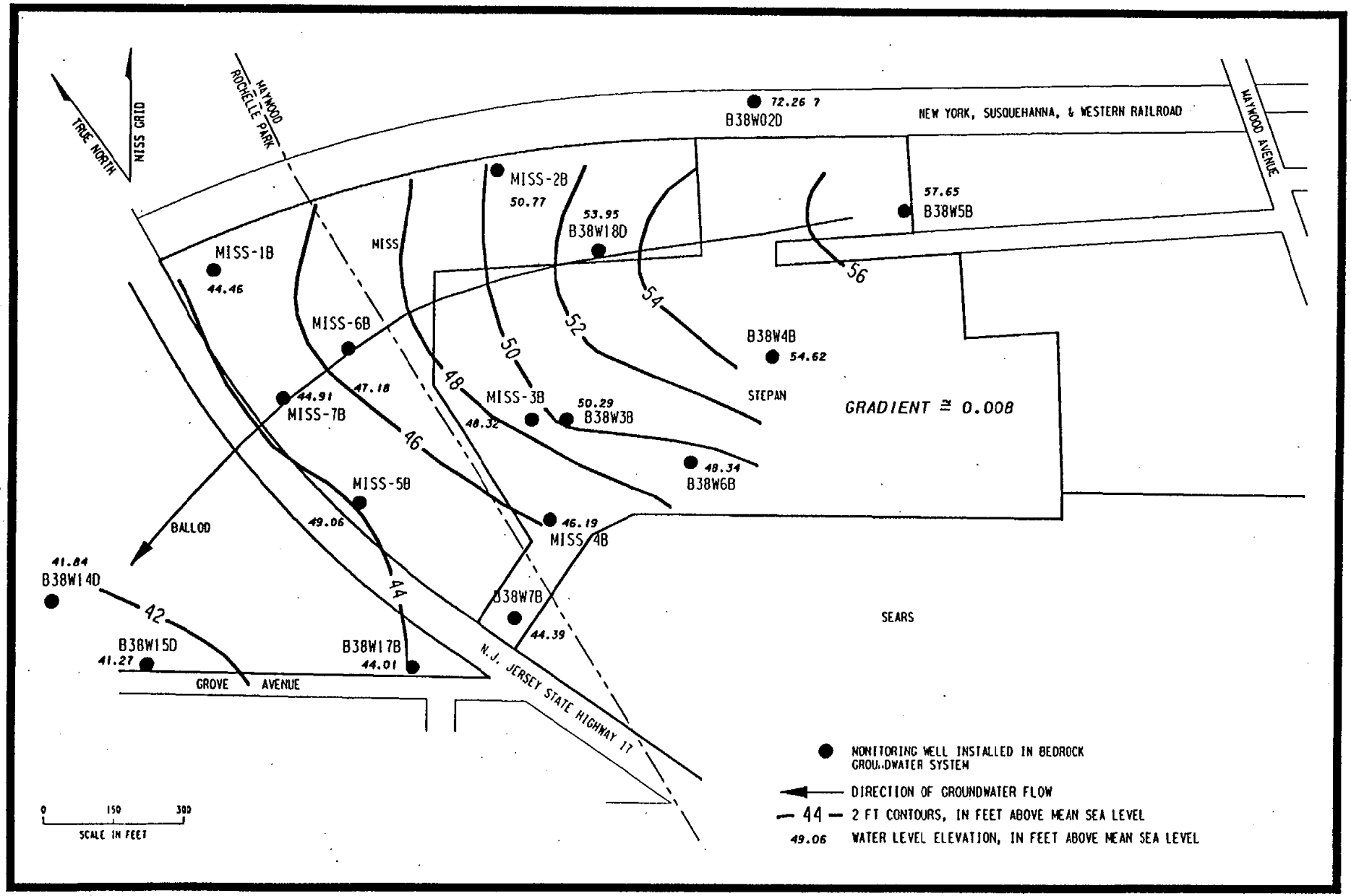

FIGURE 1-21 POTENTIOMETRIC SURFACE MAP OF THE BEDROCK GROUNDWATER SYSTEM AT MISS (12/6/89)

2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program at MISS, which began in 1984, was continued during 1989. The program includes quarterly sampling and radiological analysis of air, water, and sediments and chemical analysis of well water. The potential radiation dose that might be received by a hypothetical maximally exposed individual was calculated to determine the degree of compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 12).

Annual average concentrations of radon (including background) ranged from 4×10^{-10} to 1.0×10^{-9} μCi/ml (0.4 to 1.0 pCi/L). The average background radon concentration for MISS was 4×10^{-10} μCi/ml (0.4 pCi/L). Thoron concentrations (including background) ranged from 1×10^{-10} to 7.3×10^{-9} μCi/ml (0.1 to 7.3 pCi/L). The average background thoron concentration for MISS was less than the minimum detectable limit. A discussion of 1989 radon and thoron concentrations is provided in Subsection 3.1.

Annual average external gamma radiation levels measured at MISS ranged from 9 to 173 mrem/yr above background. The maximum was measured in an area of known contamination with no significant occupancy factor (Ref. 3). These rates may be compared with the external gamma radiation levels from natural radiation in the vicinity of MISS, which averaged 61 mrem/yr. External radiation levels are discussed in Subsection 3.2.

In surface waters at MISS (Subsection 3.3), measured concentrations of uranium in 1989 were equal to concentrations measured upstream of the site. Concentrations of radium-226 were slightly below those measured at the upstream location. Concentrations of thorium-232 were equal to or slightly higher than those measured at the upstream location. Concentrations of uranium, thorium-232, and radium-226 have remained stable since 1984 (Refs. 13-17).

In groundwater at MISS (Subsection 3.4.1), the highest annual average concentration of uranium in 1989 was 8.0×10^{-9} μCi/ml (8.0 pCi/L). The highest measured concentration of thorium-232 was 3.4×10^{-9} μCi/ml (3.4 pCi/L); for radium-226 it was

3.8×10^{-9} μCi/ml (3.8 pCi/L). These thorium-232 and radium-226 levels were both measured in well 4A, which was dry during three of the four sampling attempts in 1989. The highest annual averages for thorium-232 and radium-226 in a well sampled all four quarters are 5×10^{-10} μCi/ml (0.5 pCi/L) and 1.6×10^{-9} μCi/ml (1.6 pCi/L), respectively. These levels are similar to those found in background wells. All groundwater radionuclide measurements are within DOE derived concentration guidelines.

Chemical analyses of well water show a total of 18 organic pollutants at relatively low concentrations. Groundwater at MISS is chemically of poor quality but is typical of groundwater underlying areas with a long history of industrial use.

The highest annual average concentrations of total uranium, radium-226, and thorium-232 in sediments (Subsection 3.5) were 1.7 pCi/g, 0.6 pCi/g, and 0.3 pCi/g, respectively. Currently there are no DOE derived concentration guidelines for radionuclides in sediment. Measured against soil guidelines, radionuclides in MISS sediments are within limits.

Calculations were made of the radiological dose received by a hypothetical maximally exposed individual (Subsection 3.6.1). This hypothetical 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. Exposure to external gamma radiation was the only exposure pathway quantified because it is the only feasibly significant pathway. The maximum exposure this individual would receive is less than 1 mrem/yr above background. This exposure is less than 1 percent of the DOE radiation protection standard.

The cumulative dose to the population within an 80-km (50-mi) radius of MISS 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 MISS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1989 environmental monitoring at MISS and includes descriptions of the sampling, monitoring, and analytical procedures. 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 MISS included measurement of radon, thoron, and external gamma radiation levels, and sampling of surface water, sediments, and groundwater monitoring wells.

Tables 3-10 through 3-13 show radon and thoron concentrations, external gamma radiation levels, and radionuclide concentrations in surface water and groundwater at MISS. These tables list annual averages for each monitoring location for 1985 through 1989 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.7).

3.1 RADON MONITORING

Two forms of radon are present at MISS. The more common form, radon-222, is part of the natural uranium decay chain. The other form, radon-220, is part of the natural thorium decay chain. To distinguish between these two forms of radon, the term thoron (the common name for radon-220) is used in this report.

Radon detectors are maintained on site near the storage pile and at approximately equal intervals along the site perimeter. One of the detectors is designated for quality control. The locations of the 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 radon and/or thoron can diffuse. The type of membrane used is dictated by the analyte desired. Radon and/or thoron will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, they will equilibrate with radon and/or thoron in the outside air. Alpha particles from the radioactive decay of radon and/or 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 in air. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling station and return the exposed monitors to Terradex for analysis.

