

DOE/OR/20722--264

DE91 002527

NIAGARA FALLS 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

MASTER

EP

**SUMMARY ASSESSMENT  
ENVIRONMENTAL COMPLIANCE ACTIVITY  
U.S. DEPARTMENT OF ENERGY  
SURPLUS FACILITIES MANAGEMENT PROGRAM  
NIAGARA FALLS STORAGE SITE**

**BACKGROUND AND OVERVIEW**

To evaluate the environmental compliance record of the Niagara Falls Storage Site (NFSS), managed as part of the Surplus Facilities Management Program, it is necessary to describe the history of the site.

NFSS is a remnant of the original approximately 610-ha (1,500-acre) site that was used during World War II by the Manhattan Engineer District (MED) project and was a portion of the Department of the Army's Lake Ontario Ordnance Works (LOOW). Except for nonradioactive boron-10 enriching operations during the periods 1954 to 1958 and 1964 to 1971, the site's major use from 1944 to the present has been for storage of radioactive residues produced as by-products of uranium production during the MED project and subsequent Atomic Energy Commission projects.

As a result of the storage and transshipment operations involving radioactive materials, some portions of the former LOOW other than the present NFSS were also contaminated. In addition, some of the radioactive materials stored at NFSS over the years were subject to water and wind erosion. As a result, radioactive materials migrated off site, chiefly through the NFSS drainage ditches.

NFSS covers 77 ha (191 acres) of the approximately 610 ha (1,500 acres) originally used for shipment, storage, and burial of radioactive materials and wastes. In 1979 and 1980, comprehensive radiological characterization was conducted at NFSS. Radiological surveys of the vicinity properties were performed from 1981 to 1985.

Remedial action began in 1981 on the vicinity properties with the cleanup of a small piece of property adjacent to the site. Remedial action on the remaining vicinity properties was performed from 1983 through 1986. Remedial action at NFSS itself began in 1982 and continued through 1986. All contaminated materials remediated from 1981 to 1986 are stored in the interim waste containment facility (IWCF).

In 1988, several isolated areas of residual radioactivity were excavated and the materials were placed in temporary storage. At present, all areas of residual radioactivity on site have been remediated, with the exception of one localized area suspected to be both radiologically and chemically contaminated.

The 4-ha (10-acre) IWCF is the dominant feature of NFSS. The IWCF is enclosed within a dike and cutoff wall, each constructed of compacted clay. The cutoff wall extends a minimum of 46 cm (18 in.) into the underlying gray clay unit. The dike and cutoff wall, in conjunction with the engineered earthen drainage cover or cap, enclose the wastes in a clay envelope that provides a barrier to migration of waste constituents.

During its history, NFSS 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)**

NFSS 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 the Environmental Protection Agency (EPA). A strategy for determining compliance with the radon flux standard in Subpart Q was transmitted 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.

#### **Department of Energy (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 NFSS is in compliance with DOE orders.

#### **Clean Water Act (CWA)**

NFSS 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 July 1989 did not find any deficiencies under the CWA. The amendments to the CWA in 1987 required EPA to promulgate regulations requiring permits for stormwater discharges from industrial facilities; therefore, a stormwater discharge permit may be required in the future.

#### **Resource Conservation and Recovery Act (RCRA)**

RCRA-regulated waste is not present at NFSS. Additionally, an environmental compliance assessment conducted by ORNL in October 1989 did not find any deficiencies under RCRA.

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

NFSS is not on the National Priorities List. Any remaining remediation of the site will be managed by DOE under the authority of CERCLA.

### **Toxic Substances Control Act (TSCA)**

TSCA-regulated wastes, which were identified at NFSS during 1989, are no longer present. The environmental compliance assessment of the site by ORNL found four deficiencies under TSCA that involved improper storage of PCB-contaminated materials. The materials have been shipped to a permitted disposal facility.

### **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 and an environmental impact statement (EIS) and corresponding record of decision (ROD). Removal actions at the vicinity properties have been handled with action description memoranda and corresponding memoranda-to-file and have been determined to have had no significant impact on the environment. The EIS and ROD were issued in 1986 to state the decision on the long-term disposition of NFSS. For the radioactive wastes, DOE has selected long-term, in-place management consistent with EPA regulations governing uranium mill tailings.

## ABSTRACT

The environmental monitoring program, which began in 1981, was continued during 1989 at the Niagara Falls Storage Site (NFSS), a United States Department of Energy (DOE) surplus facility located in Niagara County, New York, that is currently used for interim storage of radioactive residues, contaminated soils, and rubble. The monitoring program is being conducted by Bechtel National, Inc.

The monitoring program at NFSS measures radon concentrations in air; external gamma radiation levels; and uranium and radium concentrations in surface water, groundwater, and sediment. Additionally, several nonradiological parameters are measured in groundwater. To verify that the site is in compliance with the DOE radiation protection standard and to assess its potential effect on public health, the radiation dose was calculated for a hypothetical maximally exposed individual. Based on the conservative scenario described in this report, this hypothetical individual receives an annual external exposure equivalent to approximately 2 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is less than a person receives during a one-way flight from New York to Los Angeles (because of the greater amounts of cosmic radiation at higher altitudes).

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

## CONTENTS

	<u>Page</u>
Figures .....	x
Tables .....	xii
1.0 INTRODUCTION .....	1
1.1 LOCATION AND DESCRIPTION .....	1
1.2 SITE HISTORY .....	6
1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE .....	14
1.3.1 Upper Groundwater System .....	14
1.3.2 Lower Groundwater System .....	24
1.3.3 Bedrock Groundwater System .....	35
1.3.4 Conclusions .....	35
2.0 SUMMARY OF MONITORING RESULTS .....	38
3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION .....	40
3.1 RADON MONITORING .....	41
3.2 EXTERNAL GAMMA RADIATION .....	43
3.3 SURFACE WATER SAMPLING .....	47
3.4 GROUNDWATER SAMPLING .....	50
3.4.1 Radiological .....	54
3.4.2 Chemical .....	54
3.5 SEDIMENT SAMPLING .....	64
3.6 RADIATION DOSE .....	66
3.6.1 Dose to the Maximally Exposed Individual ..	67
3.6.2 Dose to the Population in the Vicinity of NFSS .....	67
3.7 TRENDS .....	68
3.7.1 Radon .....	69
3.7.2 External Gamma Radiation .....	69
3.7.3 Surface Water .....	69
3.7.4 Groundwater .....	69
4.0 RELATED ACTIVITIES AND SPECIAL STUDIES .....	78
4.1 RELATED ACTIVITIES .....	78
4.2 SPECIAL STUDIES .....	78
REFERENCES .....	79
APPENDIX A: Quality Assurance .....	A-1
APPENDIX B: Environmental Standards and Conversion Factors .....	B-1
APPENDIX C: Abbreviations and Acronyms .....	C-1
APPENDIX D: Radiation in the Environment .....	D-1

	<u>Page</u>
APPENDIX E: Sample Well Construction Logs .....	E-1
APPENDIX F: Distribution List for Niagara Falls Storage Site Environmental Report for Calendar Year 1989 .....	F-1

## FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Location of NFSS .....	2
1-2	Aerial View of the NFSS Interim Waste Containment Facility (IWCF) .....	3
1-3	Present Configuration of NFSS .....	4
1-4	Annual Wind Rose for NFSS .....	7
1-5	Generalized Land Use in the Vicinity of NFSS ....	8
1-6	NFSS Prior to Remedial Actions .....	10
1-7	Locations of Groundwater Monitoring Wells at NFSS .....	15
1-8	Hydrographs of Upper Groundwater System Wells OW-1B, OW-2B, OW-3B, and OW-4B .....	19
1-9	Hydrographs of Upper Groundwater System Wells OW-5B, OW-6B, OW-7B, and OW-8B .....	20
1-10	Hydrographs of Upper Groundwater System Wells OW-10B, OW-11B, OW-12B, and OW-9B .....	21
1-11	Hydrographs of Upper Groundwater System Wells OW-13B, OW-14B, OW-15B, and OW-16B .....	22
1-12	Hydrographs of Upper Groundwater System Wells OW-17B and OW-18B .....	23
1-13	Hydrographs of Lower Groundwater System Wells OW-1A, OW-2A, OW-3A, and OW-4A .....	25
1-14	Hydrographs of Lower Groundwater System Wells OW-5A, OW-6A, OW-7A, and OW-8A .....	26
1-15	Hydrographs of Lower Groundwater System Wells OW-10A, OW-11A, OW-12A, and OW-9A .....	27
1-16	Hydrographs of Lower Groundwater System Wells OW-13A, OW-14A, OW-15A, and OW-16A .....	28
1-17	Hydrographs of Lower Groundwater System Wells OW-17A and OW-18A .....	29

**FIGURES**  
(continued)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-18	Hydrographs of Lower Groundwater System Wells BH-49, BH-59, BH-64, and BH-70 .....	30
1-19	Hydrographs of Lower Groundwater System Wells BH-5 and BH-61 .....	31
1-20	Comparison Hydrographs for Wells OW-11A, OW-7A, and BH-64 .....	32
1-21	Potentiometric Map of Lower Groundwater System (7/5/89) .....	33
1-22	Potentiometric Map of Lower Groundwater System (11/1/89) .....	34
1-23	Hydrographs of Bedrock Groundwater System Wells A-23A and A-49 .....	36
3-1	Radon and External Gamma Radiation Monitoring Locations at NFSS .....	42
3-2	On-Site Surface Water and Sediment Sampling Locations at NFSS .....	48
3-3	Off-Site Surface Water and Sediment Sampling Locations in the Vicinity of NFSS .....	49

**TABLES**

<b>Table</b>	<b>Title</b>	<b>Page</b>
1-1	Residues and Middlesex Sands Stored at NFSS .....	9
1-2	NFSS Upper System Monitoring Well Construction Summary .....	16
1-3	NFSS Monitoring Well Construction Summary for Lower and Bedrock Groundwater Systems .....	17
3-1	Concentrations of Radon-222 Measured by Terradex Monitors at the NFSS Boundary, 1989 .....	44
3-2	External Gamma Radiation Levels at NFSS, 1989 ...	46
3-3	Concentrations of Total Uranium in NFSS Water Samples, 1989 .....	51
3-4	Concentrations of Radium-226 in NFSS Water Samples, 1989 .....	52
3-5	Concentrations of Total Uranium in NFSS IWCF Monitoring Wells, 1989 .....	55
3-6	Concentrations of Radium-226 in NFSS IWCF Monitoring Wells, 1989 .....	56
3-7	Ranges of Water Quality Parameters in Groundwater at NFSS, 1989 .....	58
3-8	Ranges of Concentrations of Metal Ions Detected in Groundwater at NFSS, 1989 .....	60
3-9	Total Uranium and Radium-226 Concentrations in NFSS Sediment Samples, 1989 .....	65
3-10	Annual Average Concentrations of Radon-222 Measured at NFSS Boundary, 1985-1989 .....	70
3-11	Annual Average External Gamma Radiation Levels at NFSS, 1985-1989 .....	71
3-12	Annual Average Concentrations of Total Uranium in NFSS Water Samples, 1985-1989 .....	73
3-13	Annual Average Concentrations of Radium-226 in NFSS Water Samples, 1985-1989 .....	74

**TABLES**  
(continued)

<b>Table</b>	<b>Title</b>	<b>Page</b>
3-14	Annual Average Concentrations of Total Uranium in NFSS Containment Monitoring Wells, 1987-1989 .	76
3-15	Annual Average Concentrations of Radium-226 in NFSS Containment Monitoring Wells, 1987-1989 .	77
A-1	Summary Comparison of Water Sample Results (EPA and TMA/E) .....	A-3
B-1	Conversion Factors .....	B-2

## 1.0 INTRODUCTION

Environmental monitoring has been conducted at the Niagara Falls Storage Site (NFSS) since 1981. This report presents the findings of the environmental monitoring program conducted at the NFSS during calendar year 1989. NFSS is part of the United States Department of Energy (DOE) Surplus Facilities Management Program.

### 1.1 LOCATION AND DESCRIPTION

NFSS occupies approximately 77 ha (190 acres) located in northwestern New York within the Township of Lewiston (Niagara County). The site is approximately 6 km (4 mi) south of Lake Ontario, 16 km (10 mi) north of the City of Niagara Falls, and is in a generally rural setting. NFSS and its regional setting are shown in Figure 1-1; Figure 1-2 is an aerial photograph of the site that highlights the interim waste containment facility (IWCF).

NFSS was developed as an interim waste storage area for radioactive residues from pitchblende processing and radium-contaminated sand, soil, and building rubble. Work on the IWCF was completed in late 1986.

The dominant feature of NFSS as presented in Figure 1-3 is the 4-ha (10-acre) IWCF, which is enclosed within a dike and cutoff wall, each constructed of compacted clay. The cutoff wall extends a minimum of 45.7 cm (18 in.) into an underlying gray clay unit. The dike and cutoff wall, in conjunction with the engineered earthen drainage cover or cap, enclose the wastes in a clay envelope that provides a barrier to migration of waste constituents. More detailed information on the design of IWCF is provided in Ref. 1.

The site is generally level but slopes gently to the northwest at elevations between 96.9 and 97.8 m (318 and 321 ft) above mean sea level (msl). The site drains poorly because of soil characteristics and the flatness of the terrain. Soils at NFSS are predominantly silt loams underlain by a clayey glacial till and a

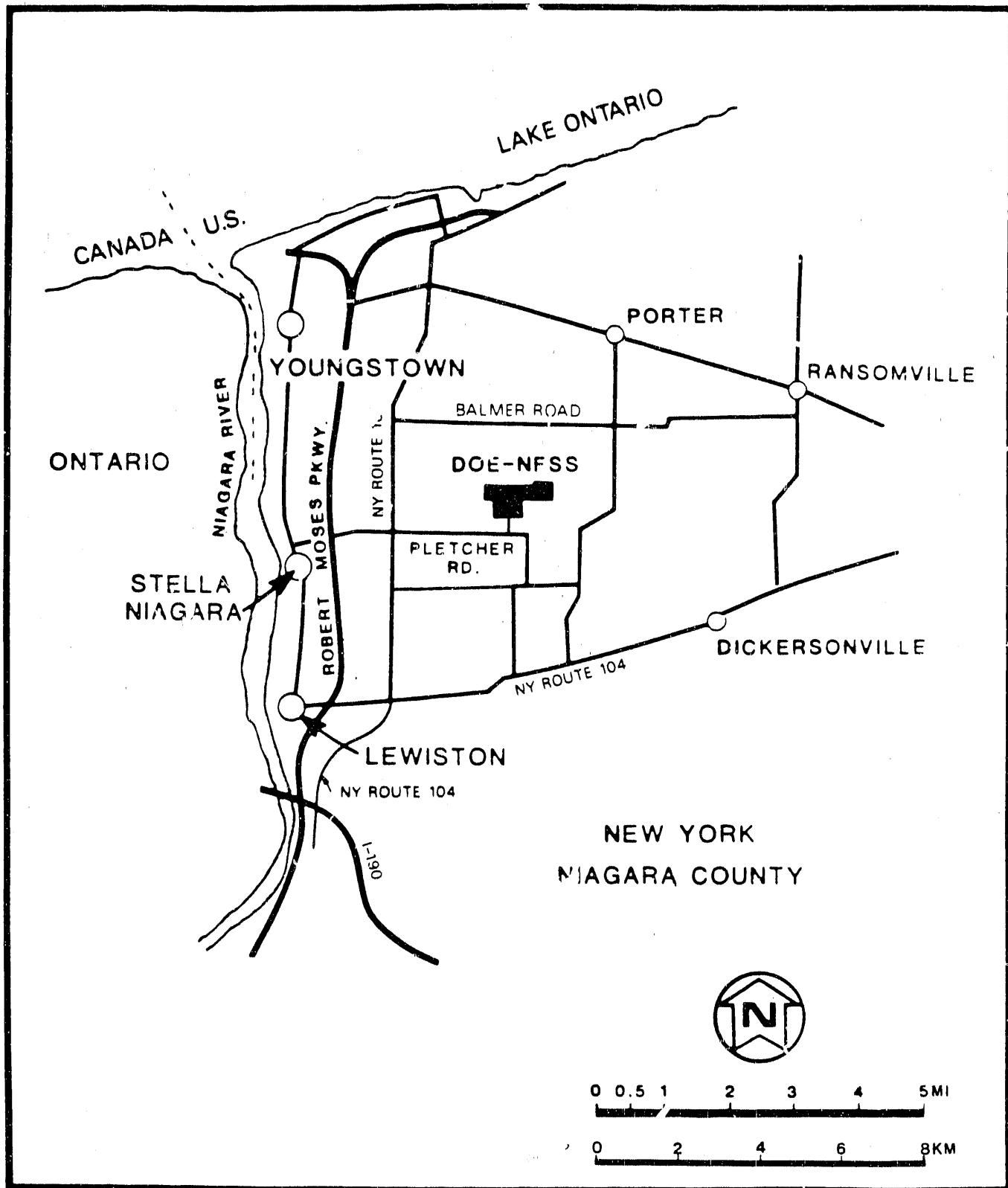


FIGURE 1-1 LOCATION OF NFSS

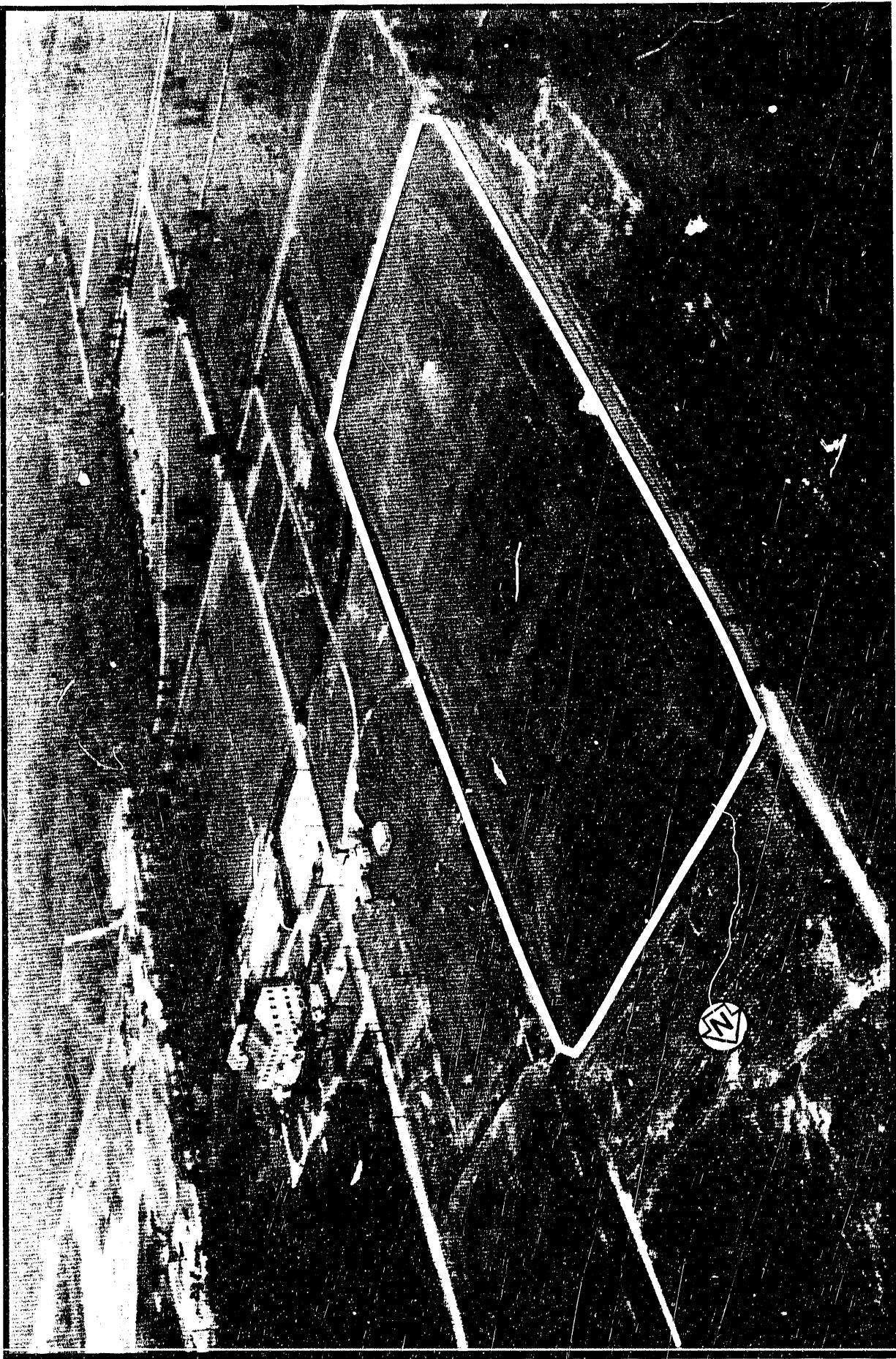


FIGURE 1-2 AERIAL VIEW OF THE NFSS INTERIM WASTE  
CONTAINMENT FACILITY (IWCF)

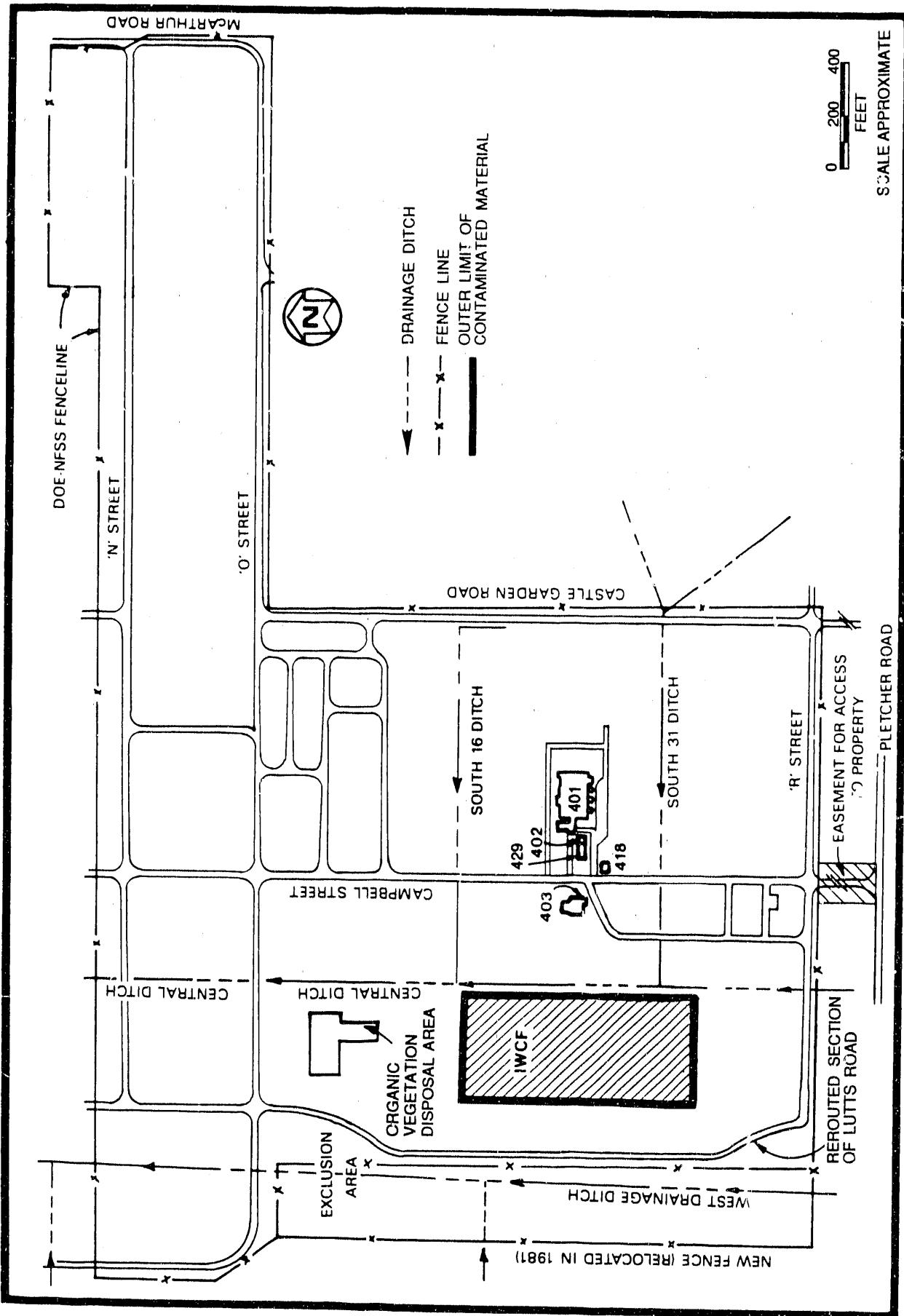


FIGURE 1-3 PRESENT CONFIGURATION OF NFSS

lacustrine clay. Sand-gravel lenses are common. Bedrock lies 9.1 to 15 m (30 to 50 ft) beneath the surface and consists of Queenston shale.

All surface water from the site discharges via the Central Drainage Ditch and its tributary ditches into Fourmile Creek, located northwest of the site. Groundwater is present in a sand-gravel zone above bedrock and in fractures in the bedrock surface (the primary groundwater system beneath the site) and in saturated clay zones at depths of 1.5 to 6.1 m (5 to 20 ft). Groundwater level contours indicate that groundwater flows to the north-northwest at a hydraulic gradient of approximately 3 m/km (16 ft/mi). The groundwater probably discharges into the northern reaches of the Niagara River close to Lake Ontario (Ref. 2).

Lake and river water are the predominant sources of potable water in the area surrounding NFSS; approximately 90 percent of the population in Niagara and Erie counties uses these sources. Water from Lake Erie serves 65 percent of the population, and water from the upper Niagara River serves 25 percent of the population (Ref. 3). Communities north of the Niagara escarpment, including Lewiston and Porter Townships, receive much of their water from these sources.

Groundwater is used to supply approximately 10 percent of the population in Niagara and Erie Counties. The primary uses are for small domestic and farm supplies in rural sections. The dominant source of this water, the Lockport dolomite aquifer, is absent north of the Niagara escarpment, where NFSS is located. Wells in the vicinity of NFSS generally have a low yield and supply water of poor quality. The upper groundwater systems in the glacial deposits near NFSS are sometimes capable of supplying adequate groundwater for domestic use, although these sources may be depleted during dry seasons (Ref. 3).

The climate in the NFSS area is classified as humid continental, with a considerable moderating influence from Lake Ontario. The normal temperature range is -3.9 to 24.4°C (25 to 76°F), with a mean annual temperature of 8.9°C (48°F). Mean annual precipitation is 81 cm (32 in.). Snowfall averages 140 cm/yr

(56 in./yr), accounting for about 10 percent of the annual total precipitation (Ref. 4).

