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

ST. LOUIS AIRPORT SITE
ANNUAL SITE ENVIRONMENTAL REPORT

St. Louis, Missouri

Calendar Year 1997

April 1998

Bechtel National, Inc.

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Subject: Bechtel Job No. 14501, FUSRAP Project
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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 20, 1988.

Very truly yours,

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

AMF/amf
Enclosures: As Stated

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CONCURRENCE

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DOE/OR/20722-199

ST. LOUIS AIRPORT 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

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ABSTRACT

During 1987, the environmental monitoring program was continued at the St. Louis Airport Site (SLAPS) in St. Louis County, Missouri. The ditches north and south of the site were designated for cleanup as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a United States Department of Energy (DOE) program to identify, decontaminate, or control sites where residual radioactive material remains from the early years of the nation's atomic energy program. The site is currently owned by the City of St. Louis and controlled by the St. Louis Airport Authority and is being monitored under the authority of the DOE. The environmental monitoring program is conducted by Bechtel National, Inc., Project Management Contractor for FUSRAP.

The monitoring program at the SLAPS measures radon gas concentrations in air; external gamma dose rates; and uranium, thorium, and radium concentrations in surface water, groundwater, and sediment.

To assess the potential effect of the SLAPS on the public health, the radiation dose was calculated for the maximally exposed individual. Based on the scenario described in this report, the maximally exposed individual would receive an external exposure approximately equivalent to 5.5 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is approximately the same as a person would receive from increased cosmic radiation during six round-trip flights from New York to Los Angeles (due to greater amounts of cosmic radiation at higher altitudes).

The dose to the population within an 80-km (50-mi) radius of the SLAPS that would result from radioactive materials present at the site would be indistinguishable from the dose the population would receive from naturally occurring radioactive sources.

Results of 1987 monitoring show that the SLAPS is in compliance with the DOE radiation protection standard.

TABLE OF CONTENTS

		Page
1.0	Introduction	1
1.1	Location and Description	1
1.2	Site History	8
2.0	Summary of Monitoring Results	10
3.0	Data Collection, Analysis, and Evaluation	13
3.1	Radon Sampling	14
3.2	External Gamma Radiation Levels	15
3.3	Water Sampling	19
3.3.1	Surface Water	19
3.3.2	Groundwater	21
3.4	Sediment Sampling	24
3.5	Radiation Dose	24
3.5.1	Dose to Maximally Exposed Individual	26
3.5.2	Dose to the Population in the Vicinity of the SLAPS	27
3.6	Trends	28
3.6.1	Radon	28
3.6.2	External Gamma Radiation Levels	30
3.6.3	Surface Water	32
3.6.4	Groundwater	32
4.0	Related Activities and Special Studies	36
4.1	Related Activities	36
4.2	Special Studies	36
References		39

Appendix A	Quality Assurance	A-1
Appendix B	Environmental Standards	B-1
Appendix C	Abbreviations	C-1
Appendix D	Radiation in the Environment	D-1
Appendix E	Distribution List for St. Louis Airport Site Annual Site Environmental Report	E-1

LIST OF FIGURES

Figure	Title	Page
1-1	Location of the SLAPS	2
1-2	Aerial View of the SLAPS and Its Vicinity	3
1-3	Annual Wind Rose for the SLAPS	6
1-4	Generalized Land Use in the Vicinity of the SLAPS	7
3-1	SLAPS Environmental Monitoring Locations	15

LIST OF TABLES

Table	Title	Page
3-1	Concentrations of Radon-222 at the SLAPS, 1987	16
3-2	External Gamma Radiation Levels at the SLAPS, 1987	18
3-3	Concentrations of Total Uranium, Radium-226, and Thorium-230 in Surface Water in the Vicinity of the SLAPS, 1987	20
3-4	Concentrations of Total Uranium, Radium-226, and Thorium-230 in Groundwater at the SLAPS, 1987	22
3-5	Concentrations of Total Uranium, Radium-226, and Thorium-230 in Sediment in the Vicinity of the SLAPS, 1987	25
3-6	Annual Average Concentrations of Radon at the SLAPS, 1984-1987	29
3-7	Annual Average External Gamma Radiation Levels at the SLAPS, 1984-1987	31
3-8	Annual Average Concentrations of Total Uranium, Radium-226, and Thorium-230 in Surface Water in the Vicinity of the SLAPS, 1984-1987	33
3-9	Annual Average Concentrations of Total Uranium, Radium-226, and Thorium-230 in Groundwater at the SLAPS, 1984-1987	34
4-1	Indicator Parameters in Groundwater at the SLAPS, 1987	38
B-1	Conversion Factors	B-2

1.0 INTRODUCTION

This report presents the findings of the environmental monitoring program conducted at the St. Louis Airport Site (SLAPS) during calendar year 1987. The SLAPS and its vicinity properties were designated for remedial action under the Department of Energy (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP is a program to identify, clean up, 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. The 1985 Energy and Water Appropriations Act (Public Law 98-360) authorized DOE to acquire the SLAPS from the City of St. Louis for use as a permanent disposal site; the property has not yet been transferred to DOE. However, routine radiological monitoring of the site has been authorized by the DOE to be conducted by Bechtel National, Inc. (BNI), Project Management Contractor for FUSRAP. As part of this monitoring, BNI began sampling Coldwater Creek in March 1983. The on-site well monitoring program, which BNI began performing in October 1983, is a continuation of the the program formerly conducted by Oak Ridge National Laboratory. In October 1984 BNI began measuring radon and external gamma radiation levels.

1.1 LOCATION AND DESCRIPTION

The SLAPS is an 8.8-ha (21.7-acre) site located in St. Louis County, Missouri, approximately 24 km (15 mi) from downtown St. Louis. SLAPS lies immediately north of the Lambert-St. Louis International Airport and is bounded by the Norfolk and Western Railroad and Banshee Road on the south, Coldwater Creek on the west, and McDonnell Boulevard on the north and east. It is 0.8 km (0.5 mi) south of the Hazelwood Interim Storage Site (HISS), a DOE facility located in the City of Hazelwood, Missouri. Figure 1-1 shows the location of the SLAPS, and Figure 1-2 is a photograph of the site.

