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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 1988

MASTER

April 1989

Bechtel National, Inc.

0189-0260.4

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DOE/OR/20722--220

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ST. LOUIS AIRPORT SITE

ANNUAL SITE ENVIRONMENTAL REPORT

CALENDAR YEAR 1988

APRIL 1989

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

The environmental monitoring program, which began in 1984, continued during 1988 at the St. Louis Airport Site (SLAPS) in St. Louis County, Missouri. SLAPS and its vicinity properties, including 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 and decontaminate or otherwise 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. The DOE environmental monitoring program at SLAPS is conducted by Bechtel National, Inc., project management contractor for FUSRAP.

The monitoring program at SLAPS measures radon 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 SLAPS on public health, the potential radiation dose was estimated for a hypothetical maximally exposed individual. Based on the scenario described in this report, this hypothetical individual would receive an external exposure approximately equivalent to 7.5 percent of the DOE radiation protection standard of 100 mrem/yr. This exposure is approximately the same as a person receives during two round-trip flights from New York to Los Angeles (because of greater amounts of cosmic radiation at higher altitudes).

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

Results of 1988 monitoring show that SLAPS is in compliance with the DOE radiation protection standard.

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1.0 INTRODUCTION

Environmental monitoring began at the St. Louis Airport Site (SLAPS) in 1984. This report presents the findings of the environmental monitoring program conducted at SLAPS during calendar year 1988. 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, 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. The 1985 Energy and Water Appropriations Act (Public Law 98-360) authorized DOE to acquire 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 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 1984. The on-site groundwater monitoring program, which BNI began performing in October 1983, is a continuation of the the program formerly conducted by Oak Ridge National Laboratory (ORNL). In October 1984 BNI began measuring radon and external gamma radiation levels.

1.1 LOCATION AND DESCRIPTION

SLAPS is an 8.8-ha (21.7-acre) site located in the Cities of Hazelwood and Berkeley, 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 SLAPS, and Figure 1-2 is a photograph of the site.