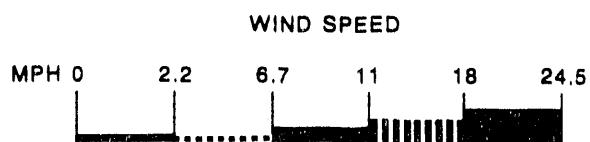
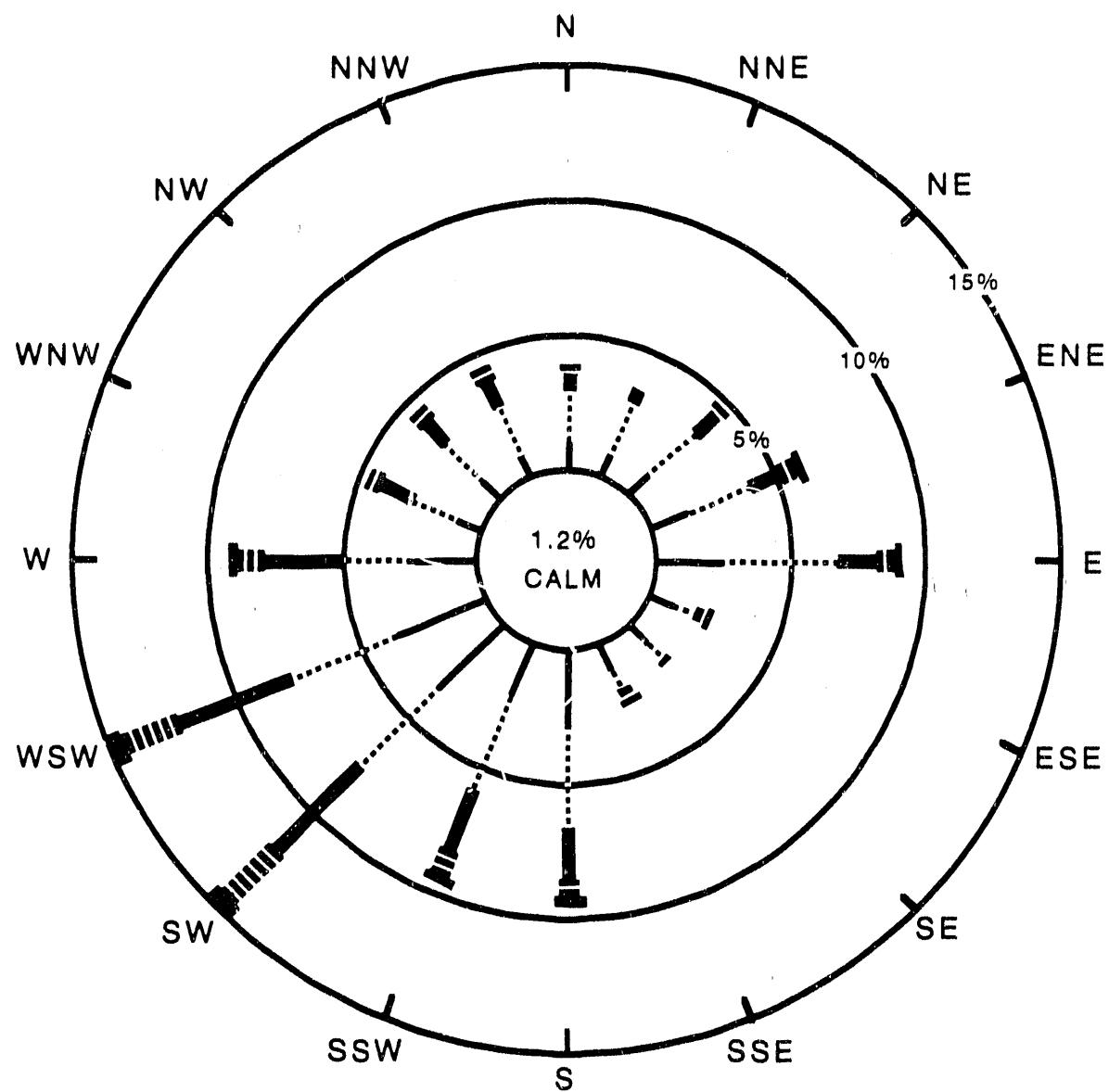
Wind speeds and directions recorded in the vicinity of NFSS are given in Figure 1-4. The data show that the wind originates predominantly from the southwest. The average monthly wind speed ranges from 15 to 23 km/h (9.9 to 14 mph) (Ref. 4).

The primary areas of population near NFSS are the towns of Lewiston (population: 16,200), Niagara (population: 9,650), Porter (population: 7,250), and Niagara Falls City (population: 71,400) (Ref. 3). Almost three-fourths of the 227,000 people residing in Niagara County live in urban areas. Population density in Niagara County in 1980 was about 170 persons/km<sup>2</sup> (430 persons/mi<sup>2</sup>) (Ref. 3). Land uses immediately adjacent to the site are varied (see Figure 1-5). The site is bordered by a hazardous waste disposal site, a sanitary landfill, and land that is currently vacant.

Land in the vicinity is also used for truck farms, orchards, and rural single-family dwellings. Lewiston-Porter Central Schools are located 2.4 km (1.5 mi) west of the site on Blairville/Creek Road. The nearest permanent residence is 1.1 km (0.68 mi) southwest of the site.

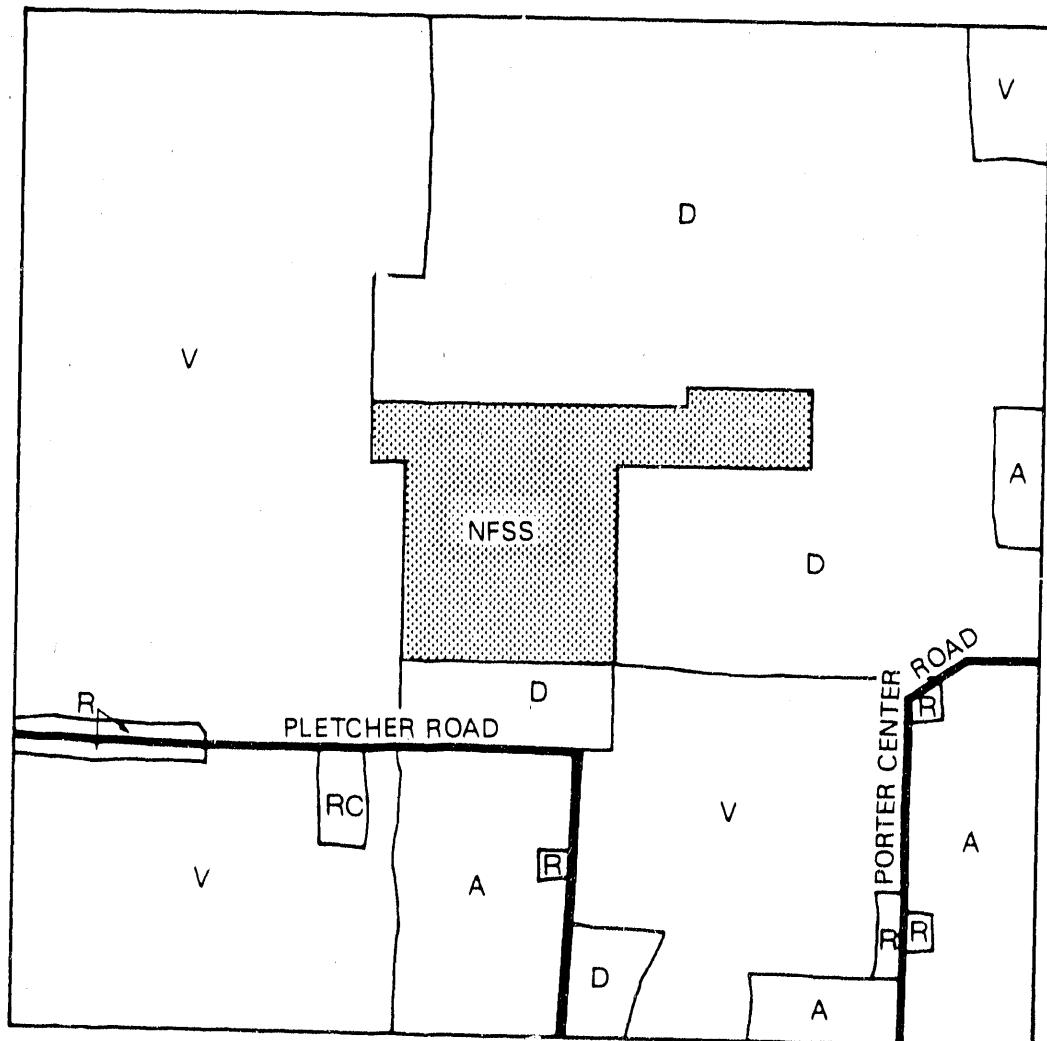
## 1.2 SITE HISTORY

NFSS is a remnant of the original 611.5-ha (1,511-acre) site that was used during World War II by the Manhattan Engineer District (MED) project and was a portion of the Department of the Army's Lake Ontario Ordnance Works (LOOW). Except for nonradioactive boron-10 enriching operations during the periods 1954 to 1958 and 1964 to 1971, the site's major use from 1944 to the present has been for the storage of radioactive residues produced as by-products of uranium production during the MED project and subsequent Atomic Energy Commission (AEC) projects. The weight and volume of the residues and sands stored at NFSS are summarized in Table 1-1. Buildings and other features of NFSS existing before recent remedial actions are illustrated in Figure 1-6.



BASED ON DATA FROM  
ON-SITE METEOROLOGICAL  
STATION DURING 1985

FIGURE 1-4 ANNUAL WIND ROSE FOR NFSS



BASED ON AERIAL PHOTOGRAPHS, SITE VISITS, AND USGS TOPOGRAPHIC MAP, 1:24000 SCALE,  
RANSOMVILLE QUADRANGLE, (PHOTO REVISED 1980)

R RESIDENTIAL  
RC RECREATIONAL  
A AGRICULTURAL

D WASTE DISPOSAL  
V VACANT

0 0.5 MI  
0 0.8 KM



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

TABLE 1-1  
RESIDUES AND MIDDLESEX SANDS STORED AT NFSS<sup>a</sup>

Residue	Weight (tons)	Volume [m <sup>3</sup> (yd <sup>3</sup> ) ]
K-65	3,051	2,447 (3,200)
L-30	8,227	6,086 (7,960)
L-50	1,878	1,644 (2,150)
F-32	138	336 (440)
R-10	8,235	7,187 (9,400)
Middlesex Sands	2	175 (229)

<sup>a</sup>Source: Reference 5.

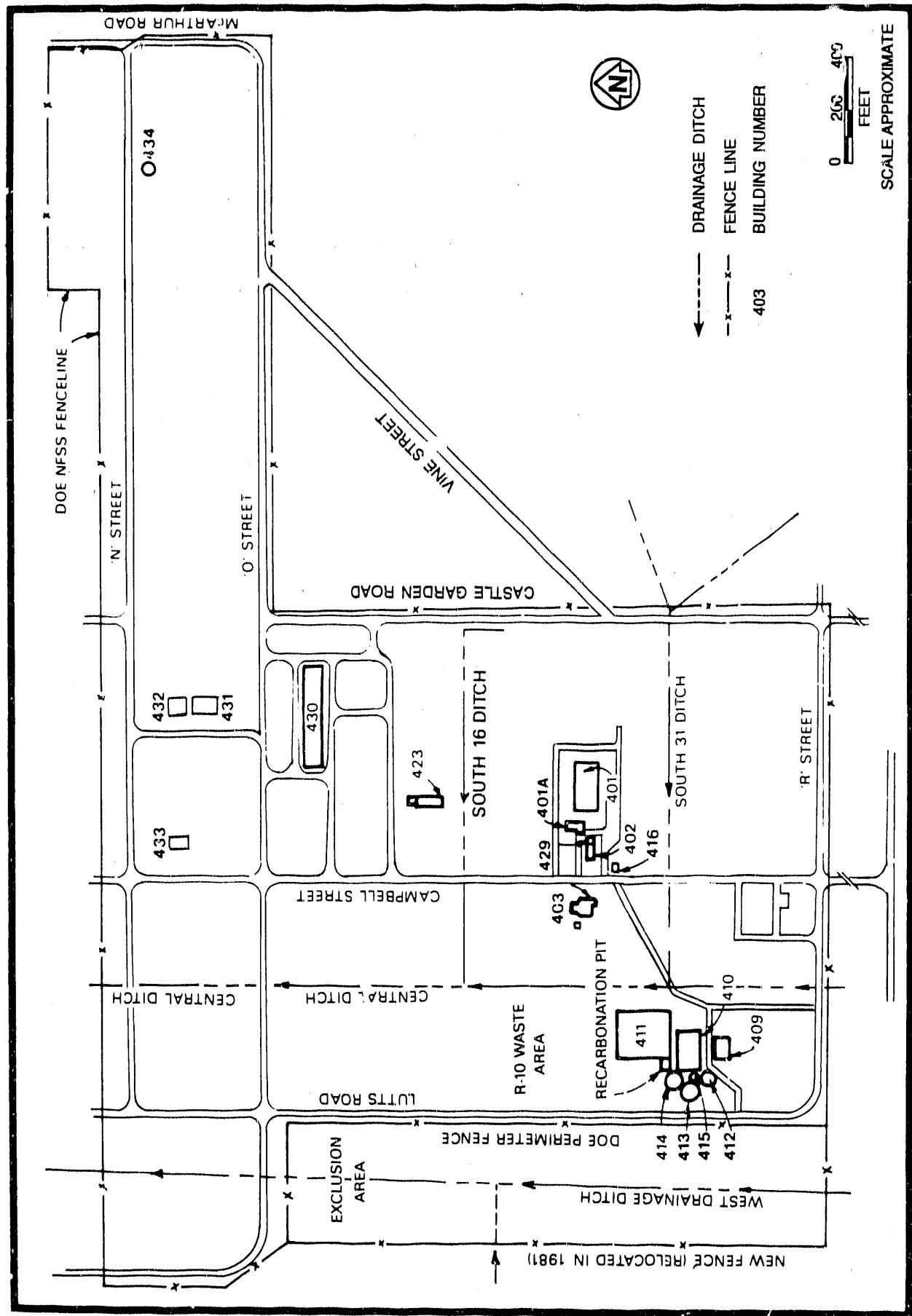


FIGURE 1-6 NFSS PRIOR TO REMEDIAL ACTIONS

The first materials to arrive at the site were low-grade residues and by-products from the Linde Air Products Division in Tonawanda, New York (the L-30, L-50, and R-10 residues) and from the Middlesex Sampling Plant in Middlesex, New Jersey (the F-32 residues). The L-30 and L-50 residues were stored in Buildings 411, 413, and 414, and the F-32 residues were stored in the recarbonation pit directly west of Building 411. The R-10 residues and associated iron cake were stored in an open area north of Building 411. These residues were subject to weathering and erosion that transported contaminants into the soil and drainage pathways, resulting in the contamination of other portions of the site and of off-site drainage pathways. A small quantity of Middlesex sands resulting from decontamination activities at the Middlesex Sampling Plant was stored in Building 410. In 1949 pitchblende residues (the K-65 residues) resulting from uranium extraction conducted at a St. Louis plant were transported to the LOOW in drums. Some of these were stored outdoors along existing roads and rail lines; others were stored in Building 410. From 1950 to 1952, the K-65 residues were transferred to a renovated concrete water tower (Building 434).

In 1979, Battelle Columbus Laboratories performed a radiological survey of NFSS. The survey report published by Battelle in June 1981 served as the basis for initial interim remedial action planning for the site (Ref. 5). Bechtel National, Inc. (BNI) was chosen by DOE as the project management contractor for the NFSS project in 1981. BNI helped plan and execute remedial action at the site. BNI currently maintains site security, performs maintenance as required, and implements the environmental monitoring program. Access to the site is controlled by a 2-m- (7-ft-) high fence that encloses the DOE property.

Since 1980, various steps have been taken at NFSS to minimize potential radiological risks and prevent migration of residues. In the fall of 1980, the vent at the top of Building 434 (the former water tower in which the K-65 residues were stored) was capped to reduce radon emissions to the environment. Also during 1980, pipes

penetrating the walls of the residue storage buildings were sealed or resealed as necessary to prevent radionuclide migration.

Because radon levels at the site's western boundary were exceeding DOE limits, the site fence was relocated approximately 150 m (500 ft) to the west in mid-1981, creating an exclusion area to protect the public from exposure to the higher radon levels. Radon levels at the new boundary were well below applicable guidelines.

In 1981, remedial action was performed on a triangular-shaped area adjacent to NFSS, bounded by Vine and O streets and Castle Garden Road. Approximately 340 m<sup>3</sup> (450 yd<sup>3</sup>) of contaminated material was excavated from this vicinity property and placed in storage.

To further reduce the levels of radon emanating from the site, Buildings 413 and 414 (used for storing the L-50 residues) were upgraded and sealed in 1982. Also in 1982, to prevent further migration of residues, contaminated soil near the R-10 pile was moved onto the pile, and a dike and cutoff wall were constructed around the R-10 area. The R-10 pile was then covered with an ethylene propylene diene monomer (EPDM) liner, which markedly reduced radon emanation from the R-10 area. This action effectively reduced radon concentrations at the old site boundary (along Lutts Road) to levels that were below DOE guidelines.

In 1983 and 1984 the EPDM liner was removed, additional contaminated soils and rubble from on- and off-site areas were placed on the pile, and the pile was covered with the first layer of the interim clay cap. These actions constituted the beginning of the IWCF. In 1984, 93 percent of the K-65 residues were transferred from Building 434 to Building 411.

Construction activities during 1985 included completion of the transfer of K-65 residues from Building 434 to the IWCF, demolition of Building 434, completion of remedial action on vicinity properties, and continuation of installation of the cap over the wastes in the IWCF. These activities involved excavating approximately 11,000 m<sup>3</sup> (14,000 yd<sup>3</sup>) of contaminated materials from on- and off-site areas, transferring 1,109 m<sup>3</sup> (1,450 yd<sup>3</sup>) of building rubble to the IWCF, and discharging 12,050,000 L

(3,183,000 gal) of treated, impounded water in accordance with New York State Department of Environmental Conservation (NYSDEC) permit requirements. The permit, which expired May 1, 1988, was not renewed because the site is inactive except for environmental monitoring and surveillance and maintenance of the IWCF.

During 1986, the cap over the IWCF was completed and vibrating wire pressure transducers and pneumatic pressure transducers were installed to monitor the integrity of the waste facility. Also in 1986, another 26 million L (6.8 million gal) of contaminated water was treated and released, and four of the six water treatment ponds were reduced to grade. In 1987 the impounded water in the remaining two ponds was treated and released [an additional 38.6 million L (10.2 million gal)]. These two ponds were reduced to grade, and NFSS was closed.

The DOE record of decision on the long-term disposition of NFSS was issued in August 1986. For the radioactive wastes, DOE has selected long-term, in-place management consistent with the guidance provided in the U.S. Environmental Protection Agency (EPA) regulations governing uranium mill tailings. For the radioactive residues, it is the DOE intent to provide for long-term, in-place management consistent with future applicable EPA guidance. If future analyses show that in-place management cannot meet EPA guidance, another option will be selected that meets EPA guidance and is environmentally acceptable.

In 1988, several isolated areas of residual radioactivity were excavated and the contaminated materials were placed in temporary storage. This material will remain in temporary storage until IWCF is reopened so that additional materials can be added. All of the residual radioactivity on site has been remediated, with the exception of one localized area suspected to be both radiologically and chemically contaminated. This remaining area will be remediated in the future.

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

### 1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

The interpretations presented here are based on monthly groundwater levels measured during calendar year 1989. Fewer groundwater monitoring wells were actively monitored in 1989 (Figure 1-7) than in previous years (Ref. 6). The 1989 data do not vary substantially from those obtained in previous years (Refs. 7-13). A summary of well construction information is shown in Tables 1-2 and 1-3. Examples of well construction details are presented in Appendix E.

The three groundwater systems monitored at NFSS have been referred to as "upper," "lower," and "bedrock" by previous investigators. The lower and bedrock systems are thought to be hydraulically connected, but for the purposes of this discussion they are described separately. Further background information on site geology, hydrogeology, and well installation methods can be found in Refs. 2 and 14 through 16.

#### 1.3.1 Upper Groundwater System

The upper groundwater system occurs in a zone of discontinuous silts, sands, and clays approximately 1.5 to 8.5 m (5 to 28 ft) below ground surface (Ref. 2). Wells in this zone are screened in unconsolidated silts and sands at depths of 2.4 to 6.7 m (8 to 22 ft). Elevations of water levels measured in upper system wells in 1989 are shown as hydrographs in Figures 1-8 through 1-12. Precipitation records for NFSS as measured on site are presented in Figure 1-8. The upper system water levels display seasonal variation, with the highest value occurring in the spring and the lowest in the fall.

The hydrographs show inconsistent correlation in groundwater levels from well to well, probably because of the discontinuous nature of the screened materials over the distance between the wells.

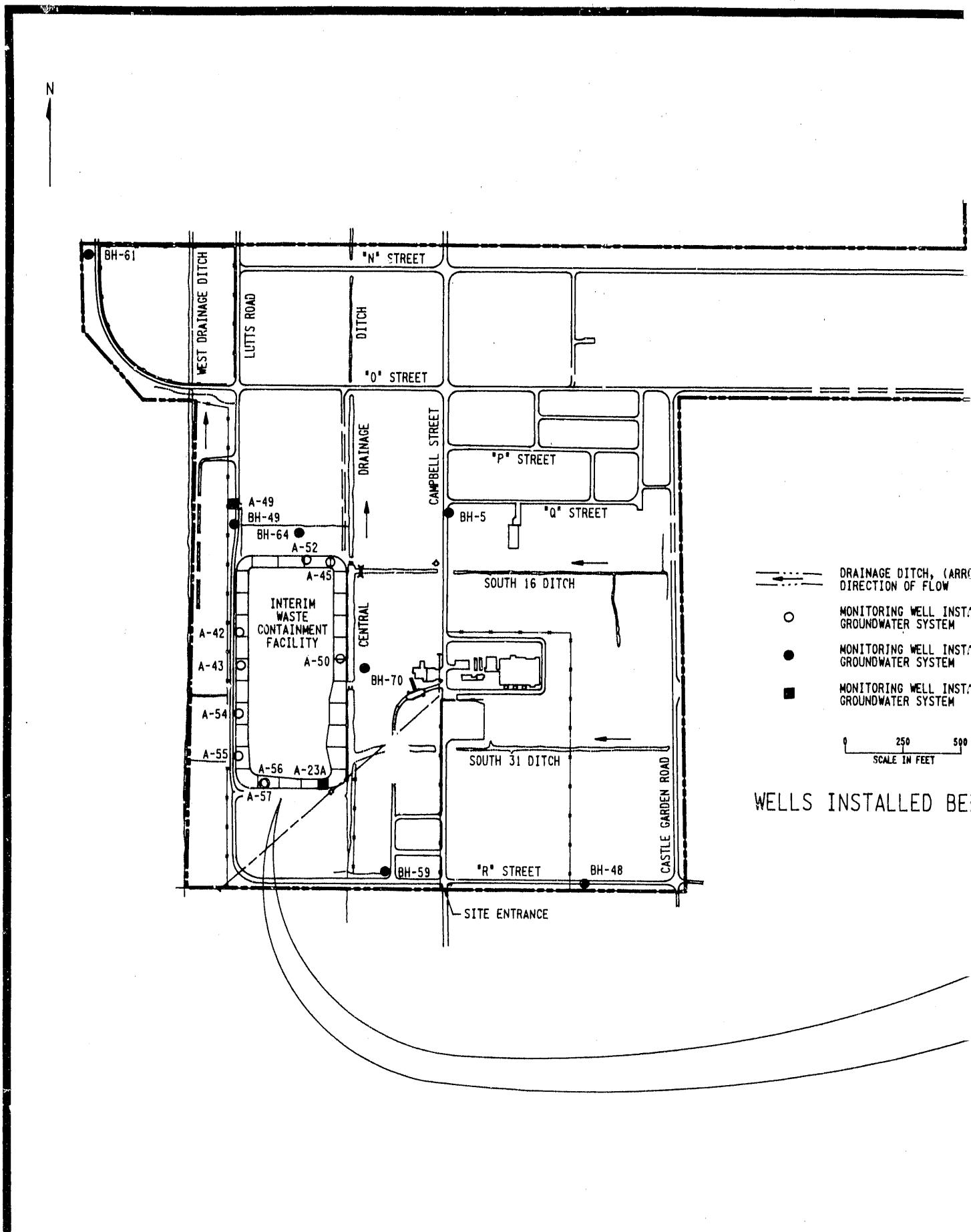


FIGURE 1-7 LOCATIONS OF GROU

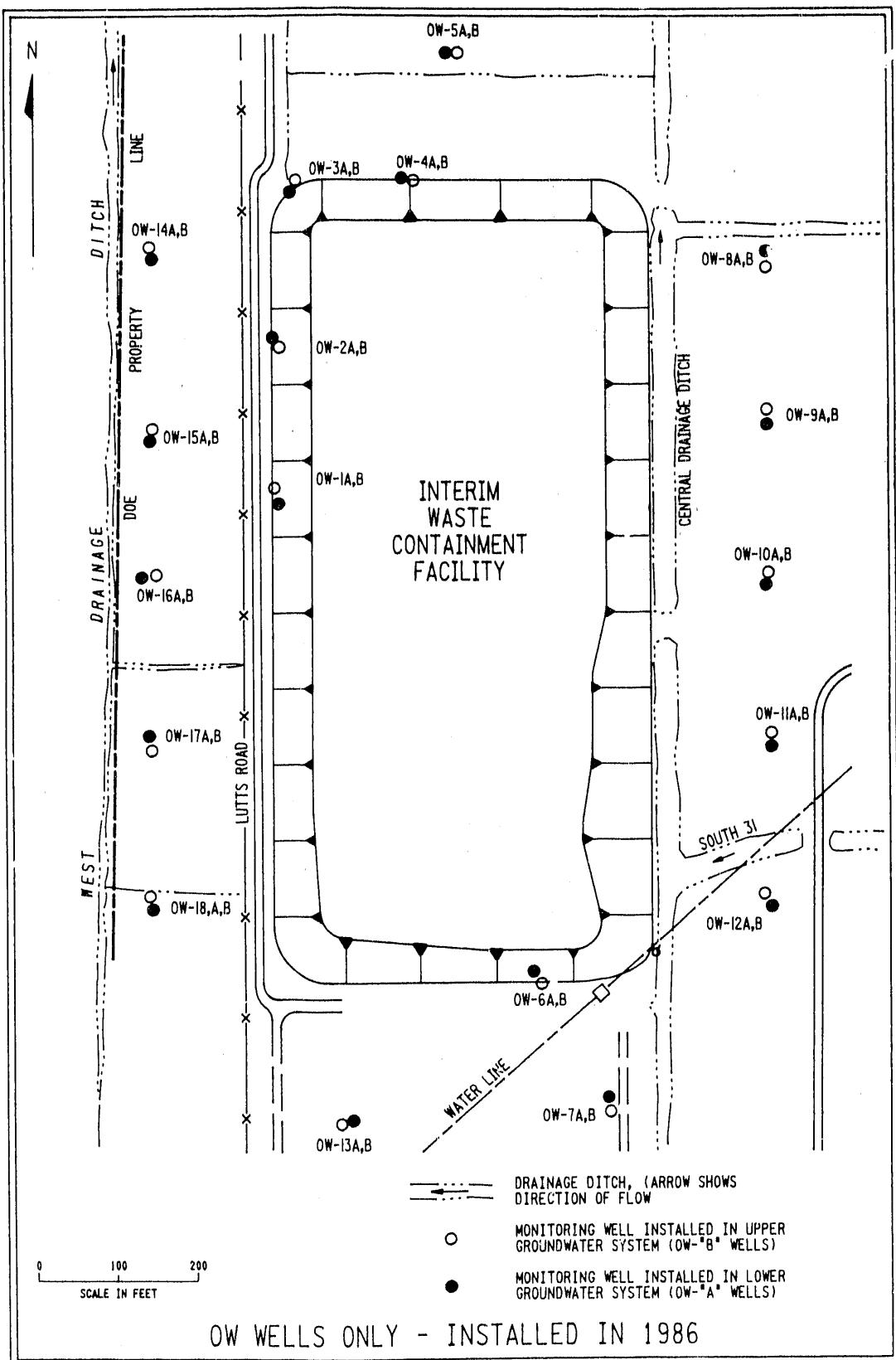


TABLE 1-2  
NFSS UPPER SYSTEM MONITORING WELL CONSTRUCTION SUMMARY

Well Number	Completion Date	Total Depth [m (ft)]	Monitored or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
A-42	Mar. 1983	6.86 (22.5)	3.17-6.86 (10.4-22.5)	PVC <sup>a</sup>
A-43	Mar. 1983	4.27 (14.0)	2.1-4.27 (7.0-14.0)	PVC
A-45	Mar. 1983	6.10 (20.0)	2.4-6.10 (8.0-20.0)	PVC
A-50	Mar. 1983	7.01 (23.0)	3.05-6.71 (10.0-22.0)	PVC
A-52	Mar. 1983	4.58 (15.0)	1.8-4.58 (6.0-15.0)	PVC
OW-1B	Oct. 1986	5.18 (17.0)	3.11-4.73 (10.2-15.5)	316 Stainless Steel
OW-2B	Sept. 1986	6.10 (20.0)	4.12-5.64 (13.5-18.5)	316 Stainless Steel
OW-3B	Oct. 1986	4.88 (16.0)	2.9-4.42 (9.5-14.5)	316 Stainless Steel
OW-4B	Oct. 1986	5.18 (17.0)	3.11-4.73 (10.2-15.5)	316 Stainless Steel
OW-5B	Oct. 1986	5.18 (17.0)	2.9-4.42 (9.5-14.5)	316 Stainless Steel
OW-6B	Oct. 1986	5.18 (17.0)	3.14-4.73 (10.3-15.5)	316 Stainless Steel
OW-7B	Oct. 1986	3.97 (13.0)	1.9-3.45 (6.3-11.3)	316 Stainless Steel
OW-8B	Nov. 1986	3.66 (12.0)	1.7-3.20 (5.5-10.5)	316 Stainless Steel
OW-9B	Nov. 1986	4.45 (14.6)	2.5-4.03 (8.2-13.2)	316 Stainless Steel
OW-10B	Nov. 1986	8.85 (29.0)	5.28-8.42 (17.3-27.6)	316 Stainless Steel
OW-11B	Nov. 1986	4.88 (16.0)	2.3-3.81 (7.5-12.5)	316 Stainless Steel
OW-12B	Nov. 1986	3.66 (12.0)	1.8-3.29 (5.8-10.8)	316 Stainless Steel
OW-13B	Nov. 1986	4.27 (14.0)	2.2-3.72 (7.2-12.2)	316 Stainless Steel
OW-14B	Oct. 1986	4.64 (15.2)	2.6-4.12 (8.5-13.5)	316 Stainless Steel
OW-15B	Oct. 1986	3.66 (12.0)	1.7-3.26 (5.7-10.7)	316 Stainless Steel
OW-16B	Oct. 1986	3.97 (13.0)	2.1-3.63 (6.9-11.9)	316 Stainless Steel
OW-17B	Oct. 1986	5.18 (17.0)	3.20-4.73 (10.5-15.5)	316 Stainless Steel
OW-18B	Oct. 1986	5.06 (16.6)	3.11-4.64 (10.2-15.2)	316 Stainless Steel

<sup>a</sup>PVC - polyvinyl chloride.

