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

HAZELWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL REPORT

Hazelwood, Missouri

Calendar Year 1987

April 1988

Bechtel National, Inc.

052532

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Attention: Peter J. Gross, Director
Technical Services Division

Subject: Bechtel Job No. 14501, FUSRAP Project
DOE Contract No. DE-AC05-81OR20722
Publication of the Hazelwood Interim Storage Site Annual Site Environmental Report - Calendar Year 1987
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Dear Mr. Gross:

Enclosed are 28 copies of the subject document for distribution to DOE-HQ and DOE-ORO. This published report incorporates comments received from DOE-TSD, DOE-HQ, and DOE-EPD on the first and second drafts. The distribution list (Appendix E) has also been reviewed and updated. Publication of the report was approved by Jerry Wing in a meeting with Alice Feldman of BNI on April 22, 1988.

Very truly yours,

SD Goodle
for G. K. Hovey
Program Manager - FUSRAP

AMP/amf
Enclosures: As Stated

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1424x

DOE/OR/20722-200

HAZELWOOD INTERIM STORAGE SITE
ANNUAL SITE ENVIRONMENTAL REPORT
CALENDAR YEAR 1987

APRIL 1988

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

ABSTRACT

During 1987, the environmental monitoring program was continued 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, the HISS is presently used for the storage of soils contaminated with residual radioactive material. The 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 mandated 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 the HISS measures radon concentrations in air; external gamma radiation levels; and uranium, radium, and thorium concentrations in surface water, groundwater, and sediment. 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 the maximally exposed individual. Based on the scenario described in this report, the maximally exposed individual at the HISS would receive an annual external exposure approximately equivalent to 1 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is less than the exposure a person would receive during a round-trip 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 the 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.

The results of 1987 monitoring show that the HISS is in compliance with the DOE radiation protection standard.

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1.0 INTRODUCTION

This report presents the findings of the environmental monitoring conducted at the Hazelwood Interim Storage Site (HISS) during calendar year 1987. Environmental monitoring has been conducted at the HISS since 1984. 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

The 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. Some of the vicinity properties are located within the corporate limits of the adjacent City of Berkeley. The HISS lies 3.2 km (2 mi) northeast of the control tower of Lambert-St. Louis International Airport. Figure 1-2 is an aerial photograph of the HISS and its vicinity.

The 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 storm drainage ditches on both sides of Latty Avenue before discharging into Coldwater Creek, the main receiving body for site