Table 3-1 lists thoron and radon concentrations (including background) recorded at MISS in 1989. Annual average concentrations of thoron ranged from 1×10^{-10} to 7.3×10^{-9} μCi/ml (0.1 to 7.3 pCi/L). The average background concentration, as measured over three locations, was below the limit of sensitivity [1×10^{-10} μCi/ml (0.1 pCi/L)]. Annual average concentrations of

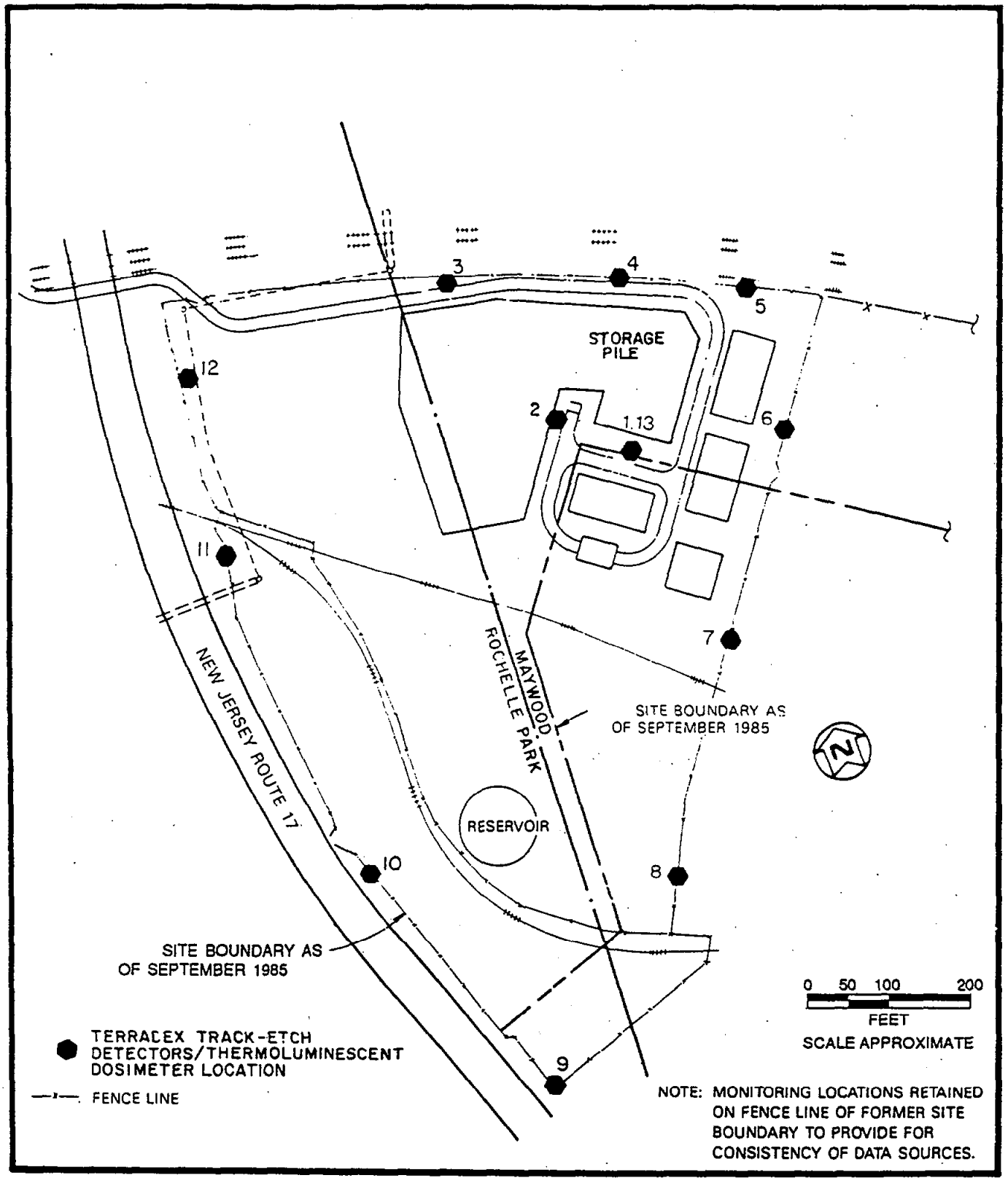

FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT MISS

TABLE 3-1

CONCENTRATIONS OF THORON AND RADON AT MISS, 1989

Sampling Station[a]	Number of Measurements	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Thoron (Rn-220)				
1	4	0.1	0.8	0.5
2	4	<0.1	1.0	0.5
3	4	0.1	0.9	0.4
4	4	<0.1	0.7	0.4
5	4	<0.1	11.2	7.3
6	4	<0.1	1.2	0.7
7	4	<0.1	1.9	0.6
8	4	<0.1	0.8	0.3
9	4	<0.1	0.3	0.1
10	4	0.1	0.8	0.4
11	4	<0.1	0.7	0.2
12	4	<0.1	0.5	0.3
13[d]	4	<0.1	0.1	0.1
Background				
14[e]	4	<0.1	<0.1	<0.1
18[f]	3[g]	<0.1	0.3	0.1
19[h]	2[i]	<0.1	<0.1	<0.1
Radon (Rn-222)				
1	4	0.3	0.5	0.4
2	4	0.2	0.6	0.4
3	4	0.3	0.4	0.4
4	4	0.4	1.4	0.9
5	4	0.4	1.7	1.0
6	4	0.4	1.0	0.6
7	4	0.3	0.9	0.6
8	4	0.3	0.5	0.4
9	4	0.3	0.5	0.5
10	4	0.4	1.0	0.6
11	4	0.3	0.7	0.5
12	4	0.3	1.0	0.8
13[d]	4	0.3	0.7	0.5
Background				
14[e]	4	0.4	0.5	0.5
18[f]	3[g]	0.3	0.4	0.4
19[h]	2[i]	0.3	0.4	0.4

TABLE 3-1

(continued)

[a]Locations of sampling stations are shown in Figure 3-1.

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

[c]All results include background.

[d]Station 13 is a quality control for station 1.

[e]Located at the Department of Health, Paterson, NJ, approximately 23 km (14 mi) west of MISS.

[f]Located at the Rochelle Park Fire Department, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in January 1989.

[g]Data available only for last three quarters.

[h]Located at the Rochelle Park Post Office, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in January 1989.

[i]Data available only last two quarters.

radon ranged from 4 x 10^{-10} to 1.0 x 10^{-9} μCi/ml (0.4 pCi/L to 1.0 pCi/L). The 1989 background radon concentration, averaged from three locations, was 4 x 10^{-10} μCi/ml (0.4 pCi/L).

Radon and thoron levels were highest at station 5, reflecting its proximity to the storage pile and the prevailing wind directions at MISS (see Figures 1-4 and 3-1). Except for station 5, thoron levels were at or near background and radon levels were essentially equal to background. For a comparison of radon and thoron concentrations measured at MISS from 1985-1989, see Subsection 3.7.1.

3.2 EXTERNAL GAMMA RADIATION

External gamma radiation levels were measured at 12 monitoring stations. Sampling locations (shown in Figure 3-1) were selected to monitor radiation levels at the site boundary and in the area adjacent to the contaminated storage pile.

External gamma radiation levels are measured using lithium fluoride thermoluminescent dosimeters (TLDs). Since 1988, the measurement system has utilized tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to tissues of the body at a depth of 1 cm (0.4 in.). Each monitoring station contains a minimum of four dosimeters, which are exchanged after approximately one year of accumulated exposure. For example, a dosimeter placed in a 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 is 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. 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. Therefore, some stations that previously demonstrated no measurable external gamma radiation value in excess of background now exhibit a small measurable value. Similarly, at other stations values are higher or lower because of the improved method of measurement, not because of deterioration of site conditions or remedial action.

Monitoring results for external gamma radiation are presented in Table 3-2. For each quarter, an average of the measured background levels was subtracted from the site boundary measurements to provide an estimate of radiation levels resulting from residual materials at the site. Of the seven stations (on the northern and western boundaries of the site) to which members of the public might have access, but which have no significant occupancy factor, the highest average external gamma radiation level (173 mrem/yr) was recorded at station 10 (near Route 17), an area known to be contaminated before DOE acquired the property (Ref. 3).

In April 1988, two additional background monitoring stations were established at the Rochelle Park Fire Station and the Rochelle Park Post Office. Because of the measurement system operating parameters, data from the new sites were not available for the first quarter of 1989. The background value for first quarter came solely from station 14 (Department of Health, Paterson). Data for the other quarters were obtained from all three background sites.

The background external gamma radiation value for a given location is not a constant. Because the background value is a combination of both natural terrestrial sources and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT MISS, 1989

Sampling Station[a]	Number of Measurements	Radiation Level (mrem/yr)[b] Minimum	Maximum	Average
Fenceline				
3	4	18	41	29
4	4	87	140	112
5	4	130	175	154
7	4	--	23	13
8	4	3	15	9
9	3	9	24	17
10[c]	4	146	230	173
11	4	25	53	35
12	4	73	117	90
On Site				
1	4	21	42	28
2	4	27	43	35
6	4	17	102	68
13[d]	4	13	42	27
Background				
14[e]	4	53	80	63
18[f]	3[g]	59	70	64
19[h]	3[g]	50	60	56

[a]Locations of sampling stations are shown in Figure 3-1.

[b]Measured background radiation has been subtracted from external gamma radiation levels measured at the site boundary and at on-site locations.

[c]Station 10 is in an area of known contamination (Ref. 3).

[d]Station 13 is a quality control for station 1.

[e]Station 14 is located at the Department of Health, Paterson, NJ, approximately 22.5 km (14 mi) west of MISS.

[f]Station 18 is located at the Rochelle Park Fire Department, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in April 1988.