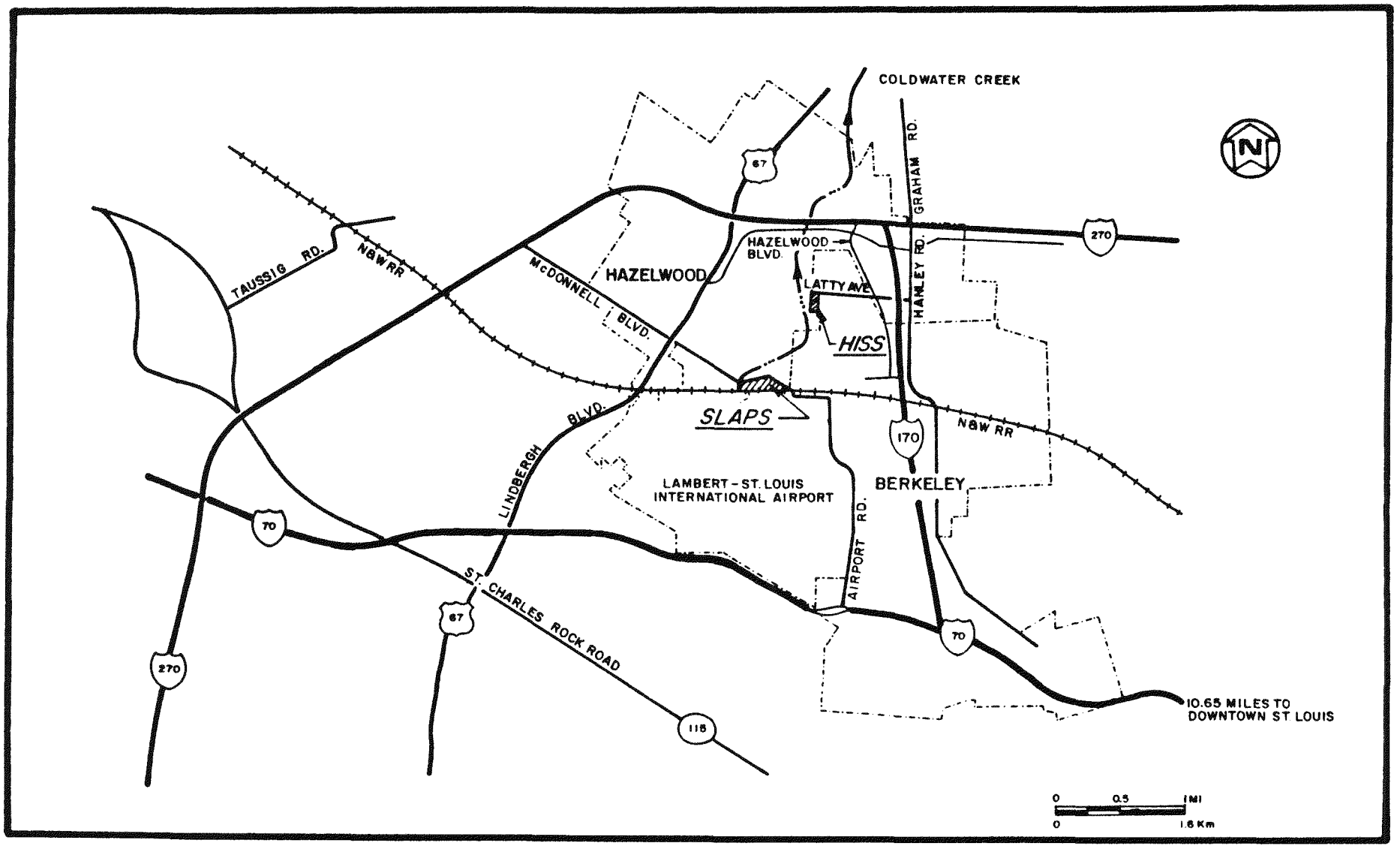


FIGURE 1-1 LOCATION OF SLAPS

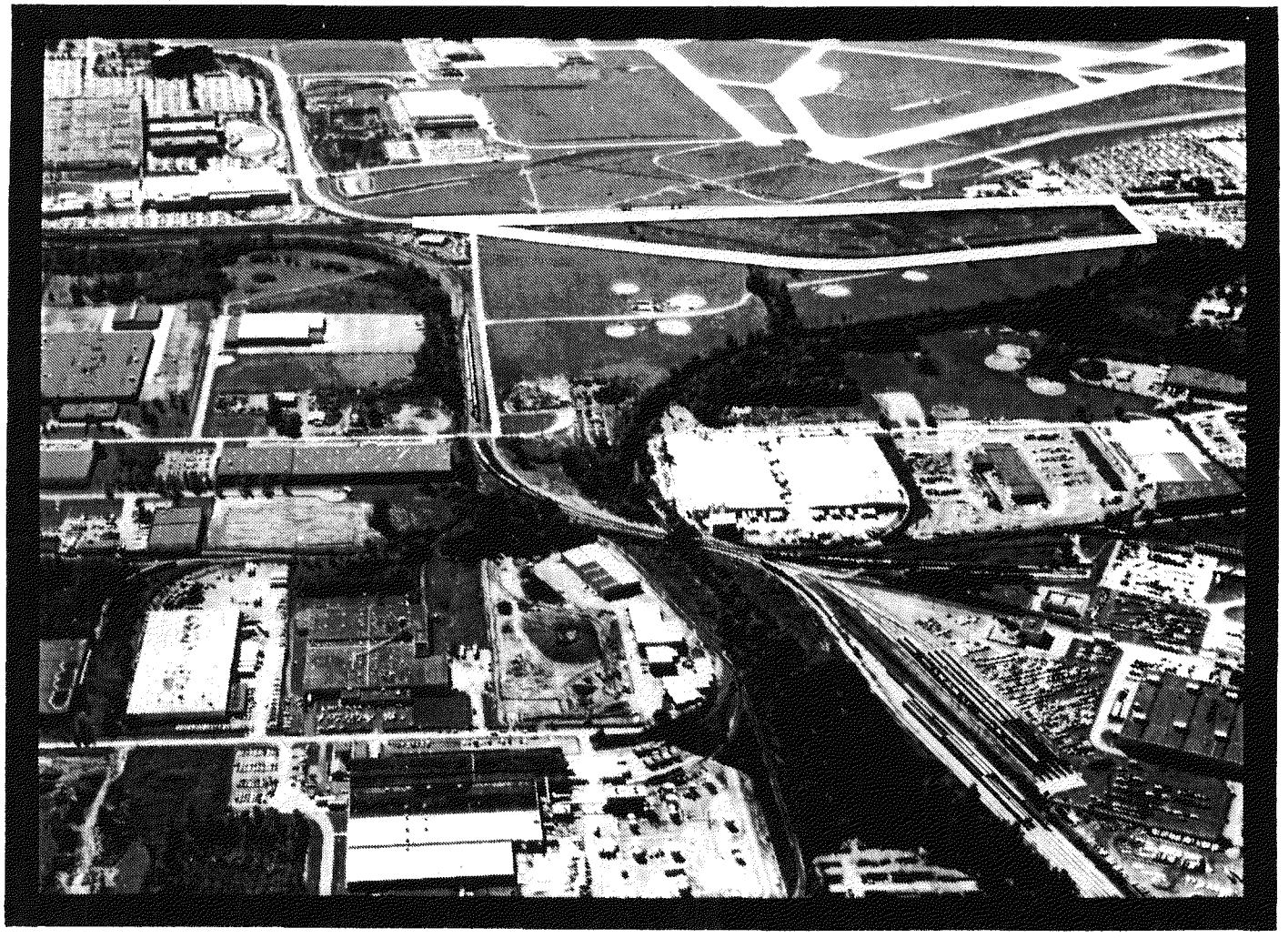


FIGURE 1-2 AERIAL VIEW OF SLAPS AND ITS VICINITY

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 culverts under the Lambert-St. Louis International Airport, flow in Coldwater Creek is influenced by stormwater runoff from the upstream areas of residential, commercial, industrial, and airport land (Ref. 1) (see Figure 3-1).

Rainwater runoff from SLAPS leaves the site by evaporation, seepage into groundwater, or surface drainage to Coldwater Creek. Surface drainage from the site is intercepted by drainage channels along the northern and southern boundaries of the site that direct flow into Coldwater Creek. To halt erosion of the western end of SLAPS, a gabion wall consisting of rock-filled wire baskets was constructed in 1985 along the section of Coldwater Creek bordering the site.

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

Groundwater at SLAPS occurs in two basic systems. The first is the groundwater being monitored at the site as the "upper" and "lower" groundwater systems that occur in unconsolidated glacial sediments and are thought to be hydraulically connected. These groundwater systems yield insufficient quantities of water to wells installed at the site to be considered aquifers. The second basic system is the bedrock aquifer located in Paleozoic limestones several hundred feet beneath the site. The groundwater in the bedrock aquifer is typically of poor quality (Ref. 2), containing more than 1,000 ppm of dissolved solids, and is classified as saline (Ref. 3). In addition, yields from wells in this aquifer are very low, with

reported specific yields of less than 7.6 l/min/m (2 gal/min/ft) of drawdown. There are no plans at present to install monitoring wells in the bedrock aquifer at the site. Groundwater is not generally used for any purpose in the SLAPS area, and the nearest well is about 2.4 km (1.5 mi) north of the site. The water needs for the area are met with treated Mississippi River water.

The climate at 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 (about 1,500 people) is about 1.6 km (1 mi) northwest of the site along Chapel Ridge Drive. 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.

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 SLAPS to store residues resulting from the processing of uranium ores at a facility in St. Louis.