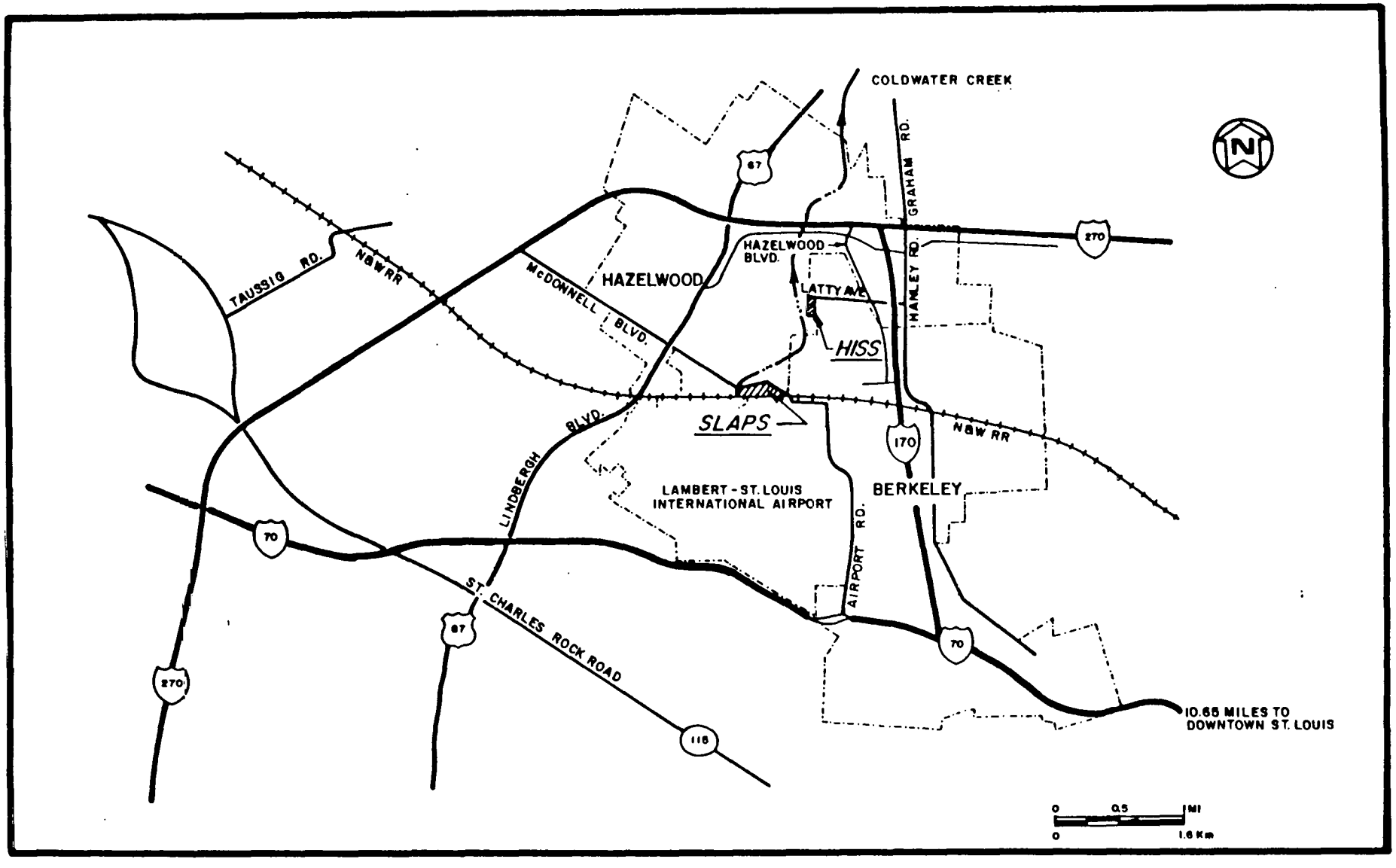


FIGURE 1-1 LOCATION OF THE SLAPS

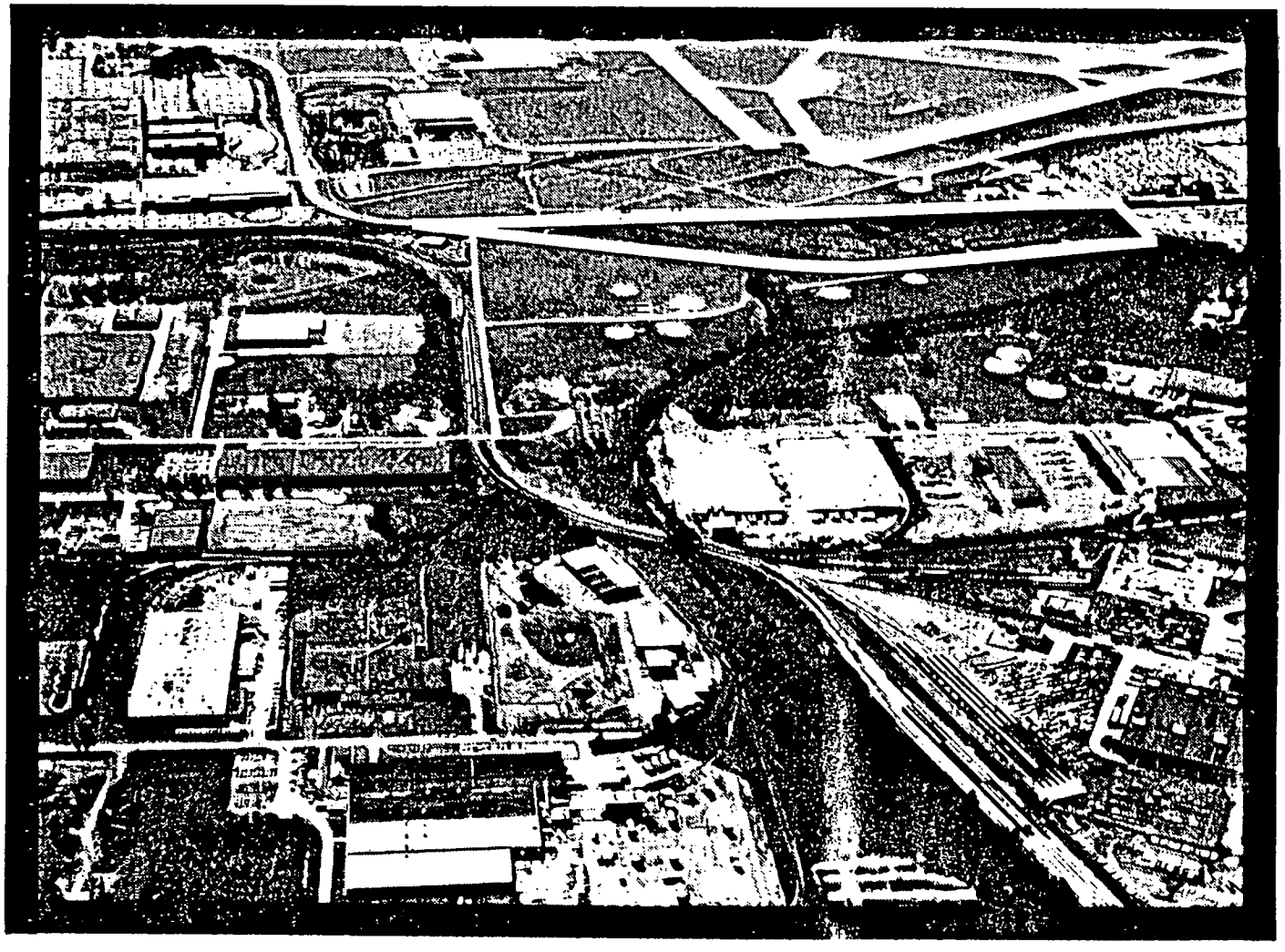


FIGURE 1-2 AERIAL VIEW OF SLAPS AND ITS VICINITY

A revised estimate of the volume of contaminated material at the SLAPS was generated in 1987 based on an evaluation of data from the radiological and chemical characterizations of the site performed during 1986. Volume estimates are also being calculated for the ditches north of the site along McDonnell Boulevard and for Coldwater Creek, as well as for the HISS vicinity properties. The results of these calculations will be used during the evaluation of remedial action alternatives for these sites.

The SLAPS is located in the upper half of the Coldwater Creek watershed. Coldwater Creek originates about 5.8 km (3.6 mi) south of SLAPS at a small spring-fed lake in Overland, Missouri, flows along the western end of the site, and discharges to the Missouri River approximately 6.4 km (4 mi) upstream of its confluence with the Mississippi River. Passing through the culverts under the Lambert-St. Louis International Airport, the flow in Coldwater Creek is influenced by stormwater runoff from the upstream areas of residential, commercial, industrial, and airport land (Ref. 1).

Runoff leaves the SLAPS by evaporation, seepage into the groundwater system, or through surface drainage to Coldwater Creek. Surface drainage from the site is intercepted by drainage channels along the northern and southern boundaries of the site and flows into Coldwater Creek. To halt erosion of the western end of the SLAPS into Coldwater Creek, a gabion wall was constructed in 1985 along the section of Coldwater Creek bordering the SLAPS.

There are no facilities on Coldwater Creek that withdraw water for human consumption. The closest water treatment facility is on the Mississippi River, approximately 12.8 km (8 mi) downstream of the confluence of Coldwater Creek and the Missouri River (Ref. 2).

Groundwater at the SLAPS, in the paleozoic limestones, is of very poor quality (Ref. 2). It typically contains more than 1000 ppm of dissolved solids and is classified as saline (Ref. 3). In addition, yields from wells in these rocks are very low, with reported

specific yields being less than 7.6 l/min/m (2 gal/min/ft) of drawdown. Groundwater is not generally used for any purpose in the area around the airport site. The nearest well is about 2.4 km (1.5 mi) north of the site. There are no records of any producing wells within a 1.6-km (1-mi) radius of the site. The water needs of the area are met by treated Mississippi River water. No monitoring wells are planned for installation in the deeper aquifer. The monitoring wells at the site are installed in shallower aquifers above the bedrock aquifer.

