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

HAZELWOOD INTERIM STORAGE SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1989

Hazelwood, Missouri

May 1990



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HAZELWOOD INTERIM STORAGE SITE
ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1989

MAY 1990

Prepared for
UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.
P.O. Box 350
Oak Ridge, Tennessee
Bechtel Job No. 14501

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

BACKGROUND AND OVERVIEW

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

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 residues and wastes were moved to a storage site at 9200 Latty Avenue, a part of which is the present-day HISS. These wastes had been generated by a St. Louis plant from 1942 through 1957 under contract with the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District (MED). In January 1967, the Commercial Discount Corporation of Chicago purchased the residues. Much of the material was then dried and shipped to the Cotter Corporation facilities in Canon City, Colorado. The material remaining at the Latty Avenue site was sold to 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 December 1970, an estimated 18,700 tons of material remained at the Latty Avenue site. By mid-1973, the material classified as Colorado raffinate had been shipped to Canon City without drying. The remaining material, classified as leached barium sulfate, and a reported 30 to 46 cm (12 to 18 in.) of topsoil were removed and transported to the Westlake Landfill in St. Louis County.

The site was assigned to the Department of Energy (DOE) as part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Appropriations Act. DOE placed responsibility for the site under its existing program, FUSRAP.

In FY 1984, cleanup along Latty Avenue and storage of contaminated materials in the interim storage pile at HISS began. During 1985 and 1986, contaminated material removed from along Latty Avenue during installation of a storm sewer was stored in a supplementary pile at HISS. In 1987, contaminated material removed from along Latty Avenue was placed on the supplementary pile and covered. In September 1989, HISS was added to the Environmental Protection Agency's (EPA) National Priorities List (NPL).

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

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

HISS does not have any state or federal air permits. As a non-operating facility, only Subparts H and Q of NESHAPs are applicable. Compliance with the non-radon radionuclide standards in Subpart H will be determined by evaluating the site using a computer model (e.g., AIRDOS-PC) approved by EPA. A strategy for determining compliance with the radon flux standard in Subpart Q has been submitted to EPA for approval. Compliance, pending EPA approval, shall be attained during 1990.

DOE Orders for Radionuclide Releases

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

Clean Water Act (CWA)

HISS does not have any state or federal water permits. An environmental compliance assessment conducted by Oak Ridge National Laboratory (ORNL) in October 1989 did not find any deficiencies under the CWA. The Missouri Department of Natural Resources (MoDNR) has requested that a permit application be submitted for stormwater discharge from HISS. The application was completed and submitted to MoDNR on April 13, 1990.

Resource Conservation and Recovery Act (RCRA)

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

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

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

Toxic Substances Control Act (TSCA)

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

National Environmental Policy Act (NEPA)

In the past, compliance with NEPA has been accomplished through the use of action description memoranda and corresponding memoranda-to-file. Actions taken to date have been determined to have had no significant impact on the environment. While a formal NEPA determination has not been made for final cleanup of the site, completion of an environmental impact study (EIS) is expected to be required as part of the overall effort for St. Louis sites 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.

ABSTRACT

The environmental monitoring program, begun in 1984, was continued during 1989 at the Hazelwood Interim Storage Site (HISS), a U.S. Department of Energy (DOE) facility located in the City of Hazelwood, Missouri. Originally known as the Cotter Corporation site on Latty Avenue, HISS is currently used for storage of soils contaminated with residual radioactive material. HISS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to decontaminate or otherwise control sites where residual radioactive material remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. As part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Appropriations Act, remedial action is being conducted at the site and at vicinity properties by Bechtel National, Inc. (BNI), project management contractor for FUSRAP. The environmental monitoring program is also carried out by BNI.

The monitoring program at HISS measures radon concentrations in air; external gamma radiation levels; and uranium, radium, and thorium concentrations in surface water, groundwater, and sediment. Additionally, several nonradiological parameters are measured in groundwater. To verify that the site is in compliance with the DOE radiation protection standard (100 mrem/yr) and assess its potential effect on public health, the radiation dose was calculated for a hypothetical maximally exposed individual. Based on the scenario described in this report, this hypothetical individual at HISS would receive an annual external exposure approximately equivalent to 1.5 percent of the DOE radiation protection standard. This exposure is less than the exposure a person receives during a flight from New York to Los Angeles (because of the greater amounts of cosmic radiation at higher altitudes). The cumulative dose to the population within an 80-km (50-mi) radius of HISS that results from radioactive materials present at the site is indistinguishable from the dose that the

same population receives from naturally occurring radioactive sources. The results of 1989 monitoring show that HISS is in compliance with the DOE radiation protection standard.

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1.0 INTRODUCTION

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

1.1 LOCATION AND DESCRIPTION

HISS is located in northern St. Louis County within the city limits of Hazelwood, Missouri, at 9200 Latty Avenue (Figure 1-1). (The site was originally known as the Cotter Corporation site on Latty Avenue.) The vicinity properties lie along Latty Avenue from Coldwater Creek to Interstate Highway 170 in Hazelwood, and HISS lies 3.2 km (2 mi) northeast of the control tower of the Lambert-St. Louis International Airport. Figure 1-2 is an aerial photograph of HISS and its vicinity.

HISS is located on a broad, shallow bedrock depression known as the Florissant Basin. During glacial times, drainage from the area was blocked, and the Florissant Basin was filled with silts, clays, and sands. The surface and near-surface soils are fine-grained sandy silts and clayey silts. These materials are unconsolidated to poorly consolidated, erode easily, and have poor load-bearing capacity (Ref. 1).

Surface water runoff follows surface elevation contours and flows to the north and the south across the site. Water flowing to the north enters a municipal storm sewer along Latty Avenue before discharging into Coldwater Creek, the main receiving body for site runoff. Water flowing to the south leaves the site via two ditches, one located near the western boundary and the other

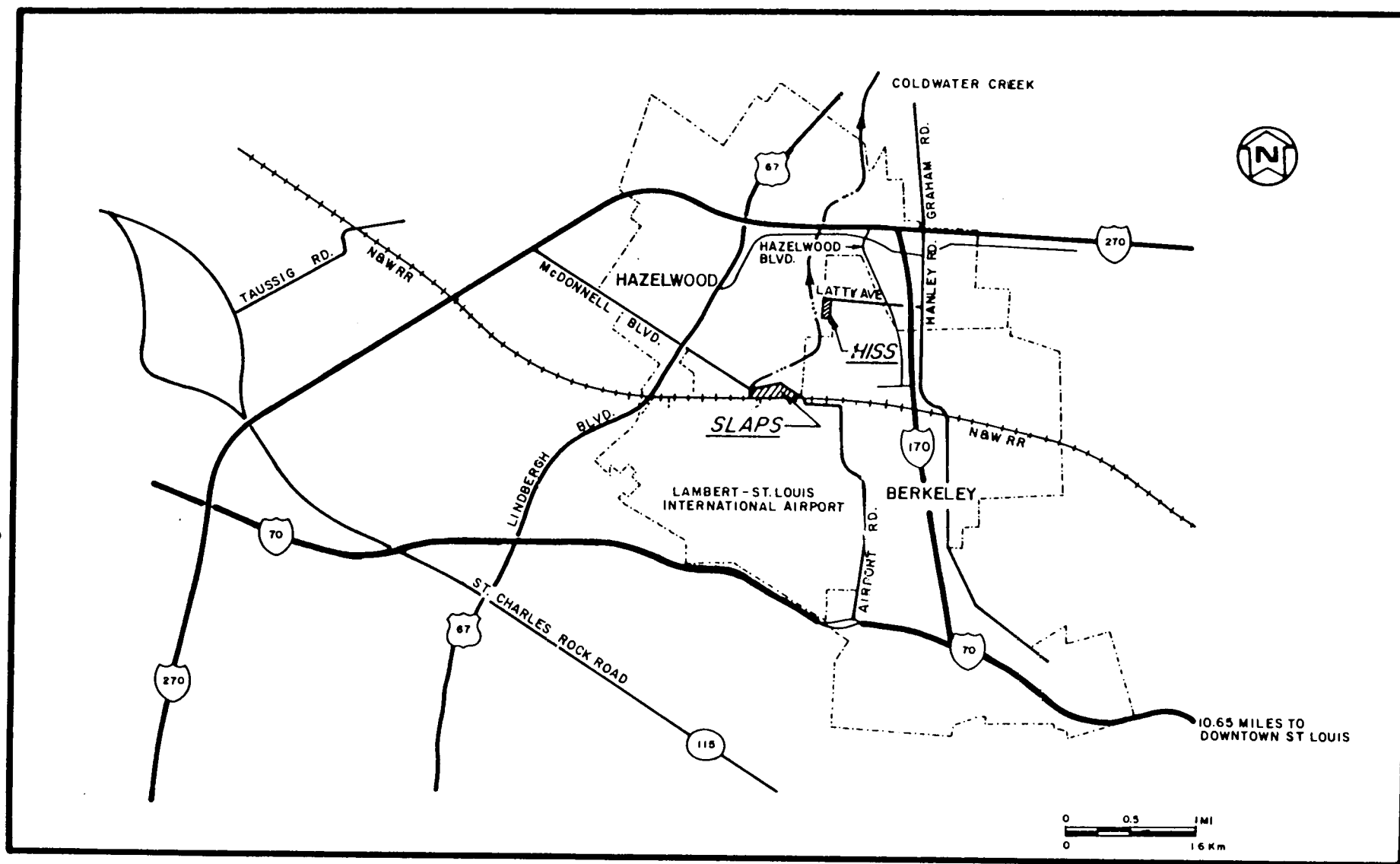


FIGURE 1-1 LOCATION OF HISS



FIGURE 1-2 AERIAL VIEW OF HISS AND ITS VICINITY

near the southeastern boundary. These ditches discharge into an unnamed tributary before discharging into Coldwater Creek (see Figure 3-2). The 100-yr flood elevation for HISS is approximately 158 m (520 ft) above sea level (Ref. 2). Portions of the site are located in the 100-yr floodplain.

Groundwater in St. Louis County occurs in unconsolidated deposits and in bedrock aquifers. Shallow groundwater flow in the vicinity of the site generally follows surface topography; thus, the direction of flow is toward Coldwater Creek and its tributary channel (Ref. 1). In the area surrounding HISS, water content of the subsoils is very high, but percolation rates are low. Treated water from the Mississippi River is used for municipal drinking water in this area (Ref. 3).

The average annual daily maximum temperature for the HISS area is 18.6°C (65.5°F), and the average daily minimum is 7.4°C (45.4°F). The highest average monthly temperature is 32°C (89°F) (July) and the lowest is -6.7°C (19.9°F) (January). Average annual precipitation is 86 cm (34 in.), with an average annual snowfall of 66.8 cm (26.3 in.) (Ref. 4). As shown in Figure 1-3, prevailing winds in the vicinity of HISS are primarily from the south during the summer and fall. Wind speeds during these months average 14 km/h (8.7 mph). Winds during the winter months are from the west and west-northwest, averaging 18 km/h (11 mph) (Refs. 4, 5).

The residential areas nearest the site are approximately 0.5 km (0.3 mi) east in the City of Hazelwood. Residences in the City of Berkeley lie southeast of the site. In 1980, the populations of Berkeley and Hazelwood were 16,146 and 8,819, respectively (Ref. 6). There are no churches, schools, hospitals, municipal buildings, or other community facilities adjacent to HISS or Latty Avenue.

As shown in Figure 1-4, land use in the vicinity is predominantly industrial. Other land uses (in descending order of prevalence) are commercial, transportation-related, vacant, and residential (Ref. 1).

There are no continuing industrial or remedial activities at HISS; therefore, there are no airborne radioactive effluents