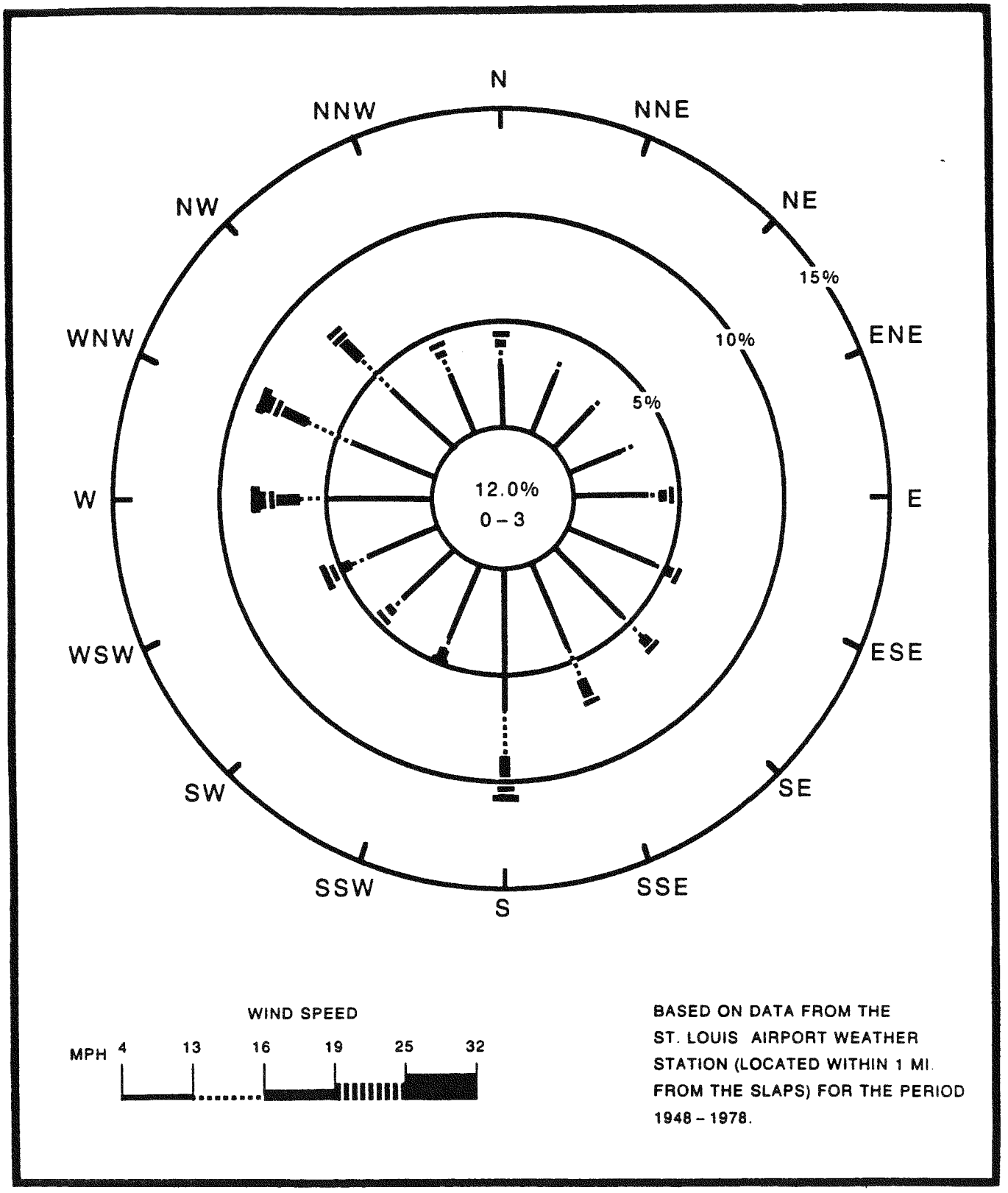
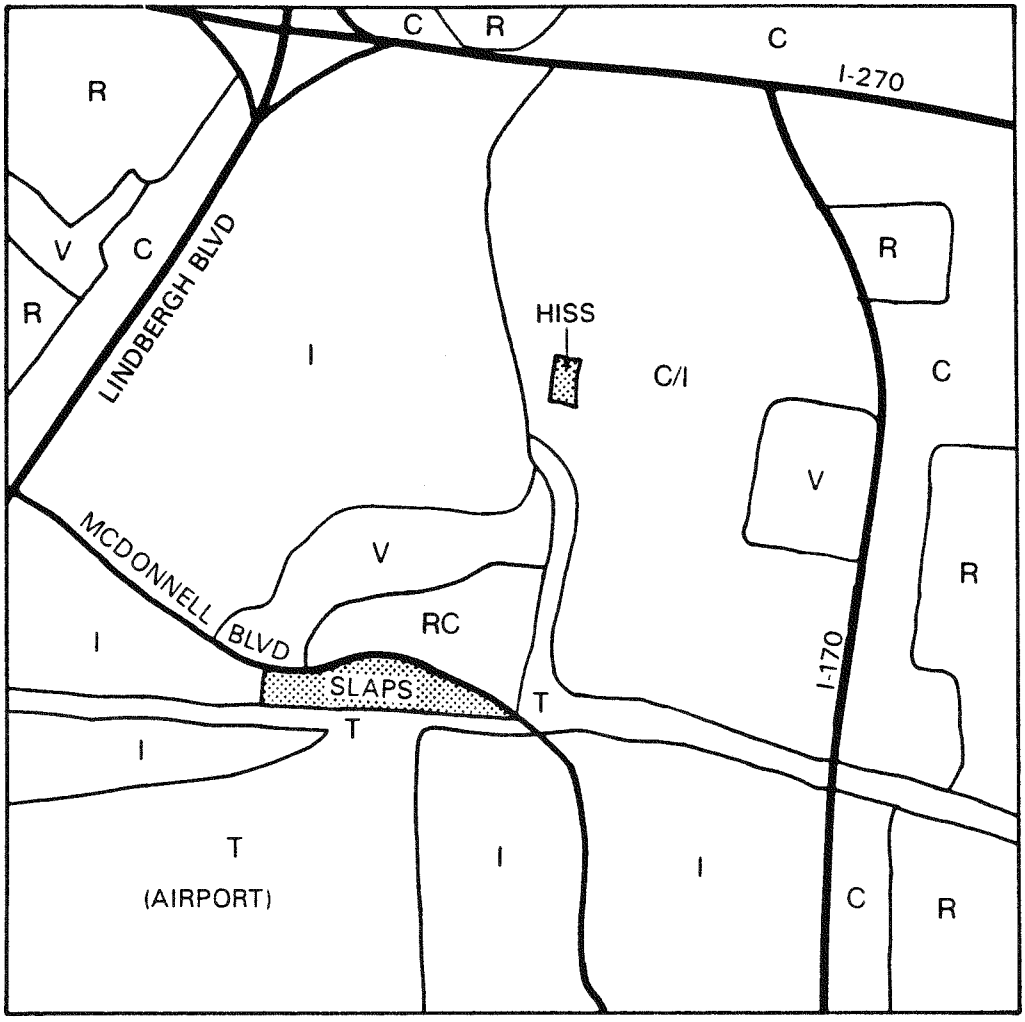


FIGURE 1-3 ANNUAL WIND ROSE FOR SLAPS



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 SLAPS

Uranium processing at this facility was conducted under a contract with MED/AEC until 1957. Processing residues sent to the tract now known as SLAPS 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 AEC to the City of St. Louis, at the City's request. 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, ORNL conducted a radiological investigation of 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 reanalyzed to determine thorium-230 content, and new samples from the ditches and Coldwater Creek were radiologically and chemically analyzed.