The climate of the SLAPS is classified as modified continental. The average annual daily temperature ranges from 7.4 to 18.6°C (45.4 to 65.5°F). The highest average monthly temperature is 31.6°C (89°F) (July) and the lowest is -6.7°C (19.9°F) (January). Normal annual precipitation is slightly over 87.5 cm (35 in.). The average annual snowfall is 65.8 cm (26.3 in.). Prevailing winds tend to be from the south, the northwest, and west-northwest. Average wind speeds range from 12.2 to 18.9 km/h (7.6 to 11.8 mph). Figure 1-3 shows the distribution of wind direction and speed for the SLAPS vicinity (Ref. 4).

There are no sizeable residential population centers within 1.6 km (1 mi) of the site. The nearest population center comprises 75 to 100 people residing about 0.8 km (0.5 mi) west of the site in an industrially zoned area of Hazelwood. The next nearest population center (about 1500 people) is about 1.6 km (1 mi) northwest of the site along Chapel Ridge Drive. However, most of Hazelwood's population is north of Interstate 270, more than 2.4 km (1.5 mi) north of the site (Ref. 2). Land use immediately adjacent to the site is varied (Figure 1-4, Ref. 2). More than two-thirds of the land within 0.8 km (0.5 mi) of the site is used for transportation - related purposes -- primarily Lambert-St. Louis International Airport. Land immediately adjacent to the site is also used for commercial and recreational purposes.

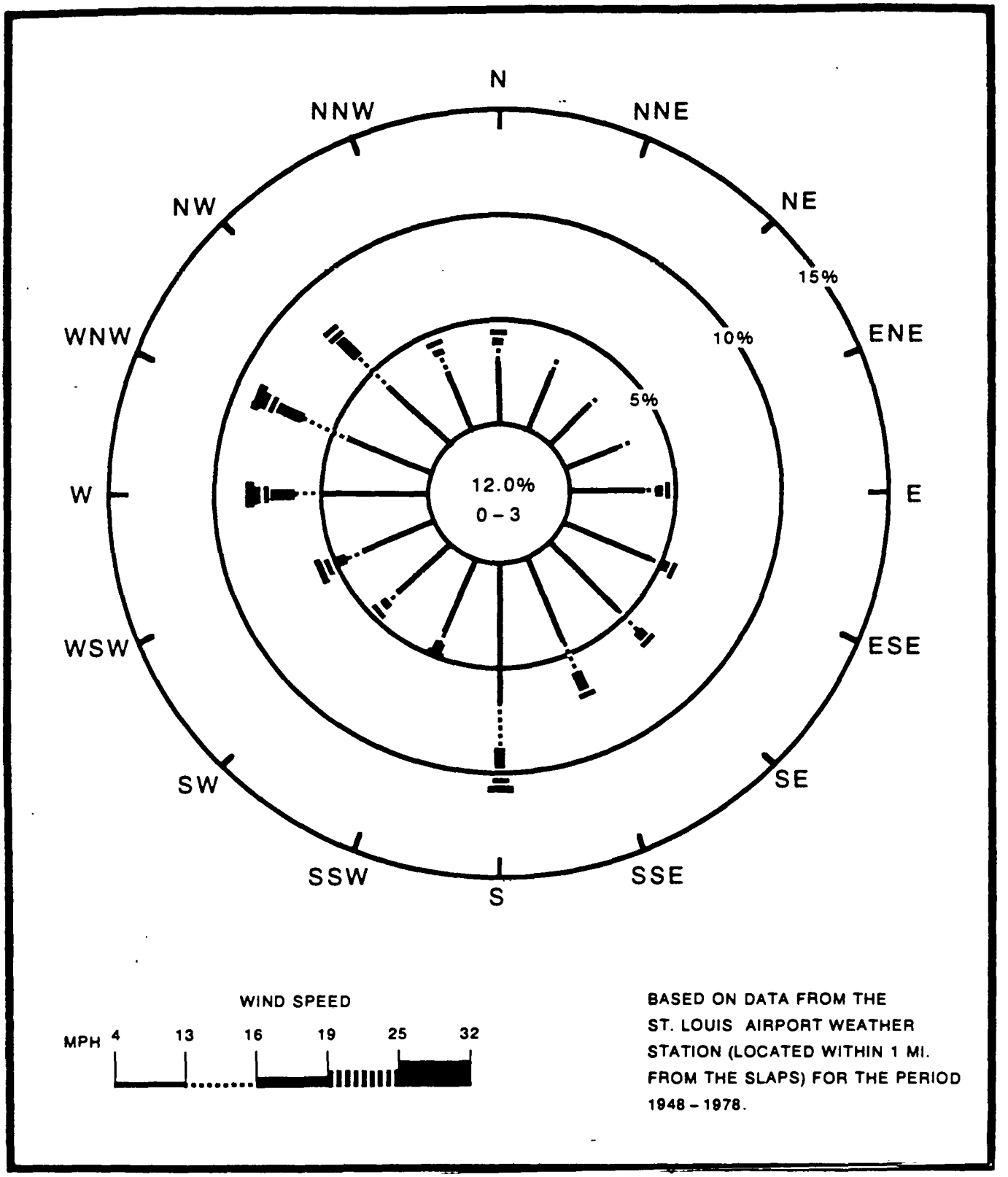
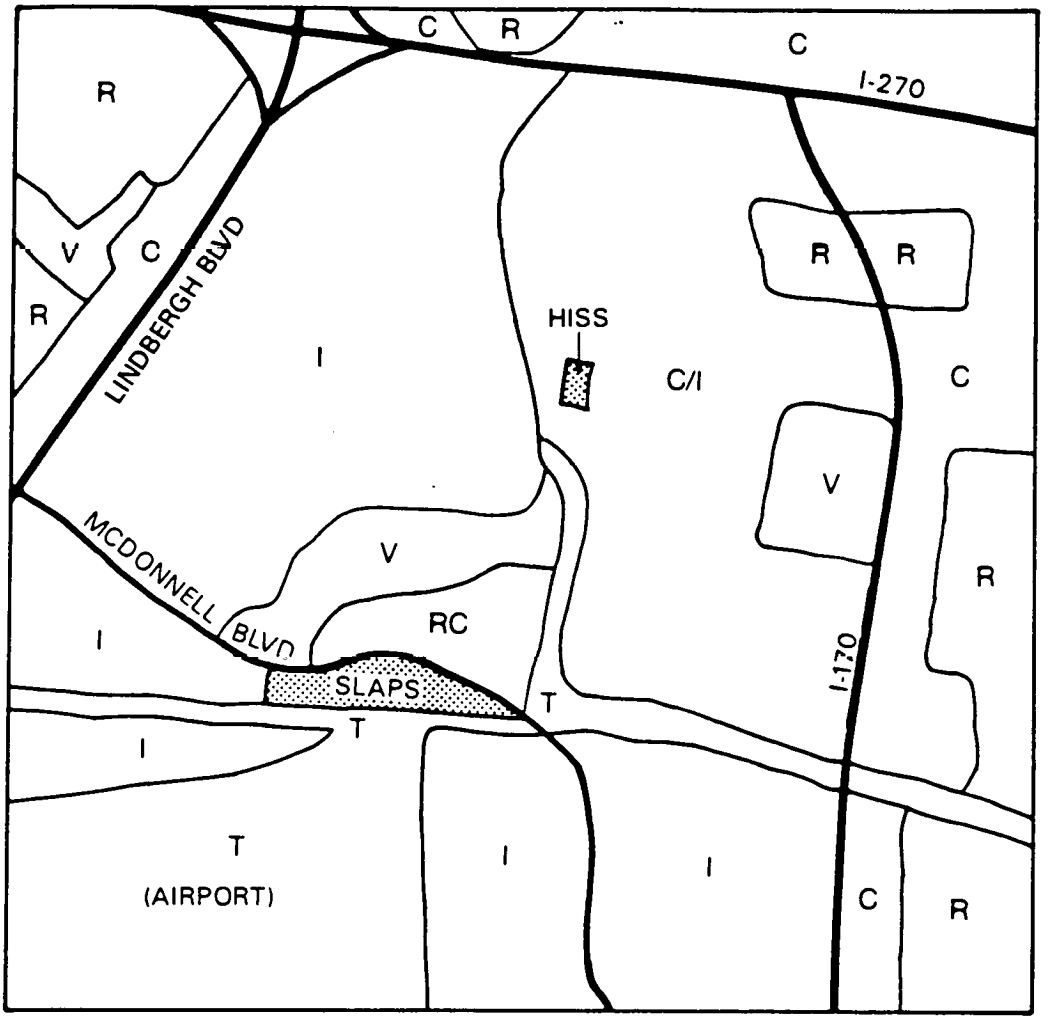