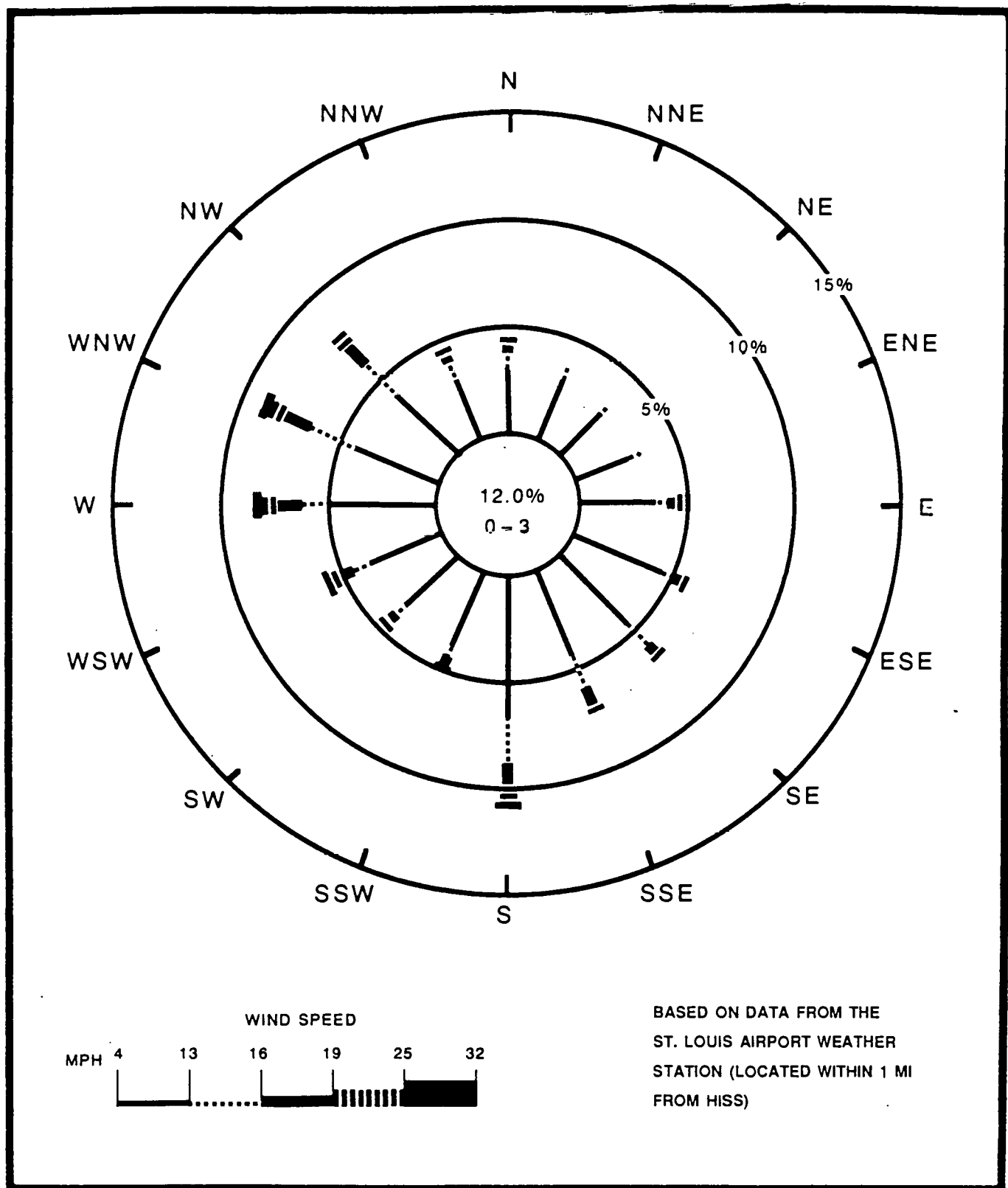
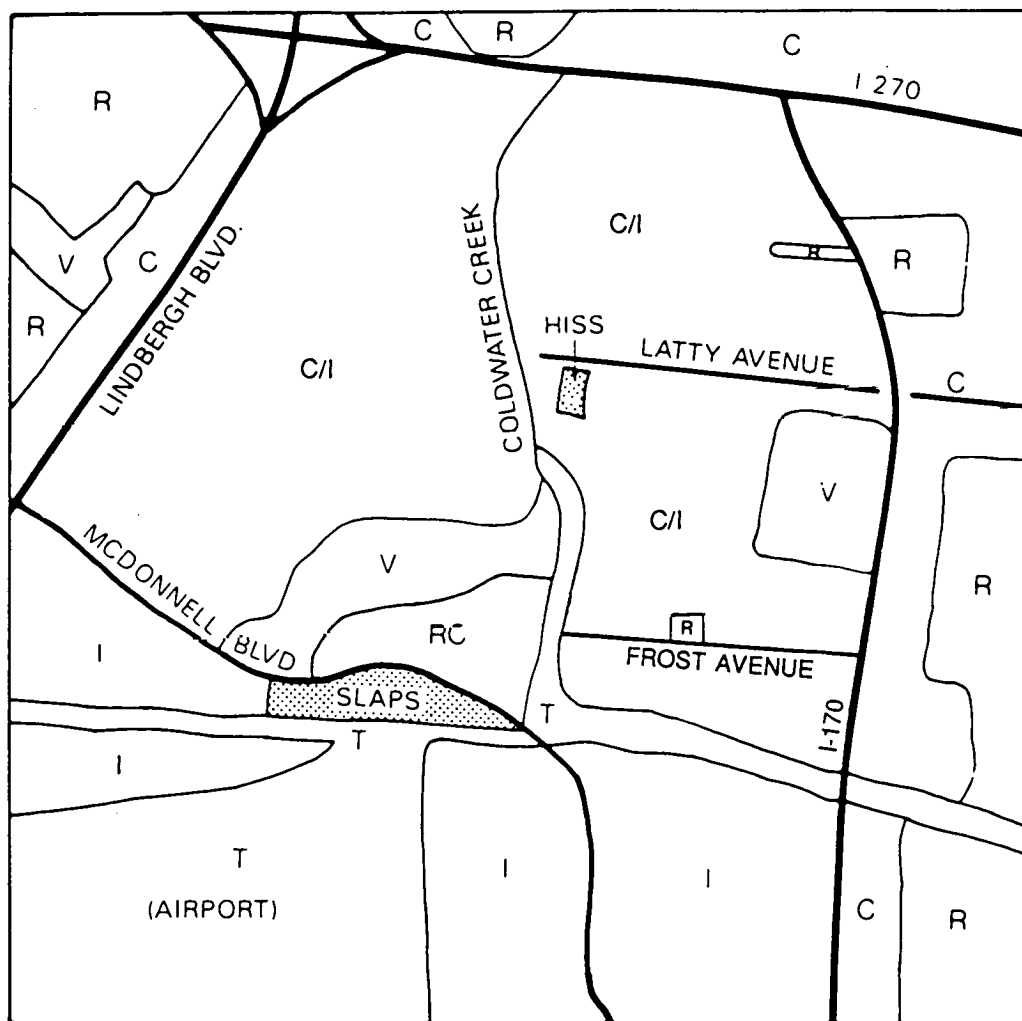


FIGURE 1-3 ANNUAL WIND ROSE FOR HISS



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

R RESIDENTIAL
C COMMERCIAL
T TRANSPORTATION
I INDUSTRIAL

C/I MIXED COMMERCIAL AND INDUSTRIAL
V VACANT
RC RECREATIONAL

0 0.5 MI
0 0.8 KM



FIGURE 1-4 GENERALIZED LAND USE IN THE VICINITY OF HISS

resulting from these activities, and waterborne radioactive effluents are limited to extremely low concentrations in surface drainage.

1.2 SITE HISTORY

In early 1966, 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 residues and wastes were moved to a storage site at 9200 Latty Avenue, a part of which is the present-day HISS. These wastes had been generated by a St. Louis plant from 1942 through the late 1950s under contracts with the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District (MED). Residues on the site at that time included 74,000 tons of Belgian Congo pitchblende raffinate containing approximately 113 tons of uranium; 32,500 tons of Colorado raffinate containing roughly 48 tons of uranium; and 8,700 tons of leached barium sulfate containing about 7 tons of uranium. In January 1967, the Commercial Discount Corporation of Chicago purchased the residues. Much of the material was then dried and shipped to the Cotter Corporation facilities in Canon City, Colorado. The material remaining at the Latty Avenue site was sold to 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 December 1970, an estimated 10,000 tons of Colorado raffinate and 8,700 tons of leached barium sulfate remained at the Latty Avenue site.

In April 1974, the newly established Nuclear Regulatory Commission (NRC) was informed by Cotter Corporation that the remaining Colorado raffinate had been shipped in mid-1973 to Canon City without drying and that the leached barium sulfate and 30 to 46 cm (12 to 18 in.) of topsoil had been removed and transported to a landfill area in St. Louis County.

Before the present owner occupied the site, a radiological characterization was performed by Oak Ridge National Laboratory

(ORNL) (Ref. 7). Thorium and radium contamination in excess of DOE guidelines was found in and around the buildings, and in the soil to depths as great as 46 cm (18 in.). Consequently, in preparing the property for use, the owner demolished one building, excavated portions of the western half of the property, and paved certain areas in addition to erecting several new buildings. The material excavated during these activities was piled on the eastern portion of the property.

In 1981, Oak Ridge Associated Universities (ORAU) characterized the pile and surveyed the northern and eastern boundaries of the property for radioactivity (Ref. 8). Levels of contamination (principally thorium-230) similar to those on site were found in both boundary areas. As a followup to this survey, ORNL conducted a detailed radiological survey for DOE of the north and south shoulders of Latty Avenue in January and February 1984. Results indicated that contamination in excess of DOE guidelines was present along the road up to a location near its intersection with Hazelwood Boulevard. Properties adjacent to HISS were also found to be contaminated.

BNI is conducting remedial action at HISS and at a portion of the vicinity properties, which parallel Latty Avenue, in two phases. Phase I began in FY 1984 with the radiological characterization and initial cleanup of Latty Avenue and storage of the contaminated materials in the interim storage pile at HISS. In addition, an area of the site north of the pile was cleared, a decontamination facility was constructed, environmental monitoring stations were installed, and a perimeter fence was installed around the site (Ref. 9). During 1985 and 1986 cleanup along Latty Avenue continued, and additional contaminated material removed along Latty Avenue during the installation of a storm sewer by the Cities of Berkeley and Hazelwood was stored in a supplementary pile at HISS (Figure 1-2). In 1987 additional contaminated material removed from along Latty Avenue was placed on the supplementary pile and covered.

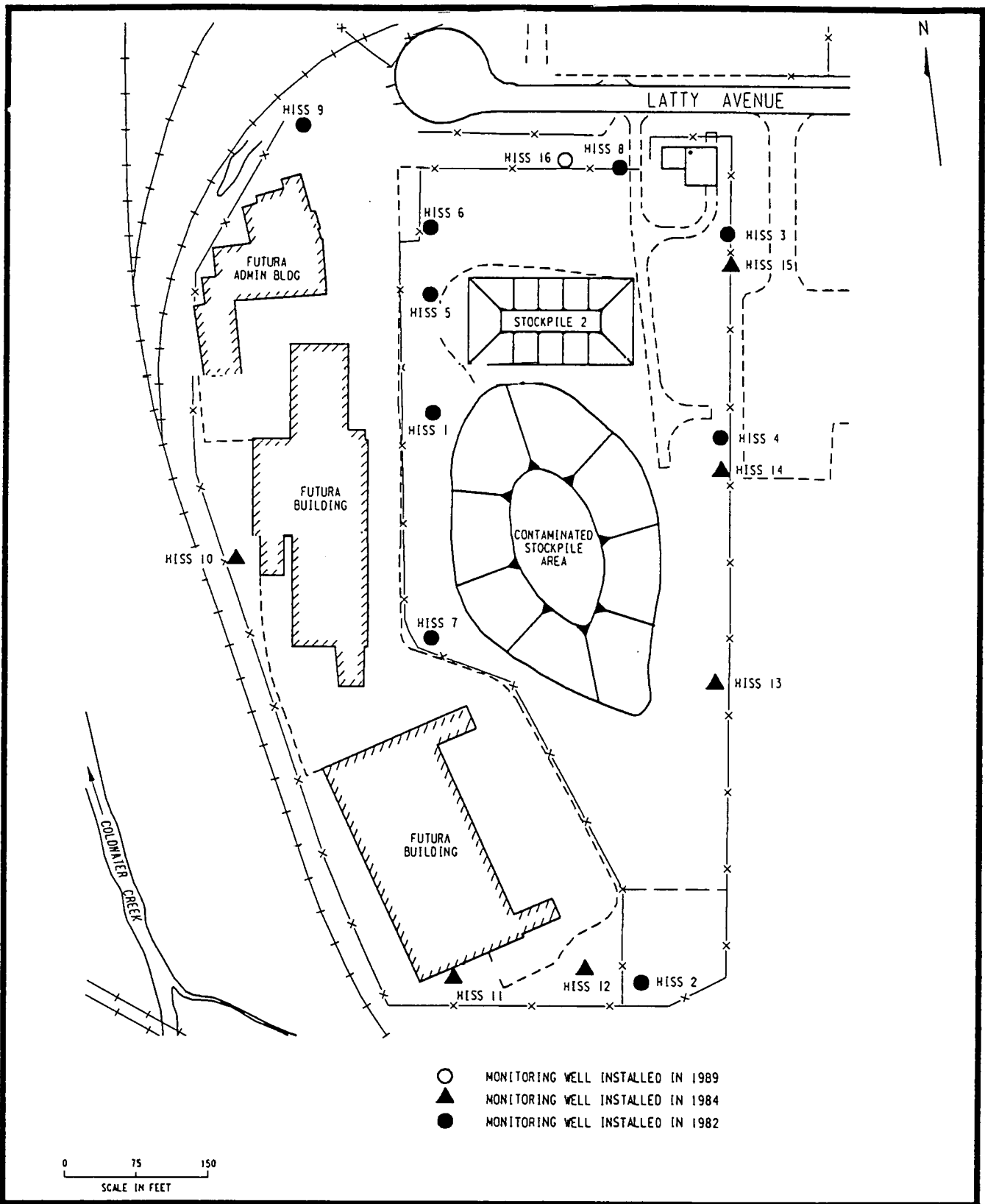
Phase I also included radiological and chemical characterization of the property at 9200 Latty Avenue and radiological characterization of the vicinity properties along Latty Avenue. These activities began in 1986 and were completed in early 1988. In October 1989, HISS was added to the Environmental Protection Agency's (EPA) National Priorities List. Characterization activities in 1989 included collection of soil samples from a section of the Coldwater Creek bank adjacent to HISS and from the left and right creek banks for a distance of 2.4 km (1.5 mi) north of Pershall Road. Analytical results revealed thorium-230 concentrations bordering HISS in excess of DOE guidelines. Samples from the banks upstream and downstream of HISS did not exhibit high levels of contamination. A remedial investigation/feasibility study will be conducted to evaluate alternatives for cleanup.

During Phase II, the contaminated soil at the Latty Avenue properties (i.e., the Futura Coatings property), HISS, and the vicinity properties will be removed to a permanent disposal site pending completion of appropriate environmental compliance documentation.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

Hydrogeological conditions at the site remain unchanged from previous years. Groundwater on site is an unconfined system with a radial flow pattern from a central point next to the western edge of the contaminated pile.

The interpretations presented in this section are based on groundwater levels measured in calendar year 1989. Groundwater monitoring wells (Figure 1-5) were installed at HISS in two phases. The first-phase wells (HISS-1 through HISS-8) were installed in 1982 as part of the radiological site assessment program conducted by ORAU (Ref. 10). Details of the geology and construction for the first-phase wells are not available. The second-phase wells (HISS-9 through HISS-15) were installed by BNI in late 1984 (Ref. 10). An additional well (HISS-16) was



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FIGURE 1-5 HISS MONITORING WELL LOCATIONS

installed in June 1989 to supplement readings from HISS-8, which has no documented construction history. A summary of well construction information is presented in Table 1-1. Further background information on site geology, hydrogeology, and well installation methods can be found in Ref. 10. An example of well construction details is included in this report as Appendix E.

Groundwater levels at HISS were measured with an electric downhole probe water level indicator. Water level measurements for 1989 were taken at weekly intervals.