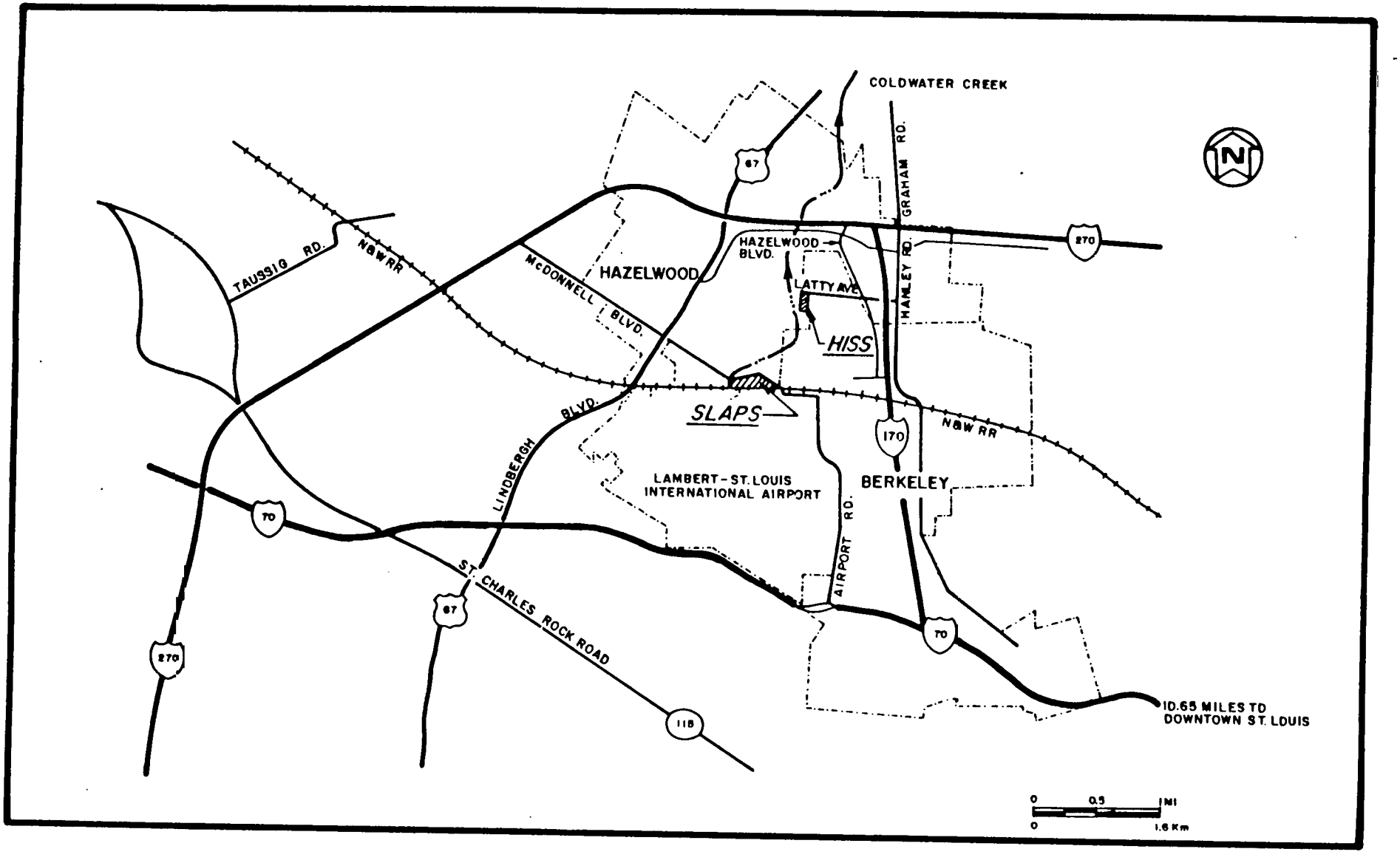


FIGURE 1-1 LOCATION OF THE HISS

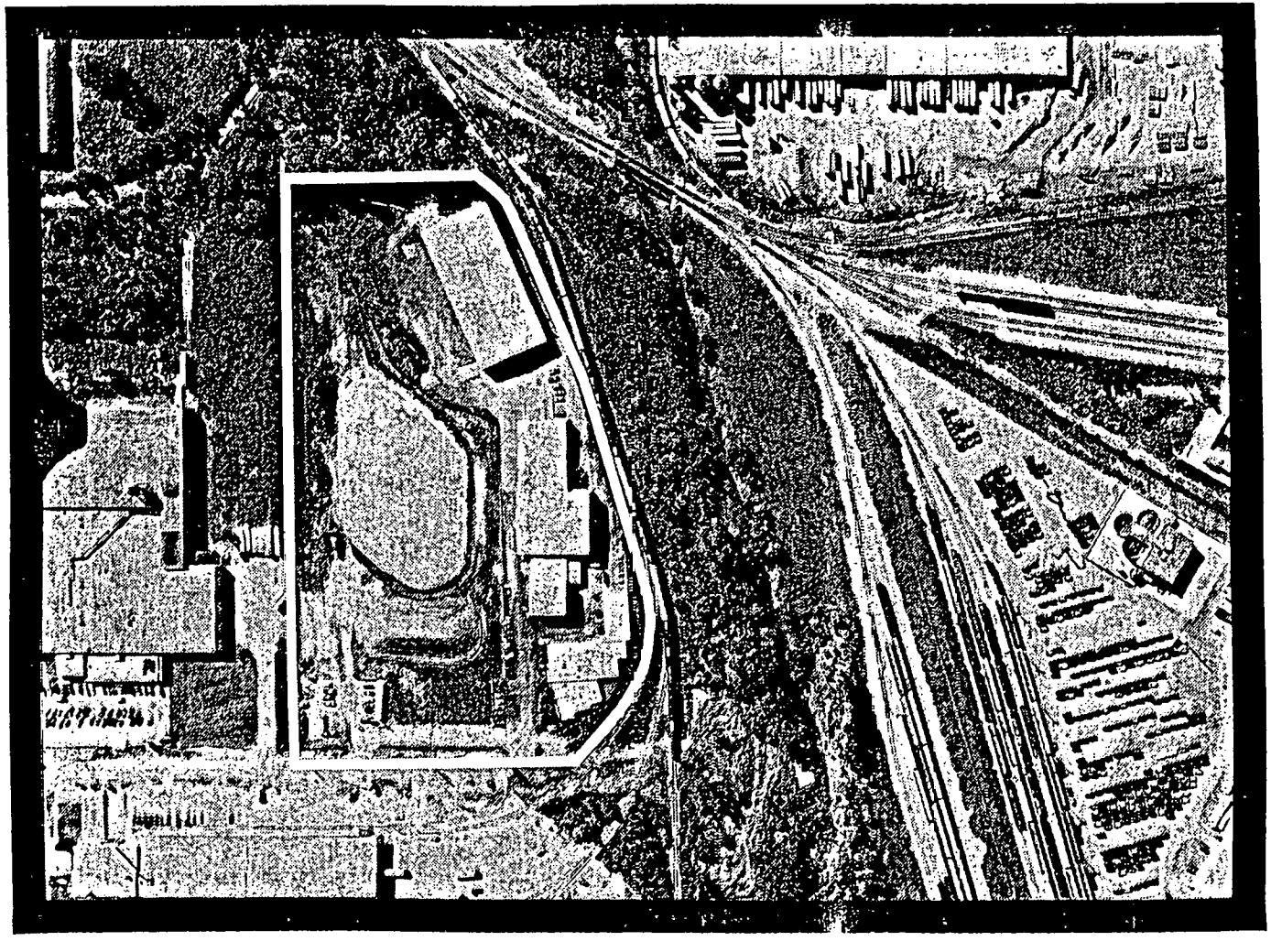


FIGURE 1-2 AERIAL VIEW OF HISS AND ITS VICINITY

runoff. Water flowing to the south leaves the site via two ditches; one located near the western boundary of the site, the other near the southeastern boundary. These ditches flow into an unnamed tributary before discharging into Coldwater Creek. The 100-yr flood elevation for the HISS is approximately 158.5 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. Groundwater flow in the vicinity of the site generally follows surface topography; thus, the direction of flow is toward Coldwater Creek (Ref. 1). In the area surrounding the 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 31.7° (89°F) (July) and the lowest is -6.7°C (19.9°F) (January). Average annual precipitation is 85 cm (34 in.), with an average annual snowfall of 65.8 cm (26.3 in.) (Ref. 4). As shown in Figure 1-3, prevailing winds in the vicinity of the HISS are primarily from the south during the summer and fall. Wind speeds during these months average 13.9 km/h (8.7 mph). Winds during the winter months were from the west and west-northwest, averaging 17.6 km/h (11 mph) (Refs. 4 and 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 the Hazelwood site or Latty Avenue.