FIGURE 1-3 ANNUAL WIND ROSE FOR THE SLAPS



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

N

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

1.2 SITE HISTORY

In 1946, the Manhattan Engineer District (MED), a predecessor of the Atomic Energy Commission (AEC) and DOE, acquired the 8.8-ha (21.7-acre) tract now known as the SLAPS to store residues resulting from the processing of uranium ores at a facility in St. Louis.

The uranium processing (under a contract with the MED) continued through 1953; the resulting radioactive residues accumulated on the SLAPS. These materials included pitchblende raffinate residues, radium-bearing residues, barium sulfate cake, Colorado raffinate residues, and contaminated scrap. Most of the residues were stored in bulk on open ground. Some contaminated materials and scrap were buried at the western end and in other parts of the site. To limit direct radiation exposure to the public, the site was fenced to prevent casual entry.

In 1966 and 1967, most of the stored residues were sold and moved approximately 0.8 km (0.5 mi) north to a site on Latty Avenue. On-site structures were razed, buried on the site, and covered with 0.3 to 1 m (1 to 3 ft) of clean fill. Although these activities reduced the surface dose rates to acceptable levels, buried deposits of residue containing uranium-238, radium-226, and thorium-230 remained on the site (Ref. 5).

In 1973, the tract was transferred by quitclaim deed from the AEC to the City of St. Louis. The 1985 Energy and Water Appropriations Act (Public Law 98-360) authorized DOE to take the necessary steps to consolidate and dispose of waste materials from the Latty Avenue site and the nearby St. Louis Airport vicinity properties locally by reacquiring, stabilizing, and using the old 8.8-ha (21.7-acre) AEC airport site in a manner acceptable to the City of St. Louis.

From 1976 through 1978, the Oak Ridge National Laboratory conducted a radiological investigation of the SLAPS (Ref. 6). This survey indicated the presence of elevated concentrations of uranium-238 and

radium-226 in drainage ditches north and south of McDonnell Boulevard. In 1981, the drainage ditches were designated for remedial action under FUSRAP.

In 1982, BNI performed radiological characterizations of the ditches on either side of McDonnell Boulevard and portions of Coldwater Creek (Ref. 7). Neither of these surveys included measuring thorium-230 in soil. During 1986, however, archived soil samples from the ditches were again analyzed to determine thorium-230 content, and new samples from the ditches and Coldwater Creek were radiologically and chemically analyzed.

Additional radiological characterization as well as limited geological and chemical characterization of the SLAPS was undertaken during 1986, and 10 groundwater monitoring wells were installed at the site. Radiological characterization was also performed on three properties immediately adjacent to the SLAPS: the property north of the site, currently used as a recreation area; the railroad bordering the site on the south; and a triangular area between the SLAPS fence line and McDonnell Boulevard at the eastern end of the site.

2.0 SUMMARY OF MONITORING RESULTS

During 1987, the environmental monitoring program at the SLAPS continued; water and sediments were sampled, and radon and external gamma radiation levels were measured to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 8). The potential radiation dose that might be received by the maximally exposed individual was calculated to determine whether or not the site was in compliance with the radiation protection standard.

Annual average radon concentrations (including background) ranged from 5×10^{-10} to 3.6×10^{-9} uCi/ml (0.5 to 3.6 pCi/l) (see Subsection 3.1). The average background level in 1987 was 4×10^{-10} uCi/ml (0.4 pCi/l). Slight decreases were exhibited at some monitoring locations; slight increases were measured at others. Radon levels have risen steadily at only one location since the monitoring program began (see Subsection 3.6.1) (Refs. 11-13).

Average external gamma radiation levels measured at the SLAPS boundary ranged from 25 to 1557 mR/yr above background, which was 77 mR/yr in 1987. The highest value was measured in an area of known contamination (see Subsection 3.2).

In surface waters, the highest average concentrations of total uranium, radium-226, and thorium-230 were less than 4.2×10^{-9}, 4×10^{-10}, and 4×10^{-10} uCi/ml (less than 4.2, 0.4, and 0.4 pCi/l), respectively (see Subsection 3.3.1). These values are approximately the same as the background concentrations measured upstream of the SLAPS. Measured concentrations of the radionuclides in surface water at the SLAPS have remained basically consistent since 1984 (see Subsection 3.6.3) (Refs. 11-13).

The highest annual average uranium concentration in groundwater was 5.83×10^{-6} uCi/ml (5829 pCi/l). The highest average radium-226 concentration was 4×10^{-10} uCi/ml (0.4 pCi/l), and the highest average thorium-230 concentration was 1.7×10^{-9} uCi/ml (1.7 pCi/l) (see Subsection 3.3.2). Concentrations of radionuclides

in surface water and groundwater at the SLAPS may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D of this report.

In April 1987, 10 new wells were added to the groundwater monitoring program. Since there is no basis for comparison of data from these wells with groundwater data for prior years, the comparison of groundwater data for 1984-1987 is restricted to Wells A-F. Radionuclide concentrations in groundwater have shown no overall trend, with some monitoring wells exhibiting increases and others showing decreases (see Subsection 3.6.4) (Refs. 11-13).

When compared to the lowest annual average uranium concentration in groundwater, [1.3 x 10^{-8} uCi/ml (13 pCi/l)], concentrations of uranium in several of the wells are high because the wells are located in or adjacent to buried radioactive materials. Because the SLAPS is fenced, the public does not have access to these wells. Furthermore, there is no known consumption of groundwater in the vicinity of the site. Groundwater that might escape to Coldwater Creek is monitored as part of the surface water monitoring program. Current indications are that this mechanism not resulted in degradation of surface water quality.

In sediments collected downstream from the site, the highest annual average concentration was 1.6 pCi/g for total uranium, 1.4 pCi/g for radium-226, and 1.4 pCi/g for thorium-230 (see Subsection 3.4). These concentrations are approximately equal to or lower than background concentrations measured upstream of the site. These concentrations may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D, Radiation in the Environment.

The radiological dose received by the maximally exposed individual was calculated. This individual is one who is assumed to be adjacent to the site and who was assumed to walk the northern fence line of the site twice a day, five days a week. The maximum exposure this individual would be exposed to is 5.5 mR/yr above

background. Since 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 5.5 percent of the DOE radiation protection standard.

The cumulative dose to the population within a 80-km (50-mi) radius of the SLAPS that would result from radioactive materials present at the site would be indistinguishable from the dose the same population would receive from naturally occurring radioactive sources.

Results of 1987 monitoring show that the SLAPS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1987 environmental monitoring at the SLAPS (Ref. 9). A description is also given of the sampling, monitoring, and analytical procedures used. Calculations were made to determine the estimated maximum possible radiation dose based on environmental conditions, measurements recorded, and evaluation of potential exposure pathways.

Data are presented in summary tables which 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, values are considered as being equal to the limit of sensitivity and the "average" value is reported without the "less than" notation.

During 1987, the routine environmental monitoring program for SLAPS and the off-site ditches included radon monitoring, external gamma radiation measurements, surface water and sediment sampling of Coldwater Creek, and groundwater sampling of monitoring wells within the site boundary (which is a fenced and posted area).