TABLE 1-3  
NFSS MONITORING WELL CONSTRUCTION SUMMARY  
FOR LOWER AND BEDROCK GROUNDWATER SYSTEMS

Page 1 of 2

Well Number	Completion Date	Total Depth [m (ft)]	Monitored or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
-------------	-----------------	----------------------	-----------------------------------------------------------	-----------------------

Wells Installed in Bedrock

A-23A	Mar. 1983	23.9 (78.5)	12.2-23.3 (40.0-76.3)	PVC <sup>a</sup>
A-35	Mar. 1983	24.4 (80.1)	12.2-24.7 (40.0-81.0)	PVC
A-49	Mar. 1983	27.5 (90.0)	14.0-27.5 (46.0-90.0)	PVC
BH-12	June 1981	29.0 (95.0)	13.4-29.0 (44.0-95.0)	PVC
BH-15	June 1981	31.9 (104.5)	16.5-31.9 (54.0-104.5)	PVC
BH-57	June 1981	31.0 (101.5)	15.0-31.0 (49.0-101.5)	PVC
BH-62	June 1981	30.0 (98.0)	15.0-30.0 (49.0-98.0)	PVC

Wells Installed in Soil (Lower System)

BH-46	June 1981	16.5 (54.0)	7.6-14.7 (25.0-48.3)	PVC
BH-48	May 1981	13.4 (44.0)	5.5-11.3 (18.0-37.1)	PVC
BH-49	May 1981	15.5 (50.9)	8.2-14.3 (27.0-47.0)	PVC
BH-5	June 1981	15.9 (52.2)	7.3-14.4 (24.0-47.2)	PVC
BH-50	May 1981	13.4 (44.0)	6.2-11.7 (20.3-38.3)	PVC
BH-59	May 1981	12.4 (40.5)	7.0-11.5 (23.0-37.7)	PVC
BH-60	May 1981	14.0 (45.8)	6.4-12.4 (21.0-40.5)	PVC
BH-61	May 1981	14.0 (46.0)	7.3-12.7 (24.0-41.6)	PVC
BH-64	June 1981	14.9 (48.7)	8.5-13.1 (28.0-43.0)	PVC
BH-70	June 1981	13.7 (45.0)	6.1-12.2 (20.0-40.0)	PVC
OW-1A	Oct. 1986	14.3 (47.0)	10.6-13.7 (34.8-45.0)	316 Stainless Steel
OW-2A	Oct. 1986	14.0 (46.0)	10.3-13.4 (33.7-44.0)	316 Stainless Steel
OW-3A	Oct. 1986	12.8 (42.0)	9.9-11.4 (32.4-37.4)	316 Stainless Steel

TABLE 1-3  
(continued)

Page 2 of 2

Well Number	Completion Date	Total Depth [m (ft)]	Monitored or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
-------------	-----------------	----------------------	-----------------------------------------------------------	-----------------------

Wells Installed in Soil (continued)

OW-4A	Oct. 1986	12.4 (40.6)	8.6-11.7 (28.1-38.4)	316 Stainless Steel
OW-5A	Oct. 1986	13.5 (44.3)	9.8-12.8 (32.0-42.0)	316 Stainless Steel
OW-6A	Oct. 1986	12.3 (40.2)	8.6-11.7 (28.1-38.4)	316 Stainless Steel
OW-7A	Oct. 1986	12.1 (39.6)	8.5-11.7 (27.9-38.2)	316 Stainless Steel
OW-8A	Nov. 1986	13.6 (44.6)	10.0-13.1 (32.7-43.0)	316 Stainless Steel
OW-9A	Nov. 1986	12.5 (41.1)	8.7-11.9 (28.6-38.9)	316 Stainless Steel
OW-10A	Nov. 1986	12.3 (40.3)	10.2-11.7 (33.5-38.5)	316 Stainless Steel
OW-11A	Nov. 1986	11.4 (37.2)	7.7-10.8 (25.2-35.5)	316 Stainless Steel
OW-12A	Nov. 1986	11.7 (38.3)	7.6-12.1 (25.0-39.7)	316 Stainless Steel
OW-13A	Oct. 1986	12.5 (41.1)	9.0-13.2 (29.4-43.4)	316 Stainless Steel
OW-14A	Oct. 1986	13.7 (44.8)	10.0-13.2 (33.1-43.4)	316 Stainless Steel
OW-15A	Oct. 1986	13.9 (45.5)	11.9-13.4 (39.0-44.0)	316 Stainless Steel
OW-16A	Oct. 1986	13.8 (45.2)	9.9-13.0 (32.4-42.7)	316 Stainless Steel
OW-17A	Oct. 1986	13.0 (42.5)	9.2-12.3 (30.1-40.4)	316 Stainless Steel
OW-18A	Oct. 1986	14.6 (47.8)	10.9-14.0 (35.7-46.0)	316 Stainless Steel

<sup>a</sup>PVC - polyvinyl chloride.

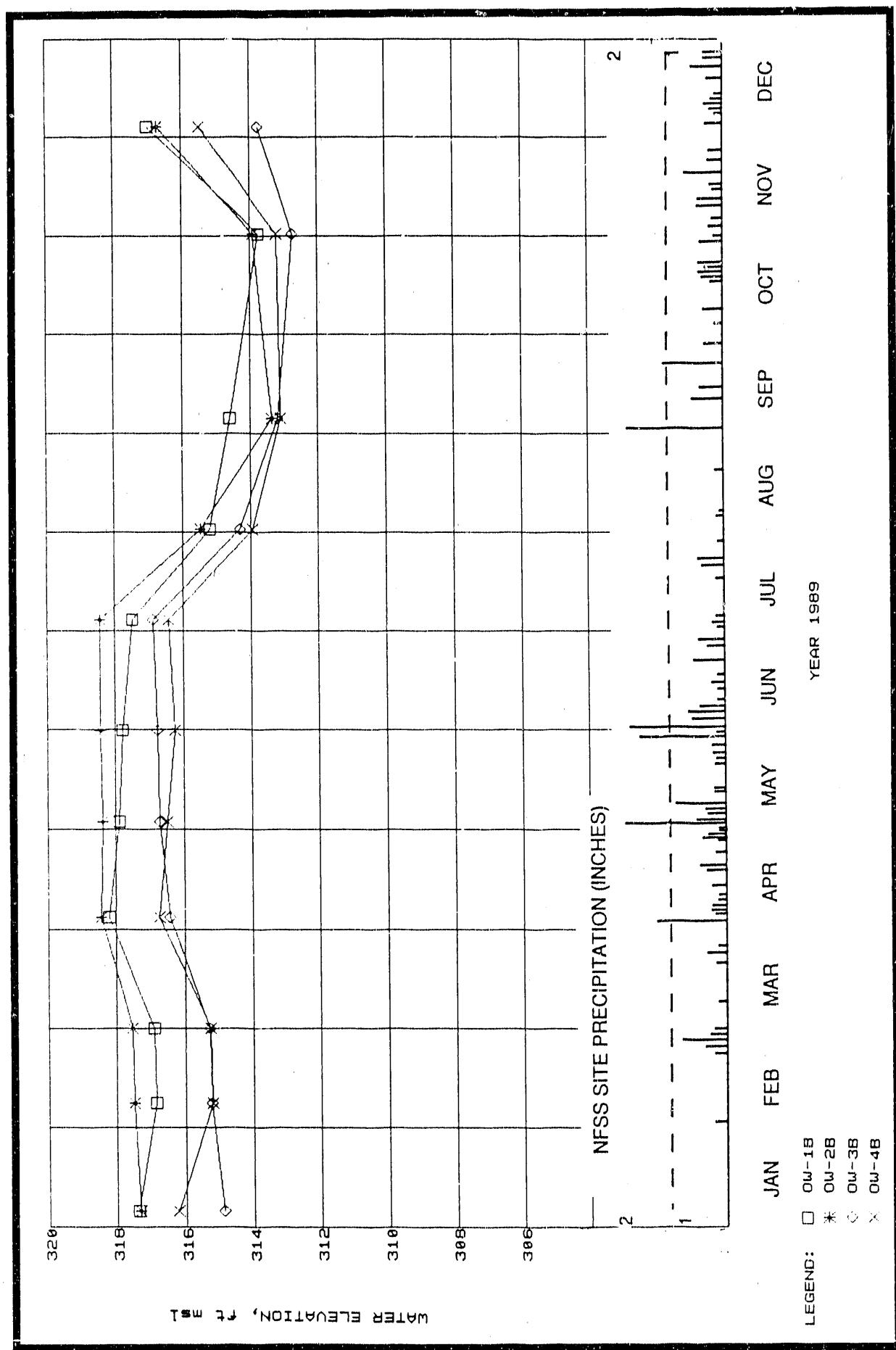
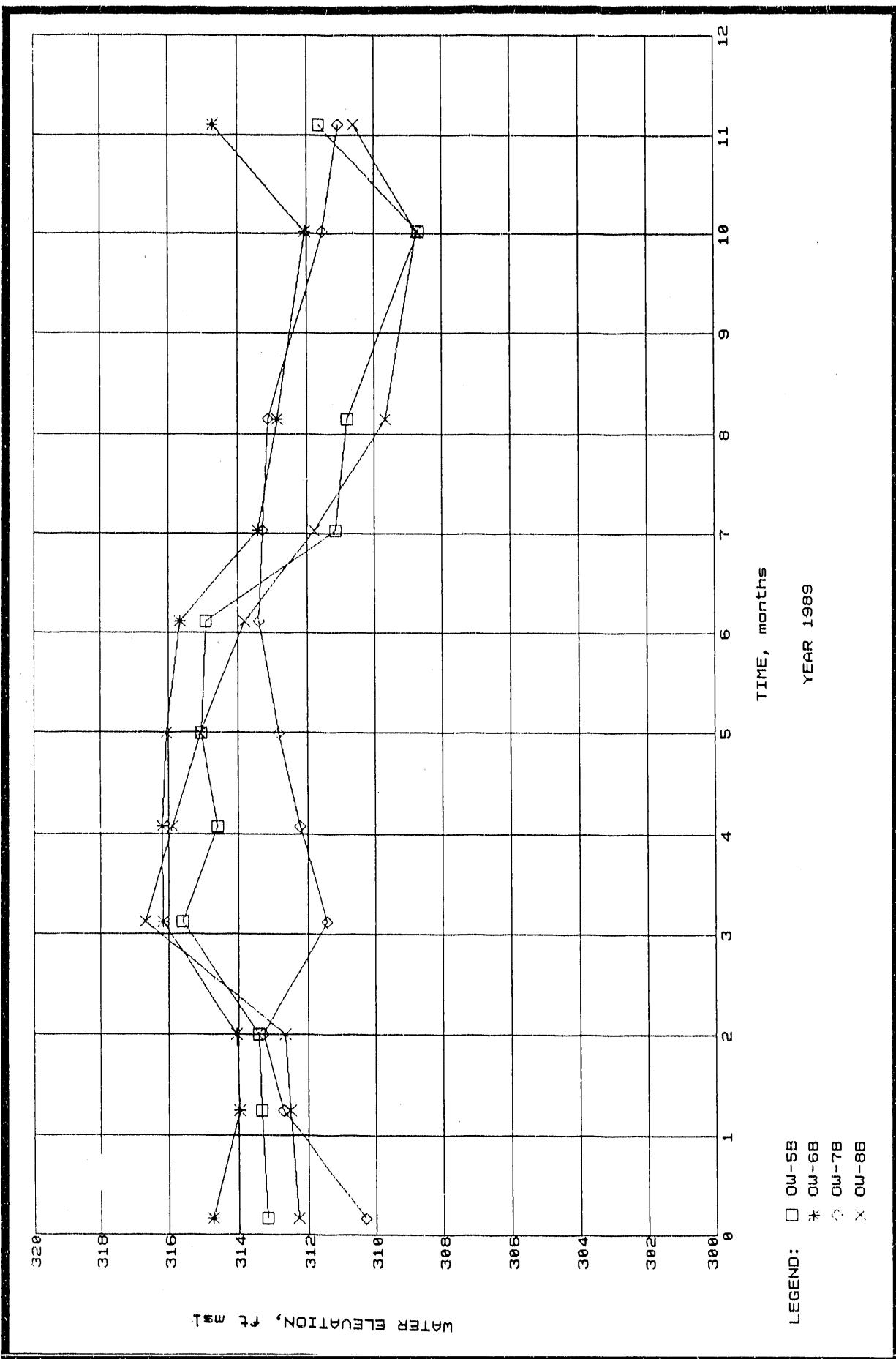


FIGURE 1-8 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS  
OW-1B, OW-2B, OW-3B, AND OW-4B

FIGURE 1-9 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS  
OW-5B, OW-6B, OW-7B, AND OW-8B



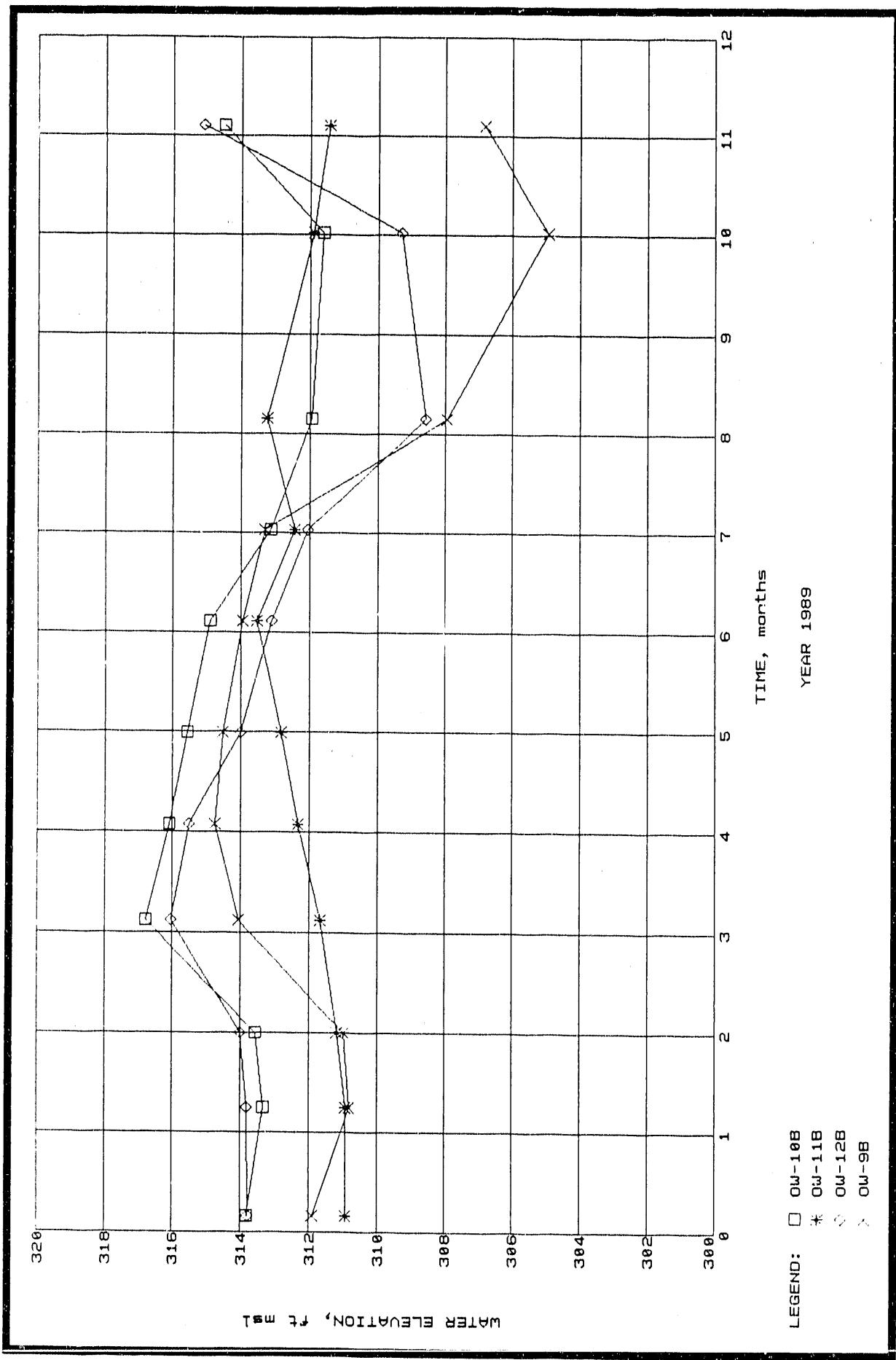


FIGURE 1-10 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS  
OW-10B, OW-11B, OW-12B, AND OW-9B

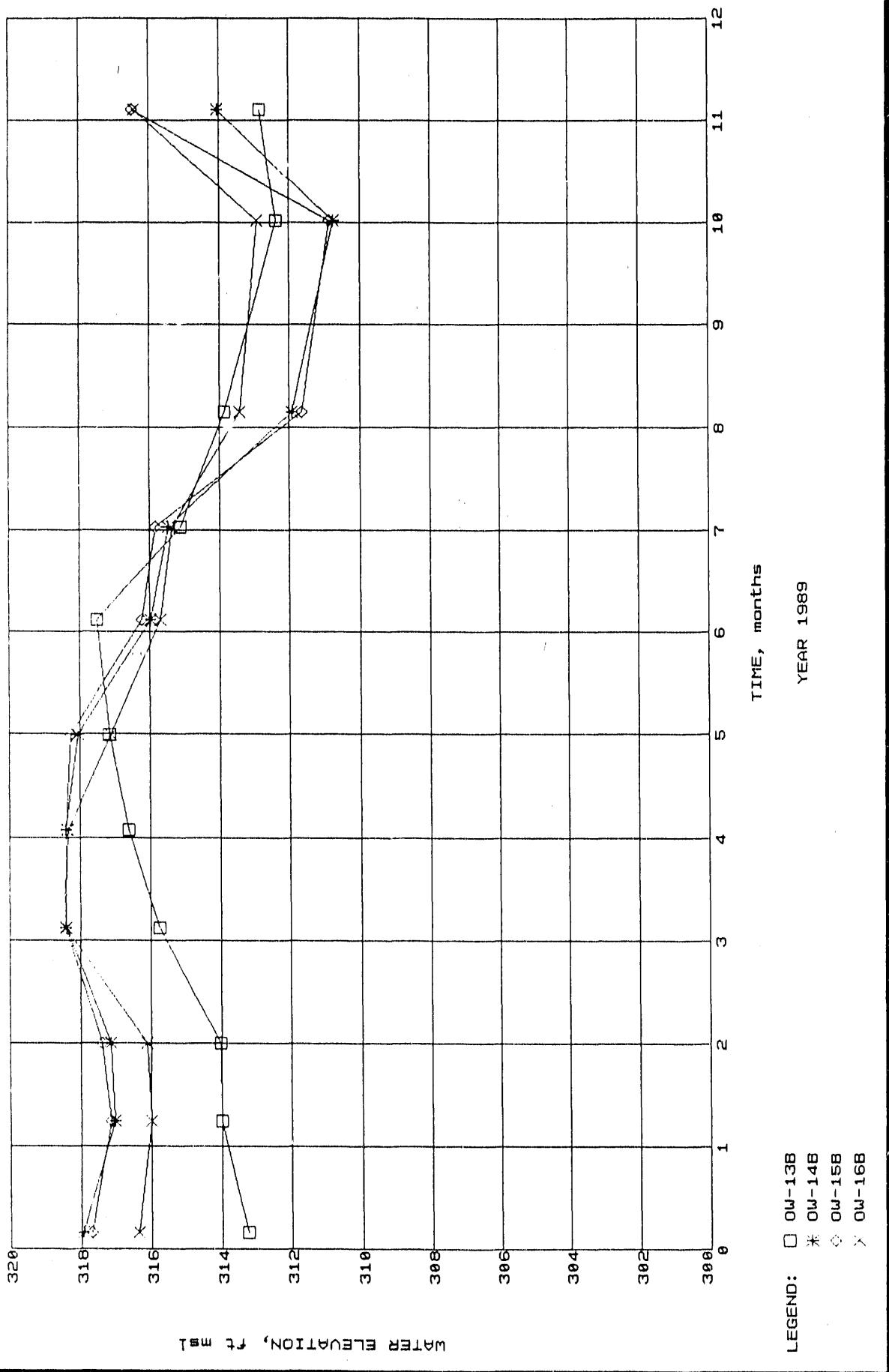


FIGURE 1-11 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS  
OW-13B, OW-14B, OW-15B, AND OW-16B

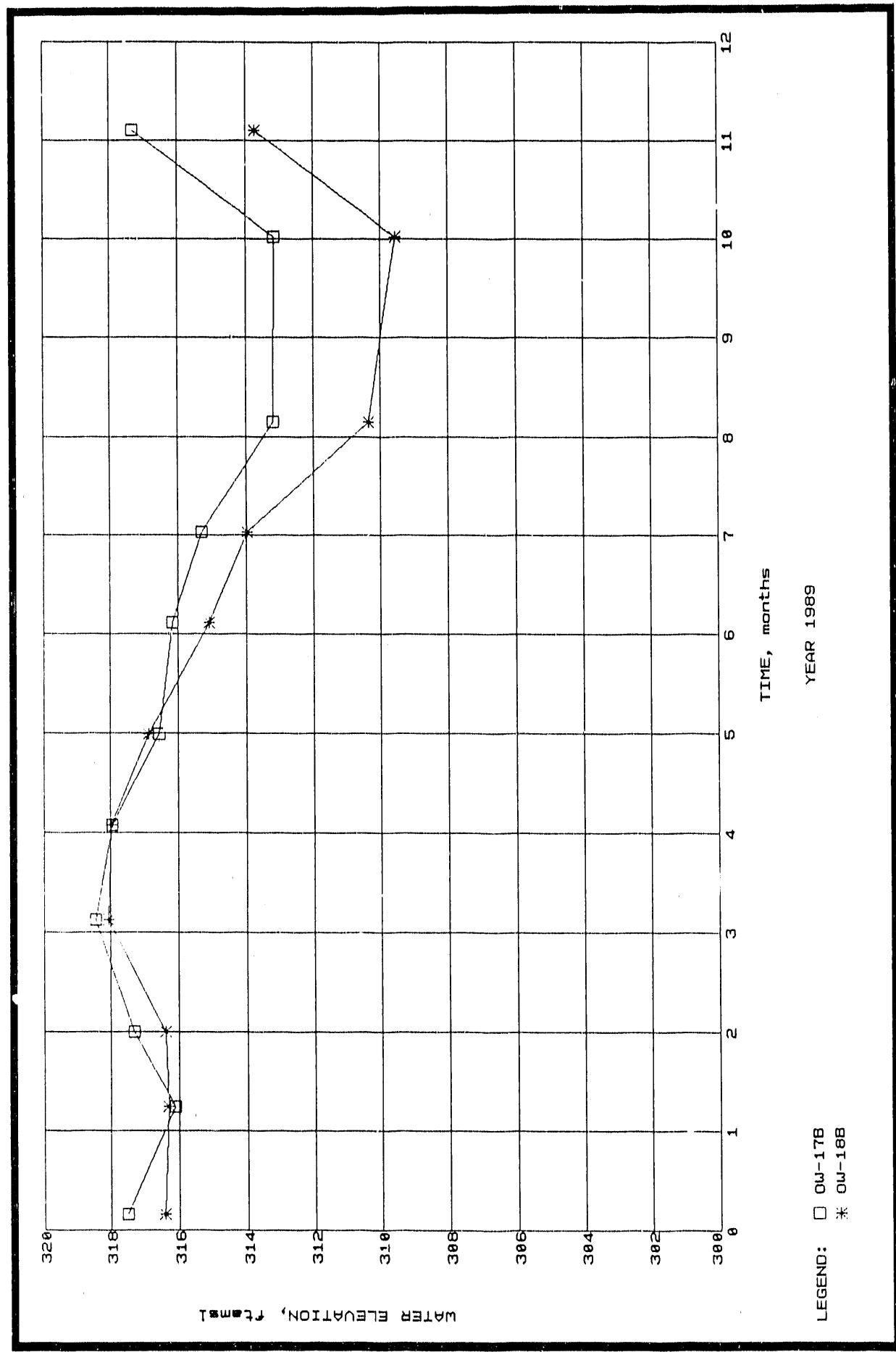


FIGURE 1-12 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS OW-17B AND OW-18B

Because of the horizontal discontinuities in the unconsolidated materials that contain the upper groundwater system, potentiometric surface maps were not prepared. (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 hydraulic gradient and flow direction.) Therefore, gradient and flow direction are not presented for this system.