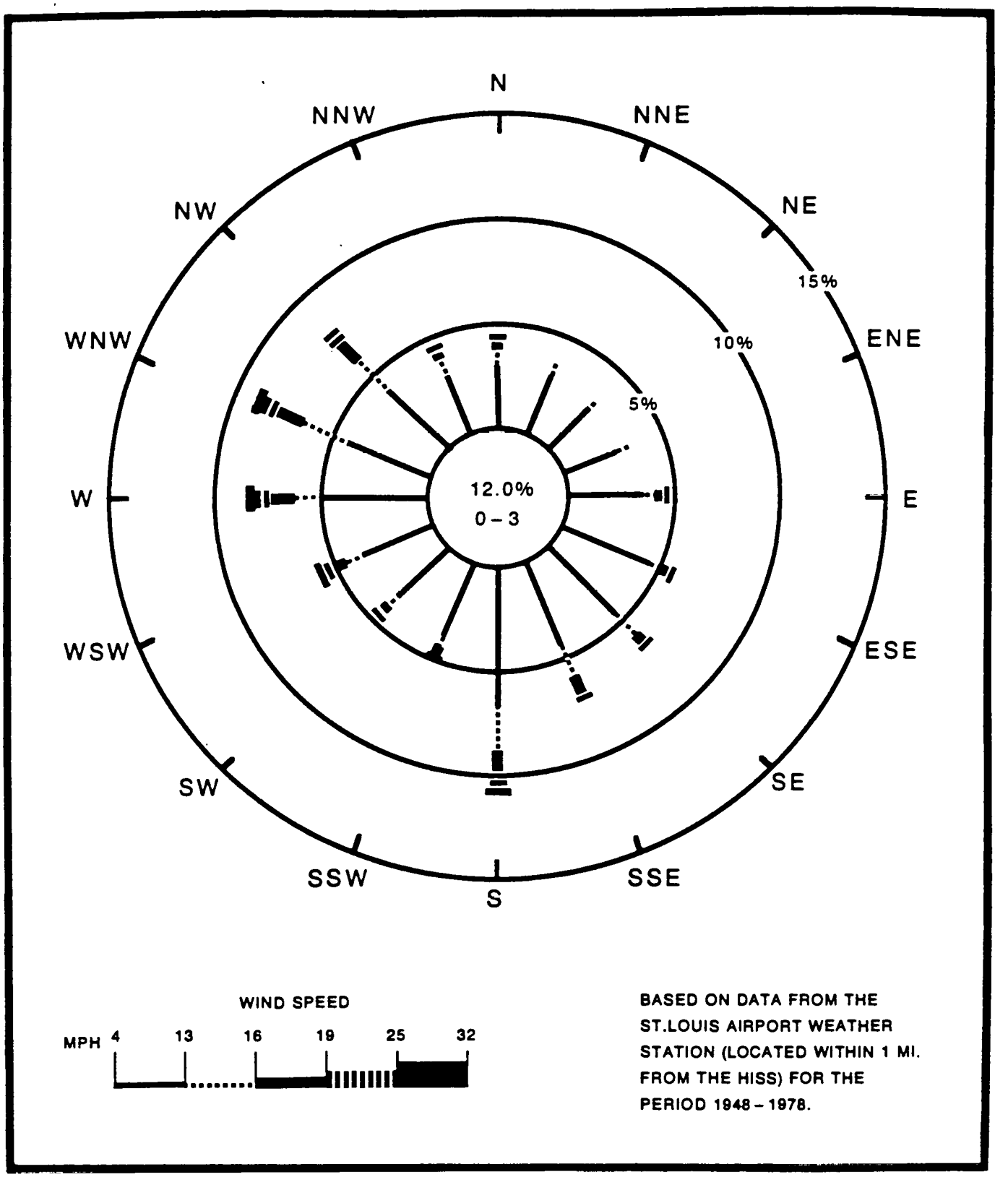


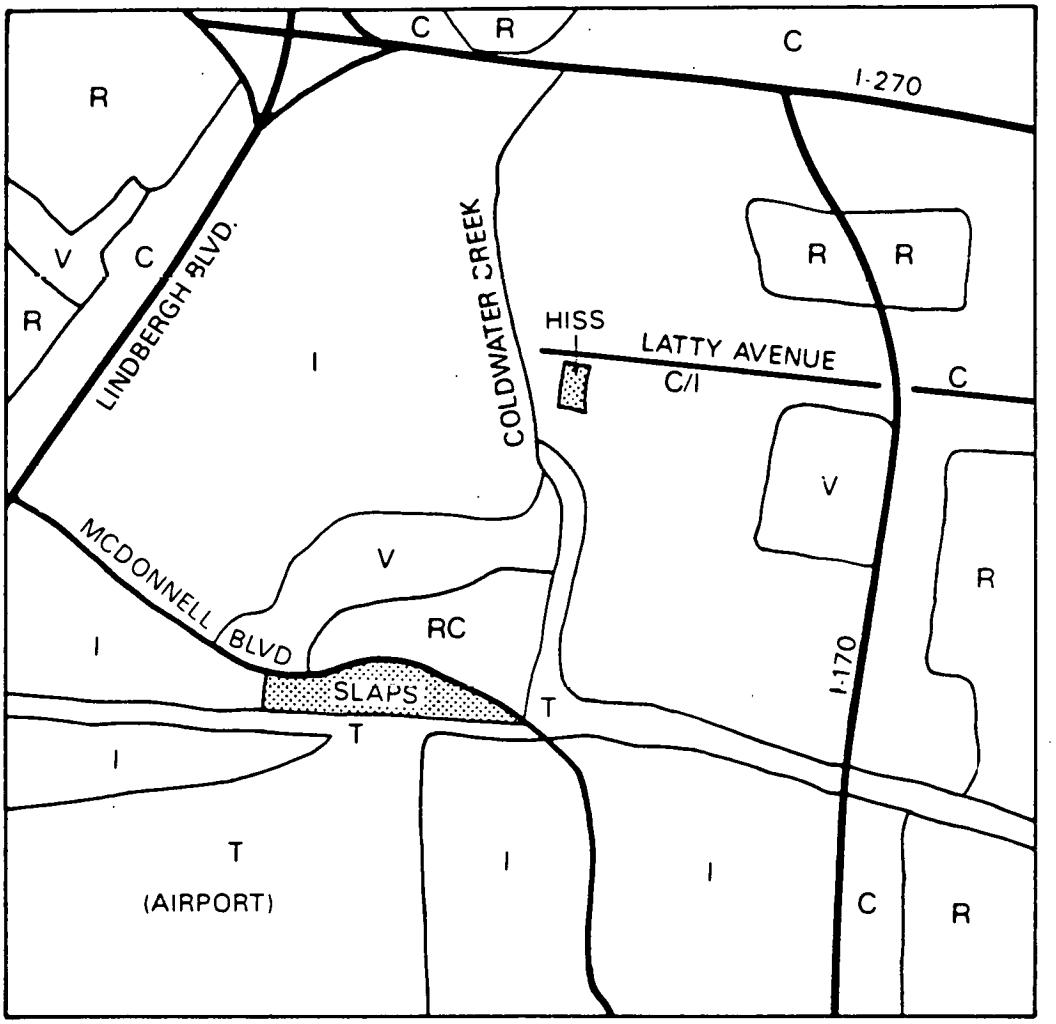
FIGURE 1-3 ANNUAL WIND ROSE FOR THE HISS

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, unused (vacant), and residential (Ref. 1).

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 on Latty Avenue. 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, Illinois, 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 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 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 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 45 cm (12 to 18 in.) of topsoil had been removed and transported to a landfill area in St. Louis County.



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

Before the present owner occupied the site, a radiological characterization was performed by the Oak Ridge National Laboratory (ORNL). Thorium and radium contamination in excess of DOE guidelines was found in and around the buildings, and in the soil to depths of up to 45 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. 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 of the north and south shoulders of Latty Avenue for DOE 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 the HISS were also found to be contaminated.

As part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Appropriations Act, BNI is conducting remedial action at the site and at vicinity properties. The remedial action project at the HISS is divided into 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 the HISS. In addition, the area around the pile was cleared, a decontamination facility was constructed, environmental monitoring stations were installed, and a fence was installed around the HISS. During 1985 and 1986 cleanup along Latty Avenue continued, and additional contaminated material removed from Latty Avenue during the installation of a storm sewer by the City of Berkeley was stored in a supplementary pile at the HISS

(Figure 1-2). In 1987 additional contaminated material was placed on the supplementary pile, and a cover was placed over the pile. In addition, cleanup along Latty Avenue was completed.

Phase I also includes characterization of the Futura Coatings site, the HISS itself, and vicinity properties along Latty Avenue. These activities began in 1986 and were completed in early 1988.

During Phase II, the contaminated soil at the Futura Coatings site, the HISS, and the vicinity properties will be removed to a permanent disposal site.

2.0 SUMMARY OF MONITORING RESULTS

During 1987, the environmental monitoring program at the HISS continued; 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. 7). The potential radiation dose that might be received by the maximally exposed individual was calculated to determine the degree of compliance with the radiation protection standard.

Annual average radon concentrations ranged from 3×10^{-10} uCi/ml (0.3 pCi/l) to 1.8×10^{-9} uCi/ml (1.8 pCi/l), including background (Table 3-1). The background radon concentration in the vicinity of the HISS was 4×10^{-10} uCi/ml (0.4 pCi/l). Subsection 3.1 contains a discussion of radon concentrations at the HISS in 1987. There have been no significant trends in radon concentrations measured at the HISS since the initiation of environmental monitoring in 1984 (see Subsection 3.6.1) (Refs. 8-10).

Annual average external radiation levels measured at the HISS in 1987 ranged from 17 to 113 mR/yr above background, which was 77 mR/yr (Table 3-2). External radiation levels are discussed in Subsection 3.2. Since 1984, external gamma radiation levels have decreased sharply at almost all monitoring locations (see Subsection 3.6.2) (Refs. 8-10).

In surface water (Subsection 3.3.1), concentrations of uranium, radium-226, and thorium-230 were at approximately background levels. Since 1984, concentrations of uranium in surface water have declined significantly. Concentrations of radium-226 and thorium-230 have remained basically stable (see Subsection 3.6.3) (Refs. 8-10).

In groundwater (Subsection 3.3.2), the highest annual average concentration of uranium was 4.0×10^{-8} uCi/ml (40 pCi/l)

(Table 3-4). For radium-226, the highest annual average concentration was 1.2×10^{-9} uCi/ml (1.2 pCi/l). The highest annual average thorium-230 concentration was 2.9×10^{-9} uCi/ml (2.6 pCi/l). There have not been enough data collected to draw any conclusions regarding trends for radionuclide concentrations in groundwater at the HISS. However, there has been little change in such concentrations since 1985 (see Subsection 3.6.4) (Refs. 8-10).

Concentrations of radionuclides in surface water and groundwater may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D.