Additional radiological characterization and limited geological and chemical characterization of SLAPS were undertaken during 1986 and included installation of 10 groundwater monitoring wells at the site. Radiological characterization was also performed on three properties immediately adjacent to SLAPS: the ball field property north of the site, the railroad bordering the site on the south, and a triangular-shaped area between the SLAPS fence line and McDonnell Boulevard at the eastern end of the site.

There are no continuing commercial or industrial activities at SLAPS; therefore, no radioactive effluents exist at the site.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

This section presents data on the hydrogeology at SLAPS. The interpretations are based on groundwater levels measured in calendar year 1988. An early set of monitoring wells at the site was installed by Roy F. Weston, Inc., in 1981 (Ref. 8). These wells are not used for groundwater level measurements but are used to obtain samples for environmental monitoring. The groundwater monitoring wells where water levels were measured to collect data for this report (Figure 1-5) were installed at SLAPS by BNI in mid-1986 (Ref. 9). Twenty-seven additional wells were installed by BNI in 1988 at the adjacent ball field. The ball field wells nearest to SLAPS supplement the groundwater level monitoring presented in this report and are also shown in Figure 1-5. A summary of well construction information is given in Table 1-1. An example of well construction details is included as Appendix E.

In previous reports the two groundwater systems at SLAPS have been referred to as "shallow" and "deep" (Refs. 8 and 9). In this report the two groundwater systems monitored are designated "upper" and "lower" to be consistent with data being reported for the ball field

