Department of Energy
Field Office, Oak Ridge
P.O. Box 2001
Oak Ridge, Tennessee 37831—8723

September 29, 1992

Distribution

SITE ENVIRONMENTAL REPORT - HAZELWOOD INTERIM STORAGE SITE

Enclosed for your information is a copy of the 1991 Site Environmental Report for the U.S. Department of Energy's Hazelwood Interim Storage Site located in your region. This report is prepared and published annually for distribution to interested local, state, and federal agencies and members of the public.

If you have any questions on content of this report or desire additional information, please contact me directly at (615) 576-9634 or by calling toll-free (800) 253-9759.

Sincerely,

David G. Adler, Site Manager
Former Sites Restoration Division

Enclosure

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DOE/OR/21949-340

HAZELWOOD INTERIM STORAGE SITE

ANNUAL ENVIRONMENTAL REPORT

FOR CALENDAR YEAR 1991

HAZELWOOD, MISSOURI

SEPTEMBER 1992

Prepared for

United States Department of Energy

Oak Ridge Field Office

Under Contract No. DE-AC05-91OR21949

By

Bechtel National, Inc.

Oak Ridge, Tennessee

Bechtel Job No. 14501

1.0 INTRODUCTION

Environmental monitoring of the U.S. Department of Energy's (DOE) Hazelwood Interim Storage Site (HISS) and surrounding area began in 1984. This document describes the environmental monitoring program, implementation of the program, monitoring results for 1991, and special occurrences (if any) during 1991 and the first quarter of 1992.

1.1 DOE INVOLVEMENT

HISS was assigned to DOE as part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Development Appropriations Act. DOE placed responsibility for HISS under the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

DOE and the Environmental Protection Agency (EPA) Region VII negotiated a federal facilities agreement (FFA) defining the specific responsibilities and interactions of both agencies regarding DOE's remedial action activities at HISS and the other FUSRAP properties that comprise the St. Louis site (EPA 1990). The final agreement was signed in June 1990.

The FFA states that its intent is to:

- Ensure that the environmental impacts associated with past and present activities at the St. Louis site are thoroughly investigated and that appropriate remedial action is taken as necessary to protect public health or welfare and the environment

- Establish a procedural framework and schedule for developing, implementing, and monitoring appropriate

response actions at the St. Louis site in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Oil and Hazardous Substances Contingency Plan, and Superfund guidance and policy

- Facilitate cooperation, exchange of information, and participation of the parties in such actions

1.2 SITE DESCRIPTION

HISS occupies approximately 2.1 ha (5.3 acres) in eastern Missouri within the City of Hazelwood (St. Louis County) (Figure 1-1). The HISS property includes two office trailers, a decontamination pad, and two interim storage piles. The piles are covered with geotextile material, which is secured with steel cables and a geogrid fabric, and have surface areas of approximately 5,546 and 1,486 m^2 (59,700 and 16,000 ft^2) (Figure 1-2). HISS is currently being used for storage of radioactively contaminated soil from vicinity properties, and no effluents are generated. The site is entirely fenced, and public access is restricted (BNI 1987a).

1.3 SITE HISTORY

In early 1966, uranium ore residues and uranium- and radium-bearing process wastes that had been stored at the St. Louis Airport Site (SLAPS) were purchased by the Continental Mining and Milling Company, Chicago, Illinois. The wastes had been generated by a plant at the St. Louis Downtown Site (SLDS) from 1942 through 1957 under contract with the Atomic Energy Commission and its predecessor, the Manhattan Engineer District. The wastes were moved to a storage site at 9200 Latty Avenue, a part of which is the present-day HISS. The Commercial Discount Corporation of Chicago, Illinois, purchased the residues in January 1967; much of the material was then dried and shipped to the Cotter Corporation facilities in Canon City, Colorado. The source material remaining

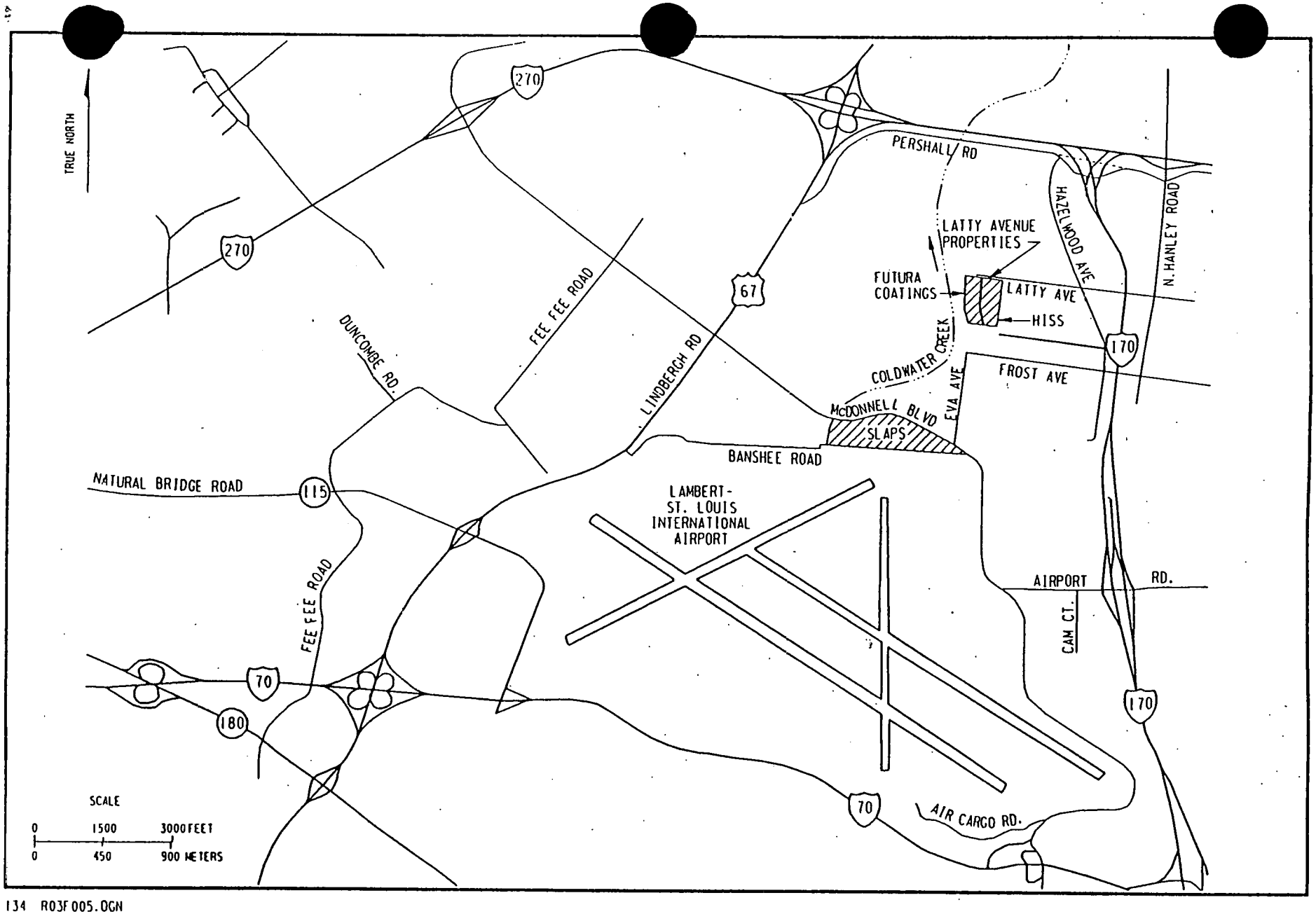

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Figure 1-1
Location of HISS

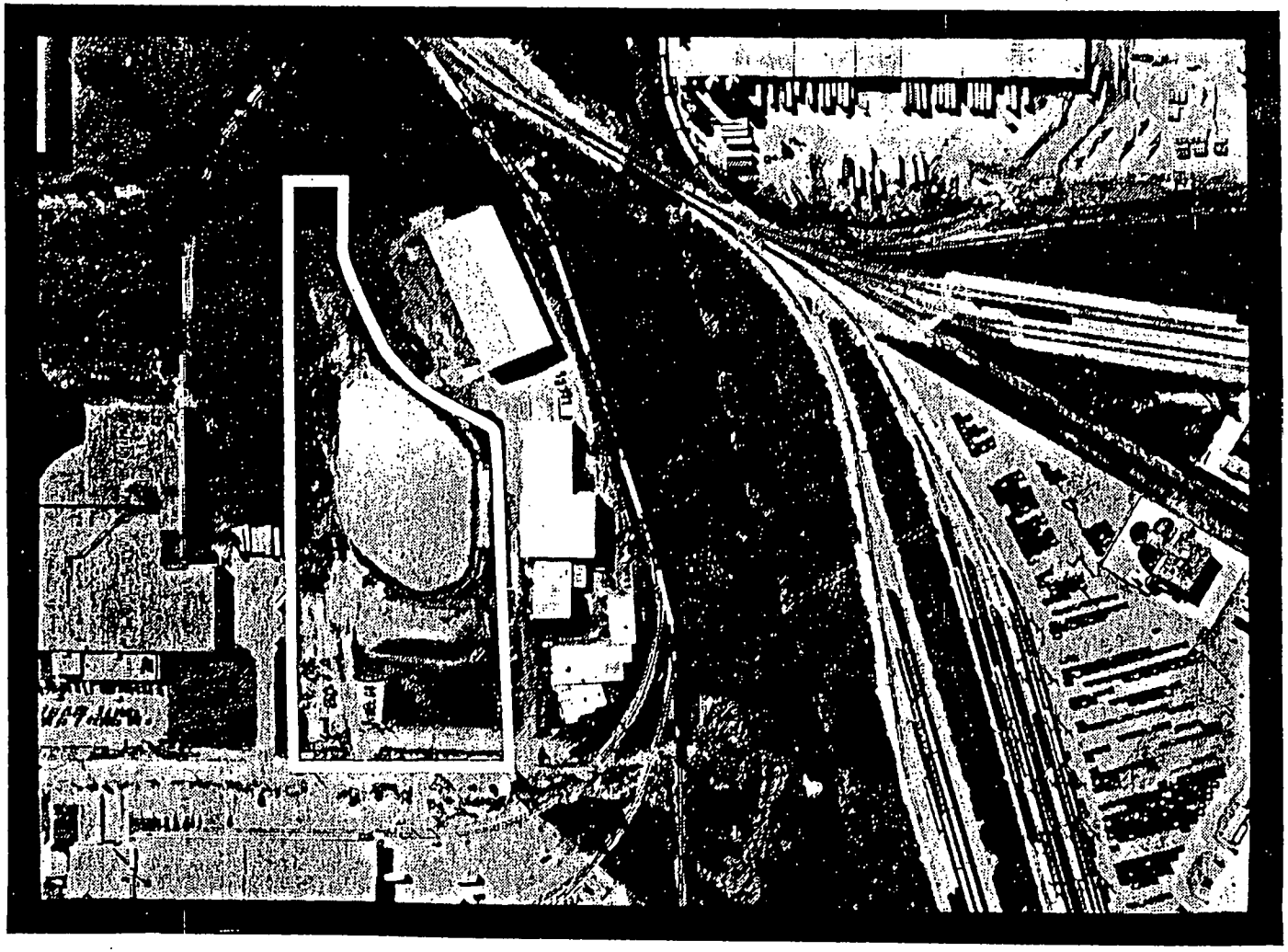


Figure 1-2
Aerial View of HISS and Its Vicinity

at 9200 Latty Avenue was sold to the Cotter Corporation in December 1969. From August through November 1970, Cotter Corporation dried some of the remaining residues at the site and shipped them to its mill in Canon City.

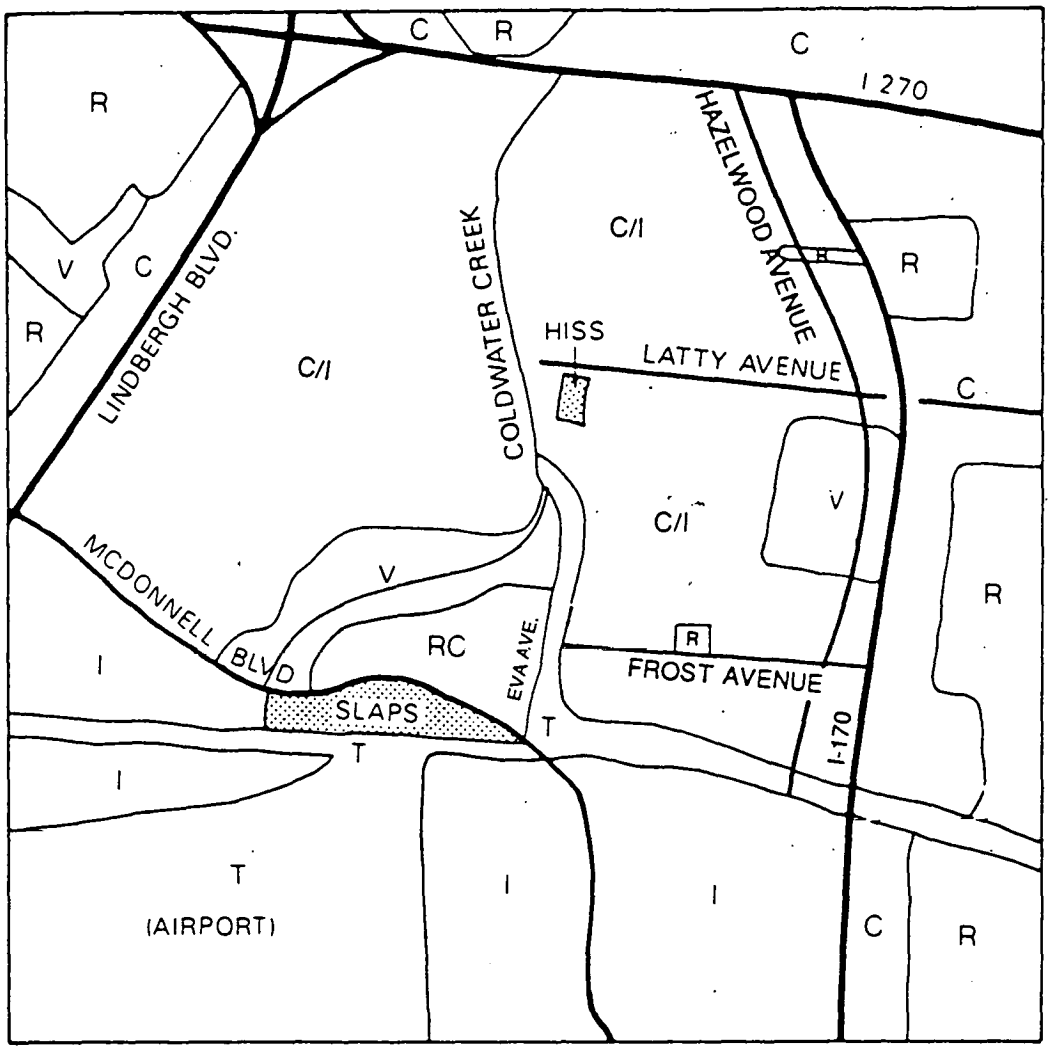
In April 1974, the newly established Nuclear Regulatory Commission (NRC) was informed by the Cotter Corporation that the remaining Colorado raffinate had been shipped in mid-1973 to Canon City without drying and that the barium sulfate residues had been diluted with site soil and transported, without NRC consent, to a landfill area in St. Louis County. Reportedly, 30.5 to 45.7 cm (12 to 18 in.) of topsoil had been removed with the residues. An NRC license for storage was terminated, and the property was released for sale.

The site currently contains two piles of contaminated soils that will be held in interim storage until a suitable disposal site is selected. The piles were generated as a result of a partial cleanup of the site in 1977 and from roadway improvements along Latty Avenue in 1986. The piles contain, in total, approximately 24,500 m^3 (32,000 yd^3) of soil and are covered with low-permeability liners.

1.4 LAND USE

As shown in Figure 1-3, land use in the vicinity of HISS is predominantly industrial and commercial. The site is bordered by manufacturing companies to the north and west, a wooded area and Coldwater Creek to the south, and a warehouse to the east.

The principal source of potable water in the HISS area is treated water from the Mississippi River; approximately 100 percent of the City of Hazelwood uses this source. Water to be treated for public use is taken from the Mississippi River approximately 32 km (20 mi) downstream of HISS (Chain-of-Rocks Water Treatment Facility). Coldwater Creek (not used as a source of drinking water) empties into the Missouri River, which discharges into the Mississippi River. The nearest potable surface water supply facilities on the Missouri River are Central Plant and Howard Bend Plant.



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

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

0 0.5 MI
0 0.8 KM

N

Figure 1-3
Generalized Land Use in the Vicinity of HISS

The nearest residential areas are approximately 0.5 km (0.3 mi) east of HISS in Hazelwood (population 12,800) and 0.8 km (0.5 mi) south in Berkeley (population 20,300). The residences are primarily single-family dwellings. The total population of the area within an 80-km (50-mi) radius of HISS is approximately 2.5 million.

1.5 CLIMATE

Table 1-1 is a summary of climatological data from the National Oceanic and Atmospheric Administration (NOAA) at the Lambert-St. Louis International Airport for 1991. This data is considered representative of HISS because of the proximity of the site to the airport. Temperature extremes during 1991 ranged from -18 to 38.9°C (8 to 102°F). Monthly average wind speeds ranged from 5 to 19 km/h (7.6 to 12.4 mph), and the predominant wind direction was from the southwest. Meteorological events that could have affected monitoring results were the high precipitation during the fourth quarter and periods of low precipitation in the first, second, and third quarters. Precipitation totals for October exceeded normal October precipitation by 8.6 cm (3.38 in.), and 2.6 cm (1.01 in.) of this precipitation fell in a 20-minute period. Precipitation for February, June, and August was 2.9 cm (1.16 in.), 8.4 cm (3.29 in.), and 4.0 cm (1.57 in.), respectively, which is below normal.

Table 1-1

Summary of Climatological Data for the St. Louis Vicinity, 1991

Month	Temperature (°F) Min	Max	Avg	Total Precip (in.)	Wind Avg Speed (mph)	Resultant Direction
January	10	49	29.3	1.52	9.1	WNW
February	8	73	41.7	0.98	10.6	W
March	24	87	50.1	3.2	12.4	SW
April	39	85	61.5	3.27	10.3	SSE
May	47	93	73.0	3.87	9.1	S
June	61	97	79.9	0.44	8.2	SSE
July	60	100	80.9	5.18	8.5	SW
August	59	102	79.7	0.98	7.6	SE
September	41	97	72.4	2.98	8.2	SSW
October	35	85	60.5	5.70	9.9	SSW
November	8	75	42.4	3.26	11.6	SW
December	10	74	39.2	2.10	9.8	WSW

Source: NOAA 1992.

2.0 SUMMARY OF ENVIRONMENTAL COMPLIANCE

The primary regulatory guidelines and limits are given in the DOE orders and are authorized by six federal acts: the Clean Air Act (CAA); the Clean Water Act (CWA); the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); CERCLA; and the National Environmental Policy Act (NEPA). The following summaries describe compliance requirements as they existed in 1991, as well as anticipated regulatory requirements that may affect the site in the future.

2.1 PRIMARY REGULATORY GUIDELINES

DOE Orders for Radionuclide Releases

Site releases must comply with specific DOE orders [5400 series and DOE Order 5820.2A, "Radioactive Waste Management" (DOE 1988a)] that establish quantitative limits, derived concentration guides (DCGs), and dose limits for radiological releases from DOE facilities. The applicable guidelines and dose limits are presented in Appendix A. DOE orders are treated as legal requirements, and releases of source, special nuclear, or by-product material in compliance with DOE orders at DOE facilities are considered "federally permitted actions" (54 FR 22524).

A review of environmental monitoring results for calendar year 1991 shows that 6 out of 20 thorium-230 sediment samples were not in compliance with DOE guidelines. Detailed monitoring results for radionuclides are presented in Section 4.0.

On March 27, 1991, an incident occurred at HISS that was classified by DOE as an unusual occurrence. High winds in excess of 100 km/h (70 mph) tore and removed a 30- by 60-m (100- by 200-ft) section of the pile cover, resulting in a small amount of soil being blown from the pile. To comply with DOE Order 5400.1 ["General Environmental Protection Program" (DOE 1988b)] and DOE Order 5000.3A ["Unusual Occurrence Reporting" (DOE 1990c)], the National Response Center and state and local engineering response

agencies were notified of the incidence. Results of subsequent surveys and sampling indicate that no significant soil deposition downwind of the site had occurred (DOE 1991).

Clean Air Act and National Emission Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA. The only potential sources of air emissions from HISS are radionuclide emissions from the waste piles and the remainder of the site. To date, HISS is not required to have any state or federal air permits. Subparts H and Q of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) are applicable (DOE 1990a).

A strategy for determining compliance with the radon flux standard in Subpart Q was approved by EPA in 1990, and compliance with the EPA-approved strategy was attained and maintained in 1991. Radon flux rates measured to demonstrate compliance with Subpart Q are provided in Subsection 4.1.1. A waiver from compliance with the radon emission standard for all short-term remedial action activities at HISS has been granted by the regional EPA office.

Radionuclide emissions (excluding radon) from the HISS storage piles and the remainder of the site have been modeled and the effective dose to members of the public has been calculated for calendar year 1991 using the EPA-approved AIRDOS computer model (Version 3.0), as required by Subpart H of NESHAPs. As Subsection 4.3 of this document shows, radionuclide emissions were in compliance with applicable regulations in 1991.

Clean Water Act

Pollutants discharged to waters of the United States are regulated under the federal CWA.

Missouri Department of Natural Resources (MDNR) regulates stormwater discharges under its state-authorized National Pollutant Discharge Elimination System (NPDES) permit program. Stormwater

converges at two outfalls at HISS (Figure 2-1) and is conveyed to Coldwater Creek. An NPDES permit (No. MO-0111252) was issued for HISS on December 28, 1990, requiring monthly effluent monitoring and quarterly reporting of the results. Monitoring parameters and requirements are listed in Table 2-1. The permit expired on December 31, 1991, and a renewal application was submitted as required, 180 days before the date of expiration. The renewal is pending, and HISS will continue operating under its existing permit until a new permit is issued.

In August 1991, the provisions of 40 CFR 122 were incorporated into the state regulations. The permit renewal application for HISS had already been submitted. On August 28, 1991, MDNR conducted an inspection at HISS of its stormwater discharge to determine compliance with the permit. On October 27, 1991, DOE met with MDNR to discuss their findings and develop a strategy for bringing the site into compliance. As a result, an engineering design was produced to improve the consistency, completeness, and representativeness of stormwater samples. The design consisted of the construction of berms to direct the stormwater runoff into concrete flumes where a bubble flowmeter was installed with a data logger to record the flow of runoff. All instances of noncompliance identified in the October 27, 1991, meeting have been resolved.

Resource Conservation and Recovery Act

RCRA is the principal federal statute governing the management of hazardous waste and radioactive mixed waste that contains hazardous constituents. Missouri is authorized to implement the RCRA program.

Results from past characterization studies indicate that neither RCRA-regulated wastes nor radioactive wastes containing RCRA-regulated wastes are present at HISS.

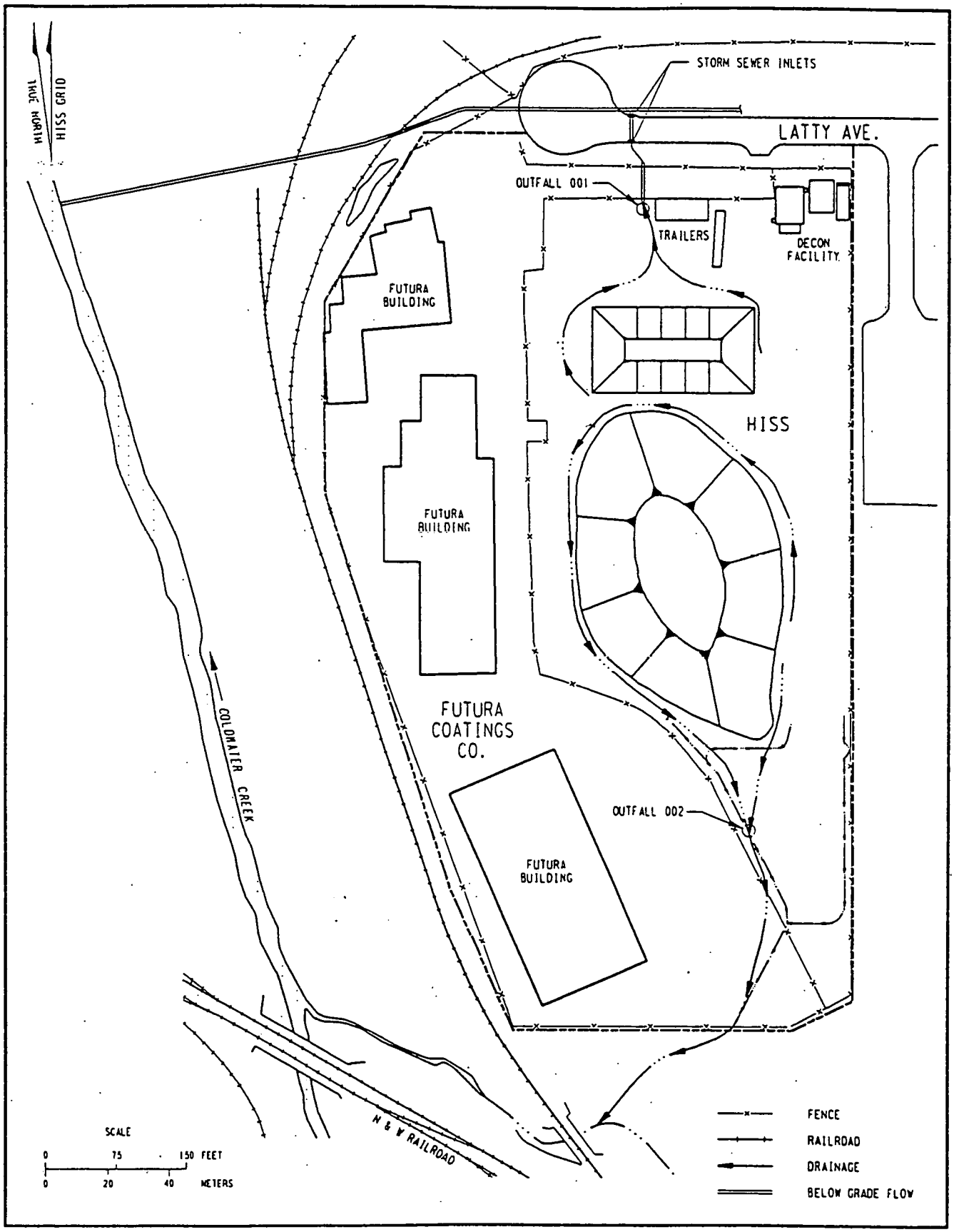


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Figure 2-1
Map Showing Locations of NPDES Outfalls 001 and 002 at HISS

Table 2-1

Monitoring Requirements for NPDES Permit (No. MO-0111252) for Outfalls 001 and 002 at HISS

Parameter[a]	Units[b]
Flow - m^3/day	MGD
Settleable solids	ml/L/h
pH	SU
Dissolved oxygen	mg/L
Temperature	°F
Specific conductivity	µmhos/cm
Total organic carbon	mg/L
Total organic halides	mg/L
Gross alpha	pCi/L
Gross beta	pCi/L
Lead-210	pCi/L
Total radium	pCi/L
Radium-226	pCi/L
Radium-228	pCi/L
Total uranium	pCi/L
Thorium-230	pCi/L
Thorium-232	pCi/L

[a]The final effluent limitations for settleable solids are 1.5 ml/L/h (daily maximum) and 1.0 ml/L/h (monthly average). The limitation for pH is a set range from 6.0 to 9.0. All other parameters are monitoring requirements only.

[b]MGD = millions of gallons per day; SU = standard units.

Toxic Substances Control Act

The most common toxic substances regulated by TSCA are polychlorinated biphenyls (PCBs) and asbestos. HISS contains only uranium ore residues and uranium- and radium-bearing process wastes. TSCA-regulated waste has not been detected at HISS.

Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA is the primary source of statutory authority for the response actions to be conducted at HISS. Because HISS is on the National Priorities List (NPL), an FFA is required for site remedial action. EPA and DOE signed an FFA on June 26, 1990, that integrates all response actions at the HISS/Futura Coatings, Inc. site, as well as at other FUSRAP properties that comprise the St. Louis site including SLAPS, SLDS, and vicinity properties.

The FFA integrates the provisions of CERCLA with other applicable and relevant laws. Specifically, the parties to the FFA agreed that activities covered by the agreement will achieve compliance with CERCLA and will meet or exceed applicable or relevant and appropriate requirements. Compliance with CERCLA during remediation of the St. Louis site is ensured by regular interactions with EPA Region VII.

National Environmental Policy Act

Remedial action at HISS will be conducted under an integrated CERCLA/NEPA process. Information on this process is provided in Subsection 2.3.

Other Major Environmental Statutes and Executive Orders

In addition to the aforementioned DOE orders and statutes, several other major environmental statutes have been reviewed for applicability. For example, the Federal Insecticide, Fungicide, and Rodenticide Act; the Endangered Species Act; the Safe Drinking

Water Act; and the National Historic Preservation Act have all been found to impose no current requirements on HISS. In addition, Executive Orders 11988 ("Floodplain Management") and 11990 ("Protection of Wetlands") and state laws and regulations have been reviewed for applicability and compliance. Except for Executive Order 11988, HISS is in compliance with all applicable environmental statutes, regulations, and executive orders.

2.2 APPLICABLE ENVIRONMENTAL PERMITS

The floodplain assessment in the engineering evaluation/cost analysis-environmental assessment (EE/CA-EA) identified the floodplain ordinance in the Hazelwood City code as a requirement. According to CERCLA, a floodplain building permit is not required, but the substantive requirements of a permit must be met. A self-inspection was conducted, and in September 1991, site engineers met with the City of Hazelwood Public Works Department. Several conditions at the site did not comply with the substantive requirements of the code [e.g., the site trailer is 0.3 m (1 ft) below the elevation specified in the floodplain ordinance] but are being corrected.

2.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS

Completion of an environmental impact statement (EIS) is required as part of the overall effort for the St. Louis FUSRAP properties on the NPL. Compliance with NEPA for site remedial actions will be accomplished by incorporating those elements required by an EIS into the format of the CERCLA remedial investigation/feasibility study (RI/FS) (currently being developed) to produce an RI/FS-EIS for the St. Louis site. This document is scheduled for completion in fiscal year 1994.

In June 1991, an EE/CA that assesses CERCLA waste removal alternatives for the HISS/SLAPS vicinity properties was submitted to DOE-Headquarters for approval. An EA, for NEPA purposes, was integrated into the EE/CA to produce an EE/CA-EA of a proposed plan

to store contaminated soil from the vicinity properties at HISS. The EE/CA-EA was approved by DOE-Headquarters in March 1992 and was issued in April for public review.