In stream sediments, (Subsection 3.4) the highest annual average concentration of total uranium was 2.1 pCi/g; the highest annual average radium-226 concentration was 2.0 pCi/g; and the highest annual average concentration of thorium-230 was 20.0 pCi/g (Table 3-5). The maximum annual average concentration of thorium-230 is biased high because a concentration of 58 pCi/g was measured at one upstream location during the third quarter. Thorium concentrations at this location ranged from 0.6 to 0.8 pCi/g for the remainder of 1987. The concentrations of radionuclides in sediments at the HISS may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

Calculations were made of radiological doses received by the maximally exposed individual. Exposure to external gamma radiation was the exposure pathway quantified. This individual is one who, when all potential routes of exposure are considered, would receive the greatest dose. Exposure to external gamma radiation was the exposure pathway quantified. The highest annual average external gamma radiation level at the HISS boundary was 113 mR/yr above background. When occupancy is considered, this radiation level would result in an annual exposure to the maximally exposed individual of 1 mR/yr above background (Subsection 3.5.1). Since 1 mR is approximately equivalent to 1 mrem, this exposure is equivalent to 1 percent of the DOE radiation protection standard of

100 mrem/yr. This exposure is less than the exposure a person would receive during a round-trip flight from New York to Los Angeles (due to greater amounts of cosmic radiation at higher altitudes). The cumulative dose to the population within an 80-km (50-mi) radius of the 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 sources.

Results of the 1987 monitoring show that the 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 the HISS in 1987 (Ref. 11) 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 by sample category. Summaries of data include minimum and maximum values recorded, number of data points collected, and average value. The average value for a given sampling location is the average of individual results for that location. Individual sources of error (e.g., analytical error or sampling error) were not estimated. The "less than" notation (<) is used to denote sample analysis results that are below the limit of sensitivity of the analytical method, based on a statistical analysis of parameters. In computing the averages, where no more than one value is less than the limit of sensitivity of the analytical method, that value is considered as being equal to the limit of sensitivity and the average value is reported without the "less than" notation.

During 1987, the environmental monitoring program for the 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 (which is a fenced and posted area).

In 1987, a change was initiated in the schedule for quarterly monitoring of all FUSRAP sites, such that sampling is conducted in January, April, July, and October. Previously, quarterly sampling was conducted in March, June, September, and December. The schedule was modified to allow sufficient time for more complete data analysis activities. To implement this change, data from the fourth quarter of 1986 were carried over to the first quarter of 1987. Any bias resulting from the use of 1986 data is considered negligible.

Trend tables are provided for radon, external gamma radiation levels, surface water, and groundwater. These tables list annual averages for each monitoring location for 1984-1987 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.6).

3.1 RADON SAMPLING

Radon detectors were maintained at 11 locations on the site and along the site boundary at the HISS, as shown in Figure 3-1. Two of these locations were added in August 1986. One location is maintained some distance off-site to measure the background level. Detectors are spaced along the site boundary to ensure adequate detection capability under most atmospheric conditions.

The radon gas monitors are Terradex Type-F Track-Etch detectors. Detectors are obtained from the Terradex Corporation, placed at the sampling locations, collected by site personnel on a quarterly exchange, and then returned to Terradex for analysis.

Table 3-1 reports the measured concentrations of radon in the air at the HISS. Annual average concentrations ranged from 3×10^{-10} to 1.8×10^{-9} uCi/ml (0.3 to 1.8 pCi/l), including background, which was 4×10^{-10} uCi/ml (0.4 pCi/l).

For a comparison of radon concentrations measured at the site from 1984 through 1987, see Subsection 3.6.1.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at 11 locations, all of which correspond to the radon (Terradex) detector locations shown in Figure 3-1. Detectors are located around the site boundary to ensure adequate measurement of external gamma radiation levels where the potential for exposure to members of the public is expected to be highest.

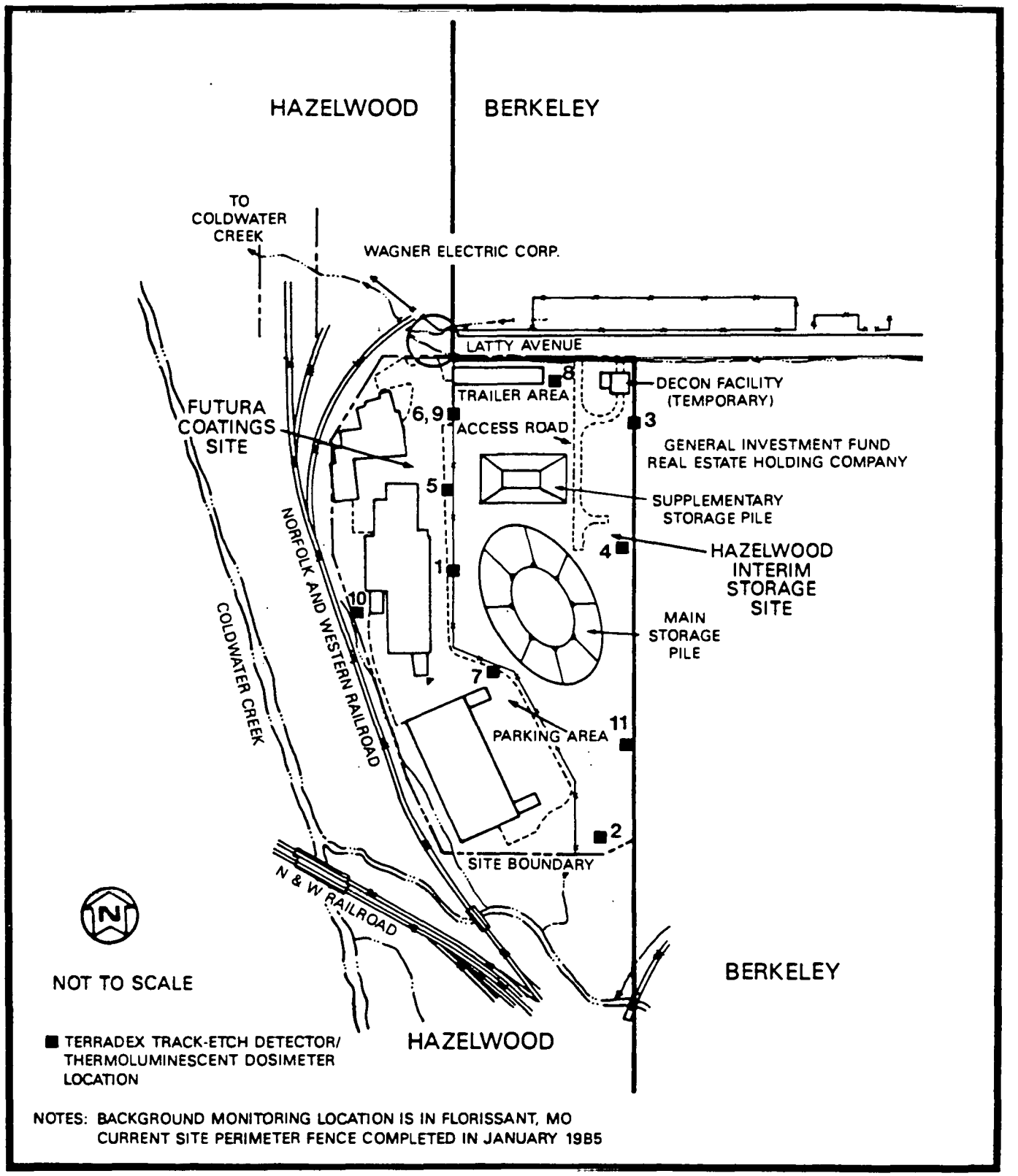


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE HISS

TABLE 3-1

CONCENTRATIONS OF RADON-222 AT THE HISS, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
1	4	0.1	2.5	1.0
2	4	0.0	1.3	0.7
3	4	0.2	1.1	0.6
4	4	0.7	3.4	1.5
5	4	0.1	0.6	0.3
6	4	0.1	2.6	0.8
7	4	0.2	3.2	1.8
8	4	0.1	0.8	0.3
9[d]	4	0.1	0.7	0.3
10	4	0.1	1.2	0.4
11	4	0.2	3.3	1.2
Background[e]	4	0.3	0.5	0.4

[a]Sampling locations are shown in Figure 3-1.