1.3.1 Groundwater System

The groundwater at HISS is an unconfined system. The water table is in a zone approximately 1.5 to 4.9 m (5 to 16 ft) below the ground surface. (The water table, or potentiometric surface, is defined as the level to which water will rise in tightly cased wells. Delineation of the potentiometric surface of an aquifer indicates groundwater slope and flow direction.) 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). Groundwater surface elevations measured in 1989 for each well are shown as hydrographs (Figures 1-6 through 1-10). Precipitation records for the St. Louis area were available from the U.S. Weather Service and are presented beneath the hydrographs in Figures 1-6 through 1-10. The hydrographs for the HISS groundwater system show slight seasonal fluctuations in groundwater elevation levels. During the spring, groundwater levels rose several feet, a slight amount, or not at all. This may have been due to differences in spring thaw conditions from well to well. The lowest water levels are in the fall, repeating the seasonal fluctuation pattern seen in 1988 (Ref. 11). Correlation of water levels with precipitation events is highest for wells HISS-1, HISS-10, HISS-11, and HISS-5 (Figures 1-6 and 1-9). This indicates that the wells installed on the Futura site (Figure 1-5) are experiencing rapid recharge from precipitation events.

TABLE 1-1
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	6.3 (20.5)	No Documentation	PVC ^a
HISS-2	Jan. 1982	9.8 (32.2)	No Documentation	PVC
HISS-3	Jan. 1982	6.6 (21.6)	No Documentation	PVC
HISS-4	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	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
B53W01S ^b Steel	Nov. 1987	8.4 (27.5)	5.2-8.4 (17.0-27.5)	316 Stainless
B53W01D ^b Steel	Nov. 1987	28.5 (93.5)	24.3-28.5 (79.7-93.5)	316 Stainless

^aPVC - polyvinyl chloride.

^bBackground well, located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of HISS.