2.4 SUMMARY OF REGULATORY COMPLIANCE IN CALENDAR YEAR 1992 (FIRST QUARTER)

During the first quarter of 1992, environmental monitoring continued, as did review of potentially applicable federal and state regulations. HISS is not in full regulatory compliance with all applicable laws and regulations. A Hazelwood City ordinance prohibits certain structures below the 100-yr flood elevation, and the site trailer at HISS is 0.3 m (1 ft) below this elevation. Options for bringing the trailer into compliance are being examined.

On February 21, 1992, MDNR issued a new stormwater discharge permit for HISS. The new permit requires quarterly sampling of chemical and radioactive contaminants, daily measurement of rainfall and flow rates, and monthly measurement of settleable solids (dependent on precipitation). The monitoring results are to be reported quarterly; the first report was due on April 28, 1992.

Two major documents received approval from EPA in the first quarter of 1992: the work plan for the St. Louis site (in January) and the remedial investigation report (in March). In addition, the EE/CA-EA for the vicinity property removal action was released by DOE-Headquarters for public comment from April 8, 1992, to May 8, 1992.

3.0 ENVIRONMENTAL PROGRAM INFORMATION

Routine monitoring for radiation, radioactive materials, and chemical substances at HISS is used to document compliance with appropriate standards, provide the public with information, provide a historical record for year-to-year comparisons, and identify environmental impacts. The environmental monitoring program assists in fulfilling the DOE policy of protecting public health and the environment and mitigating environmental impacts.

The objectives of this report are to:

- Describe efforts to control stored pollutants until future remediation
- Describe the environmental monitoring program for the site
- Report the radiological and nonradiological conditions of the site and surrounding areas during 1991
- Provide comparison of monitoring results and applicable regulations (Appendix A)
- Provide trend analyses, where applicable, to indicate increases or decreases in environmental impact

To ensure that the environmental monitoring data are of sufficient quality to meet these objectives, all personnel involved in sampling are trained in site-specific requirements and sampling techniques. This training is conducted before each sampling event begins and is followed up by a "lessons learned" analysis after sampling is completed. The environmental monitoring group supervisor is responsible for ensuring that all Oak Ridge support staff and site support personnel are trained.

The primary audience for the environmental monitoring results may include the general public; property owners; community interest groups; technical staffs of federal, state, and local government agencies; and regulatory personnel.

3.1 SUMMARY OF ENVIRONMENTAL MONITORING PROGRAM

3.1.1 Environmental Monitoring Requirements

Requirements for environmental monitoring of radioactive materials are found in the DOE orders dealing with radiation protection of the public and the environment. These requirements include the monitoring of radionuclides in groundwater, surface water, and sediment at all DOE sites. Requirements for environmental monitoring of airborne pollutants (radon and other radionuclides) are found in NESHAPs. Radon monitoring was conducted at the HISS property boundary to ensure compliance with DOE orders.

Requirements for environmental monitoring of nonradiological parameters are found in DOE Order 5400.1 (DOE 1988b). Nonradiological parameters were monitored to obtain baseline information on groundwater quality.

3.1.2 Monitoring Networks

The environmental monitoring networks at HISS are as follows:

- All radon and external gamma radiation exposure monitoring stations, except background stations, are onsite and only accessible to employees and authorized visitors. For purposes of this report, because site security includes the Futura Coatings property, the boundary of HISS was extended to include this area. Therefore, onsite monitoring stations are actually located on the boundary line between HISS and Futura.

- Background stations are located offsite in areas known to be uncontaminated; measured background values are compared with site values to determine compliance with DOE orders.

Details on the monitoring networks (including locations) are provided in Sections 4.0 and 5.0.

3.2 SUMMARY OF SPECIAL ENVIRONMENTAL ACTIVITIES

There were no special studies conducted at HISS in 1991. Environmental activities consisted of routine environmental monitoring for radionuclides in sediment, surface water, and groundwater; external gamma radiation and radon levels; and the indicator parameters total organic carbon (TOC), total organic halides (TOX), specific conductivity, and pH.

3.3 SELF-ASSESSMENTS

Two major self-assessments were conducted at HISS in 1991. In August the Oak Ridge National Laboratory conducted an environmental compliance assessment; the only finding was considered a minor deficiency related to the Missouri NPDES permit. In October Bechtel National, Inc. (BNI), the project management contractor for FUSRAP, conducted a quality assurance assessment and found three problems, none of which were severe enough to warrant a formal written audit finding; these problems have been corrected.

An action remaining open from 1990 assessments was to develop environmental monitoring plans [required by DOE Order 5400.1 (DOE 1988b)] to document the rationale for the environmental monitoring networks at FUSRAP sites. The plans were published in November 1991.

Any deficiencies identified in self-assessments are processed through the corrective action process established by BNI. Depending on the nature of the deficiency, a corrective action request, nonconformance report, or observation report is used to document the deficiency and begin the corrective action process. The method of identification, documentation, and final corrective action enables the information to be retained and improvements incorporated into the program.

4.0 RADIOLOGICAL ENVIRONMENTAL PROGRAM

HISS is not an active site and produces no waste material; thus, the only possibility for contamination to be released from the site would be through contaminant migration.

Radiological environmental monitoring at HISS in 1991 included sampling for:

- Radon concentrations in air
- External gamma radiation exposure
- Total uranium, radium-226, and thorium-230 concentrations in surface water, sediment, and groundwater

The monitoring systems included onsite, property-line, and offsite stations to provide sufficient information on the potential effects of the site on human health and the environment. The analytical methods performed on each matrix are presented in Appendix B.

This section of the report contains the quarterly radiological data for each sampling point, yearly averages, and trend information. The methodology for calculating the averages and standard deviations is provided in Appendix C. All quarterly data are reported as received from the laboratory; however, the averages and expected ranges are reported using the smallest number of significant figures from the quarterly data (e.g., 3.2 and 32 both have two significant figures). Where appropriate, data are presented using powers of ten (e.g., $0.32 = 3.2 \times 10^{-1}$).

Some of the quarterly results are reported using a "less than" (<) sign. This 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. For computing annual averages, quarterly values reported as less than a given limit of sensitivity are considered equal to that limit.

The following subsections discuss the radiological monitoring program, results for 1991, and any possible radioactive contaminant migration indicated by the results. Concentration trends are also shown in graphical representations, which include up to six of the

highest values for each analyte and matrix sampled during the past five years. The scales for these graphs are set to a percentage of the appropriate guideline based on the values of the samples to ensure maximum resolution. Background values are also displayed when appropriate.

4.1 ENVIRONMENTAL MONITORING FOR RADIOACTIVE CONTAMINANTS

4.1.1 Radon Monitoring

One pathway of radiation exposure from the uranium-238 decay series arises from inhalation of the short-lived radionuclides, radon and radon daughter products. Radon is an alpha-particle-emitting gas that is very mobile in air. Radon monitoring was conducted at HISS to assess the impacts of the contaminants at the site on radon levels near the site and to ensure compliance with environmental regulations.

Data and discussion

The maximum quarterly ambient air radon level detected was 1.1×10^{-9} μCi/ml (0.04 Bq/L), at locations 2, 4, and 8 (Figure 4-1); annual average concentrations at the site ranged from 0.4×10^{-9} to 0.8×10^{-9} μCi/ml (0.01 to 0.03 Bq/L) (see Table 4-1). No annual average was greater than 30 percent of the DOE guideline of 3.0×10^{-9} μCi/ml.

Monitoring results (DOE 1991a) demonstrate that the larger (main storage) pile had an average radon flux rate of 6.21 pCi/m^2/s (0.23 Bq/m^2/s) and minimum and maximum values of 0.1 and 107 pCi/m^2/s (0.004 and 4.0 Bq/m^2/s), respectively. The smaller (supplementary storage) pile had an average flux rate of 0.305 pCi/m^2/s (0.011 Bq/m^2/s) and minimum and maximum values of 0.3 and 0.4 pCi/m^2/s (0.011 and 0.015 Bq/m^2/s), respectively. Both piles were in compliance with the limit of 20 pCi/m^2/s (an averaged value) specified in 40 CFR Part 61 Subpart Q. The elevated readings are thought to be in areas of weakness in the pile cover;

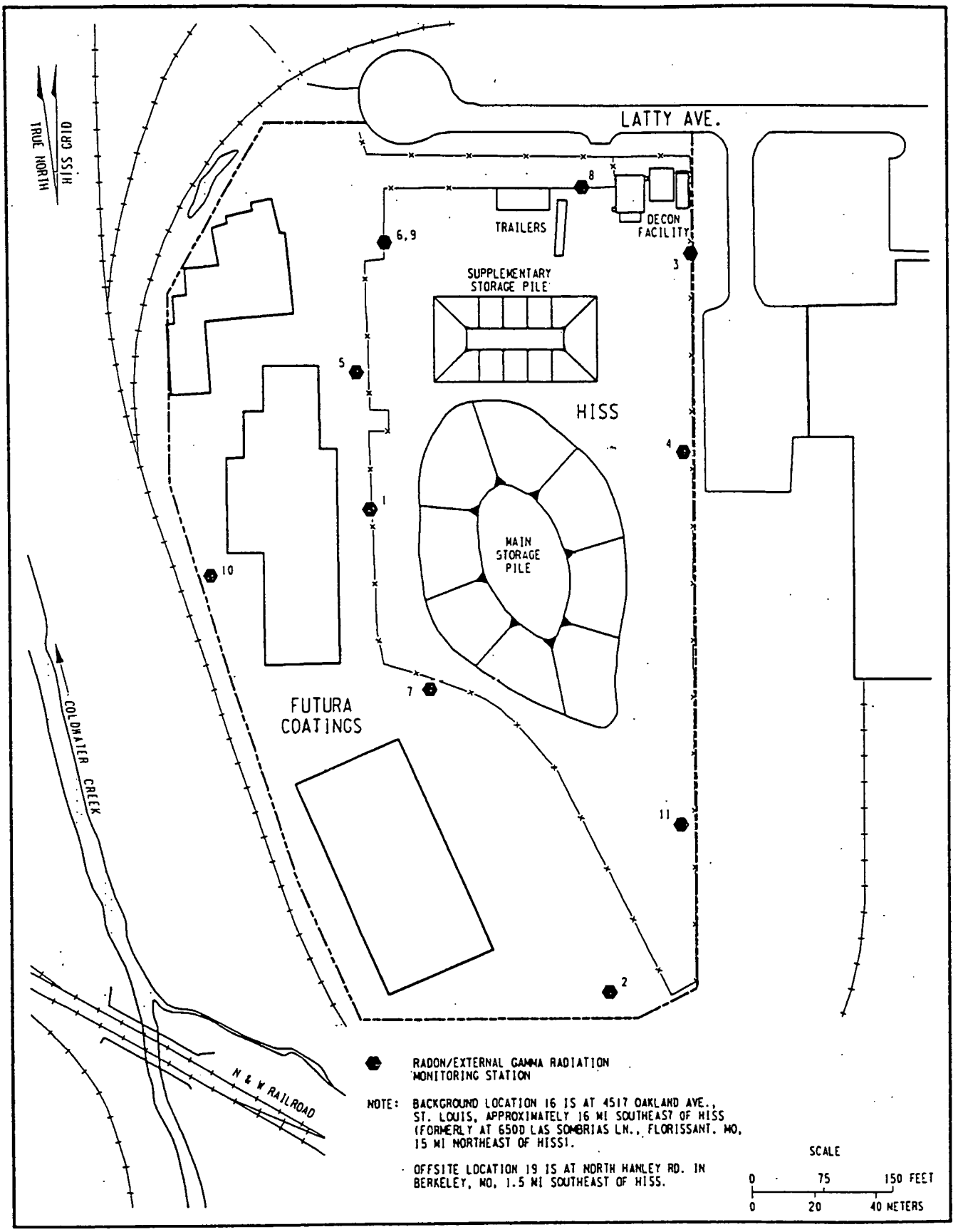

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Figure 4-1
Radon and External Gamma Radiation
Monitoring Locations at HISS

Table 4-1

Average Concentrations[a,b] of Radon at HISS, 1991

Sampling Location[c]	Quarter 1	2	3	4	Avg
(Concentrations are in 10^{-9} µCi/ml)					
Property Line					
2	1.1	<0.4	0.9	0.9	0.8
3	0.3	<0.4	<0.3	0.4	0.4
4	0.7	0.4	1.1	0.8	0.8
10	0.4	<0.4	<0.3	<0.3	0.4
11	0.6	<0.4	0.6	0.6	0.6
Onsite					
1	0.7	<0.4	0.4	<0.3	0.5
5	0.7	<0.4	0.4	0.6	0.5
6	0.7	<0.4	0.7	0.4	0.6
7	0.6	<0.4	<0.3	0.4	0.4
8	0.9	<0.4	1.1	<0.3	0.7
Quality Control					
9[d]	0.6	<0.4	<0.3	0.5	0.5
Background					
16[e]	0.9	0.4	<0.3	<0.3	0.5
19[f]	0.7	<0.4	0.5	<0.3	0.5

[a] 1×10^{-9} µCi/ml is equivalent to 0.037 Bq/L. The DOE guideline is 3.0×10^{-9} µCi/ml.

[b] Background level has not been subtracted from property-line and onsite readings.
Note: Concentrations at some stations were below the background level.

[c] Sampling locations are shown in Figure 4-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[d] Quality control for station 6.

[e] Located at 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS.

[f] Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS.

a program was developed to identify and repair these areas. The northern portion of the pile was patched with Hypalon (a geotextile covering) to reduce radon flux and then covered with a geogrid and anchored with steel cables to prevent wind from damaging and/or lifting the cover above its contents.

Trends

Trends for concentrations of radon in air measured from 1986 through 1991 are presented in Table 4-2 and shown in Figure 4-2. All annual average radon concentrations for 1991 fell within the expected value ranges and were comparable to background concentrations. This is a good indication that there is no upward trend in radon concentrations at HISS, which is to be expected because there have been no recent activities that would disturb the source of the radon.

4.1.2 External Gamma Radiation Exposure Monitoring

External gamma radiation exposure rates were measured as part of the routine environmental monitoring program to confirm that gamma radiation exposures from HISS were not significantly above natural background rates and to ensure compliance with environmental regulations.

Although the tissue-equivalent thermoluminescent dosimeters used for monitoring are state-of-the-art, the dosimeter accuracy is approximately ±10 percent at radiation exposure rates between 100 and 1,000 mR/yr and ±25 percent at rates between 0 and 70 mR/yr.

The external gamma radiation background value is not constant for a given location or from one location to another, even over a short time, because the value is affected by a combination of both natural terrestrial and cosmic radiation sources and factors such as the location of the dosimeter in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil. Dosimeters are also influenced by site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Eisenbud 1987). Thus, external gamma radiation exposure

Table 4-2

Trend Analysis for Radon Concentrations[a,b] at HISS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
			(Concentrations are in 10^{-9} µCi/ml)				
Property Line							
2	0.8	0.7	0.7	0.9	0.4	0.3 - 1	0.8
3	0.3	0.6	0.6	0.5	0.4	0.3 - 0.7	0.4
4	1.3	1.5	1.3	0.9	0.5	0.2 - 2	0.8
10	0.2	0.4	0.4	0.5	0.4	0.2 - 0.6	0.4
11	1.8	1.2	0.8	0.6	0.4	0 - 2	0.6
Onsite							
1	0.9	1	0.9	0.8	0.4	0.4 - 1	0.5
5	0.6	0.3	0.9	0.5	0.4	0.1 - 0.9	0.5
6	0.6	0.8	0.7	0.5	0.4	0.4 - 0.8	0.6
7	1.1	1.8	0.6	0.6	0.4	0.0 - 2	0.4
8	0.2	0.3	0.6	0.5	0.4	0.2 - 0.6	0.7
Quality Control							
9[e]	0.5	0.3	0.9	0.5	0.4	0.1 - 0.9	0.5
Background							
16[f]	0.3	0.4	0.4	0.5	0.6	0.2 - 0.6	0.5
19[g]	--	--	0.7	0.5	0.4	0.3 - 0.7	0.5

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987b, 1988, 1989, 1990b, 1991a).

[a]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L. The DOE guideline is 3.0 x 10^{-9} µCi/ml.

[b]Measured background has not been subtracted from property-line and onsite readings.

Table 4-2

(continued)

[c]Sampling locations are shown in Figure 4-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

[e]Quality control for station 6.

[f]Relocated during fourth quarter 1990 to 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS; formerly located in Florissant, Mo., approximately 24 km (15 mi) southeast of HISS.

[g]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS; established in April 1988.

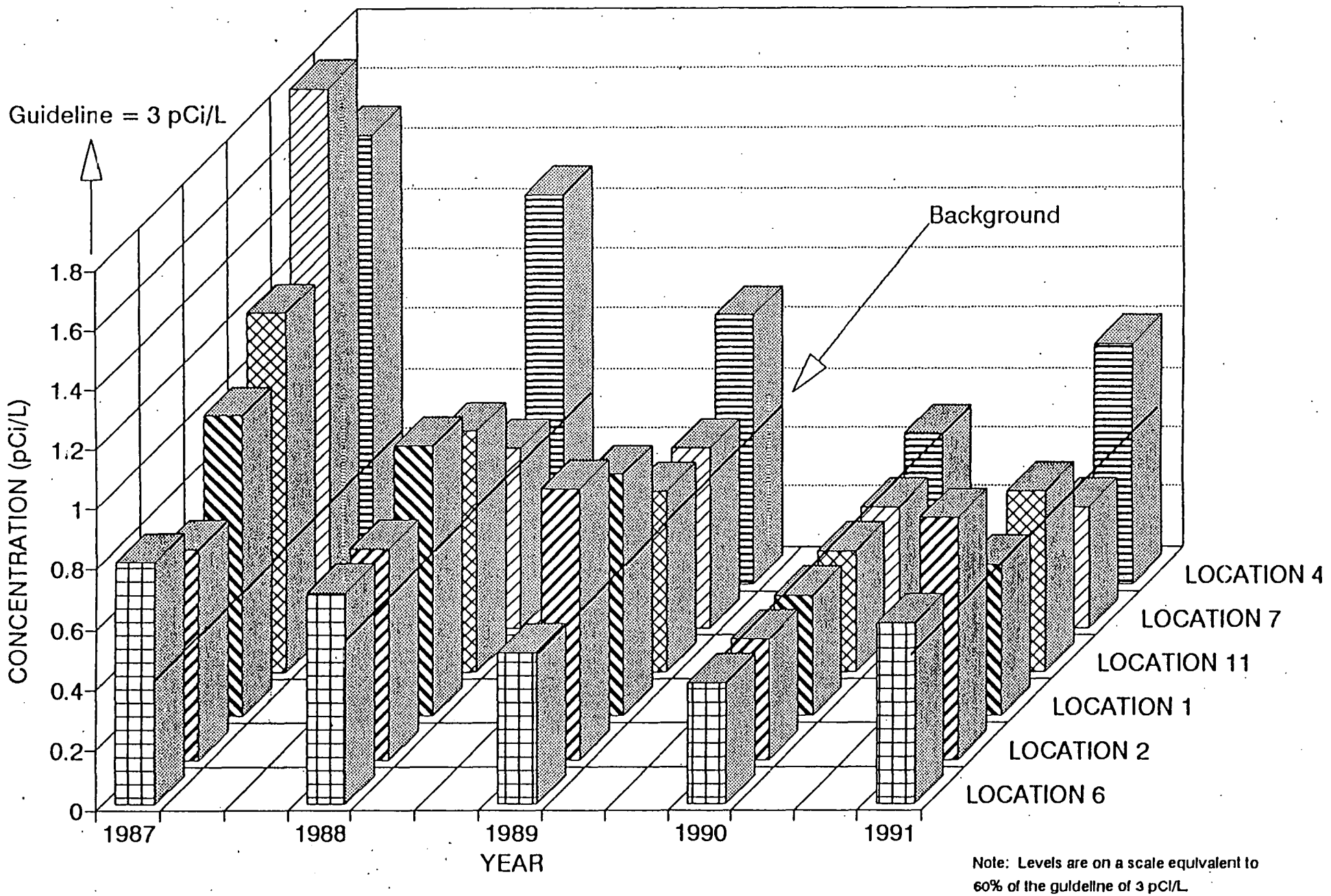

Figure 4-2
Average Annual Radon Levels at HISS

rates at the boundary could be less than the background rate measured some distance from the site, and rates onsite could be lower than at the boundary.

Data and discussion

The results of external gamma radiation monitoring are presented in Table 4-3; locations are shown in Figure 4-1. The annual average exposure rate at location 2 (120 mR/yr) exceeded the DOE guideline of 100 mR/yr above background (Figure 4-3); average exposure rates at all other locations were below this guideline.

For comparison, Figure 4-4 shows the average annual external gamma radiation exposure rates for locations onsite, at the site boundary, offsite, and across the nation. Based on these data, the radioactive waste stored at HISS does not present a threat to the public from external gamma radiation exposure because the rates are so low and access to the material is restricted.

Trends

Trends in external gamma radiation exposure rates measured from 1986 through 1991 are presented in Table 4-4 and shown in Figure 4-5. The expected values shown are based on calculation of the standard deviation of the yearly means. The expected range provides a rough check on whether there are any trends present in the data.

Since 1986, several of the average annual radiation exposure rates at HISS have shown a significant decrease, probably because of shielding (fill dirt) that was placed along the western edge of the site in 1987. Based on evaluation of the data, there do not appear to be any upward trends.

Table 4-3

Average External Gamma Radiation Exposure Rates[a] at HISS, 1991

Sampling Location[b]	Quarter 1	2	3	4	Avg
	(Rates are in mR/yr)				
Property Line (measured background subtracted)[c]					
2	119	127	125	108	120
3	[d]	[d]	[d]	[d]	[d]
4	66	65	62	59	63
10	[d]	[d]	[d]	[d]	[d]
11	34	29	37	35	34
				Average	43
Onsite (measured background subtracted)[c]					
1	2	[d]	[d]	[d]	0.5
5	1	[d]	[d]	[d]	0.3
6	[d]	[d]	[d]	[d]	[d]
7	29	32	35	20	29
8	[d]	[d]	[d]	[d]	[d]
				Average	6
Quality Control					
9[e]	[d]	[d]	[d]	[d]	[d]
Background					
16[f]	59	59	65	69	63
19[g]	98	98	94	97	97
				Average	80

[a]Dosimeters evaluated each quarter have been in place for 1 yr. The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

[b]Sampling locations are shown in Figure 4-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[c]Average annual measured background of 80 mR/yr has been subtracted from the property-line and onsite readings.

[d]Indicates a measurement that is not distinguishable from background values.

[e]Quality control for station 6.

[f]Located at 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS.

[g]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS.

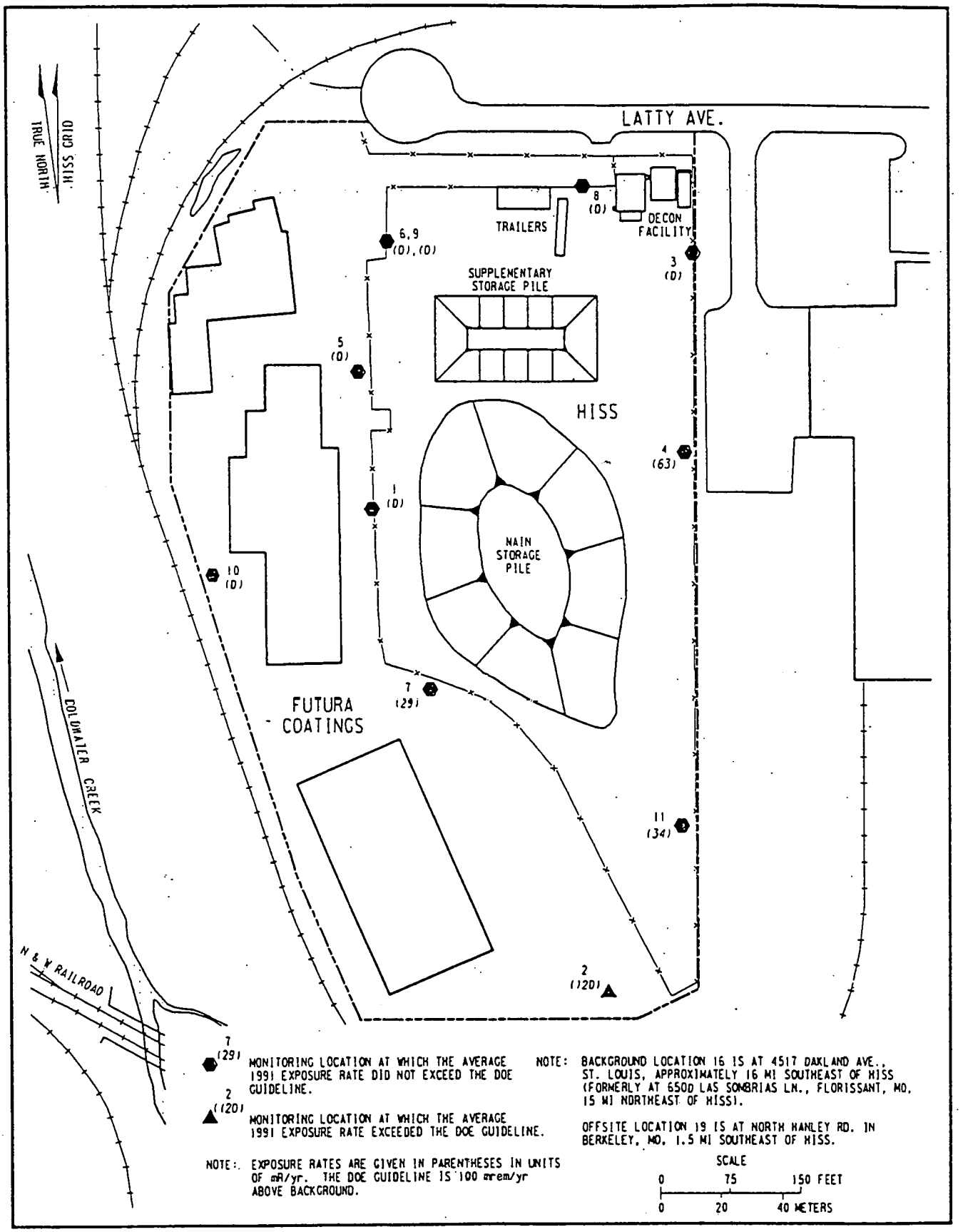

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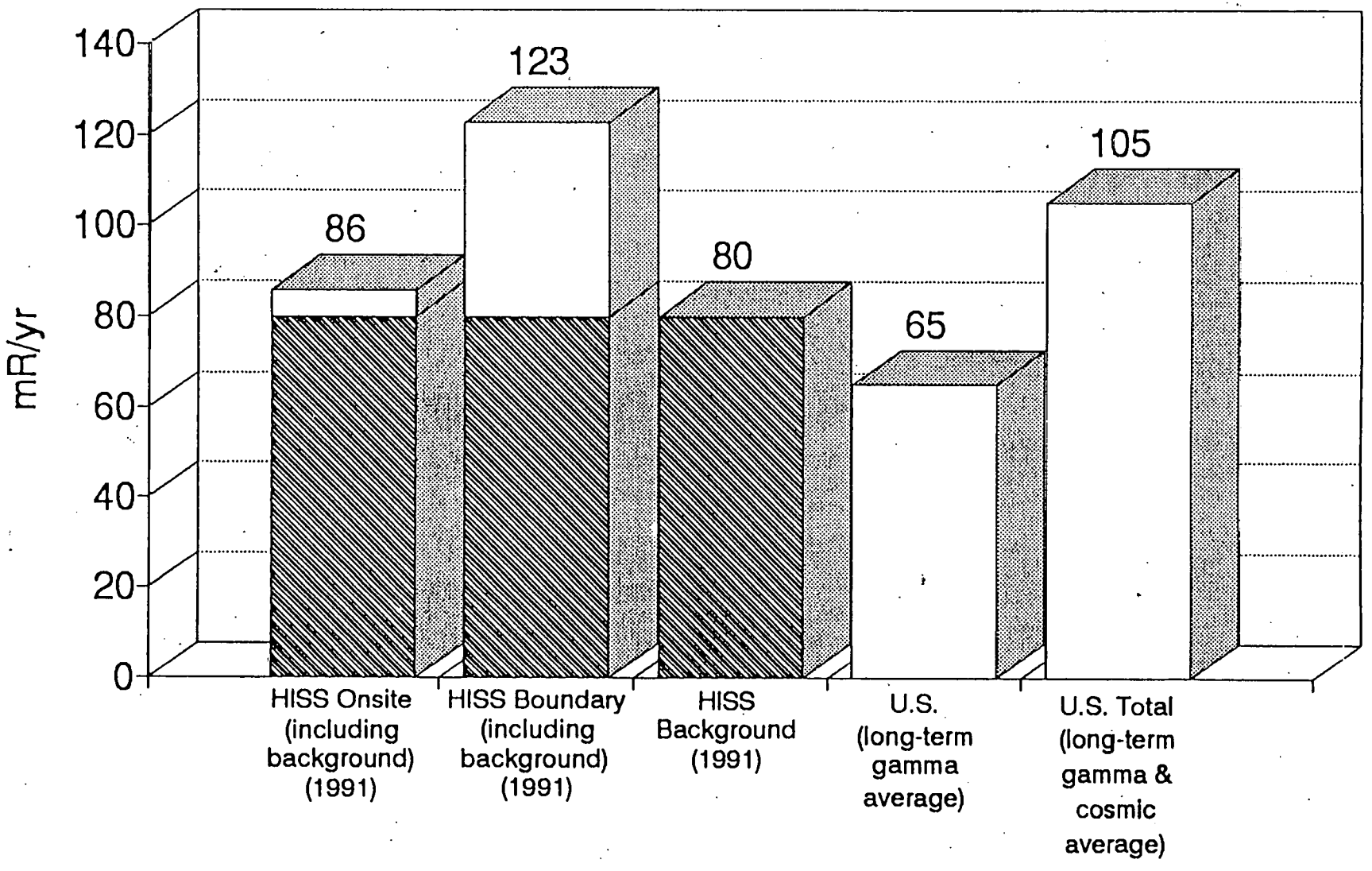
Figure 4-3
Annual Average External Gamma Radiation
Exposure Rates at HISS



Note: The DOE guideline for external gamma radiation exposure is 100 mrem/yr above background level (DOE 1990b). 1 mrem is approximately equivalent to 1 mR.
Source: Martin Marietta Energy Systems, Inc., 1989.