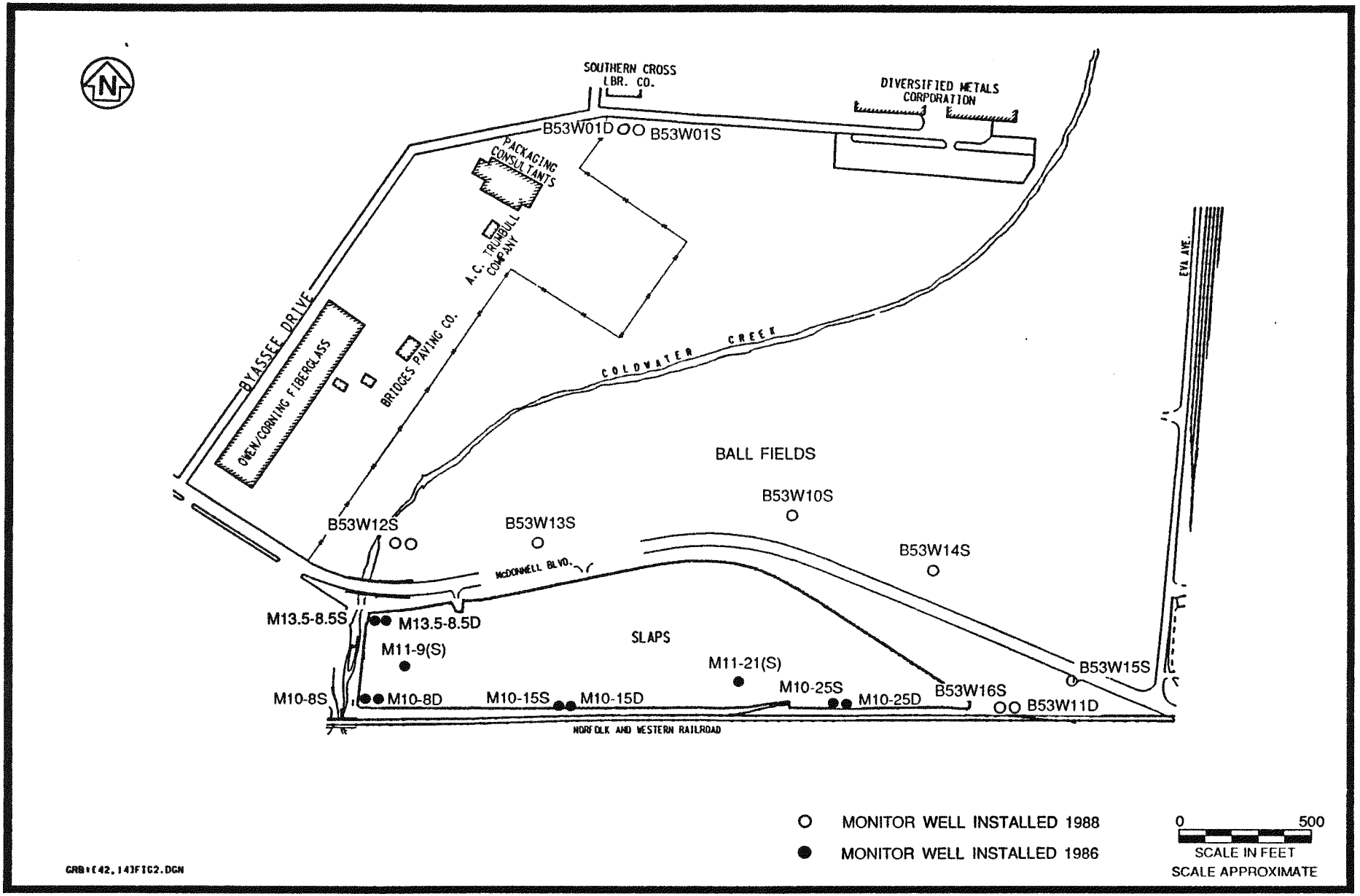


FIGURE 1-5 MONITORING WELL LOCATIONS FOR SLAPS AREA WATER LEVEL MEASUREMENTS

TABLE 1-1

SLAPS MONITORING WELL CONSTRUCTION SUMMARY

Well Number[a]	Completion Date	Total Depth [m (ft)]	Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
A[b]	1979	9.0 (29.5)	No Documentation	PVC[c]
B[b]	1979	8.8 (29.0)	No Documentation	PVC
C[b]	1979	6.7 (22.0)	No Documentation	PVC
D[b]	1979	6.7 (22.0)	No Documentation	PVC
E[b]	1979	6.1 (20.0)	No Documentation	PVC
F[b]	1979	6.7 (22.0)	No Documentation	PVC
B53W10S	Jan. 1988	14.9 (49.0)	12.5-14.0 (40.9-45.9)	Stainless Steel
B53W12S	Jan. 1988	10.7 (35.0)	8.7-10.2 (28.5-33.5)	Stainless Steel
B53W13S	Feb. 1988	9.0 (29.5)	6.3-7.9 (20.8-25.8)	Stainless Steel
B53W14S	Feb. 1988	10.4 (34.0)	6.9-8.4 (22.7-27.7)	Stainless Steel
B53W15S	Jan. 1988	6.6 (21.5)	4.6-6.2 (15.2-20.2)	Stainless Steel
B53W16S	Feb. 1988	7.3 (24.0)	4.8-6.3 (15.8-20.8)	Stainless Steel
M10-15S	July 1986	8.8 (29.0)	4.0-7.4 (14.2-24.2)	Stainless Steel
M10-25S	July 1986	8.2 (27.0)	4.3-7.3 (14.0-24.0)	Stainless Steel
M10-8S	July 1986	8.8 (29.0)	5.8-7.3 (18.9-24.0)	Stainless Steel
M11-21[d]	July 1986	7.0 (23.0)	4.2-5.7 (13.8-18.8)	Stainless Steel
M11-9[d]	July 1986	10.0 (33.0)	5.9-8.9 (19.3-29.3)	Stainless Steel
M13.5-8.5S	July 1986	9.8 (32.0)	5.9-8.9 (19.3-29.3)	Stainless Steel
B53W01S[e]	Nov. 1987	8.4 (27.7)	6.1-7.7 (20.0-25.1)	Stainless Steel
B53W10D	Jan. 1988	25.0 (82.3)	21.7-24.7 (71.1-81.1)	Stainless Steel
B53W11D	Jan. 1988	24.3 (79.8)	20.9-24.0 (68.5-78.5)	Stainless Steel
B53W01D[e]	Nov. 1987	28.5 (93.5)	25.1-28.2 (82.5-92.5)	Stainless Steel

TABLE 1-1

(continued)

Well Number[a]	Completion Date	Total Depth [m (ft)]	Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
M10-15D	July 1986	26.5 (87.1)	24.4-26.0 (80.0-85.0)	Stainless Steel
M10-25D	July 1986	15.8 (52.0)	12.0-13.5 (39.3-44.3)	Stainless Steel
M10-8D	July 1986	22.4 (73.5)	19.6-21.1 (64.4-69.3)	Stainless Steel
M13.5-8.5D	July 1986	22.6 (74.0)	19.6-21.2 (64.4-69.4)	Stainless Steel

[a]Wells designated with an "S" are shallow; wells designated with a "D" are in the lower system.

[b]Wells installed by Roy F. Weston, Inc. Limited information is available; being investigated.

[c]PVC - polyvinyl chloride.

[d]Shallow monitoring wells.

[e]Well used to represent background conditions.

area (Ref. 10). Background information on site geology, hydrogeology, and well installation methods can be found in Refs. 8-10.

Groundwater levels at SLAPS were measured weekly with an electric downhole probe water level indicator.

1.3.1 Upper Groundwater System

The unconfined upper groundwater system occurs in a zone approximately 3.4 to 10.7 m (11 to 35 ft) below the ground surface (Ref. 8). Wells in this zone are screened in unconsolidated glacial materials at depths from 3.4 to 10.1 m (11 to 33 ft) above a clayey aquitard (Ref. 9). Groundwater surface elevations measured in 1988 for each well are shown as hydrographs (Figures 1-6 and 1-7). Precipitation records for the St. Louis area are presented with the hydrographs in Figures 1-6 and 1-7.

The hydrographs for the upper groundwater system show apparent seasonal fluctuations in groundwater levels. The water levels are highest during late winter-early spring, then slowly fall 0.6 to 2.4 m (2 to 8 ft) until the lowest water levels are reached in the fall. Except during December, the changes in water levels correlate from well to well. In December the water levels for wells M10-8S, M13.5-8.5S, and M11-9 dropped, while the rest of the water levels were relatively steady. This behavior may be associated with discharge of shallow groundwater into the Coldwater Creek channel.

Correlation between precipitation and water levels is not consistent. Apparently, minimal recharge occurs at the site.

The slope and flow direction of the upper groundwater system were determined from potentiometric surface maps. (Potentiometric surface is defined as the level to which water will rise in tightly cased wells. Delineation of the potentiometric surface of an aquifer indicates groundwater slope and flow direction.) The dates for the information shown on these two maps (Figures 1-8 and 1-9)