In 1987 a change was initiated in the quarterly monitoring of all FUSRAP sites. Monitoring quarters were shifted such that each site is sampled in the months of January, April, July, and October, whereas monitoring operations were previously conducted in March, June, September, and December. This change was implemented to provide additional time for analysis activities. In order to implement this change, it was necessary to carry over data from the last quarter of 1986 to the first quarter of 1987. Any bias resulting from this measure is considered negligible.

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

3.1 RADON SAMPLING

Nine radon detectors (two of which are quality control detectors) are maintained along the site boundary. Detectors are spaced so as to ensure adequate detection capability under most atmospheric conditions. The locations of the radon monitors are shown in Figure 3-1. A background detector is maintained off-site.

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

Table 3-1 reports the radon concentrations measured at the nine monitoring locations. The annual average concentrations ranged from 5×10^{-10} to 3.6×10^{-9} uCi/ml (0.5 to 3.6 pCi/l). The background concentration of 4×10^{-10} uCi/ml (0.4 pCi/l) has not been subtracted. Based on measured radon concentrations at the SLAPS, the on-site radon source has a minimal effect on radon concentrations in the area.

For comparisons of radon concentrations measured from 1984 through 1987, see Subsection 3.6.1.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at the nine monitoring locations that correspond to the radon (Terradex) detector locations shown in Figure 3-1.

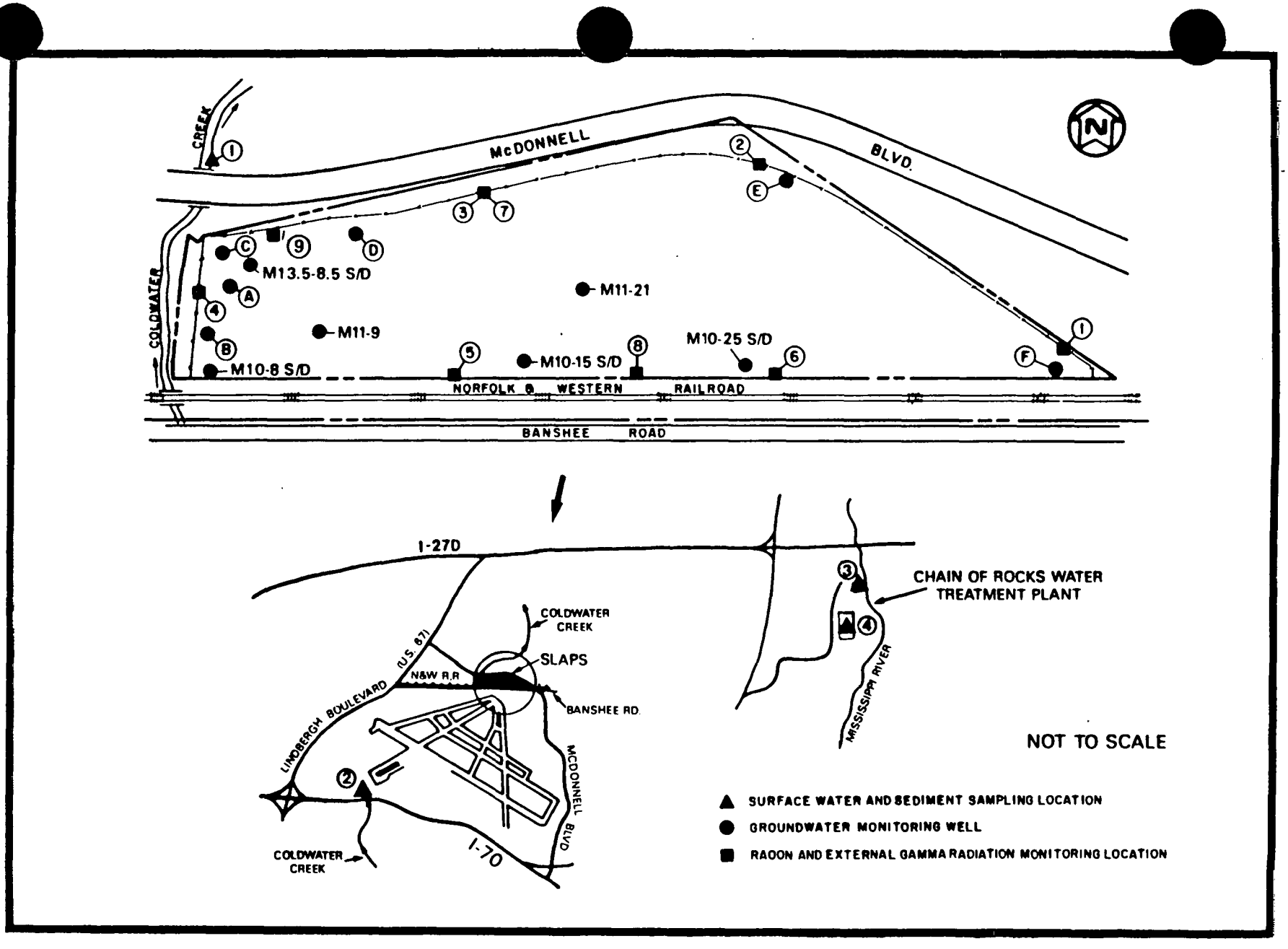


FIGURE 3-1 SLAPS ENVIRONMENTAL MONITORING LOCATIONS

TABLE 3-1

CONCENTRATIONS OF RADON-222 AT THE SLAPS, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
1	4	0.1	5.6	1.6
2	4	0.5	6.3	3.6
3[d]	4	0.2	1.2	0.7
4	4	0.2	2.1	0.8
5	4	0.2	6.7	2.1
6	4	0.1	1.1	0.5
7[d]	4	0.2	1.4	0.8
8[e]	4	0.2	2.3	1.3
9	2[f]	3.0	3.3	3.1
Background[g]	4	0.3	0.5	0.4

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

[b]Background has not been subtracted.

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

[d]Locations 3 and 7 are quality control stations.

[e]Location 8 was moved in April 1987.

[f]Sampling location was established in April 1987.

[g]Located in Florissant, MO.

External gamma radiation levels were measured using lithium fluoride (LiF) thermoluminescent elements that are exchanged quarterly. In addition, an improved external gamma radiation monitoring system was introduced at the SLAPS 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. In both types of TLDs, each dosimeter contains five individual chips, the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). Effective April 15, 1988, tissue-equivalent TLDs will be used exclusively. Measurements obtained using the new TLD system will be presented in the environmental reports for 1988 and subsequent years.

The results of the measurements for external gamma radiation are presented in Table 3-2. Annual radiation levels ranged from 25 to 1557 mR/yr above background at the monitoring locations. The highest radiation level occurred at Location 2, which is in an area known to be contaminated. This location is contaminated because of its proximity to the contaminated ditch lying between the site fence and McDonnell Boulevard, rather than as a result of remedial action conducted at the site. The radioactive contamination in the ditches will be cleaned up as part of the remedial action to be conducted at the site, and these areas will be monitored along with the site itself until remedial action is complete.

The next highest annual average gamma radiation level measured at the SLAPS in 1987 was 110 mR/yr above background. The annual average background radiation level was 77 mR/yr. For comparisons of external radiation levels measured from 1984 through 1987, see Subsection 3.6.2.

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT THE SLAPS, 1987

Sampling Location[a]	Number of Measurements	Radiation Level (mR/yr)[b]		
		Minimum	Maximum	Average
1	4	13	86	34
2	4	1180	2358	1557
3[c]	4	60	165	87
4	4	0[i]	126	38
5	4	2	205	67
6	4	6	85	35
7[c]	3[f]	53	61	58
8[d]	4	0[i]	53	25
9	3[g]	86	147	110
Background[e]	3[h]	59	97	77

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

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

[c]Locations 3 and 7 are quality control locations.

[d]Location 8 was moved in April 1987.

[e]Located in Florissant, MO.

[f]Detector was missing in the second quarter.

[g]Sampling location established in April 1987.