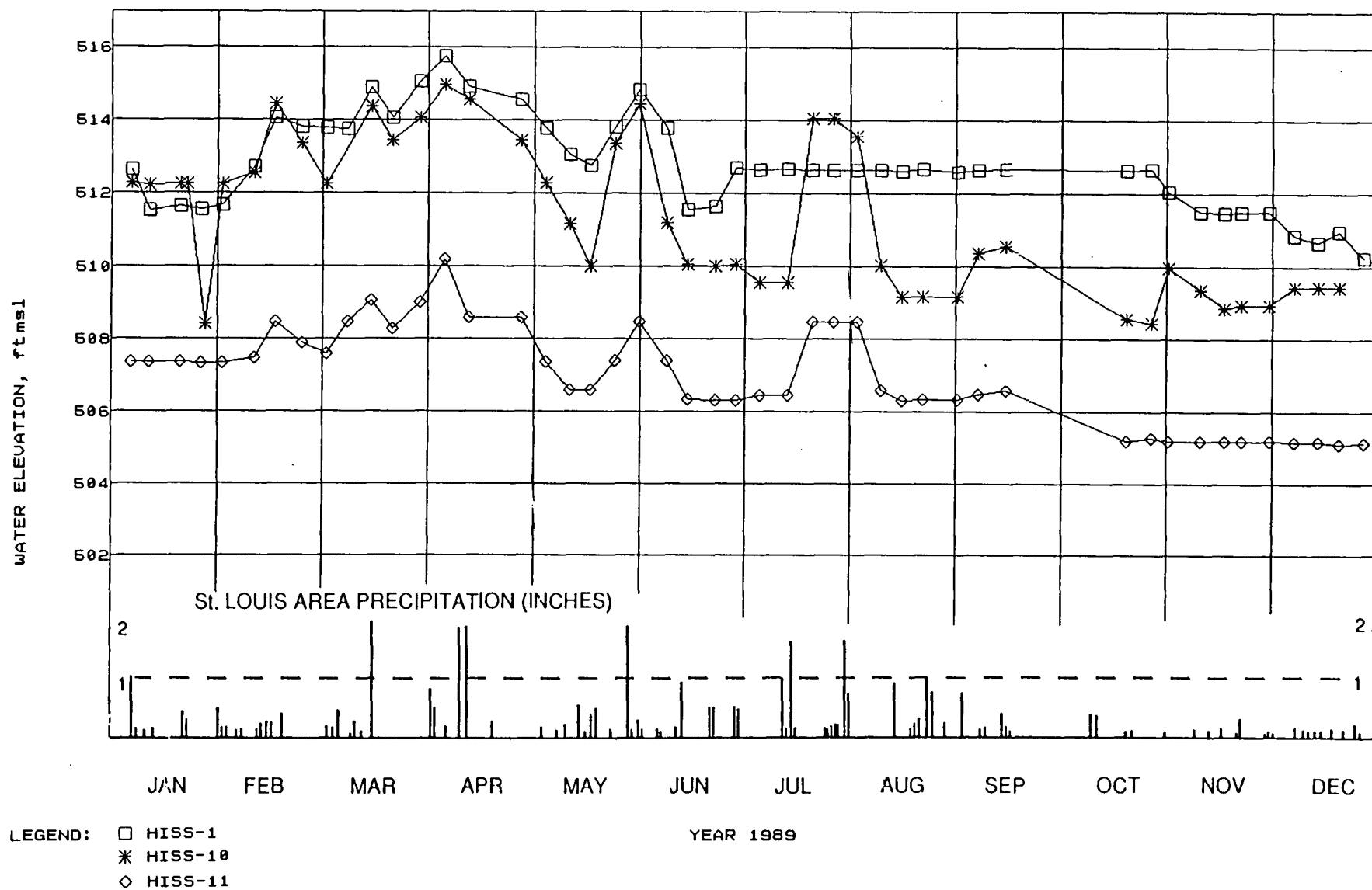


FIGURE 1-6 HYDROGRAPHS OF WELLS HISS-1, HISS-10, AND HISS-11

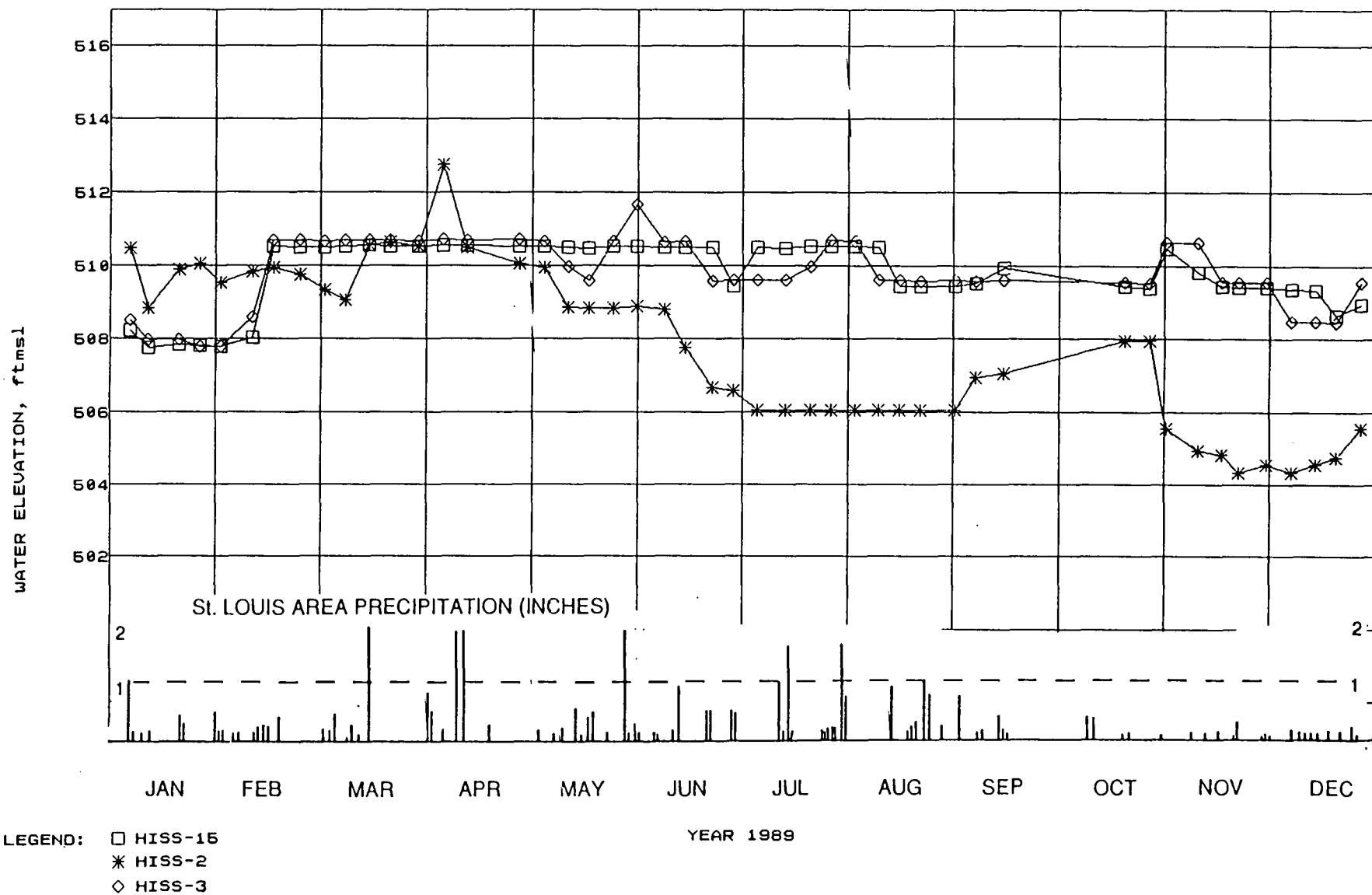


FIGURE 1-7 HYDROGRAPHS OF WELLS HISS-15, HISS-2, AND HISS-3

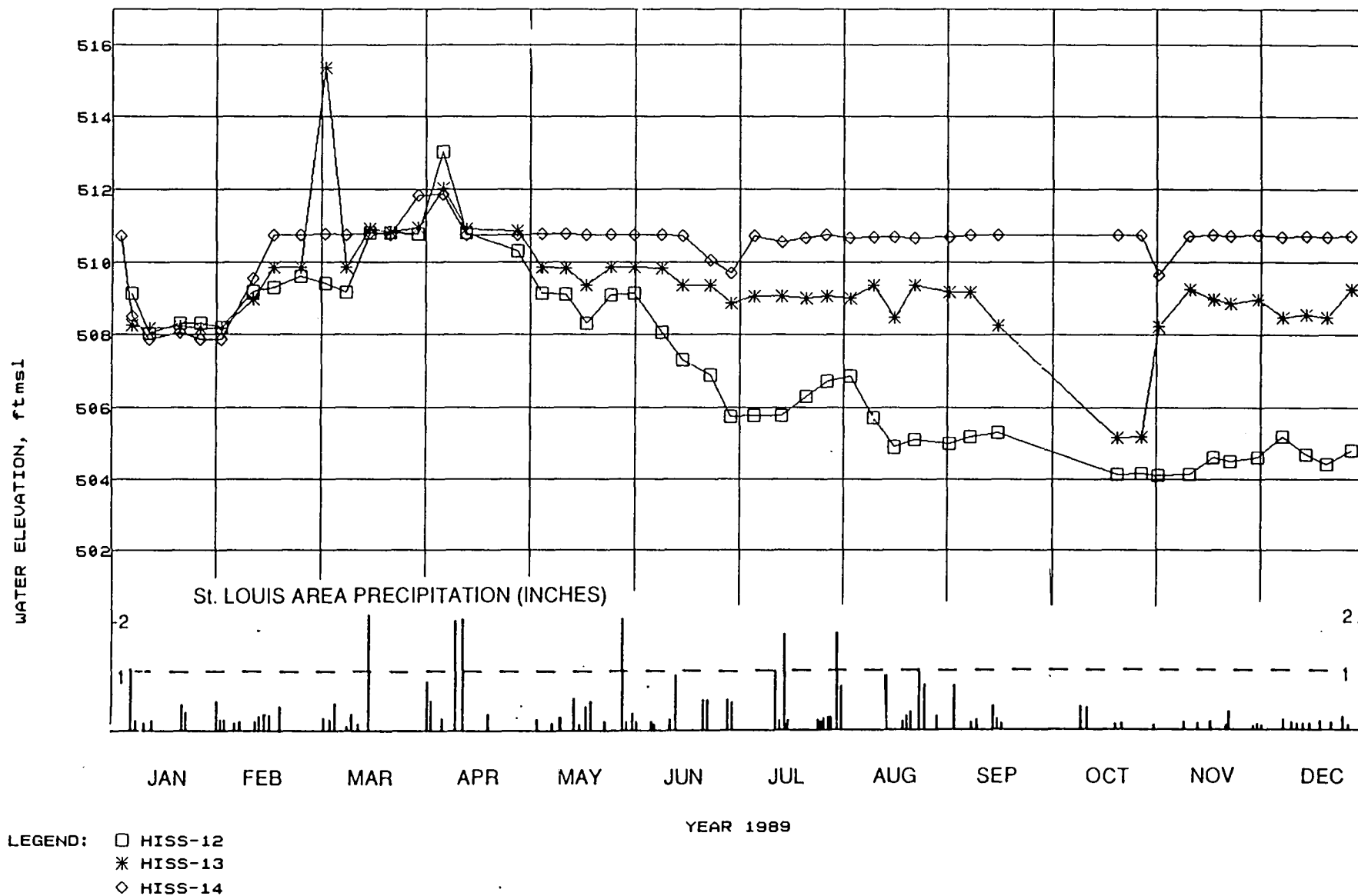


FIGURE 1-8 HYDROGRAPHS OF WELLS HISS-12, HISS-13, AND HISS-14

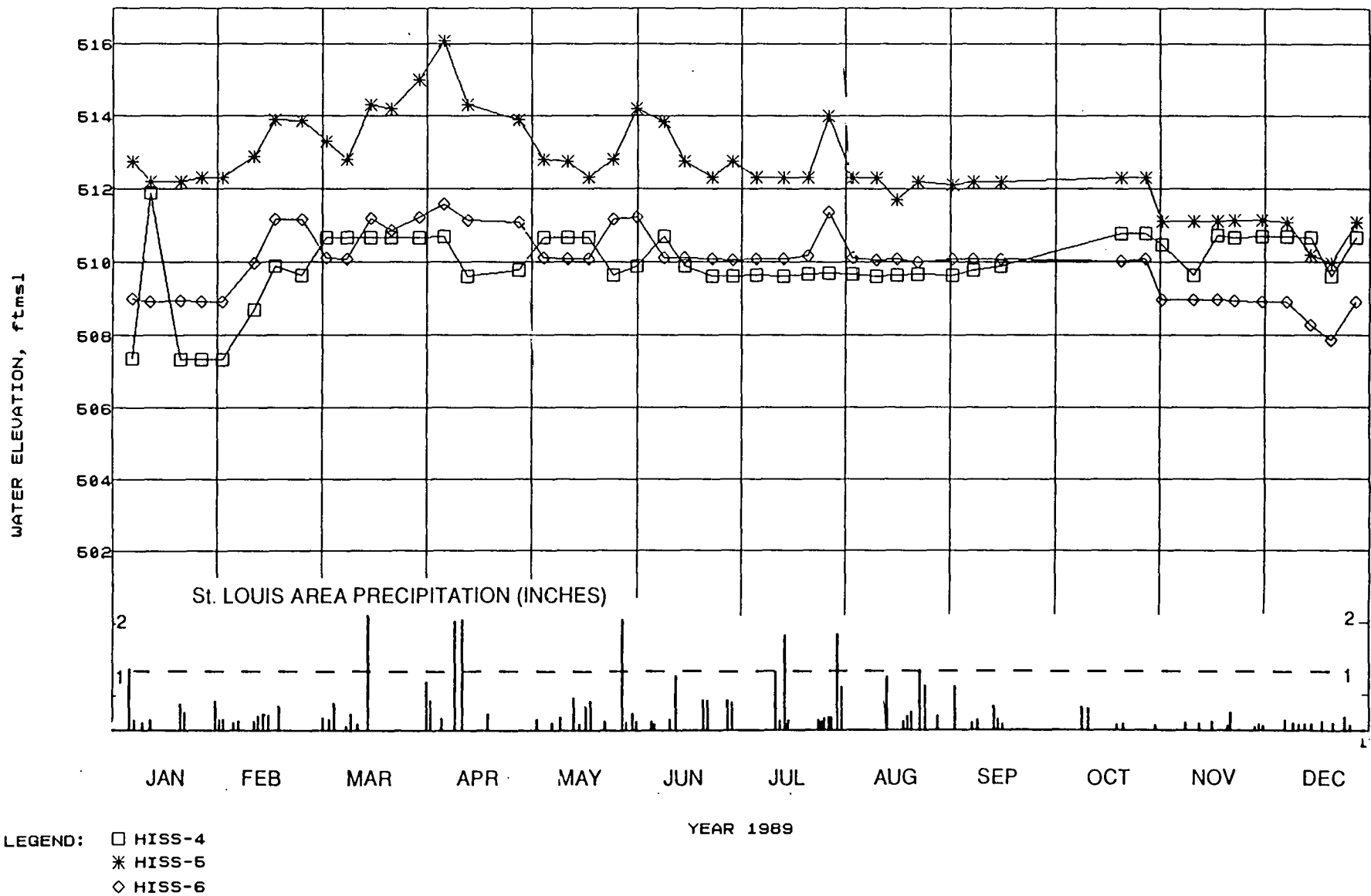


FIGURE 1-9 HYDROGRAPHS OF WELLS HISS-4, HISS-5, AND HISS-6

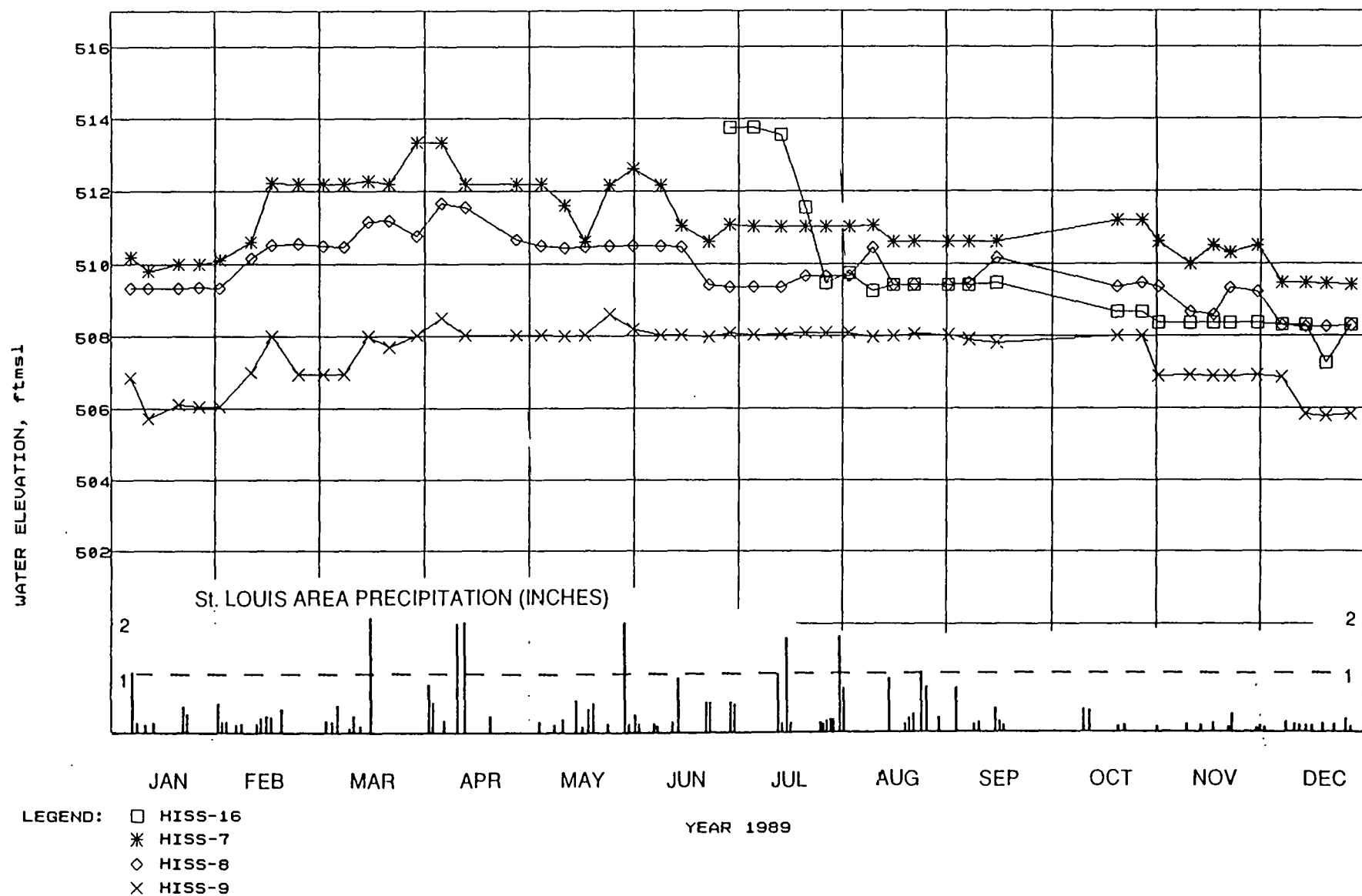


FIGURE 1-10 HYDROGRAPHS OF WELLS HISS-16, HISS-7, HISS-8, AND HISS-9

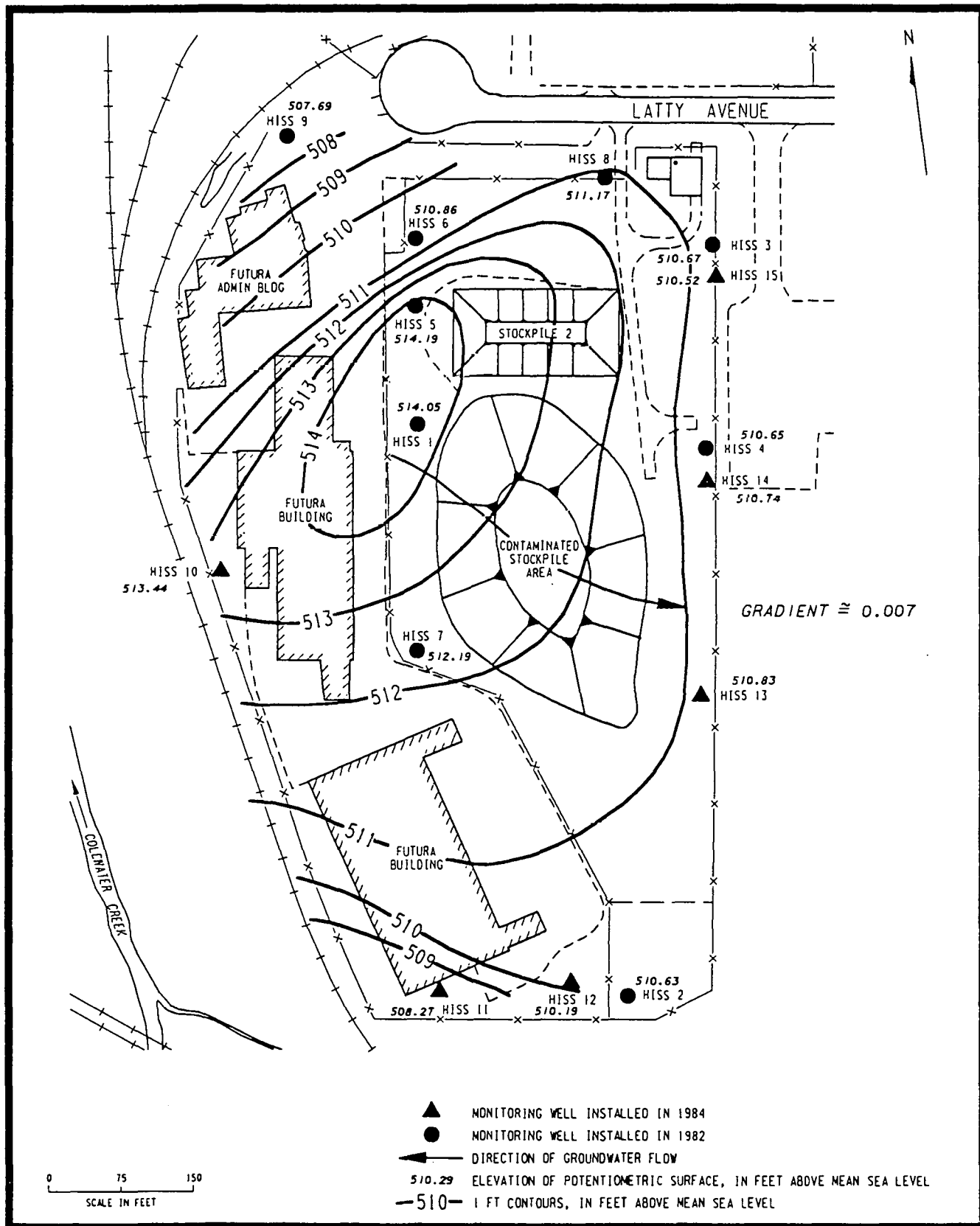
The slope and flow direction of the HISS groundwater system were determined from potentiometric surface maps (Figures 1-11 and 1-12). The two dates plotted were chosen as representative of the seasonal high and low points. Figure 1-11 represents conditions in the spring, and Figure 1-12 represents conditions in the winter. The general flow pattern is radial, with the groundwater flowing outward primarily from wells HISS-1 and HISS-5, toward the other wells. The slope for both potentiometric surfaces was calculated using the southeast flow direction. The same flow direction and gradient were evident in 1988. The calculated gradients are 0.007 for spring (3/22/89) and 0.013 for winter (11/22/89).

1.3.2 Discussion

The apparent slight seasonal variations from spring to winter shown by the hydrographs (Figures 1-6 through 1-10) do not affect the slope of the potentiometric surface or the direction of groundwater flow (Figures 1-11 and 1-12). In both seasons the slope of the potentiometric surface and the direction of flow are radial, away from HISS-1 and HISS-5, which are probably located in an area of surface recharge. Further monitoring will help to determine whether this condition is due to precipitation or to some other condition.