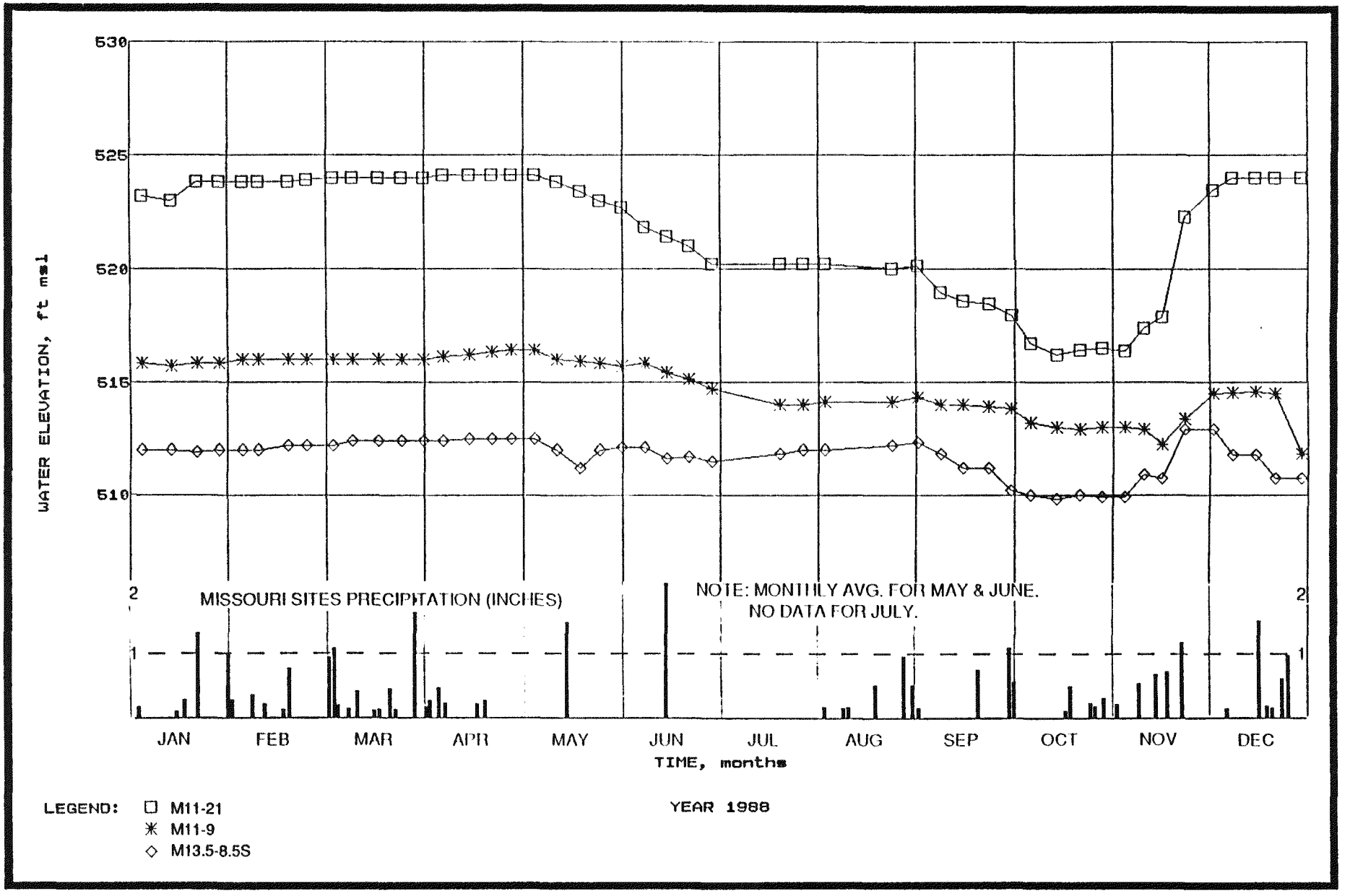


FIGURE 1-6 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM WELLS M11-21, M11-9, AND M13.5-8.5S