### 1.3.2 Lower Groundwater System

The silt and sand layer that contains the lower groundwater system is approximately 9.2 to 14 m (30 to 45 ft) below ground surface. This layer is between an underlying red silt and an overlying gray clay and is in hydraulic connection with the bedrock system. The water-bearing red silt zone above bedrock is absent in a few locations across the site (Ref. 2).

Hydrographs of wells screened in the lower groundwater system (Figures 1-13 through 1-19) show a definite seasonal variation of water levels. The water levels are highest in the summer [about 315 ft above mean sea level (ft msl)] and lowest in the winter (about 310 ft msl). Except for BH-64, OW-7A, and OW-11A, all of the hydrographs appear to correlate well with each other.

Wells BH-64 (Figure 1-18), OW-7A (Figure 1-14), and OW-11A (Figure 1-15), which are screened in the lower groundwater system, show irregular water level elevations with respect to the other lower system wells (Ref. 13). The behavior of these three wells correlates more with the upper groundwater system than with the lower (Figure 1-20), which explains the anomalous groundwater elevations shown in Figure 1-22.

Gradient and flow direction for the lower groundwater system in 1989 were determined using two potentiometric surface maps (Figure 1-21 for July 5 and Figure 1-22 for November 11). The dates chosen are representative of water levels during high and low periods.

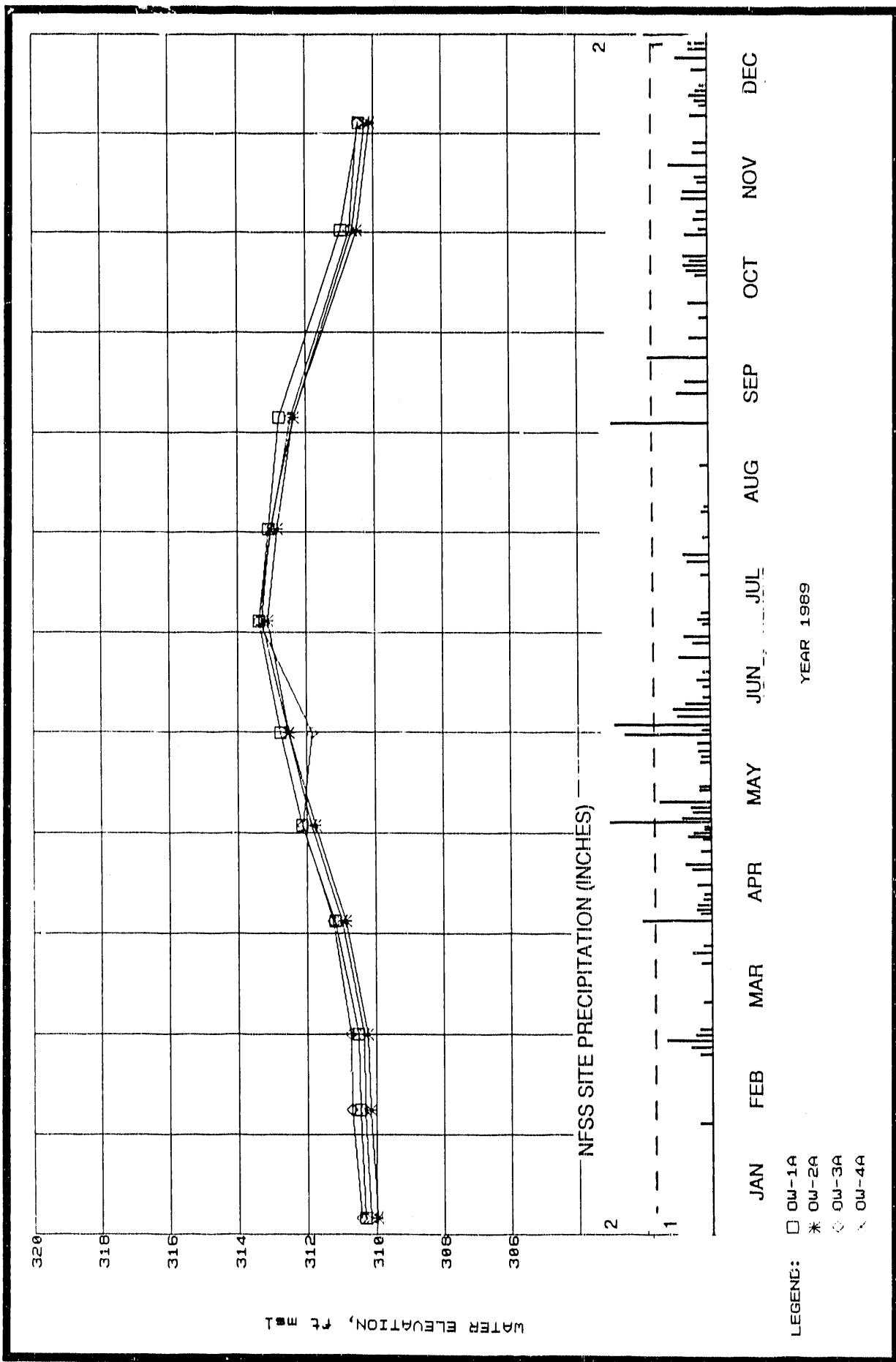


FIGURE 1-13 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
OW-1A, OW-2A, OW-3A, AND OW-4A

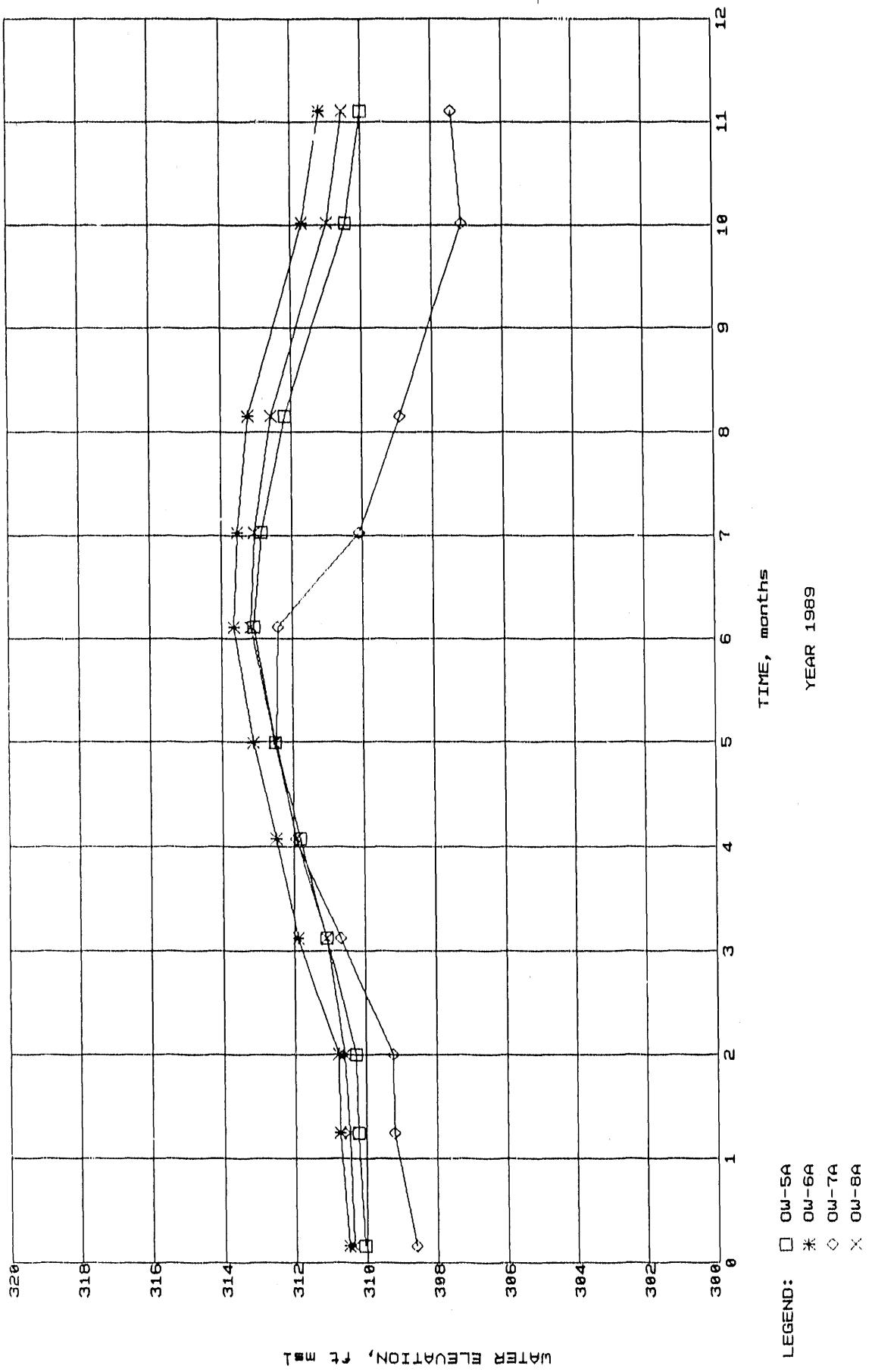


FIGURE 1-14 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
OW-5A, OW-6A, OW-7A, AND OW-8A

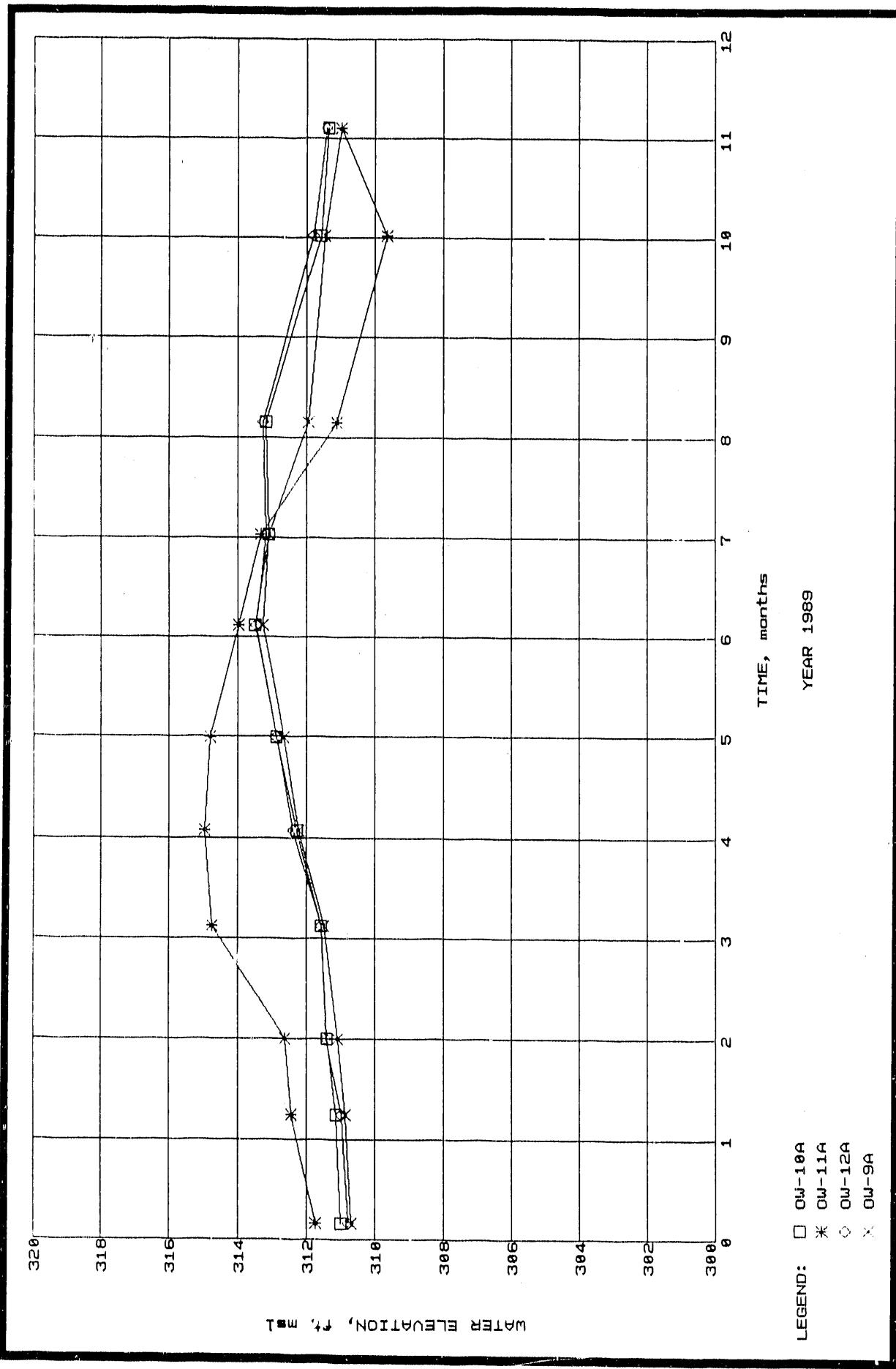


FIGURE 1-15 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
OW-10A, OW-11A, OW-12A, AND OW-9A

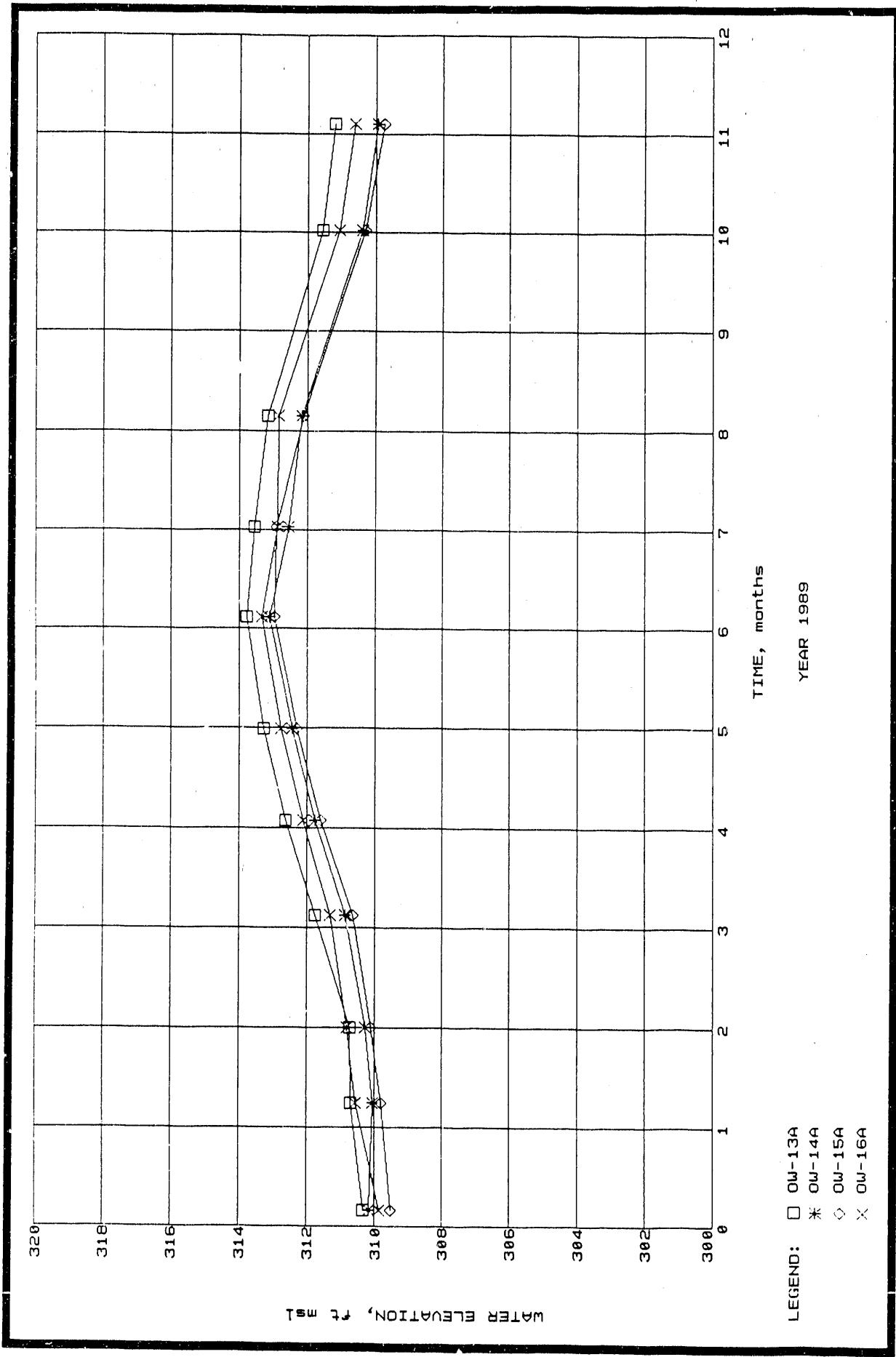


FIGURE 1-16 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
OW-13A, OW-14A, OW-15A, AND OW-16A

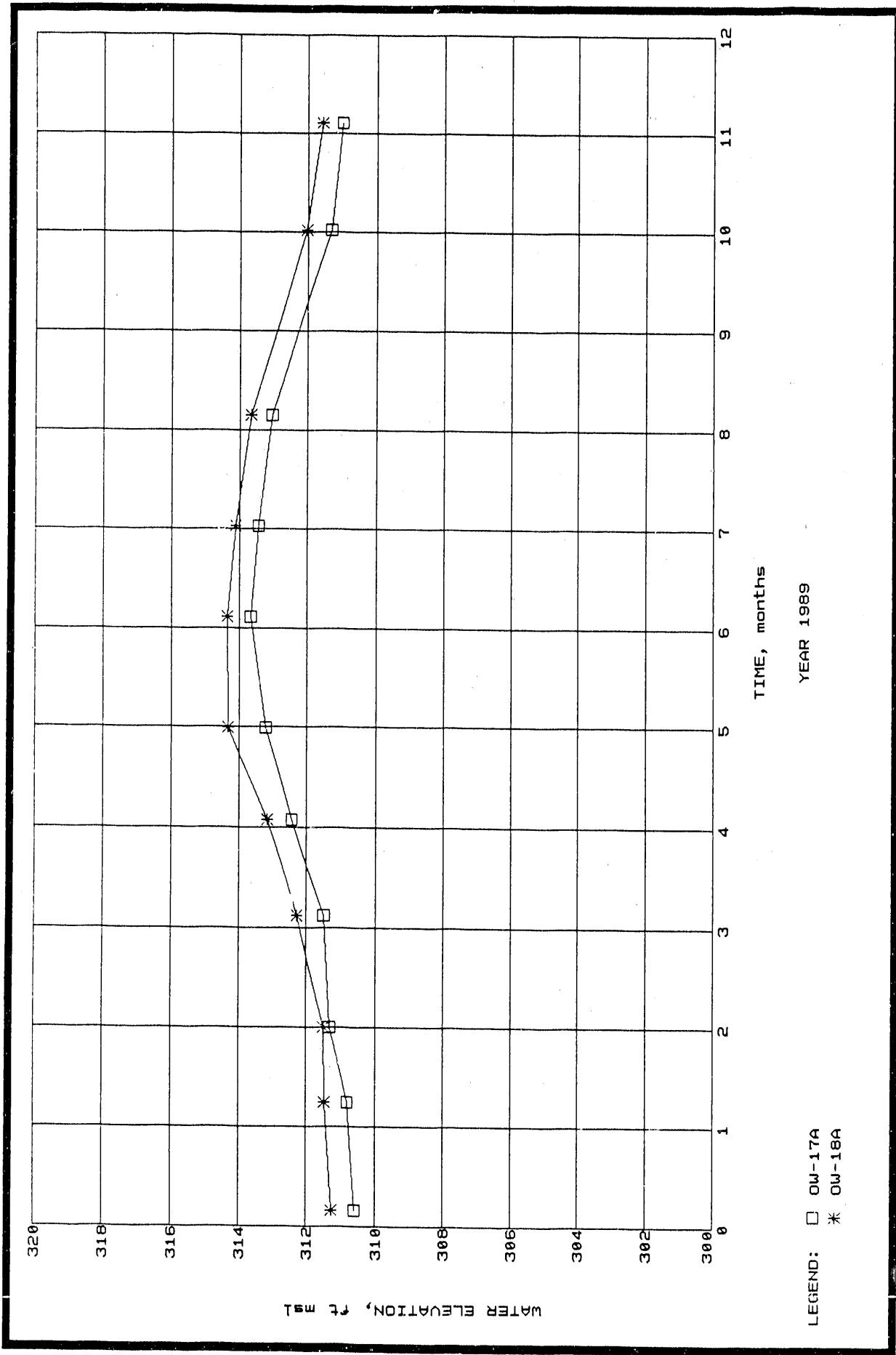
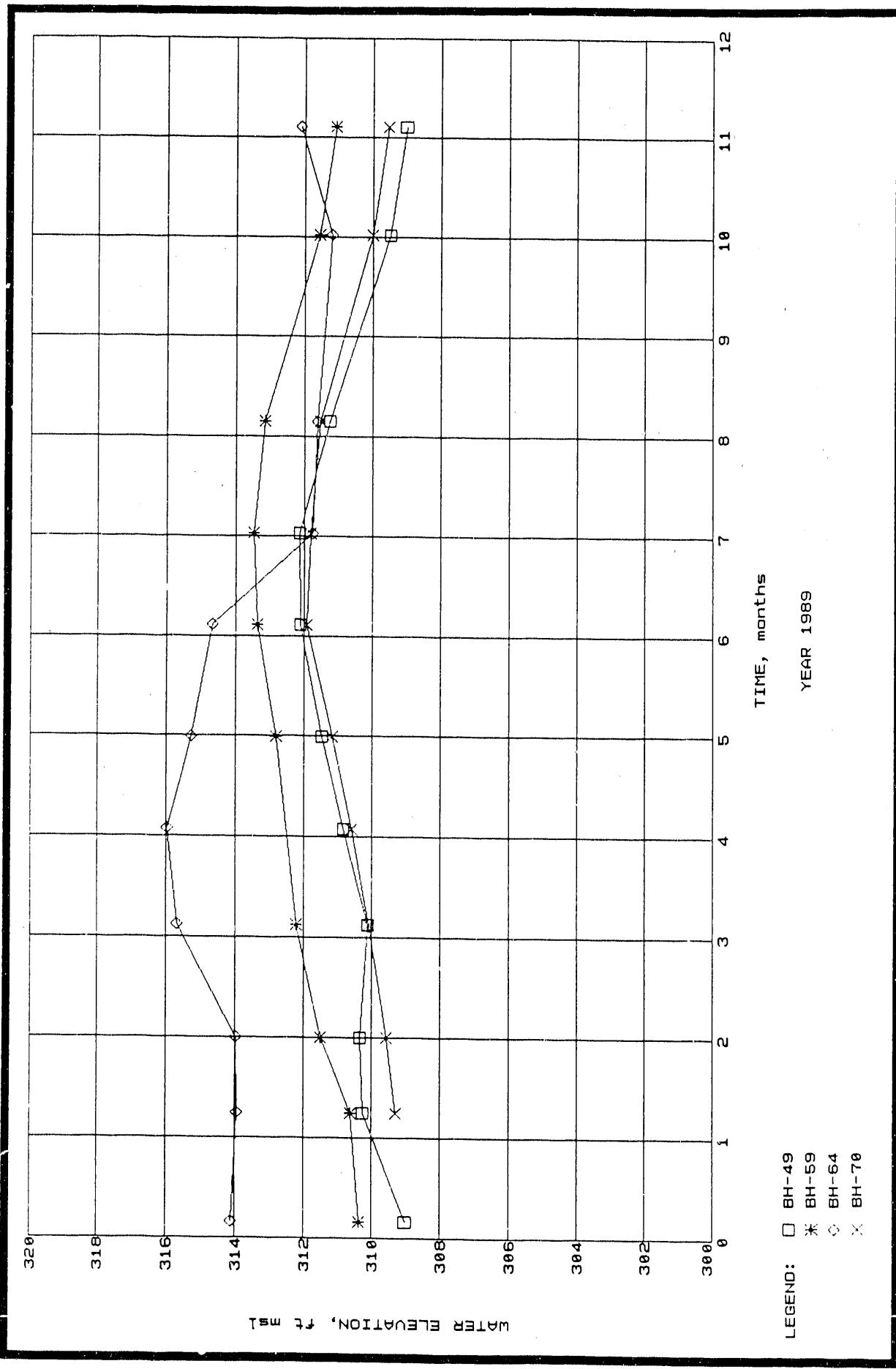


FIGURE 1-17 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
OW-17A AND OW-18A

FIGURE 1-18 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS  
BH-49, BH-59, BH-64, AND BH-70