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

[c]Background has not been subtracted.

[d]Location 9 is a quality control for Location 6.

[e]Located in Florissant, MO.

The external gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs), which are exchanged quarterly. In addition, as part of the 1987 environmental monitoring program at the HISS, an improved external gamma radiation monitoring system was introduced in April 1987. This system utilizes tissue-equivalent TLDs, which permit direct evaluation of the accumulated dose of gamma radiation to the deep tissue of the body (assumed to be at a depth of 1 cm). In addition to providing values that are more realistic in terms of potential tissue dose, the tissue-equivalent dosimeter system is more sensitive to external gamma radiation. In both types of TLD system, each monitor contains five TLD chips, the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). Effective April 15, 1988, the new type of system will be used exclusively. Environmental reports for 1988 and subsequent years will present the data generated by the tissue-equivalent TLDs.

The results of external gamma monitoring are presented in Table 3-2. The background external gamma radiation level for the HISS area (77 mR/yr) has been subtracted from the measured levels in Table 3-2 to provide an estimate of the effect of the site on levels measured at the site boundary. The highest annual average external gamma radiation level was 113 mR/yr at Location 2, where a 2-h/week occupancy factor is appropriate. On this basis, the external exposure to an individual working on this property would be 1 mR/yr. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 1 percent of the DOE radiation protection standard of 100 mrem/yr.

For comparisons of external gamma radiation levels measured from 1984 to 1987, see Subsection 3.6.2.

3.3 WATER SAMPLING

During 1987, sampling was performed to determine the concentrations of uranium, radium-226, and thorium-230 in surface water in the

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT THE HISS, 1987

Sampling Location[a]	Number of Measurements	Radiation Levels (mR/yr)[b]		
		Minimum	Maximum	Average
1	4	3	90	44
2	4	1	207	113
3	4	0	47	20
4	4	0[c]	148	74
5	4	0[c]	103	46
6	4	0[c]	80	29
7	4	5	106	50
8	4	0[c]	57	27
9[d]	4	0[c]	110	61
10[e]	3	0[c]	51	17
11	4	2	87	45
Background[f]	3[g]	58	83	77

[a]Sampling locations are shown in Figure 3-1.

[b]Measured background has been subtracted from the readings taken at the sampling locations shown in Figure 3-1. Measurements are obtained in mR/quarter, normalized to 1 year, and reported in the table as mR/yr.

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

[d]Location 9 is a quality control for Location 6.

[e]Detector lost in transit to the laboratory during the fourth quarter.

[f]Located in Florissant, MO.

[g]Detector missing in first quarter.

vicinity of the HISS and in groundwater at the site. The six surface water sampling locations and seven groundwater sampling locations are shown in Figure 3-2.

3.3.1 Surface Water

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 the vicinity. Sampling Locations 1 and 2 were on a surface stream but were removed during July 1986 during installation of a subsurface sewer system.

Nominal 1-liter (0.26-gal) grab samples were collected to fill a 4-liter (1-gal) container. Samples 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 the sulfate and transferring the treated sulfate to a radon bubbler, wherein radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 gas is then withdrawn into a scintillation cell and counted using 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 significantly from background. These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D.

For comparisons of radionuclide concentrations measured in surface water from 1984 through 1987, see Subsection 3.6.3.

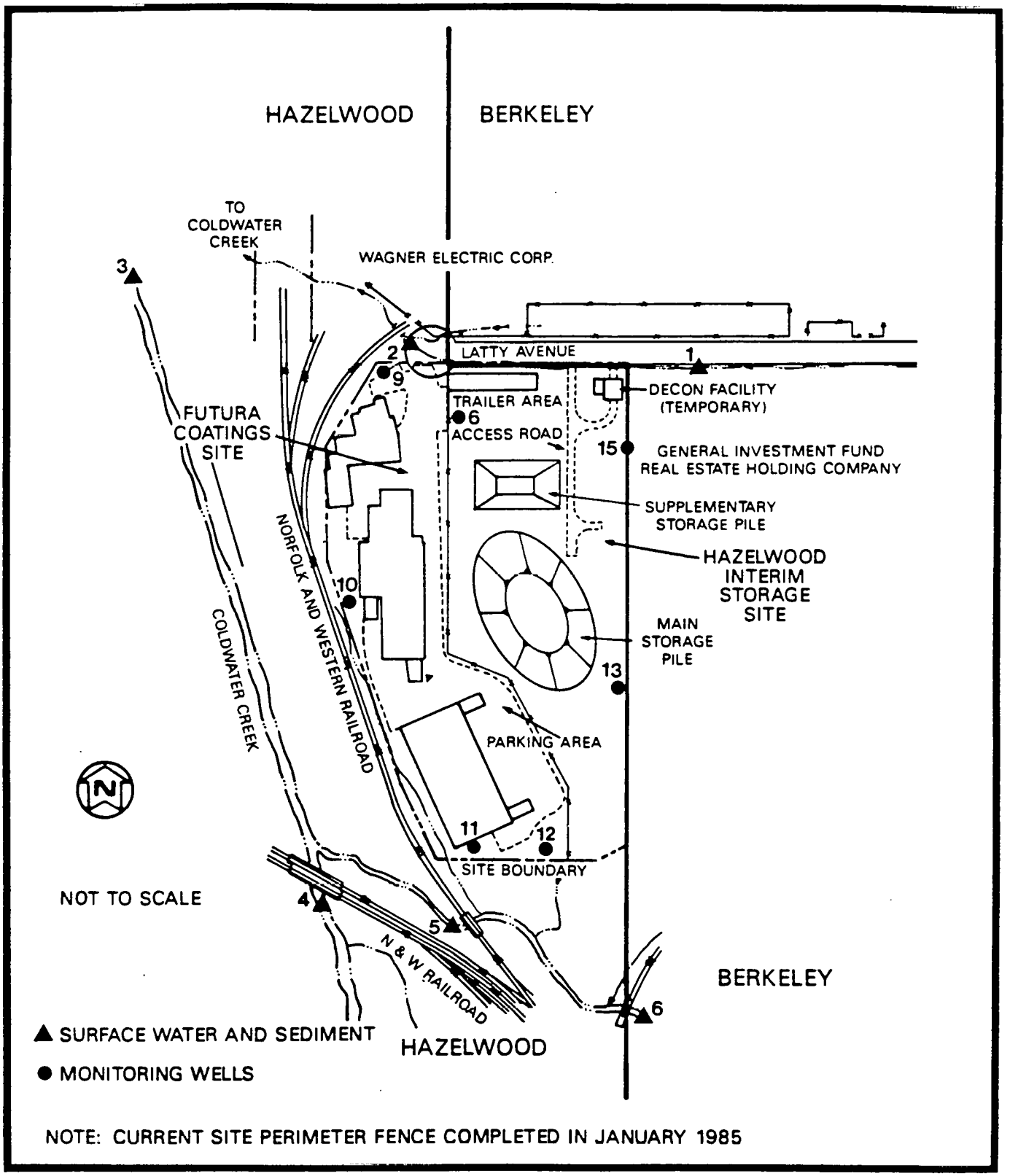


FIGURE 3-2 SURFACE WATER, GROUNDWATER, AND SEDIMENT SAMPLING LOCATIONS AT THE HISS

TABLE 3-3

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SURFACE WATER IN THE VICINITY OF THE HISS, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
1[d]	0	-	-	-
2[d]	0	-	-	-
3	4	<3.0	5.0	4.0
4	4	<3.0	10.0	5.0
5	4	<3.0	<3.0	<3.0
6	4	<3.0	<3.0	<3.0
Radium-226				
1[d]	0	-	-	-
2[d]	0	-	-	-
3	4	<0.1	0.4	0.2
4	4	0.1	0.4	0.2
5	4	0.2	0.4	0.3
6	4	0.2	0.2	0.2
Thorium-230				
1[d]	0	-	-	-
2[d]	0	-	-	-
3	4	<0.2	0.6	0.3
4	4	0.1	<0.9	0.4
5	4	0.1	0.4	0.3
6	4	<0.1	0.1	<0.1

[a]Locations shown in Figure 3-2; Locations 1, 4, and 6 are background.