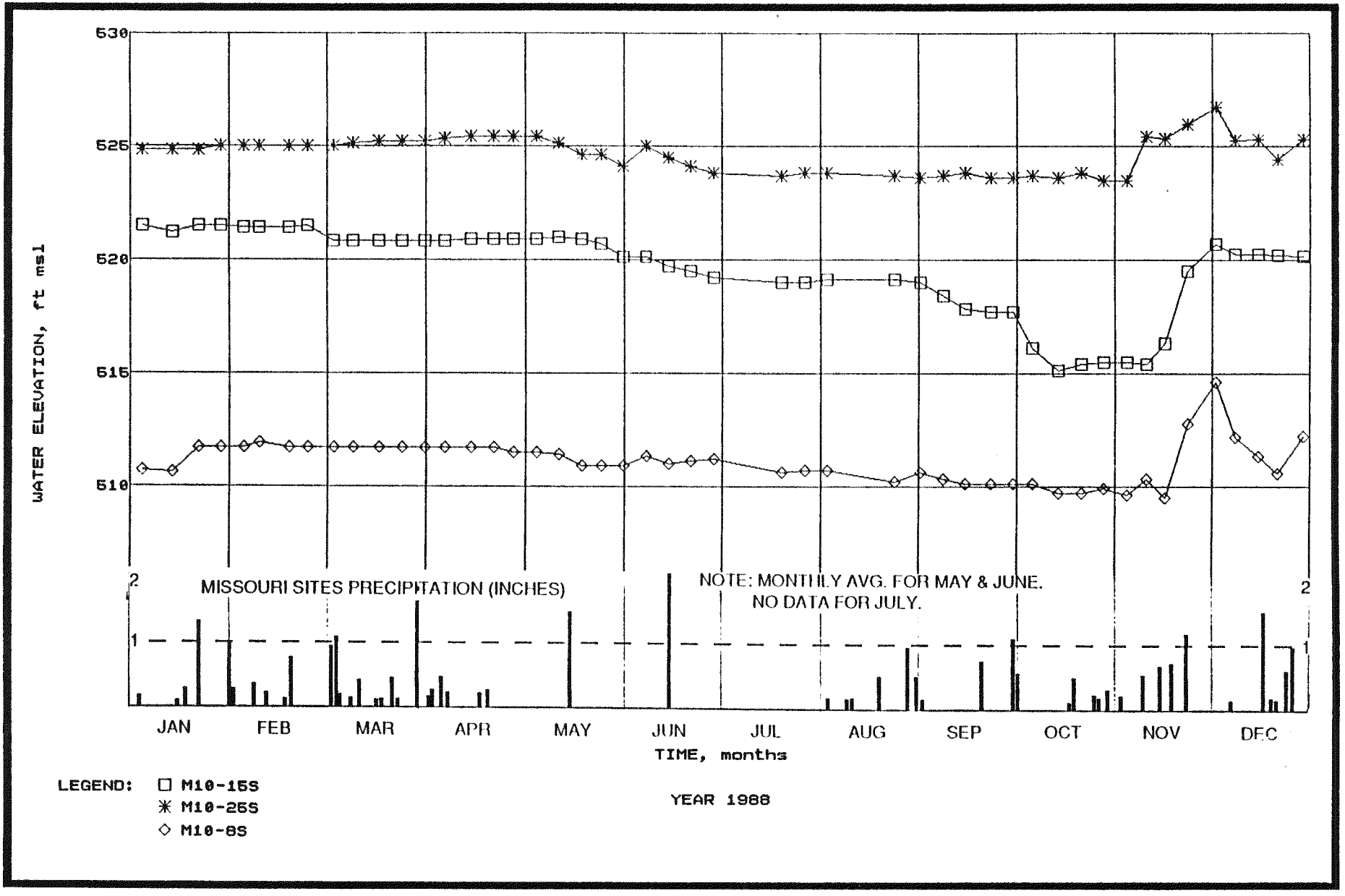


FIGURE 1-7 HYDROGRAPHS OF UPPER GROUNDWATER SYSTEM
WELLS M10-15S, M10-25S, AND M10-8S

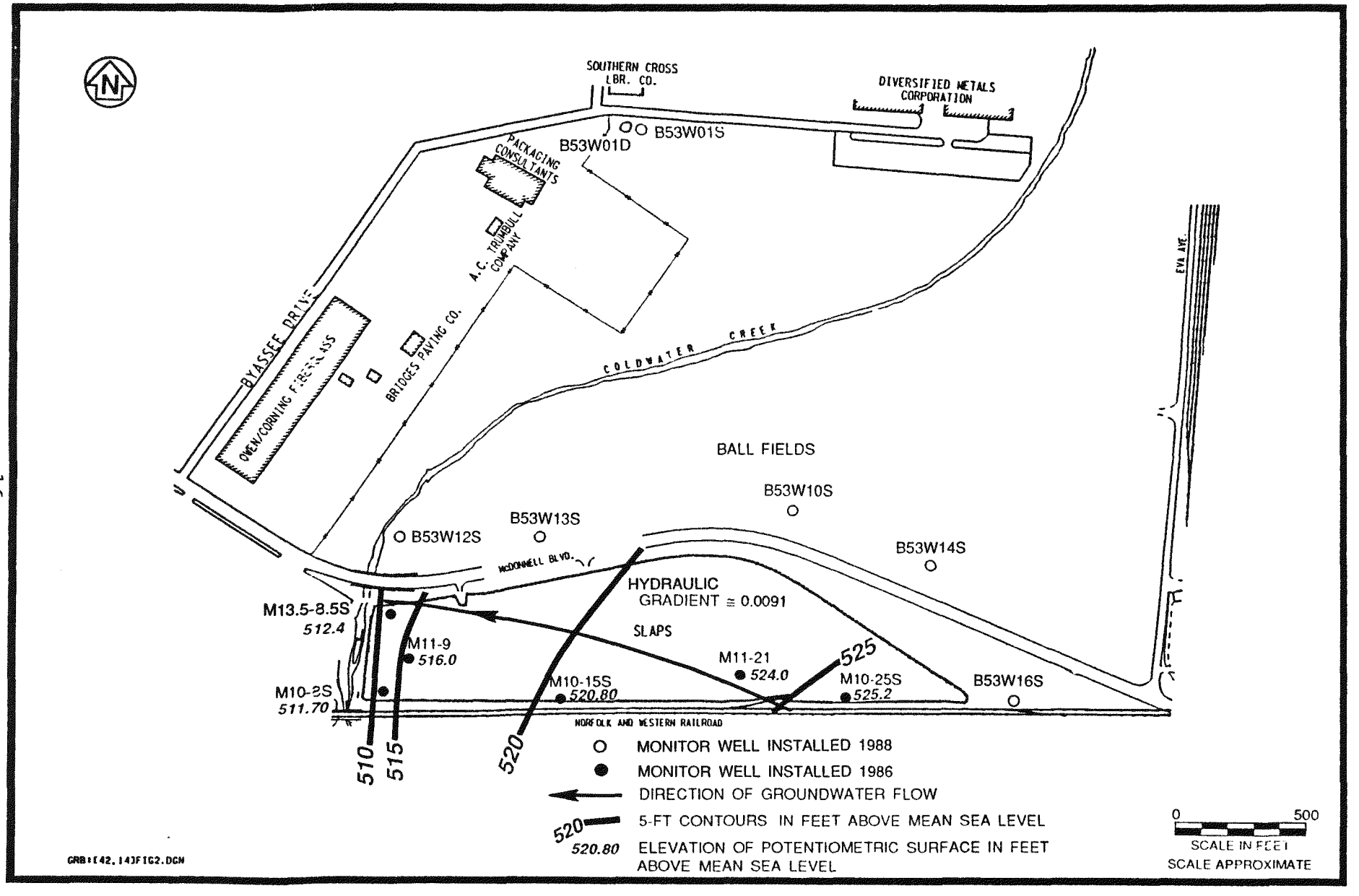


FIGURE 1-8 SLAPS UPPER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE (3/18/88)

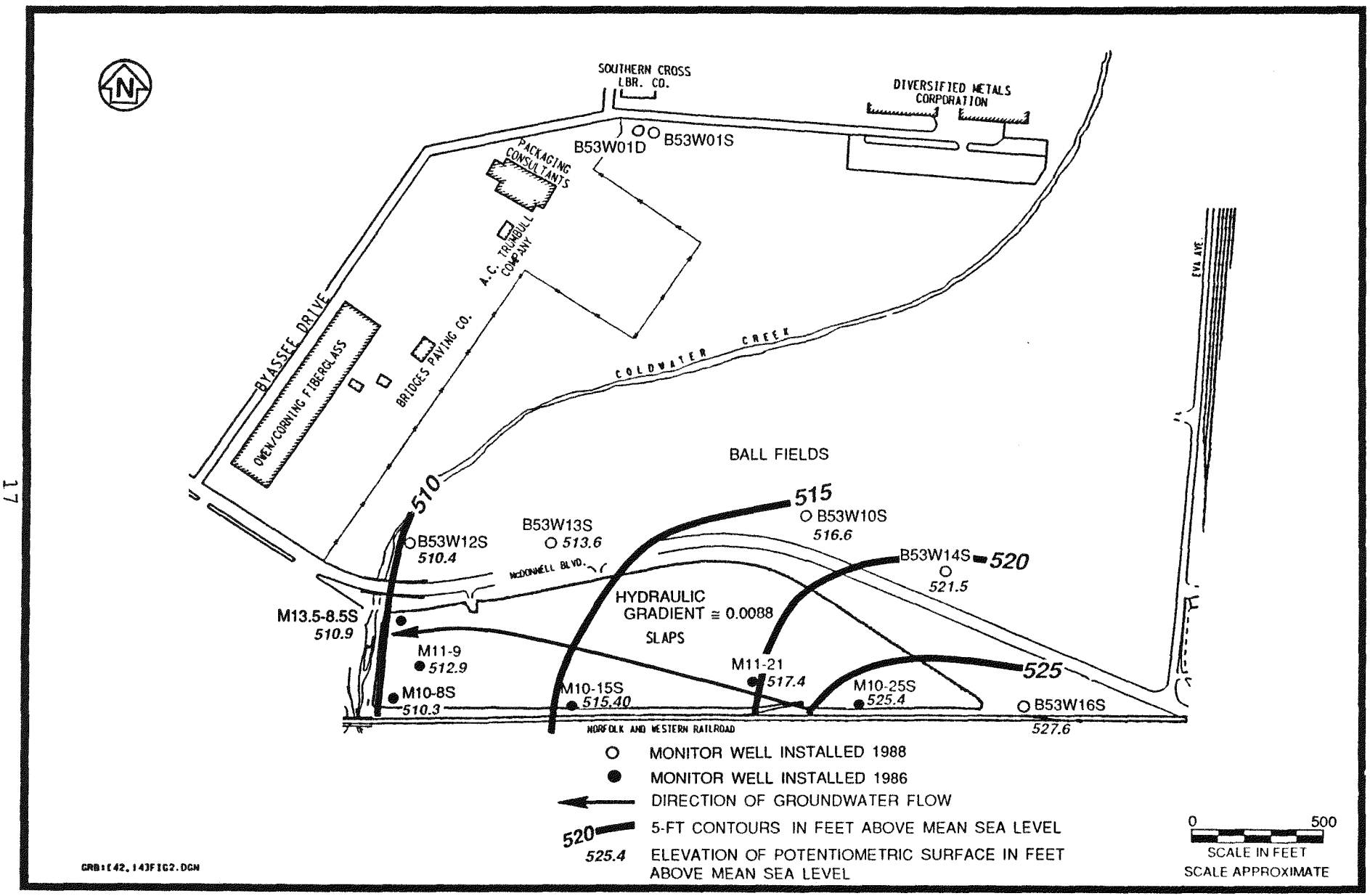


FIGURE 1-9 SLAPS UPPER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE (11/11/88)