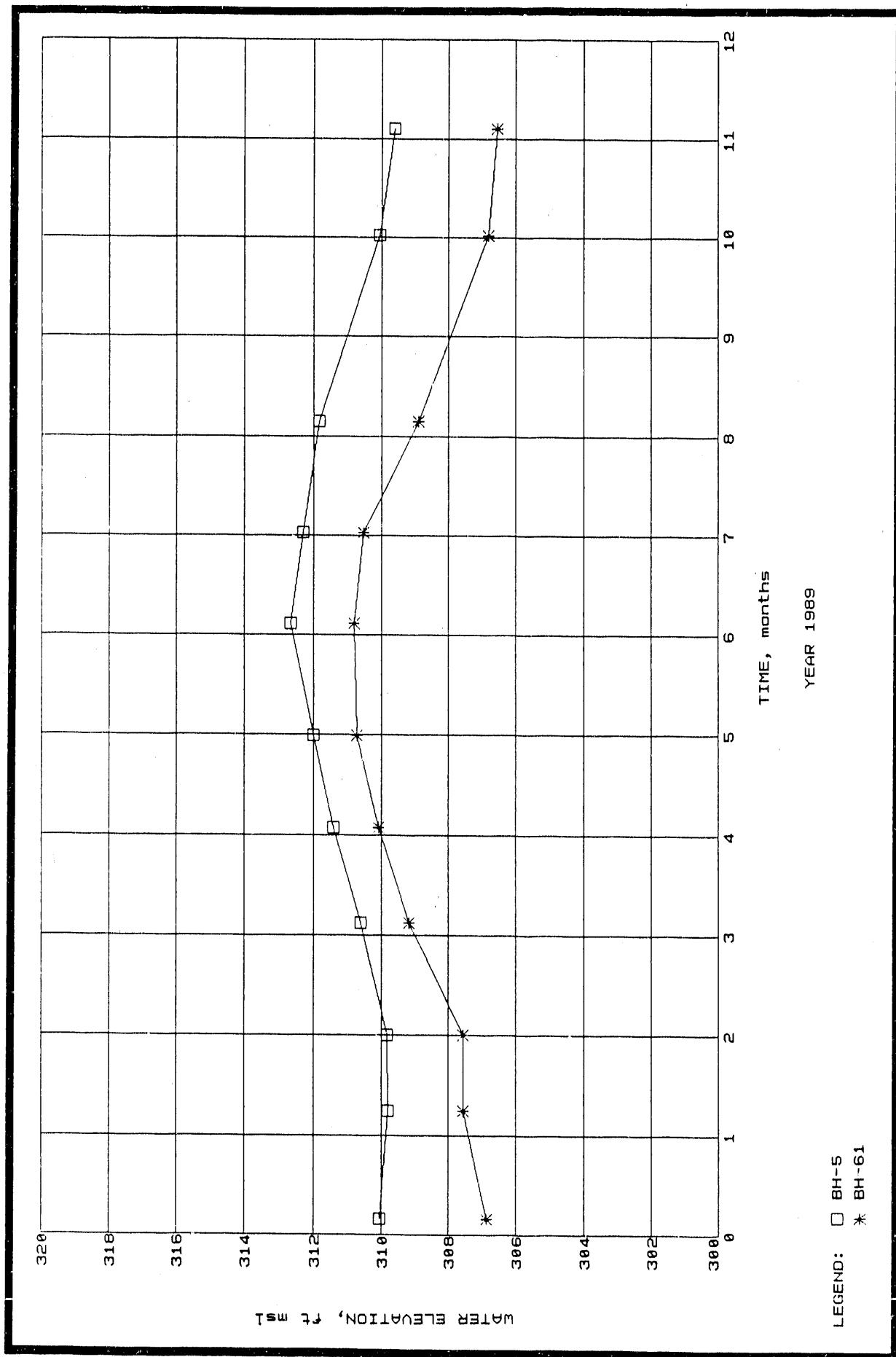


FIGURE 1-19 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM WELLS BH-5 AND BH-61

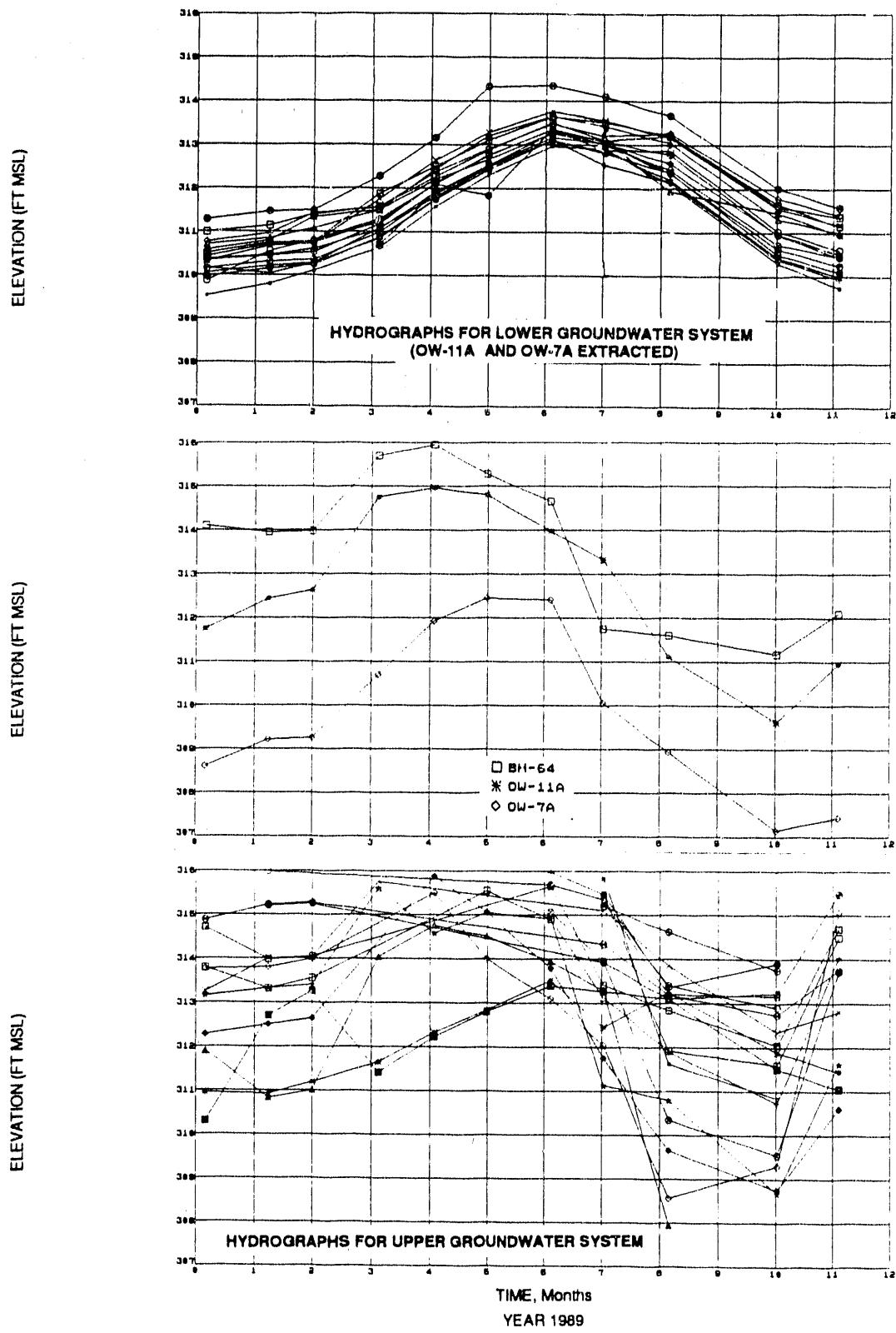
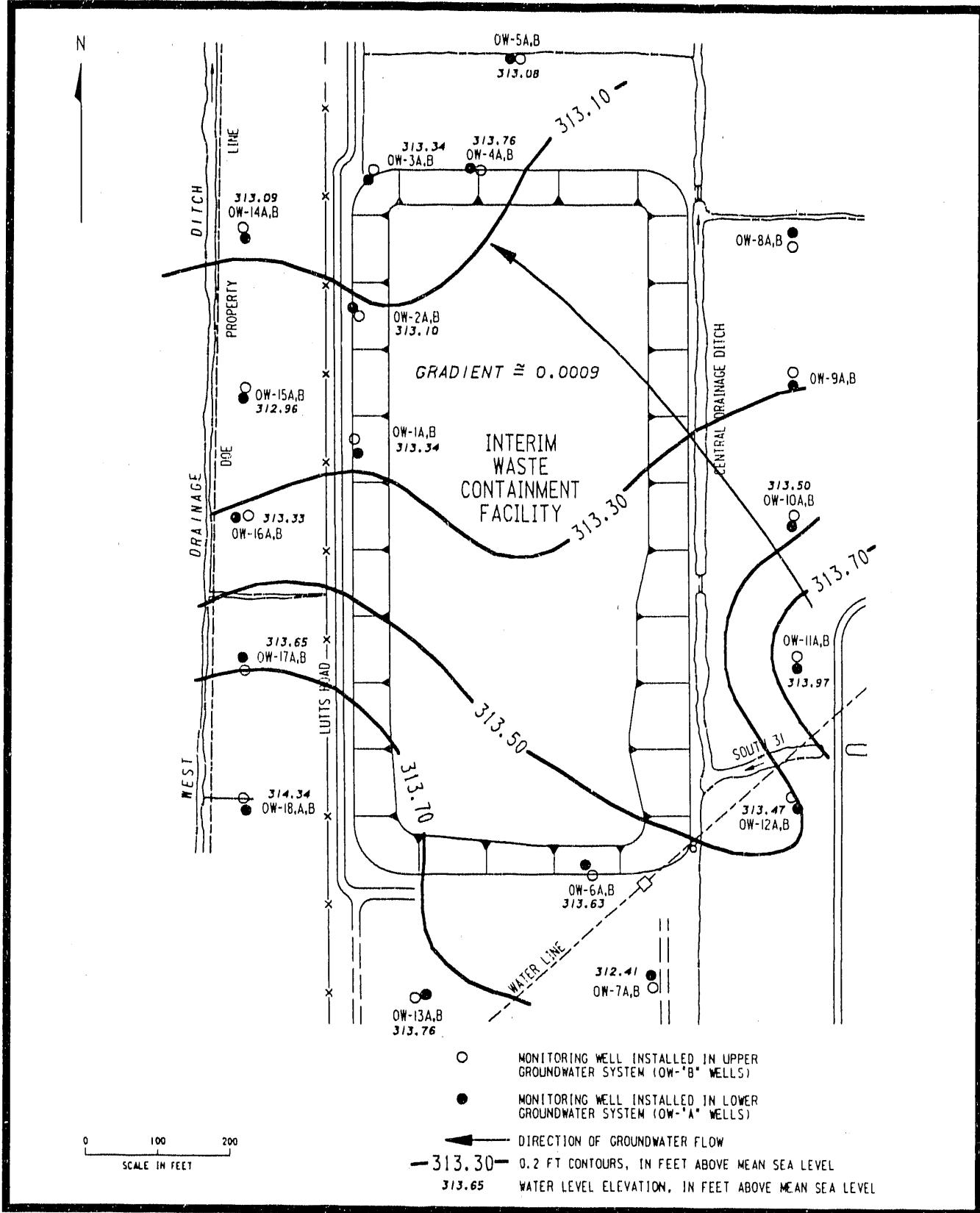
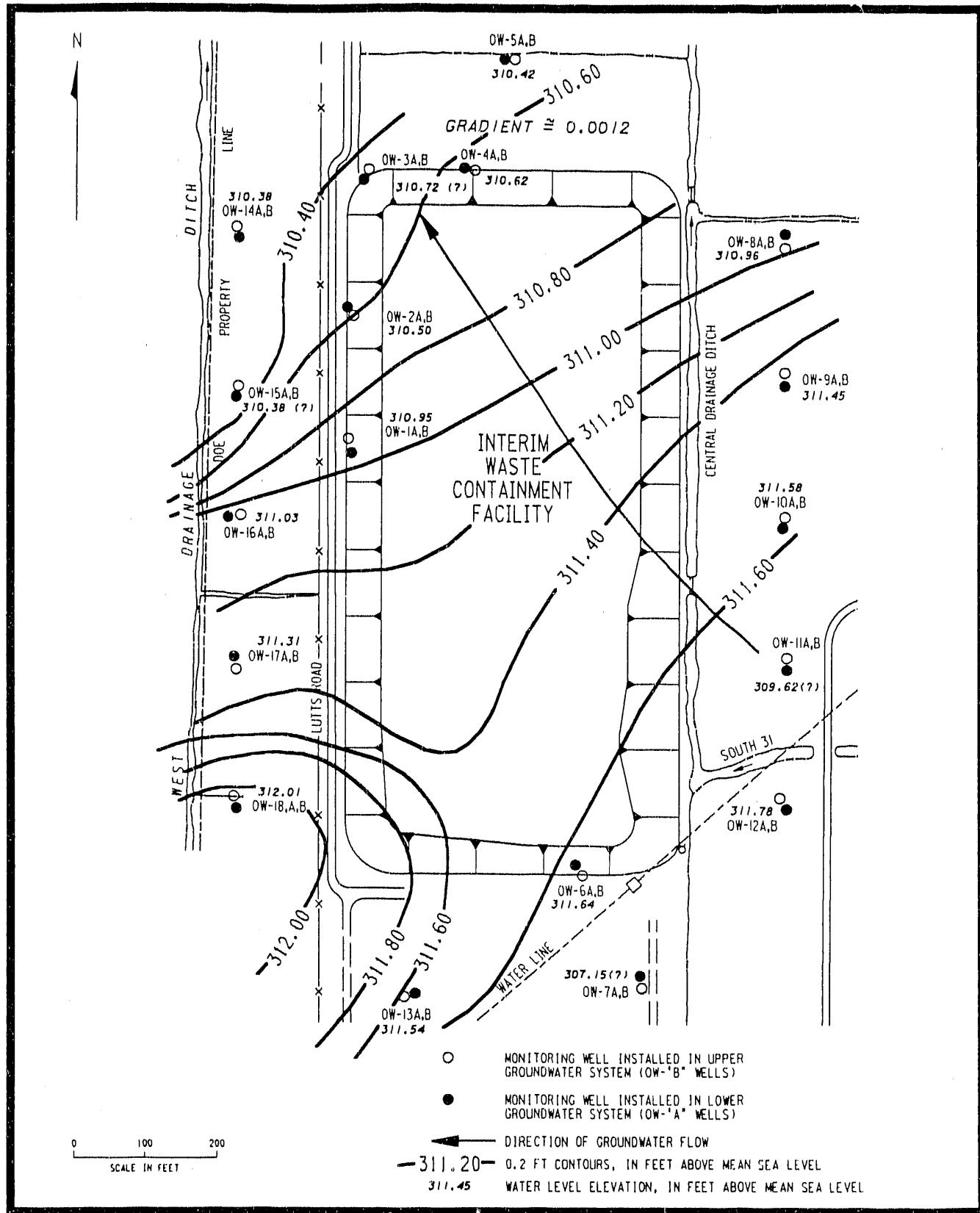


FIGURE 1-20 COMPARISON HYDROGRAPHS FOR WELLS OW-11A, OW-7A, AND BH-64



**FIGURE 1-21 POTENTIOMETRIC MAP OF LOWER GROUNDWATER SYSTEM (7/5/89)**



**FIGURE 1-22 POTENTIOMETRIC MAP OF LOWER GROUNDWATER SYSTEM (11/1/89)**

Figures 1-21 and 1-22 show a generalized flow direction from southeast to northwest, with a gradient of approximately 0.001. Seasonal variations in gradient or flow direction are not evident.

### **1.3.3 Bedrock Groundwater System**

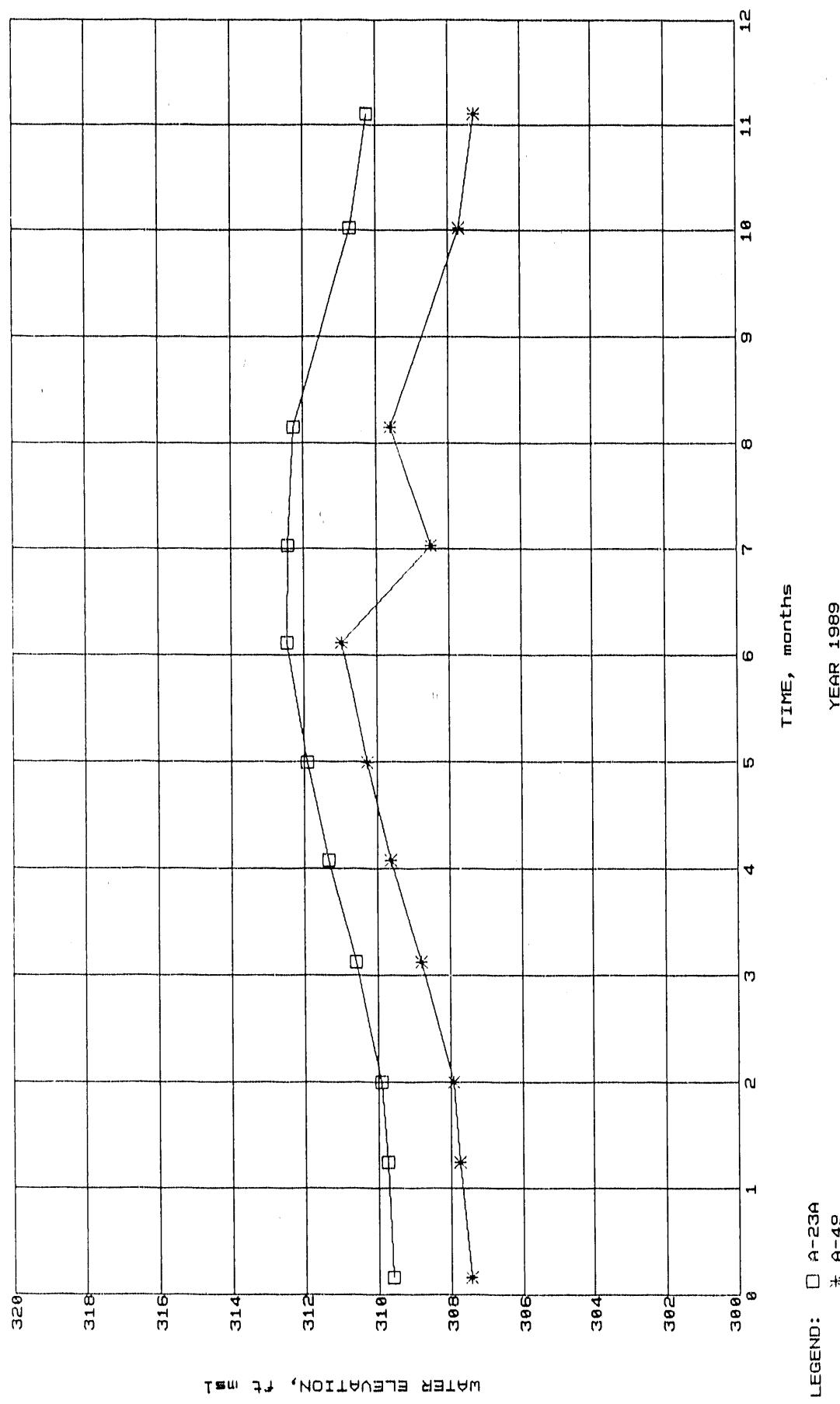
The bedrock groundwater system occurs in the Queenston formation, located more than 13.7 m (45 ft) below ground surface at the site. The Queenston formation consists of shales, siltstone, and mudstone, and is slightly to moderately weathered along its upper surface (Ref. 2). The hydrographs for bedrock wells monitored in 1989 (Figure 1-23) are similar to those in previous years; direction and magnitude of gradient remain unchanged, on the order of 0.001 to the west-northwest.

Because the lower and bedrock systems are in hydraulic connection, the wells in the bedrock system show the same seasonal variation in water levels as those in the lower system, with highest levels in the summer and lowest in the winter.

### **1.3.4 Conclusions**

- The upper groundwater system displays highest water level elevations in the spring and lowest elevations in the fall. The lower and bedrock groundwater systems monitored at the site display highest water level elevations in the summer and lowest elevations in the winter.
- The upper groundwater system occurs from 1.5 to 8.5 m (5 to 28 ft) below the ground surface in discontinuous media.
- The lower groundwater system occurs from 10.7 to 12.2 m (35 to 40 ft) below the ground surface in a mostly continuous silt and sand layer, and is confined by a gray clay unit 3.4 to 8.9 m (11 to 29 ft) thick. The lower system has a year-round direction of flow from the east to the northwest, and a gradient of approximately 0.001.

FIGURE 1-23 HYDROGRAPHS OF BEDROCK GROUNDWATER SYSTEM WELLS A-23A AND A-49



- The bedrock groundwater system occurs in the upper part of the Queenston formation, located 13.7 m or more (45 ft or more) below the site. The gradient and direction of flow are unchanged from previous years.
- Hydrographs of wells OW-7A, OW-11A, and BH-64 in the lower groundwater system show potentiometric surface elevations similar to those shown on hydrographs of wells in the upper groundwater system. Some communication between the two systems may exist in the vicinity of these wells.

## 2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program, which began in 1981, continued in 1989. Air, water, and sediments were sampled, and gamma radiation levels were monitored to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 17). The potential radiation dose that might be received by a hypothetical maximally exposed individual was estimated to determine whether the site remains in compliance with the radiation protection standard.

Annual average radon concentrations (including background) at all monitoring stations were within the normal variation associated with background measurements for this area (see Subsection 3.1). The average background concentrations of radon ranged from 4 to  $14 \times 10^{-10} \mu\text{Ci}/\text{ml}$  (0.4 to 1.4 pCi/L). Radon concentrations have remained stable at approximately background levels since 1986 (see Subsection 3.7.1) (Refs. 7-13).

Annual average gamma radiation levels recorded at the NFSS boundary ranged from background levels to 8 mrem/yr above background. These levels may be compared with naturally occurring background radiation levels in the vicinity of NFSS, which averaged 77 mrem/yr in 1989. External gamma radiation levels are discussed in Subsection 3.2. Annual average radiation levels generally have decreased since 1985 (see Subsection 3.7.2) (Refs. 10-13).

In surface waters (Subsection 3.3), annual average concentrations of total uranium ranged from  $4 \times 10^{-9}$  to  $2.1 \times 10^{-8} \mu\text{Ci}/\text{ml}$  (4 to 21 pCi/L); radium-226 concentrations ranged from  $5 \times 10^{-10}$  to  $2.5 \times 10^{-9} \mu\text{Ci}/\text{ml}$  (0.5 to 2.5 pCi/L). Average concentrations of both total uranium and radium-226 have decreased since 1985 (see Subsection 3.7.3) (Refs. 10-13).

In groundwater (Subsection 3.4), the highest annual average concentration of total uranium in an on-site well was  $6.7 \times 10^{-8} \mu\text{Ci}/\text{ml}$  (67 pCi/L), measured in well A-42. Well A-42 is located in a sand lens of unknown extent. Discussion of results of a December 1988 investigation of well A-42 is provided in

Subsection 3.4. For radium-226, the maximum annual average concentration in an on-site well was  $7 \times 10^{-10} \mu\text{Ci}/\text{ml}$  (0.7 pCi/L), measured in well BH-48. From 1984 through 1989, concentrations of total uranium and radium-226 have remained basically stable (see Subsection 3.7.4) (Refs. 9-13). In groundwater from wells surrounding the IWC, the highest annual average concentrations of total uranium and radium-226 were  $3.2 \times 10^{-8} \mu\text{Ci}/\text{ml}$  (32 pCi/L) and  $1 \times 10^{-9} \mu\text{Ci}/\text{ml}$  (1.0 pCi/L), respectively. Concentrations of radionuclides in surface water and groundwater at NFSS are within DOE derived concentration guidelines.

Chemical analyses of groundwater revealed the presence of 16 metals. Twelve of these metals were detected in an upgradient well, which is indicative of the typically low-quality groundwater found in industrial urban areas.

In stream sediments (Subsection 3.5), the highest annual average concentration was 8.8 pCi/g for total uranium and 1.8 pCi/g for radium-226. Though DOE currently does not have guidelines for radioactivity levels in sediments, these concentrations are within DOE guidelines for soils.

Calculations were made of the potential 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. Evaluation of monitoring results indicates that exposure to external gamma radiation represents the only plausible route of public exposure. Accordingly, this pathway was the only one quantified.

The exposure to the hypothetical maximally exposed individual from external gamma radiation was 2 mrem/yr above background. This exposure is approximately equivalent to 2 percent of the DOE radiation protection standard.

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

### 3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1989 environmental monitoring at NFSS. A description is also given of the sampling, monitoring, and analytical procedures used. Calculations were made to estimate the 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 NFSS included on-site and off-site radon monitoring, external gamma radiation measurements, and measurement of radionuclide concentrations in surface water, sediment, and groundwater. In addition, several nonradiological parameters were measured in groundwater.

Trend tables are provided for radon and external gamma radiation levels and for radionuclides measured in surface water

and groundwater. 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

Forty-seven radon detectors are maintained on the site and at site boundary stations, with three of the detectors (stations 31, 32, and 33) designated as quality controls. Three off-site detectors are maintained to measure the natural background level: station 30, at 6.4 km (4 mi) west-southwest; station 120, at 1.6 km (1 mi) southwest; and station 121, at 1.6 km (1 mi) south. Detectors are placed along the site boundary at intervals designed to ensure adequate detection capability under most atmospheric conditions. Detectors are more closely spaced along the perimeter of the IWCF, where the potential for release of contaminants is greater. In April 1987, monitoring stations 13, 14, 15, and 29 were moved approximately 220 m (240 yd) eastward to make them more accessible and thereby facilitate routine exchange of detectors. Locations of radon monitors are shown in Figure 3-1.

Radon concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which radon can diffuse. Radon will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, it will equilibrate with radon in the outside air. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. When returned to 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<sup>2</sup>) is related through calibration to the concentration of radon in air.

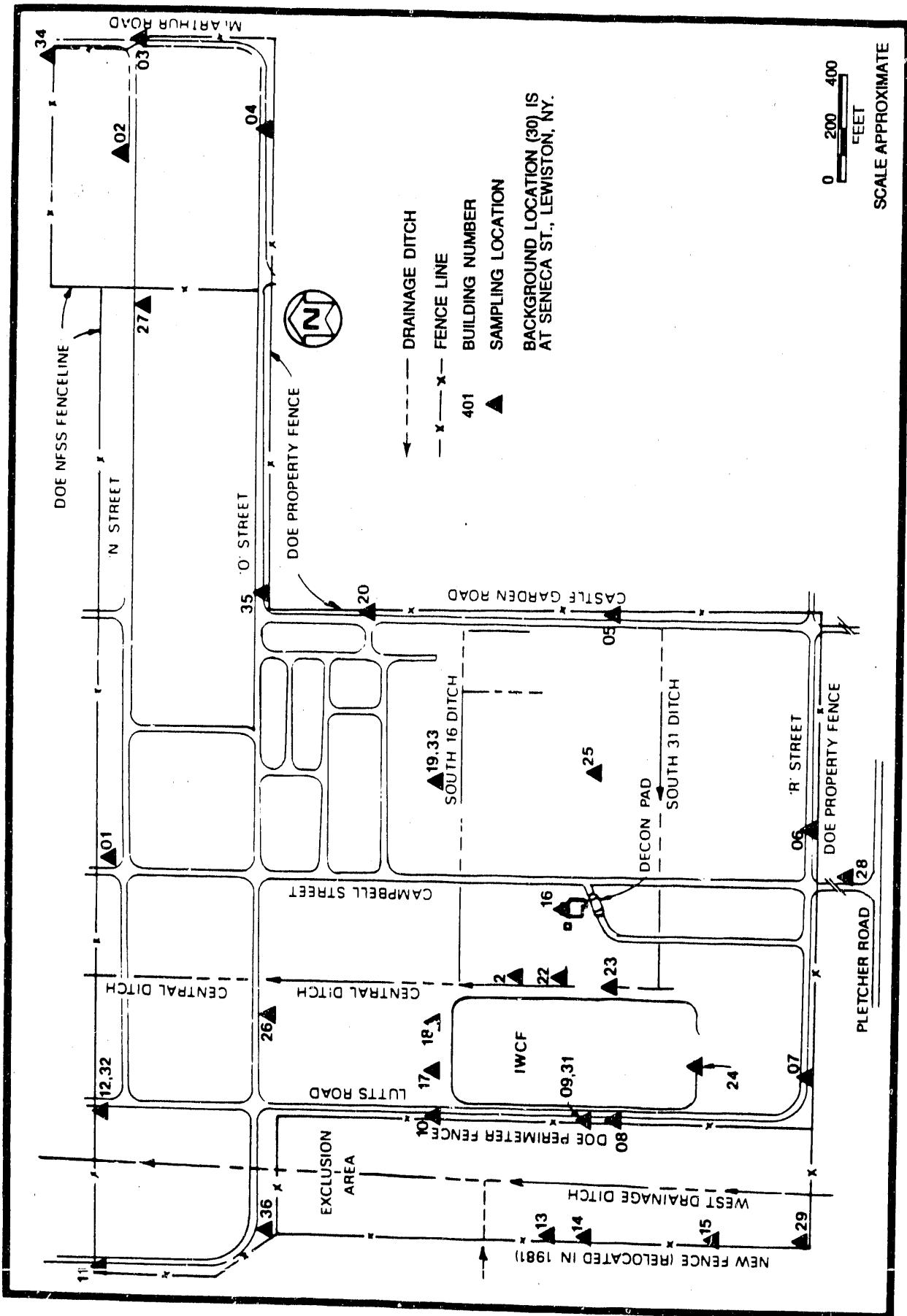


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT NESS

Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling location and return the exposed monitors to Terradex for analysis.