[h]Detector was vandalized in the first quarter.

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

3.3 WATER SAMPLING

During 1987, sampling was performed to determine the concentrations of uranium, radium, and thorium in surface water and groundwater at both off-site and on-site locations (Figure 3-1).

3.3.1 Surface Water

Surface water samples were collected quarterly from four off-site locations. Water samples were taken from Coldwater Creek approximately 15 m (50 ft) downstream of the ditch that runs along McDonnell Boulevard (Location 1) and at the creek and Interstate 70 (Location 2). Location 2 is upstream of SLAPS and provides an indication of background concentrations. Locations 3 and 4 are at the Chain of Rocks Water Treatment Plant downstream of the point at which Coldwater Creek discharges into the Missouri River, which then discharges into the Mississippi River.

Samples were collected using nominal 1-liter (0.26-gal) grab samples to fill a 4-liter (1-gal) container. Samples were analyzed by TMA/E. Total uranium was determined by a fluormetric method. Radium-226 concentrations in water were determined by radon emanation. This method consists of precipitating radium as a 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 for uranium, radium-226, and thorium-230 at all sampling locations are presented in Table 3-3. The average concentrations of each of these radionuclides at the three sampling locations downstream of the SLAPS were nearly equal to the

TABLE 3-3

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

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
1	4	<3.4	6.7	<4.2
2	4	<3.4	<3.4	<3.4
3	4	<3.4	5.4	<3.9
4	4	<3.4	4.7	<3.7
Radium-226				
1	4	0.1	0.4	0.4
2	4	0.1	0.6	0.3
3	4	0.1	0.9	0.3
4	4	<0.1	0.6	0.3
Thorium-230				
1	4	<0.1	0.6	0.4
2	4	<0.1	0.3	0.2
3	4	<0.1	0.5	0.3
4	4	<0.1	<0.4	<0.2

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

[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."

background concentrations measured upstream of the site. These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D of this report.

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

3.3.2 Croundwater

During 1987, groundwater samples were collected quarterly from 16 on-site wells. Samples were collected using a hand bailer after the wells had been pumped dry or 3 well 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 and dissolved radium-226 using the methods applied to surface water analyses.

Results of analyses for concentrations of uranium, radium, and thorium in groundwater are presented in Table 3-4. Averages for radium-226 ranged from 1×10^{-10} to 5×10^{-10} uCi/ml (0.1 to 0.5 pCi 1). For thorium-230, averages ranged from less than 1×10^{-10} to 1.5×10^{-8} uCi/ml (less than 0.1 to 15 pCi/1). Averages for uranium in groundwater ranged from less than 3.0×10^{-9} to 5.82×10^{-6} uCi/ml (less than 3.0 to 5829 pCi/1).

Concentrations of uranium in several of the shallow wells at the SLAPS are high because the wells are located in areas of known subsurface contamination. However, because the SLAPS is fenced, the public does not have access to these wells; furthermore, there is no known consumption of groundwater in the vicinity of the site. Groundwater that might escape to Coldwater Creek is monitored as part of the surface water monitoring program. Current indications are that this mechanism has not resulted in degradation of surface water quality. As a result, there is no evidence that anyone is being exposed to levels of radiation that approach the DOE radiation protection standard of 100 mrem/yr.

TABLE 3-4

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

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
Well A	4	938	1340	1139
Well B	4	5159	6834	5829
Well C	3[d]	8	21	13
Well D	3[d]	516	737	637
Well E	4	132	1809	576
Well F	4	9	181	106
Well M10-25S	3[e]	19	35	25
Well M10-25D	3[e]	<3	5	4
Well M11-21	3[e]	17	69	45
Well M10-15S	3[e]	10	11	11
Well M10-15D	3[e]	9	9	9
Well M10-8S	3[e]	30	34	32
Well M10-8D	3[e]	3	6	5
Well M11-9	3[e]	3819	5561	4578
Well M13.5-8.5S	3[e]	4	5	4
Well M13.5-8.5D	3[e]	<3	<3	<3
Radium-226				
Well A	4	<0.1	0.6	0.3
Well B	4	0.2	0.4	0.3
Well C	3[d]	0.3	0.6	0.4
Well D	3[d]	<0.1	0.2	0.1
Well E	4	<0.1	0.5	0.3
Well F	4	<0.1	0.7	0.3
Well M10-25S	3[e]	0.1	0.4	0.2
Well M10-25D	3[e]	<0.1	0.4	0.2
Well M11-21	3[e]	0.2	0.8	0.5
Well M10-15S	3[e]	0.2	0.5	0.3
Well M10-15D	3[e]	0.1	0.9	0.4
Well M10-8S	3[e]	0.1	0.6	0.4
Well M10-8D	3[e]	0.2	0.5	0.3
Well M11-9	3[e]	0.4	0.5	0.5
Well M13.5-8.5S	3[e]	0.3	0.7	0.5
Well M13.5-8.5D	3[e]	0.2	0.8	0.5

TABLE 3-4

(Continued)

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Thorium-230				
Well A	4	<0.1	2.4	0.8
Well B	4	0.2	3.7	1.4
Well C	3[d]	0.1	2.2	0.9
Well D	3[d]	0.2	1.8	0.9
Well F	4	0.4	5.1	1.7
Well M10-25S	3[e]	<0.1	0.3	0.2
Well M10-25D	3[e]	<0.1	2.2	<0.8
Well M11-21	3[e]	1.7	27.0	15.2
Well M10-15S	3[e]	0.3	3.9	1.8
Well M10-15D	3[e]	0.3	0.6	0.4
Well M10-8S	3[e]	0.2	0.2	0.2
Well M10-8D	3[e]	<0.1	<0.1	<0.1
Well M11-9	3[e]	0.1	0.5	0.3
Well M13.5-8.5S	3[e]	0.2	0.7	0.4
Well M13.5-8.5D	3[e]	<0.1	<0.1	<0.1

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

[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]Well obstructed first quarter.

[e]New wells; first sampled in April 1987.

For a discussion of the comparisons of radionuclide concentrations in groundwater measured from 1984 through 1987, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

During 1987, sediment samples consisting of approximately 500 g (1.1 lb) were collected off-site at surface water sampling Locations 1 and 2 (Figure 3-1). TMA/E analyzed the samples for uranium, radium-226, and thorium-230. The total uranium concentration was obtained by summing the results from isotopic uranium analyses. Isotopic uranium and thorium-230 were determined by alpha spectrometry, wherein the uranium and thorium-230 are leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by radon emanation.

Analytical results for uranium, radium-225, and thorium-230 (based on dry weight) are presented in Table 3-5. The annual average concentration of total uranium at the downstream sampling location was 1.3 pCi/g; those of radium-226 and thorium-230 were 1.4 and 1.3 pCi/g, respectively. These concentrations are approximately equal to or lower than background concentrations measured at upstream Location 2, and can be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D to this report.

3.5 RADIATION DOSE

To assess the impact of the radioactive materials stored at the SLAPS, radiological exposure pathways were evaluated to calculate the dose to the maximally exposed individual. The maximally exposed individual is one who is assumed to be adjacent to the site and who would, when all potential routes of exposure are considered, receive the greatest dose. An appraisal of potential pathways (exposure to external radiation, ingestion of water, and inhalation of radon) suggested that external gamma radiation was the principal exposure mode.

TABLE 3-5

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

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Radium-226				
1	3[c]	1.2	1.9	1.4
2	3[c]	0.8	1.2	1.0
Thorium-230				
1	3[c]	0.7	2.2	1.3
2	3[c]	0.5	2.3	1.4
Uranium-234				
1	3[c]	0.6	0.7	0.6
2	3[c]	0.6	1.0	0.8
Uranium-235				
1	3[c]	<0.02	<0.1	<0.05
2	3[c]	0.03	<0.1	0.06
Uranium-238				
1	3[c]	0.6	0.7	0.6
2	3[c]	0.4	0.9	0.7
Total Uranium[b]				
1	3[c]	1.2	1.5	1.3
2	3[c]	1.0	2.0	1.6

[a]Sampling locations are shown in Figure 3-1. Location 1 is downstream and Location 2 is upstream.