Figure 4-4
External Gamma Radiation Exposure Rates

Table 4-4

Trend Analysis for External Gamma Radiation Exposure Rates[a] at HISS, 1986-1991

Sampling Location[b]	Average Annual Rate 1986	1987	1988	1989	1990	Expected Range[c] ($\bar{x} \pm 2s$)	Average Annual Rate 1991
				(Rates are in mR/yr)			
Property Line (measured background subtracted)[d]							
2	68	113	116	129	107	65 - 150	120
3	23	20	14	2	0[e]	0 - 30	0[e]
4	71	74	83	68	62	58 - 84	63
10	21	17	13	1	0[e]	0 - 30	0[e]
11	15	45	56	36	35	7 - 68	34
Onsite (measured background subtracted)[d]							
1	34	44	40	6	0[e]	0 - 70	0.5
5	77	46	51	5	0[e]	0 - 100	0.3
6	179	29	44	5	0[e]	0 - 200	0[e]
7	46	50	61	61	28	30 - 70	29
8	17	27	11	0[e]	0[e]	0 - 30	0[e]
Quality Control							
9[f]	151	61	49	6	0.5	0 - 200	0[e]
Background							
16[g]	99	77	73	61	59	42 - 110	63
19[h]	--	--	--	92	96	90 - 98	97

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987b, 1988, 1989, 1990b, 1991a).

[a]The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

Table 4-4

(continued)

[b]Sampling locations are shown in Figure 4-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[c]Average value ±2 standard deviations (approximately 95 percent confidence level).

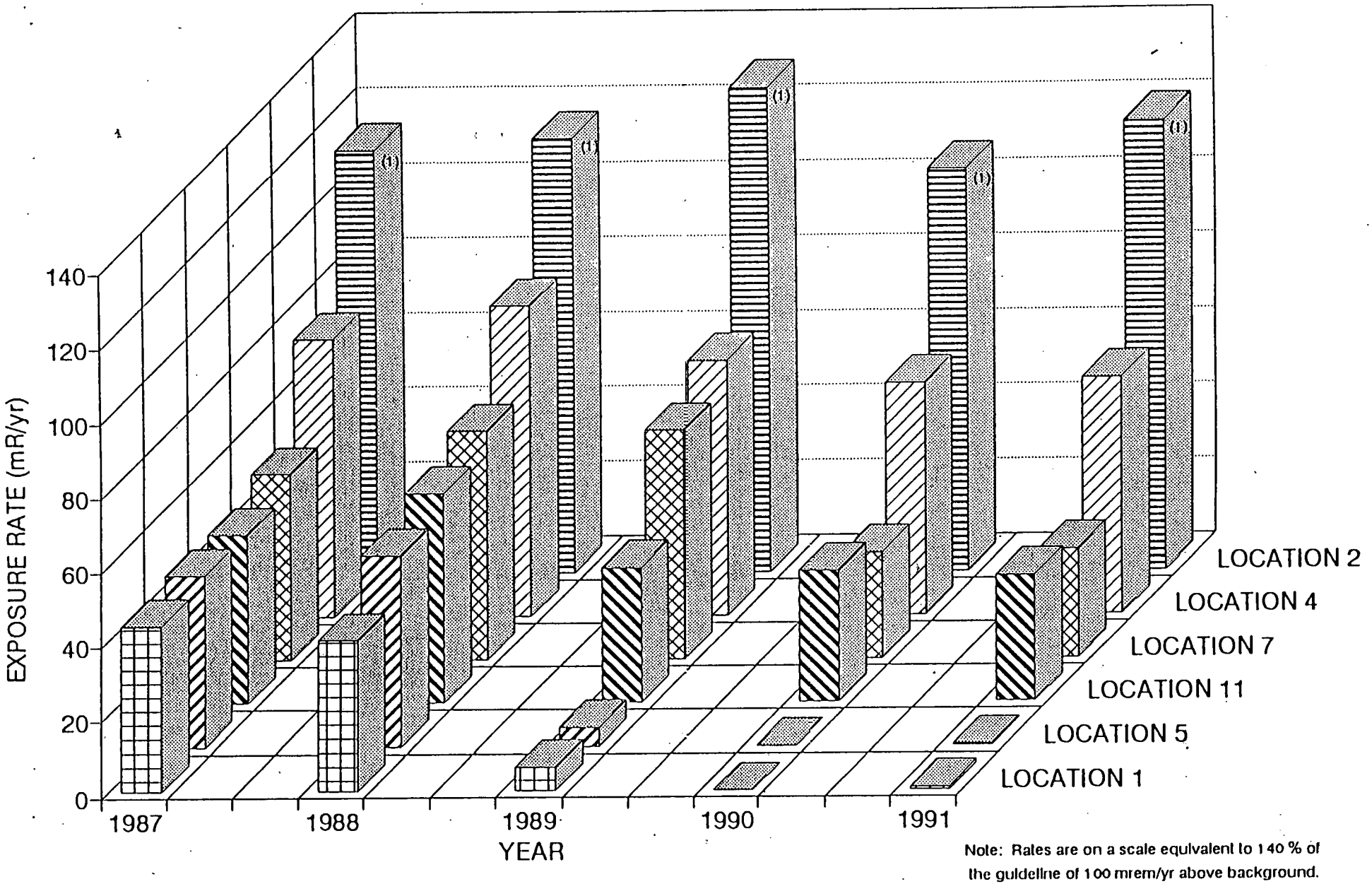
[d]Average annual measured background of 80 mR/yr has been subtracted from the property-line and onsite readings.

[e]A zero value indicates a measurement that is not distinguishable from the average annual measured background rate.

[f]Quality control for station 6.

[g]Relocated during fourth quarter 1990 to 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS; formerly located in Florissant, Mo., approximately 24 km (15 mi) southeast of HISS.

[h]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS; established in April 1988.



Note: Rates are on a scale equivalent to 140 % of the guideline of 100 mrem/yr above background.
(1) A person standing at this location for one year would receive a dose in excess of the guideline of 100 mrem/yr above background.

Figure 4-5
Average Annual External Gamma Radiation Exposure Rates (above background) at HISS

4.1.3 Surface Water Monitoring

Surface water monitoring is conducted to ensure compliance with environmental regulations and to determine whether runoff from HISS contributes to contamination of surface water in the area. Surface water monitoring locations are shown in Figure 4-6.

Data and discussion

Table 4-5 presents 1991 radionuclide concentrations in surface water. All surface water samples analyzed for total uranium, radium-226, and thorium-230 were well below the respective DOE guidelines of 600×10^{-9}, 100×10^{-9}, and 300×10^{-9} μCi/ml.

Trends

Trends in average annual radionuclide concentrations measured in surface water from 1986 through 1991 are presented in Table 4-6 and shown in Figures 4-7 through 4-9. Based on evaluation of the data, in general, the ranges were fairly consistent among data sets, as compared with data from previous years. Some values were slightly above expected ranges because of several possible factors, the primary factor being that the extremely low radionuclide concentrations in surface water give very narrow ranges for expected values. Nevertheless, all radionuclide concentrations were less than 1.5 percent of applicable DOE guidelines and were well below the concentrations specified in the Safe Drinking Water Act. These data do not represent a trend for radionuclide concentrations in surface water.

4.1.4 Sediment Monitoring

Sediment monitoring is conducted to determine whether contaminants are accumulating in onsite and/or offsite sediment and to ensure compliance with environmental regulations (see Figure 4-6 for locations).

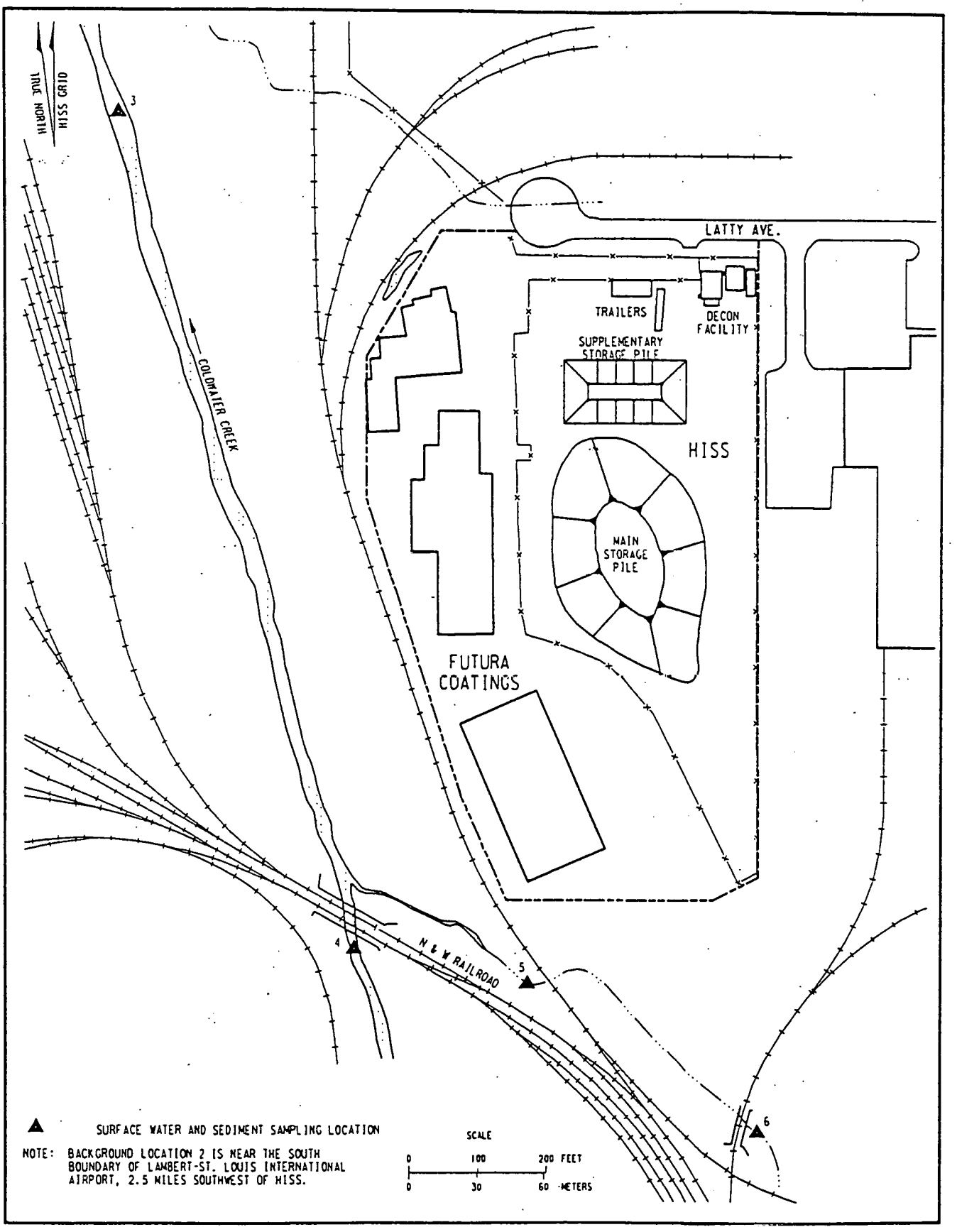


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Figure 4-6
Surface Water and Sediment Sampling Locations at HISS

Table 4-5

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Surface Water in the Vicinity of HISS, 1991

Sampling Location[c]	Quarter 1	2	3	4	Avg
			(Concentrations are in 10^{-9} µCi/ml)		
			Total Uranium[d]		
2[e]	<5	<5	<5	0.07	4
3	14	9	<5	2	8
4	<5	11	<5	2	6
5	<5	9	<5	2	5
6	14	<5	<5	3	7
			Radium-226		
2[e]	0.1	0.2	0.2	0.1	0.2
3	0.8	0.2	0.2	0.2	0.3
4	0.5	0.1	0.2	0.1	0.2
5	0.5	0.1	0.2	0.1	0.2
6	0.8	0.1	0.2	0.2	0.3
			Thorium-230		
2[e]	<0.1	0.2	1.1	0.1	0.4
3	<0.3	0.0	<0.8	0.8	0.5
4	<0.2	0.0	1.2	0.8	0.6
5	<0.1	<0.0	1.0	0.8	0.5
6	<0.1	0.1	<0.9	0.8	0.5

[a] 1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600 x 10^{-9}, 100 x 10^{-9}, and 300 x 10^{-9} µCi/ml, respectively.

[b] Measured background has not been subtracted.

[c] Sampling locations are shown in Figure 4-6.

[d] Total uranium concentrations were determined by fluorometric analysis during the first three quarters and by kinetic phosphorescence analysis during the fourth quarter.

[e] Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

Table 4-6

Trend Analysis for Total Uranium, Radium-226, and Thorium-230 Concentrations[a,b] in Surface Water in the Vicinity of HISS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
				(Concentrations are in 10^{-9} µCi/ml)			
				Total Uranium[e]			
2[f]	3	3	4	3	3	2 - 4	4
3	4	4	4	4	3	3 - 5	8
4	4	5	4	5	4	3 - 5	6
5	3	3	4	4	3	2 - 4	5
6	3	3	3	4	3	2 - 4	7
				Radium-226			
2[f]	0.3	0.3	0.5	0.3	0.3	0.1 - 0.5	0.2
3	0.3	0.2	0.3	0.4	0.3	0.2 - 0.4	0.3
4	0.3	0.2	0.3	0.3	0.4	0.2 - 0.4	0.2
5	0.2	0.3	0.3	0.3	0.3	0.2 - 0.4	0.2
6	0.2	0.2	0.3	0.3	0.2	0.1 - 0.3	0.3
				Thorium-230			
2[f]	0.2	0.2	0.1	0.1	0.2	0.1 - 0.3	0.4
3	0.4	0.3	0.2	0.2	0.1	0 - 0.4	0.5
5	0.2	0.3	0.1	0.1	0.5	0.1 - 0.5	0.5
4	0.4	0.4	0.3	0.2	0.2	0 - 0.7	0.6
6	0.2	0.1	0.3	0.1	0.1	0 - 0.4	0.5

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987b, 1988, 1989, 1990b, 1991a).

[a] 1×10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600×10^{-9}, 100×10^{-9}, and 300×10^{-9} µCi/ml, respectively.

Table 4-6

(continued)

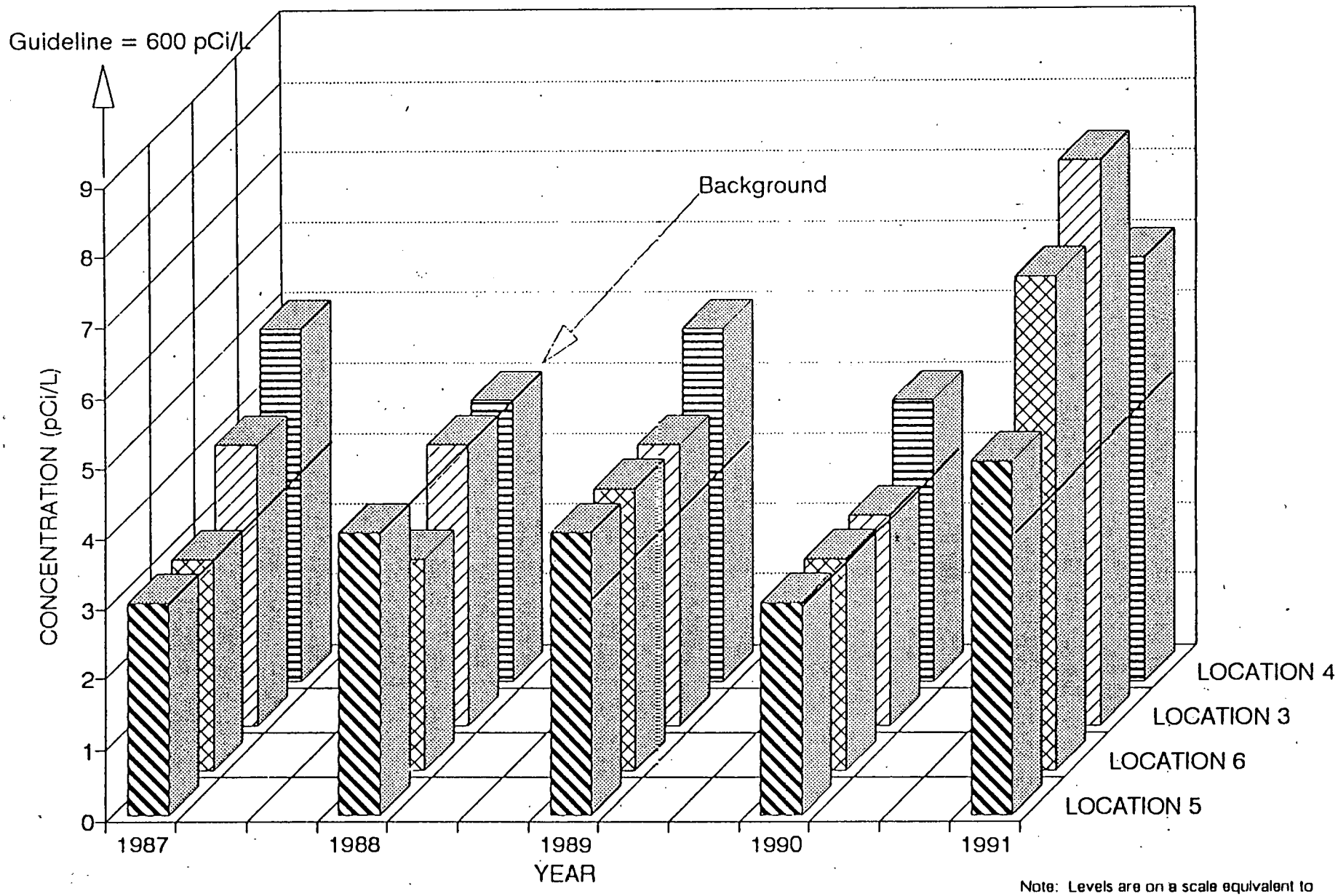
[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figure 4-6.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

[e]Total uranium concentrations were determined by fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis during the last quarter of 1991.

[f]Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.



Note: Levels are on a scale equivalent to 1.5% of the guideline of 600 pCi/L

Figure 4.7
Average Annual Total Uranium [illegible] in Surface Water at HISS

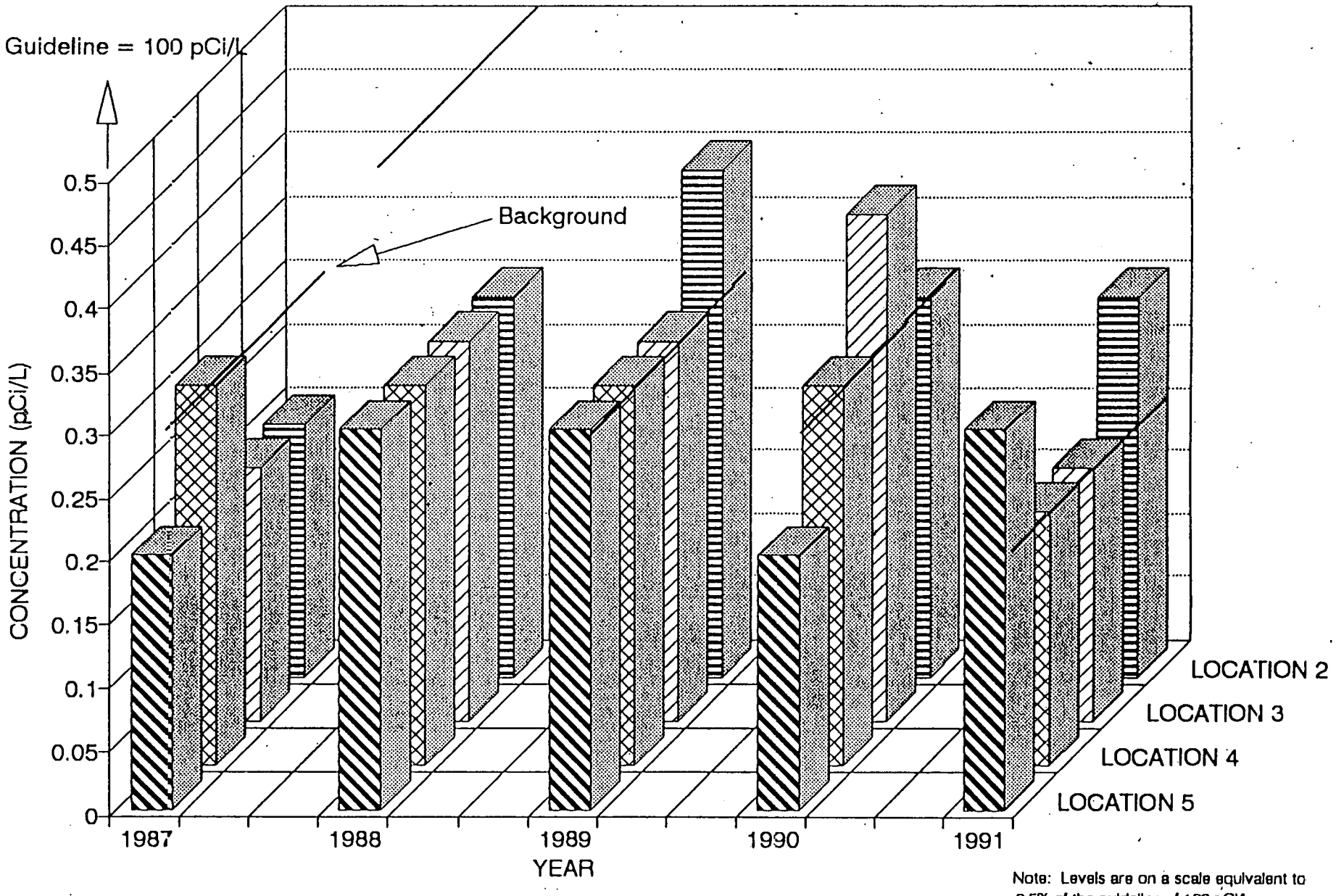


Figure 4-8
Average Annual Radium-226 Levels in Surface Water at HISS

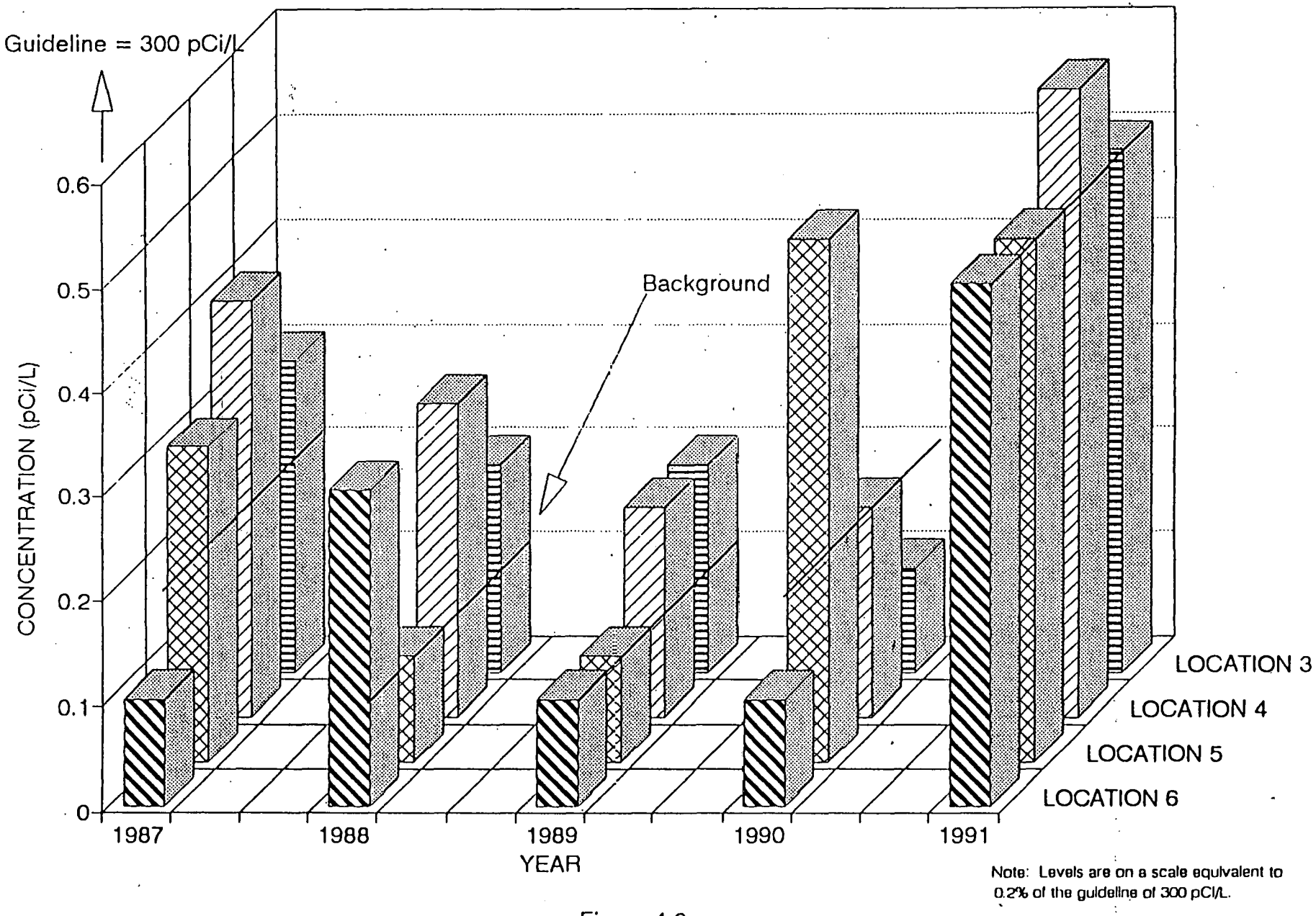


Figure 4-9
Average Annual Thorium-230 Levels in Surface Water at HISS

Data and discussion

Currently, there are no DCGs for radionuclides in sediment; therefore, sediment concentrations have been compared with FUSRAP soil guidelines (Appendix A). Table 4-7 presents 1991 concentrations of total uranium, radium-226, and thorium-230 in sediment. All total uranium and radium-226 samples were well below the respective proposed DOE guidelines of 50 and 5 pCi/g. Six of the quarterly thorium-230 results exceeded the DOE guideline of 5 pCi/g (Figure 4-10); this is thought to be a result of migration of contaminated material known to exist in Coldwater Creek and the drainage ditch south of HISS.

Trends

Table 4-8 and Figures 4-11 through 4-13 show the trends in average annual radionuclide concentrations measured in sediment from 1986 through 1991. Radium-226 and total uranium concentrations have remained fairly consistent since monitoring began. The lack of discernible trends for thorium-230 may be due to the fact that contaminated sediment could migrate, re-collect elsewhere, and thus influence the sampling results without an obvious trend.

4.1.5 Groundwater Monitoring

Groundwater monitoring is conducted to provide information on potential migration of contaminants through the groundwater system and to ensure compliance with environmental regulations. Groundwater monitoring locations are shown in Figure 4-14.

The monitoring well system is designed to provide sufficient indication of area groundwater conditions. Offsite sampling points (wells B53W01S and B53W01D) were used to establish background conditions; these wells are 0.8 km (0.5 mi) southwest of HISS. The highest potentiometric surface is a central area next to the western edge of the storage pile, which makes all onsite wells

Table 4-7

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Sediment in the Vicinity of HISS, 1991

Sampling Location[c]	Quarter 1	2	3	4	Avg
(Concentrations are in pCi/g)					
Total Uranium[d]					
2[e]	2.0	1.6	2.4	1.8	2.0
3	1.2	1.9	1.8	2.2	1.8
4	1.8	1.8	2.7	2.6	2.2
5	1.0	1.8	3.9	5.8	3.1
6	3.3	2.5	2.6	3.4	3.0
Radium-226					
2[e]	1.2	0.9	1.2	1.2	1
3	0.7	1.1	0.7	1.1	0.9
4	1.5	1.2	0.9	0.7	1
5	0.9	0.9	1.3	0.9	1
6	2.8	1.2	0.9	0.6	1
Thorium-230					
2[e]	0.9	0.9	0.8	2.8	1
3	4.1	0.9	3.0	11.4	5
4	0.9	3.4	4.6	4.3	3
5	0.8	8.9	17.9	35.9	20
6	20	9	1.4	4.5	9

[a]1 pCi/g is equivalent to 0.037 Bq/g. FUSRAP soil guidelines for total uranium, radium-226, and thorium-230 are 50, 5, and 5 pCi/g, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figure 4-6.

[d]Total uranium concentrations were determined by summing the concentrations of uranium-234, uranium-235, and uranium-238.