[g]Because sampling parameters dictate that a station be in place for a full year before sampling, the station was not ready to be sampled until second quarter.

[h]Station 19 is located at the Rochelle Park Post Office, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in April 1988.

highly mineralized soil can affect the value measured. Independent of the placement of the detector are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 18).

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 stations at the boundary of a site to have an external gamma radiation value 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, quarterly sampling was performed to determine the concentrations of total uranium, thorium-232, and radium-226 in surface water at both on-site and off-site locations (Figure 3-2).

Surface water sampling locations were established on the Saddle River (location 1) and on Westerley Brook (locations 2, 3, and 4). Location 4 was formerly accessible by way of a manhole that is now welded shut. Locations 5 and 6 were established on the Ballod property west of MISS.

Because no standing water was present at locations 5 and 6 during 1989 quarterly sampling, no surface water samples could be obtained from these locations. Surface water collection locations were selected based on migration potential and discharge routes from the site. Because surface water runoff from the site discharges via underground Westerley Brook, samples were collected both upstream (location 3) and downstream (locations 1 and 2) of the site.

For each location, 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, and radium-226. The concentration of total uranium was determined by a fluorometric method. Radium-226 concentrations in water were determined by radon emanation. (This method consists of precipitating radium as

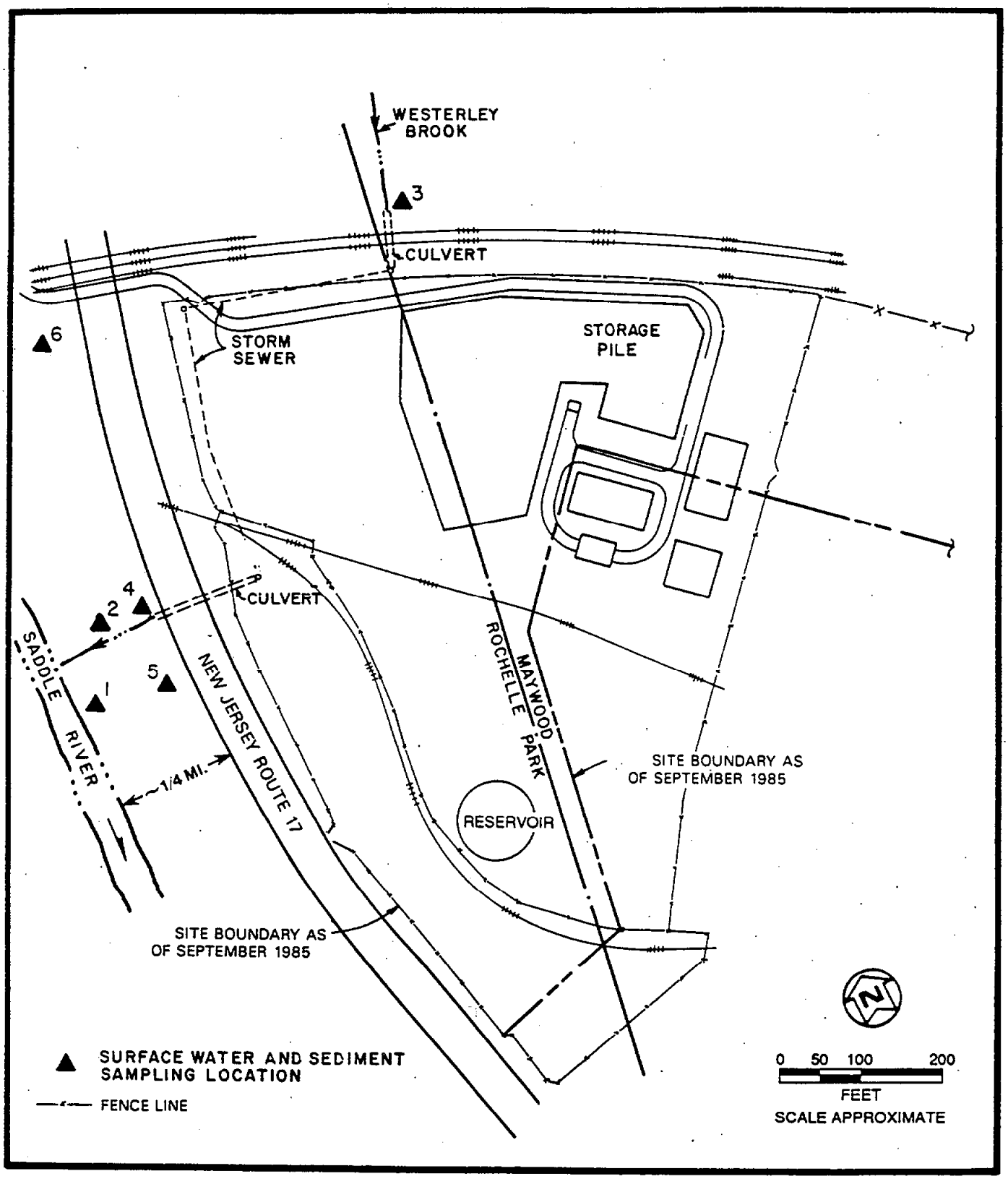

FIGURE 3-2 SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS IN THE VICINITY OF MISS

a 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 gas 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.) Thorium-232 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

Analytical results are presented in Table 3-3. The annual average concentration of total uranium in surface water was $<5.0 \times 10^{-9}$ μCi/ml (<5.0 pCi/L) at all three locations available for sampling. The annual average concentrations of radium-226 in surface water ranged from 3 to 4 x 10^{-10} μCi/ml (0.3 to 0.4 pCi/L). Annual average thorium-232 concentrations in all cases were less than or equal to the limit of sensitivity of the analytical method, which is 1 x 10^{-10} μCi/ml (0.1 pCi/L). Thorium-232, total uranium, and radium-226 concentrations were all very low and were the same upstream as downstream.

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 18 on-site and off-site wells at 12 locations (see Figure 1-7). Monitoring wells designated "A" or "S" are installed in the upper groundwater system and range in depth from 2.4 to 7.0 m (8 to 23 ft) below ground; "B" or "D" wells extend into the Brunswick formation of the bedrock groundwater system and range in depth from 11.1 to 17.8 m (36.3 to 58.5 ft) below ground. Groundwater flows generally from east to west in both the upper and bedrock systems; therefore, wells MISS-2A, MISS-2B, B38W01S, and B38W02D are being used to represent groundwater quality that is probably free of influence from the waste storage pile (the latter two are off site). All other wells are downgradient monitoring locations, and B38W14S, B38W14D, B38W15S, and B38W15D are off site. Well B38W18D

TABLE 3-3

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226,

AND THORIUM-232 IN SURFACE WATER AT MISS, 1989

Sampling Location[a]	Number of Samples[b]	Concentration (10^{-9} µCi/ml)[c,d]		
		Minimum	Maximum	Average
Total Uranium				
1	3	<5.0	<5.0	<5.0
2	3	<5.0	<5.0	<5.0
3	3	<5.0	<5.0	<5.0
Radium-226				
1	3	0.2	0.5	0.3
2	3	0.3	0.4	0.3
3	3	0.3	0.5	0.4
Thorium-232				
1	3	<0.1	0.1	0.1
2	3	<0.1	<0.1	<0.1
3	3	<0.1	<0.1	<0.1

[a]Sampling locations are shown in Figure 3-2. Location 3 is upstream of MISS and represents background. No water was available at sampling locations 5 and 6. Location 4 is no longer accessible.

[b]Sampling was inadvertently omitted in the fourth quarter.

[c]All results include background.

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

is located near the southwest corner of the contaminated area (see Figure 1-6). Wells MISS-1A, -5A, -5A-1, and -7A were dry during all sampling periods. Well locations were selected on the basis of available geohydrological data.

After the wells had been bailed dry and allowed to recover or three casing volumes had been removed, grab samples were collected and analyzed by TMA/E for total uranium, thorium-232, and radium-226 by the same methods described in Subsection 3.3. In addition, groundwater samples were taken quarterly and analyzed for total organic carbon (TOC), total organic halides (TOX), pH, and specific conductance. Groundwater samples were taken during a single quarter and were analyzed for volatile organics, base/neutral and acid extractable (BNAE) compounds, pesticides, and polychlorinated biphenyls (PCBs).

3.4.1 Radiological

Analytical results are presented in Tables 3-4, 3-5, and 3-6. Annual average total uranium concentrations ranged from 8×10^{-10} to 8×10^{-9} μCi/ml (0.8 to 8.0 pCi/L). Average thorium-232 concentrations ranged from $<2 \times 10^{-10}$ to 3.4×10^{-9} μCi/ml (<0.2 to 3.4 pCi/L). The highest "average" thorium-232 concentration (found in well MISS-4A) is actually only one measurement and, therefore, is not a good representation of average levels in that well. Average radium-226 concentrations ranged from 7×10^{-10} to 3.8×10^{-9} μCi/ml (0.7 to 3.8 pCi/L). These radionuclide levels are low and are within DOE derived concentration guidelines. For a comparison of radionuclide concentrations measured in groundwater at MISS from 1985 through 1989, see Subsection 3.7.4.