[b]Total uranium concentration for each location is determined by summing the measured concentrations of each isotope for the respective location.

[c]Third quarter samples lost in shipment.

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

Radon concentrations measured at all boundary sampling locations except one were within the normal variations associated with background measurements. Given the amount of time that the maximally exposed individual would spend near this location, the dose from radon inhalation would be indistinguishable from the dose received from background concentrations. Consequently, this pathway would not contribute additional dose to the maximally exposed individual and was not considered in dose calculations presented in Subsection 3.5.1. Measured radon concentrations are discussed fully in Subsection 3.1.

3.5.1 Dose to Maximally Exposed Individual

To identify the individual in the vicinity of the SLAPS 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. From these calculations, it was determined that the highest overall dose would be received by an individual who walks daily along the northern site boundary. Because the area adjacent to the SLAPS is normally unoccupied, exposure was calculated assuming that the maximally exposed individual walked along the fence line twice a day, 5 days per week. It was also assumed that the individual walks at a rate of 4.8 km/h (3 mph) along the 0.8 km (0.5 mi) northern site boundary and receives an average annual exposure of 559 mR/yr from Locations 1, 2, and 3.

The external exposure to this individual would be 5.5 mR/yr above background. Since 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 5.5 percent of the DOE radiation protection standard of 100 mrem/yr, and is approximately equal to the exposure a person would receive during six round-trip flights from Los Angeles to New York (because of the greater amounts of cosmic radiation at higher altitudes) (see Appendix D).

3.5.2 Dose to the Population in the Vicinity of the SLAPS

The dose to the population represents the conceptual cumulative radiation dose to all residents within a 80-km (50-mi) radius of a given site. This calculated dose includes contributions from all potential pathways. For the SLAPS, 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 on-site radioactive materials 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 1 m (3 ft) from a small-area radioactive source were 100 mR/yr, the exposure rate at a distance of 6.3 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. 10). Therefore, radon exposure does not contribute significantly to population dose.

On the basis of radionuclide concentrations measured in water leaving the site, it also appears that there is no 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, lowering potential doses to even less significant levels.

Since the contributions to population dose via all potential exposure pathways are inconsequential, calculation of dose to the population is not warranted. The cumulative dose to the population within a 80-km (50-mi) radius of the SLAPS that would result from radioactive materials present at the site would be indistinguishable from the dose the same population would receive from naturally occurring radioactive sources.

3.6 TRENDS

The environmental monitoring program at the SLAPS was established to allow an annual assessment of the environmental conditions at the site, to provide a historical record for year-to-year comparisons, and permit detection of trends. In the following subsections, 1987 annual averages for each monitoring location for radon, external gamma radiation, surface water, and groundwater are compared with results for 1984 through 1986 (Refs. 11-13). As the environmental monitoring program at the SLAPS continues and more data are collected, comparisons and analyses of trends will become more valid.

3.6.1 Radon

As shown in Table 3-6, radon concentrations at the SLAPS are elevated in 1987 in comparison with those measured in previous years. Statistical analysis indicates that annual averages for Location 2 have demonstrated a consistent rise since environmental monitoring was initiated in 1984. Radon levels at other locations along the northwestern boundary of the site (Locations 1, 4, 5, 7, and 8) demonstrate a similar pattern over the same period. Radon levels have remained relatively stable at the other locations (Locations 3, 4, and 6).

TABLE 3-6

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

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c,d]			
	1984	1985	1986	1987
1	0.1	0.5	0.4	1.6
2	0.5	1.2	3.5	3.6
3	0.3	0.8	0.8	0.7
4	0.6	0.4	0.9	0.8
5	-[e]	0.8	0.6	2.1
6	0.4	0.5	0.6	0.5
7	-[e]	0.5	0.7	0.8
8	-[e]	1.0	0.7	1.3
9	-[f]	-[f]	-[f]	3.1
Background	-[g]	0.5	0.3	0.4

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 11-13).

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

[c]Background has not been subtracted.

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

[e]Detector installed in 1985.

[f]Detector installed in April 1987.

[g]Background detector installed in 1985.

Radon concentrations along the northern boundary of the site are heavily influenced by soil moisture and the presence or absence of standing water in the ditch that abuts the fence line. During 1987 dry weather persisted throughout the year. There was a net deficit in rainfall of 2.65 in. for the St. Louis area, which resulted in low moisture content in the soil. This in turn caused more rapid release of soil gases into the surrounding atmosphere than is normal. This factor and the general lack of standing water in the ditches along the northern border of the site together resulted in an increase in radon concentrations in 1987. A similar phenomenon occurred during the first three quarters of 1986 and contributed to the elevated radon concentrations measured in that year as compared to 1985 concentrations.

3.6.2 External Gamma Radiation Levels

As shown in Table 3-7, external gamma radiation levels at the site boundary have not demonstrated a significant change since monitoring was initiated in 1984. Gamma radiation levels at Location 2 have decreased since 1984 as a result of the natural deposition of clean sediments in the ditches along the northern site boundary and, to a lesser extent, because contamination has been transported along the ditches towards the point of discharge to Coldwater Creek. External gamma radiation levels have generally decreased at Locations 1, 2, 3, and 7 following major rainfall and flooding events that have occurred subsequent to the fall of 1986. External gamma radiation levels were elevated slightly in 1987 when compared to 1986 levels, but the increase was not statistically significant. The slight elevation is the result of the dry condition of the soils and the ditches along the northern site boundary, and reflects the fact that dry earth is less effective as a radiation shield than is moist earth. Remedial action will be conducted to clean up radioactive contamination in the ditches, and monitoring of these areas will continue until remedial action is complete.

TABLE 3-7

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

Sampling Location[b]	Radiation Level (mR/yr)[c]			
	1984	1985	1986	1987
1	59[d]	46	14	34
2	2157[d]	2087	1363	1557
3	115[d]	116	67	87
4	51[d]	57	21	38
5	-[e]	3	81	67
6	28[d]	41	10	35
7	-[e]	93	43	58
8	-[e]	12	17	25
9	-[f]	-[f]	-[f]	110
Background	-[g]	99	97	77

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 11-13).
[b]Sampling locations are shown in Figure 3-1.
[c]Measured background has been subtracted from the readings taken at the nine sampling locations shown in Figure 3-1. Measurements are obtained in mR/quarter, normalized to 1 year, and expressed in the table as mR/yr.
[d]Monitoring location installed in late 1984; data are for fourth quarter only.
[e]Sampling location established in early 1985.
[f]Location 9 was established in April 1987.
[g]Background detector installed in 1985.

3.6.3 Surface Water

Measured concentrations of radionuclides in surface water at the SLAPS have remained relatively stable since 1984. Surface water data for the 1984-1987 period are given in Table 3-8.

3.6.4 Groundwater

In April 1987, 10 new wells were added to the groundwater monitoring program. Since there is no basis for comparison of data from these wells with groundwater data for prior years, the comparison of groundwater data for 1984-1987 is restricted to Wells A-F.

As shown in Table 3-9, concentrations of total uranium in groundwater have remained consistently high in Wells A and B. Uranium concentrations in Well C exhibit a definite downward trend over the 1984-1987 period. These three wells are located on the western end of the site (Figure 3-1).

Uranium concentrations in Wells D and E have demonstrated a rising trend since monitoring was initiated in 1984. As shown in Table 3-9, concentrations of uranium in Wells D and E rose sharply in 1986. In 1987, uranium concentrations did not differ significantly from those measured in 1986. Uranium concentrations in Well F (located on the far eastern end of the site) have remained stable.

Levels of radium-226 and thorium-230 have been generally stable at low levels. A statistically insignificant increase in levels of thorium-230 was observed in 1987.

Uranium concentrations in groundwater are strongly influenced by the rate at which groundwater moves through the site. For years in which there is a significant deficit in rainfall and thus a reduced recharge of the groundwater, uranium levels can be expected to rise.