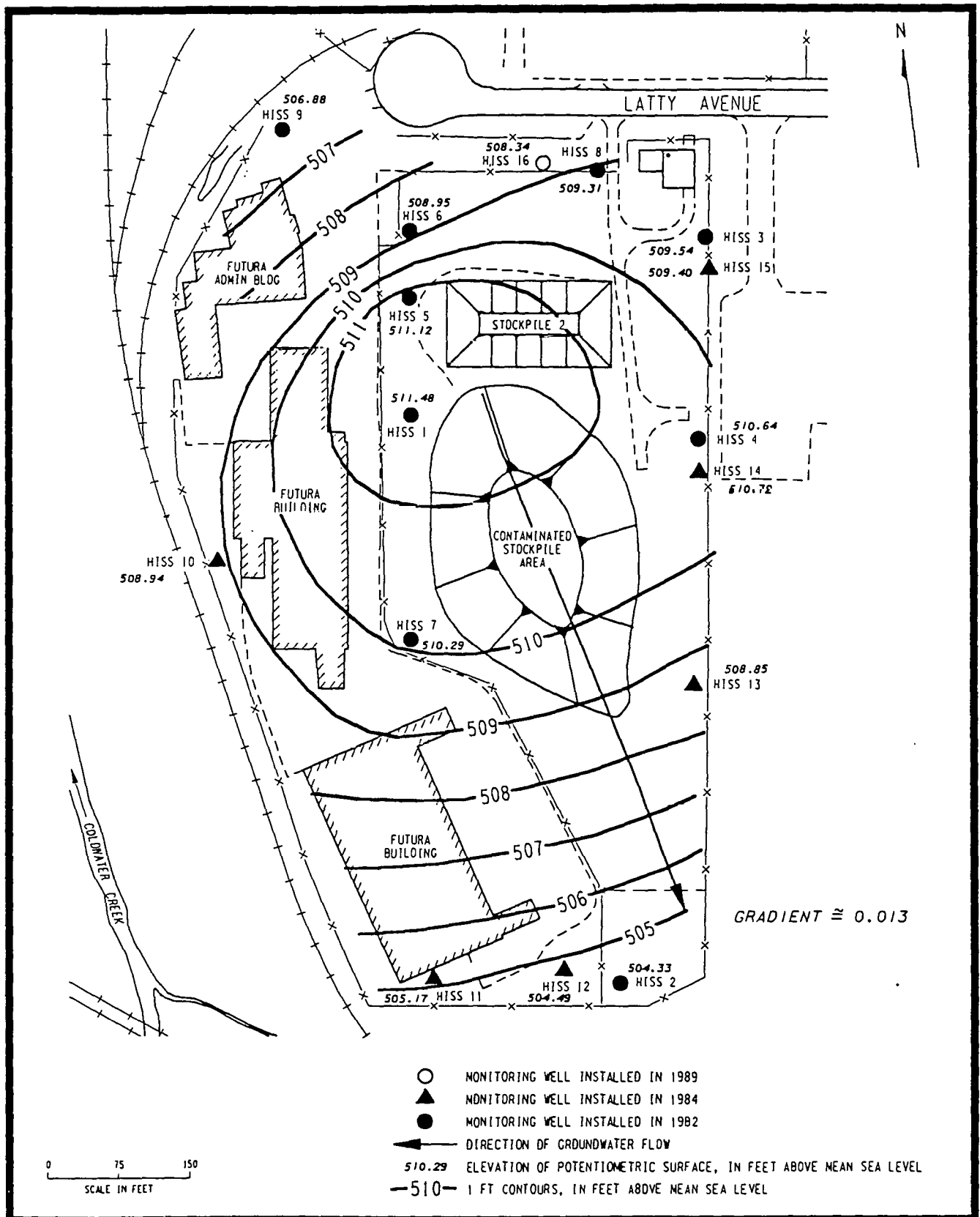
1.3.3 Conclusions

- The HISS groundwater surface is consistently 1.5 to 4.9 m (5 to 16 ft) below the ground surface, depending upon location on the site and season. Groundwater flows radially from the general area of HISS-1 and HISS-5 (primarily), with a slope on the order of 0.01.
- No change in previously observed conditions was observed in 1989.



140FD16.DGN FI

FIGURE 1-11 HISS POTENTIOMETRIC SURFACE MAP (3/22/89)



140FD16.DGN F2

FIGURE 1-12 HISS POTENTIOMETRIC SURFACE MAP (11/22/89)

2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program at HISS, which began in 1984, continued in 1989; air, water, and sediment samples were taken, and radon levels and external gamma radiation levels were monitored to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 12). The potential radiation dose that might be received by a hypothetical maximally exposed individual was calculated to evaluate the site's compliance status with the current radiation protection standard.

Annual average radon concentrations in air ranged from 5 to 9×10^{-10} $\mu\text{Ci/ml}$ (0.5 to 0.9 pCi/L), including background. The average background radon concentration in the vicinity of HISS was 5×10^{-10} $\mu\text{Ci/ml}$ (0.5 pCi/L). Subsection 3.1 contains a discussion of radon concentrations at HISS in 1989. There have been no notable trends in radon concentrations measured at HISS as compared with background levels since the initiation of environmental monitoring in 1984 (see Subsection 3.7.1) (Refs. 11, 13-16).

Annual average external gamma radiation levels measured at HISS in 1989 ranged from below the average background level (76 mrem/yr) to 129 mrem/yr above background. External radiation levels are discussed in Subsection 3.2. Since 1985, external gamma radiation levels have decreased at almost all monitoring stations (see Subsection 3.7.2) (Refs. 11, 14-16).

In surface water (Subsection 3.3), concentrations of total uranium, radium-226, and thorium-230 remain at approximately background levels (see Subsection 3.7.3) (Refs. 11, 14-16).

In groundwater (Subsection 3.4.1), the highest annual average concentrations of total uranium, radium-226, and thorium-230 were 82×10^{-9} $\mu\text{Ci/ml}$ (82 pCi/L), 1.6×10^{-9} $\mu\text{Ci/ml}$ (1.6 pCi/L), and 8.6×10^{-9} $\mu\text{Ci/ml}$ (8.6 pCi/L), respectively. There has been little change in concentrations since 1985 (see Subsection 3.7.4) (Refs. 11, 14-16).

Chemical analyses of well water detected 1 organic pollutant and 11 metals at relatively low concentrations (Subsection 3.4.2). Chemically, groundwater at HISS approximates background conditions in the vicinity.

In creek sediments (Subsection 3.5), the highest annual average concentrations of total uranium, radium-226, and thorium-230 were 2.1 pCi/g, 2.3 pCi/g, and 44.4 pCi/g, respectively. The concentrations of radionuclides in sediments at HISS may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

Calculations were made of the radiological dose received by a hypothetical maximally exposed individual who, when all potential routes of exposure are considered, receives the greatest dose. Exposure to external gamma radiation was the exposure pathway quantified because it is the only one that is plausibly significant. The highest annual average external gamma radiation level at the HISS boundary was 129 mrem/yr above background. When occupancy is considered, this radiation level results in an annual exposure to the hypothetical maximally exposed individual of 1.5 mrem/yr above background (Subsection 3.6.1). This exposure is equivalent to 1.5 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is less than the exposure a person receives during a flight from New York to Los Angeles from the greater amounts of cosmic radiation at higher altitudes. The cumulative dose to the population within an 80-km (50-mi) radius of HISS that results from radioactive materials present at the site is indistinguishable from the dose that the same population receives from naturally occurring sources. Results of the 1989 monitoring show that HISS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of environmental monitoring conducted at HISS in 1989 and includes descriptions of the sampling, monitoring, and analytical procedures used. Calculations were made to determine the estimated possible maximum radiation dose based on environmental conditions, measurements recorded, and evaluation of potential exposure pathways.

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

During 1989, the environmental monitoring program for HISS included radon monitoring, measurement of external gamma radiation levels, sampling of surface water and sediment, and sampling of groundwater from monitoring wells within the site boundary.

Trend tables are provided for radon and external gamma radiation levels and for radionuclides measured in surface water and groundwater. These tables list annual averages for each monitoring location for 1985-1989 to allow for comparisons of data

and identification of trends in monitoring results (see Subsection 3.7).

3.1 RADON SAMPLING

Radon detectors were maintained at 10 locations on the site and along the site boundary, as shown in Figure 3-1. Two of these stations were added in August 1986. Detectors are spaced along the site boundary to ensure adequate detection capability under most atmospheric conditions. Additional detectors are in place at station 6 for quality control. To measure background radon levels, monitoring stations are maintained off site approximately 24 km (15 mi) northeast and 8 km (5 mi) east of HISS.

Radon concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which radon can diffuse. Radon will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, it will equilibrate with radon in the outside air. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. When returned to Terradex for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification, the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm²) is related through calibration to the concentration of radon in air. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units at each sampling station and return the exposed monitors to Terradex for analysis.

Table 3-1 reports the measured concentrations of radon in the air at HISS. Annual average concentrations ranged from 5 to 9×10^{-10} $\mu\text{Ci/ml}$ (0.5 to 0.9 pCi/L), including background, which was 5×10^{-10} $\mu\text{Ci/ml}$ (0.5 pCi/L). All measurements were below the DOE guideline of 3.0 pCi/L.

For a comparison of radon concentrations measured at the site from 1985 through 1989, see Subsection 3.7.1.

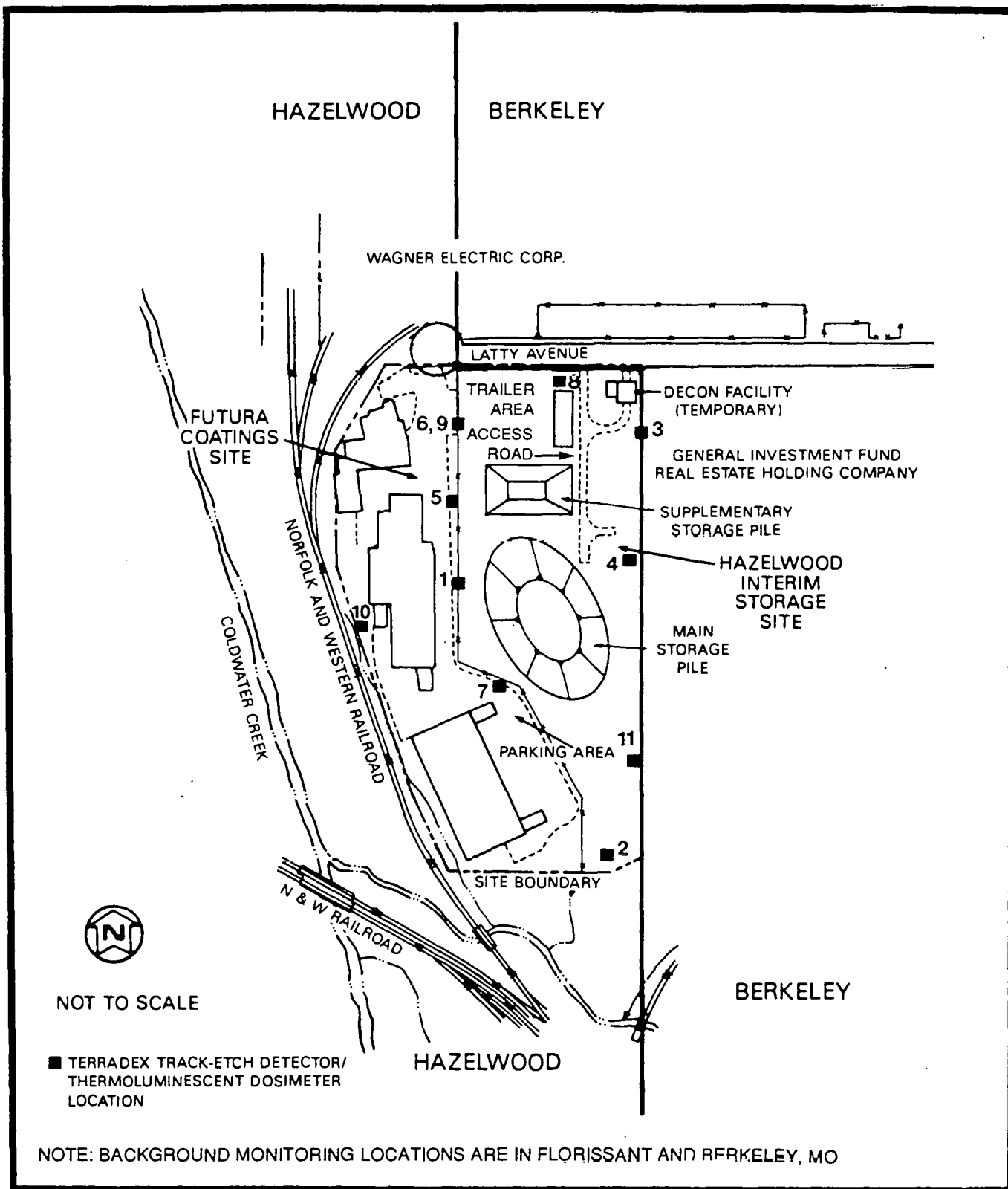


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT HISS

TABLE 3-1
CONCENTRATIONS OF RADON-222 AT HISS, 1989

Sampling Station ^a	Number of Samples	Concentration (10^{-9} μ Ci/ml) ^{b, c}		
		Minimum	Maximum	Average
1	4	<0.3	1.9	0.8
2	4	0.3	1.7	0.9
3	4	<0.3	1.1	0.5
4	4	0.5	1.2	0.9
5	4	<0.3	0.6	0.5
6	4	<0.3	0.7	0.5
7	4	0.4	1.0	0.6
8	4	<0.3	0.7	0.5
9 ^d	4	<0.3	0.7	0.5
10	4	<0.3	0.8	0.5
11	4	0.4	1.2	0.6
<u>Background</u>				
16 ^e	4	<0.3	0.8	0.5
19 ^f	4	0.3	0.6	0.5

^aLocations of sampling stations are shown in Figure 3-1.

^b 1×10^{-9} μ Ci/ml is equivalent to 1 pCi/L.

^cBackground has not been subtracted from the reported values.
Note: Some stations have concentrations below background.

^dStation 9 is a quality control for station 6.

^eLocated in Florissant, MO, approximately 24 km (15 mi) north-east of HISS.

^fLocated at North Hanley Road, Berkeley, MO, approximately 8 km (5 mi) east of HISS.

3.2 EXTERNAL GAMMA RADIATION

External gamma radiation levels were measured at 10 locations, all of which correspond to the radon (Terradex) detector locations shown in Figure 3-1.

External gamma radiation levels are measured using lithium fluoride thermoluminescent dosimeters (TLDs). The system of measurement used in 1989 utilizes tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to the tissues of the body at a depth of 1 cm. Each monitoring station contains a minimum of four dosimeters, which are exchanged after approximately one year of accumulated exposure. For example, a dosimeter placed in a station in October 1988 would be removed in October 1989 and replaced with a new dosimeter. Each dosimeter contains five individual lithium fluoride chips (each group of five chips is preselected on the basis of having a reproducibility of ± 3 percent across a series of laboratory exposures), the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). The average value is then corrected for the shielding effect of the shelter housing (approximately 8 percent). The corrected value is then converted to millirem per year by dividing by the number of days of exposure and subsequently multiplying by 365 days.