3.4.2 Chemical

Groundwater samples from MISS were analyzed quarterly for the indicator parameters. 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

TABLE 3-4

CONCENTRATIONS OF TOTAL URANIUM IN GROUNDWATER AT MISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
MISS-1B	4	1.7	3.3	2.2
MISS-3A	4	0.7	1.9	1.2
MISS-3B	4	<0.6	0.9	0.8
MISS-4A	1[c]	--	--	5.5
MISS-4B	4	0.6	1.3	1.0
MISS-5B	4	<0.6	3.1	1.5
MISS-6A	3[d]	5.5	10.1	8.0
MISS-6B	4	0.8	1.5	1.2
MISS-7B	4	5.2	8.5	7.0
B38W14S[e]	3[f]	2.9	3.4	3.2
B38W14D[e]	3[f]	0.8	7.0	4.1
B38W15S[e]	3[f]	2.5	2.8	2.6
B38W15D[e]	3[f]	1.3	7.7	4.8
B38W18D[e]	3[f]	2.5	7.0	4.8
Background				
MISS-2A	4	1.2	3.1	2.1
MISS-2B	4	0.7	1.4	1.0
B38W04B	4	0.6	1.4	0.9
B38W01S[e]	4	1.3	2.9	2.0
B38W02D[e]	4	1.4	3.7	2.2

[a]Sampling locations are shown in Figure 1-7. Wells MISS-1A, MISS-5A, MISS-5A-1, and MISS-7A were dry during all sampling periods and are therefore not listed.

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

[c]Well was dry in the first, second, and fourth quarters.

[d]Well was dry in the first quarter.

[e]Installed in late 1988.

[f]Not sampled during first quarter.

TABLE 3-5

CONCENTRATIONS OF THORIUM-232 IN GROUNDWATER AT MISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
MISS-1B	4	<0.2	<0.4	<0.3
MISS-3A	4	<0.2	0.9	0.5
MISS-3B	4	<0.2	<0.3	<0.2
MISS-4A	1[c]	--	--	3.4
MISS-4B	4	<0.2	0.3	<0.2
MISS-5B	4	<0.2	<0.4	<0.3
MISS-6A	3[d]	<0.3	0.7	0.5
MISS-6B	4	<0.2	<0.2	<0.2
MISS-7B	4	<0.2	<0.2	<0.2
B38W14S[e]	3[f]	0.4	0.5	0.4
B38W14D[e]	3[f]	<0.2	0.3	0.3
B38W15S[e]	3[f]	0.3	0.9	0.5
B38W15D[e]	3[f]	<0.2	0.2	<0.2
B38W18D[e]	3[f]	<0.2	0.3	0.3
Background				
MISS-2A	4	0.1	0.7	0.5
MISS-2B	4	<0.2	0.5	0.3
B38W04B	4	<0.2	<0.2	<0.2
B38W01S[e]	4	<0.2	0.3	0.2
B38W02D[e]	4	0.2	0.4	0.3

[a]Sampling locations are shown in Figure 1-7. Wells MISS-1A, MISS-5A, MISS-5A-1, and MISS-7A were dry during all sampling periods and are therefore not listed.

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

[c]Well was dry in the first, second, and fourth quarters.

[d]Well was dry in the first quarter.

[e]Installed in late 1988.

[f]Not sampled during first quarter.

TABLE 3-6

CONCENTRATIONS OF RADIUM-226 IN GROUNDWATER AT MISS, 1989

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average
MISS-1B	4	1.1	1.7	1.4
MISS-3A	4	0.9	2.1	1.6
MISS-3B	4	0.7	1.3	1.0
MISS-4A	1[c]	--	--	3.8
MISS-4B	4	0.8	1.9	1.3
MISS-5B	4	0.8	1.1	1.0
MISS-6A	3[d]	1.1	1.5	1.3
MISS-6B	4	0.6	1.2	0.9
MISS-7B	4	0.5	1.2	0.8
B38W14S[e]	3[f]	0.8	1.1	1.0
B38W14D[e]	3[f]	0.7	1.2	1.0
B38W15S[e]	3[f]	0.9	1.5	1.2
B38W15D[e]	3[f]	0.6	0.8	0.7
B38W18D[e]	3[f]	0.4	1.0	0.7
Background				
MISS-2A	4	0.4	2.0	1.3
MISS-2B	4	0.8	1.5	1.0
B38W04B	4	0.5	1.7	1.2
B38W01S[e]	4	0.6	1.8	1.1
B38W02D[e]	4	0.6	1.1	0.9

[a]Sampling locations are shown in Figure 1-7. Wells MISS-1A, MISS-5A, MISS-5A-1, and MISS-7A were dry during all sampling periods and are therefore not listed.

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

[c]Well was dry in the first, second, and fourth quarters.

[d]Well was dry in the first quarter.

[e]Installed in late 1988.

[f]Not sampled during first quarter.

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.

As shown in Table 3-7, TOC and TOX levels across the site varied from below detection limits to 126 mg/L and 480 µg/L, respectively. Specific conductance ranged from 237 to 13,000 µmhos/cm, and pH ranged from 5.8 to 12.0.

Analytical results of chemical indicator parameters show that the groundwater at MISS is generally of poor quality, which is typical of groundwater in industrial/urban areas.

Analyses are performed annually for New Jersey priority pollutants. Table 3-7 lists results for chemical contaminants detected in groundwater at MISS. Although the presence of these contaminants would not be expected in pristine groundwater, their occurrence at trace levels is not unusual in groundwater underlying areas with a long history of industrial use. The overall low groundwater quality of the area is exemplified by the analytical results for the upgradient wells 2A, 2B, and B38W01S. Numerous other chemical contaminants for which analyses were completed were not detected in any of the groundwater samples (see Table 3-8). No pesticides or PCBs were detected in MISS groundwater in 1989.

3.5 SEDIMENT SAMPLING

Sediment samples that consisted of composites weighing approximately 500 g (1.1 lb) were obtained at surface water sampling locations where sediment was present (see Figure 3-2).

TABLE 3-7

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

Parameter	Sampling Location (Monitoring Well Number)					
	MISS-1B	MISS-2A[b]	MISS-2B[b]	MISS-3A	MISS-3B	MISS-4A[c,d]
pH (standard units)	7.2-7.5	7.1-7.4	7.2-8.1	5.8-6.4	6.1-6.3	6.0
Total organic carbon (mg/L)	2.1-7.0	19.0-122	48.1-84.8	6.4-8.2	ND-5.7[e]	10.2
Total organic halides (µg/L)	26-61	ND-140	27-220	44-70	39-65	ND
Specific conductance (µmhos/cm)	653-1,030	4,200-9,860	9,480-13,000	557-886	1,290-2,310	1,390
Benzene (µg/L)	ND	ND	70	ND	ND	
Bis(2-chloroethyl)ether (µg/L)	ND	ND	65	ND	ND	
Chloroform (µg/L)	ND	ND	ND	ND	ND	
1,1-dichloroethane (µg/L)	ND	ND	ND	ND	ND	
1,1-dichloroethene (µg/L)	ND	ND	ND	ND	ND	
1,2-dichloroethene (µg/L)	11	ND	ND	ND	ND	
Ethyl benzene (µg/L)	ND	ND	ND	ND	ND	
2-methylnaphthalene (µg/L)	ND	ND	ND	ND	ND	
4-methyl-2-pentanone (µg/L)	ND	ND	ND	ND	ND	
Naphthalene (µg/L)	ND	ND	ND	ND	ND	
Phenol (µg/L)	ND	ND	ND	ND	ND	
Tetrachloroethene (µg/L)	58	ND	ND	ND	ND	
1,1,2,2-tetrachloroethane (µg/L)	ND	ND	ND	ND	ND	
Toluene (µg/L)	ND	ND	ND	ND	ND	
1,1,1-trichloroethane (µg/L)	ND	ND	ND	ND	ND	
Trichloroethene (µg/L)	ND	ND	ND	ND	ND	
Vinyl chloride (µg/L)	ND	ND	ND	ND	ND	
Xylene (µg/L)	ND	ND	ND	ND	ND	

TABLE 3-7

(continued)

Parameter	Sampling Location (Monitoring Well Number)					
	MISS-4B	MISS-5B[d]	MISS-6A	MISS-6B	MISS-7B[d]	B38W01S[b]
pH (standard units)	6.9-7.6	6.9-8.0	6.8-7.1	8.4-8.9	7.3-8.3	11.4-12.0
Total organic carbon (mg/L)	11.9-17.0	3.0-14.4	9.0-126	8.0-10.6	2.7-8.5	7.2-12.0
Total organic halides (µg/L)	73-480	ND-94	ND	ND-58	ND-49	ND-87
Specific conductance (µmhos/cm)	1,290-1,430	2,420-6,420	1,930-2,640	2,430-3,560	3,670-9,680	1,890-3,200
Benzene (µg/L)	140		ND	ND		ND
Bis(2-chloroethyl)ether (µg/L)	ND		17	330		ND
Chloroform (µg/L)	ND		ND	ND		ND
1,1-dichloroethane (µg/L)	ND		ND	ND		ND
1,1-dichloroethene (µg/L)	ND		ND	ND		ND
1,2-dichloroethene (µg/L)	750		ND	ND		ND
Ethyl benzene (µg/L)	15		ND	ND		ND
2-methylnaphthalene (µg/L)	18		ND	ND		ND
4-methyl-2-pentanone (µg/L)	75		ND	ND		ND
Naphthalene (µg/L)	150		ND	ND		ND
Phenol (µg/L)	ND		ND	ND		34
Tetrachloroethene (µg/L)	ND		ND	ND		ND
1,1,2,2-tetrachloroethane (µg/L)	ND		ND	ND		ND
Toluene (µg/L)	180		ND	ND		ND
1,1,1-trichloroethane (µg/L)	ND		ND	ND		ND
Trichloroethene (µg/L)	ND		ND	ND		ND
Vinyl chloride (µg/L)	340		ND	ND		ND
Xylene (µg/L)	1,800		ND	ND		ND