[e]Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

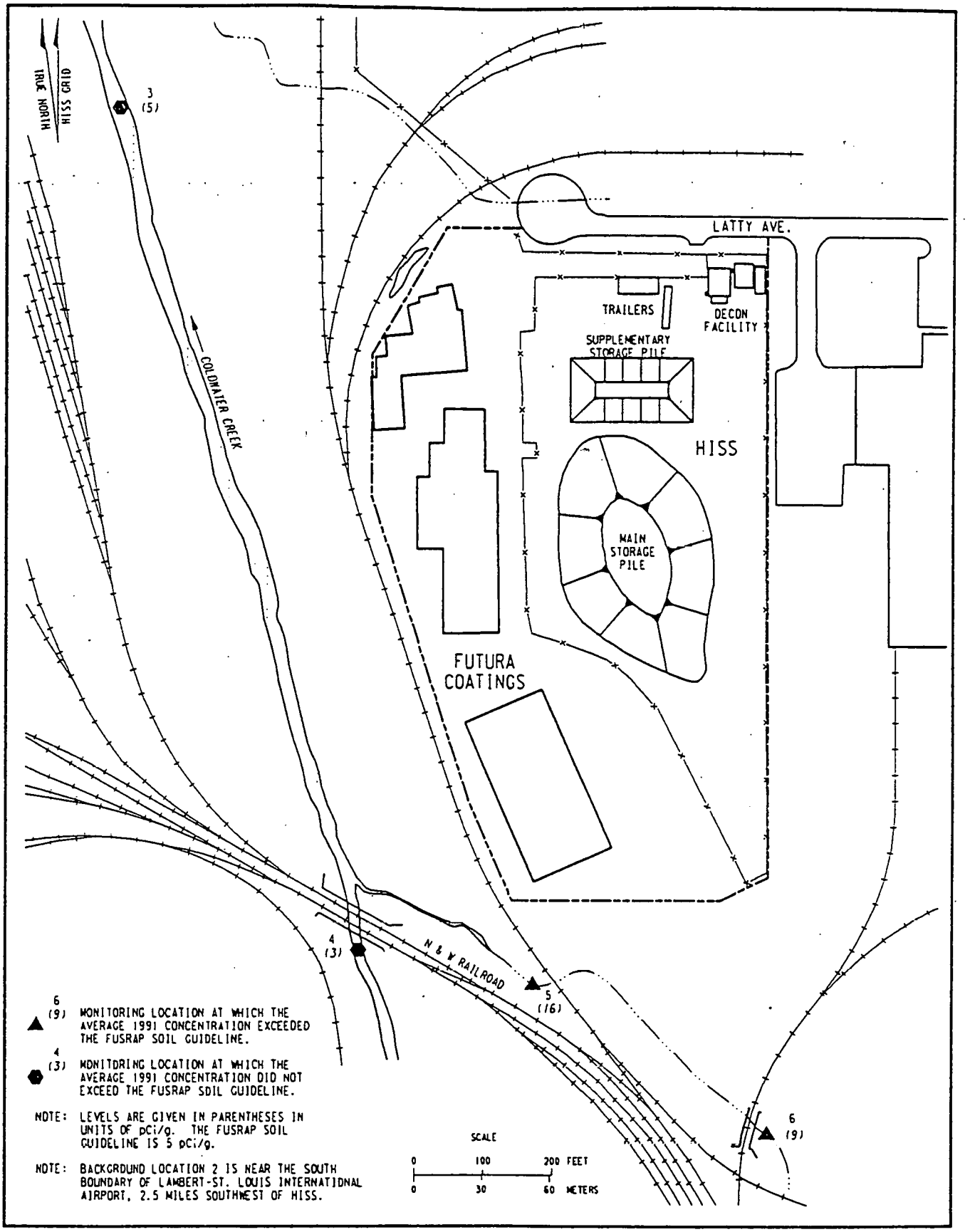


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Figure 4-10
Annual Average Thorium-230 Concentrations
in Sediment at HISS

Table 4-8

Trend Analysis for Total Uranium, Radium-226, and Thorium-230 Concentrations[a,b] in Sediment in the Vicinity of HISS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986[d]	1987	1988	1989	1990	Expected Range[e] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
				(Concentrations are in pCi/g)			
				Total Uranium[f]			
2[g]	--	1.6	1.7	1.9	1.6	1.4 - 2.0	2.0
3	--	2	1.4	2.1	1	1 - 3	1.8
4	--	2.1	2.2	1.9	2.3	1.8 - 2.4	2.2
5	--	1.8	2.1	1.9	2	2 - 2[h]	3.1
6	--	1.5	1.4	1.9	1.6	1.2 - 2.0	3.0
				Radium-226			
2[g]	--	1	1.5	1.2	3	0 - 4	1
3	--	1.2	1	2.3	1.4	0.5 - 3	0.9
4	--	1.2	1.2	1.2	2	0.2 - 2	1
5	--	1.4	1.6	1.4	1	0.4 - 2	1
6	--	1.2	0.8	1.4	1	0.4 - 2	1
				Thorium-230			
2[g]	--	1.6	1.3	0.8	0.7	0.3 - 2	1
3	--	2.7	5.8	44.4	12	0 - 54	5
4	--	0.9	4.3	2.2	5	0 - 7	3
5	--	2.9	7.5	2.1	6	0 - 10	20
6	--	20	1.5	2	1	0 - 30	9

NOTE: Sources for 1986-1989 data are the annual site environmental reports for those years (BNI 1987b, 1988, 1989, 1990b, 1991a).

[a]Note: 1 pCi/g is equivalent to 0.037 Bq/g. DOE guidelines for total uranium, radium-226, and thorium-230 are 50, 5, and 5 pCi/g, respectively.

[b]Measured background has not been subtracted.

Table 4-8

(continued)

[c]Sampling locations are shown in Figure 4-6.

[d]No sediment taken in 1986 at these locations due to excavation.

[e]Average value ±2 standard deviations (approximately 95 percent confidence level).

[f]Total uranium concentrations were determined by summing the concentrations of uranium-234, uranium-235, and uranium-238.

[g]Background sampling location located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

[h]Calculated range is shown as a single digit because the range is statistically insignificant.

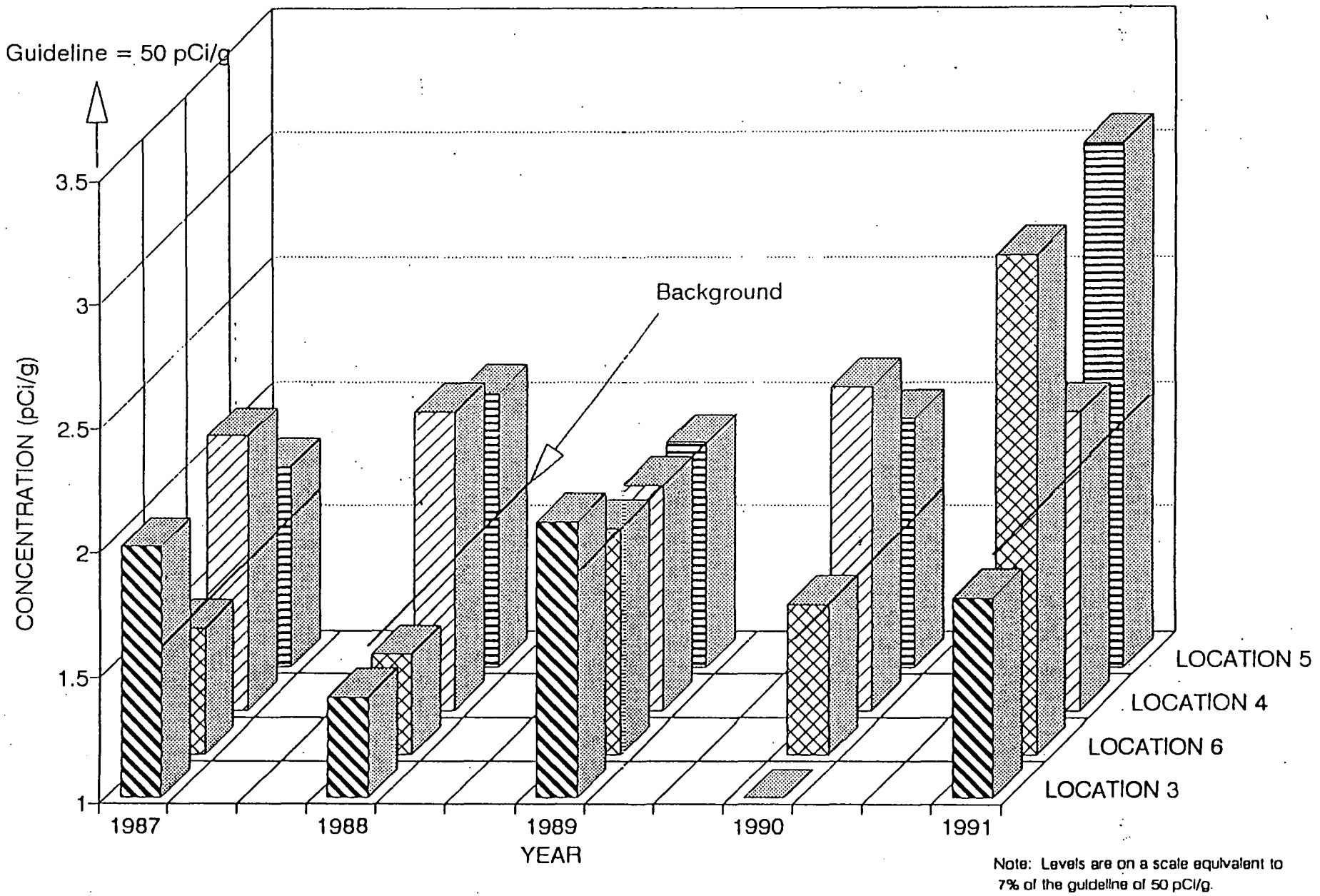

Figure 4-11
Average Annual Total Uranium Levels in Sediment at HISS

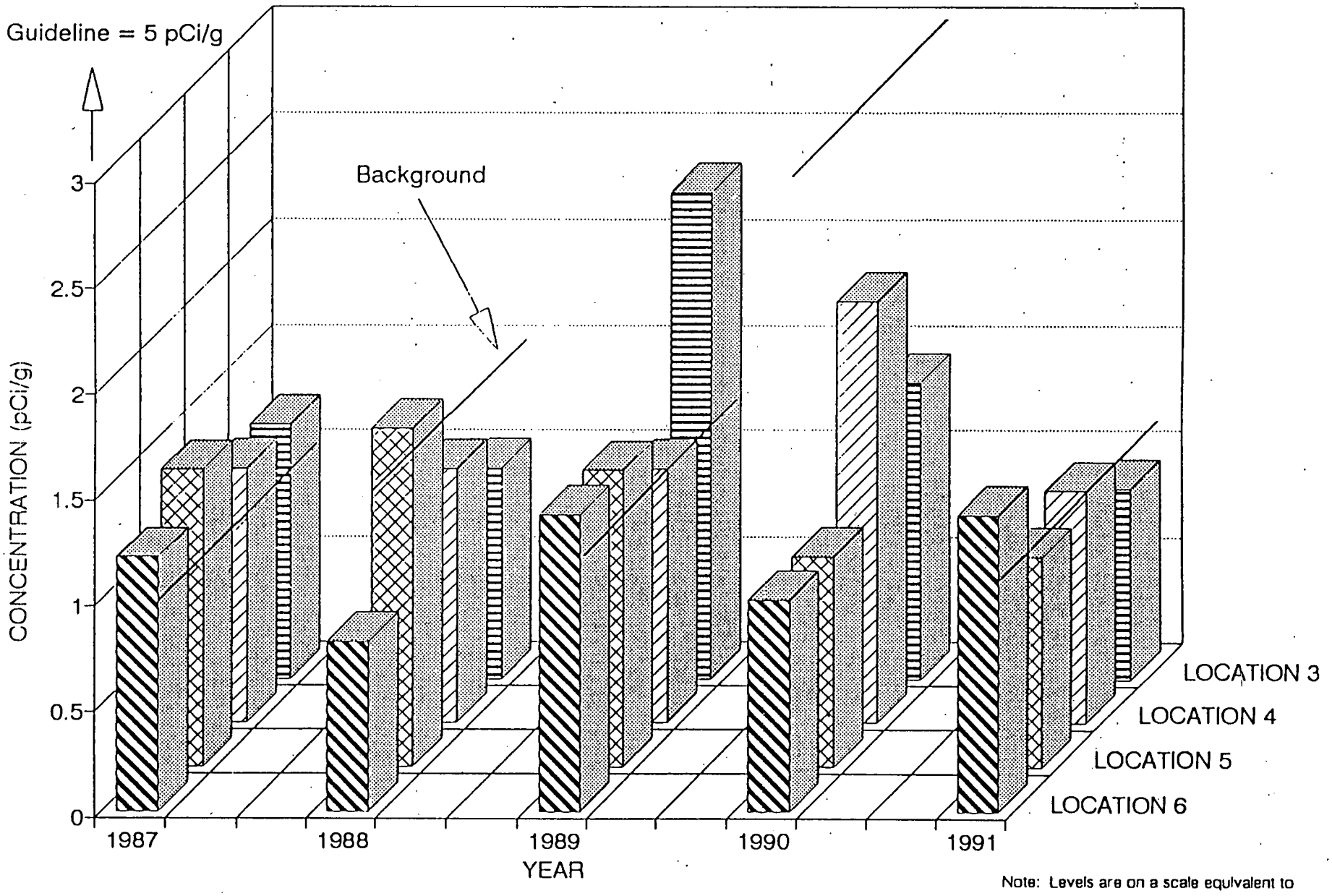

Figure 4-12
Average Annual Radium-226 Levels in Sediment at HISS

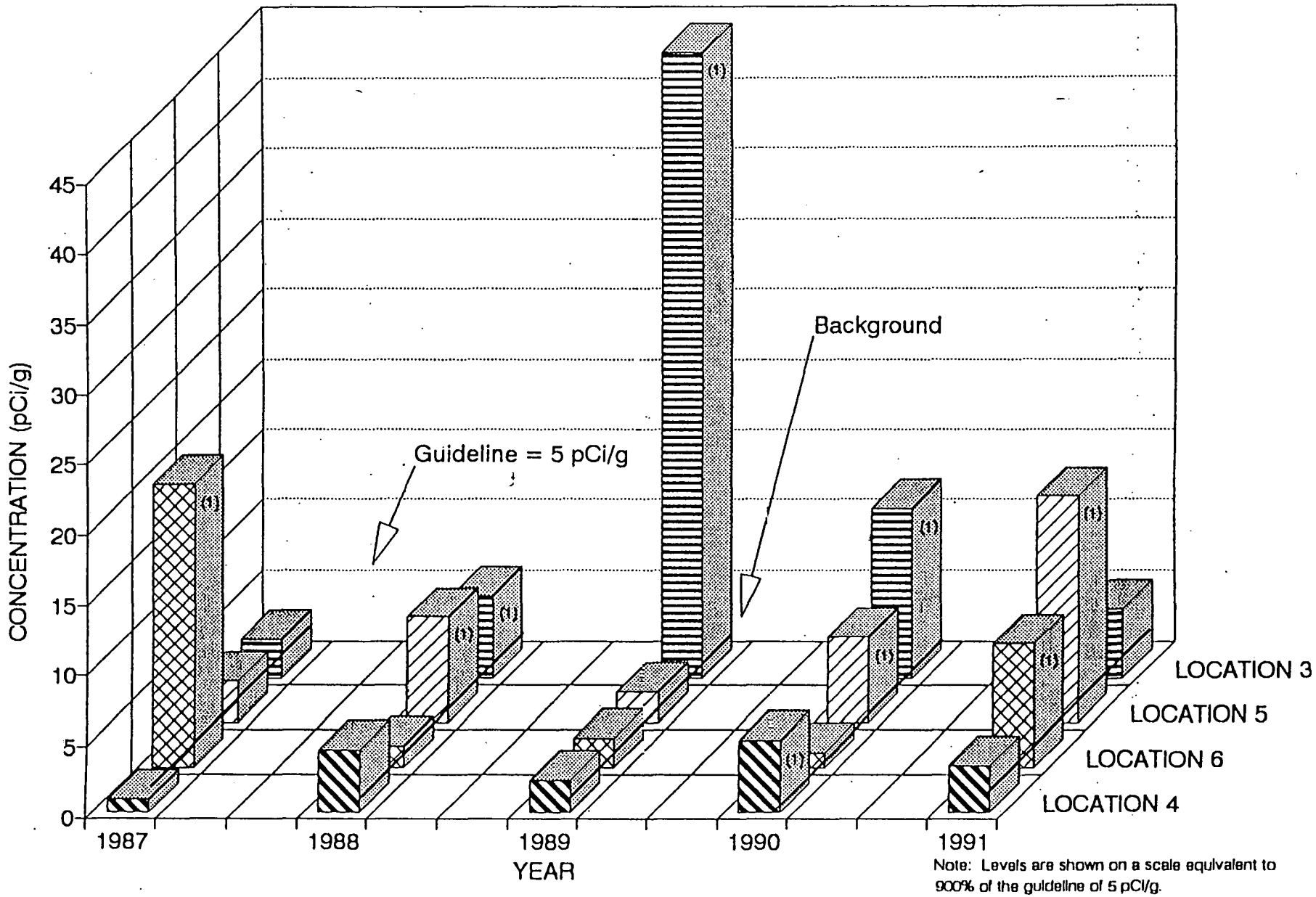

Figure 4-13
Average Annual Thorium-230 I[illegible]s in Sediment at HISS

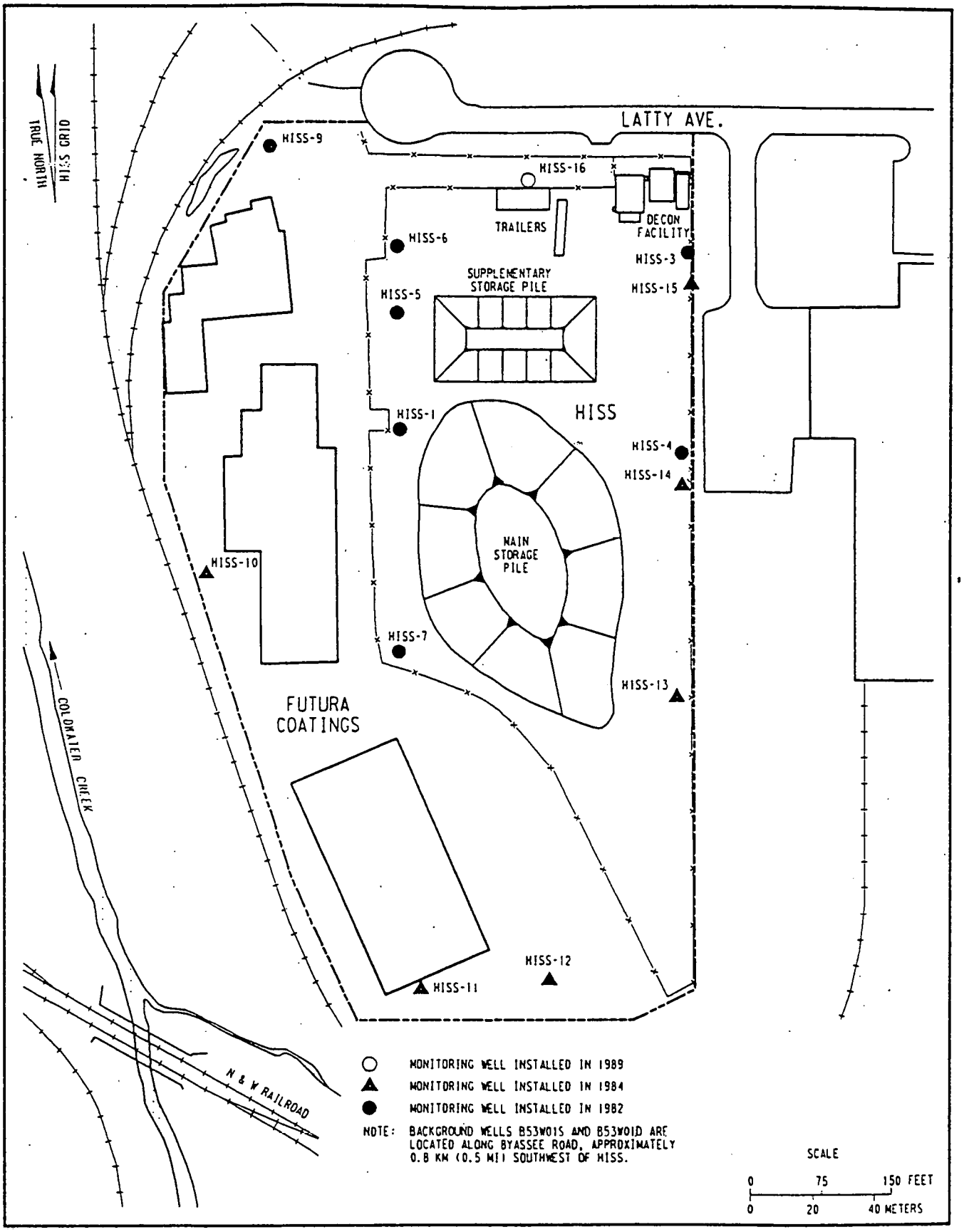

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Figure 4-14
Groundwater Sampling Locations
at HISS in 1991

downgradient (Figure 4-14). Section 6.0 provides information on potentiometric conditions at HISS.

Quarterly groundwater samples were analyzed for total uranium, radium-226, and thorium-230 by the same methods used for surface water samples.

Data and discussion

Table 4-9 presents 1991 concentrations of total uranium, radium-226, and thorium-230 in groundwater. All groundwater samples were below their respective guidelines and, except for background concentrations of total uranium during the first quarter, were consistent with past results. The high values during the first quarter were probably caused by an analytical error. Values for the second, third, and fourth quarters were consistent with historical values and were used to calculate average background values.

Trends

Trends in average annual radionuclide concentrations in groundwater measured from 1986 through 1991 are presented in Table 4-10 and shown in Figures 4-15 through 4-17. Values tended to fall within the expected ranges, except for thorium-230 levels in HISS-15, which have increased over the past three years. The cause of the elevated levels will be investigated. Because thorium-230 is typically less than 1 percent soluble in water, the most logical explanation for the elevated readings would be a broken screen or leaking seal on the well. Therefore, HISS-15 will be inspected for these potential problems. Also, HISS-6 showed increased levels of total uranium from 1987 through 1989, but levels decreased during 1990 and 1991.

Table 4-9

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Groundwater at HISS, 1991

Sampling Location[c]	Quarter 1	2	3	4	Avg
	(Concentrations are in 10^{-9} μCi/ml)				
	Total Uranium[d]				
HISS-5	<5	166	100	36	80
HISS-6	<5	86	52	20	40
HISS-7	<5	19	12	4	10
HISS-9	<5	7	6	7	6
HISS-10	<5	8	12	4	7
HISS-11	8	10	14	8	10
HISS-12	9	11	11	6	9
HISS-13	<5	16	9	7	9
HISS-14	<5	10	13	10	9
HISS-15	13	<5	16	2	9
HISS-16	<5	5	11	12	8
B53W01S[e]	386[f]	11	6	0	6
B53W01D[e]	447[f]	8	<5	3	5
	Radium-226				
HISS-5	0.2	0.2	0.2	0.1	0.2
HISS-6	0.4	0.9	1.2	1.5	1
HISS-7	1.5	1.3	1.2	0.6	1
HISS-9	1.1	0.7	1.0	2.6	1
HISS-10	0.7	0.0	0.7	2.7	1
HISS-11	0.4	1.5	0.9	9.3	3
HISS-12	1.5	1.3	0.7	0.7	1
HISS-13	5.2	0.4	0.4	0.3	2
HISS-14	3.9	1.9	1.1	7.0	3.5
HISS-15	0.9	0.5	0.7	1.0	0.8
HISS-16	1.3	1.0	1.1	5.6	2.3
B53W01S[e]	1.0	0.5	0.8	1.3	0.9
B53W01D[e]	0.9	0.3	1.3	1.2	0.9
	Thorium-230				
HISS-5	0.1	1.7	3.0	0.8	1
HISS-6	17.0	2.5	1.4	9.8	7.7
HISS-7	3.7	4.2	<0.6	2.0	3
HISS-9	1.5	0.9	1.3	1.0	1
HISS-10	0.5	0.5	<0.9	1.1	0.7
HISS-11	<0.1	9.3	4.1	2.2	4

Table 4-9

(continued)

Sampling Location[c]	Quarter 1	2	3	4	Avg
		Thorium-230 (continued)			
HISS-12	1.5	7.3	5.8	5.3	5.0
HISS-13	3.4	3.2	1.1	0.6	2
HISS-14	7.6	11.0	3.3	0.5	6
HISS-15	45.0	23.4	36.5	38.4	35.8
HISS-16	1.2	2.5	1.9	7.0	3.1
B53W01S[e]	0.2	0.5	2.2	<0.2	0.8
B53W01D[e]	0.3	0.3	<0.9	1.0	0.6

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600 x 10^{-9}, 100 x 10^{-9}, and 300 x 10^{-9} μCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figure 4-14.

[d]Total uranium concentrations were determined by fluorometric analysis during the first three quarters and by kinetic phosphorescence analysis during the fourth quarter.

[e]Background well located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of the site.

[f]Values are elevated because of a laboratory error. Second, third, and fourth quarter data were used to calculate average value.

Table 4-10

Trend Analysis for Total Uranium, Radium-226, and Thorium-230 Concentrations[a,b] in Groundwater at HISS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
(Concentrations are in 10^{-9} µCi/ml)							
Total Uranium[e]							
HISS-5[f]	--	--	--	--	57	--	80
HISS-6	33	40	50	82	48	10 - 90	40
HISS-7[f]	--	--	--	--	4	--	10
HISS-9	3	3	3	3	3	3 - 3[g]	6
HISS-10	6	4	4	5	3	2 - 7	7
HISS-11	5	4	5	6	3	2 - 7	10
HISS-12	4	5	6	4	4	3 - 6	9
HISS-13	8	8	8	5	5	4 - 10	9
HISS-14[f]	--	--	--	--	6	--	9
HISS-15	5	3	6	5	3	2 - 7	9
HISS-16[f]	--	--	--	--	22	--	8
B53W01S[h]	--	--	3	3	3	3 - 3[g]	6
B53W01D[h]	--	--	4	3	3	2 - 5	5
Radium-226							
HISS-5[f]	--	--	--	--	0.6	--	0.2
HISS-6	0.7	1.2	1.8	1.6	1	0.2 - 2	1
HISS-7[f]	--	--	--	--	1	--	1
HISS-9	0.2	0.2	0.6	0.6	0.4	0 - 0.8	1
HISS-10	0.1	0.2	0.4	0.3	0.2	0 - 0.4	1
HISS-11	0.4	0.2	1	0.7	0.5	0 - 1	3
HISS-12	0.4	0.5	1.3	0.7	0.6	0.1 - 1	1
HISS-13	0.3	0.3	0.6	0.7	0.6	0.1 - 0.9	2
HISS-14[f]	--	--	--	--	0.8	--	3.5

Table 4-10

(continued)

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
Radium-226 (cont'd)							
HISS-15	0.4	0.4	0.8	1.2	0.8	0.1 - 1	0.8
HISS-16[f]	--	--	--	--	0.4	--	2.3
B53W01S[g]	--	--	0.6	0.7	0.4	0.4 - 0.8	0.9
B53W01D[g]	--	--	1.1	1	1	1 - 1[i]	0.9
Thorium-230							
HISS-5[f]	--	--	--	--	0.5	--	1
HISS-6	2.6	2.9	24	5	3.7	0 - 20	7.7
HISS-7[f]	--	--	--	--	0.7	--	3
HISS-9	0.6	0.2	0.2	0.2	0.2	0 - 0.7	1
HISS-10	0.7	0.3	0.7	0.1	0.2	0 - 1	0.7
HISS-11	1.3	0.8	1.5	0.7	0.4	0.1 - 2	4
HISS-12	2	0.8	2.3	2.3	2	0.8 - 3	5.0
HISS-13	1	0.3	0.6	0.9	0.7	0.3 - 1	2
HISS-14[f]	--	--	--	--	0.8	--	6
HISS-15	1.3	0.8	5.7	8.6	11	0 - 14	35.8
HISS-16[f]	--	--	--	--	0.5	--	3.1
B53W01S[h]	--	--	0.2	0.3	0.2	0.1 - 0.3	0.8
B53W01D[h]	--	--	0.2	0.4	0.4	0.1 - 0.5	0.6

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987b, 1988, 1989, 1990b, 1991a).

[a] 1×10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 500×10^{-9}, 100×10^{-9}, and 300×10^{-9} µCi/ml, respectively.

[h] asured background has not been subtract

Table 4-10

(continued)

[c]Sampling locations are shown in Figure 4-14.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

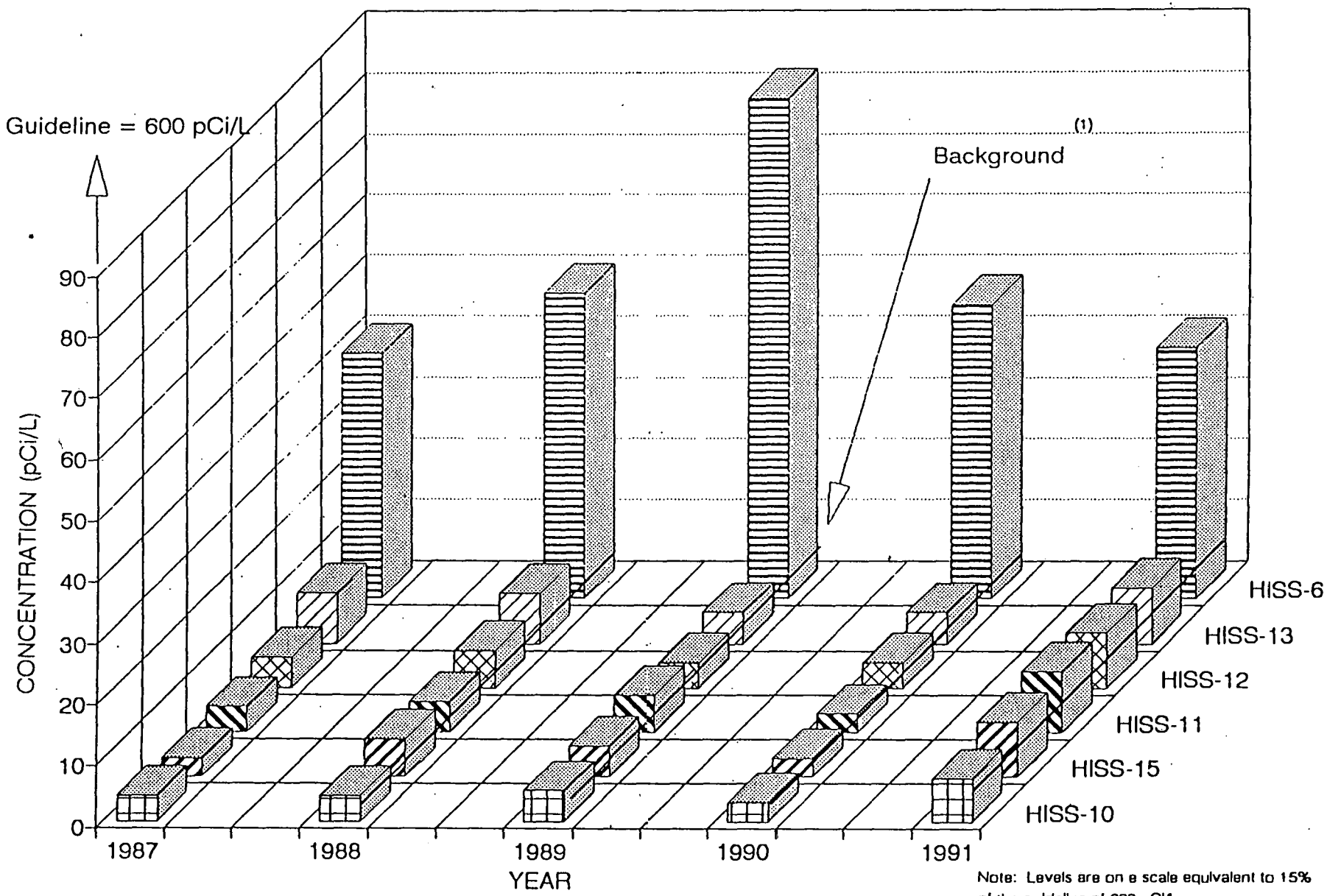
[e]Total uranium concentrations were determined by fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis during the fourth quarter of 1991.

[f]Added to the monitoring program in first quarter 1990.

[g]There is no range because all values have been the same to date.