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

The results of external gamma monitoring are presented in Table 3-2. For each quarter, an average of the background levels measured was subtracted from the site boundary measurements

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

Sampling Station ^a	Number of Measurements	Radiation Level (mrem/yr) ^b		
		Minimum	Maximum	Average
1	4	- ^c	20	6
2	4	108	156	129
3	4	- ^c	7	2
4	4	48	82	68
5	4	- ^c	19	5
6	4	- ^c	19	5
7	4	25	113	61
8	4	- ^c	1	- ^c
9 ^d	4	- ^c	21	6
10	4	- ^c	5	1
11	4	19	48	36

Background

16 ^e	4	52	71	61
19 ^f	4	84	103	92

^aLocations of sampling stations are shown in Figure 3-1.

^bMeasured background has been subtracted from the readings taken at the sampling stations shown in Figure 3-1.

^cMeasurement was less than or equal to the measured background value.

^dStation 9 is a quality control for station 6.

^eLocated in Florissant, MO, approximately 24 km (15 mi) northeast of HISS.

^fLocated at North Hanley Rd., Berkeley, MO, approximately 8 km (5 mi) east of HISS.

to provide an estimate of radiation levels resulting from residual materials at the site. The highest annual average external gamma radiation level was 129 mrem/yr at station 2, where a 2-h/week occupancy factor is conservatively appropriate, given the current use of the property. On this basis, the external exposure to an individual working on this property would be 1.5 mrem/yr. This exposure is approximately equivalent to 1.5 percent of the DOE radiation protection standard of 100 mrem/yr.

The background external gamma radiation value for a given station is not constant. Because the background radiation value is a combination of both natural terrestrial sources and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil can affect the value measured. Independent of the placement of the detector at the site are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 17). Because of these factors, it is not abnormal for stations at the boundary of a site to have an external gamma radiation value less than the background level measured some distance from the site.

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

3.3 SURFACE WATER SAMPLING

During 1989, sampling was performed to determine the concentrations of total uranium, radium-226, and thorium-230 in surface water at four monitoring locations (Figure 3-2). Surface water samples were collected quarterly at sampling locations established on the basis of potential contaminant migration and discharge routes from the site. Sampling points were both upstream, to establish background conditions; and downstream, to determine the effect of runoff from the site on surface waters in

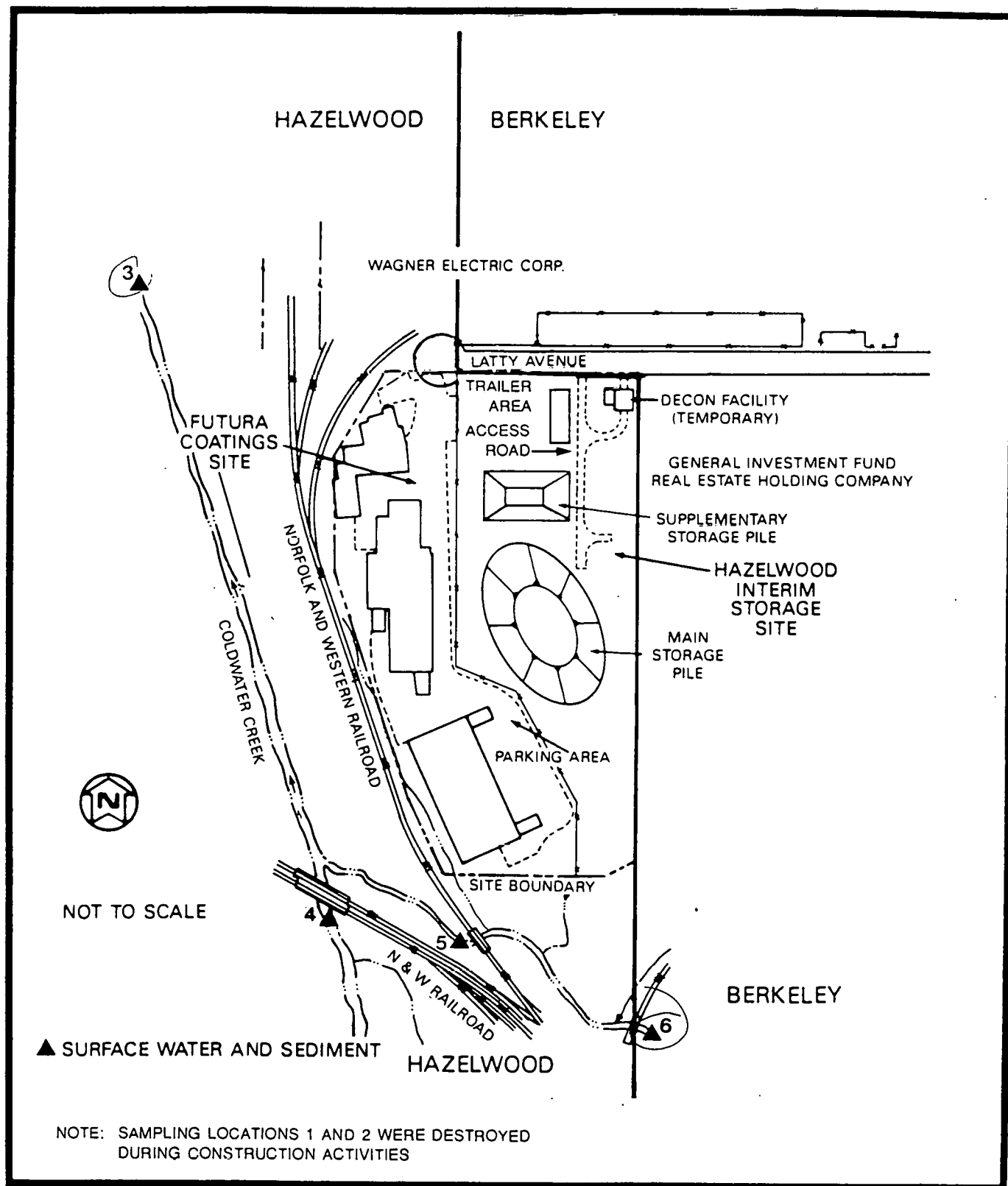


FIGURE 3-2 SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS AT HISS

the vicinity. Sampling locations 1 and 2 were destroyed by construction activities in July 1987 and therefore are no longer included in the monitoring program.

Nominal 1-L (0.26-gal) unfiltered grab samples were collected to fill a 3.8-L (1.0-gal) container and were analyzed by TMA/E. The concentration of total uranium was determined by a fluorometric method. Radium-226 concentrations in water were determined by radon emanation. (This method consists of precipitating radium as sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.) Thorium-230 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

The results of analyses of surface water samples are presented in Table 3-3. Average total uranium, radium-226, and thorium-230 concentrations did not vary much from background and are within the DOE derived concentration limit guidelines.

For comparisons of radionuclide concentrations measured in surface water from 1985 through 1989, see Subsection 3.6.3.

3.4 GROUNDWATER SAMPLING

Groundwater samples were collected quarterly in 1989 from seven monitoring wells established along the perimeter of the property and from two off-site background wells. After the wells had been bailed dry or three casing volumes had been removed, the wells were allowed to recharge before nominal 1-L (0.26-gal) grab samples were collected to fill a 3.8-L (1.0-gal) container. Samples were analyzed by TMA/E for total uranium, dissolved radium-226, and dissolved thorium-230 using the methods applied to surface water analyses (see Subsection 3.3). Analyses

TABLE 3-3
CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230
IN SURFACE WATER IN THE VICINITY OF HISS, 1989

Sampling Location ^{a, b}	Number of Samples	Concentration (10 ⁻⁹ μCi/ml) ^c		
		Minimum	Maximum	Average
<u>Total Uranium</u>				
3	4	<3	6	4
4	4	<3	7	5
5	4	<3	5	4
6	4	<3	4	4
7d	4	<3	<3	<3
<u>Radium-226</u>				
3	4	0.2	0.7	0.4
4	4	0.1	0.6	0.3
5	4	0.1	0.5	0.3
6	4	0.1	0.4	0.3
7d	4	0.1	0.4	0.3
<u>Thorium-230</u>				
3	4	<0.1	0.3	0.2
4	4	0.1	0.2	0.2
5	4	<0.1	0.1	0.1
6	4	<0.1	0.1	0.1
7d	4	<0.1	0.2	0.1

^aLocations are shown in Figure 3-2.

^bSampling locations 1 and 2 were destroyed by construction activities conducted during July 1987.

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

^dLocated south of Runway 6 at Lambert Airport, upstream of any influence from SLAPS or HISS.

for chemical indicator parameters, metals, organic compounds, pesticides, and polychlorinated biphenyls (PCBs) were performed by Weston Analytical Laboratory.

3.4.1 Radiological

Results of the radionuclide analyses of groundwater samples are presented in Table 3-4. The highest annual average total uranium, radium-226, and thorium-230 concentrations were $82 \times 10^{-9} \mu\text{Ci/ml}$ (82 pCi/L), $1.6 \times 10^{-9} \mu\text{Ci/ml}$ (1.6 pCi/L), and $8.6 \times 10^{-9} \mu\text{Ci/ml}$ (8.6 pCi/L), respectively. These values are all within DOE guidelines and, except for HISS-6, values are quite close to measured background values. For a comparison of radionuclide concentrations measured in groundwater at HISS from 1985 through 1988, see Subsection 3.7.4.

3.4.2 Chemical

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

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

Groundwater is analyzed for TOC and TOX to determine organic content. TOC measures the total organic carbon content of water but is not specific to a given contaminant. TOX measures organic compounds containing halogens because many pollutants contain

TABLE 3-4
CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230
IN GROUNDWATER AT HISS, 1989

Page 1 of 2

Page 1 of 1

Sampling Location ^a	Number of Samples	Concentration (10 ⁻⁹ μ Ci/ml) ^b		
		Minimum	Maximum	Average
<u>Total Uranium</u>				
HISS-6	4	57	122	82
HISS-9	4	<3	<3	<3
HISS-10	4	<3	7	5
HISS-11	4	<3	9	6
HISS-12	4	<3	5	4
HISS-13	4	<3	7	5
HISS-15	4	<3	10	5
<u>Background</u>				
B53W01S ^C	4	<3	<3	<3
B53W01D ^C	4	<3	<3	<3
<u>Radium-226</u>				
HISS-6	4	1.2	2.4	1.6
HISS-9	4	0.4	0.9	0.6
HISS-10	4	0.1	0.7	0.3
HISS-11	4	0.4	1.1	0.7
HISS-12	4	0.5	0.8	0.7
HISS-13	4	0.6	0.9	0.7
HISS-15	4	0.6	2.5	1.2
<u>Background</u>				
B53W01S ^C	4	0.2	1.9	0.7
B53W01D ^C	4	0.9	1.1	1.0
<u>Thorium-230</u>				
HISS-6	4	<0.3	9.6	5.0
HISS-9	4	<0.1	0.4	0.2
HISS-10	4	<0.1	0.2	0.1
HISS-11	4	0.2	1.3	0.7
HISS-12	4	1.4	3.3	2.3
HISS-13	4	0.4	1.3	0.9
HISS-15	4	3.1	18.0	8.6

TABLE 3-4
(continued)

Page 2 of 2

Sampling Location ^a	Number of Samples	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^b		
		Minimum	Maximum	Average

Thorium-230 (continued)

Background

B53W01S ^c	4	<0.1	0.8	0.3
B53W01D ^c	4	0.3	0.6	0.4

^aSampling locations are shown in Figure 1-5.

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

^cLocated at Byassee Road, approximately 0.8 km (0.5 mi) southwest of the site.

halogenated hydrocarbons, which are organic compounds containing fluorine, chlorine, bromine, and iodine.

As shown in Table 3-5, pH, TOC, and TOX are within approximately ± 20 percent of the levels in wells B53W01S and B53W01D, which represent background concentrations. Indicator parameters for 1989 show an overall decrease in TOX values to levels that approximate those in the background wells.

Specific conductance across the site varied from a low of 714 to a high of 8,380 μmhos . The groundwater at the site contains corresponding levels of dissolved solids. Analytical results for chemical indicators indicate that the groundwater at HISS is of poor quality, which is typical of groundwater in industrial urban areas.

In January 1989, analyses were performed for priority pollutant organics, including 36 volatile organic compounds (VOCs); 65 base/neutral and acid extractable compounds (BNAEs); and 27 pesticides and polychlorinated biphenyls (PCBs). The analyses were performed on a one-time basis to investigate previously elevated specific conductance and total organic halides. The samples were also filtered and analyzed for the following metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. Some of these metals (e.g., molybdenum and selenium) were chosen because they are typically found associated with uranium ores that were associated with the processing at the site.

Concentrations of many of the analytes were below the limit of detection for the respective analytical method. Table 3-6 lists the parameters for which analyses were conducted, but for which analytes were not detected.

Only one organic BNAE compound [bis(2-ethylhexyl)phthalate] was found in two wells. Because of the low solubility of the compound, and because the compound was detected in similar concentrations in laboratory blanks, the presence of

TABLE 3-5
ANALYTICAL RESULTS FOR INDICATOR PARAMETERS
IN GROUNDWATER AT HISS, 1989

Sampling Location (Well No.) ^b	Parameter			
	pH (Standard Units) ^c	Total Organic Carbon (mg/L)	Total Organic Halides ^a (μg/L)	Specific Conductance (μmhos/cm)
HISS-6	6.9 - 7.0	2.9 - 5.7	ND - 29	3980 - 6340
HISS-9	7.1 - 8.2	3.2 - 8.6	ND - 20	837 - 910
HISS-10	7.2 - 7.4	1.6 - 22.1	ND - 40	714 - 966
HISS-11	7.0	1.4 - 21.2	ND - 29	1400 - 1650
HISS-12	6.2 - 6.8	3.4 - 12.6	ND - 30	2960 - 3740
HISS-13	6.5 - 6.8	5.7 - 21.2	ND - 20	7420 - 8380
HISS-15	6.9 - 7.0	3.0 - 33.5	ND - 52	988 - 1190
<u>Background</u>				
B53W01S ^d	6.9 - 7.1	2.8 - 44.8	ND - 32	909 - 958
B53W01D ^d	7.1 - 7.3	5.5 - 23.3	ND - 45	1040 - 1100

^aND - no detectable concentration.