TABLE 3-7

(continued)

Parameter	Sampling Location (Monitoring Well Number)					
	B38W02D[b]	B38W14S	B38W14D	B38W15S	B38W15D	B38W18D
pH (standard units)	7.5-9.3	7.3-7.6	8.1-11.6	7.5-7.8	7.7-11.6	6.9-7.2
Total organic carbon (mg/L)	2.4-3.4	3.6-6.3	9.8-34.9	4.4-109	4.0-9.5	3.6-5.1
Total organic halides (µg/L)	ND	54-430	36-270	77-115	180-350	ND-42
Specific conductance (µmhos/cm)	237-531	628-762	476-1,240	1,780-1,890	1,770-2,780	529-1,100
Benzene (µg/L)	ND	ND	ND	ND	ND	ND
Bis(2-chloroethyl)ether (µg/L)	ND	ND	ND	ND	ND	ND
Chloroform (µg/L)	ND	5	6	ND	ND	ND
1,1-dichloroethane (µg/L)	ND	ND	ND	7	ND	ND
1,1-dichloroethene (µg/L)	ND	9	5	ND	7	ND
1,2-dichloroethene (µg/L)	ND	38	17	6	68	ND
Ethyl benzene (µg/L)	ND	ND	ND	ND	ND	ND
2-methylnaphthalene (µg/L)	ND	ND	ND	ND	ND	ND
4-methyl-2-pentanone (µg/L)	ND	ND	ND	ND	ND	ND
Naphthalene (µg/L)	ND	ND	ND	ND	ND	ND
Phenol (µg/L)	ND	ND	ND	ND	ND	ND
Tetrachloroethene (µg/L)	ND	640	500	ND	570	ND
1,1,2,2-tetrachloroethane (µg/L)	ND	ND	16	ND	ND	ND
Toluene (µg/L)	ND	ND	5	ND	470	ND
1,1,1-trichloroethane (µg/L)	ND	18	ND	ND	60	ND
Trichloroethene (µg/L)	ND	55	64	ND	150	ND
Vinyl chloride (µg/L)	ND	ND	ND	57	ND	ND
Xylene (µg/L)	ND	ND	ND	ND	ND	ND

[a]Does not include parameters for which concentrations were below the limit of sensitivity of the analytical method used.
[b]Background well.
[c]Sampled only during third quarter.
[d]Well was dry during annual New Jersey priority pollutant sampling period.
[e]ND-no detectable concentration.

TABLE 3-8

CHEMICAL CONTAMINANTS NOT DETECTED IN GROUNDWATER AT MISS, 1989

Acetone
Acrolein
Acrylonitrile
Bromoform
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloroethane
2-chloroethyl vinyl ether
Dichlorobromomethane
1,2-dichloroethane
1,2-dichloropropane
1,3-dichloropropene
Methyl bromide
Methyl chloride
Methylene chloride
Total xylenes
Styrene
1,1,2,2-tetrachloroethane
Trichlorofluoromethane
1,1,2-trichloroethane
Anthracene
Acenaphthene
Acenaphthylene
Benzo(a)anthracene
Benzo(k)fluoranthene
Benzo(a)pyrene
Benzo(g,h,i)perylene
Benzyl alcohol
Benzoic acid
Bis(2-chloroethoxy)methane
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
4-bromophenyl phenyl ether
Butylbenzyl phthalate
2-chloronaphthalene
4-chlorophenyl phenyl ether
4-chloroaniline
4-chloro-3-methylphenol
Chrysene
Dibenzo(a,h)anthracene
Dibenzofuran
Di-n-butyl phthalate
Di-n-octyl phthalate
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
3,3-dichlorobenzidine
Diethyl phthalate
Dimethyl phthalate
2,4-dinitrotoluene
2,6-dinitrotoluene
4,6-dinitro-2-methylphenol
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachloroethane
Hexachlorocyclopentadiene
Indeno(1,2,3-cd)pyrene
Isophorone
2-methylphenol
4-methylphenol
Nitrobenzene
2-nitroaniline
3-nitroaniline
4-nitroaniline
N-nitroso-di-n-propylamine
Phenanthrene
Pyrene
2-chlorophenol
2,4-dichlorophenol
2,4-dimethylphenol
2,4-dinitrophenol
2-nitrophenol
4-nitrophenol
Pentachlorophenol
2,4,5-trichlorophenol
2,4,6-trichlorophenol
Aldrin
BHC, alpha
BHC, beta
BHC, gamma
BHC, delta
Alpha chlordane
Beta chlordane
Dieldrin
Endosulfan, I
Endosulfan, II
Endosulfan sulfate
Endrin
Endrin ketone
Heptachlor
Heptachlor epoxide
4,4'-DDT
4,4'-DDE
4,4'-DDD
Methoxychlor
Aroclor 1016
Aroclor 1221
Aroclor 1232
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260
Toxaphene

The rationale for selection of the individual sampling locations is given in Subsection 3.3. Samples were analyzed by TMA/E for isotopic uranium, radium-226, and thorium-232. The concentrations of isotopic uranium and thorium-232 were determined by alpha spectrometry after the uranium and thorium-232 had been leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by the radon emanation method described in Subsection 3.3.

Isotopic uranium concentrations in sediment were summed to estimate the total uranium concentrations shown in Table 3-9. Results for total uranium showed concentrations ranging from 0.8 to 1.7 pCi/g.

Analytical results for radium-226 (based on dry weight) (Table 3-9) showed concentrations ranging from 0.3 to 0.6 pCi/g. Results for thorium-232 (based on dry weight) are also presented in Table 3-9. The average annual concentration of thorium-232 was 0.3 pCi/g for all sites sampled. All of the radionuclide concentrations measured in sediment are within the DOE guidelines for soils. (DOE does not currently have guidelines for radioactivity levels in sediments.)

3.6 RADIATION DOSE

To assess the potential health effects of the radioactive materials stored at MISS, 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 evaluation of potential pathways (exposure to external gamma radiation, ingestion of water, and inhalation of radon) indicates that external gamma radiation is the only feasibly significant exposure mode.

The dose from ingesting groundwater or surface water from sources at MISS was not calculated because it was considered improbable that ingestion of this water would occur. The MISS is

TABLE 3-9

CONCENTRATIONS OF RADIUM-226, THORIUM-232, AND TOTAL URANIUM IN SEDIMENT IN THE VICINITY OF MISS, 1989

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Radium-226				
1	3[b]	0.3	0.8	0.5
2	3[b]	0.3	0.6	0.4
3	2[b,c]	0.4	0.7	0.6
Thorium-232				
1	3[b]	<0.1	0.5	0.3
2	3[b]	<0.1	0.5	0.3
3	2[b,c]	<0.1	0.4	0.3
Total Uranium				
1	3[b]	0.6	2.4	1.5
2	3[b]	0.6	0.9	0.8
3	2[b,c]	1.6	1.8	1.7

[a]Sampling locations are shown in Figure 3-2. Location 3 is upstream of MISS and represents background. No sediment was available at sampling locations 5 and 6. Location 4 is no longer accessible.

[b]Sampling routine was inadvertently omitted during fourth quarter.

[c]Location was frozen during the first quarter.

fenced and locked and security is maintained, so a member of the public could only consume water on the site by trespassing on the property. Furthermore, the trespasser would have to be equipped with a means of removing the well cap (which is locked) and of extracting the groundwater, such as a bailer or pump.

Except for station 5, radon concentrations measured at the MISS boundary were within the normal variations associated with background measurements. Given the amount of time that the hypothetical maximally exposed individual would spend near the boundary (and in particular station 5, which borders the railroad tracks), the dose from radon inhalation would be indistinguishable from that received from background concentrations. Consequently, this pathway would not contribute additional dose to the hypothetical maximally exposed individual and was not considered in the dose calculations presented in Subsection 3.6.1. Measured radon and thoron concentrations are discussed fully in Subsection 3.1.

3.6.1 Dose to the Maximally Exposed Individual

To identify the maximally exposed individual in the vicinity of MISS 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. These doses were then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points.