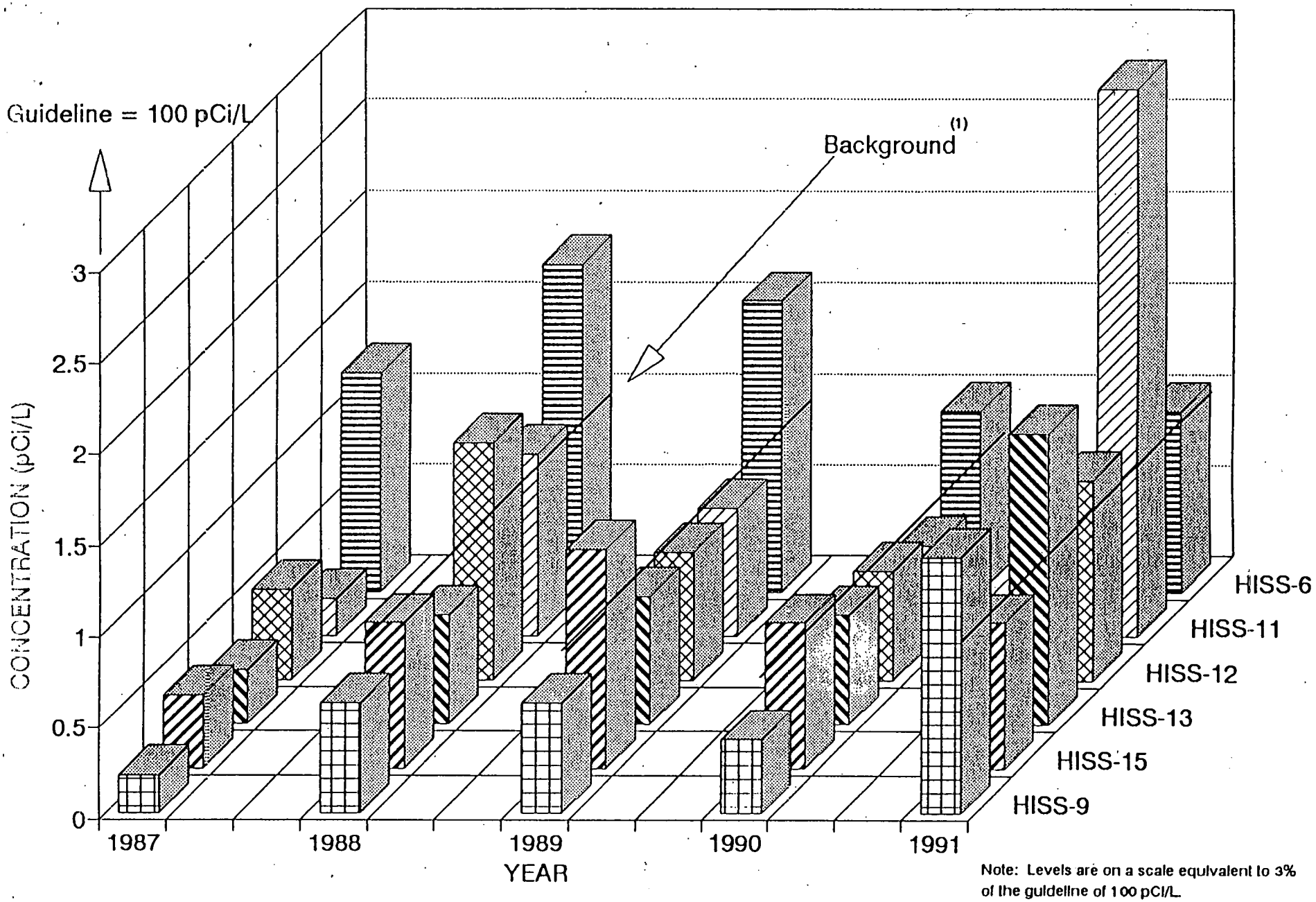
[h]Background well located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of the site; added to the monitoring program in July 1988.

[i]Calculated range is shown as a single digit because the range is statistically insignificant.



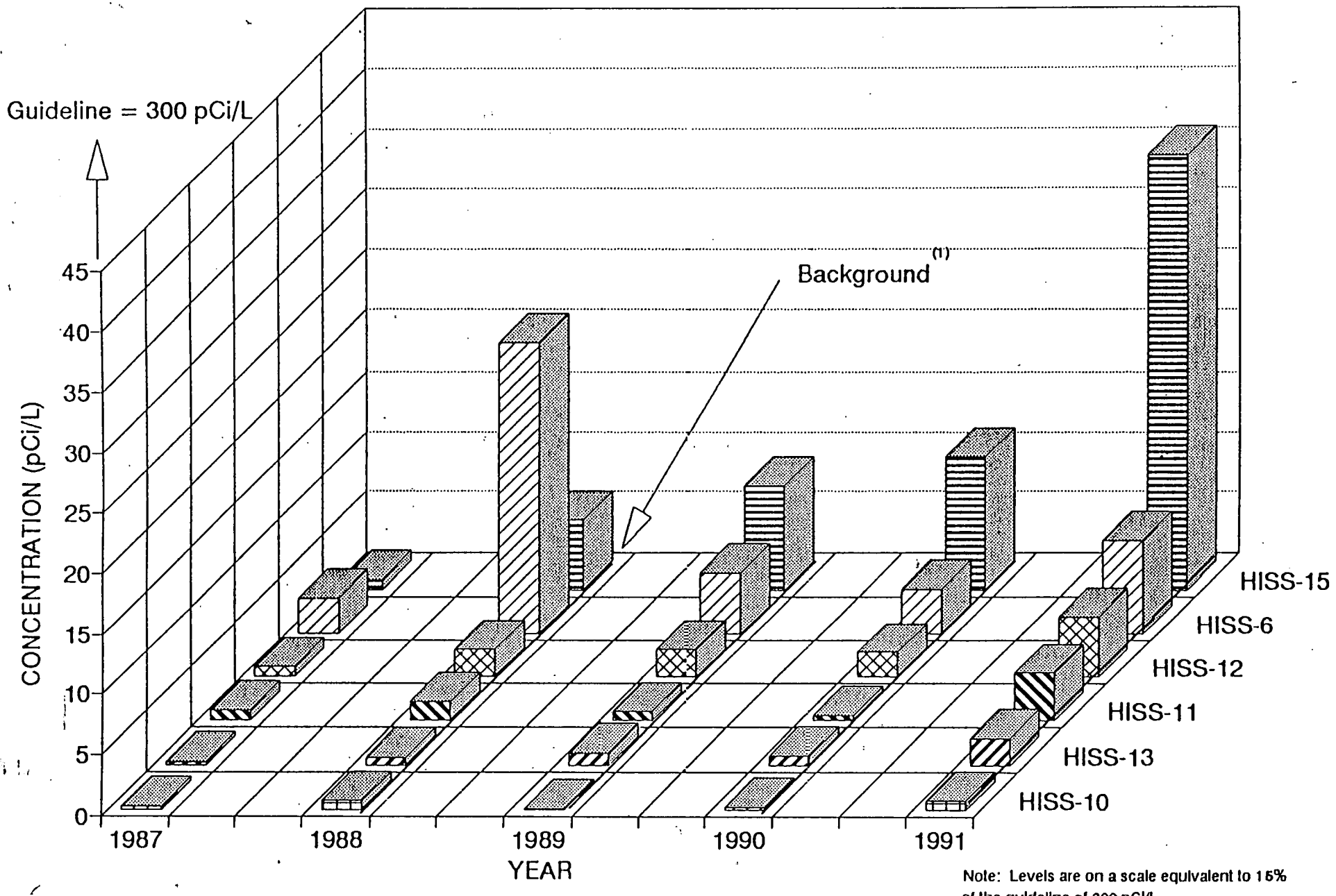
Note: Levels are on a scale equivalent to 15% of the guideline of 600 pCi/L.
(1) Background values were not collected for total uranium in groundwater during 1987.

Figure 4-15
Average Annual Total Uranium Levels in Groundwater at HISS



Note: Levels are on a scale equivalent to 3% of the guideline of 100 pCi/L.
(1) Background values were not collected for radium-226 in groundwater during 1987.

Figure 4-16
Average Annual Radium-226 Levels in Groundwater at HISS



Note: Levels are on a scale equivalent to 15% of the guideline of 300 pCi/L.
(1) Background values were not collected for thorium-230 in groundwater during 1987.

Figure 4-17
Average Annual Thorium-230 Levels in Groundwater at HISS

4.2 UNPLANNED RADIOACTIVE RELEASES

On March 27, 1991, an incident occurred at HISS that was reportable under DOE Order 5000.3A. A detailed discussion of this event is in Subsection 2.1.

4.3 POTENTIAL DOSE TO THE PUBLIC

This section contains information on exposures to the general public and a hypothetical maximally exposed individual from the radioactive materials at HISS. As expected for a relatively stable site such as HISS, all calculated doses were below the DOE guidelines. Doses to the general public can come from either external or internal exposures. Exposures to radiation from radionuclides outside the body are called external exposures; exposures to radiation from radionuclides deposited inside the body are called internal exposures. The distinction is important because external exposures occur only when a person is near the external radionuclides, but internal exposures continue as long as the radionuclides reside in the body.

To assess the potential health effects of the materials stored at HISS, radiological exposure pathways were evaluated and radiation doses were calculated for a hypothetical maximally exposed individual and for the population within 80 km (50 mi) of the site. The combined effects from all pathways (surface water, groundwater, air, and direct exposure) from all DOE sources were then compared with DOE guidelines. Exposures from radon and radon daughters are not considered in these calculations because radon exposure is in compliance with concentration requirements for boundaries (Appendix D). All doses presented in this section are estimates and do not represent actual doses. A summary is provided in Table 4-11.

4.3.1 Hypothetical Maximally Exposed Individual

The hypothetical maximally exposed individual is assumed to live near the site and work at Futura Coatings (next to HISS); this

Table 4-11

Summary of Calculated Doses[a] for HISS, 1991

Exposure Pathway	Dose to Hypothetical Maximally Exposed Individual (mrem/yr)[b]	Collective Dose to Population Within 80 km of Site (person-rem/yr)[b]
Direct gamma radiation[c]	0.1	--[d]
Drinking water	--[d]	--[d]
Ingestion	--[d]	--[d]
Air immersion	--[d]	--[d]
Inhalation[e]	0.004	0.01[f]
Total	0.104[g]	0.01
Background[h]	80	2.0×10^5 [i]

[a]Does not include radon.

[b]1 mrem/yr = 0.01 mSv/yr; 1 person-rem/yr = 0.01 person-Sv/yr.

[c]Does not include contribution from background.

[d]Exposure from this pathway is negligible.

[e]Calculated using EPA's AIRDOS model (Version 3.0, Appendix E). Based on the AIRDOS PC user manual, the 50-yr effective dose equivalent factors were used to determine the committed effective dose equivalent to various critical organs. Therefore, the "mrem/yr" unit of effective dose equivalent from internal deposition of radionuclides should be interpreted as the "50-yr" committed dose equivalent based on total radiological particulate intake for a given year.

[f]Derived from Table 4-10.

[g]DOE guideline for total exposure to an individual is 100 mrem (DOE 1990b).

[h]Direct gamma radiation exposure only.

[i]Calculated by the following: (80 mrem/yr) (2.5×10^6 people).

individual's average distance from the site would be 300 m (980 ft). Using these assumptions, the following doses have been calculated.

Direct gamma radiation pathway

The yearly dose to a hypothetical worker at Futura Coatings can be calculated by using the equation in Appendix D for direct gamma radiation exposure. The calculated dose for this individual is 0.1 mrem/yr (0.001 mSv/yr), well below the DOE guideline of 100 mrem above background for effective dose equivalent in a year. This approach is conservative because an individual would not likely work outside at Futura Coatings for an entire year.

Drinking water pathway

Only one water pathway, either groundwater or surface water, is used to determine the committed dose to the hypothetical maximally exposed individual. This individual would obtain 100 percent of his/her drinking water from either surface water or groundwater in the vicinity of the site. Concentrations of total uranium, radium-226, and thorium-230 in groundwater in the vicinity of HISS are barely detectable above normal background levels. Because there are currently no domestic wells in use within 3.2 km (2 mi) of the site, groundwater is not a credible exposure pathway; therefore, the dose contribution from these radionuclides in groundwater to the hypothetical maximally exposed individual was not calculated. There was also no credible exposure from surface water; radionuclide concentrations at sampling locations upstream and downstream of HISS are essentially equivalent to the background levels measured at location 2.

Air pathway (ingestion, air immersion, inhalation)

Air doses determined using the AIRDOS computer model, Version 3.0, were found to be negligible, 0.004 mrem/yr, which is well below the regulatory limit of 10 mrem/yr given in 40 CFR 61

Subpart H. The 1991 AIRDOS compliance report is provided in Appendix E; the appendix also gives the calculated amount of each primary radionuclide of concern released to the air in 1991.

Total dose

The total dose for the hypothetical maximally exposed individual is the sum of the 50-yr committed effective dose equivalent and the external effective dose equivalent, based on the total estimated radioactive particulates released in 1991 and the effective dose equivalent due to total external direct gamma radiation measured at the fenceline in 1991. When these doses are added together, the total dose is 0.104 mrem/yr (1.04×10^{-3} mSv/yr). This dose is less than the exposure a person receives while travelling in an airplane at 12,000 m (39,000 ft) for one hour because of greater amounts of cosmic radiation at higher altitudes (see Appendix F).

4.3.2 Population Dose

The collective dose to the general population living within 80 km (50 mi) of the site was also calculated.

Direct gamma radiation pathway

HISS is located in an industrial area and thus is remote from the general population. Distance from the site to the nearest residential areas and the presence of intervening structures reduce direct gamma radiation exposure from HISS (see Table 4-12). Therefore, it is assumed that there is no detectable exposure to the general public.

Drinking water pathway

There are no wells used for public drinking water within 4.8 km (3 mi) of the site (see Subsection 6.1.2), and there is a

Table 4-12
Maximum Effective Dose to the General Public
from HISS, 1991

Distance from the Site (m) (inner radius)	(outer radius)	Effective Dose Equivalent (mrem/yr)[a,b]	Population Dose (person-rem/yr)[c,d]
0	1,000	3.6×10^{-3} *	0.001
1,000	3,000	3.0×10^{-4}	0.0001
3,000	10,000	3.8×10^{-5}	0.001
10,000	80,000	4.1×10^{-6}	0.01
		Total Dose	0.01

[a]To be conservative, the effective dose equivalent used for each range was that for the distance closest to the site. The DOE DCG is 100 mrem above background for effective dose equivalent in a year.

[b]Values were obtained using AIRDOS (Appendix E).

[c]A population density of 1.24×10^{-4} person/m^2 was used in the calculation.

[d]Calculated using:
Population dose = [population density] [π(outer radius)^2 - π(inner radius)^2] [effective dose equivalent].

[e]Effective dose equivalent for 300 m.

significant distance [32 km (20 mi)] to a drinking water intake point on the Mississippi River; therefore, it is reasonable to assume that the general public would not receive a committed dose in drinking water from radionuclides from HISS.

Air pathway (ingestion, air immersion, inhalation)

The AIRDOS model provides an effective dose equivalent for contaminants transported via the atmospheric pathway at different distances from the site (Table 4-12). The collective dose for the general population within 80 km (50 mi) of HISS was calculated using these effective dose equivalents and the population density. The calculated collective population dose (see Appendix E) is 0.01 person-rem/yr (1×10^{-4} person-Sv/yr).

Total population dose

The total population dose is the sum of the doses from all exposure pathways. Because the only pathway with a major potential contribution to the collective population dose is the air, the total population dose is equal to that calculated for that pathway [0.01 person-rem/yr (1×10^{-4} person-Sv/yr)].

5.0 NONRADIOLOGICAL ENVIRONMENTAL PROGRAM

Site characterization (BNI 1990b) has shown that nonradioactive contamination of the soil at HISS is not substantially different from background levels and does not pose a potential threat to human health or the environment via an airborne pathway (e.g., resuspension of soil) or a surface water pathway (e.g., runoff from the site and/or collection in sediments). Monitoring of airborne particulates is conducted during site construction operations to evaluate worker health hazards (e.g., inhalation of dust) and to monitor any unexpected releases. Nonradiological parameters in groundwater at HISS are monitored to collect baseline information on groundwater quality in the area. HISS is not an active site; therefore, the only "effluents" would be contaminants that migrate.

5.1 GROUNDWATER MONITORING

Groundwater samples were collected from the same locations as those in the radiological groundwater monitoring system (Figure 4-14). Monitoring points were both offsite (wells B53W01S and B53W01D), to establish background conditions, and onsite, to determine the effect of the site on groundwater in the vicinity. Quarterly groundwater samples were analyzed for the indicator parameters specific conductivity, pH, TOC, and TOX, as described in Appendix B. These parameters indicate changes in the inorganic and organic composition of the groundwater.

Specific conductivity and pH readings indicate changes in inorganic composition. Specific conductivity measures the capacity of water to conduct an electrical current; generally, conductivity increases with an elevated concentration of dissolved solids or salinity. Acidity or alkalinity of the water is expressed as pH. A change in pH affects the solubility and mobility of chemical contaminants in water. Typically these measurements are taken by field personnel at the time of sample collection.

Groundwater is analyzed for TOC and TOX to determine organic content. TOC measures the total organic content of the groundwater

but is not specific to a given organic contaminant, and TOX measures organic compounds containing halogens (e.g., halogenated hydrocarbons).

Data and discussion

Analytical results for indicator parameters show that groundwater at HISS is generally of poor quality, which is typical in industrial/urban areas. Overall, specific conductivity, pH, TOC, and TOX average results for 1991 remained relatively stable as compared with 1990 results (Tables 5-1 and 5-2).

Trends

Indicator parameters such as TOC and TOX are analyzed as gross indicators for the presence of organics. These indicator parameters can fluctuate between sampling events; therefore, trend analysis is not feasible. In cases where broad-screen organic analyses are performed to support a site characterization or remedial investigation, the data will be presented in the annual site environmental report, but trend analyses will not be performed.

5.2 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

An NPDES permit (No. MO-0111252) was issued for HISS on December 28, 1990. A detailed discussion of the permit and corrective actions performed to address nonconformances is in Subsection 2.1.

5.3 OTHER EMISSIONS MONITORING

HISS is not an active site and therefore produces no emissions other than those already discussed.

Table 5-1
Inorganic Indicator Parameters in Groundwater at HISS, 1991

Sampling Location[a]	Quarter 1	2	3	4	Avg
Conductivity (μmhos)					
5	917	772	1070	NA[b]	920
6	1614	3480	4310	NA	3140
7	8500	7400	7610	NA	7800
9	851	555	1030	852	822
10	663	444	830	703	660
11	1260	834	1447	1274	1200
12	2180	1270	2350	2110	1980
13	5680	5880	6750	NA	6100
14	6950	7620	8720	NA	7760
15	910	592	1070	NA	860
16	4210	312	1051	976	1640
B53W01D[c]	940	956	1110	1012	1000
B53W01S[c]	850	880	960	929	910
pH					
5	7.53	7.11	6.86	NA	7.17
6	7.42	6.91	6.68	NA	7.00
7	7.08	6.67	6.57	NA	6.77
9	7.38	7.06	7.07	6.95	7.12
10	7.44	7.27	7.16	6.98	7.21
11	6.94	6.92	6.69	6.81	6.84
12	6.84	6.87	6.61	6.55	6.72
13	6.83	6.61	6.39	NA	6.61
14	6.93	6.77	6.57	NA	6.76
15	6.94	6.8	6.48	NA	6.7
16	7.28	7.65	7.11	7.07	7.28
B53W01D[c]	7.4	7.08	7.01	7.16	7.2
B53W01S[c]	7.15	6.81	7.22	6.86	7.01

[a]Sampling locations are shown in Figure 4-14.

[b]NA - Data are not available because of equipment malfunction.

[c]Background well located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS.

Table 5-2

Total Organic Carbon and Total Organic Halides in Groundwater at HISS, 1991

Sampling Location[a]	Quarter 1	2	3	4	Avg
	Total Organic Carbon (mg/L)				
5	2.3	3.1	5.9	7.2	4.6
6	4.2	3.1	2.5	2.8	3.2
7	1.7	2.3	9.4	1.2	3.7
9	2.8	3.1	3.4	1.9	2.8
10	1.3	3.1	3.4	1.6	2.4
11	1.6	2.7	1.5	2.7	2.1
12	1.3	2.6	10.7	2.2	4.2
13	1.8	3.3	2.6	1.4	2.3
14	1.3	1.5	2.1	1.3	1.6
15	3.7	6.3	4.5	4.5	4.8
16	6.1	3.3	5.4	7.4	5.6
B53W01D[b]	5.6	5.3	6.8	7.9	6.4
B53W01S[b]	0.81	10.1	3.3	1.5	3.9
	Total Organic Halides (µg/L)				
5	38	20[c]	47	20[c]	30
6	63	44	41	35	46
7	27	22	20[c]	20[c]	20
9	26	23	46	20[c]	30
10	20[c]	20[c]	20[c]	82	40
11	35	20[c]	20[c]	32	30
12	20[c]	20[c]	20[c]	20[c]	20
13	30	20[c]	21	20[c]	20
14	20[c]	20[c]	45	20[c]	30
15	100	29	48	35	50
16	800	20[c]	90	20[c]	200
B53W01D[b]	29	20[c]	27	27	30
B53W01D[b]	20[c]	25	20[c]	20[c]	20

[a]Sampling locations are shown in Figure 4-14.

[b]Background well located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS.

[c]Concentration is actually below the detection limit of 20 µg/L.

5.4 ENVIRONMENTAL OCCURRENCES

No nonradiological releases occurred during 1991 at HISS.

5.5 SARA TITLE III REPORTING

No reports under Section 313 of the Emergency Preparedness and Community Right-to-Know Act were filed during 1991. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1991. However, in accordance with the spirit and language of DOE Order 5400.1, FUSRAP evaluates and inventories toxic chemicals used onsite to ensure that no threshold planning quantities (TPQs) are exceeded.

Toxic chemicals, such as nitric acid, are used at FUSRAP sites for sampling and other purposes. However, the quantities of such chemicals stored onsite are well below TPQs. If a TPQ is exceeded at a site, the Toxic Chemical Release Inventory Reporting Form (Form R) under 40 CFR 372.85 will be filed with EPA.

6.0 GROUNDWATER PROTECTION PROGRAM

6.1 HYDROGEOLOGICAL CHARACTERISTICS

6.1.1 Site Hydrogeology

HISS is located within a shallow subsurface depression in bedrock known as the Florissant Basin, the site of a glacial lake that was filled with more than 30 m (100 ft) of silts, clays, and fine-grained sand. The bedrock underlying these lacustrine deposits at HISS is believed to be limestone of Mississippian geologic age. Because of the relatively shallow depth of the observation wells installed at HISS, bedrock was not encountered during drilling.

Groundwater at the site occurs as an unconfined system characterized by radial flow away from a central area near the western edge of the main storage pile. The water table occurs approximately 1.0 to 5.0 m (3.5 to 16.5 ft) below the ground surface. The HISS wells are screened in unconsolidated silty clays and clayey silts at depths of 3.7 to 7.9 m (12 to 26 ft). Figure 6-1 shows the locations of monitoring wells used for water level measurements.

6.1.2 Groundwater Quality and Usage

The most productive bedrock aquifers in the HISS area are typically Pennsylvanian and Mississippian limestones and sandstones. Wells installed in these units have yields of 1 to 10 gpm (0.06 to 0.6 L/s) and were completed at various depths to 137 m (450 ft). Below 137 m (450 ft), the aquifers yield mineralized water with high chloride and sulfate content that is considered unsuitable for drinking (State of Missouri 1963). Water obtained from glaciolacustrine deposits overlying bedrock tends to have excessive iron and magnesium content, significant quantities of sulfate, and variable dissolved solids content (Miller et al. 1974).

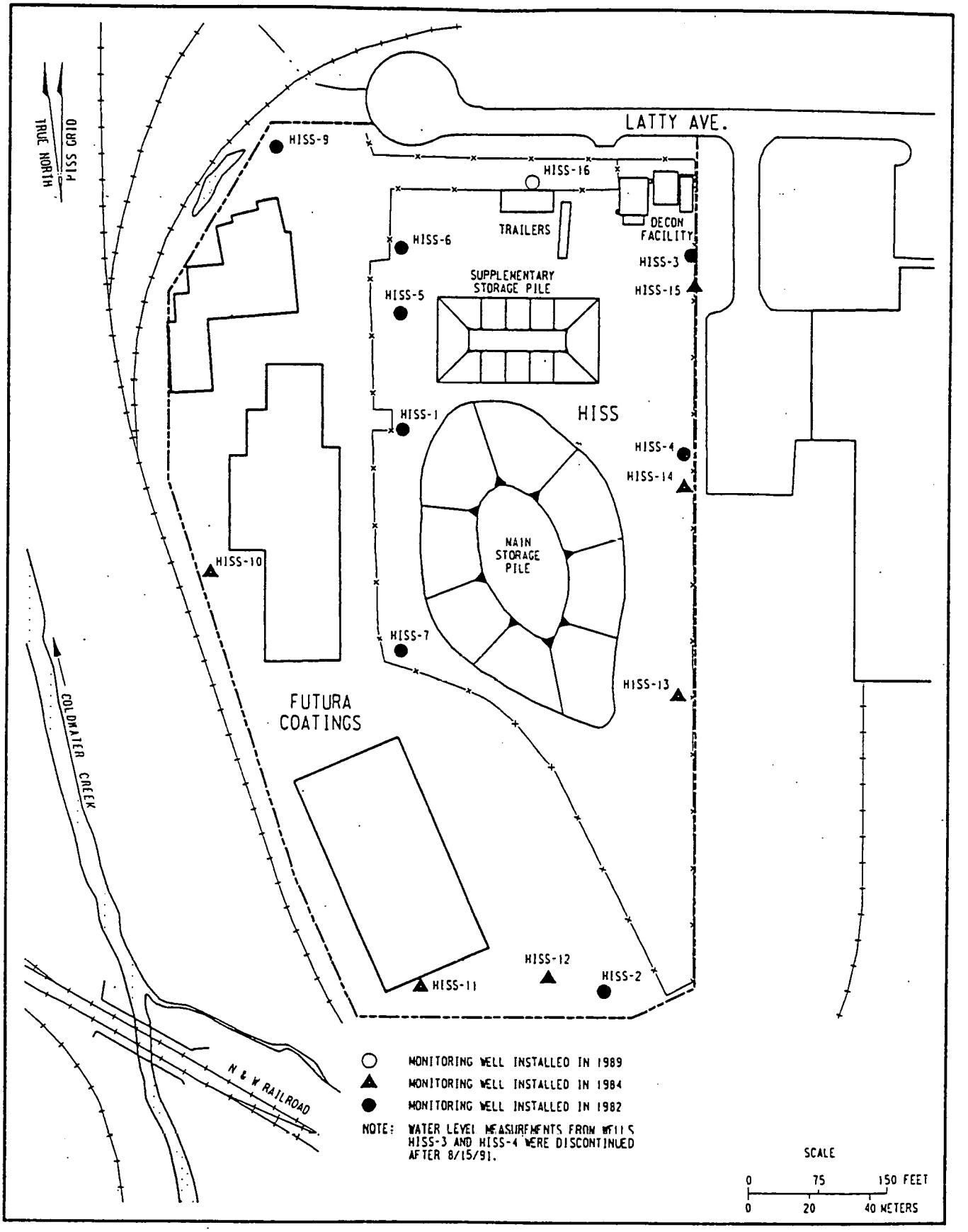


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Figure 6-1
Monitoring Wells Used for Water Level Measurements at HISS

A well canvass of the combined HISS and SLAPS areas conducted in 1987 and 1988 yielded records of eight wells: four had been drilled to obtain water for irrigation, one was for industrial purposes, and three were for domestic (i.e., private drinking water) use. The three domestic wells were abandoned in 1962, 1968, and 1979. Figure 6-2 is a map showing the locations of private wells in the vicinity of HISS. There are no known wells within 4.8 km (3 mi) of HISS that are used to furnish drinking water for the public. Public water needs in the area are met by using treated Mississippi River water.

6.2 GROUNDWATER MONITORING

6.2.1 Methods

The hydrogeological interpretations presented here are based on groundwater levels measured in monitoring wells during 1991; these levels were measured at weekly intervals using an electric downhole probe water level indicator.

Groundwater monitoring wells (Figure 6-1) were installed at HISS in two phases. Eight first-phase wells (HISS-1 through HISS-8) were installed in 1982 as part of the radiological site assessment program conducted by Oak Ridge Associated Universities. The geologic logs and details of construction methods for the first-phase wells are not available. BNI installed seven second-phase wells (HISS-9 through HISS-15) in late 1984 and an additional well (HISS-16) in June 1989 to supplement readings from HISS-8, which was permanently closed in August 1990. A summary of well construction information for wells installed in 1984 and 1989 is presented in Table 6-1, and an example of well construction is shown in Appendix G. Further background information on site geology, hydrogeology, and well construction can be found in the Report on Drilling and Observation Well Installations at the Hazelwood Interim Storage Site, St. Louis County, Missouri (BNI 1985).