^bSampling locations are shown in Figure 1-5.

^cOnly three quarters of data available.

^dBackground well, located at Byassee Rd., approximately 0.8 km (0.5 mi) southwest of the site.

bis(2-ethylhexyl)phthalate in wells HISS-9 (650 $\mu\text{g/L}$) and B53W01D (2,200 $\mu\text{g/L}$) is believed to be a result of laboratory contamination.

Metal ions are normal constituents of groundwater originating from the soil through which the groundwater flows. Metal ions can also be introduced as a result of previous waste management activities. Concentrations of metals detected in groundwater are given in Table 3-7. Barium, calcium, iron, magnesium, manganese, sodium, and zinc were found in groundwater at levels that approximate those found in groundwater from background well locations. In general, elevated levels of calcium and magnesium, which are common in the area (as evidenced by their concentrations in area background wells), reduce the acceptability of groundwater for industrial or residential use. Metals that were not found at background well locations but were found in groundwater from the site included aluminum, boron, chromium, and selenium. These metals are typically present in trace ($<100 \mu\text{g/L}$) levels in groundwater (Ref. 18). The slightly elevated concentrations of these metals may be a result of waste at the site. Additional groundwater data for the site will be evaluated as part of the remedial investigation report that is being prepared for the St. Louis FUSRAP sites.

3.5 SEDIMENT SAMPLING

Sediment samples consisting of composites weighing approximately 0.5 kg (1.1 lb) were collected quarterly at surface water sampling locations where sediment is present. The bases for selection of the individual sampling locations are the same as those given for surface water sampling in Subsection 3.3.

TMA/E analyzed the samples for total uranium, radium-226, and thorium-230. The total uranium concentration was calculated by summing the analytical results for isotopic uranium. Isotopic uranium and thorium-230 were determined by alpha spectrometry, where the uranium and thorium-230 are leached, extracted, and

TABLE 3-7

ANALYTICAL RESULTS FOR METALS DETECTED IN GROUNDWATER AT HISS, 1989

Sampling Location (Well Number) ^a	Concentration ($\mu\text{g/L}$) ^b										
	Al	Ba	B	Ca	Cr	Fe	Mg	Mn	Se	Na	Zn
HISS-6	ND	ND	ND	209,000	ND	ND	54,700	ND	544	59,400	ND
HISS-9	ND	219	196	56,600	23.4	ND	37,500	37.3	ND	44,300	35.2
HISS-10	ND	ND	146	86,100	26.6	145	46,500	ND	ND	28,700	25.2
HISS-11	ND	279	166	158,000	23.1	256	67,800	21.4	ND	46,400	47.4
HISS-12	290	399	125	314,000	22.1	109	154,000	ND	ND	88,700	35.9
HISS-13	327	ND	ND	517,000	ND	185	238,000	27.9	146	109,000	48.0
HISS-15	ND	386	224	121,000	23.8	265	48,500	920	ND	30,900	ND
<u>Background</u>											
B53W01S ^c	ND	311	ND	112,000	ND	141	47,400	1,150	ND	21,500	31.3
B53W01D ^c	ND	540	ND	112,000	ND	ND	42,000	2,100	ND	48,000	13.8

^aSampling locations are shown in Figure 1-5.

^bND--below limit of detection.

^cBackground well, located at Byassee Rd., approximately 0.8 km (0.5 mi) southwest of the site.

electroplated on metal substrates. Radium-226 concentrations were determined by radon emanation (described in Subsection 3.3).

Results of these analyses, based on dry weight, are presented in Table 3-8. Average total uranium concentrations ranged from 1.8 to 2.1 pCi/g, average radium-226 concentrations from 1.2 to 3.3 pCi/g, and average thorium-230 concentrations from 0.8 to 44.4 pCi/g. Except for the highest thorium-230 annual average, these values are within DOE guidelines for soils and less than levels of radioactivity in Florida concentrated superphosphate fertilizers (Appendix D). (DOE does not currently have guidelines for radioactivity levels in sediments.) The annual average thorium-230 concentration (44.4 pCi/g) is a result of one elevated measurement at location 3; the concentration there of 140 pCi/g during the third quarter is not consistent with previous and subsequent sampling results. Subsection 1.2 discusses the elevated levels of thorium-230 found during characterization activities at Coldwater Creek.

3.6 RADIATION DOSE

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

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

TABLE 3-8
CONCENTRATIONS OF RADIUM-226, THORIUM-230, AND
TOTAL URANIUM IN SEDIMENT IN THE VICINITY OF HISS, 1989

Sampling Location ^{a, b}	Number of Samples	Concentration [pCi/g (dry)] ^c		
		Minimum	Maximum	Average
<u>Radium-226</u>				
3	4	0.7	5.2	2.3
4	4	1.1	1.3	1.2
5	4	1.1	1.7	1.4
6	4	1.1	1.8	1.4
7	4	0.8	1.8	1.2
<u>Thorium-230</u>				
3	4	4.3	140.0	44.4
4	4	0.1	3.7	2.2
5	4	1.1	3.7	2.1
6	4	0.7	3.9	2.0
7	4	0.5	0.9	0.8
<u>Total Uranium</u>				
3	4	1.9	2.3	2.1
4	4	1.3	2.3	1.9
5	4	1.4	2.2	1.9
6	4	1.1	2.6	1.9
7	4	0.8	2.8	1.9

^aSampling locations are shown in Figure 3-2. Location 7 is upstream of the site (south of Runway 6 at Lambert Airport) and is a background location.

^bConstruction activities in July 1987 destroyed sampling locations 1 and 2.

^cBackground has not been subtracted.

groundwater from a well at the site, the trespasser would have to be equipped with a means of removing the well cap (which is locked) and would also need means of extracting water, such as a bailer or pump.

Most of the annual average radon concentrations measured at the boundary of HISS were within the normal variation associated with background measurements for this area. Given the amount of time that the hypothetical maximally exposed individual would spend near the higher-than-background locations, the dose from radon would be indistinguishable from the dose received from background. Consequently, this pathway would not contribute additional dose to the maximally exposed individual.

3.6.1 Dose to the Maximally Exposed Individual

To identify the individual in the vicinity of HISS who would receive the highest dose from on-site radioactive materials, the dose from exposure to external gamma radiation was calculated at various monitoring locations that could be accessible to the public. This dose was then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points. For the properties surrounding HISS, the highest overall dose would be received by an individual west of the site. Because this is a commercial area parking lot, the calculated dose was based on an estimated exposure period of 2 h/week. Exposure to workers in nearby commercial buildings is negligible because of the distance of the buildings from the site perimeter and the attenuation provided by the building walls.

The highest average external gamma radiation exposure rate above background was 129 mrem/yr, as measured at monitoring location 2 (Figure 3-1). Exposure at this rate for 2 h/week would result in an annual exposure to the total body of approximately 1.5 mrem. This exposure is approximately equivalent to 1.5 percent of the DOE radiation protection standard of 100 mrem/yr. This scenario is highly conservative because it is unlikely that any individual would spend so much time at this location. This

exposure is less than the exposure a person receives during a flight from New York to Los Angeles from the greater amounts of cosmic radiation at higher altitudes.

3.6.2 Dose to the Population in the Vicinity of HISS

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

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

Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 19). Therefore, exposure from the low radon concentrations at HISS does not contribute measurably to population dose.

On the basis of radionuclide concentrations measured in water leaving HISS, it also appears that there is no plausible pathway by which ingestion of water could result in a critical dose to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, thereby lowering potential doses to even less harmful levels. Because the contributions to population dose via all three potential exposure pathways are inconsequential, calculation of dose to the population is not warranted. The cumulative dose to the population within an 80-km (50-mi) radius of HISS that would result from radioactive materials present at the site would be indistinguishable from the

dose that the same population would receive from naturally occurring radioactive sources.

3.7 TRENDS

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

3.7.1 Radon

As shown in Table 3-9, there have been no discernible trends in radon concentrations at HISS since 1985. Overall, radon concentrations have remained basically stable.

3.7.2 External Gamma Radiation

As shown in Table 3-10, external gamma radiation levels measured at HISS have declined since 1985 at all monitoring locations except locations 2, 4, 7, and 11. The overall decline possibly reflects the progress of remedial action at the site, specifically the partial consolidation of contaminated soil under a membrane liner. Another factor that could have influenced gamma radiation levels is drainage of rainwater due to surface elevations of the pile.

3.7.3 Surface Water

As shown in Table 3-11, concentrations of uranium, radium-226, and thorium-230 in surface water in the vicinity of HISS have remained low since 1985. There is no measurable effect from HISS that is distinguishable from upstream concentrations.

TABLE 3-9
ANNUAL AVERAGE CONCENTRATIONS OF RADON-222
AT HISS, 1985-1989^a

Sampling Station ^b	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^{c,d}				
	1985	1986	1987	1988	1989
1	0.3	0.9	1.0	0.9	0.8
2	0.5	0.8	0.7	0.7	0.9
3	0.4	0.3	0.6	0.6	0.5
4	0.5	1.3	1.5	1.3	0.9
5	0.4	0.6	0.3	0.9	0.5
6	0.7	0.6	0.8	0.7	0.5
7	0.4	1.1	1.8	0.6	0.6
8	0.3	0.2	0.3	0.6	0.5
9	0.5	0.5	0.3	0.9	0.5
10 ^e	--	0.2	0.4	0.4	0.5
11 ^e	--	1.8	1.2	0.8	0.6
<u>Background</u>					
16 ^f	0.5	0.3	0.4	0.4	0.5
19 ^g	--	--	--	0.7	0.5

^aData sources for 1985-1988 are the annual site environmental reports for those years (Refs. 11, 14-16).

^bLocations of sampling stations are shown in Figure 3-1.

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

^dMeasured background has not been subtracted.

^eSampling station established in August 1986.

^fLocated approximately 24 km (15 mi) northeast of HISS.

^gBackground station established in April 1988, approximately 8 km (5 mi) east of HISS.

TABLE 3-10
ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS
AT HISS, 1985-1989^a

Sampling Station ^b	Radiation Level (mrem/yr) ^c				
	1985	1986	1987	1988	1989
1	58	34	44	40	6
2	87	68	113	116	129
3	25	23	20	14	2
4	83	71	74	83	68
5	141	77	46	51	5
6	287	179	29	44	5
7	89	46	50	61	61
8	7	17	27	11	0
9 ^d	261	151	61	49	6
10 ^e	--	21	17	13	1
11 ^e	--	15	44	56	36
<u>Background</u>					
16 ^f	99	97	77	73	61
19 ^g	--	--	--	--	92

^aData sources for 1984-1987 are the annual site environmental reports for those years (Refs. 11, 14-16).

^bLocations of sampling stations are shown in Figure 3-1.

^cMeasured background has been subtracted from the readings taken at the sampling stations shown in Figure 3-1.

^dStation 9 is a quality control for station 6.

^eSampling station established in August 1986.

^fLocated approximately 24 km (15 mi) northeast of HISS.

^gStation was established in April 1988 at the Berkeley City Hall, approximately 8 km (5 mi) east of HISS.

TABLE 3-11
ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM,
RADIUM-226, AND THORIUM-230 IN SURFACE WATER
IN THE VICINITY OF HISS, 1985-1989^a

Sampling Location ^b	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^c				
	1985	1986	1987	1988	1989
<u>Total Uranium</u>					
1 ^d	<3.0	<3.0	--	--	--
2 ^d	<3.0	<3.0	--	--	--
3	4.3	4.0	4.0	4.0	4.0
4	4.3	4.0	5.0	4.0	5.0
5	<3.0	<3.0	<3.0	4.0	4.0
6	<3.0	<3.0	<3.0	<3.0	4.0
7 ^e	<3.0	<3.0	<3.0	4.0	<3.4
<u>Radium-226</u>					
1 ^d	0.1	0.3	--	--	--
2 ^d	0.1	0.1	--	--	--
3	0.1	0.3	0.2	0.3	0.4
4	0.2	0.3	0.2	0.3	0.3
5	0.1	0.2	0.3	0.3	0.3
6	0.2	0.2	0.2	0.3	0.3
7 ^e	0.1	0.3	0.3	0.5	0.3
<u>Thorium-230</u>					
1 ^d	0.1	0.2	--	--	--
2 ^d	0.4	<0.1	--	--	--
3	3.3	0.4	0.3	0.2	0.2
4	0.2	0.2	0.4	0.3	0.2
5	0.2	0.4	0.3	0.1	0.1
6	2.9	0.2	0.1	0.3	0.1
7 ^e	<0.4	<0.2	0.4	0.3	0.1

^aData sources for 1985-1989 are the annual site environmental reports for those years (Refs. 11, 14-16).

^bSampling locations are shown in Figure 3-2.

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

^dConstruction activities in July 1987 destroyed the sampling location.

^eLocated south of Runway 6 at Lambert Airport, upstream of any influence from SLAPS or HISS.

3.7.4 Groundwater

Because of the remedial action conducted at HISS, all but two wells monitored at the site during 1984 were removed from the sampling program, and new monitoring wells were put into service in 1985. Average uranium, radium-226, and thorium-230 concentrations (Table 3-12) were all relatively unchanged in 1989 as compared with monitoring years 1985 through 1988. Some fluctuations exist from year to year, but no trends are evident and all measurements are well within DOE guidelines. As in previous years, well 6 contained the highest concentrations of total uranium, radium-226, and thorium-230 in 1989.