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

[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

[d]Sampling location was destroyed by construction activities conducted during the first quarter. Although the sampling location was reestablished in October 1987, there was no surface water present during the fourth quarter.

3.3.2 Groundwater

During 1987, groundwater samples were collected quarterly from seven monitoring wells established along the perimeter of the property on the basis of available geohydrological data. After the wells had been bailed dry or three casing volumes had been removed, nominal 1-liter (0.26-gal) grab samples were collected to fill a 4-liter (1-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.

Results of the analyses of groundwater samples are presented in Table 3-4. The highest annual average total uranium concentration was 4.0×10^{-8} uCi/ml (40 pCi/l). The highest annual average radium concentration was 1.2×10^{-9} uCi/ml (1.2 pCi/l), and the highest annual average thorium concentration was 2.9×10^{-9} uCi/ml (2.9 pCi/l). These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D. For a comparison of radionuclide concentrations measured in groundwater at the HISS in 1985, 1986, and 1987, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

Sediment samples that consisted of composites weighing approximately 500 g (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 given in Subsection 3.3.1.

TMA/E analyzed the samples for uranium, radium-226, and thorium-230. The uranium concentration was calculated by summing the analysis results for isotopic uranium. Isotopic uranium and thorium-230 were determined by alpha spectrometry, where the uranium and thorium-230 are leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by radon emanation (described earlier).

TABLE 3-4

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT THE HISS, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
6	4	23	52	40
9	4	<3	<3	<3
10	4	3	7	4
11	4	3	5	4
12	4	<3	6	5
13	4	5	10	8
15	4	<3	5	3
Radium-226				
6	4	0.9	1.7	1.2
9	4	<0.1	0.3	0.2
10	4	0.1	0.3	0.2
11	4	0.2	0.6	0.2
12	4	0.2	0.8	0.5
13	4	0.1	0.6	0.3
15	4	<0.2	0.6	0.4
Thorium-230				
6	4	0.1	8.0	2.9
9	4	0.1	0.3	0.2
10	4	<0.1	0.4	0.3
11	4	<0.3	1.2	0.8
12	4	<0.1	1.1	0.8
13	4	0.1	0.5	0.3
15	4	0.2	1.9	0.8

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

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

[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

Results of the analyses, based on dry weight, are presented in Table 3-5. Average annual uranium concentrations ranged from 1.5 to 2.1 pCi/g, while radium-226 concentrations ranged from 1.2 to 2.0 pCi/g. Average annual thorium-230 concentrations ranged from 0.5 to 20 pCi/g. These values may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

The maximum annual average concentration of thorium-230 is biased high because a concentration of 58 pCi/g was measured at Location 6 during the third quarter. Thorium-230 concentrations at this location ranged from 0.6 to 0.8 pCi/g for the remainder of 1987. Thorium-230 concentrations at Locations 3 and 5 were also elevated during the third quarter -- although to a much lesser degree -- indicating that erosional mechanisms associated with runoff from autumn storms may have transported thorium contamination downstream.

3.5 RADIATION DOSE

To assess the health effects of the radioactive materials stored at the HISS, radiological exposure pathways were evaluated to calculate the dose to the 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, would receive the greatest dose. An appraisal of potential pathways (ingestion of water, exposure to external gamma radiation, and inhalation of radon) suggested that exposure to external gamma radiation was the principal exposure mode.

The dose from ingesting groundwater or surface water from sources on the HISS property was not calculated because it was considered unrealistic to assume that ingestion of this water could occur. The HISS is fenced and locked, and security is well maintained, and a member of the public could only consume water on the site by trespassing on the property every day to gain access to the water. To consume groundwater from a well at the site, the trespasser would also have to be equipped with a means of removing the well cap and would need a power source, a pump, and a hose.

TABLE 3-5

CONCENTRATIONS OF RADIUM-226, THORIUM-230, AND URANIUM IN SEDIMENT IN THE VICINITY OF THE HISS, 1987

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Radium-226				
1	1[b]	1.2	1.2	1.2
2	1[b]	2.0	2.0	2.0
3	3[c]	0.9	1.6	1.2
4	3[c]	1.1	1.4	1.2
5	3[c]	1.3	1.5	1.4
6	3[c]	0.9	1.4	1.2
Thorium-230				
1	1[b]	4.2	4.2	4.2
2	1[b]	0.5	0.5	0.5
3	3[c]	0.2	6.2	2.7
4	3[c]	0.7	1.1	0.9
5	3[c]	1.5	4.9	2.9
6	3[c]	0.6	58.0	20.0
Uranium-234				
1	1[b]	0.9	0.9	0.9
2	1[b]	0.8	0.8	0.8
3	3[c]	0.9	1.5	1.1
4	3[c]	0.8	1.6	1.0
5	3[c]	0.7	1.2	0.9
6	3[c]	0.5	1.0	0.7
Uranium-235				
1	1[b]	<0.1	<0.1	<0.1
2	1[b]	<0.1	<0.1	<0.1
3	3[c]	0.04	0.1	0.07
4	3[c]	<0.04	0.1	0.06
5	3[c]	<0.03	0.1	0.06
6	3[c]	<0.01	0.1	0.06
Uranium-238				
1	1[b]	0.9	0.9	0.9
2	1[b]	0.7	0.7	0.7
3	3[c]	0.7	1.2	0.9
4	3[c]	0.8	1.7	1.1
5	3[c]	0.8	1.3	0.9
6	3[c]	0.5	1.4	0.8

TABLE 3-5

(Continued)

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Total Uranium				
1	1[b]	1.9	1.9	1.9
2	1[b]	1.6	1.6	1.6
3	3[c]	1.6	2.8	2.0
4	3[c]	1.6	3.4	2.1
5	3[c]	1.5	2.6	1.8
6	3[c]	1.0	2.5	1.5

[a]Sampling locations shown in Figure 3-2. Location 1 is upstream of the site and is a background location.

[b]Construction activities destroyed the sampling location during the first quarter. The sampling location was reestablished in October 1987, and a sediment sample was obtained in the fourth quarter.

[c]No sediment at sampling location in the first quarter.

Most of the annual average radon concentrations measured at the boundary of the HISS were within the normal variation associated with background measurements for this area. Given the amount of time that the 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.

3.5.1 Dose to Maximally Exposed Individual

To identify the individual in the vicinity of the 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 by 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 the HISS, the highest overall dose would be received by an individual west of the site. Since this is a commercial area parking lot, the calculated dose was based on an estimated 2-h/week exposure period. (Exposure to workers in nearby commercial buildings would be negligible due to the distance of the buildings from the site perimeter and the attenuation provided by the building walls.)

The highest average exposure rate above background was 113 mR/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 mR. Since 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 1 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is less than the exposure a person would receive during a round-trip flight from New York to Los Angeles (due to greater amounts of cosmic radiation at higher altitudes).