Table 3-1 shows radon concentrations (including background) measured in the air at site boundary monitoring stations and the background stations. Annual average concentrations at the site boundary ranged from  $4 \times 10^{-10}$  to  $8 \times 10^{-10}$   $\mu\text{Ci}/\text{ml}$  (0.4 to 0.8 pCi/L). The annual average background measurements ranged from  $4 \times 10^{-10}$  to  $1.4 \times 10^{-9}$   $\mu\text{Ci}/\text{ml}$  (0.4 to 1.4 pCi/L). The validity of the single highest reading of 3.8 pCi/L at background station 30 is suspect; the other three 1989 measurements at this station were all less than 1.0 pCi/L. For a comparison of radon concentrations measured from 1985 through 1989, see Subsection 3.6.1.

Because of the nature of the radon source (i.e., large surface areas emanating radon at rates that vary widely with changes in climatic/atmospheric conditions), accurate determination of the annual radon release rate is not feasible. Measured radon concentrations at the site boundary and in the environs show that the on-site radon source makes a minimal contribution over natural radon concentrations in the area.

### 3.2 EXTERNAL GAMMA RADIATION

External gamma radiation levels were measured at 47 monitoring stations; 17 of these are on the site boundary and 3 are on the perimeter of the former location of the tower that was used to store K-65 residues. Three of the monitoring stations are off site to measure the background radiation level. In April 1987, monitoring stations 13, 14, 15, and 29 were moved approximately 220 m (240 yd) eastward to make them more accessible for quarterly exchange of detectors. All locations correspond to the radon (Terradex) detector locations shown in Figure 3-1. The locations of the detectors are selected to ensure adequate measurement of radiation levels.

External gamma radiation levels are measured by lithium fluoride thermoluminescent dosimeters (TLDs). This system of measurement, used since 1988, utilizes tissue-equivalent

TABLE 3-1  
 CONCENTRATIONS OF RADON-222  
 MEASURED BY TERRADEX MONITORS AT THE NFSS BOUNDARY, 1989

Sampling Station <sup>a</sup>	Number of Samples	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>b,c</sup>		
		Minimum	Maximum	Average
1	4	0.3	0.5	0.4
3	4	<0.3	0.6	0.4
4	4	<0.3	0.6	0.4
5	4	<0.4	1.6	0.7
6	4	<0.3	0.5	0.4
7	4	<0.4	2.0	0.8
11	4	<0.3	0.5	0.4
12	4	<0.3	0.8	0.5
13	4	<0.4	1.7	0.7
14	3	<0.4	0.6	0.5
15	4	<0.3	0.7	0.4
20	4	<0.3	0.4	0.4
28	4	0.3	1.0	0.5
29	4	0.4	1.9	0.8
32 <sup>d</sup>	4	0.4	1.3	0.6
34	4	<0.3	0.8	0.5
35	4	<0.3	0.4	0.4
36	4	0.3	0.6	0.4
<u>Background</u>				
30 <sup>e</sup>	4	0.3	3.8	1.4
120 <sup>f</sup>	4	<0.4	0.7	0.5
121 <sup>g</sup>	4	<0.3	0.5	0.4

<sup>a</sup>Locations of sampling stations are shown in Figure 3-1.

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>c</sup>Background has not been subtracted. Note that values for several stations are below background levels.

<sup>d</sup>Station 32 is a quality control for station 12.

<sup>e</sup>Background sampling station, located at Seneca St., Lewiston, NY, approximately 6.4 km (4 mi) southwest of NFSS.

<sup>f</sup>Background sampling station, located at Pletcher Rd., Lewiston, NY, approximately 1.6 km (1 mi) southwest of NFSS.

<sup>g</sup>Background sampling station, located at the intersection of Route 104 and Swain Rd., Lewiston, NY, approximately 1.6 km (1 mi) south of NFSS.

dosimeters to provide values that are more realistic in terms of radiation dose to tissues of the body at a depth of 1 cm. 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 preselected on the basis of having a reproducibility of  $\pm 3$  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.

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  $\pm 10$  percent at levels from 100 mrem/yr to 1 rem/yr and  $\pm 25$  percent at radiation levels around 70 mrem/yr.

Monitoring results for the 17 site boundary stations, the 3 background stations, and the quality control station are presented in Table 3-2. For each quarter, an average of the background levels measured was subtracted from the site boundary measurements to provide an estimate of radiation levels resulting from residual materials at the site. The highest level was measured at a station adjacent to a sanitary landfill to which access is controlled by the owner. At this station, the maximum annual average level was 8 mrem/yr above the average background level of 77 mrem/yr. Based on a very conservative 40-h/week occupancy factor, the maximum exposure to workers in this area of the landfill would be 2 mrem/yr.

In April 1988, two additional background stations were established at the Lewiston Town Hall and the Lewiston Water Pollution Control Center. Because of the measurement system operating parameters, data from the new stations were not available for the first quarter of 1989. Background value for first quarter

TABLE 3-2  
EXTERNAL GAMMA RADIATION LEVELS AT NFSS, 1989

Sampling Station <sup>a</sup>	Number of Measurements	Radiation Level (mrem/yr) <sup>b</sup>		
		Minimum	Maximum	Average
<u>Site Boundary</u>				
1	4	-c	-c	-c
3	4	-c	-c	-c
4	4	-c	1	-c
5	4	-c	7	2
6	4	-c	-c	-c
7	4	-c	8	2
11	4	-c	-c	-c
12	4	-c	-c	-c
13	4	-c	5	1
14	4	-c	-c	-c
15	4	-c	8	3
20	4	5	13	8
28	4	-c	10	2
29	4	-c	-c	-c
32 <sup>d</sup>	4	-c	1	-c
34	4	-c	-c	-c
35	4	-c	3	1
36	4	-c	1	-c
<u>Background</u>				
30 <sup>e</sup>	4	54	70	61
120 <sup>f</sup>	3	80	87	83
121 <sup>g</sup>	3	84	90	87

<sup>a</sup>Locations of sampling stations are shown in Figure 3-1.

<sup>b</sup>Average of measured backgrounds has been subtracted from measurements taken at site boundary locations.

<sup>c</sup>Measurement was less than or equal to the measured background value.

<sup>d</sup>Station 32 is a quality control for station 12.

<sup>e</sup>Located at Seneca St., Lewiston, NY, approximately 6.4 km (4 mi) southwest of NFSS.

<sup>f</sup>Located at Pletcher Rd., Seneca, NY, approximately 1.6 km (1 mi) south of NFSS; first sampled in April 1989.

<sup>g</sup>Located at the intersection of Route 104 and Swain Rd., Lewiston, NY, approximately 1.6 km (1 mi) west of NFSS; first sampled in April 1989.

comes solely from station 30 at Seneca Street, Lewiston, New York. Data for the other quarters were obtained from all three background stations.

The background external gamma radiation value for a given station is not 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 highly mineralized soil can affect the value measured. Independent of the placement of the detector at the site are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 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 distance from the site.

For comparisons of external gamma radiation levels measured from 1985 through 1989, see Subsection 3.7.2.

### 3.3 SURFACE WATER SAMPLING

During 1989, sampling was performed to determine the concentrations of total uranium and radium in surface water and groundwater at on-site and off-site locations. On-site sampling locations for surface water are shown in Figure 3-2, and off-site locations are shown in Figure 3-3. Samples were collected quarterly at locations 9, 10, 11, 12, and 20. Locations 12 and 20 are 1.6 and 3.2 km (1 mi and 2 mi) downstream, respectively, of the northern boundary of NFSS. Location 9 is a background location established at the South 31 Ditch in October 1988. Locations 10 and 11 are in the Central Drainage Ditch.

Surface water collection locations were selected on the basis of potential for contaminant migration and discharge routes from the site. Because surface water runoff from the site discharges via the Central Drainage Ditch, all sampling locations except location 9 were placed along the ditch.

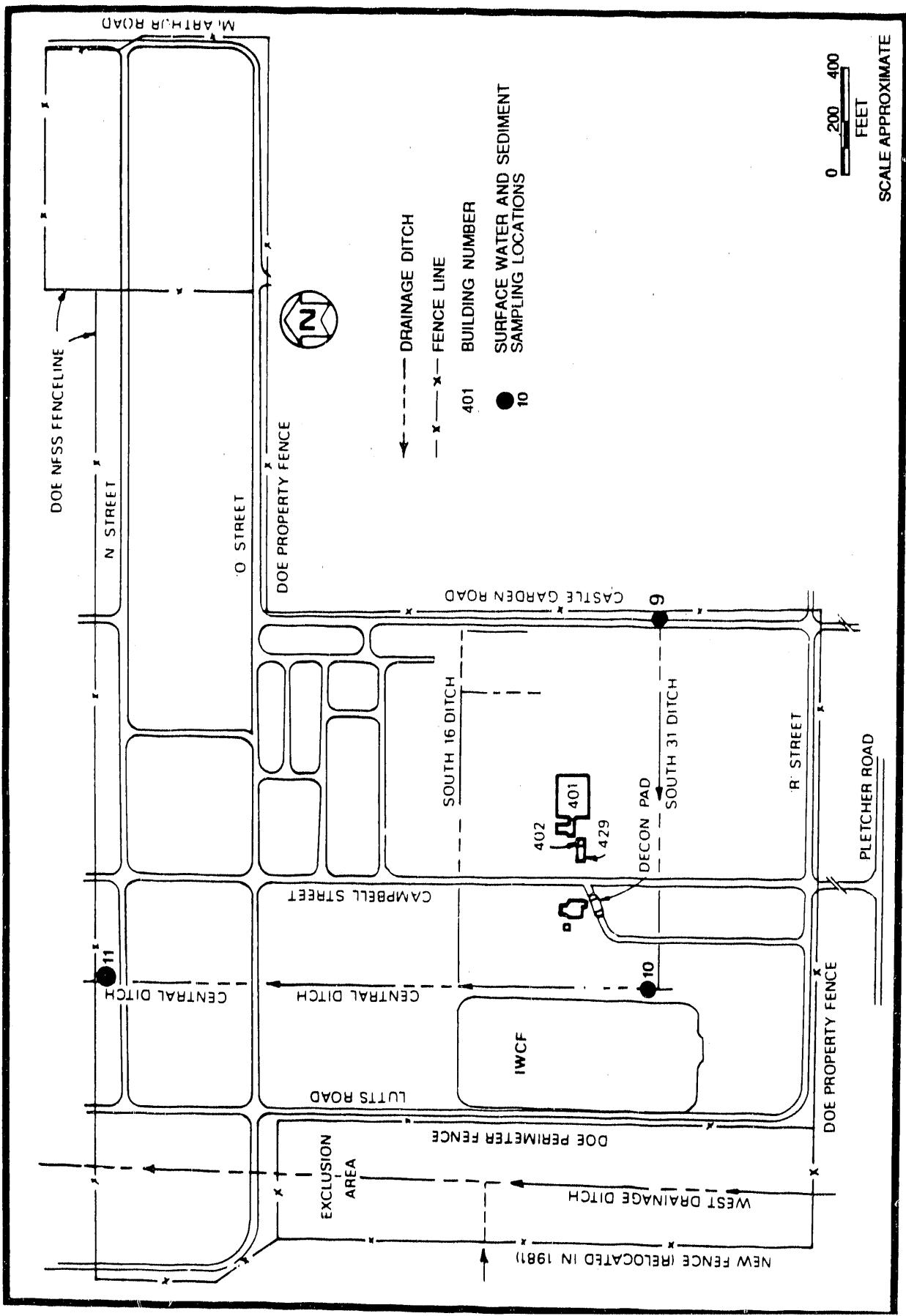


FIGURE 3-2 ON-SITE SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS AT NFSS

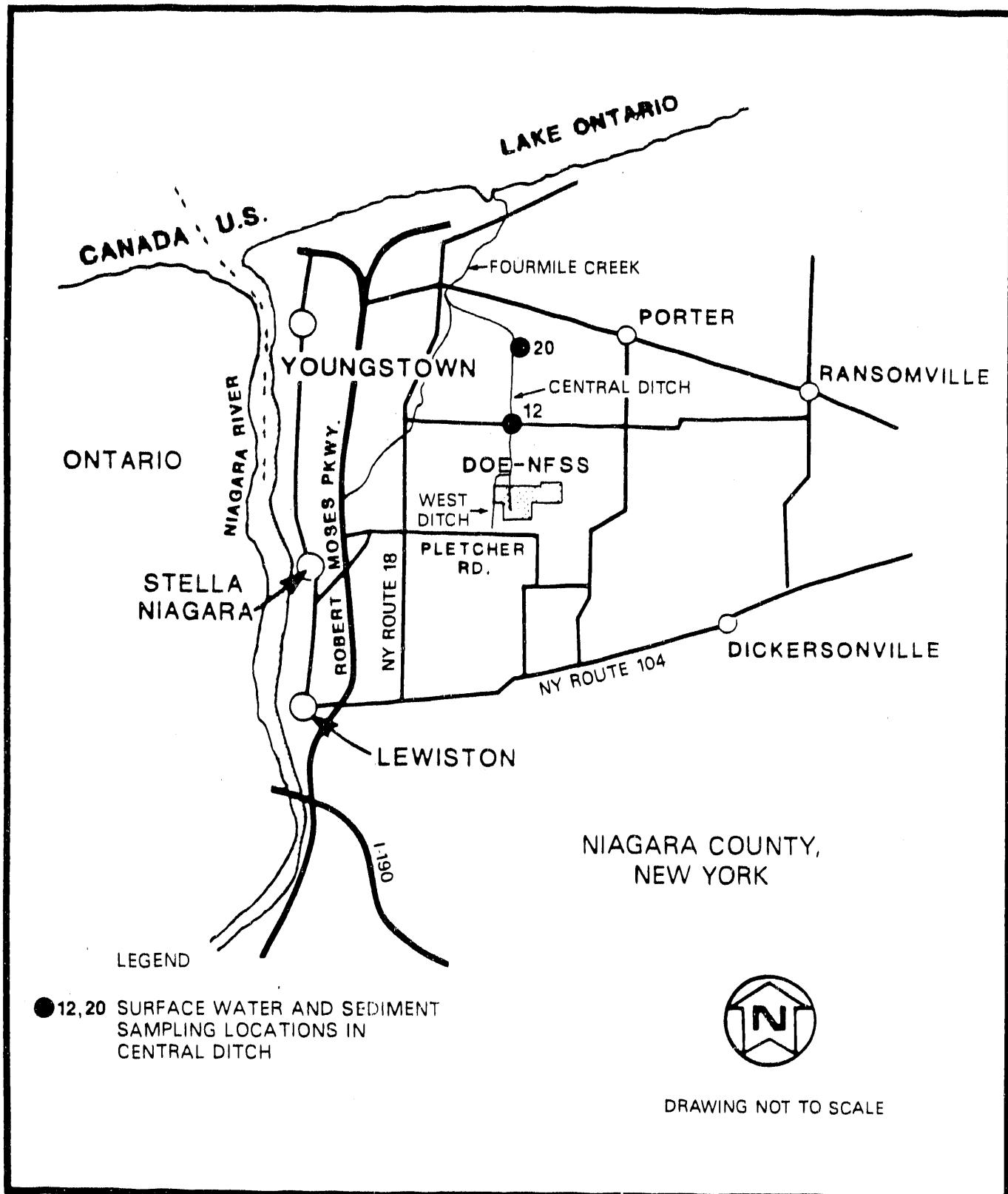


FIGURE 3-3 OFF-SITE SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS IN THE VICINITY OF NFSS

Nominal 1-L (0.26-gal) grab samples were collected to fill a 3.8-L (1.0-gal) container and were analyzed by TMA/E. 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 sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.)

Results of analyses of surface water for total uranium content are given in Table 3-3; radium-226 results are given in Table 3-4. Annual average total uranium concentrations in on-site surface water ranged from 1.6 to  $2.1 \times 10^{-8} \mu\text{Ci}/\text{ml}$  (16 to 21 pCi/L); in off-site surface water, concentrations ranged from  $4 \times 10^{-9}$  to  $1 \times 10^{-8} \mu\text{Ci}/\text{ml}$  (4 to 10 pCi/L). The highest annual average concentration of radium-226 in surface water was  $2.5 \times 10^{-9} \mu\text{Ci}/\text{ml}$  (2.5 pCi/L). Radionuclide concentrations in surface water are well within DOE derived concentration guidelines and off-site sampling locations approximate background levels.

Sampling of water supplied by a local municipal water system was suspended in 1986. This system draws water from the upper Niagara River approximately 16 km (10 mi) south of NFSS. Sampling was suspended because the draw point of the system was upstream of NFSS and because data from previous years indicated no total uranium or radium-226 concentrations discernibly different from background levels in these waters.

For comparisons of radionuclide concentrations in surface water measured at the site from 1985 through 1989, see Subsection 3.7.3.

### 3.4 GROUNDWATER SAMPLING

During 1989, groundwater samples were collected quarterly from 42 on-site wells. Sampling locations were selected based on the

TABLE 3-3  
CONCENTRATIONS OF TOTAL URANIUM IN NFSS WATER SAMPLES, 1989

Sampling Location <sup>a</sup>	Number of Samples	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>b</sup>			
		Minimum	Maximum	Average	
<u>Surface Water</u>					
<u>On Site</u>					
10	3 <sup>c</sup>	10	36	21	
11	3 <sup>c</sup>	14	18	16	
<u>Off Site</u>					
12	3 <sup>c</sup>	9	13	10	
20	3 <sup>c</sup>	3	7	4	
<u>Background</u>					
9	3 <sup>c, d</sup>	3	13	9	
<u>Groundwater<sup>e</sup></u>					
<u>On Site</u>					
BH-5	4	<3	<18	7	
BH-48 <sup>f</sup>	4	<3	10	5	
BH-61 <sup>g</sup>	4	<3	<3	<3	
A-42	4	<3	100	67	
A-50	4	<3	13	7	
A-52	4	<3	21	13	

<sup>a</sup>Sampling locations are shown in Figures 3-2 and 3-3 (surface water) and 1-7 (groundwater).

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>c</sup>Location was frozen in the first quarter.

<sup>d</sup>Background location on site at the South 31 Ditch.  
Established in October 1988.

<sup>e</sup>Wells with the prefix "A" are in the upper groundwater system;  
those with the prefix "BH" are in the lower groundwater system.

<sup>f</sup>Upgradient well.

<sup>g</sup>Downgradient well.

TABLE 3-4  
CONCENTRATIONS OF RADIUM-226 IN NFSS WATER SAMPLES, 1989

Sampling Location <sup>a</sup>	Number of Samples	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>b</sup>			
		Minimum	Maximum	Average	
<u>Surface Water</u>					
<u>On Site</u>					
10	3 <sup>c</sup>	0.3	0.9	0.6	
11	3 <sup>c</sup>	0.6	4.8	2.5	
<u>Off Site</u>					
12	3 <sup>c</sup>	0.2	1.2	0.6	
20	3 <sup>c</sup>	0.2	0.8	0.5	
<u>Background</u>					
9	3 <sup>c,d</sup>	0.3	2.3	1.5	
<u>Groundwater<sup>e</sup></u>					
<u>On Site</u>					
BH-5	4	0.3	0.5	0.4	
BH-48 <sup>f</sup>	4	0.5	0.8	0.7	
BH-61 <sup>g</sup>	4	0.3	0.5	0.4	
A-42	4	0.2	1.1	0.6	
A-50	4	0.2	0.7	0.5	
A-52	4	0.6	0.6	0.6	

<sup>a</sup>Sampling locations are shown in Figures 3-2 and 3-3 (surface water) and 1-7 (groundwater).

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>c</sup>Location was frozen in the first quarter.

<sup>d</sup>Background location established on site at the South 31 Ditch. Established in October 1988.

<sup>e</sup>Wells with the prefix "A" are in the upper groundwater system; those with the prefix "BH" are in the lower groundwater system.

<sup>f</sup>Upgradient well.

<sup>g</sup>Downgradient well.

inventory of radioactive materials in various areas of the site and available hydrogeological data. Most of the monitoring wells are located near the IWCF. Other wells are located both upgradient and downgradient to provide background data and to monitor any migration of contaminants off site in the upper and lower groundwater systems. In late 1986, 36 wells ("OW" wells in Figure 1-7) were installed along the IWCF perimeter to monitor its performance. These wells were added to the environmental monitoring program in April 1987.

Wells BH-5 and BH-48 also monitor the lower groundwater system. Six on-site wells--BH-49, BH-51, BH-63, BH-64, BH-70, and BH-71 in the lower groundwater system--were monitored from 1983 through 1988 and then dropped from the program in January 1989. All parameters measured in these wells were consistently at or very close to background levels. Measurements for these wells are listed in Refs. 8 through 13.

Wells A-42, A-50, and A-52 also monitor the upper groundwater system around the IWCF (but are not among the 36 new wells). Well A-42 is drilled into a sand lens of unknown extent. The chemical, radiological, and hydrogeological behavior of this well was investigated in December 1988. Results indicate that the sand lens into which this well is completed is not in good hydraulic connection with the zones of completion in adjacent wells. Additionally, results of sequential sampling indicate that radioactive contamination in well A-42 may be associated with contaminated soils in or near the well.

Monitoring wells BH-48 and BH-61, which are installed in the lower groundwater system outside the IWCF area, represent upgradient and downgradient, respectively. Locations of these wells are shown in Figure 1-7.

Groundwater samples were collected after the wells had been bailed dry and allowed to recover or three casing volumes had been removed and a 24-h period had been allowed for well recharge. Nominal 1-L (0.26-gal) grab samples were collected with a bailer to fill a 3.8-L (1.0-gal) container. Using the analysis methods described for surface water, TMA/E analyzed the samples for

dissolved total uranium and radium-226, and Weston Analytical Laboratory analyzed samples for several chemical indicator parameters and heavy metals.

#### **3.4.1 Radiological**

Analytical results for total uranium concentrations in groundwater are listed in Table 3-3; radium results are given in Table 3-4. Table 3-5 gives results for total uranium in the monitoring wells along the perimeter of the IWCF; Table 3-6 gives the results for radium-226. Annual average concentrations of total uranium in groundwater ranged from  $<3 \times 10^{-9}$  to  $6.7 \times 10^{-8}$   $\mu\text{Ci}/\text{ml}$  ( $<3$  to  $67$   $\text{pCi}/\text{L}$ ). Annual average concentrations of radium-226 in groundwater ranged from  $4$  to  $7 \times 10^{-10}$   $\mu\text{Ci}/\text{ml}$  ( $0.4$  to  $0.7$   $\text{pCi}/\text{L}$ ). Annual averages for total uranium in water in the wells monitoring the IWCF area ranged from  $<3 \times 10^{-9}$  to  $3.2 \times 10^{-8}$   $\mu\text{Ci}/\text{ml}$  ( $<3$  to  $32$   $\text{pCi}/\text{L}$ ). Radium-226 annual average values for the area around IWCF ranged from  $3.0 \times 10^{-10}$  to  $1.0 \times 10^{-9}$   $\mu\text{Ci}/\text{ml}$  ( $0.3$  to  $1.0$   $\text{pCi}/\text{L}$ ). These values are all below DOE derived concentration guidelines.

For a comparison of radionuclide concentrations measured in groundwater at NFSS from 1985 through 1989, see Subsection 3.7.4.

#### **3.4.2 Chemical**

In April 1987, monitoring of the groundwater for chemical indicator parameters began at NFSS. These indicator parameters are pH, specific conductance, total organic carbon (TOC), and total organic halides (TOX). These parameters indicate changes in the inorganic and organic composition of the groundwater.

Specific conductance and pH measure changes in the inorganic composition of the groundwater. Acidity or basicity of water is expressed as pH. A change in pH affects the solubility and mobility of chemical contaminants in groundwater. Specific

TABLE 3-5  
 CONCENTRATIONS OF TOTAL URANIUM IN NFSS IWCF  
 MONITORING WELLS, 1989

Sampling Location <sup>a</sup>	Number of Samples	Concentration ( $10^{-9} \mu\text{Ci}/\text{ml}$ ) <sup>b</sup>		
		Minimum	Maximum	Average
OW-1A	4	<3	5	4
OW-1B	4	<3	12	8
OW-2A	4	<3	5	4
OW-2B	4	7	12	9
OW-3A	4	5	10	8
OW-3B	4	15	20	17
OW-4A	4	<3	3	3
OW-4B	4	<3	11	7
OW-5A	4	<3	4	4
OW-5B	4	10	14	12
OW-6A	4	<3	3	3
OW-6B	4	9	18	13
OW-7A	4	9	12	10
OW-7B	4	<3	4	3
OW-8A	4	<3	9	5
OW-8B	4	16	22	20
OW-9A	4	<3	10	5
OW-9B	3 <sup>c</sup>	13	25	20
OW-10A	4	<3	<3	<3
OW-10B	4	3	12	7
OW-11A	4	26	40	32
OW-11B	4	<3	<3	<3
OW-12A	4	<3	16	7
OW-12B	3 <sup>c</sup>	7	13	10
OW-13A	4	<3	<3	<3
OW-13B	4	<3	26	17
OW-14A	4	<3	<3	<3
OW-14B	4	<3	8	6
OW-15A	4	<3	<3	<3
OW-15B	4	8	27	14
OW-16A	4	<3	3	3
OW-16B	4	4	21	11
OW-17A	4	<3	6	4
OW-17B	4	5	12	8
OW-18A	4	<3	9	5
OW-18B	4	8	26	19

<sup>a</sup>Sampling locations are shown in Figure 1-7.

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci}/\text{ml}$  is equivalent to 1 pCi/L.

<sup>c</sup>Well was dry in the fourth quarter.