Water level measurements from monitoring wells are used to prepare two types of graphic exhibits (hydrographs and

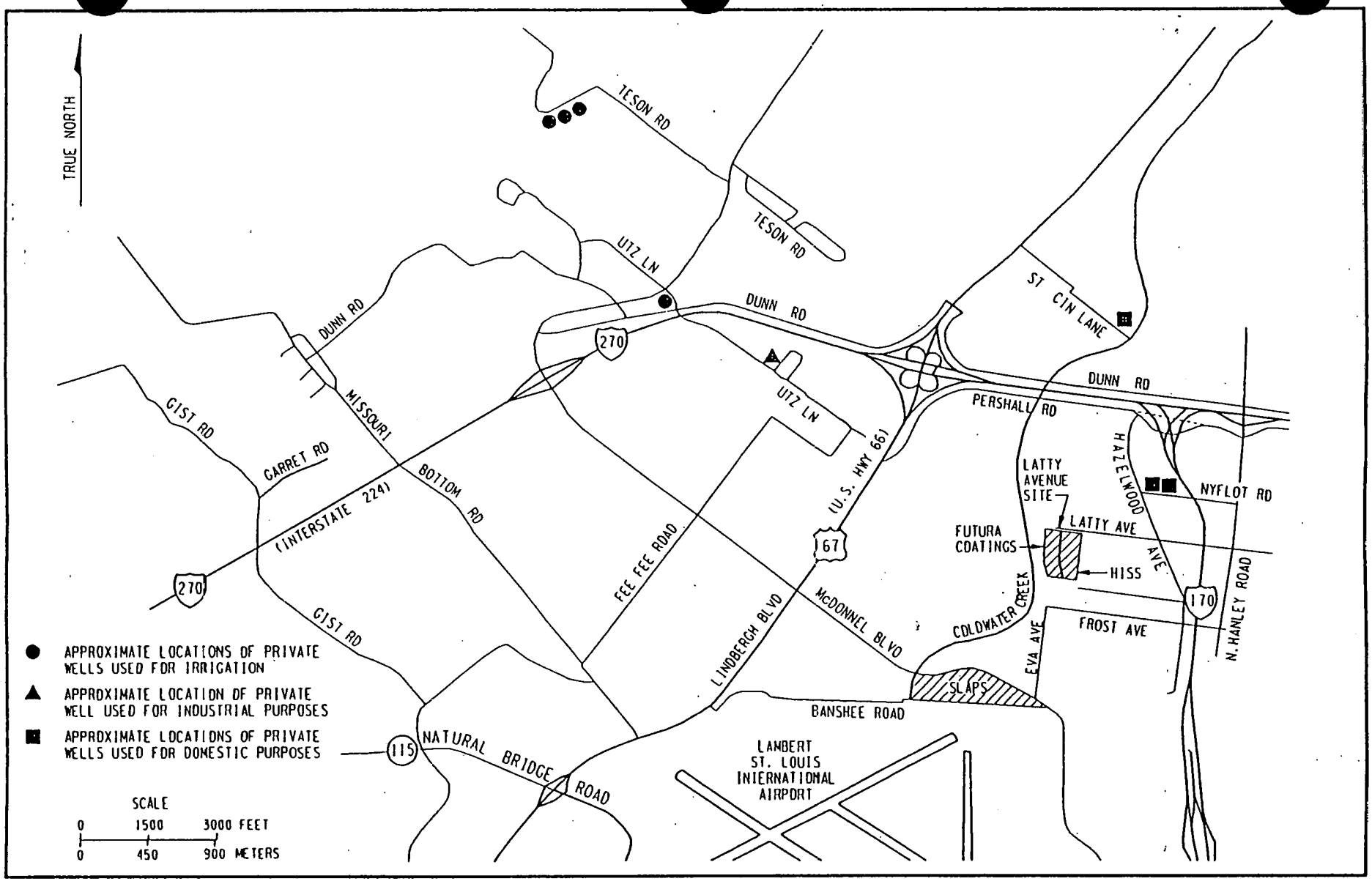

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Figure 6-2
Locations of Private Wells in HISS Vicinity

Table 6-1
HISS Monitoring Well Construction Summary

Well Number	Completion Date	Total Depth [m (ft)]	Monitored or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
HISS-1	Jan. 1982	7.6 (25.0)	No Documentation	PVC[a]
HISS-2	Jan. 1982	9.8 (32.2)	No Documentation	PVC
HISS-3[b]	Jan. 1982	6.6 (21.6)	No Documentation	PVC
HISS-4[b]	Jan. 1982	6.8 (22.2)	No Documentation	PVC
HISS-5	Jan. 1982	6.4 (21.1)	No Documentation	PVC
HISS-6	Jan. 1982	4.6 (15.1)	No Documentation	PVC
HISS-7	Jan. 1982	5.2 (17.0)	No Documentation	PVC
HISS-8[c]	Jan. 1982	6.4 (21.0)	No Documentation	PVC
HISS-9	Dec. 1984	8.7 (28.5)	5.9-8.7 (19.4-28.5)	PVC
HISS-10	Dec. 1984	7.6 (25.0)	4.3-7.2 (14.1-23.5)	PVC
HISS-11	Dec. 1984	7.3 (23.8)	3.9-6.8 (12.7-22.3)	PVC
HISS-12	Dec. 1984	6.1 (20.0)	3.1-5.6 (10.0-18.5)	PVC
HISS-13	Dec. 1984	7.6 (25.0)	3.1-7.2 (10.0-23.5)	PVC
HISS-14	Dec. 1984	9.2 (30.0)	2.8-8.7 (9.3-28.5)	PVC
HISS-15	Dec. 1984	6.3 (20.5)	3.1-5.8 (10.3-19.0)	PVC
HISS-16	June 1989	6.7 (22.0)	3.2-6.3 (10.4-20.6)	Enco Fiberglass Epoxy
B53WO1S[d]	Nov. 1987	8.4 (27.5)	5.2-8.4 (17.0-27.5)	316 Stainless Steel
B53WO1D[d]	Nov. 1987	28.5 (93.5)	24.3-28.5 (79.7-93.5)	316 Stainless Steel

[a]PVC - polyvinyl chloride.

[b]Well dropped from monitoring program in August 1991.

[c]Well closed in August 1990.

[d]Background well located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS.

NOTE: Water level elevations for wells monitored in 1991 are shown as hydrographs in Appendix G.

potentiometric surface maps) that demonstrate hydrogeological conditions. Hydrographs are line graphs that display changes in water levels for each monitoring well throughout the year (Appendix G). The HISS hydrographs also include bar graphs showing U.S. Weather Service precipitation measurements for the St. Louis area as an aid in evaluating the influence of precipitation on water level behavior.

The hydraulic gradient and the flow direction of the HISS groundwater system are determined from potentiometric surface (water level) maps (Figures 6-3 through 6-5). These maps are prepared by plotting water level elevations for selected dates on a base map and contouring the values. The potentiometric surface of the groundwater system can change as a result of varying amounts of recharge to groundwater, which are caused by inconsistent amounts of precipitation and infiltration. As a result, the potentiometric surface map for any given time may not reflect the configuration of the potentiometric surface at another period in time.

An inspection conducted during April 1991 revealed several deficiencies in the integrity of several HISS monitoring wells. These deficiencies included damaged surface seals, accumulation of silt on screens, and inadequately labeled wells. Nonconformance reports were issued to ensure that all of the deficiencies were properly repaired. A follow-up inspection of the wells was conducted in April 1992 to verify that repairs had been made and to identify additional deficiencies. The results of the second inspection are not yet available. Future activities will address the need to document well performance through time, will continue to identify deficiencies in well integrity, and will ensure that all deficiencies are corrected.

6.2.2 Results and Conclusions

Hydrographs prepared for water levels measured in 1991 (shown in Appendix G) show slight seasonal fluctuations in groundwater levels. HISS-3 and HISS-4 were dropped from the water level monitoring program after the August 15, 1991, reading because data from these wells were duplicated by data collected from HISS-15 and

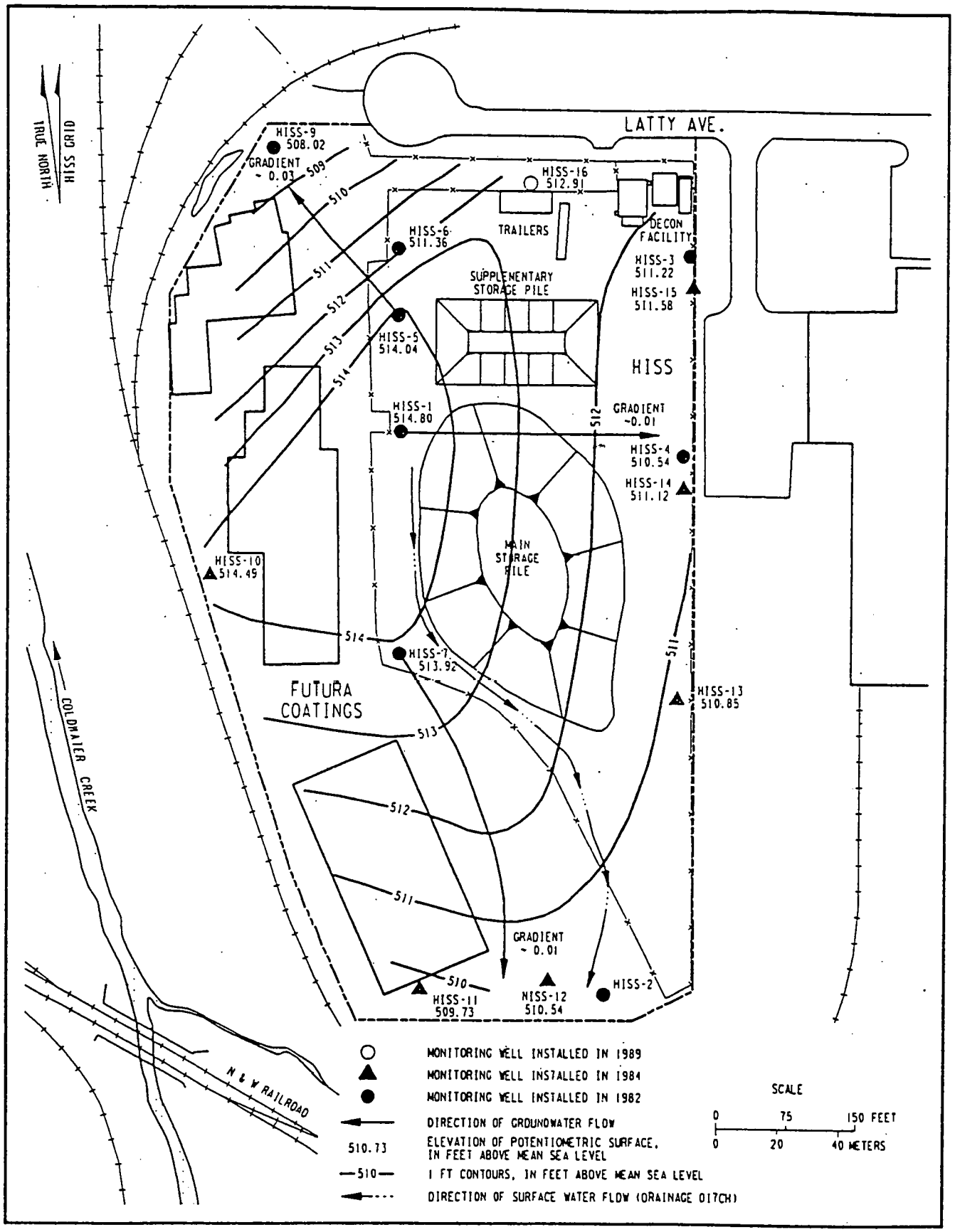

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Figure 6-3
HISS Potentiometric Surface Map (3/14/91)

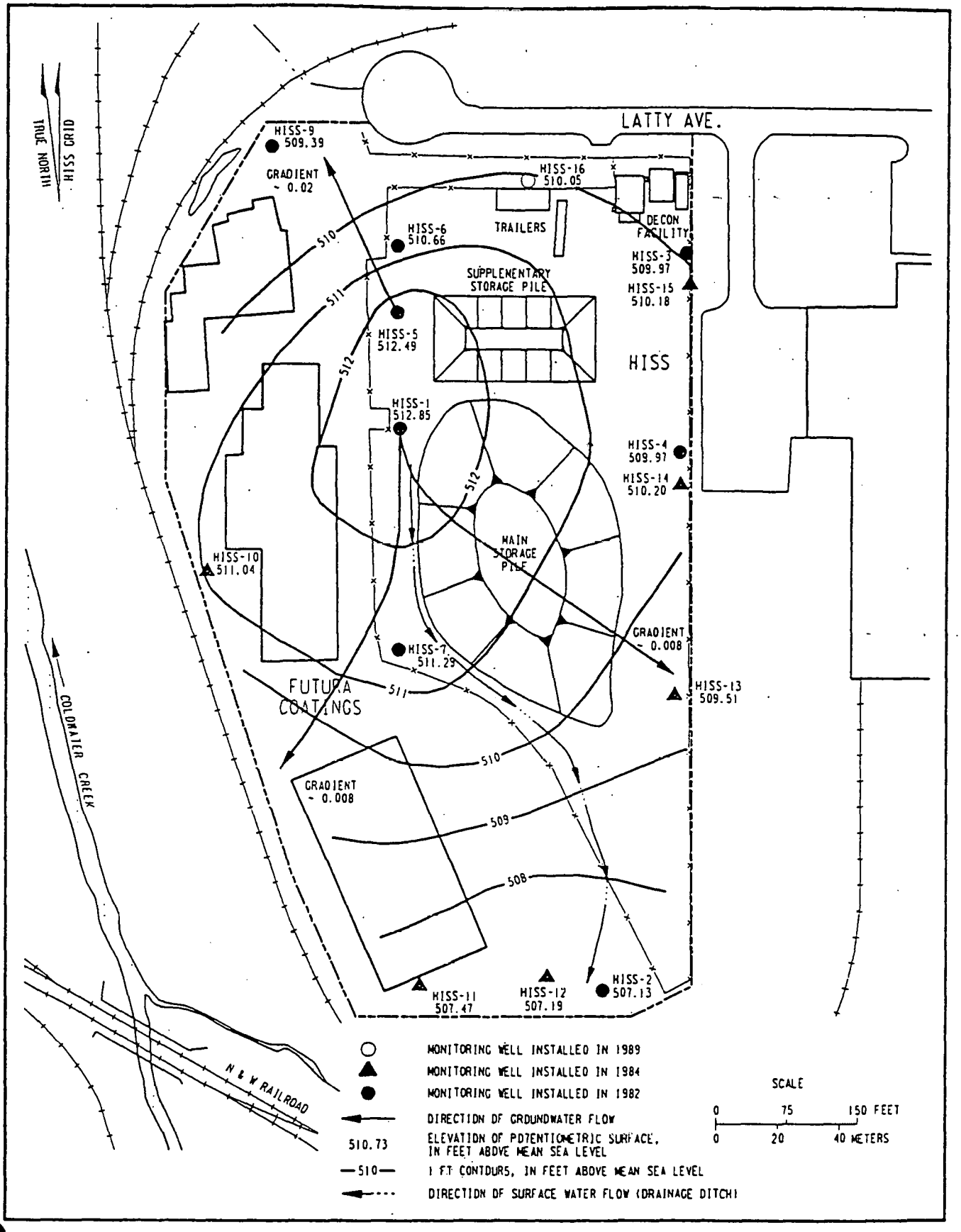

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Figure 6-4
HISS Potentiometric Surface Map (7/18/91)

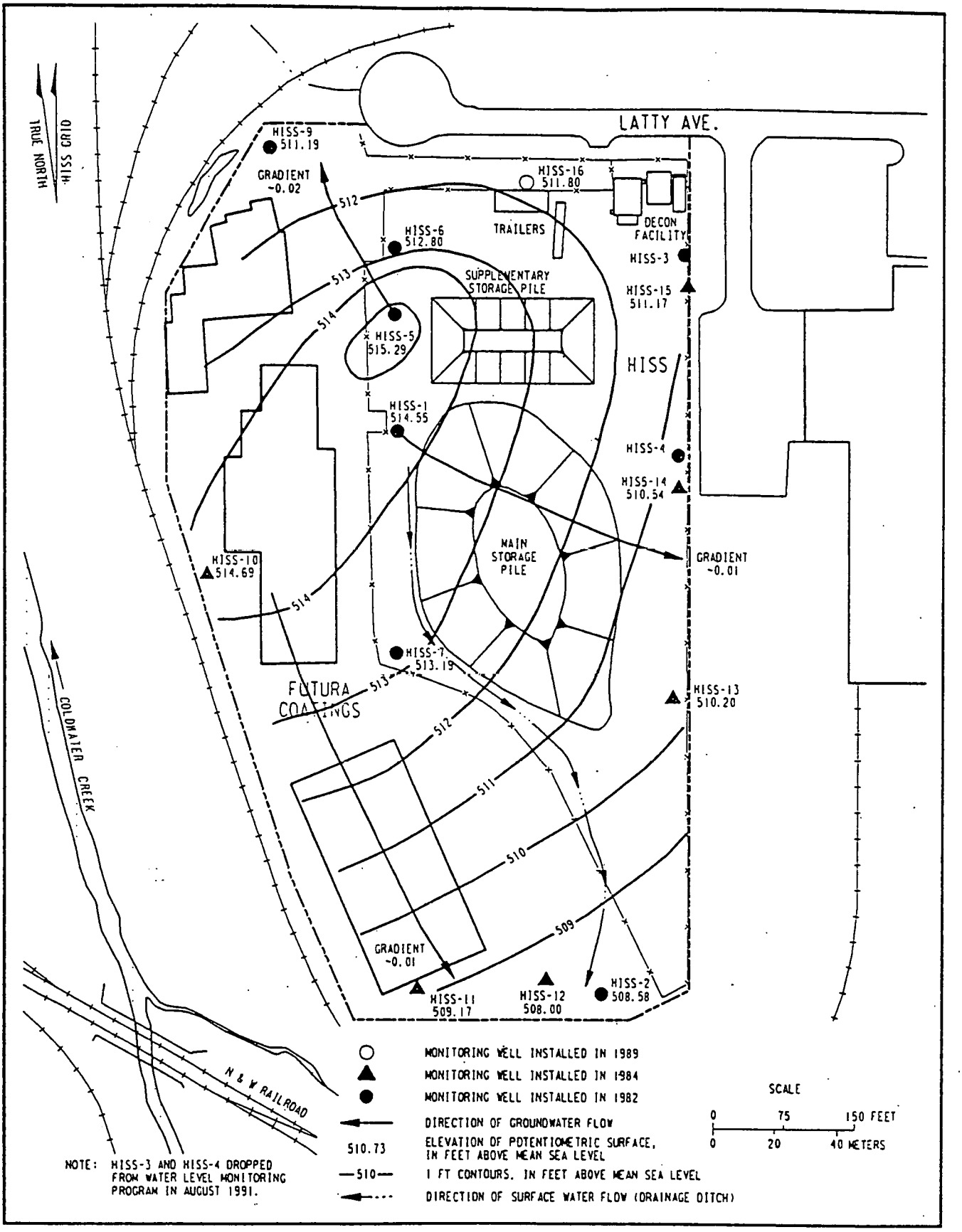

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Figure 6-5
HISS Potentiometric Surface Map (11/1/91)

HISS-14, respectively. Approximate trends have been added to each hydrograph to aid in interpreting the data. The rise in water levels that typically is seen in the spring was not observed in 1991 (except in HISS-16). This change in water level behavior may be the result of a relatively mild winter during which infiltration was not inhibited by the presence of snow and ice on the ground surface. Infiltration therefore would be more evenly distributed throughout the year. The water levels were lowest in the fall, repeating the seasonal fluctuation pattern seen in 1988, 1989, and 1990 (BNI 1989, 1990b, 1991a). Comparison of water levels with precipitation events shown on the hydrographs reveals a close relationship between the two in many of the wells. The water level response to precipitation indicates that the area around the responding wells is experiencing rapid infiltration from precipitation events.

The general groundwater flow pattern is radial, with the groundwater flowing outward from the area around wells HISS-1 and HISS-5 toward the other wells. The hydraulic gradients for 1991 were calculated for several flow directions. The southwestern flow direction was representative of flow beneath the HISS pile with a value consistent with results from previous years. The calculated flow direction was to the southeast in previous years. The calculated southeastern flow direction for 1991 is similar to those for 1988, 1989, and 1990 (BNI 1989, 1990b, 1991a). The 1991 gradients for the southeastern and eastern flow directions are 0.01 for spring (3/14/91; Figure 6-3), 0.008 for summer (7/18/91; Figure 6-4), and 0.01 for fall (11/01/91; Figure 6-5). The hydraulic gradient to the south is similar to that of flow to the southeast and east. The hydraulic gradient to the northeast is slightly greater, ranging from 0.02 to 0.03.

The slight seasonal variations from spring to winter shown on the hydrographs do not affect the slope of the potentiometric surface or the direction of groundwater flow (Figures 6-3 through 6-5). In all seasons the hydraulic gradients and the direction of flow are radial, away from HISS-1 and HISS-5, which are located in an area of greater surface recharge. To detect contaminants that might migrate from the HISS pile, groundwater downgradient of wells

HISS-1 and HISS-5 is sampled and analyzed. Results of groundwater monitoring in 1991 for radiological parameters are reported in Subsection 4.1.5 and for nonradiological parameters are reported in Subsection 5.1.

Preliminary investigation of radial flow in the area around these wells has revealed that they are underlain by soils with high electromagnetic terrain conductivity values. The highest of these values occur where standing water is occasionally present, suggesting that the soils may be saturated. Water accumulates and stands in a drainage ditch along the western edge of the HISS pile (see Figures 6-3 through 6-5). Water that has accumulated in the ditch probably preferentially recharges groundwater under the ditch, which could result in the elevated water levels observed along the western side of the pile. The amount and occurrence of standing water in the ditch is currently being evaluated to determine the effects of standing water on the water table at the site.

7.0 QUALITY ASSURANCE

7.1 INTRODUCTION

This section summarizes the quality assurance (QA) assessment of environmental surveillance activities at HISS, which were conducted to ensure that onsite contamination is not posing a threat to human health and the environment. Based on this criterion, the overall data quality objective (DQO) for the environmental monitoring program is to provide data of a sufficient quality to allow reliable detection and quantification of any potential release of contaminated material from HISS.

7.2 PROCEDURES

The Quality Assurance Program Plan for the U.S. DOE FUSRAP (QAPmP) (BNI 1990c) addresses the quality requirements for all work being performed as part of FUSRAP. In addition, all subcontractors adhere to or implement a QA system that is compatible with the program. The objectives of the QAPmP are to maintain quality through a system of planned work operations and to verify the preservation of quality standards through a system of checks and reviews.

Established QA procedures are detailed in project procedures and instructions and an instruction guide and are implemented for all field sampling activities. Sampling methodology and techniques are consistent with the methods detailed in A Compendium of Superfund Field Operations Methods (EPA 1987). Laboratory QA procedures, which have been reviewed by BNI, are implemented to control applicable laboratory activities. In addition, various activities (such as data reviews, calculations, and evaluations) are conducted to monitor the information being generated and to prevent or identify quality problems. Quality control (QC) sample requirements, data use information, and QA/QC procedures are provided in project instruction guides.

7.3 QUALITY ASSURANCE SUMMARY

QA/QC activities are an integral part of environmental monitoring activities at HISS. The quality of the data collected for the 1991 monitoring program is considered to be appropriate for these reporting purposes.

The QA/QC program implemented at HISS satisfies the 1991 requirements of DOE Orders 5400.1, 5400.5, and 5700.6B. The programmatic controls in place during the 1991 environmental monitoring program are discussed in the project instruction guide.

The specific methods and formulas used to evaluate the QA/QC program are described in an internal BNI QA document for annual site environmental reports; the QA document also discusses the requirements of precision, accuracy, representativeness, comparability, and completeness (PARCC). This subsection summarizes the results of the QA/QC program at HISS.

7.3.1 Data Usability

To determine data usability, the analytes of interest for HISS were evaluated for the PARCC parameters; Table 7-1 lists each analyte and indicates whether it meets these and other parameters. All elements of the PARCC parameters have been satisfied for the following analytes:

- TOC in groundwater
- TOX in groundwater
- Radium-226 in groundwater, surface water, and sediments
- Thorium-230 in groundwater, surface water, and sediments
- Total uranium in groundwater and surface water

Other analytes were also evaluated, and certain elements did not fully meet PARCC requirements or could not be completely evaluated because some QC data were not retrievable. Corrective actions were initiated for all identified data deficiencies and nonconformances. As part of the ongoing FUSRAP QA program,

Table 7-1

Data Usability Summary

ANALYTE	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY	QUANTITATIVE	QUALITATIVE	DQO[1]
Total organic carbon	YES[2]	YES	YES	YES	YES	YES	YES	YES
Total organic halides	YES	YES	YES	YES	YES	YES	YES	YES
Radium-226	YES	YES	YES	YES	YES	YES	YES	YES
Thorium-230	YES	YES	YES	YES	YES	YES	YES	YES
Total uranium	YES	YES	YES	YES	YES	YES	YES	YES
Uranium-233/234	3	4	5	YES	6	7	YES	YES
Uranium-234	YES	4	5	YES	6	7	YES	YES
Uranium-235	YES	4	5	YES	6	7	YES	YES
Uranium-238	YES	YES	5	YES	YES	YES	YES	YES
Radon-222	YES	YES	8	YES	YES	9	YES	YES
External gamma radiation	YES	YES	8	YES	YES	9	YES	YES

NOTE: Further information on any of the above PARCC parameters can be found in the corresponding summaries of the text.

1 The data quality objective for the environmental monitoring program is to detect and quantify any release from HISS that could be potentially harmful to human health and environment.

2 The term "Yes" indicates that data are usable based on the analyses of the indicated PARCC parameters.

3 Total variation could not be measured because laboratory duplicate data were not available or were incomplete for this parameter.

4 Data on laboratory spikes (standard reference materials) and blanks were not available or were incomplete for this parameter.

5 Data on laboratory blanks were not available or were incomplete for this parameter.

6 Comparability factor could not be calculated because precision and accuracy information was not available was incomplete for this parameter.

7 Data do not meet quantitative goals because they do not meet the overall goal of 80 percent for the PARCC parameters.

8 Representativeness could not be assessed for this parameter because there were no applicable elements to which a value could be assigned.

9 A value could not be assigned for this parameter because representativeness elements could not be assessed.

appropriate actions have been implemented including root-cause analyses and procedure development and revision.

Results of the evaluation indicate that the data quality for the following analytes did meet the intended end use. After a thorough review of all site information (including non-QC data), the results were determined to be of sufficient quality to achieve reliable detection and quantification of any potential release of contaminated material from HISS.

- Isotopic uranium (uranium-233/234, uranium-234, uranium-235, uranium-238) in sediment
- Radon-222 in air
- External gamma radiation

7.3.2 Precision

The precision goal of 80 percent, as measured by analytical results for matrix spike duplicates (MSDs) and field and laboratory duplicates, was met for all chemical parameters at HISS. This goal indicates that a minimum of 80 percent of the QC results fell within acceptable ranges. MSDs were analyzed for the chemical parameters of TOC and TOX; all results met the established method criteria, which demonstrates that the laboratory methods met the program objectives. Calculations indicate that minimal variability was introduced by sampling. TOX values indicate slightly elevated sampling variability; because of the volatile nature of some organic halides, a greater degree of variability was expected, but the values are still within acceptable project limits.

The precision goal of 80 percent was met for all analytes of concern except uranium-233/234 in sediments. Radiological QC data indicate that some degree of variability was present (except for external gamma radiation data, which showed minimal variability). A high degree of variability was seen in field duplicate results as measured by relative percent differences (RPDs); however, the RPDs were calculated from a limited data population. (As more data become available, the statistical reliability of these values increases, control limits become tighter, and data more accurately

reflect true site conditions.) The radiological methods used have no defined criteria for RPD values near the method detection limits; therefore, sampling variation cannot be quantitatively separated from laboratory variation. Because the laboratory precision criterion has not been established, the calculated upper control limit from the field duplicates (the mean plus three standard deviations) was used as the standard of data quality.

Values for radiological sediment analyses are considered qualitative because no field duplicate samples were taken and, consequently, total variability could not be quantified. Qualitative data are useful for estimating the approximate concentration or activity of an analyte, but the amount of variation associated with the data remains unknown.

Data from the FUSRAP radiological laboratory's monthly QC reports indicate that all analytes met the overall laboratory duplicate requirements for precision, except for uranium-233/234. Data for this analyte are considered qualitative; however, the program's DQOs for precision have been met.

7.3.3 Accuracy

QC sample analyses for TOC and TOX indicated that all samples met the accuracy goal; no contamination was detected in rinse blanks, and all matrix spikes reported were within acceptable recovery limits.

QC sample analyses for thorium-230 indicated that all samples met the program requirements for radiological accuracy. Samples analyzed for radium-226, uranium-235, uranium-238, and total uranium had some minute blank contamination within acceptable accuracy requirements.

Accuracy requirements were not met for uranium-233/234, uranium-234, and uranium-235 analyses because results were not available for standard reference materials (SRMs) and laboratory blanks. All values associated with these parameters have been estimated and are considered qualitative. Accuracy results are based on twelve months of laboratory data.

Evaluation of radiological accuracy was limited because it was based on the total reported results for all FUSRAP sites where environmental monitoring was conducted in 1991. Laboratory QC data were summarized in a monthly report that provided an overall assessment of the laboratory's performance for that period. Because of the summary nature of the reports, HISS QC data may be more accurate than actually reported.

7.3.4 Representativeness

The program's required objective for representativeness was met for all chemical and radiological data with the exception of analytical results for the uranium isotopes, for which blank information was incomplete. In addition, representativeness could not be assessed for radon and external gamma radiation because none of the elements used to assess representativeness are applicable for these analytes.

7.3.5 Completeness

At HISS, 100 percent of the groundwater, surface water, and sediment samples requested were analyzed for the specified radiological and chemical analytes, fulfilling the required objective for completeness. Air monitoring was conducted for radon, and external gamma radiation, and all required data were collected.

7.3.6 Comparability

HISS data met the program requirements for comparability for all nonradiological, radium-226, thorium-230, total uranium, radon, and external gamma radiation samples. Analyses for the uranium isotopes could not be fully evaluated because precision and accuracy data were unavailable.

7.4 PROGRAMMATIC FACTORS

FUSRAP has also established specific requirements for qualifications and training of personnel, data management and recordkeeping, chain-of-custody procedures, audits, performance reporting, independent data verification, and laboratory certification. These topics are covered in more detail in the QA/QC document.

7.5 DOE LABORATORY QUALITY ASSESSMENT PROGRAM FOR RADIOACTIVE MATERIAL

Results of the radiological laboratory's participation in the DOE Environmental Measurements Laboratory Quality Assessment Program are presented in Table 7-2. The range of ratios presented has been determined to satisfy the requirements of the quality assessment program for radioactive material.