Residents of homes on Central Avenue north of the site boundary would receive exposures equivalent to background for the area because of the distance of these homes from the site. The highest annual average external gamma radiation levels at the MISS boundary in 1989 were measured along the western side of the site, with an average value of 79 mrem/yr at monitoring locations 9 through 12. Therefore, the highest overall exposure from external gamma radiation would be received by an individual walking at a speed of 5 km/h (3 mph) along the western boundary of the site twice a day,

365 days/yr, spending 8 min/day (50 h/yr) in the area. This maximally exposed individual would receive an exposure of less than 1 mrem/yr above background. This scenario is, however, highly conservative because it is unlikely that any individual would spend so much time at this location. This exposure is equivalent to less than 1 percent of the DOE radiation protection standard of 100 mrem/yr and is less than the exposure a person receives during a flight between New York and Los Angeles through the increased cosmic radiation present at higher altitudes.

3.6.2 Dose to the Population in the Vicinity of MISS

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 MISS, these pathways are direct exposure to gamma radiation and inhalation of radon and thoron.

The contribution to the population dose made by gamma radiation, radon, and thoron from on-site radioactive materials is too small to be measured; gamma radiation levels decrease rapidly as distance from the source of contamination increases. Similarly, radon and thoron are known to dissipate rapidly with distance from a source (Ref. 19).

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 dose to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, thereby lowering potential doses to even less significant levels.

The cumulative dose to the population within an 80-km (50-mi) radius of MISS 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 MISS 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 and thoron, external gamma radiation, and uranium, radium-226, and thorium-232 in surface water and groundwater are compared with results for 1985 through 1988. As the environmental monitoring program continues at MISS and more data are collected, comparisons and analyses of trends will become more valid.

3.7.1 Radon and Thoron

Table 3-10 lists annual average concentrations of radon and thoron for each monitored location for the period 1985 through 1989. Elevated concentrations can be seen at location 5 (see Figure 3-1), which is near an area of known contamination that is scheduled for remedial action. Disturbances of the surface soil cover near this location during characterization activities in 1986 may be responsible for the rise in radon levels that began in 1986 and continued, with some climatic moderation, in 1987.

3.7.2 External Gamma Radiation

As shown in Table 3-11, external gamma radiation levels remained relatively unchanged from 1988 to 1989. Levels at station 10 have dropped in the last two years, possibly because clean fill shielding was emplaced in the vicinity in August 1987.

3.7.3 Surface Water

Concentrations of uranium, radium-226, and thorium-232 in surface water remain stable and essentially equal to the upstream concentrations at MISS. As shown in Table 3-12, little change has occurred in these levels since 1985.

TABLE 3-10

ANNUAL AVERAGE CONCENTRATIONS OF THORON AND RADON AT MISS, 1985-1989[a]

Sampling Station[b]	Concentration (10^{-9} µCi/ml)[c,d]				
	1985	1986	1987	1988	1989
Thoron (Rn-220)					
1	0.5	<0.04	0.2	0.4	0.5
2	0.6	<0.04	0.3	0.5	0.5
3	0.3	0.1	0.4	0.2	0.4
4	0.5	<0.04	<0.1	1.4	0.4
5	3.2	9.2	9.2	6.4	7.3
6	1.0	0.6	1.3	1.0	0.7
7	0.3	<0.04	0.5	0.3	0.6
8	0.02	0.07	0.4	0.1	0.3
9	0.2	<0.04	0.1	0.2	0.1
10	2.7	6.0	4.0	0.5	0.4
11	0.2	0.04	0.1	0.4	0.2
12[e]	1.2	1.7	1.7	0.6	0.3
13[e]	2.9	0.6	0.2	0.1	0.1
Background					
14[f]	0.1	0.4	0.3	<0.01	<0.1
18[g]	--	--	--	--	0.1
19[h]	--	--	--	--	<0.1
Radon (Rn-222)					
1	0.3	0.6	0.7	0.6	0.4
2	0.2	1.2	1.2	0.9	0.4
3	0.3	1.2	1.5	0.6	0.4
4	0.4	1.6	1.1	1.9	0.9
5	0.5	9.9	9.7	7.4	1.0
6	0.2	1.9	2.4	1.4	0.6
7	0.2	0.9	1.1	0.8	0.6
8	0.3	0.8	1.0	0.4	0.4
9	0.2	0.9	1.1	0.5	0.5
10	0.4	6.5	4.9	1.0	0.6
11	0.2	1.3	0.8	0.8	0.5
12	0.2	2.6	2.3	1.1	0.8
13[e]	0.3	1.2	1.1	0.4	0.5
Background					
14[f]	0.4	1.0	0.8	0.3	0.5
18[g]	--	--	--	--	0.4
18[h]	--	--	--	--	0.4

TABLE 3-10

(continued)

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 14-17).

[b]Locations of sampling stations are shown in Figure 3-1.

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

[d]All results include background.

[e]Station 13 is a quality control for station 1.

[f]Background detector located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of MISS.

[g]Background detector located at the Rochelle Park Fire Station, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in January 1989.

[h]Background detector located at the Rochelle Park Post Office, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in January 1989.

TABLE 3-11

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

Sampling Station[b]	Radiation Level (mrem/yr)[c] 1985	1986	1987	1988	1989
Boundary					
3	27	38	29	21	29
4	130	91	69	109	112
5	272	172	121	186	154
6	106	83	67	85	68
7	15	24	36	16	13
8	15	18	37	30	9
9	38	23	39	32	17
10[d]	627	496	521	317	173
11	57	50	61	59	35
12	180	88	79	106	90
On Site					
1	48	41	36	40	28
2	50	51	43	52	35
13[e]	46	35	33	39	27
Background					
14[f]	108	63	58	78	63
18[g]	--	--	--	--	64
18[h]	--	--	--	--	56

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 14-17).
[b]Locations of sampling stations are shown in Figure 3-1.
[c]Measured background has been subtracted at on-site and boundary locations.
[d]Station 10 is in an area of known contamination (Ref. 3).
[e]Station 13 is a quality control for station 1.
[f]Located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of MISS.
[g]Located at the Rochelle Park Fire Station, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in April 1988.
[h]Located at the Rochelle Park Post Office, Rochelle Park, NJ, approximately 0.8 km (0.5 mi) south of MISS. Established in April 1988.

TABLE 3-12

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-232 IN SURFACE WATER AT MISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c,d]				
	1985	1986	1987	1988	1989
Total Uranium					
1	<3.0	<3.0	<3.0	3.0	<5.0
2[e]	<3.0	<3.0	<3.0	4.3	<5.0
3[e]	<3.0	<3.0	<3.0	3.8	<5.0
Radium-226					
1	0.2	0.4	0.4	0.4	0.3
2[e]	0.4	0.4	0.2	0.3	0.3
3[e]	0.4	0.6	0.3	0.3	0.4
Thorium-232					
1	0.2	<0.1	<0.1	<0.1	0.1
2[e]	0.1	0.1	<0.1	<0.1	<0.1
3[e]	0.1	0.1	<0.1	0.1	<0.1

[a] Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 14-17).

[b] Sampling locations are shown in Figure 3-2. Locations 4, 5, and 6 are not reported because there were no data.

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

[d] All results include background.

[e] Location is upstream of MISS and represents background.

3.7.4 Groundwater

Groundwater monitoring has been conducted at MISS since 1985. Table 3-13 lists the annual average concentrations of the three radionuclides of primary concern at each monitoring well location. Concentrations of total uranium, thorium-232, and radium-226 have remained stable since 1985.

Generally, slightly higher concentrations of uranium are found in wells installed in the upper groundwater system within the site boundary. These wells are located within the disturbed zone (see Subsection 3.7.1) and capture primarily surface water percolating through the topsoil (as opposed to groundwater in an aquifer). Typically, these wells produce only limited quantities of water and are often dry during periods when rainfall is minimal.

Uranium, thorium-232, and radium-226 concentrations in the deeper wells that are drilled to bedrock to monitor the available groundwater on the site have remained relatively constant since 1985.

TABLE 3-13

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-232 IN GROUNDWATER AT MISS, 1985-1989[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Total Uranium					
MISS-1A[d]	27.0	--	--	--	--
MISS-1B	<3.0	1.6	3.3	2.4	2.2
MISS-3A	<3.0	0.6	2.0	1.5	1.2
MISS-3B	<3.0	0.3	3.3	1.3	0.8
MISS-4A[d]	<3.0	--	--	3.9	5.5
MISS-4B	<3.0	0.5	2.0	0.7	1.0
MISS-5A[d]	63.0	100.0	98.8	--	--
MISS-5A-1[d]	--	--	--	--	--
MISS-5B	<3.0	0.3	1.5	0.7	1.5
MISS-6A	9.0	8.4	12.1	8.4	8.0
MISS-6B	5.0	0.8	2.2	1.1	1.2
MISS-7A[d]	--	--	15.9	--	--
MISS-7B	12.0	4.7	5.0	6.3	7.0
B38W14S[f]	--	--	--	--	3.2
B38W14D[f]	--	--	--	--	4.1
B38W15S[f]	--	--	--	--	2.6
B38W15D[f]	--	--	--	--	4.8
B38W18D[f]	--	--	--	--	4.8
Background					
MISS-2A	3.0	0.6	2.4	1.4	2.1
MISS-2B	12.0	0.5	2.1	0.8	1.0
B38W04B[e]	--	--	--	0.8	0.9
B38W01S[f]	--	--	--	--	2.0
B38W02D[f]	--	--	--	--	2.2
Radium-226					
MISS-1A[d]	0.1	--	--	--	--
MISS-1B	0.6	0.6	0.4	0.9	1.4
MISS-3A	0.4	0.6	0.6	1.2	1.6
MISS-3B	0.3	0.5	0.3	0.8	1.0
MISS-4A[d]	0.4	--	--	2.8	3.8
MISS-4B	0.3	0.4	0.5	1.4	1.3
MISS-5A[d]	0.2	0.6	0.8	--	--