3.5.2 Dose to the Population in the Vicinity of the 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 the HISS these pathways are: direct exposure to gamma radiation, inhalation of radon gas, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from the radioactive materials present on-site is too small to be measured, since gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma exposure rate at a distance of 0.9 m (3 ft) from a small-area radioactive source were 100 mR/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 gas is known to dissipate rapidly as distance from the radon source increases (Ref. 11). Therefore, exposure from the low radon concentrations at the HISS does not contribute significantly to population dose.

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

TABLE 3-6

ANNUAL AVERAGE CONCENTRATIONS OF RADON-222 AT THE HISS, 1984-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c,d]			
	1984[e]	1985	1986	1987
1	2.2	0.3	0.9	1.0
2	0.6	0.5	0.8	0.7
3	0.3	0.4	0.3	0.6
4	0.8	0.5	1.3	1.5
5	0.4	0.4	0.6	0.3
6	0.4	0.7	0.6	0.8
7	0.5	0.4	1.1	1.8
8	2.0	0.3	0.2	0.3
9	0.4	0.5	0.5	0.3
10[e]	-[f]	-[f]	0.2[f]	0.4
11[f]	-[f]	-[f]	1.8[f]	1.2
Background[g]	-[g]	0.5	0.3	0.4

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 8-10).

[b]Sampling locations are shown in Figure 3-1.

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

[d]Background has not been subtracted.

[e]Monitoring program began in September 1984, and 1984 data are for approximately one quarter only.

[f]Sampling location established in August 1986.

[g]Background location established in 1985.

TABLE 3-7

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT THE HISS, 1984-1987[a]

Sampling Location[b]	Radiation Levels (mR/yr)[c]			
	1984[d]	1985	1986	1987
1	501	58	34	44
2	328	87	68	113
3	219	25	23	20
4	1062	83	71	74
5	466	141	77	46
6	1106	287	179	29
7	613	89	46	50
8	307	7	17	27
9	202	261	151	61
10[e]	-[e]	-[e]	21[e]	17
11[e]	-	-	15[e]	44
Background[f]	-	99	97	77

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 8-10).

[b]Sampling locations are shown in Figure 3-1.

[c]Measured background has been subtracted from the readings taken at the sampling locations shown in Figure 3-1. Measurements are obtained in mR/quarter, normalized to 1 year, and reported in the table as mR/yr.

[d]Monitoring program began in September 1984, and 1984 data are for approximately one quarter only.

[e]Sampling location established in August 1986.

[f]Background monitoring location established in 1985.

TABLE 3-8

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SURFACE WATER IN THE VICINITY OF THE HISS, 1984-1987[a]

Sampling Location[b]	Concentration (10^{-9}uCi/ml)[c] 1984	1985	1986	1987
Total Uranium				
1[d]	67.0	<3.0	<3.0	-
2[d]	69.0	<3.0	<3.0	-
3	97.0	4.3	4.0	4.0
4	116.0	4.3	4.0	5.0
5	67.0	<3.0	<3.0	<3.0
6	69.0	<3.0	<3.0	<3.0
Radium-226				
1[d]	0.3	0.1	0.3	-
2[d]	0.3	0.1	0.1	-
3	0.1	0.1	0.3	0.2
4	0.1	0.2	0.3	0.2
5	0.2	0.1	0.2	0.3
6	0.2	0.2	0.2	0.2
Thorium-230				
1[d]	0.2	0.1	0.2	-
2[d]	15.4	0.4	<0.1	-
3	0.4	3.3	0.4	0.3
4	0.5	0.2	0.2	0.4
5	0.5	0.2	0.4	0.3
6	0.5	2.9	0.2	0.1

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 8-10).

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

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

[d]Location no longer exists because surface drainage was routed through a new sewer system installed in July 1986.

This decline reflects the effects of remedial action at the HISS since 1984. Concentrations of radium-226 have remained almost unchanged over the 3-year period. Overall, thorium-230 concentrations have been relatively stable over the 4-year monitoring period.

3.6.4 Groundwater

Due to the remedial action conducted at the HISS, almost all wells monitored at the site during 1984 were removed, and new monitoring wells were established in 1985. Therefore, Table 3-9 reports data for 1985, 1986, and 1987 only, and the performance of a meaningful trend analysis is not possible. The table does show a significant decline in the concentrations of uranium in Wells 6 and 9, but comparisons of the other radionuclide concentrations at these and other wells show no significant changes. As more data are collected, trends may become more apparent.

TABLE 3-9

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT THE HISS, 1985-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c] 1985	1986	1987
Total Uranium			
6	71.6	33.0	40.0
9	25.6	<3.0	<3.0
10	3.1	6.0	4.0
11	<3.0	5.0	4.0
12	<3.0	4.0	5.0
13	<3.0	8.0	8.0
15	<3.0	5.0	3.0
Radium-226			
6	0.8	0.7	1.2
9	0.4	0.2	0.2
10	0.2	0.1	0.2
11	0.3	0.4	0.2
12	0.4	0.4	0.5
13	0.1	0.3	0.3
15	0.3	0.4	0.4
Thorium-230			
6	5.5	2.6	2.9
9	0.2	0.6	0.2
10	0.2	0.7	0.3
11	0.9	1.3	0.8
12	0.4	2.0	0.8
13	0.3	1.0	0.3
15	0.5	1.3	0.8

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 8-10).

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

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

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

In 1987, a change was initiated in the schedule for quarterly monitoring of all FUSRAP sites such that sampling is conducted in January, April, July, and October. Previously, quarterly sampling was conducted in March, June, September, and December. The schedule was modified to allow sufficient time for more complete analysis activities. To implement this change, data from the last quarter of 1986 were carried over to the first quarter of 1987. Any bias resulting from the use of 1986 data is considered negligible.

In addition, an improved external gamma radiation monitoring system was introduced at the HISS in April 1987 in conjunction with the currently used type of system. This system utilizes tissue-equivalent TLDs, which permit a direct evaluation of the accumulated dose of gamma radiation to the deep tissue of the body (at a depth of 1 cm). Besides providing values that are more realistic in terms of potential tissue dose than does the other type of TLD, the tissue-equivalent TLD is more sensitive in detecting external gamma radiation. Effective April 15, 1988, only tissue-equivalent TLDs will be used. Environmental reports for 1988 and subsequent years will report data generated by the new TLDs.

During 1987, additional contaminated material was placed in the supplementary waste storage pile at the HISS, and a cover was placed over the pile. Characterization of the Futura Coatings site, the HISS, and vicinity properties along Latty Avenue was completed.

4.2 SPECIAL STUDIES

In April 1987, monitoring of the groundwater for chemical indicator parameters was initiated at the HISS to determine the need for additional chemical sampling of water. These indicator parameters are pH, Total Organic Carbon (TOC), Total Organic Halide (TOX), and specific conductance.

The results of these tests are presented in Table 4-1.

As shown in Table 4-1, specific conductance values range from moderate to high. This indicates that the groundwater at HISS contains corresponding levels of dissolved solids and is therefore of low quality. From Well 15 south to Well 12, the specific conductance increases, which indicates increasing degradation of water quality from the north side of the site to the south side. Well 6 has a high specific conductance because of its correspondingly high concentration of dissolved solids.

Total organic carbon and total organic halide values are within normal ranges for groundwater in urban industrial areas.

The pH values for the on-site wells are slightly acidic and do not vary significantly from well to well. On the western half of the site, alkanity increases slightly from south to north.

Analysis for indicator parameters will be augmented with more detailed chemical characterization of the soil and groundwater in 1988.