TABLE 3-8

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

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c] 1984	1985	1986	1987
Total Uranium				
1	14.0	3.4	4.3	4.2
2	4.0	<3.0	<3.0	<3.0
3	-[d]	<3.0	<3.0	<4.0
4	-[d]	<3.0	3.5	<4.0
Radium-226				
1	0.2	0.2	0.2	0.4
2	0.1	0.1	0.3	0.3
3	-[d]	0.2	0.2	0.3
4	-[d]	0.1	0.2	0.3
Thorium-230				
1	0.1	0.4	<0.2	0.4
2	0.36	<0.4	<0.2	0.2
3	-[d]	<0.5	0.3	0.3
4	-[d]	<0.4	<0.2	<0.2

[a]Data sources for previous years are the annual site environmental reports for those years (Refs. 11-13).

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

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

[d]Sampling locations 3 and 4 were added in 1985.

TABLE 3-9

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT THE SLAPS, 1984-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c]			
	1984	1985	1986	1987
Total Uranium				
Well A	1287	2375	1184	1139
Well B	5700	4735	6570	5829
Well C	40	36	16	13
Well D	233	474	802	637
Well E	129	114	540	576
Well F	141	177	146	106
Radium-226				
Well A	0.3	0.2	0.3	0.3
Well B	0.3	0.2	0.3	0.3
Well C	0.3	0.2	0.3	0.4
Well D	0.2	0.1	0.3	0.1
Well E	0.6	0.2	0.5	0.3
Well F	0.2	0.1	0.2	0.3
Thorium-230				
Well A	9.5	2.3	<0.4	0.8
Well B	0.3	0.3	1.2	1.4
Well C	0.2	0.2	0.2	0.9
Well D	0.9	1.3	0.3	0.9
Well E	0.3	1.0	0.4	0.9
Well F	0.4	1.1	0.2	1.7

[a]Data sources for prior years are the annual site environmental Reports for those years (Refs. 10-13).

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

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

Though these increases cannot be definitively explained, it is known that Wells D and E are located adjacent to buried radioactive materials. Because the SLAPS is fenced, the public does not have access to these wells, and there is no known consumption of groundwater in the vicinity of the site. Based on analysis results for surface water, there is no evidence that surface water downstream of the site has been degraded by groundwater that might have entered Coldwater Creek. As such, there is no reason to suspect that any member of the public receives an internal dose of radiation that would approach the DOE radiation protection standard.

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. This change was implemented to provide additional time for analysis activities. In order to implement this change in the monitoring schedule, data from the last quarter of 1986 were carried over to the first quarter of 1987 for purposes of environmental monitoring. 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 SLAPS 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, tissue-equivalent TLDs will be used exclusively. Data collected from these new TLDs will be presented in the environmental reports for 1988 and subsequent years.

4.2 SPECIAL STUDIES

Starting in April 1987, monitoring of the groundwater for chemical indicator parameters was initiated at the SLAPS to determine the need for further water quality testing for chemical content. These indicator parameters are as follows:

- o pH
- o Total Organic Carbon (TOC)
- o Total Organic Halide (TOX)
- o Specific Conductance

Analysis results for these parameters are presented in Table 4-1.

As shown, specific conductance values range from moderate to high, indicating that the groundwater at the SLAPS contains moderate to high levels of dissolved solids and is therefore of low quality. Groundwater entering the eastern side of the site (Well F area) shows indications of degradation as it progresses toward the western boundary of the site (Wells M10-8S/D and M13.5-8.5S/D). Wells with historically high levels of uranium (Wells B, D, and E) and Well M11-9 (installed in 1986) also exhibit higher specific conductance values.

Total organic carbon and total organic halide values are within normal ranges for groundwater in an urban, industrial area. Both acidity and alkalinity as expressed by pH values decrease as groundwater crosses the site.

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

TABLE 4-1

INDICATOR PARAMETERS IN GROUNDWATER

AT THE SLAPS, 1987

Sampling Location (Well No.)	Parameter			
	pH (unitless)	Total Organic Carbon (mg/l)	Total Organic Halide (ug/l)	Specific Conductance (umhos/cm)
A	6.6 - 6.8	4.8 - 9.0	20 - 190	1320 - 1350
B	6.5 - 6.7	7.4 - 13.9	40 - 250	7540 - 8810
C	6.7 - 6.9	4.9 - 6.8	23 - 69	1600 - 1870
D	6.7 - 6.9	8.7 - 12.0	34 - 100	2100 - 2470
E	6.8 - 7.0	2.7 - 10.1	25 - 110	3550 - 5650
F[a]	7.1 - 7.3	1.7 - 44	27 - 120	636 - 746
M 13.5 - 8.5S	6.8 - 7.4	8.2 - 14.1	10 - 160	1350 - 1600
M 13.5 - 8.5D	6.8 - 7.6	7.7 - 12.0	41 - 61	770 - 898
M 11.9	6.1 - 6.6	4.0 - 17.5	10 - 160	8440 - 9510
M 10 - 8S	6.8 - 7.0	4.5 - 6.0	37 - 100	1430 - 1690
M 10 - 8D	7.3 - 7.5	6.5 - 10.7	40 - 78	700 - 886
M 10 - 15S	6.9 - 7.2	4.4 - 11.6	31 - 69	2430 - 2760
M 10 - 15D	7.4 - 7.5	4.7 - 7.9	53 - 80	840 - 971
M 11 - 21	7.0 - 7.2	5.3 - 10.1	22 - 67	2900 - 3320
M 10 - 25S	7.0 - 7.2	3.1 - 7.1	14 - 74	740 - 922
M 10 - 25D	7.2 - 9.2	3.2 - 7.9	36 - 85	330 - 703

[a]Upgradient well.

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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 an unrealistic reliance on only a few results. 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, the quality of the data was verified by a continuing program of analytical laboratory quality control, which included participation in interlaboratory crosschecks and replicate analysis. Fifth, chain-of-custody procedures 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 were 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.

Assurance of the quality of dose calculations was provided in several ways. First, comparisons were made against past calculated doses and significant differences, if any, were verified. Second, 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 calculation.

APPENDIX B
ENVIRONMENTAL STANDARDS

APPENDIX B
ENVIRONMENTAL STANDARDS

The DOE radiation protection standard of 100 mrem/yr above background level includes exposure from all pathways except medical treatments (Ref. 8). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely 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	$\cong$	1 mrem
1 mrem	$\cong$	1000 uR
100 mrem/yr	$\cong$	11.4 uR/hr (assuming 8760 hours of exposure per year)
1 uCi	=	1,000,000 pCi
1 pCi	=	0.000001 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

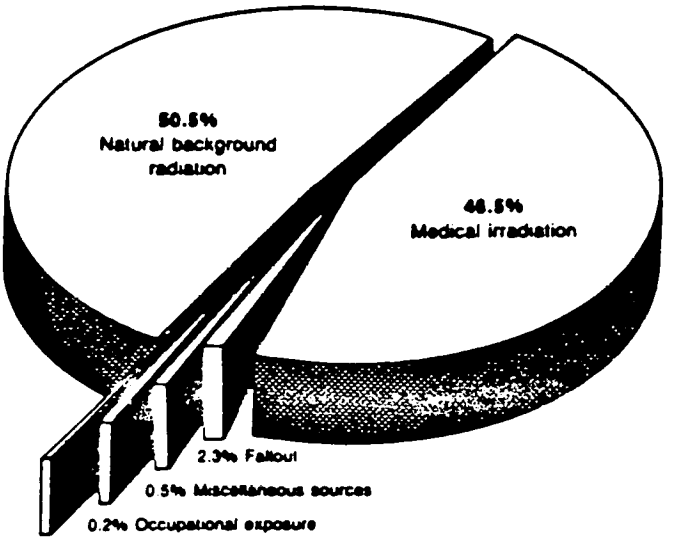
APPENDIX C
ABBREVIATIONS

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
l	liter
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	microgram 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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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 (add one for each additional 100 feet in elevation)	26 mrem/year
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	6.0	13.0	0.3

APPENDIX E

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