TABLE 3-6  
 CONCENTRATIONS OF RADIUM-226 IN NFSS IWCF  
 MONITORING WELLS, 1989

Sampling Location <sup>a</sup>	Number of Samples	Concentration ( $10^{-9} \mu\text{Ci}/\text{ml}$ ) <sup>b</sup>		
		Minimum	Maximum	Average
OW-1A	4	0.3	1.4	0.6
OW-1B	4	0.4	1.2	0.7
OW-2A	4	0.1	0.7	0.4
OW-2B	4	0.1	0.7	0.3
OW-3A	4	0.4	1.0	0.5
OW-3B	4	0.4	1.4	0.7
OW-4A	4	0.3	1.0	0.5
OW-4B	4	0.1	1.2	0.5
OW-5A	4	0.2	0.8	0.4
OW-5B	4	0.6	0.9	0.7
OW-6A	4	0.3	0.9	0.5
OW-6B	4	0.3	1.0	0.5
OW-7A	4	0.8	1.4	1.0
OW-7B	4	0.3	0.9	0.5
OW-8A	4	0.4	1.0	0.6
OW-8B	4	0.3	1.2	0.6
OW-9A	4	0.4	0.8	0.5
OW-9B	3 <sup>c</sup>	0.5	1.1	0.9
OW-10A	4	0.2	0.6	0.4
OW-10B	4	0.2	0.6	0.3
OW-11A	4	0.4	1.3	0.8
OW-11B	4	0.3	0.7	0.4
OW-12A	4	0.4	0.6	0.5
OW-12B	3 <sup>c</sup>	0.4	0.7	0.5
OW-13A	4	0.4	1.0	0.6
OW-13B	4	0.4	1.3	0.7
OW-14A	4	0.2	0.4	0.3
OW-14B	4	0.2	3.0	1.0
OW-15A	4	0.3	0.5	0.4
OW-15B	4	0.2	2.4	0.8
OW-16A	4	0.3	1.0	0.5
OW-16B	4	0.3	1.6	0.7
OW-17A	4	0.2	0.4	0.3
OW-17B	4	0.2	0.6	0.4
OW-18A	4	0.2	0.5	0.3
OW-18B	4	0.4	2.1	0.8

<sup>a</sup>Sampling locations are shown in Figure 1-7.

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci}/\text{ml}$  is equivalent to 1 pCi/L.

<sup>c</sup>Well was dry in the fourth quarter.

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 compound. TOX measures organic compounds containing halogens because many pollutants contain halogenated hydrocarbons, which are organic compounds containing fluorine, chlorine, bromine, and iodine.

As shown in Table 3-7, pH varied from slightly acid to basic in wells across the site with the exception of wells OW-13A and BH-5, where the pH remained quite basic throughout the year. Results for the other water quality parameters measured at these two wells were similar to results from upgradient well BH-48.

TOC and TOX ranged from 1.3 to 129 mg/L and below detectable limits to 125  $\mu$ g/L, respectively. The data indicate relatively unchanged levels of TOC and TOX when compared with 1988 results (Ref. 13).

Specific conductance across the site varied from a low of 1,110 to a high of 4,720  $\mu$ mhos/cm. Analytical results indicate that the groundwater at NFSS is of poor quality, which is typical of groundwater in industrial urban areas.

Dissolved metals analyses were conducted on all the "OW" wells in addition to A-42, BH-5, BH-48, and BH-61. Results from the broad screen metals analyses performed on the January samples indicated that analyses performed on a smaller, key group of metals would be a safe and more cost-effective mode of monitoring metals in NFSS groundwater. For this reason, samples for April, July, and October were analyzed for boron, aluminum, copper, iron, manganese, lead, mercury, and vanadium only. Levels recorded for the other metals presented in Table 3-8 represent single measurements.

Metal ions are normal constituents of groundwater resulting from the soil through which the groundwater flows. Metal ions can also be introduced as a result of previous waste management activities. Boron, calcium, iron, magnesium, manganese, sodium,

TABLE 3-7  
RANGES OF WATER QUALITY PARAMETERS IN GROUNDWATER  
AT NFSS, 1989

Page 1 of 2

Sampling Location (Well No.) <sup>a</sup>	Parameter			
	pH (Standard Units)	Total Organic Carbon (mg/L)	Total Organic Halides ( $\mu$ g/L)	Specific Conductance ( $\mu$ mhos/cm)
OW-1A	6.9 - 9.8	2.0 - 23.4	ND - 71 <sup>b</sup>	1640 - 1940
OW-1B	7.4 - 7.7	2.2 - 8.5	ND - 80	1180 - 1310
OW-2A	7.6 - 8.0	4.2 - 14.9	ND	1610 - 1890
OW-2B	7.2 - 8.0	2.6 - 40.3	ND - 41	1590 - 1780
OW-3A	7.4 - 7.8	3.9 - 22.9	ND	2240 - 2470
OW-3B	7.3 - 7.5	4.2 - 9.3	ND	2120 - 2460
OW-4A	7.4 - 8.0	3.2 - 14.6	ND	1320 - 1400
OW-4B	7.5 - 8.1	3.2 - 32.7	ND - 96	1380 - 1520
OW-5A	7.7 - 8.0	2.3 - 21.5	ND - 110	1260 - 1670
OW-5B	7.4 - 7.6	3.0 - 35.3	ND - 40	1620 - 1850
OW-6A	7.4 - 7.9	2.3 - 9.4	ND - 125	1770 - 1940
OW-6B	7.2 - 7.3	2.8 - 22.5	ND - 46	1770 - 2800
OW-7A	7.2 - 7.6	1.8 - 2.7	ND - 29	1800 - 2310
OW-7B	7.6 - 7.7	2.1 - 2.4	ND - 23	2080 - 2580
OW-8A	7.6 - 7.9	3.1 - 101	ND - 34	2260 - 2880
OW-8B	7.3	4.6 - 19.6	ND - 28	1770 - 2280
OW-9A	7.5 - 7.8	5.3 - 24.1	ND - 24	1920 - 2480
OW-9B	7.3 - 7.5	4.4 - 5.0	ND - 44	2140 - 3050
OW-10A	7.5 - 8.4	4.0 - 28.5	ND - 70	1260 - 1570
OW-10B	7.4 - 7.8	3.4 - 13.4	ND - 17	1300 - 1580
OW-11A	7.4 - 7.6	3.6 - 12.4	ND	1610 - 1980
OW-11B	7.5 - 7.7	2.4 - 32.7	ND - 23	1580 - 1930
OW-12A	7.4 - 7.5	5.5 - 23.2	ND - 39	1680 - 2240
OW-12B	7.4 - 7.7	3.2 - 13.1	ND - 20	1610 - 2050
OW-13A	11.1 - 11.4	3.3 - 7.5	ND - 38	1830 - 2620
OW-13B	7.3 - 7.4	3.5 - 38.8	ND - 22	1830 - 2940
OW-14A	7.4 - 8.1	2.2 - 7.0	ND - 33	1670 - 1960
OW-14B	7.3 - 7.4	2.2 - 129	ND	1320 - 1550
OW-15A	7.6 - 7.7	2.0 - 2.5	ND - 10	2200 - 2420
OW-15B	7.4 - 7.6	3.0 - 19	ND - 37	1610 - 1900
OW-16A	7.7 - 8.1	2.1 - 25.4	ND - 12	2440 - 2380
OW-16B	7.4	2.4 - 52	ND - 24	1110 - 1320
OW-17A	7.7 - 8.0	2.2 - 37.4	ND	2460 - 2630
OW-17B	7.4 - 7.5	2.6 - 25.1	ND	1500 - 1720
OW-18A	7.6 - 8.3	2.9 - 36.2	ND - 54	1580 - 2410
OW-18B	7.3 - 7.8	5.3 - 37.5	ND	2110 - 3590
A-42	7.1 - 7.3	2.5 - 7.0	ND - 40	1280 - 1680
A-50	7.4 - 7.5	10.4 - 12.4	ND - 25	1720 - 2150
A-52	7.0 - 7.6	6.6 - 7.0	ND - 26	1260 - 1540

TABLE 3-7  
(continued)

Page 2 of 2

Sampling Location <sup>a</sup> (Well No.) <sup>a</sup>	Parameter			
	pH (Standard Units)	Total Organic Carbon (mg/L)	Total Organic Halides ( $\mu$ g/L)	Specific Conductance ( $\mu$ mhos/cm)
BH-5 <sup>c</sup>	11.5 - 11.6	6.2 - 7.6	ND	1200 - 1430
BH-48 <sup>c</sup>	7.4 - 7.9	1.3 - 2.7	ND	3500 - 4720
BH-61	7.4 - 9.4	2.9 - 7.0	ND - 85	957 - 1400

<sup>a</sup>Monitoring well locations are shown in Figure 1-7.

<sup>b</sup>ND - No detectable concentration.

<sup>c</sup>Upgradient well.

TABLE 3-8

RANGES OF CONCENTRATIONS OF METAL IONS DETECTED IN GROUNDWATER AT NFSS, 1989<sup>a</sup>

Page 1 of 4

Parameter (µg/L)	Ranges of Concentrations by Sampling Location (Monitoring Well Number) <sup>b,c</sup>					
	0W-1A	0W-1B	0W-2A	0W-2B	0W-3A	0W-4A
Aluminum	ND	ND	ND	ND	24.6	276
Boron	546-600	112-277	747-824	112-144	462-1010	138-754
Calcium (x 1000)	78.9	77	98.1	144	84.2	104
Chromium	ND	ND	ND	ND	ND	ND
Copper	32.9	ND	ND	ND	ND	ND
Iron	123	117	128	ND	119	148
Potassium (x 1000)	22.7	ND	ND	ND	5.78	ND
Magnesium (x 1000)	79.4	74.8	65.7	89.9	149	188
Manganese	15.4-87.5	46.7-113	21.5-106	75.7-148	41.4-198	23.2-152
Sodium (x 1000)	131	46	134	50.5	120	91.8
Nickel	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND
Zinc	73.3	124	65	41.3	25.3	47
Lead	ND	108	ND	130	178	159
Mercury	ND	0.25	ND	ND	ND	ND

TABLE 3-8

(continued)

Page 2 of 4

Parameter (mg/L)	Ranges of Concentrations by Sampling Location (Monitoring Well Number) <sup>b,c</sup>					
	OW-6B	OW-7A	OW-7B	OW-8A	OW-8B	OW-9A
Alum <sup>2+</sup> ,um	298	211	221	ND	241	252
Boron	130-224	161-233	730-862	202-1050	159	943-1090
Calcium (x 1000)	121	90	101	133	126	172
Chromium	ND	ND	ND	ND	ND	ND
Copper	ND	ND	ND	ND	26.7	ND
Iron	156	122	172	ND	126	179
Potassium (x 1000)	ND	ND	7.2	9.67	ND	10.1
Magnesium (x 1000)	187	146	131	91.2-104	154	84.6
Manganese	101-164	19.5-123	95-154	66.4-156	17.6-20.9	96.3-159
Sodium (x 1000)	57.9	56.6	115	191	53.6	153
Nickel	42.8	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND
Zinc	116	56.2	136	155	134	70.2
Lead	222	188	180	161	190	145
Mercury	ND	ND	ND	ND	ND	ND

TABLE 3-8  
(continued)

Page 3 of 4

Parameter (µg/L)	Ranges of Concentrations by Sampling Location (Monitoring Well Number) <sup>b,c</sup>					
	OW-12A	OW-12B	OW-13A	OW-13B	OW-14A	OW-14B
Aluminum	212	213	ND	223-231	ND	218
Boron	925-1090	117-276	555-661	177-246	578-601	132-391
Calcium (x 1000)	122	120	32.2	151	83.8	82.8
Chromium	ND	24.4	25.9	26.1	25.3	26.3
Copper	ND	109	ND	ND	ND	44
Iron	2540	317	ND	118	266	118
Potassium (x 1000)	9.14	ND	149	ND	6.05	ND
Magnesium (x 1000)	92.4	133	ND	202	83.8	97.9
Manganese	166-256	311-645.8	ND	15.9-31.1	35-122	34-127
Sodium (x 1000)	108	54.2	235	77.7	166	61
Nickel	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND
Zinc	504	81.7	52.5	106	44	96
Lead	104	117	ND	200	ND	102
Mercury	ND	ND	ND	ND	ND	ND
						0.44
						ND
						ND
						302
						702-888

TABLE 3-8

(continued)

Page 4 of 4

TABLE 3-8  
 Ranges of Concentrations by Sampling Location (Monitoring Well Number)<sup>b, c</sup>

Parameter (µg/L)	OW-17B	OW-18A	OW-18B	A-42	BH-5	BH-48 <sup>d</sup>	BH-61
Aluminum	277	263	322	ND	593	229	ND
Boron	154	240-700	175-779	143	279	1770-2540	560-901
Calcium (x 1000)	ND	85.2	111	180	109	484	124
Chromium	ND	25	24.2	14.5	117	12.5	13
Copper	27.2	ND	30.1	ND	ND	ND	ND
Iron	148	147	122	209	ND	255	401
Potassium (x 1000)	ND	ND	7.84	ND	15.4	27.5	9.86
Magnesium (x 1000)	ND	123	156	68.5	ND	94.6	93.9
Manganese	66.8	34.7-183	45-197	198	96.1	632	38.5
Sodium (x 1000)	ND	78.9	179	27.1	54.1	506	183
Nickel	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	183	ND	244	64.1
Zinc	ND	84.5	63.3	291	ND	166	113
Lead	159	168	286	103	ND	137	ND
Mercury	ND	ND	ND	ND	ND	ND	ND

<sup>a</sup> Does not include parameters for which the concentrations were below the limit of sensitivity of the analytical method used.

<sup>b</sup> ND = No detectable concentration. Where only one value is listed, the concentration ranged from ND to the value in the table.

<sup>c</sup> Sampling locations are shown in Figure 1-7.

<sup>d</sup> Upgradient well.

and zinc were found in groundwater at concentrations that approximate those found in groundwater from the upgradient well BH-48. In general, elevated levels of calcium and magnesium, which are common in the area (as evidenced by their concentrations in the upgradient well), reduce the acceptability of groundwater for industrial or residential use. Arsenic, barium, beryllium, cobalt, molybdenum, antimony, and vanadium, which were found in 1988, were not detected in 1989. Lead was not found in 1988 but was detected in many wells, including an upgradient well, in 1989. Mercury was detected in two wells in 1989.

Comparison of the concentrations detected with maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act indicates that water beneath NFSS would require treatment before it could be used as a public drinking water supply. The contaminants present do not exceed MCLs by more than a factor of 20, and some are present at concentrations at or below relevant MCLs. Comparison of downgradient well BH-61 with site wells and with upgradient well BH-48 indicates that NFSS is having no impact on groundwater quality outside the NFSS boundary.

### 3.5 SEDIMENT SAMPLING

During 1989, sediment samples consisting of composites weighing approximately 500 g (1.1 lb) were collected on site and off site at surface water sampling locations 9, 10, 11, 12, and 20 (see Figures 3-2 and 3-3). The rationale for placement of the sampling locations is as stated in Subsection 3.3.

TMA/E analyzed the samples for total uranium and radium-226. The uranium concentration was obtained by summing the results from isotopic uranium analyses. Isotopic uranium was determined by alpha spectrometry, where the uranium has been leached and organically extracted and electroplated on a metal substrate. Radium-226 concentrations were determined by radon emanation (described in Subsection 3.3).

The analytical results (based on dry weight) for total uranium and radium are presented in Table 3-9. The average on-site and

TABLE 3-9  
TOTAL URANIUM AND RADIUM-226 CONCENTRATIONS  
IN NFSS SEDIMENT SAMPLES, 1989

Sampling Location <sup>a</sup>	Number of Samples	Concentration [pCi/g (dry)]			
		Minimum	Maximum	Average	
<u>Uranium</u>					
<u>On Site</u>					
10	2 <sup>b</sup>	3.2	14.5	8.8	
11	3 <sup>c</sup>	1.5	2.5	2.1	
<u>Off Site</u>					
12	3 <sup>c</sup>	1.4	1.5	1.4	
20	2 <sup>b</sup>	1.4	1.6	1.5	
<u>Background</u>					
9	2 <sup>c,d</sup>	2.4	2.8	2.6	
<u>Radium-226</u>					
<u>On Site</u>					
10	2 <sup>b</sup>	0.9	3.0	1.8	
11	3 <sup>c</sup>	0.9	2.8	1.7	
<u>Off Site</u>					
12	3 <sup>c</sup>	0.5	0.9	0.8	
20	2 <sup>b</sup>	0.8	0.8	0.8	
<u>Background</u>					
9	2 <sup>c,d</sup>	1.0	1.0	1.0	

<sup>a</sup>Sampling locations are shown in Figures 3-2 and 3-3.

<sup>b</sup>Location was frozen in the first quarter; no sample taken in the third quarter.

<sup>c</sup>Location was frozen in the first quarter.

<sup>d</sup>Location was established in October 1988 at the South 31 Ditch.

off-site concentrations are approximately the same and probably reflect background concentrations. All measured concentrations are within DOE derived concentration guidelines for soils. (Currently DOE does not have guidelines for radioactivity levels in sediments.)

### 3.6 RADIATION DOSE

To assess the environmental significance of possible release of radionuclides from radioactive materials stored at NFSS, radiological exposure pathways were evaluated to calculate the dose to a hypothetical maximally exposed individual. 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 largest dose. An appraisal of potential pathways (exposure to external gamma radiation, ingestion of water, and inhalation of radon) suggested that exposure to external gamma radiation was the only plausibly significant exposure mode.

The potential dose from ingesting groundwater or surface water from sources on NFSS property was not calculated because it was considered unrealistic to assume that ingestion of this water would occur. NFSS is fenced and locked and security is well maintained, so a member of the public could consume significant volumes of water on the site only by trespassing on the property and consuming water daily. To consume groundwater from a well at NFSS, the member of the public would also have to be equipped with a means of extracting the groundwater, such as a bailer or pump. Given the levels of contamination found in surface water on the site, one would have to drink approximately 36,000 L (9,500 gal) to exceed the DOE radiation protection standard of 100 mrem/yr.

Radon concentrations measured at the boundary of NFSS were within the normal variation associated with background measurements for this area. Consequently, this pathway would not contribute additional exposure to the maximally exposed individual.

### **3.6.1 Dose to the Maximally Exposed Individual**

To identify the individual in the vicinity of NFSS who would receive the highest dose from on-site low-level radioactive materials, potential exposures from external gamma radiation were calculated at various monitoring locations that could be accessible to the public. These exposures were then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points. From these calculations, it was determined that the highest exposure would be received by an individual directly east of the site.

The highest measured radiation level above background, 8 mrem/yr, was recorded at TLD station 20. As shown in Figure 1-5, the area adjacent to this station is used as a sanitary landfill. Exposure to people in this area is therefore conservatively based on a 40-h work week, although it is highly unlikely that a worker would spend this much time near this sampling location. Applying a 40-h/week occupancy factor, the exposure to landfill workers would be a maximum of 2 mrem/yr above background. This exposure is approximately equivalent to 2 percent of the DOE radiation protection standard. This scenario is conservative in that it is highly unlikely that any individual would spend so much time at this location. By comparison, this exposure is less than a person would receive during a one-way flight from New York to Los Angeles from the greater amounts of cosmic radiation at higher altitudes (see Appendix D).

### **3.6.2 Dose to the Population in the Vicinity of NFSS**

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 estimated dose includes contributions from all potential pathways. For NFSS, these pathways are direct exposure to gamma radiation, inhalation of radon, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be measured because gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma exposure rate at a distance of 0.9 m (3 ft) from a small-area radioactive source were 100 mrem/yr, the exposure rate at a distance of 6.4 m (21 ft) from the source would be indistinguishable from naturally occurring background radiation.

Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 10). Therefore, radon exposure does not contribute significantly to population dose.

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

The cumulative dose to the population within an 80-km (50-mi) radius of NFSS 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 NFSS was established to allow an annual assessment of the environmental conditions at the site, provide a historical record for year-to-year comparisons, and permit detection of trends. In the following subsections, 1989 annual averages for each monitoring location for radon, external gamma radiation, and radionuclide concentrations in surface water and groundwater are compared with results for 1985-1988 for the corresponding locations.

In some cases, sampling locations monitored in earlier years no longer exist (because of adjustments in the monitoring program or changes resulting from remedial action). Data from such locations

would not be valid for comparisons or trends and therefore are not reported in the trend tables. Comparisons and trends are based on current monitoring locations; when there are gaps or anomalies in the data reported for these locations in past years, these are footnoted and explained in the tables. As the environmental monitoring program continues at NFSS and more data are collected, comparisons and analyses of trends will become more meaningful.

### **3.7.1 Radon**

As Table 3-10 shows, radon concentrations at the NFSS site boundary measured from 1985 through 1989 are all low, have not fluctuated notably, and approximate background levels for the area.

### **3.7.2 External Gamma Radiation**

As shown in Table 3-11, although there has been some fluctuation, external gamma radiation levels in 1989 were lower than those measured from 1985 through 1988 and are essentially equal to or less than the measured background value.

### **3.7.3 Surface Water**

As shown in Tables 3-12 and 3-13, no trends in total uranium and radium-226 concentrations in surface water are evident from 1985 to 1989. Levels have fluctuated only slightly and remain very low.

### **3.7.4 Groundwater**

As shown in Tables 3-12 and 3-13, there have been no noticeable trends in the concentrations of uranium or radium-226 in groundwater at NFSS. Since the current monitoring wells were installed in 1983, most locations have reported concentrations that have remained basically stable.



TABLE 3-10  
 ANNUAL AVERAGE CONCENTRATIONS OF RADON-222 MEASURED  
 AT NFSS BOUNDARY, 1985-1989<sup>a</sup>

Sampling Station <sup>b</sup>	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>c,d</sup>				
	1985	1986	1987	1988	1989
<u>Site Boundary</u>					
1	0.4	0.3	0.2	0.5	0.4
3	0.5	0.3	0.3	0.2	0.4
4	0.4	0.3	0.4	0.2	0.4
5	0.2	0.3	0.2	0.5	0.7
6	0.4	0.2	0.2	0.4	0.4
7	0.6	0.2	0.3	0.4	0.8
11	0.4	0.4	0.2	0.2	0.4
12	0.4	0.2	0.3	0.3	0.5
13	0.5	0.4	0.1	0.5	0.7
14	0.3	0.8	0.4	0.3	0.5
15	0.3	0.3	0.2	0.3	0.4
20	0.5	0.2	0.2	0.5	0.4
28	0.4	0.3	0.2	0.3	0.5
29	0.6	0.4	0.3	0.3	0.8
32	0.4	0.3	0.3	0.3	0.6
34	0.5	0.3	0.8	0.2	0.5
35	0.3	0.2	0.2	0.5	0.4
36	0.4	0.3	0.2	0.3	0.4
<u>Background</u>					
30 <sup>e</sup>	0.4	0.3	0.3	0.6	1.4
120 <sup>f</sup>	--	--	--	0.5	0.5
121 <sup>g</sup>	--	--	--	0.5	0.4

<sup>a</sup>Data sources for 1985-1988 are the annual site environmental reports for those years (Refs. 10-13).

<sup>b</sup>Locations of sampling stations are shown in Figure 3-1.

<sup>c</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>d</sup>Background has not been subtracted. Note that some stations have concentrations below background.

<sup>e</sup>Located at Seneca St., Lewiston, NY, approximately 6.4 km (4 mi) southwest of NFSS.

<sup>f</sup>Background station established in April 1988 at Pletcher Rd., Lewiston, NY, 1.6 km (1 mi) southwest of NFSS.

<sup>g</sup>Background station established in April 1988 at the intersection of Route 104 and Swain Rd., Lewiston, NY, 1.6 km (1 mi) south of NFSS.

TABLE 3-11  
 ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS  
 AT NFSS, 1985-1989<sup>a</sup>

Page 1 of 2

Sampling Station <sup>b</sup>	Radiation Level (mrem/yr) <sup>c</sup>				
	1985	1986	1987	1988	1989
<u>Site Boundary</u>					
1	18	16	11	11	0d
3	24	4	11	9	0d
4	48	14	13	7	0d
5	24	14	16	22	2
6	21	8	3	16	0d
7	20	8	11	7	2
11	12	4	2	5	0d
12	11	2	6	8	0d
13	14	0d	0d	6	1
14	6	3	7	14	0d
15	3	6	6	14	3
20	65	26	24	23	8
28	14	14	14	10	2
29	14	0d	0d	10	0d
32 <sup>e</sup>	10	6	5	8	0d
34	16	6	8	3	0d
35	16	15	14	14	1
36	6	5	16	10	0d
<u>Background</u>					
30 <sup>f</sup>	91	69	64	71	61
120 <sup>g</sup>	--	--	--	--	83
121 <sup>h</sup>	--	--	--	--	87

<sup>a</sup>Data sources for 1985-1988 are the annual site environmental reports for those years (Refs. 10-13).

<sup>b</sup>Site boundary stations only. Locations of sampling stations are shown in Figure 3-1.

<sup>c</sup>Measured background has been subtracted from readings taken at site boundary stations.

<sup>d</sup>Measurement was equal to or less than measured background value.

<sup>e</sup>Station 32 is a quality control for station 12.

TABLE 3-11  
(continued)

Page 2 of 2

---

<sup>f</sup>Station 30 was established in 1985, approximately 6.4 km (4 mi) southwest of NFSS at Seneca St., Lewiston, NY.

<sup>g</sup>Station 120 was established in April 1988 at Pletcher Rd., Lewiston, NY, approximately 1.6 km (1 mi) southwest of NFSS.

<sup>h</sup>Station 121 was established in April 1989 at the intersection of Route 104 and Swain Rd., Lewiston, NY, approximately 1.6 km (1 mi) south of NFSS.

TABLE 3-12  
ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM  
IN NFSS WATER SAMPLES, 1985-1989<sup>a</sup>

Sampling Location <sup>b</sup>	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>c</sup>				
	1985	1986	1987	1988	1989
<b>Surface Water</b>					
<b>On Site</b>					
10	15	8	6	7	21
11	19	5	14	10	16
<b>Off Site</b>					
12	9	4	5	6	10
20	4	5	6	7	4
<b>Background</b>					
9 <sup>d</sup>	--	--	--	8	9
<b>Groundwater</b>					
<b>On Site</b>					
BH-5	3	<3	<3	<3	7
BH-48 <sup>e</sup>	5	5	4	<3	5
BH-61 <sup>f</sup>	3	<3	<3	3	<3
A-42	62	71	78	55	67
A-50	3	4	4	<3	7
A-52	22	17	18	19	13

<sup>a</sup>Data sources for 1985-1988 are the annual site environmental reports for those years (Refs. 10-13).

<sup>b</sup>Sampling locations are shown in Figures 3-2 and 3-3 (surface water) and 1-7 (groundwater). Sampling locations that have existed in previous years but that no longer exist because of adjustments in the monitoring program or changes caused by remedial action are not reported in trend tables. Data from these locations would not be valid for comparisons or trends.

<sup>c</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>d</sup>Location established in October 1988 at the South 31 Ditch.

<sup>e</sup>Upgradient well.

<sup>f</sup>Downgradient well.

TABLE 3-13  
ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226  
IN NFSS WATER SAMPLES, 1985-1989<sup>a</sup>

Sampling Location <sup>b</sup>	Concentration ( $10^{-9} \mu\text{Ci/ml}$ ) <sup>c</sup>				
	1985	1986	1987	1988	1989
<b>Surface Water</b>					
<b>On Site</b>					
10	0.4	0.2	0.2	0.2	0.6
11	0.7	0.3	1.8	1.0	2.5
<b>Off Site</b>					
12	0.2	0.3	0.3	0.3	0.6
20	0.4	0.4	0.3	1.0	0.5
<b>Background</b>					
9 <sup>d</sup>	--	--	--	0.2	1.5
<b>Groundwater</b>					
<b>On Site</b>					
BH-5	0.5	0.5	0.4	0.3	0.4
BH-48 <sup>e</sup>	0.6	0.5	0.5	0.7	0.7
BH-61 <sup>f</sup>	0.5	0.3	0.3	0.3	0.4
A-42	0.5	0.6	0.2	0.5	0.6
A-50	0.7	0.5	0.3	0.3	0.5
A-52	0.2	0.3	0.2	0.3	0.6

<sup>a</sup>Data sources for 1985-1988 are the annual site environmental reports for those years (Refs. 10-13).