TABLE 4-1

ANALYSIS RESULTS FOR INDICATOR PARAMETERS

IN GROUNDWATER AT THE HISS, 1987

Sampling Location (Well No.)	Parameter[a] pH (unitless)	Total Organic Carbon (mg/l)	Total Organic Halide (ug/l)	Specific Conductance (umhos/cm)
6	6.7 - 6.9	1.2 - 6.2	24 - 45	3900 - 6360
9	7.2 - 8.7	2.2 - 3.0	33 - 47	510 - 846
10	7.2	3.2 - 3.9	26 - 37	922 - 1110
11	6.9 - 7.0	2.7 - 4.1	18 - 48	1560 - 1790
12	6.7	4.7 - 7.2	22 - 39	3420 - 4300
13	6.6 - 6.8	0.62 - 5.8	28 - 55	7460 - 8200
15	6.7 - 6.9	2.3 - 14.2	19 - 40	1190 - 1320

[a]The ranges in the table represent three quarters' measurements since monitoring for indicator parameters began in the second quarter. Where only one value is listed, the same reading was obtained all three quarters.

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APPENDIX A
QUALITY ASSURANCE

APPENDIX A
QUALITY ASSURANCE

A comprehensive quality assurance program was maintained to ensure that the data collected were representative of actual concentrations in the environment. First, environmental data were obtained to prevent reliance on only a few results, which might not be representative of the existing range of concentrations. Second, current monitoring data were compared with historical data for each environmental medium to ensure that deviations from previous conditions were identified and evaluated. Third, samples at all locations were collected using published procedures to ensure consistency in sample collection. Fourth, each analytical laboratory verified the quality of the data by conducting a continuing program of analytical quality control, participating in interlaboratory cross-checks, and performing replicate analyses. Fifth, chain of custody procedures were implemented to maintain traceability of samples and corresponding analytical results. This program ensures that the monitoring data can be used to evaluate accurately the environmental effects of site operations.

The majority of the routine radioanalyses for the FUSRAP Environmental Monitoring Program was performed under subcontract by Thermo Analytical/Eberline, 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 ensured through the use of standards traceable to the National Bureau of Standards, when available. 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.

Interlaboratory comparison of the TLD results was provided by participation in the International Environmental Dosimeter Project sponsored jointly by the Department of Energy, the Nuclear Regulatory Commission, and the EPA.

To ensure the accuracy of dose calculations, all computed doses were double-checked by the originator and by an independent third party who also checked all input data and assumptions used in the calculations.

APPENDIX B
ENVIRONMENTAL STANDARDS

APPENDIX B
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. 7). 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 represents 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	=	8760 h
1 liter	=	1000 ml
1 mR	$\simeq$	1 mrem
1 mrem	$\simeq$	1000 uR
100 mrem/yr	$\simeq$	11.4 uR/h (assuming 8760 hours of exposure per year)
1 uCi	=	1,000,000 pCi
1 pCi	=	0.0000001 uCi
1 pCi/l	=	10^{-9} uCi/ml
1 pCi/l	=	0.000000001 uCi/ml
1 uCi/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

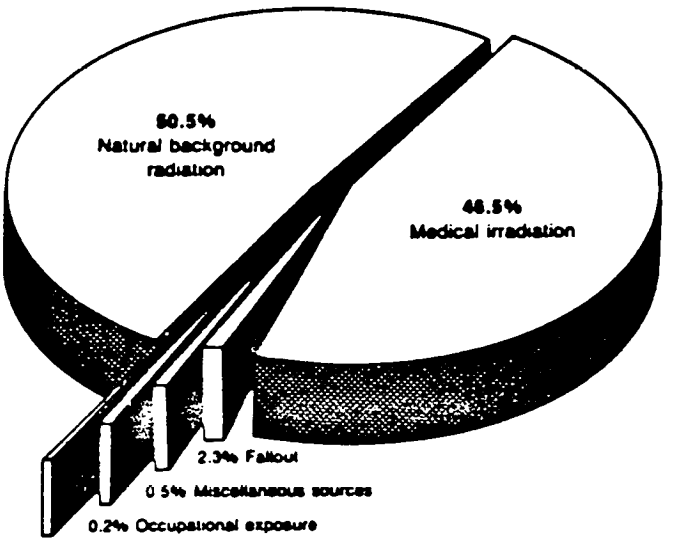
APPENDIX C
ABBREVIATIONS

cm	centimeter
cm/sec	centimeters per second
ft	foot
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
lb	pound
m	meter
m^3	cubic meters
mg	milligram
mg/l	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mR	milliroentgen
mrem	millirem
mR/yr	milliroentgens per year
mrem/yr	millirem per year
m.s.l.	mean sea level
uCi/ml	microcuries per milliliter
ug/l	micrograms per liter
uR/h	microroentgens per hour
pCi	picocurie
pCi/g	picocuries per gram
pCi/l	picocuries per liter
yd^3	cubic yards
yr	year

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.



Source: National Academy of Sciences, 1980; National Council of Radiation Protection and Measurement

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 in contact with in our everyday lives are radioactive. These materials are composed of atoms that are unstable. The unstable atoms release particles or waves as they change into more stable forms. These particles and waves are collectively referred to as *radiation*, and a quantity of the unstable atoms is referred to as *radioactivity*.

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 only move through the air 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 may 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 wall 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.

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Radiation Exposure from Consumer Products and Miscellaneous Sources: Report Number 56. National Council on Radiation Protection and Measurements, 1977.

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

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

Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either the total amount of radioactivity present in a substance, or 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 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. Quantities 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, or mrem (one-thousandth of a rem) range. On the average, people receive about 180 mrem of radiation a year. Most of this radiation is from natural radiation and medical exposure.

RADIATION IN THE ENVIRONMENT

Cosmic Radiation

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

Sea Level	26 mrem/year
(add one for each additional 100 feet in elevation)	
Atlanta, GA (1,050 feet)	37 mrem/year
Denver, CO (5,300 feet)	79 mrem/year
Minneapolis, MN (815 feet)	34 mrem/year
Salt Lake City, UT (4,400 feet)	70 mrem/year
Spokane, WA (1,890 feet)	45 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as thorium, radium, uranium, and carbon.

United States (average)	26 mrem/year
Denver, Colorado	90 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

Based on occupancy 75 percent of the time.

Wood House	35 mrem/year
Brick House	45 mrem/year
Concrete House	45 mrem/year
Stone House	50 mrem/year

Specific Buildings

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.

Typical Radon Level	1.5 pCi/liter
Occupational Working Limit	100.0 pCi/liter

The numbers given here are approximate or represent an average since samples vary.

mrem = millirem

pCi = picocurie

Foods

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

Beer	390 pCi/liter
Domestic 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
Flour	0.14 pCi/g
Peanuts and 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	20 mrem
Dental X Ray, Whole Mouth	900 mrem

International Nuclear Weapons Test Fallout

Average for a U.S. citizen	1 mrem/year

Consumer Goods

Cigarettes (2 packs/day) (Polonium-210)	8,000 mrem/year
Color Television	1 mrem/year
Gas Lantern Mantle (thorium-232)	3 mrem/hour
Highways	4 mrem/year
Jet Airplane Travel/1,500 miles (cosmic)	1 mrem
Natural Gas Stove (radon-222)	6-9 mrem/year
Phosphate Fertilizers*	4 mrem/year
Porcelain Dentures (uranium salts)	1,500 mrem/year
Radioluminescent Clock (radium-226)	9 mrem/year
Smoke Detector (americium-241)	0.2 mrem/year

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

Material	Ra-226	U-238	Th-230	Th-232
Normal Superphosphate	21.3	20.1	18.9	0.6
Concentrated Superphosphate	21.0	58.0	48.0	1.3
Gypsum	33.0	8.0	13.0	0.3

APPENDIX E

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