TABLE 3-13

(continued)

Page 2 of 3

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Radium-226 (cont'd)					
MISS-5A-1[d]	--	--	--	--	--
MISS-5B	0.3	0.2	0.3	0.7	1.0
MISS-6A	0.2	0.4	0.5	2.0	1.3
MISS-6B	0.4	0.5	0.3	0.7	0.9
MISS-7A[d]	--	--	0.1	--	--
MISS-7B	0.3	0.4	0.3	1.5	0.8
B38W14S[f]	--	--	--	--	1.0
B38W14D[f]	--	--	--	--	1.0
B38W15S[f]	--	--	--	--	1.2
B38W15D[f]	--	--	--	--	0.7
B38W18D[f]	--	--	--	--	0.7
Background					
MISS-2A	0.4	0.5	0.4	1.0	1.3
MISS-2B	0.3	1.5	0.4	0.7	1.0
B38W04B[e]	--	--	--	1.0	1.2
B38W01S[f]	--	--	--	--	1.1
B38W02D[f]	--	--	--	--	0.9
Thorium-232					
MISS-1A[d]	0.1	--	--	--	--
MISS-1B	<0.1	<0.2	<0.3	<0.3	<0.3
MISS-3A	<0.1	<0.2	<0.1	0.7	0.5
MISS-3B	<0.2	<0.1	<0.2	<0.3	<0.2
MISS-4A[d]	<0.1	--	--	1.6	3.4
MISS-4B	<0.1	<0.1	<0.1	<0.2	<0.2
MISS-5A[d]	<0.1	0.3	0.3	--	--
MISS-5A-1[d]	--	--	--	--	--
MISS-5B	<0.2	<0.1	<0.1	<0.2	<0.3
MISS-6A	<0.2	0.1	0.3	<0.2	0.5
MISS-6B	<0.3	<0.2	<0.1	0.3	<0.2
MISS-7A[d]	--	--	<0.1	--	--
MISS-7B	<0.2	<0.2	<0.1	<0.3	<0.2
B38W14S[f]	--	--	--	--	0.4
B38W14D[f]	--	--	--	--	0.3
B38W15S[f]	--	--	--	--	0.5
B38W15D[f]	--	--	--	--	<0.2
B38W18D[f]	--	--	--	--	0.3

TABLE 3-13

(continued)

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1985	1986	1987	1988	1989
Thorium-232 (cont'd)					
Background					
MISS-2A	0.3	<0.2	<0.1	0.4	0.5
MISS-2B	<0.2	<0.2	<0.1	<0.3	0.3
B38W04B[e]	--	--	--	<0.2	<0.2
B38W01S[f]	--	--	--	--	0.2
B38W02D[f]	--	--	--	--	0.3

[a]Sources for 1985-1988 data are the annual site environmental reports for those years (Refs. 14-17).

[b]Sampling locations are shown in Figure 1-7.

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

[d]Shallow well to monitor groundwater in unconsolidated material. These wells frequently do not contain water.

[e]Located at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B. Well was added to the monitoring program in April 1988 to represent background.

[f]Installed in late 1988.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

On December 30, 1989, the New Jersey Department of Environmental Protection (NJDEP) sent notification to DOE that the New Jersey Pollutant Discharge Elimination System permit for groundwater discharge (permit No. NJ0054500) 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 NJDEP satisfaction, the permit was no longer required. As a result, the sampling and analysis parameters previously followed to comply with specific permit conditions could be modified at the discretion of DOE.

4.2 SPECIAL STUDIES

There were no special studies performed at MISS 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 of 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.

For inorganic analyses, the program includes:

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.

- 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 the 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 level includes exposure from all pathways except medical treatments (Ref. 12). Evaluation of exposure pathways and resulting dose calculations is 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 year	=	8,760 hours
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/s	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 meter
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
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
yd^3	cubic yard
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
HSL	Hazardous Substances List
MCL	maximum contaminant level
MISS	Maywood Interim Storage Site
NIST	National Institute of Standards and Technology
NJDEP	New Jersey Department of Environmental Protection
NRC	Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
QA	quality assurance
QC	quality control
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides

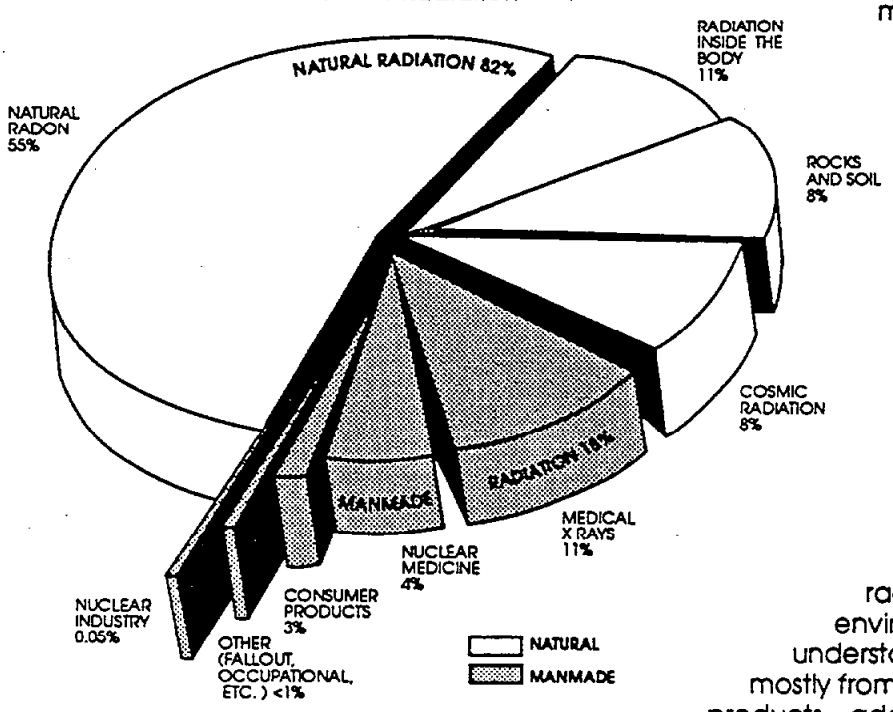
APPENDIX D
RADIATION IN THE ENVIRONMENT

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.

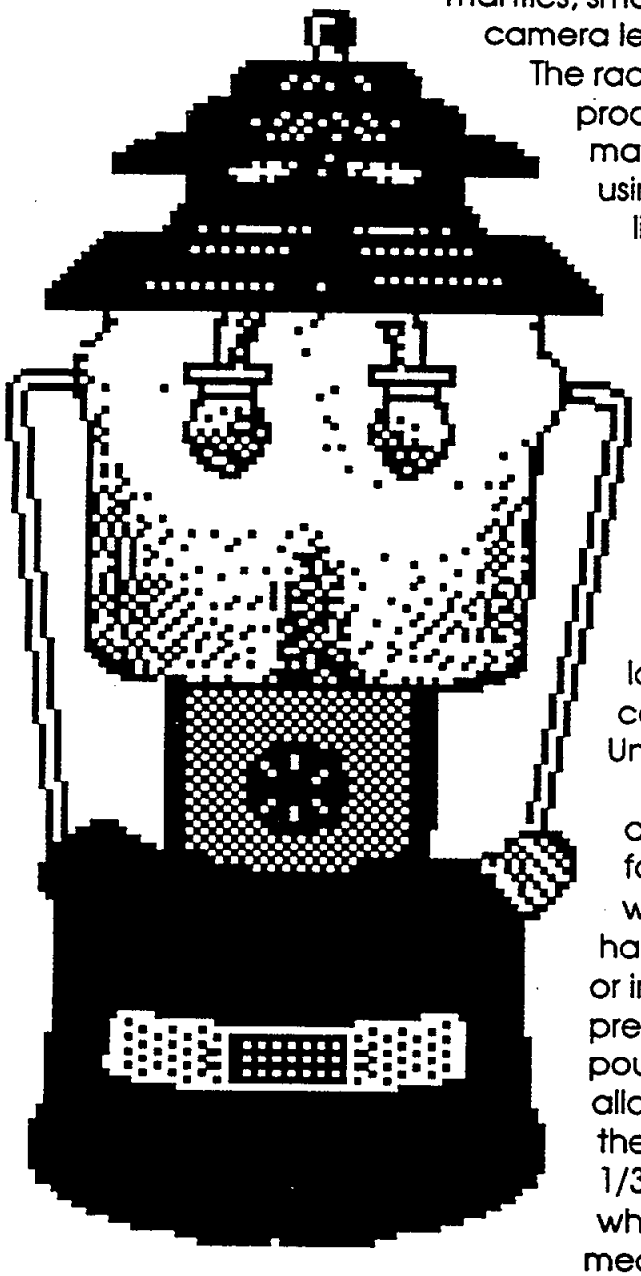
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	$2x10^{12}$ or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	$2x10^{9}$ or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	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

Chart provided by W.J. Peck, Baptist Hospital

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.