Table 7-2

Results of the Quality Assessment Program, 1991

Sample Type	Analysis	Results TMA/E[a]	Results EML[b]	Units	Ratio TMA/E:EML
Air Filter	Be-7	63.1	53.0	Bq/filter	1.19
Air Filter	Mn-54	5.90	4.80	Bq/filter	1.23
Air Filter	Sr-90	0.914	0.789	Bq/filter	1.16
Air Filter	Cs-137	5.83	4.53	Bq/filter	1.29
Air Filter	Ce-144	67.3	52.2	Bq/filter	1.29
Air Filter	Pu-239	0.146	0.154	Bq/filter	0.948
Air Filter	Am-241	0.0940	0.101	Bq/filter	0.931
Air Filter	U-234	0.0514	0.0350	Bq/filter	1.47
Air Filter	U-238	0.0444	0.0350	Bq/filter	1.27
Soil	K-40	348	374	Bq/kg	0.931
Soil	Cs-137	154	150	Bq/kg	1.03
Soil	Pu-238	10.8	11.5	Bq/kg	0.939
Soil	Pu-239	3.27	3.40	Bq/kg	0.962
Soil	Am-241	1.48	1.76	Bq/kg	0.841
Soil	U-234	26.7	29.4	Bq/kg	0.908
Soil	U-238	23.0	30.0	Bq/kg	0.767
Vegetation	K-40	492	1150	Bq/kg	0.428
Vegetation	Sr-90	151	186	Bq/kg	0.812
Vegetation	Cs-137	74.4	67.6	Bq/kg	1.10
Vegetation	Pu-238	3.50	4.06	Bq/kg	0.862
Vegetation	Pu-239	0.962	1.40	Bq/kg	0.687
Vegetation	Am-241	0.608	0.829	Bq/kg	0.733
Water	H-3	321	361	Bq/L	0.889
Water	Mn-54	194	213	Bq/L	0.911
Water	Co-57	187	230	Bq/L	0.813
Water	Co-60	178	201	Bq/L	0.886
Water	Sr-90	8.53	8.63	Bq/L	0.988
Water	Cs-137	150	169	Bq/L	0.888
Water	Ce-144	33.2	35.1	Bq/L	0.946
Water	Pu-239	0.665	0.773	Bq/L	0.860
Water	Am-241	1.23	1.19	Bq/L	1.03
Water	U-234	0.236	0.219	Bq/L	1.08
Water	U-238	0.275	0.219	Bq/L	1.26
Air Filter	Be-7	74.7	53.8	Bq/filter	1.39
Air Filter	Mn-54	27.1	24.3	Bq/filter	1.12
Air Filter	Co-57	20.0	16.6	Bq/filter	1.20
Air Filter	Co-60	23.6	23.0	Bq/filter	1.03
Air Filter	Sr-90	0.773	0.663	Bq/filter	1.17
Air Filter	Cs-137	31.6	28.0	Bq/filter	1.13
Air Filter	Ce-144	54.5	50.8	Bq/filter	1.07
Air Filter	Pu-239	0.0704	0.0840	Bq/filter	0.838
Air Filter	Am-241	0.0858	0.104	Bq/filter	0.825
Air Filter	U-234	0.0518	0.0395	Bq/filter	1.31
Air Filter	U-238	0.0585	0.0388	Bq/filter	1.51
Soil	K-40	301	430	Bq/kg	0.700
Soil	Cs-137	240	312	Bq/kg	0.769

Table 7-2

(continued)

Sample Type	Analysis	Results TMA/E[a]	Results EML[b]	Units	Ratio TMA/E:EML
Soil	Pu-239	8.25	7.35	Bq/kg	1.12
Soil	Am-241	1.31	1.58	Bq/kg	0.829
Soil	U-234	25.3	28.9	Bq/kg	0.875
Soil	U-238	26.1	28.9	Bq/kg	0.903
Vegetation	K-40	819	992	Bq/kg	0.826
Vegetation	Sr-90	308	439	Bq/kg	0.702
Vegetation	Cs-137	11.7	27.1	Bq/kg	0.432[c]
Vegetation	Pu-239	0.352	0.365	Bq/kg	0.964
Vegetation	Am-241	0.222	0.266	Bq/kg	0.835
Water	H-3	16.6	100	Bq/L	0.166[c]
Water	Mn-54	91.2	103	Bq/L	0.885
Water	Co-57	154	166	Bq/L	0.928
Water	Co-60	261	291	Bq/L	0.897
Water	Sr-90	8.40	10.1	Bq/L	0.832
Water	Cs-137	42.8	46.0	Bq/L	0.930
Water	Ce-144	201	226	Bq/L	0.889
Water	Pu-239	0.519	0.510	Bq/L	1.02
Water	Am-241	0.620	0.570	Bq/L	1.09
Water	U-234	0.426	0.462	Bq/L	0.922
Water	U-238	0.485	0.478	Bq/L	1.01

[a]TMA/E - ThermoAnalytical/Eberline, the radiological analysis subcontractor for FUSRAP.

[b]EML - the DOE Environmental Measurements Laboratory.

[c]Corrective action request has been issued.

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ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr in excess of background level includes exposure from all pathways except medical treatments and exposures from radon (DOE 1990b). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as the use of occupancy factors in determining dose due to 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 results in calculated doses that more accurately reflect the exposure potential from site activities.

DERIVED CONCENTRATION GUIDES

As referenced in Section 2.0, DOE orders provide the standards for radionuclide emissions from DOE facilities. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides the procedures and requirements for radionuclide releases.

Applicable standards are found in Chapter III of DOE Order 5400.5 and are set as derived concentration guides (DCGs). A DCG is defined as the concentration of a single radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (e.g., ingestion of water, inhalation), would result in an effective dose equivalent of 100 mrem. The following table provides reference values for conducting radiological environmental protection programs at operational DOE facilities and sites.

Radionuclide	F1 Value[a]	Ingested[b] Water DCG (μCi/ml)	Inhaled Air DCGs[c]		
			D	W	Y
Radium-226	2E-1	1E-7	--	1E-12	--
Thorium-230	2E-4	3E-7	--	4E-14	5E-14
" 232	2E-4	5E-8	--	7E-15	1E-14
Uranium-234	2E-3	5E-6	--	--	9E-14
" 235	2E-3	5E-6	--	--	1E-13
" 238	2E-3	6E-6	--	--	1E-13
Radon-222[d]	3E-9	3E-9	--	--	3E-9
" 220[d]	3E-9	3E-9	--	--	3E-9

[a]F1 is defined as the gastrointestinal tract absorption factor. This measures the uptake fraction of ingestion of a radionuclide into the body.

[b]1E-9 μCi/ml = 0.037 Bq/L = 1 pCi/L.

[c]Inhaled air DCGs are expressed as a function of time. D, W, and Y represent a measure of the time required for contaminants to be removed from the system (D represents 0.5 day; W represents 50 days; and Y represents 500 days).

[d]DOE is reassessing the DCGs for radon. Until review is completed and new values issued, the values given in the chart above will be used for releases from DOE facilities.

SOIL GUIDELINES*

Guidelines for residual radioactivity in soil established for FUSRAP are shown below.

Radionuclide	Soil Concentration (pCi/g) Above Background
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
Other Radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use. A proposed guideline of 50 pCi/g is being used for uranium for planning purposes.

Source: U.S. Department of Energy, "Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Surplus Facilities Management Program Sites," Revision 2, March 1987.

APPENDIX B

PARAMETERS FOR ANALYSIS

PARAMETERS FOR ANALYSIS AT HISS, 1991

Medium[a]	Parameter	Technique
Groundwater	Total uranium	Fluorometric/Kinetic phosphorescence analysis
	Radium-226	Emanation/Alpha spectroscopy
	Thorium-230	Alpha spectrometry
	Total organic halides	Carbonaceous analyzer
	Total organic carbon	Coulometric determination
	Specific conductivity	Electrometric
	pH	Electrometric
Surface Water	Total uranium	Fluorometric/Kinetic phosphorescence analysis
	Radium-226	Emanation/Alpha spectroscopy
	Thorium-230	Alpha spectrometry
Sediment	Total uranium	Alpha spectrometry
	Radium-226	Gamma spectrometry
	Thorium-230	Alpha spectrometry
Air	Radon-222	Track-etch
	External gamma radiation	Thermoluminescence

[a]Air samples are cumulative; all others are grab samples.

APPENDIX C
METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

Average annual concentrations are calculated by averaging the results of all four quarters of sampling. When possible, sampling results are compiled in computer spreadsheets and the average values are calculated for all quarters of data.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter			
	1	2	3	4
1	13	7	12	5

Average annual concentrations are calculated by adding the results for the year and dividing by the number of quarters for which data have been taken and reported (usually four). An example is given below.

First, results reported for the year are added.

$$13 + 7 + 12 + 5 = 37$$

Next, the sum of all results is divided by the number of quarters for which data were taken and reported. In this example there were data for all four quarters.

$$37 \div 4 = 9.25$$

Because there are two single-digit numbers (5 and 7), the result is rounded to 9 (number of significant figures is 1). This value is entered into the average value column.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter				Average Value
	1	2	3	4	
1	13	7	12	5	9

Expected concentration ranges are calculated to provide a basis for trend analysis of the data. These expected ranges are calculated by taking the average of the annual average concentrations for the past five years (when possible) and calculating a standard deviation for these data. The lower expected range is calculated by subtracting two standard deviations from the average value, and the upper range is calculated by adding two standard deviations to the average values. If site conditions do not change, 95 percent of the data points would be expected to fall within this range. An example of these calculations is shown below.

Thorium-230 Results (pCi/L)

Sampling Location	Year					Average Value	Standard Deviation
	1986	1987	1988	1989	1990		
1	10	5	14	8	5	8	4

The formula for calculation of the standard deviation of a sample xi, ..., xn is:

$$S = \sqrt{S^2} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

where: S = Standard deviation

x_i = Individual values

$\bar{x}$ = Average of values

n = Number of values

n	x_i	$\bar{x}$	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	10	8	2	4
2	5	8	-3	9
3	14	8	6	36
4	8	8	0	0
5	5	8	-3	9

$$\sum (X_i - \bar{x})^2 = 58$$

$$S = \sqrt{\frac{58}{5 - 1}} = \sqrt{\frac{58}{4}} = \sqrt{14.5} = 3.807,$$

which rounds to 4 because there is only one significant figure.

The calculation for the expected ranges for this example is shown below.

Lower expected range: $8 - 2(4) = 0$
Upper expected range: $8 + 2(4) = 20$ (rounded to one significant figure)

Annual average values for the current year are compared with these ranges to indicate a possible anomaly or trend. If a discernible trend is found from this comparison, the data are presented in the appropriate section of the report.

APPENDIX D

POPULATION EXPOSURE METHODOLOGY

POPULATION EXPOSURE METHODOLOGY

DOSE CALCULATION METHODOLOGY

DOE Order 5400.5 requires that the impacts of the site on both the hypothetical maximally exposed individual and the population within 80 km (50 mi) of the site be evaluated. For radioactive materials, this evaluation is usually conducted by calculating the dose received by a hypothetical maximally exposed individual and the general population and comparing this dose with DOE guidelines. This appendix describes the methodology used to calculate the doses given in Subsection 4.2.

PATHWAYS

The purpose of the dose calculation is to identify the potential routes or pathways that are available to transmit either radioactive material or ionizing radiation to the receptor. In general, the pathways are (1) direct exposure to gamma radiation, (2) atmospheric transport of radioactive material, (3) transport of radioactive material via surface water or groundwater, (4) bioaccumulation of radioactive materials in animals used as a food source, and (5) uptake of radioactive materials by plants used as a food source. For FUSRAP sites, the primary pathways are direct gamma radiation and transport of radioactive materials by the atmosphere, groundwater, and surface water. The others are not considered primary pathways because FUSRAP sites are not located in areas where significant sources of livestock are raised or foodstuffs are grown.

Gamma rays can travel until they expend all their energy in molecular or atomic interactions. In general, these distances are not very great and the exposure pathway would affect only the maximally exposed individual.

Contamination transported via the atmospheric pathway takes the form of contaminated particulates or dust and can provide a

potential dose only when it is inhaled. Doses from radon are intentionally excluded; radon exposure is in compliance with concentration requirements for boundaries.

Contamination is transported in surface water when runoff from a rainfall event or some other source of overland flow carries contamination from the site to the surface water system. This contamination poses an exposure problem only when the surface water is used to provide municipal drinking water or to water livestock and/or to irrigate crops. Contamination transported via groundwater when contaminants migrate into the groundwater system becomes a problem if there is a potential receptor.

Primary Radionuclides of Concern

The primary radionuclides of concern for these calculations are uranium-238, uranium-235, uranium-234, thorium-230, radium-226, and the daughter products (excluding radon). For several of the dose conversion factors used in these calculations, the contributions of the daughters with half-lives of less than one year are included with the parent radionuclide. Table D-1 lists the pertinent radionuclides, their half-lives, and dose conversion factors for ingestion.

DOSE CALCULATION METHOD

Direct Gamma Radiation Pathway

As previously indicated, direct gamma radiation exposure is important in calculating the dose to the hypothetical maximally exposed individual. The dose from direct gamma radiation exposure is determined by using data collected through the tissue-equivalent thermoluminescent dosimeter (TETLD) program (described in Section 4.0). These data provide a measure of the amount and energy (in units of mR) of the ionizing radiation at 1 m (3 ft) above the ground. For the purposes of this report, it is assumed that the hypothetical maximally exposed individual works 40 hours

Table D-1

Radionuclides of Interest

Radionuclide	Half-life[a]	Dose Conversion Factor[b] for Ingestion (mrem/pCi)
Uranium-238	4.51E+9 years	2.5E-4
Thorium-234	24.1 days	--[c]
Protactinium-234 m	1.17 minutes	--[c]
Protactinium-234	6.75 hours	--[c]
Uranium-234	2.47E+5 years	2.6E-4
Thorium-230	8.0E+4 years	5.3E-4
Radium-226	1602 years	1.1E-3
Uranium-235	7.1E+8 years	2.5E-4
Thorium-231	25.5 hours	--[d]
Protactinium-231	3.25E+4 years	1.1E-2
Actinium-227	21.6 years	1.5E-2
Thorium-227	18.2 days	--[e]
Radium-223	11.43 days	--[e]

[a]Source: Radiological Health Handbook (HEW 1970).

[b]Source: Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation Submersion (EPA-520/1-88-020) and International Dose Conversion Factors for Calculation of Dose to the Public (DOE/EH-0071).

[c]Included in the uranium-238 dose conversion factor.

[d]Included in the uranium-235 dose conversion factor.

[e]Included in the actinium-227 dose conversion factor.

per week at Futura Coatings at an average distance of 46 m (150 ft) from the site; there are no houses and, therefore, no residents near the site.

The dose to the hypothetical maximally exposed individual can be determined by assuming that the individual is exposed to a line source located along the HISS/Futura fenceline. Because the average exposure rate is known (from the TETLD program) for a distance of 1 m (3 ft) from the fenceline, the exposure at 46 m (150 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

$$\text{Exposure at 46 m} = (\text{Exposure at 1 m}) \times \frac{h_1}{h_2} \times \frac{\tan^{-1}(L/h_2)}{\tan^{-1}(L/h_1)}$$

where: h_1 = TETLD distance from the fenceline [1 m (3 ft)]

h_2 = Hypothetical maximally exposed individual's distance from the fenceline [46 m (150 ft)]

L = Half of the length of the site toward McDonnell Boulevard [152 m (500 ft)]

The exposure rate at 1 m (3 ft) can be calculated by taking the average of the results from the five dosimeters along this portion of the fenceline (1, 2, 5, 6, and 7). The average exposure rate for these dosimeters was 30 mR/yr. Using the formula above, the exposure rate at 46 m (150 ft) is approximately 0.48 mR/yr. Because 1 mR is approximately equal to 1 mrem, the resulting dose would be 0.48 mrem, assuming 24-h continuous residence. However, this is the dose for the entire year; to calculate the dose to a worker (8 h/day), the following equation must be used.

$$\text{Dose} = (\text{Dose at 46 m}) \times \frac{(40 \text{ h/wk})}{(7 \text{ days/wk} \times 24 \text{ h/day})} = 0.1 \text{ mrem}$$

Therefore, the dose from direct gamma radiation to the hypothetical maximally exposed individual is 0.1 mrem (0.001 mSv).

This exposure scenario should provide a very conservative estimate of the dose from direct gamma exposure to the hypothetical maximally exposed individual.

Surface Water Pathway

Exposures from contaminants in surface water are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the surface water dose calculation consist of measurements of concentrations of contaminants in surface water at the site and of the amount of dilution provided by tributaries or rivers between the site and the intake. Thus, the dose to the individual can be calculated by the following:

$$D_s = \sum_{i=1}^{N} C_i \times (F_s \div F_i) \times U_a \times DCF_i$$

where: D_s = Committed effective dose from surface water

C_i = Concentration of the i^{th} radionuclide in surface water at the site

F_s = Average annual flow of surface water at the site

F_i = Average flow of surface water at the intake

U_a = Annual consumption of liquid (approx. 730 L/yr)

DCF_i = Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that for the population dose, the intake point is probably not the same as that for the hypothetical maximally exposed individual.

The approach outlined above should provide a very conservative dose calculation for the surface water pathway because it does not account for radionuclides settling out or for any municipal water treatment.

Groundwater Pathway

Exposures from contaminants in groundwater are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the groundwater dose calculations consist of measurements of the concentrations of the contaminants in groundwater and an estimate of the dilution that occurs between the measurement location and the intake point. The dose for the hypothetical maximally exposed individual can be calculated by using the following equation:

$$D_{gw} = \sum_{i=1}^{N} (C_i) \times (D) \times (U_a) \times (DCF_i)$$

where:
- D_{gw} = Committed effective dose from groundwater
- C_i = Concentration of the i^{th} radionuclide in groundwater at the site
- D = Estimated dilution factor
- U_a = Annual consumption of liquid (approx. 730 L/yr)
- DCF_i = Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that the population intake point is usually different from that of the hypothetical maximally exposed individual.

The approach given above should provide a conservative dose calculation for the groundwater pathway because it does not account for any water treatment.

Air Pathway (ingestion, air immersion, inhalation)

The dose to the hypothetical maximally exposed individual from particulate radionuclides transported via the air pathway is calculated using EPA's computer model AIRDOS. Doses to the general public via this pathway are also calculated using AIRDOS results; these results are provided in Subsection 4.2.

The release of particulates was calculated using a model for wind erosion because there are no other mechanisms for releasing particulates from the site. The wind erosion model used was taken from the DOE "Remedial Action Priority System Mathematical Formulation." The input for the model consisted of site-specific average soil concentrations, local meteorological data (see Section 1.0), and areas of contamination.

The site was modeled as two areas: the interim storage piles and the remainder of the site. The average particle size for the soil at HISS is estimated at 0.05 mm for determining the emission factor for windblown material. This greatly overestimates the fraction of the airborne material that is respirable because most particles greater than 0.01 mm in diameter either would not be inhaled or would be quickly removed. Nevertheless, to provide a conservative calculation, all airborne particles were assumed to be respirable with an activity median aerodynamic diameter of 0.001 mm. Because the calculated dose was a small fraction of the NESHAPs standard of 10 mrem/yr, no effort was made to estimate the fraction of the airborne material that would be in the respirable range. Other assumptions used in the model were that the contamination at the site is 99 percent covered by vegetation and that there are very few mechanical disturbances at the site each month.

APPENDIX E

CLEAN AIR ACT COMPLIANCE REPORT FOR HAZELWOOD INTERIM STORAGE SITE

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

CLEAN AIR ACT COMPLIANCE REPORT
(Version 3.0 November 1989)

Facility: Hazelwood Interim Storage Site
Address: 9200, Latty Avenue
Hazelwood , MO. 63042
Annual Assessment for Year: 1991
Date Submitted: 3/ 4/92

Comments: INPUT DATA TAKEN FROM CALC. 140-CV-13

Prepared By:

Name: Bechtel National Inc.
Title: FUSRAP
Phone #: (615) 576-1669

Prepared for:
U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

CLEAN AIR ACT COMPLIANCE REPORT 3/ 4/92 9:52 AM

Facility: Hazelwood Interim Storage Site
Address: 9200, Latty Avenue City: Hazelwood State: MO
Comments: INPUT DATA TAKEN FROM CALC. 140-CV-13
Year: 1991

	Dose Equivalent Rates to Nearby Individuals (mrem/year)
Effective Dose Equivalent	0.0036
Highest Organ Dose is to ENDOSTEUM	0.0270

----------EMISSION INFORMATION----------

Radio-nuclide	Class	Amad	Area #1 (Ci/y)
U-238	Y	1.0	3.2E-07
RA-226	Y	1.0	1.9E-07
TH-230	Y	1.0	5.6E-07
U-234	Y	1.0	3.1E-07
U-235	Y	1.0	2.9E-08
TH-232	Y	1.0	3.5E-08
Total Area (m**2)			1.2E+04

----------SITE INFORMATION----------

Wind Data Food Source	SL_MO.WND LOCAL	Temperature (C)	15
Distance to Individuals (m)	300	Rainfall (cm/y)	85
		Lid Height (m)	1000

*NOTE: The results of this computer model are dose estimates. They are only to be used for the purpose of determining compliance and reporting per 40 CFR 61.93 and 40 CFR 61.94.

ORGAN DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL

ORGAN	DOSE EQUIVALENT RATE TO THE ORGAN (mrem/y)
GONADS	2.9E-05
BREAST	2.9E-05
RED MARROW	2.1E-03
LUNGS	2.1E-02
THYROID	2.8E-05
ENDOSTEUM	2.7E-02
REMAINDER	1.4E-04
EFFECTIVE	3.6E-03

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL BY PATHWAY FOR ALL RADIONUCLIDES

	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
INGESTION	1.3E-04	2.4E-03
INHALATION	3.5E-03	2.4E-02
AIR IMMERSION	4.8E-11	6.0E-11
GROUND SURFACE	1.5E-06	1.7E-06
TOTAL:	3.6E-03	2.7E-02

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL BY RADIONUCLIDE FOR ALL PATHWAYS

RADIONUCLIDE	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE ENDOSTEUM (mrem/y)
U-238	5.3E-04	5.3E-04
RA-226	3.7E-04	5.8E-04
TH-230	1.9E-03	2.3E-02
U-234	5.8E-04	6.0E-04
U-235	5.0E-05	5.4E-05
TH-232	1.7E-04	1.5E-03
TOTAL :	3.6E-03	2.7E-02

Hazelwood Interim Storage Site

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION OF DISTANCE IN THE DIRECTIONS OF THE MAXIMALLY EXPOSED INDIVIDUAL FOR ALL RADIONUCLIDES AND ALL PATHWAYS

DIRECTION : NORTHWEST

DISTANCE (meters)	EFFECTIVE DOSE EQUIVALENT (mrem/y)
300	3.6E-03
1000	3.0E-04
3000	3.8E-05
10000	4.1E-06
80000	1.1E-07

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION OF ALL DISTANCES AND ALL DIRECTIONS FOR ALL RADIONUCLIDES AND ALL PATHWAYS

DIRECTIONS:	N	NNE	NE	ENE	E	ESE	SE	SSE
DISTANCE (METERS):								
300	2.2E-03	1.0E-03	1.3E-03	1.9E-03	3.3E-03	2.6E-03	1.4E-03	9.0E-04
1000	2.0E-04	9.6E-05	1.1E-04	1.6E-04	2.8E-04	2.3E-04	1.3E-04	8.3E-05
3000	2.8E-05	1.4E-05	1.6E-05	2.1E-05	3.6E-05	2.9E-05	1.7E-05	1.1E-05
10000	3.8E-06	1.9E-06	2.1E-06	2.5E-06	4.0E-06	3.5E-06	2.2E-06	1.5E-06
80000	1.4E-07	7.2E-08	7.7E-08	8.2E-08	1.2E-07	1.1E-07	7.7E-08	5.5E-08

	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
300	9.5E-04	1.4E-03	1.9E-03	1.5E-03	1.7E-03	2.3E-03	3.6E-03	2.5E-03
1000	8.5E-05	1.2E-04	1.6E-04	1.2E-04	1.4E-04	1.9E-04	3.0E-04	2.1E-04
3000	1.1E-05	1.5E-05	2.0E-05	1.6E-05	1.8E-05	2.5E-05	3.8E-05	2.8E-05
10000	1.4E-06	1.7E-06	2.2E-06	1.7E-06	2.0E-06	2.9E-06	4.1E-06	3.3E-06
80000	4.9E-08	5.0E-08	5.5E-08	4.6E-08	5.2E-08	8.5E-08	1.1E-07	1.1E-07

METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO PROGRAM----

AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR (DEG K/METER)

IN STABILITY CLASS E	0.0728
IN STABILITY CLASS F	0.1090
IN STABILITY CLASS G	0.1455

PLUME DEPLETION AND DEPOSITION PARAMETERS

NUCLIDE	GRAVITATIONAL FALL VELOCITY (METERS/SEC)	DEPOSITION VELOCITY (METERS/SEC)	SCAVENGING COEFFICIENT (1/SEC)	EFFECTIVE DECAY CONSTANT IN PLUME (PER DAY)
U-238	0.000	0.00180	0.850E-05	0.000E+00
RA-226	0.000	0.00180	0.850E-05	0.000E+00
TH-230	0.000	0.00180	0.850E-05	0.000E+00
U-234	0.000	0.00180	0.850E-05	0.000E+00
U-235	0.000	0.00180	0.850E-05	0.000E+00
TH-232	0.000	0.00180	0.850E-05	0.000E+00

FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION

SECTOR	FRACTION OF TIME IN EACH STABILITY CLASS						
	A	B	C	D	E	F	G
N	0.0047	0.0339	0.1034	0.5651	0.1725	0.0886	0.0317
NNW	0.0036	0.0326	0.0970	0.5479	0.1462	0.1094	0.0634
NW	0.0055	0.0393	0.0895	0.4490	0.1396	0.1630	0.1141
WNW	0.0044	0.0623	0.1159	0.4606	0.1431	0.1286	0.0850
W	0.0098	0.0653	0.1244	0.4797	0.1099	0.1149	0.0960
WSW	0.0085	0.0923	0.1288	0.4373	0.1169	0.1149	0.1013
SW	0.0062	0.0776	0.1080	0.4110	0.1188	0.1572	0.1214
SSW	0.0079	0.0770	0.1080	0.4975	0.1085	0.1177	0.0833
S	0.0131	0.0612	0.1093	0.5924	0.1028	0.0786	0.0428
SSE	0.0086	0.0545	0.1053	0.6078	0.1248	0.0695	0.0295
SE	0.0044	0.0428	0.0853	0.6875	0.0881	0.0587	0.0332
ESE	0.0050	0.0349	0.0840	0.6136	0.1217	0.0825	0.0583
E	0.0069	0.0491	0.1115	0.4029	0.1563	0.1701	0.1032
ENE	0.0057	0.0679	0.1657	0.4158	0.1589	0.1191	0.0669
NE	0.0091	0.0782	0.1609	0.4220	0.1729	0.1192	0.0377
NNE	0.0057	0.0555	0.1287	0.5010	0.1776	0.1031	0.0284

FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGED WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.110	1.62	1.86	3.54	5.03	3.83	1.88	0.77
NNW	0.084	1.85	2.30	3.40	5.01	3.66	1.85	0.77
NW	0.079	1.30	1.82	2.88	4.35	3.29	1.75	0.77
WNW	0.061	1.45	1.63	2.79	3.86	3.29	1.75	0.77
W	0.042	1.35	1.85	3.15	3.53	3.14	1.46	0.77
WSW	0.035	1.33	1.80	2.81	3.23	3.07	1.60	0.77
SW	0.039	1.45	1.88	2.73	3.17	2.93	1.64	0.77
SSW	0.038	1.23	1.83	3.07	3.78	3.19	1.88	0.77
S	0.041	1.32	1.87	3.09	4.26	3.53	1.86	0.77
SSE	0.047	1.58	1.81	3.23	4.70	3.55	1.76	0.77
SE	0.075	1.64	1.84	3.38	5.11	3.61	1.74	0.77
ESE	0.101	1.45	1.99	3.14	5.53	3.69	1.91	0.77
E	0.079	1.38	1.63	2.88	4.47	3.55	1.86	0.77
ENE	0.061	1.54	2.06	3.38	4.43	3.61	1.88	0.77
NE	0.054	1.50	2.25	3.35	4.29	3.57	1.99	0.77
NNE	0.053	1.66	1.98	3.81	4.72	3.69	1.99	0.77

FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.110	2.12	2.70	4.40	5.97	4.01	2.29	0.77
NNW	0.084	2.27	3.06	4.24	5.98	3.88	2.27	0.77
NW	0.079	1.82	2.65	3.83	5.43	3.52	2.21	0.77
WNW	0.061	1.97	2.55	3.71	5.01	3.53	2.21	0.77
W	0.042	1.87	2.74	3.85	4.68	3.37	1.98	0.77
WSW	0.035	1.85	2.59	3.77	4.39	3.28	2.11	0.77
SW	0.039	1.97	2.61	3.82	4.43	3.11	2.13	0.77
SSW	0.038	1.73	2.71	3.80	4.98	3.42	2.29	0.77
S	0.041	1.84	2.71	3.97	5.40	3.76	2.28	0.77
SSE	0.047	2.09	2.72	4.13	5.73	3.78	2.22	0.77
SE	0.075	2.14	2.77	4.26	6.31	3.83	2.20	0.77
ESE	0.101	1.97	2.75	4.15	6.87	3.90	2.31	0.77
E	0.079	1.90	2.54	3.93	5.94	3.78	2.28	0.77
ENE	0.061	2.06	2.84	4.18	5.67	3.83	2.29	0.77
NE	0.054	2.02	3.06	4.16	5.31	3.79	2.35	0.77
NNE	0.053	2.15	2.79	4.45	5.64	3.90	2.34	0.77

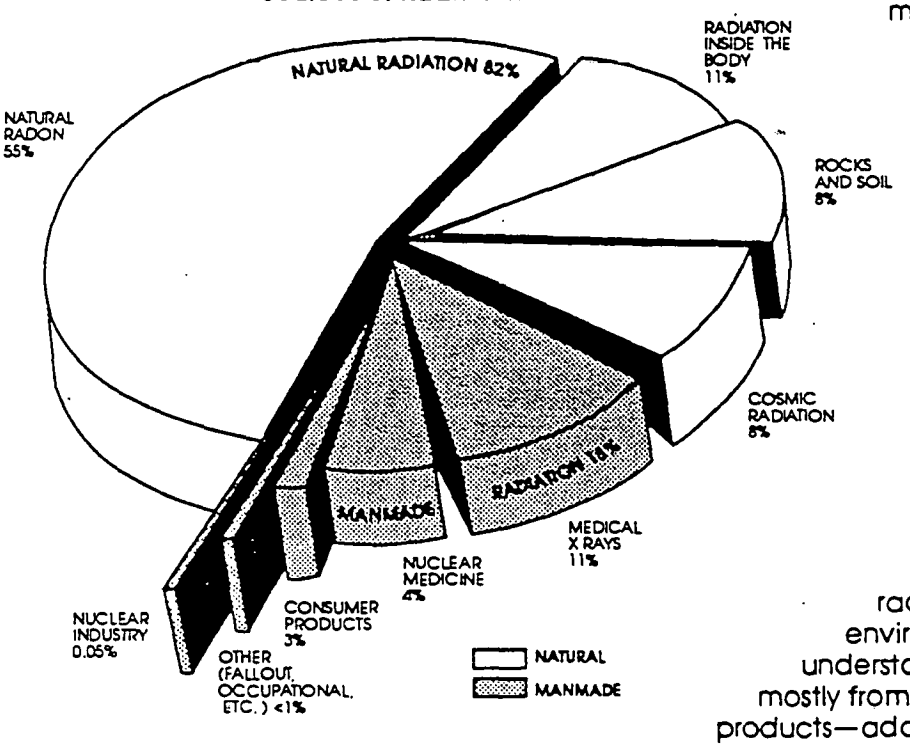
APPENDIX F
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

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

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

Sources of Radiation



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

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

TYPES OF IONIZING RADIATION

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

Alpha

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

Beta

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

Gamma

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

Units of Measure

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

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

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

RADIATION IN THE ENVIRONMENT

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

mrem = millirem
pCi = picocurie

Cosmic Radiation

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

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

Terrestrial Radiation

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

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

Buildings

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

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

Radon

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

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

Food

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

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

Medical Treatment

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

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

Consumer Goods

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

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

References

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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 Measurments, 1987.
Radiation in Medicine and Industry. A.P. Jacobson and G.P. Sokolosky, 1980.
Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

PERSPECTIVE: How Big is a Picocurie?