<sup>b</sup>Sampling locations are shown in Figures 3-2 and 3-3 (surface water) and 1-7 (groundwater). Sampling locations that have existed in previous years but that no longer exist due to adjustments in the monitoring program or changes caused by remedial action are not reported in trend tables. Data from these locations would not be valid for comparisons or trends.

<sup>c</sup> $1 \times 10^{-9} \mu\text{Ci/ml}$  is equivalent to 1 pCi/L.

<sup>d</sup>Location established in October 1988 at the South 31 Ditch.

<sup>e</sup>Upgradient well.

<sup>f</sup>Downgradient well.

The uranium concentration in well A-42 has been consistently above that measured in the other wells. This well was installed during the early days of remedial action on the site; a review of historical records indicates that it was drilled in an area that had been radioactively contaminated. An investigation was completed in 1988 in an effort to determine why data for A-42 are atypical. A summary of this effort is presented in Subsection 3.4.

Tables 3-14 and 3-15 give total uranium and radium-226 concentrations in containment monitoring wells in 1987, 1988, and 1989. No trends are evident at this time. As more data are accumulated, trends will be further evaluated.

TABLE 3-14  
ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM  
IN NFSS CONTAINMENT MONITORING WELLS, 1987-1989

Sampling Location <sup>a</sup>	Concentration ( $10^{-9}$ $\mu\text{Ci}/\text{ml}$ ) <sup>b</sup>		
	1987	1988	1989
OW-1A	4	<3	4
OW-1B	4	5	8
OW-2A	3	<3	4
OW-2B	5	8	9
OW-3A	3	4	8
OW-3B	10	14	17
OW-4A	3	<3	3
OW-4B	6	7	7
OW-5A	3	4	4
OW-5B	11	10	12
OW-6A	3	<3	3
OW-6B	15	14	13
OW-7A	8	10	10
OW-7B	3	5	3
OW-8A	3	3	5
OW-8B	17	20	20
OW-9A	3	4	5
OW-9B	14	20	20
OW-10A	5	4	<3
OW-10B	3	6	7
OW-11A	36	28	32
OW-11B	3	4	<3
OW-12A	3	5	7
OW-12B	15	14	10
OW-13A	3	4	<3
OW-13B	14	17	17
OW-14A	4	4	<3
OW-14B	5	7	6
OW-15A	3	4	<3
OW-15B	6	7	14
OW-16A	3	5	3
OW-16B	6	7	11
OW-17A	3	4	4
OW-17B	7	8	8
OW-18A	3	4	5
OW-18B	14	18	19

<sup>a</sup>Sampling locations are shown in Figure 1-7.

<sup>b</sup> $1 \times 10^{-9} \mu\text{Ci}/\text{ml}$  is equivalent to 1 pCi/L.

TABLE 3-15  
 ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226  
 IN NFSS CONTAINMENT MONITORING WELLS, 1987-1989

Sampling Location <sup>a</sup>	Concentration ( $10^{-9}$ $\mu\text{Ci}/\text{ml}$ ) <sup>b</sup>		
	1987	1988	1989
OW-1A	0.4	0.4	0.6
OW-1B	0.2	0.4	0.7
OW-2A	0.2	0.4	0.4
OW-2B	0.2	0.4	0.3
OW-3A	0.1	0.4	0.5
OW-3B	0.1	0.5	0.7
OW-4A	0.2	0.4	0.5
OW-4B	0.2	0.3	0.5
OW-5A	0.2	0.4	0.4
OW-5B	0.2	0.7	0.7
OW-6A	0.2	0.4	0.5
OW-6B	0.2	0.5	0.5
OW-7A	0.2	0.5	1.0
OW-7B	0.2	0.4	0.5
OW-8A	0.2	0.5	0.6
OW-8B	0.2	0.8	0.6
OW-9A	0.2	0.4	0.5
OW-9B	0.2	0.7	0.9
OW-10A	0.3	0.3	0.4
OW-10B	0.2	0.3	0.3
OW-11A	0.2	0.6	0.8
OW-11B	0.1	0.5	0.4
OW-12A	0.2	0.5	0.5
OW-12B	0.2	0.6	0.5
OW-13A	0.2	0.5	0.6
OW-13B	0.2	0.7	0.7
OW-14A	0.2	0.5	0.3
OW-14B	0.5	0.8	1.0
OW-15A	0.3	0.5	0.4
OW-15B	0.2	0.6	0.8
OW-16A	0.2	0.4	0.5
OW-16B	0.2	0.8	0.7
OW-17A	0.2	0.5	0.3
OW-17B	0.2	0.3	0.4
OW-18A	0.3	0.5	0.3
OW-18B	0.4	0.4	0.8

<sup>a</sup>Sampling locations are shown in Figure 1-7.

<sup>b</sup> $1 \times 10^{-9}$   $\mu\text{Ci}/\text{ml}$  is equivalent to 1 pCi/L.

## **4.0 RELATED ACTIVITIES AND SPECIAL STUDIES**

### **4.1 RELATED ACTIVITIES**

**Site maintenance, security, and monitoring continued.**

### **4.2 SPECIAL STUDIES**

**No special studies were performed in 1989.**

## REFERENCES

1. Bechtel National, Inc. Design Report for the Waste Containment Facility at the Niagara Falls Storage Site, DOE/OR/20722-21, Oak Ridge, Tenn., May 1986.
2. Bechtel National, Inc. Geologic Report for the Niagara Falls Storage Site, DOE/OR/20722-8, Oak Ridge, Tenn., June 1984.
3. U. S. Department of Energy. Final Environmental Impact Statement: Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site, DOE/EIS-0109F, Washington, D.C., April 1986.
4. Gale Research Company. Climate of the States, 3rd Edition, Vol. 1, Detroit, Mich., 1985.
5. Battelle Columbus Laboratories. A Comprehensive Characterization and Hazard Assessment of the DOE Niagara Falls Storage Site, BNI-074, Columbus, Ohio, June 1981.
6. Bechtel National, Inc. Letter, R.C. Robertson (BNI) to J.F. Wing (DOE-TSD), "Proposed Revisions to the Environmental Monitoring Program at the New York Sites," CCN 057996, Oak Ridge, Tenn., Dec. 22, 1988.
7. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report - Calendar Year 1982, Report No. 10-05-202-002, Oak Ridge, Tenn., May 1983.
8. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report - Calendar Year 1983, DOE/OR/20722-18, Oak Ridge, Tenn., July 1984.

9. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report - Calendar Year 1984, DOE/OR/20722-55, Oak Ridge, Tenn., July 1985.
10. Bechtel National, Inc. Niagara Falls Storage Site Annual Site Environmental Report - Calendar Year 1985, DOE/OR/20722-98, Oak Ridge, Tenn., April 1986.
11. Bechtel National, Inc. Niagara Falls Storage Site Annual Site Environmental Report - Calendar Year 1986, DOE/OR/20722-150, Oak Ridge, Tenn., June 1987.
12. Bechtel National, Inc. Niagara Falls Storage Site Annual Environmental Report - Calendar Year 1987, DOE/OR/20722-197, Oak Ridge, Tenn., April 1988.
13. Bechtel National, Inc. Niagara Falls Storage Site Annual Site Environmental Report - Calendar Year 1988, DOE/OR/20722-219, Oak Ridge, Tenn., April 1989.
14. Acres American, Incorporated. Hydrologic and Geologic Characterization of the DOE-Niagara Falls Storage Site, prepared for NLO, Incorporated, Buffalo, N.Y., 1981.
15. Bechtel National, Inc. Geotechnical Post-Construction Report, Niagara Falls Storage Site, Lewiston, New York, Vol. 5: Interim Cap Construction, Waste Containment Area Monitoring System and Permeability Testing, May-November 1986, DOE/OR/10-20-202-005, Oak Ridge, Tenn., November 1986.
16. Bechtel National, Inc. Instruction Guide for Well A-42 Investigation, Niagara Falls Storage Site, Lewiston, New York, No. 202-IG-007, December 1988. Issued as an attachment to a letter from R.C. Robertson (BNI) to W.M. Seay (DOE-TSD), Oak Ridge, Tenn., December 22, 1988.

17. U.S. Department of Energy. Order 5400.5, Radiation Protection of the Public and the Environment, February 8, 1990.
18. Eisenbud, M. Environmental Radioactivity. New York: Viking Press, 1987.

**APPENDIX A**  
**QUALITY ASSURANCE**

## QUALITY ASSURANCE

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

QA sampling requirements were ensured through the following:

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

Data management QA was achieved through:

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

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

documented, tracked, and resolved, as verified by the project QA supervisor.

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

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

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

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)		Ratio (TMA/E:EPA) <sup>a</sup>
	EPA	TMA/E	
<u>Alpha</u>			
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
<u>Beta</u>			
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
<u>Ra-226</u>			
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
<u>Ra-228</u>			
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>U (Natural)</u>			
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

<sup>a</sup>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 York). Continued certification hinges upon Weston's ability to pass regular performance evaluation testing.

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

**APPENDIX B**  
**ENVIRONMENTAL STANDARDS AND CONVERSION FACTORS**

## ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr includes exposure from all pathways except medical treatments (Ref. 17). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represent actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Use of such assumptions will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1  
CONVERSION FACTORS

---

1 year	=	8,760 hours
1 L	=	1,000 ml
1 $\mu$ Ci	=	1,000,000 pCi
1 pCi	=	0.000001 $\mu$ Ci
1 pCi/L	=	$10^{-9}$ $\mu$ Ci/ml
1 $\mu$ Ci/ml	=	0.000000001 $\mu$ Ci/ml
$10^{-6}$	=	0.000001
$10^{-7}$	=	0.0000001
$10^{-8}$	=	0.00000001
$10^{-9}$	=	0.000000001
$10^{-10}$	=	0.0000000001
$7 \times 10^{-10}$	=	0.000000007
1 gal	=	3.785 L
1 yd <sup>3</sup>	=	0.765 m <sup>3</sup>
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 <sup>3</sup>	cubic meter
mg	milligram
mg/L	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mrem	millirem
mrem/yr	millirem per year
$\mu$ Ci/ml	microcuries per milliliter
$\mu$ R/h	microroentgens per hour
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
yd <sup>3</sup>	cubic yard
yr	year

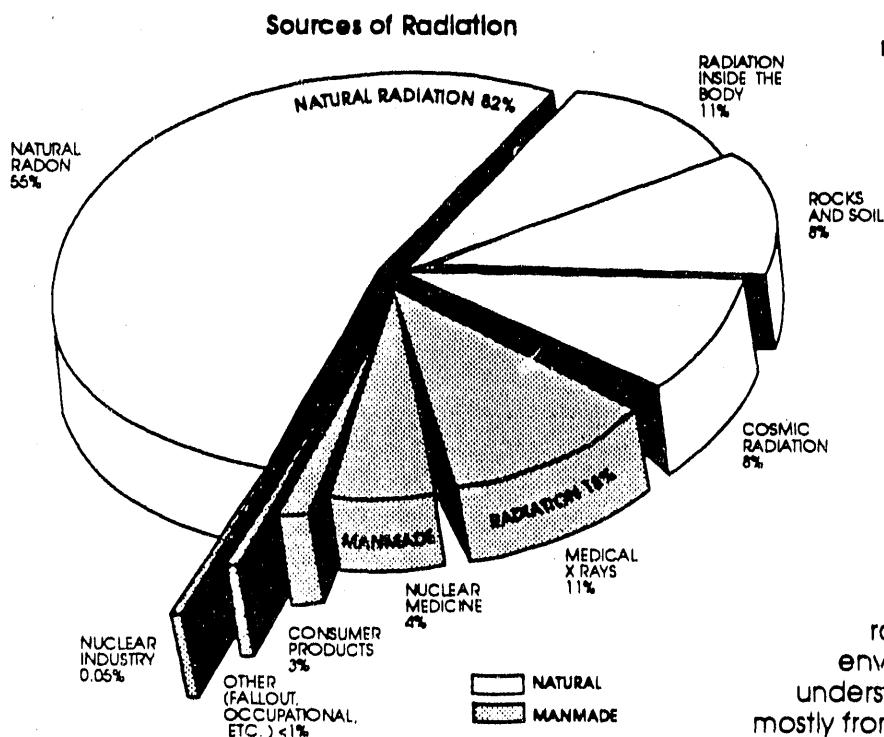
## ACRONYMS

AEC	Atomic Energy Commission
BNI	Bechtel National, Inc.
CLP	Contract Laboratory Program
DOE	Department of Energy
EPA	Environmental Protection Agency
EPDM	ethylene propylene diene monomer
HSL	Hazardous Substances List
IWCF	interim waste containment facility
LOOW	Lake Ontario Ordnance Works
NFSS	Niagara Falls Storage Site
NIST	National Institute of Standards and Technology
NYSDEC	New York State Department of Environmental Conservation
QA	quality assurance
QC	quality control
TLD	thermoluminescent dosimeter
TMA/E	Thermo Analytical/Eberline

**APPENDIX D**  
**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.



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 sieverts. 1 gray (Gy) equals 100 rad. 1 sievert (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.

### 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
McAlpine, 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

### References

Effect of Ionizing Radiation on Human Health, The. Arthur C. Upton. New York University Medical Center. Atomic Industrial Forum, 1984.

Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980. Committee on the Biological Effects of Ionizing Radiation. National Academy Press, 1984.

Ionizing Radiation Exposure of the Population of the United States: Report Number 93. National Council on Radiation Protection and Measurements, 1987.

Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources: Report Number 95. National Council on Radiation Protection and Measurements, 1987.

Radiation in Medicine and Industry. A.P. Jacobson and G.P. Saksiksky, 1980.

Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

## 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

### 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	8,000 mrem/year
(polonium-210) .....	
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

## 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 ( $2.2 \times 10^{12}$ ) 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.

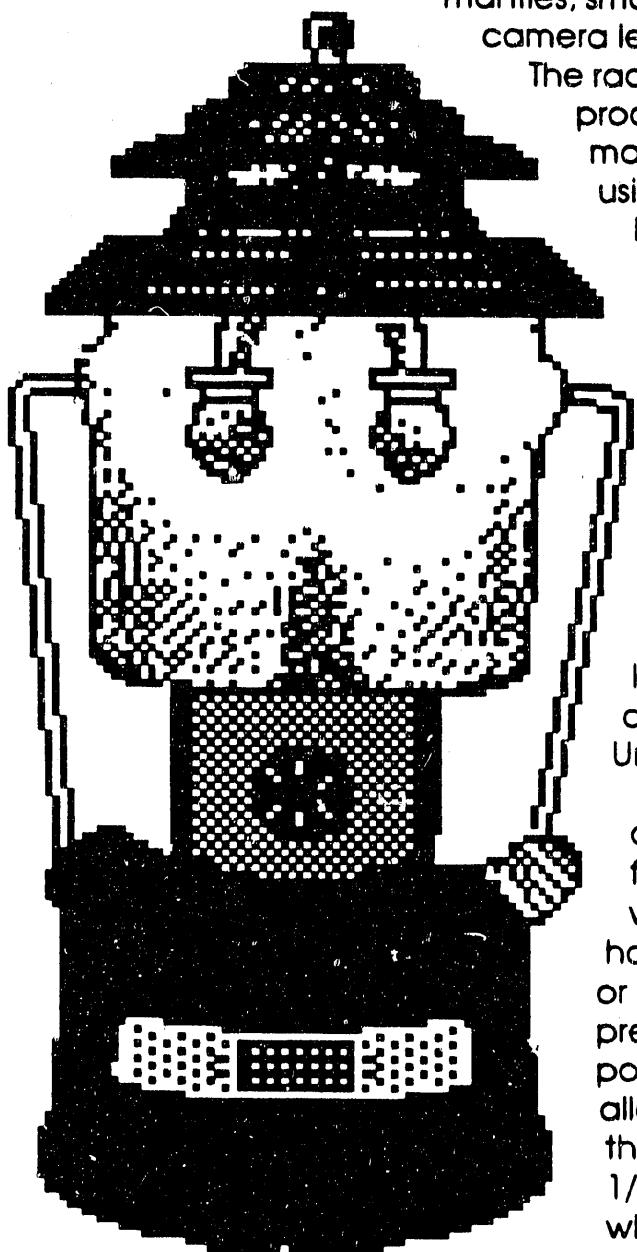
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Cl	$2 \times 10^{12}$ or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	$2 \times 10^9$ or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	$\mu$ Ci	$2 \times 10^6$ or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	$2 \times 10^3$ or 2 Thousand	Annual Home Energy Costs	Consumer Products
1 Picocurie	pCi	2	Cost of a Hamburger and Coke	Background Environmental Levels

## PERSPECTIVE: Radioactivity in Gas Lantern Mantles

### Around the House

Many household products contain a small amount of radioactivity. Examples include gas lantern mantles, smoke detectors, dentures, camera lenses, and anti-static brushes.

The radioactivity is added to the products either specifically to make them work, or as a result of using compounds of elements like thorium and uranium in producing them. The amount of radiation the products gives off is not considered significant. But with today's sensitive equipment, it can be detected.



### Lanterns: In a New Light

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

Under today's standards, the amount of natural radioactivity found in a lantern mantle would require precautions in handling it at many Government or industry sites. The radioactivity present would contaminate 15 pounds of dirt to above allowable levels. This is because the average mantle contains 1/3 of a gram of thorium oxide, which has a specific activity (a measure of radioactivity) of

approximately 100,000 picocuries per gram. The approximately 35,000 picocuries of radioactivity in the mantle would, if thrown onto the ground, be considered low-level radioactive contamination.

**APPENDIX E**  
**SAMPLE WELL CONSTRUCTION LOGS**



## MONITORING WELL

PROJECT

NIAGARA FALLS STORAGE SITE

WELL NO.  
DW-1AJOB NO.  
14501

SITE

WEST OF WASTE CONTAINMENT

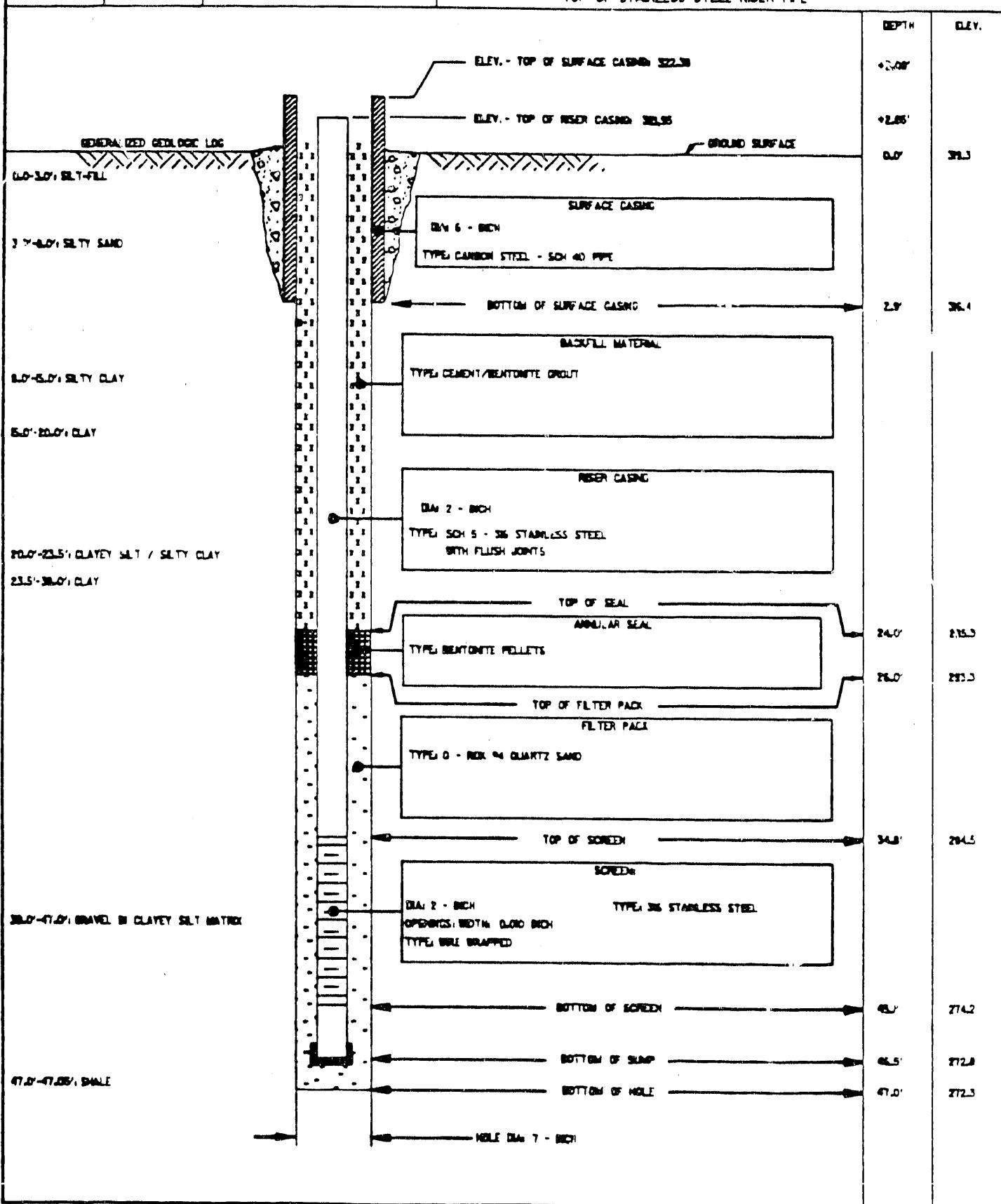
COORDINATES

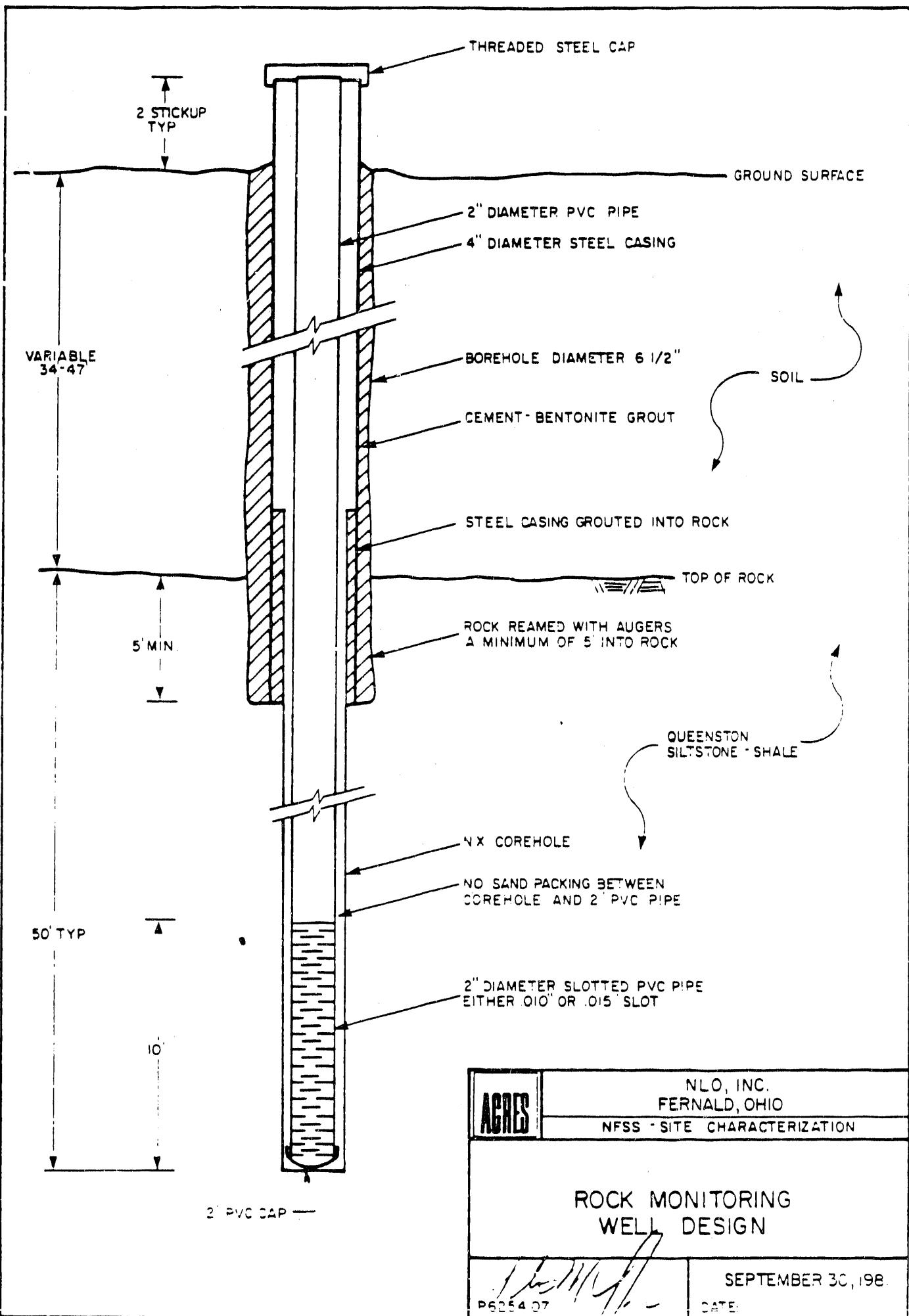
SI44 E006

BEGUN  
9/13/86COMPLETED  
10/21/86PREPARED BY  
A. ATKINSON/D. MIDDLETON

REFERENCE POINT FOR MEASUREMENTS

TOP OF STAINLESS STEEL RISER PIPE







OBSERVATION WELL		PROJECT	WELL NO																					
		FUSRAP/Niagara Falls Storage Site	A-23A																					
JOB NO	SITE	COORDINATES																						
14501	NFSS	S 1700.1 E 374.1																						
BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS																					
2/21/83	3/2/83	D. Middleton	Ground Surface																					
<table border="1"> <thead> <tr> <th>DEPTH</th> <th>ELEV</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>319.9'</td> </tr> <tr> <td>2.8'</td> <td>317.1'</td> </tr> <tr> <td>35.0'</td> <td>284.9'</td> </tr> <tr> <td>40.0'</td> <td>279.9'</td> </tr> <tr> <td>62.1'</td> <td>257.8'</td> </tr> <tr> <td>71.3'</td> <td>248.6'</td> </tr> <tr> <td>76.3'</td> <td>243.6'</td> </tr> <tr> <td>78.5'</td> <td>241.4'</td> </tr> <tr> <td></td> <td></td> </tr> </tbody> </table>					DEPTH	ELEV	0	319.9'	2.8'	317.1'	35.0'	284.9'	40.0'	279.9'	62.1'	257.8'	71.3'	248.6'	76.3'	243.6'	78.5'	241.4'		
DEPTH	ELEV																							
0	319.9'																							
2.8'	317.1'																							
35.0'	284.9'																							
40.0'	279.9'																							
62.1'	257.8'																							
71.3'	248.6'																							
76.3'	243.6'																							
78.5'	241.4'																							

END

DATE FILMED

12/31/90