From information provided by W.L. Rock, Peabody National, Inc.

APPENDIX E

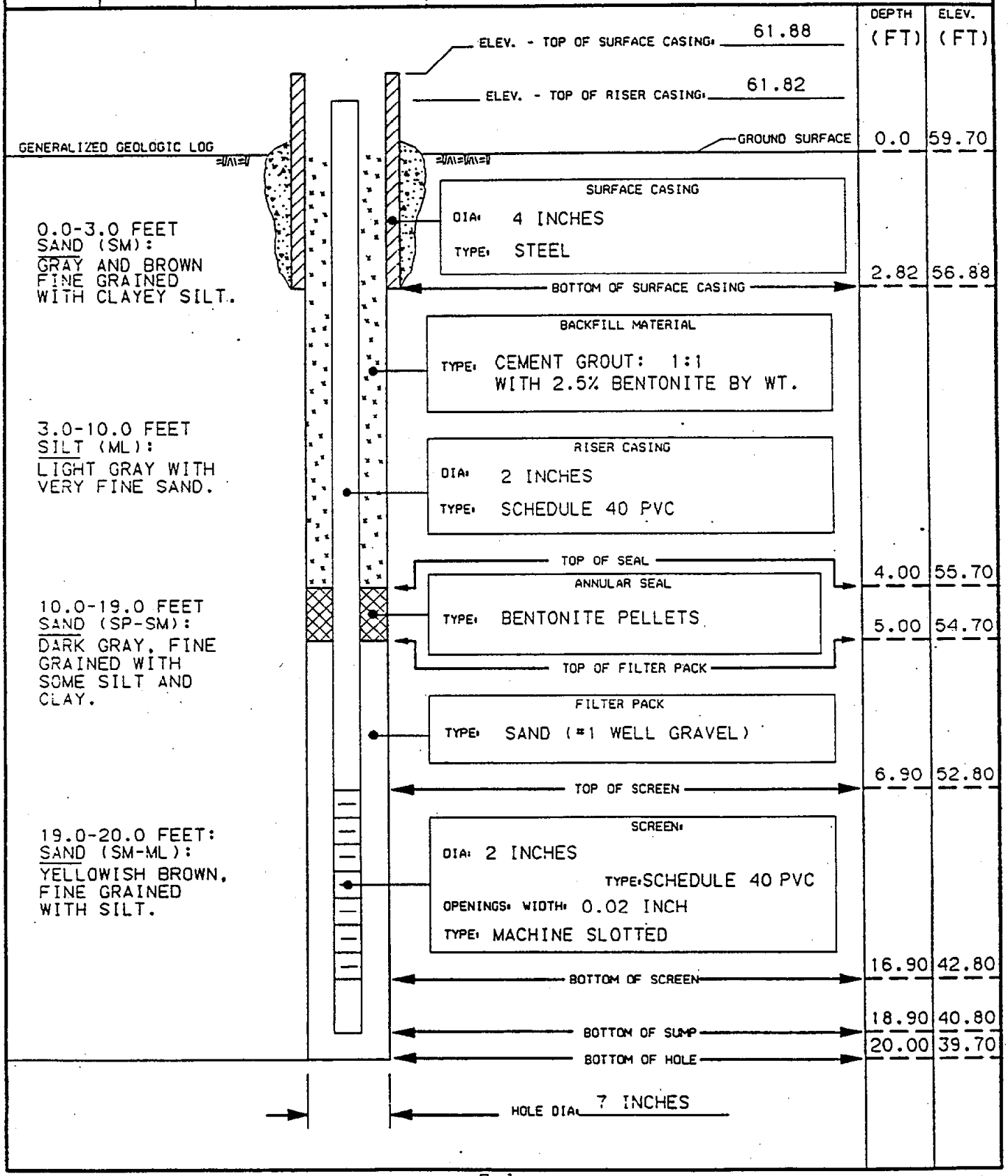
SAMPLE WELL CONSTRUCTION LOG

MONITORING WELL

PROJECT	WELL NO.
FUSRAP	MISS-2A

JOB NO.	SITE	COORDINATES (IN FEET)
14501	MAYWOOD I.S.S.	N 9973.36 E 9875.92

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
10-29-84	10-30-84	R.H.NELSON	TOP OF RISER CASING



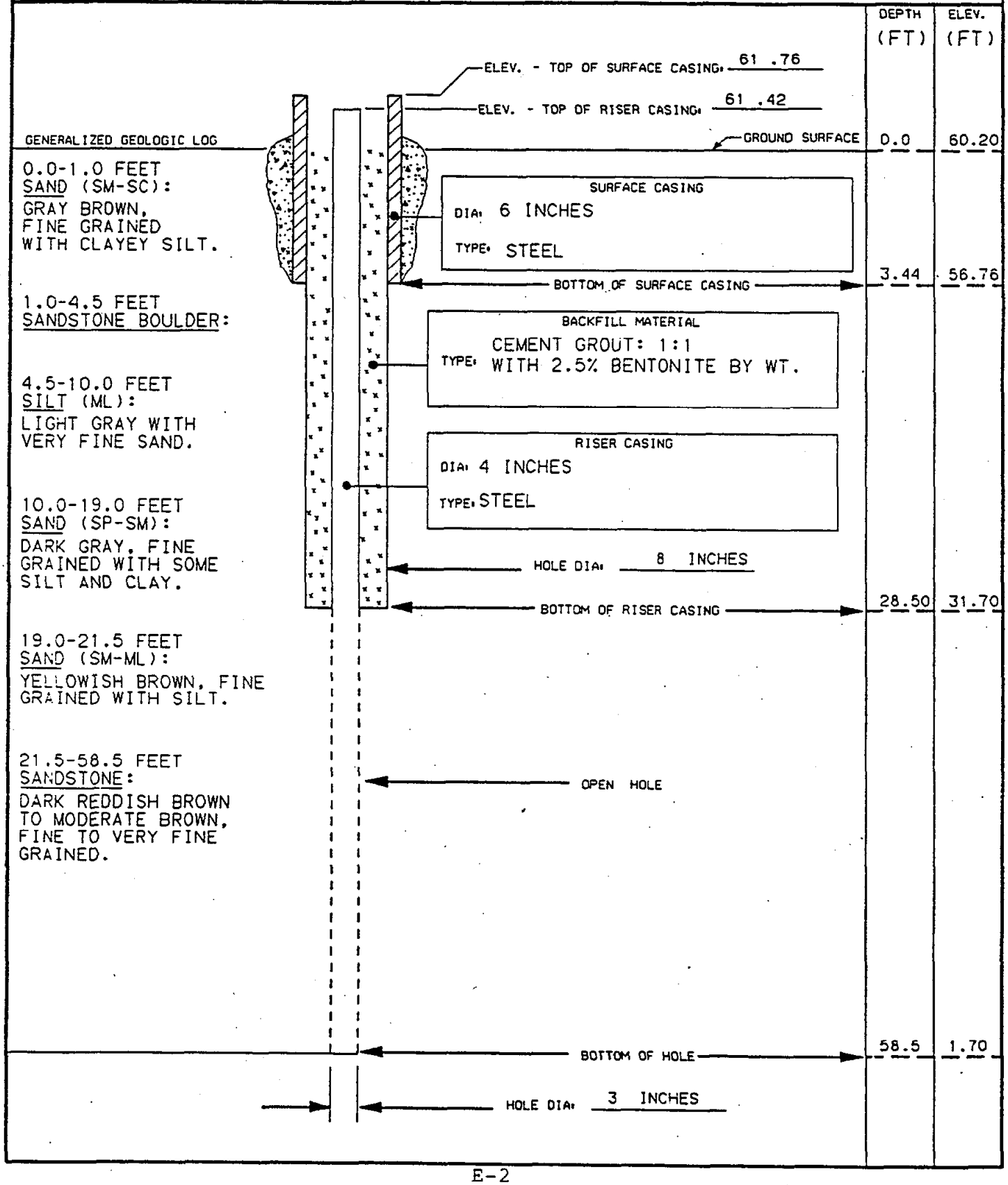
	DEPTH (FT)	ELEV. (FT)
GROUND SURFACE	0.0	59.70
BOTTOM OF SURFACE CASING	2.82	56.88
TOP OF SEAL	4.00	55.70
TOP OF FILTER PACK	5.00	54.70
TOP OF SCREEN	6.90	52.80
BOTTOM OF SCREEN	16.90	42.80
BOTTOM OF SUMP	18.90	40.80
BOTTOM OF HOLE	20.00	39.70

MONITORING WELL

PROJECT	WELL NO.
FUSRAP	MISS-2B

JOB NO.	SITE	COORDINATES (JOB-FEET)
14501	MAYWOOD I.S.S.	N 9962.48 E 9888.21

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
10-29-84	11-12-84	R. H. NELSON	TOP OF RISER CASING



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