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

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

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

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

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

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

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

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

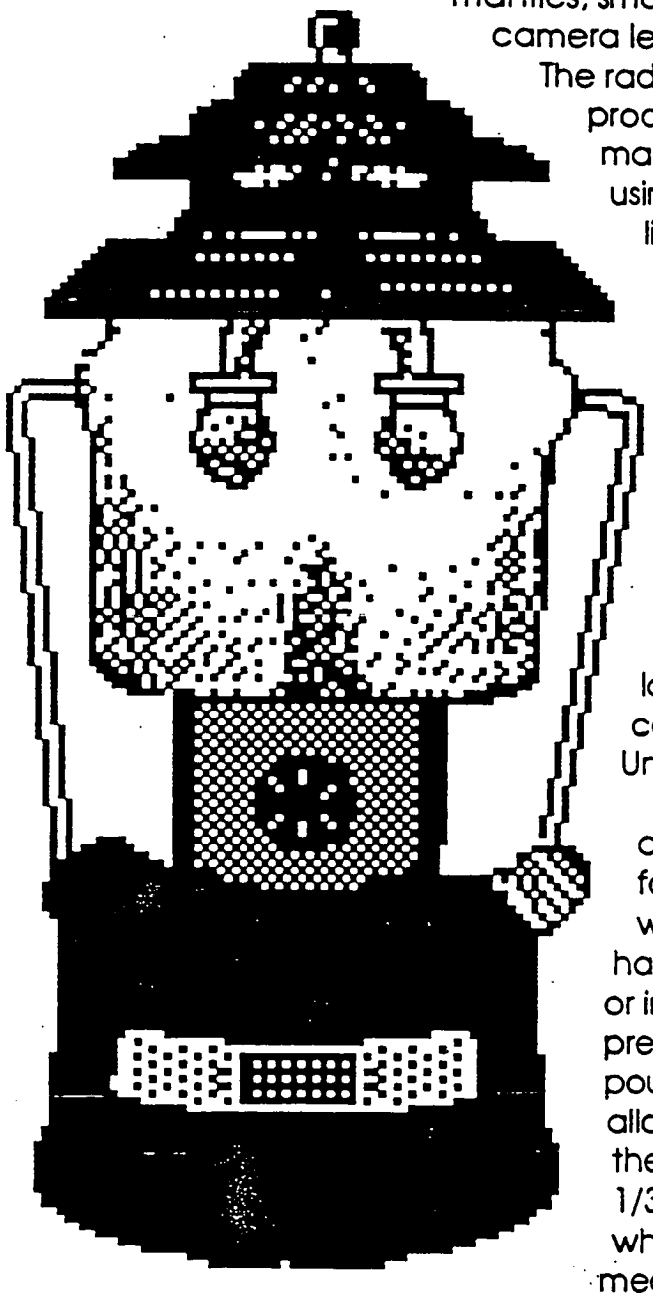
The following chart shows the relative differences between the units and gives analogies in dollars. It also gives examples of where these various amounts of radioactivity could typically be found. The number of disintegrations per minute has been rounded off for the chart.

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

PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

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



Lanterns: In a New Light

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

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

From information provided by W.L. Beck, Bechtel National, Inc.

APPENDIX G

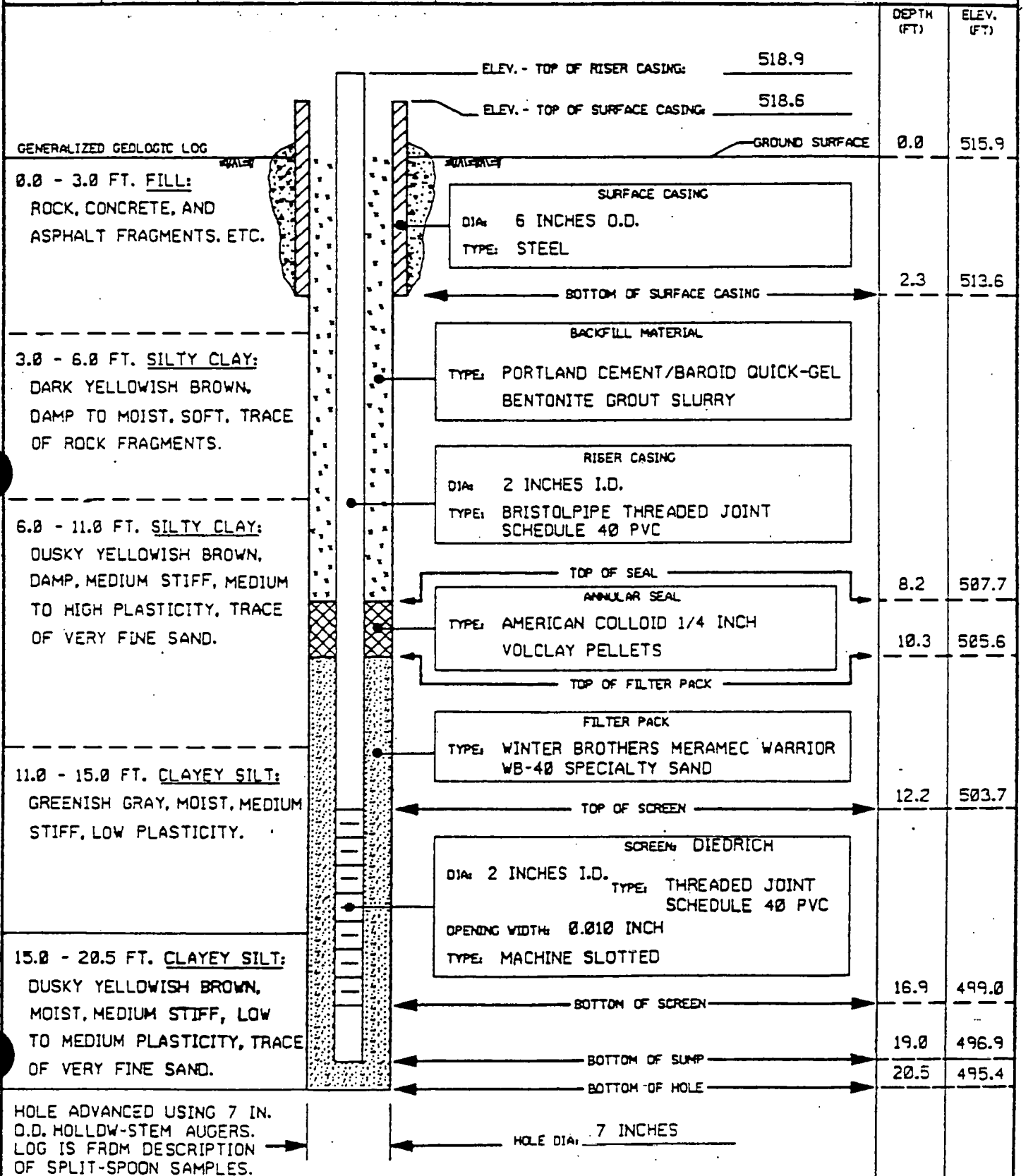
SAMPLE OBSERVATION WELL CONSTRUCTION LOG AND HYDROGRAPHS SHOWING WATER LEVEL ELEVATIONS

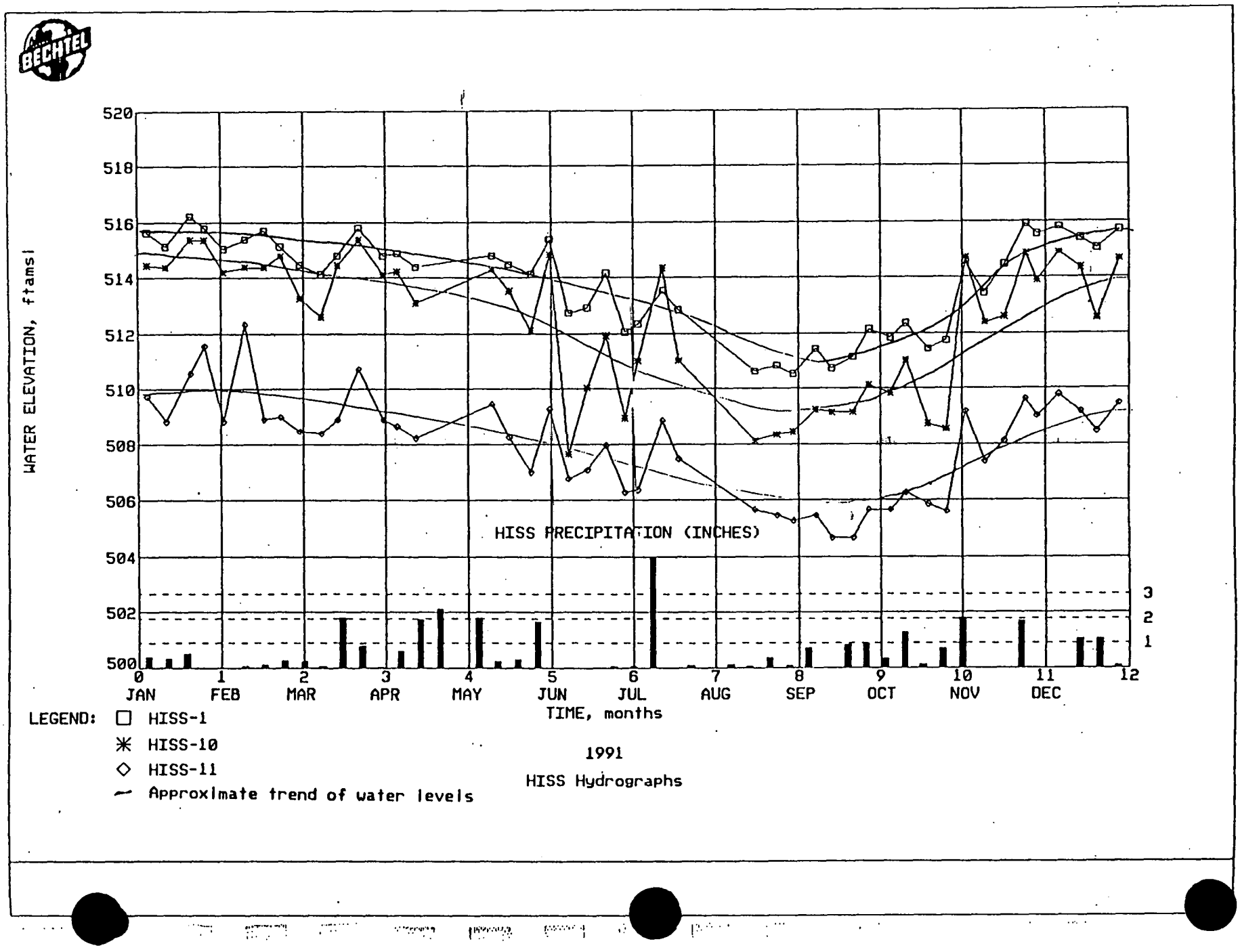
OBSERVATION WELL

PROJECT	WELL NO.
FUSRAP	HISS-15

JOB NO.	SITE	LOCATION
14501	HAZELWOOD I.S.S.	STA. 8+64.5 OFFSET 101.9 FT. RIGHT

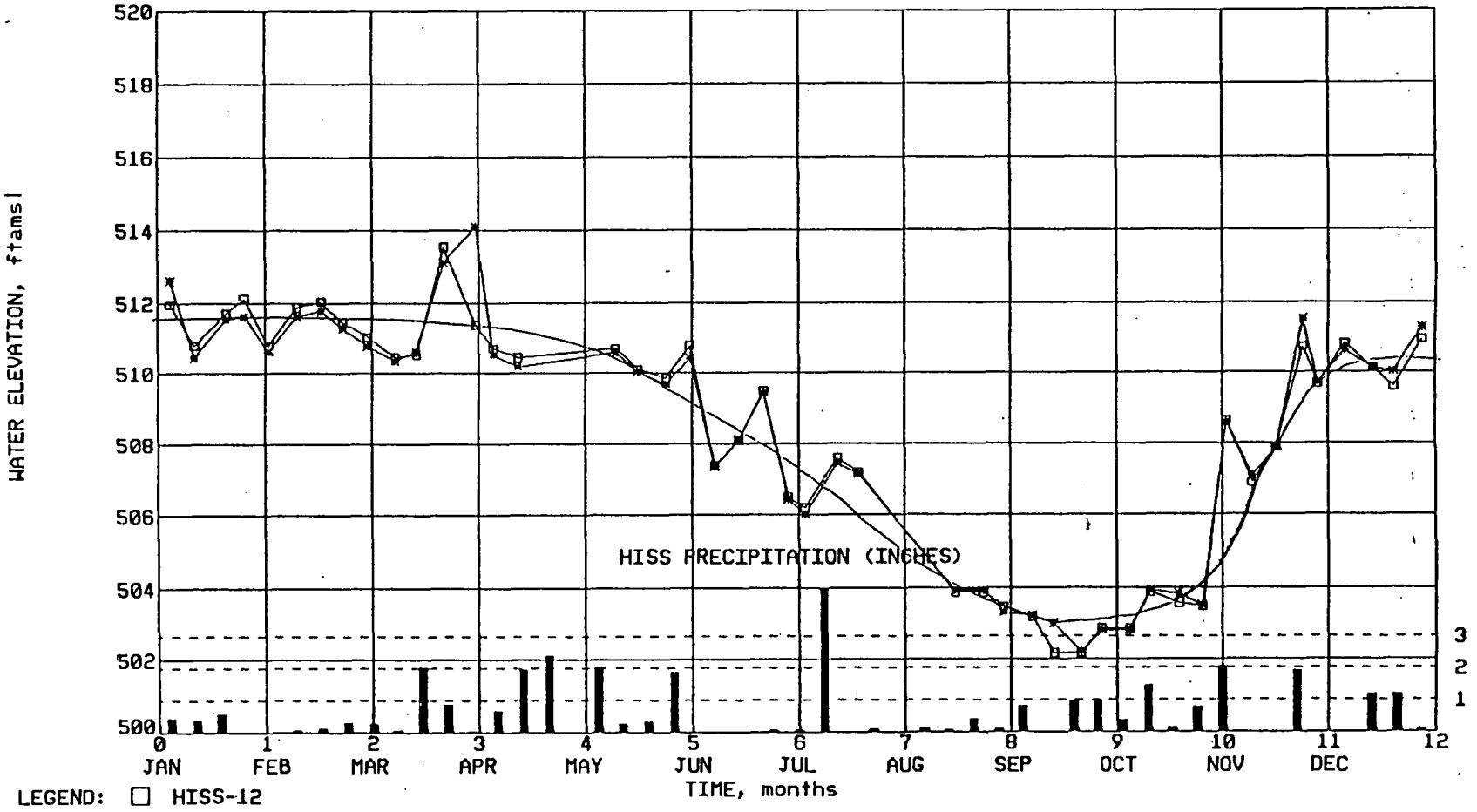
BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
12/14/84	12/14/84	L. MATTHEWS	TOP OF RISER CASING





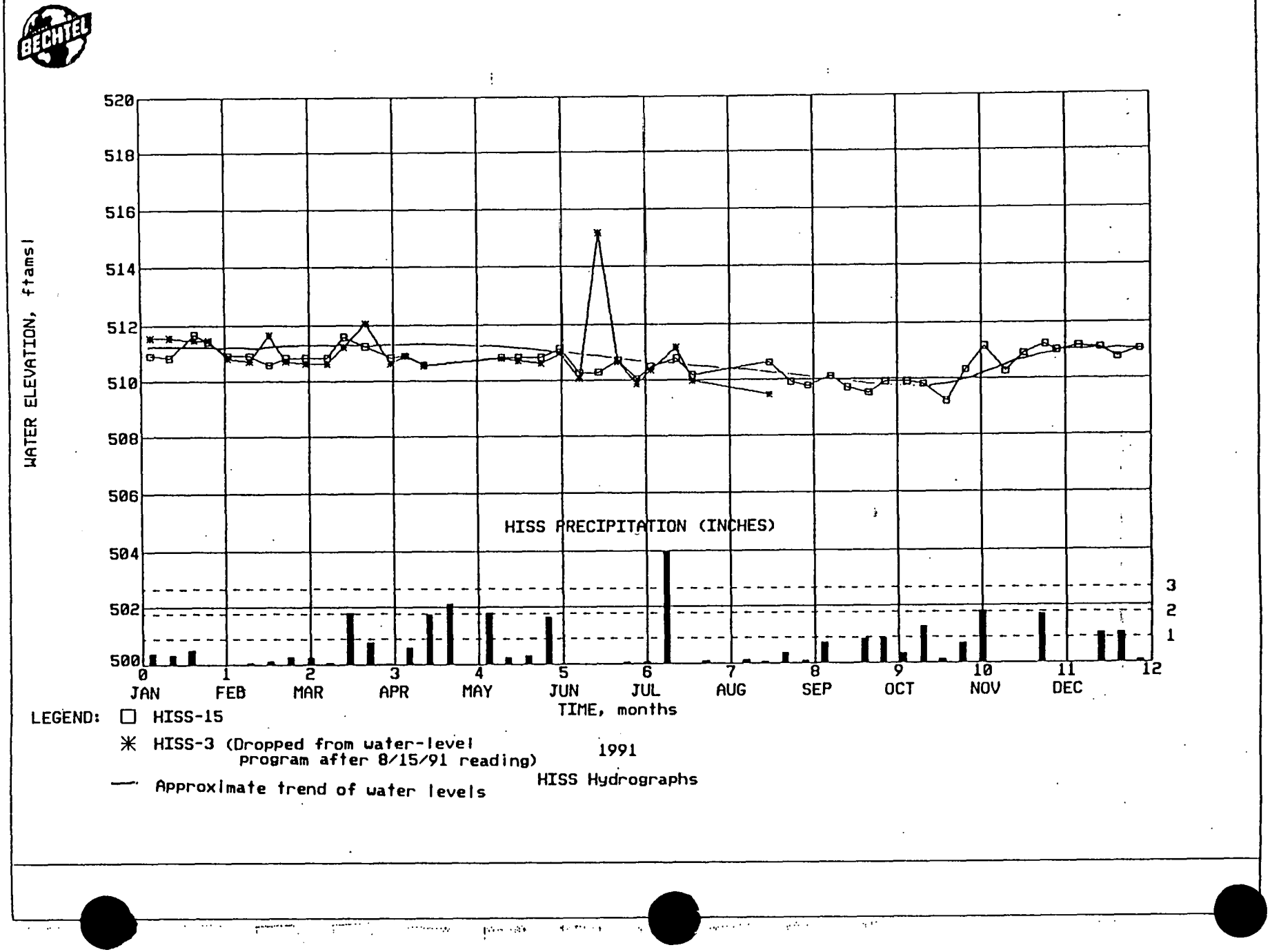
1991

HISS Hydrographs



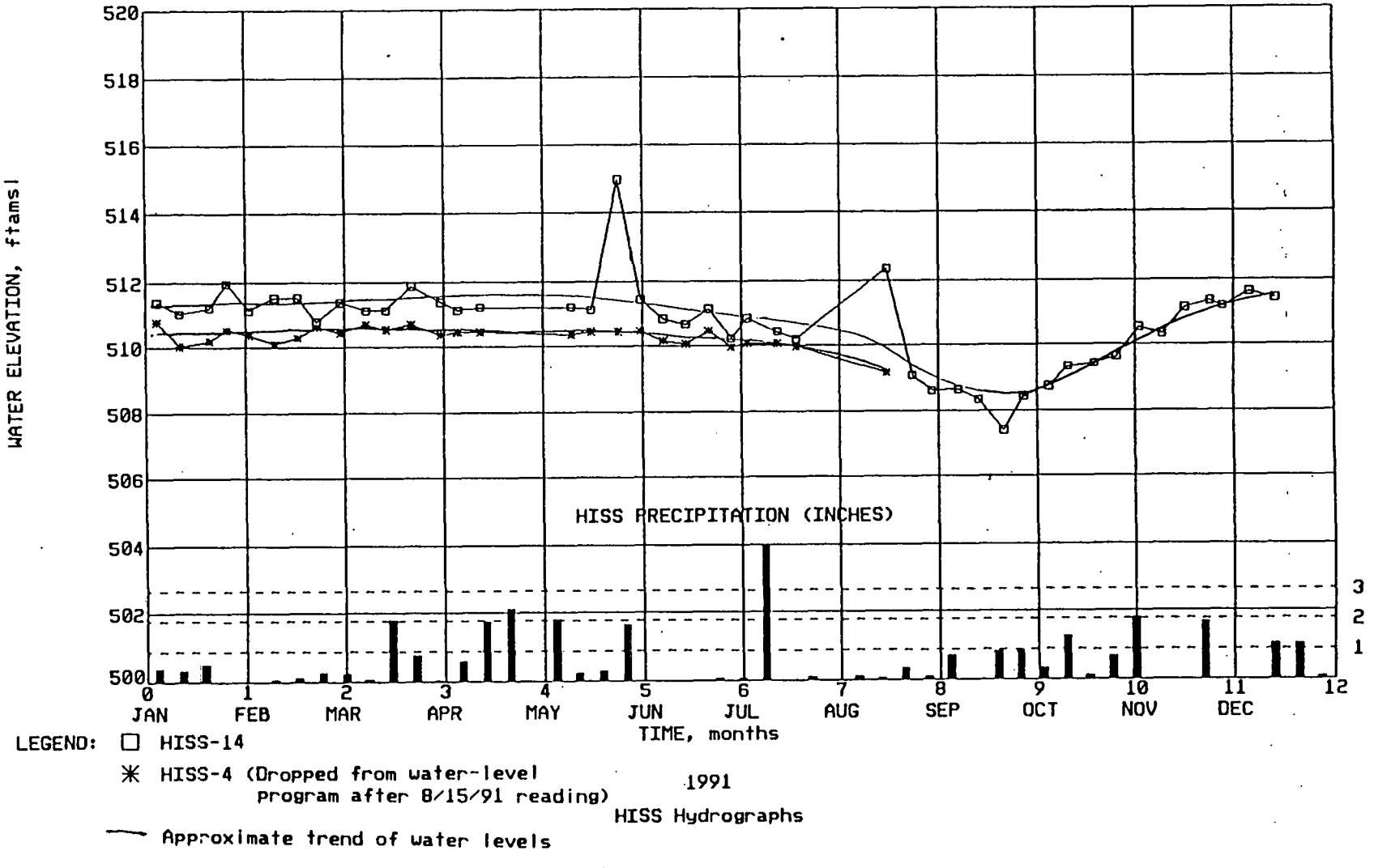
1991

HISS Hydrographs



1991

HISS Hydrographs



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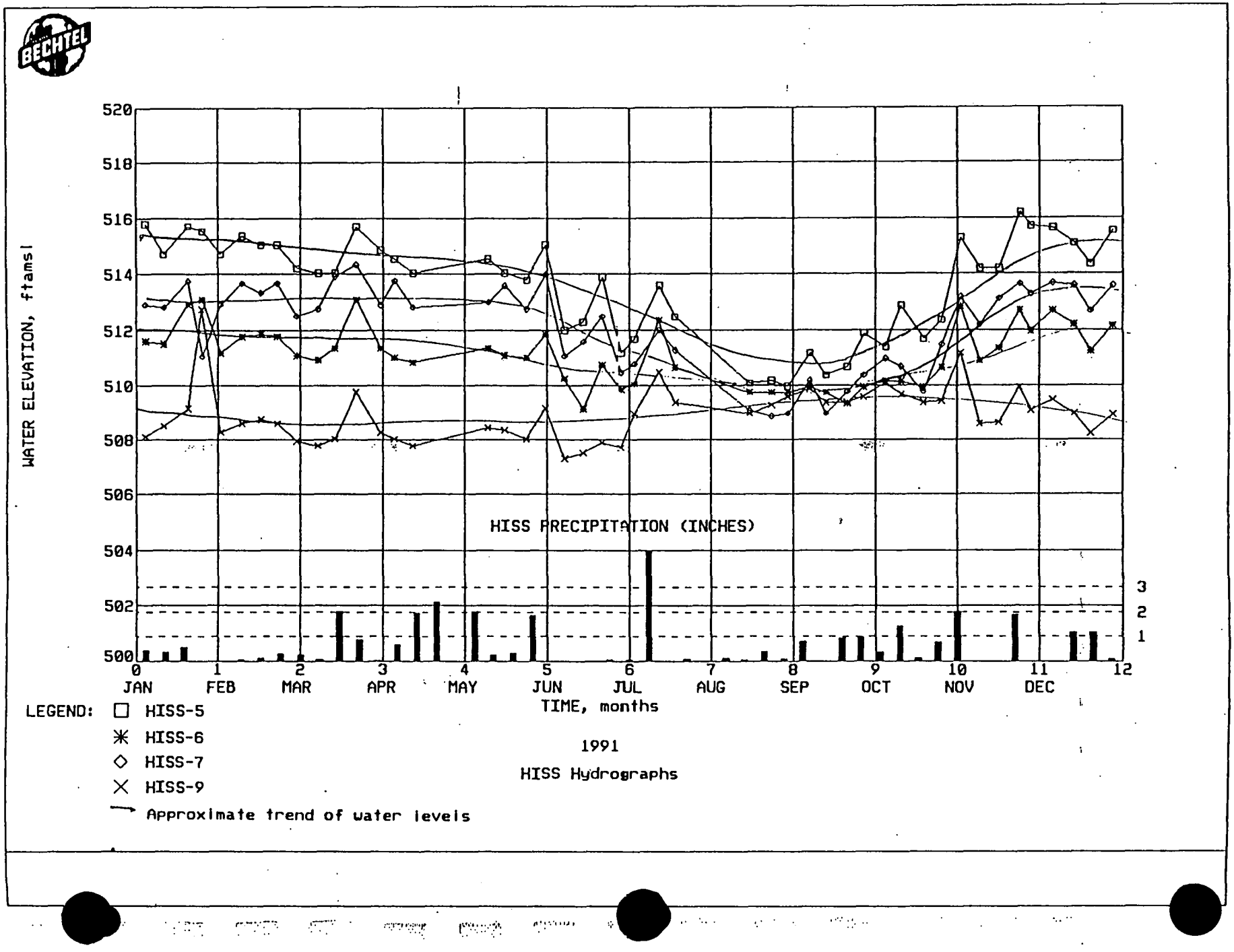
HISS Hydrographs



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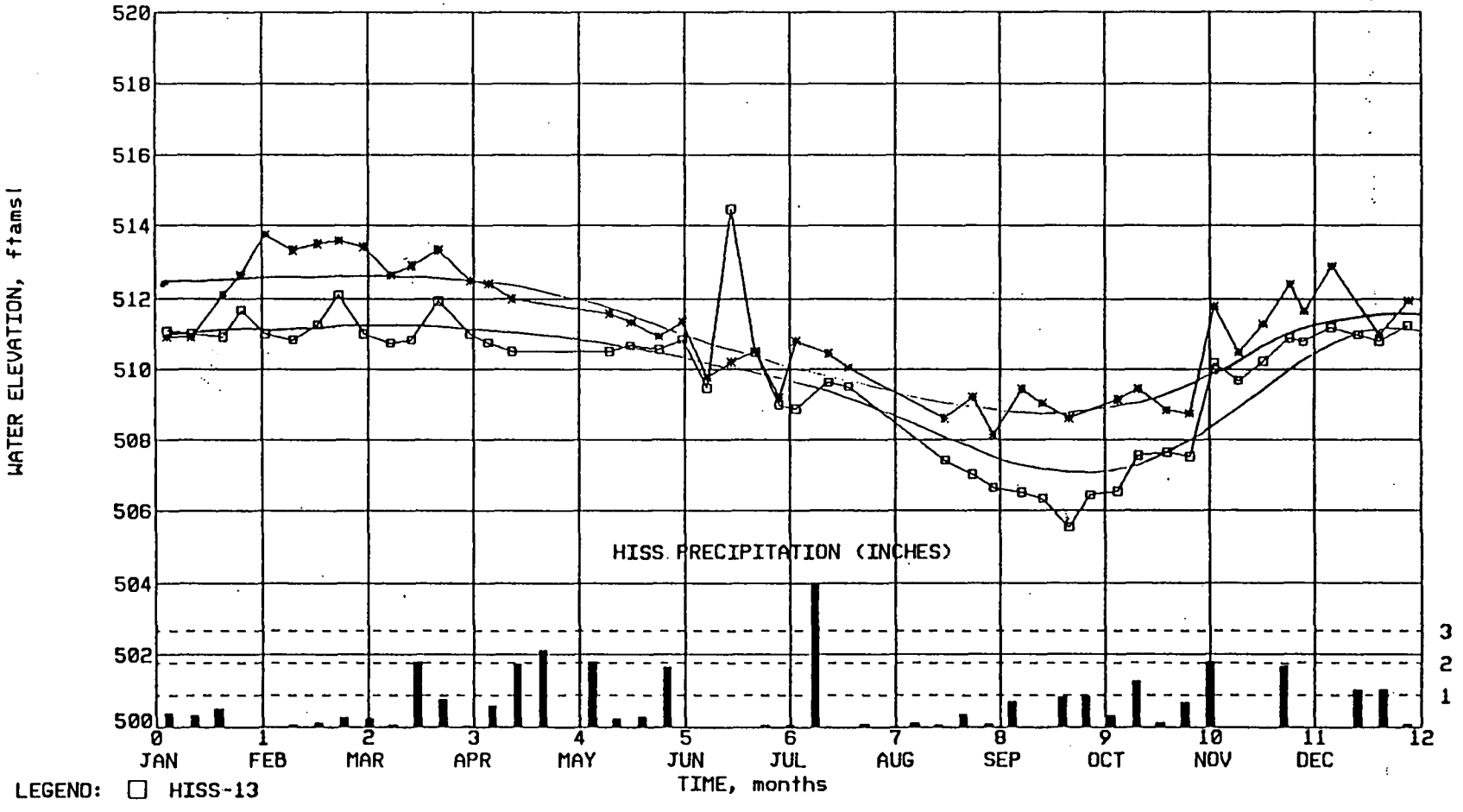
HISS Hydrographs



1991

HISS Hydrographs

APPENDIX H
CONVERSION FACTORS

TABLE H-1

CONVERSION FACTORS

1 yr	=	8,760 h
1 L	=	1,000 ml
1 μCi	=	1,000,000 pCi
1 pCi	=	0.000001 μCi
0.037 Bq/L	=	10^{-9} μCi/ml = 1 pCi/L
0.037 Bq/L	=	0.000000001 μCi/ml
1 μCi/ml	=	1,000,000,000 pCi/L
$1E^{-6}$ = 1E-6 = 1E-06	=	0.000001 = 1 x 10^{-6}
$1E^{-7}$ = 1E-7 = 1E-07	=	0.0000001 = 1 x 10^{-7}
$1E^{-8}$ = 1E-8 = 1E-08	=	0.00000001 = 1 x 10^{-8}
$1E^{-9}$ = 1E-9 = 1E-09	=	0.000000001 = 1 x 10^{-9}
$1E^{-10}$ = 1E-10	=	0.0000000001 = 1 x 10^{-10}

APPENDIX I

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