TABLE 3-12
ANNUAL AVERAGE CONCENTRATIONS OF TOTAL
URANIUM, RADIUM-226, AND THORIUM-230
IN GROUNDWATER AT HISS, 1985-1989^a

Page 1 of 2

Sampling Location ^b	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^c				
	1985	1986	1987	1988	1989
<u>Total Uranium</u>					
HISS-6	71.6	33.0	40.0	50.0	82.1
HISS-9	25.6	<3.0	<3.0	<3.0	3.0
HISS-10	3.1	6.0	4.0	4.0	5.1
HISS-11	<3.0	5.0	4.0	5.0	5.9
HISS-12	<3.0	4.0	5.0	6.0	4.4
HISS-13	<3.0	8.0	8.0	8.0	4.7
HISS-15	<3.0	5.0	3.0	6.0	5.1
<u>Background</u>					
B53W01S ^d	--	--	--	3.0	<3.4
B53W01D ^d	--	--	--	4.0	<3.4
<u>Radium-226</u>					
HISS-6	0.8	0.7	1.2	1.8	1.6
HISS-9	0.4	0.2	0.2	0.6	0.6
HISS-10	0.2	0.1	0.2	0.4	0.3
HISS-11	0.3	0.4	0.2	1.0	0.7
HISS-12	0.4	0.4	0.5	1.3	0.7
HISS-13	0.1	0.3	0.3	0.6	0.7
HISS-15	0.3	0.4	0.4	0.8	1.2
<u>Background</u>					
B53W01S ^d	--	--	--	0.6	0.7
B53W01D ^d	--	--	--	1.1	1.0
<u>Thorium-230</u>					
HISS-6	5.5	2.6	2.9	24.0	5.0
HISS-9	0.2	0.6	0.2	0.2	0.2
HISS-10	0.2	0.7	0.3	0.7	0.1
HISS-11	0.9	1.3	0.8	1.5	0.7
HISS-12	0.4	2.0	0.8	2.3	2.3
HISS-13	0.3	1.0	0.3	0.6	0.9
HISS-15	0.5	1.3	0.8	5.7	8.6

TABLE 3-12
(continued)

Page 2 of 2

Sampling Location ^b	Concentration (10^{-9} $\mu\text{Ci/ml}$) ^c				
	1985	1986	1987	1988	1989
<u>Background</u>					
B53W01S ^d	--	--	--	0.2	0.3
B53W01D ^d	--	--	--	0.2	0.4

^aData sources for 1985-1988 are the annual site environmental reports for those years (Refs. 11, 14-16).

^bSampling locations are shown in Figure 1-5.

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

^dNew well; first sampled in July 1988. Located at Byassee Rd., approximately 0.8 km (0.5 mi) southwest of HISS.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

Site maintenance, security, and monitoring continued.

4.2 SPECIAL STUDIES

No special studies were carried out in 1989.

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APPENDIX A
QUALITY ASSURANCE

QUALITY ASSURANCE

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

QA sampling requirements were ensured through the following:

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

Data management QA was achieved through:

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

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

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

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

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

For inorganic analyses, the program includes:

- Initial calibration and calibration verification
- Continuing calibration verification

TABLE A-1
SUMMARY COMPARISON OF WATER SAMPLE RESULTS
(EPA and TMA/E)

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

^aThis ratio can be used to determine the accuracy of TMA/E's analytical procedures.

- Reagent blank analyses
- Matrix spike analyses•Duplicate sample analyses
- Laboratory control sample analyses
- Interlaboratory QA/QC

For organic analyses, the program includes:

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

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

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

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

APPENDIX B
ENVIRONMENTAL STANDARDS AND CONVERSION FACTORS

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr above background level includes exposure from all pathways except medical treatments (Ref. 12). 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 will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1
CONVERSION FACTORS

1 yr	=	8,760 h
1 L	=	1,000 ml
1 μ Ci	=	1,000,000 pCi
1 pCi	=	0.000001 μ Ci
1 pCi/L	=	10^{-9} μ Ci/ml
1 pCi/l.	=	0.000000001 μ Ci/ml
1 μ Ci/ml	=	1,000,000,000 pCi/L
10^{-6}	=	0.000001
10^{-7}	=	0.0000001
10^{-8}	=	0.00000001
10^{-9}	=	0.000000001
10^{-10}	=	0.0000000001
7×10^{-10}	=	0.0000000007

APPENDIX C
ABBREVIATIONS AND ACRONYMS

ABBREVIATIONS

Al	aluminum
Ba	barium
B	boron
Ca	calcium
cm	centimeter
cm/sec	centimeters per second
Cr	chromium
Fe	iron
ft	foot
ft msl	feet above mean sea level
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
lb	pound
m	meter
m ³	cubic meter
Mg	magnesium
mg	milligram
mg/L	milligrams per liter
mi	mile
ml	milliliter
Mn	manganese
mph	miles per hour
mrem	millirem
mrem/yr	millirem per year
μCi/ml	microcuries per milliliter
μg/L	micrograms per liter
μR/h	microrentgens per hour

Na	sodium
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
Se	selenium
yd ³	cubic yard
yr	year
Zn	zinc

ACRONYMS

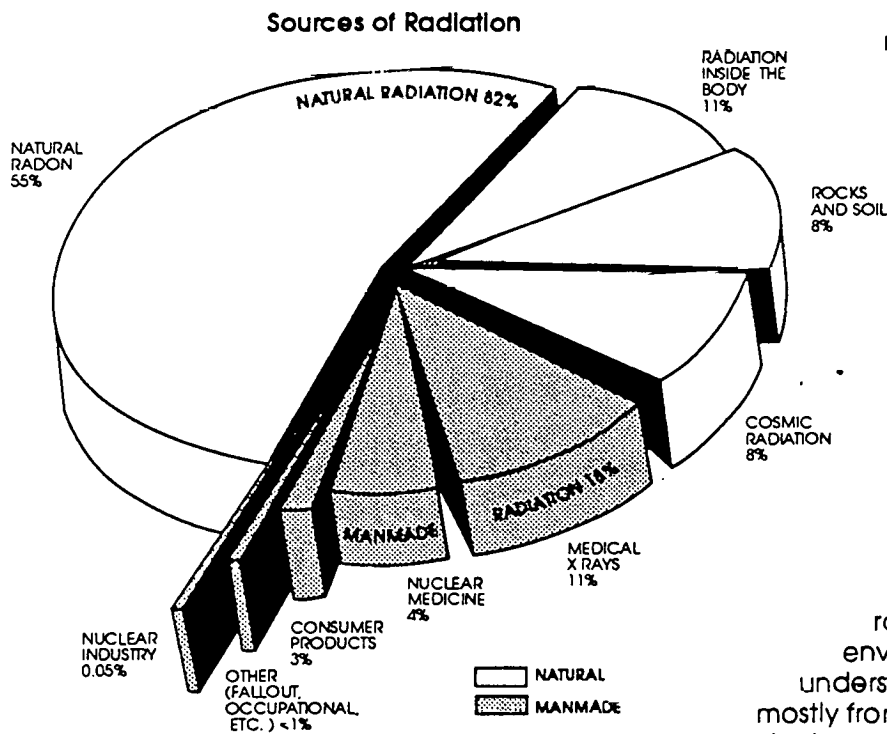
AEC	Atomic Energy Commission
BNAE	base/neutral and acid extractable
BNI	Bechtel National, Inc.
CLP	Contract Laboratory Program
DOE	Department of Energy
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
HISS	Hazelwood Interim Storage Site
HSL	Hazardous Substances List
MED	Manhattan Engineer District
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
SLAPS	St. Louis Airport Site
TLD	thermoluminescent dosimeter
TMA/E	Thermo Analytical/Eberline
TOC	total organic carbon
TOX	total organic halides
VOC	volatile organic compound

APPENDIX D
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

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

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



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

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

TYPES OF IONIZING RADIATION

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

Alpha

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

Beta

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

Gamma

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

Units of Measure

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

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

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

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
Macipe, 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. Capital 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

RADIATION IN THE ENVIRONMENT

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

mrem = millirem
pCi = picocurie

Food

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

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

Medical Treatment

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

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

Consumer Goods

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

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

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

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

International Nuclear Weapons Test Fallout from pre-1980 atmospheric tests

(average for a U.S. citizen) 1 mrem/year

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PERSPECTIVE: How Big is a Picocurie?

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

The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations (2.2×10^{12}) per minute. A *picocurie* is one trillionth of a curie. Thus, a picocurie represents 2.2 disintegrations per minute.

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

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

Millicurie =	$\frac{1}{1,000}$ (one thousandth) of a curie
Microcurie =	$\frac{1}{1,000,000}$ (one millionth) of a curie
Nanocurie =	$\frac{1}{1,000,000,000}$ (one billionth) of a curie
Picocurie =	$\frac{1}{1,000,000,000,000}$ (one trillionth) of a curie

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

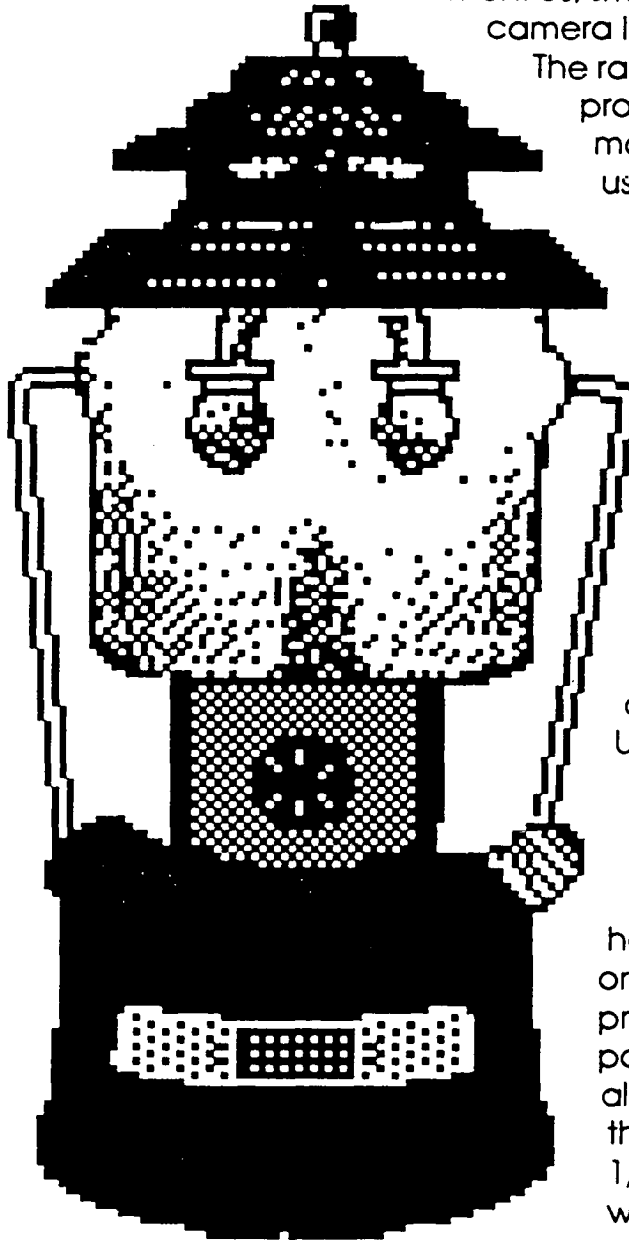
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	2×10^{12} or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	2×10^9 or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco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

PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

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

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



Lanterns: In a New Light

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

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

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

APPENDIX E
SAMPLE WELL CONSTRUCTION DETAILS



OBSERVATION WELL		PROJECT	FUSRAP	WELL NO.	MISS-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		

GENERALIZED GEOLOGIC LOG	DEPTH (FT)	ELEV. (FT)
0.0 - 3.0 FT. <u>FILL</u> : ROCK, CONCRETE, AND ASPHALT FRAGMENTS, ETC.		
3.0 - 6.0 FT. <u>SILTY CLAY</u> : DARK YELLOWISH BROWN, DAMP TO MOIST, SOFT, TRACE OF ROCK FRAGMENTS.		
6.0 - 11.0 FT. <u>SILTY CLAY</u> : DUSKY YELLOWISH BROWN, DAMP, MEDIUM STIFF, MEDIUM TO HIGH PLASTICITY, TRACE OF VERY FINE SAND.		
11.0 - 15.0 FT. <u>CLAYEY SILT</u> : GREENISH GRAY, MOIST, MEDIUM STIFF, LOW PLASTICITY.		
15.0 - 20.5 FT. <u>CLAYEY SILT</u> : DUSKY YELLOWISH BROWN, MOIST, MEDIUM STIFF, LOW TO MEDIUM PLASTICITY, TRACE OF VERY FINE SAND.		

WELL COMPONENTS	DEPTH (FT)	ELEV. (FT)
ELEV. - TOP OF RISER CASING:		518.9
ELEV. - TOP OF SURFACE CASING:		518.6
GROUND SURFACE	0.0	515.9
SURFACE CASING DIA: 8 INCHES O.D. TYPE: STEEL		
BOTTOM OF SURFACE CASING	2.3	513.6
BACKFILL MATERIAL TYPE: PORTLAND CEMENT/BAROID QUICK-GEL BENTONITE GROUT SLURRY		
RISER CASING DIA: 2 INCHES I.D. TYPE: BRISTOLPIPE THREADED JOINT SCHEDULE 40 PVC		
TOP OF SEAL ANNULAR SEAL TYPE: AMERICAN COLLOID 1/4 INCH VOLCLAY PELLETS	8.2	507.7
TOP OF FILTER PACK	10.3	505.6
FILTER PACK TYPE: WINTER BROTHERS MERAMEC WARRIOR WB-40 SPECIALTY SAND		
TOP OF SCREEN	12.2	503.7
SCREEN: DIEDRICH DIA: 2 INCHES I.D. TYPE: THREADED JOINT SCHEDULE 40 PVC OPENING WIDTH: 0.010 INCH TYPE: MACHINE SLOTTED		
BOTTOM OF SCREEN	16.9	499.0
BOTTOM OF SUMP	19.0	496.9
BOTTOM OF HOLE	20.5	495.4
HOLE DIA: 7 INCHES		

LOG ADVANCED USING 7 IN. O.D. HOLLOW-STEM AUGERS. LOG IS FROM DESCRIPTION OF SPLIT-SPOON SAMPLES.

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DISTRIBUTION LIST FOR HAZELWOOD INTERIM STORAGE SITE
ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1989

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Community Health and Medical Care
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Clayton, Missouri 63105

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146 Clarkson Executive Park
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Mallinckrodt Institute
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St. Louis, Missouri 63110

Mr. Samuel R. Price
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Oak Ridge Associated Universities
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