were chosen because they represent seasonal high and low water level periods and are the same dates used to prepare potentiometric surface contour maps for the adjacent ball field area characterization report (Ref. 10). The groundwater flow direction is generally east to west. The contours suggest a flow direction approximately parallel to the site topography (Ref. 8, p. 4-3) with discharge into Coldwater Creek. The hydraulic gradient for both dates is on the order of 0.009.

1.3.2 Lower Groundwater System

The lower groundwater system is located in the glacial sediments below the clayey aquitard and above bedrock (Ref. 9), approximately 10.7 to 26.5 m (35 to 87 ft) below the ground surface. The lower system wells are screened at depths ranging from 11 to 26.5 m (36 to 87 ft). Hydrographs of wells monitoring the lower groundwater system are shown in Figure 1-10. Precipitation records for the St. Louis area collected at the St. Louis Airport are also shown on the hydrographs.

The hydrographs for the lower system (Figure 1-10) show little seasonal variation of water levels. Water levels in wells M10-15D and M10-25D show a slow but steady drop amounting to almost 0.9 m (3 ft) over the course of the year. Well M13.5-8.5D water levels fluctuated 2.4 m (8 ft) during September-October and the year-end level declined 5 ft in 1988, as did those of M10-15D and M10-25D. Water levels in M10-8D rose during 1988, except for the last measurement. The reason for the inconsistent behavior of the lower system wells is not known, but the overall effect of this behavior on hydraulic gradient and flow direction is minimal. Correlation of the water levels with the precipitation record is inconsistent.

Hydraulic gradient and flow direction for the lower groundwater system were determined using two potentiometric surface contour maps (Figures 1-11 and 1-12) from the water level measurements for the same dates as those for Figures 1-8 and 1-9. The potentiometric surface maps show a consistent flow direction from east to west,

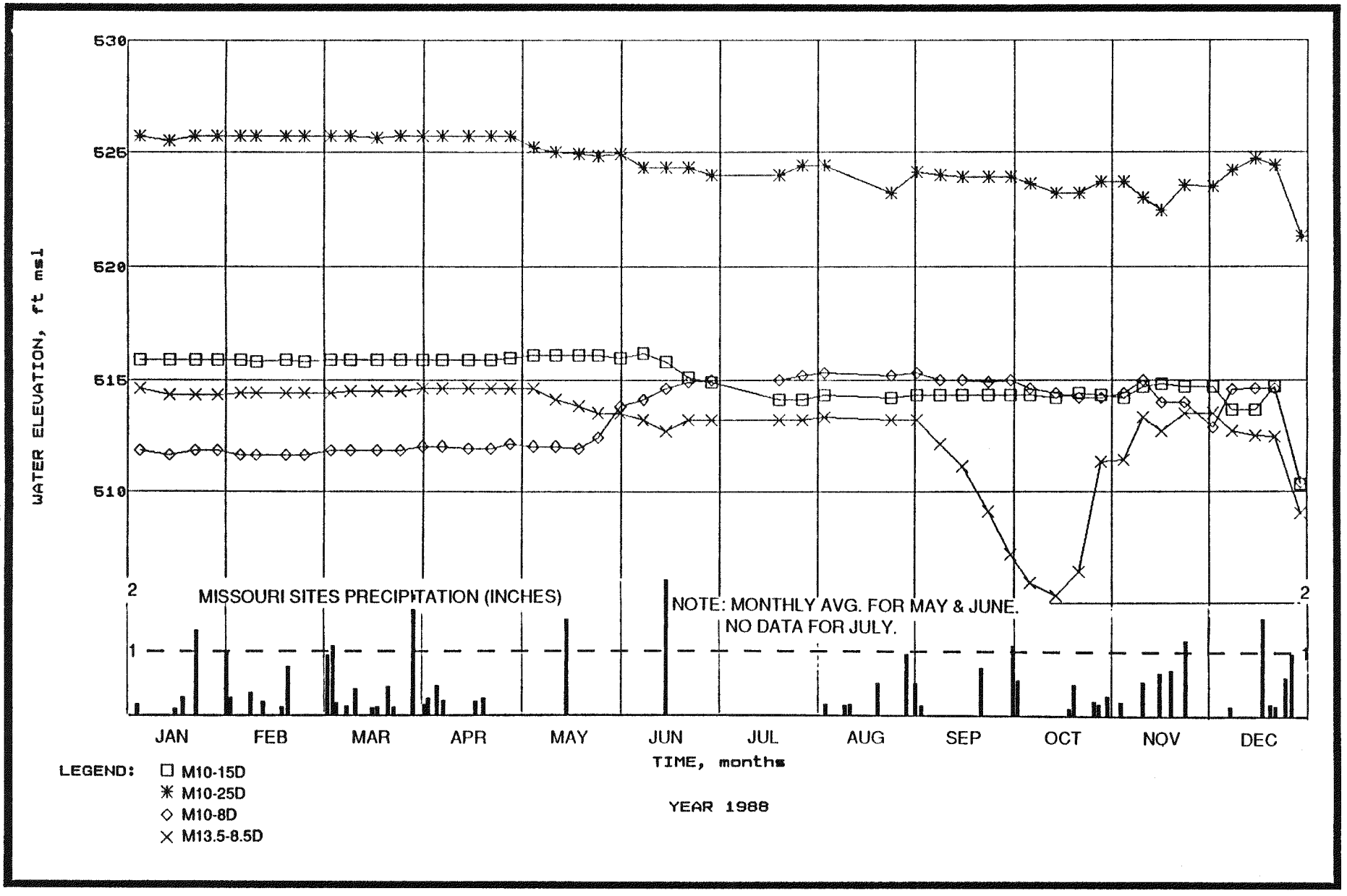


FIGURE 1-10 HYDROGRAPHS OF LOWER GROUNDWATER SYSTEM
WELLS M10-15D, M10-25D, M10-8D, AND M13.5-8.5D

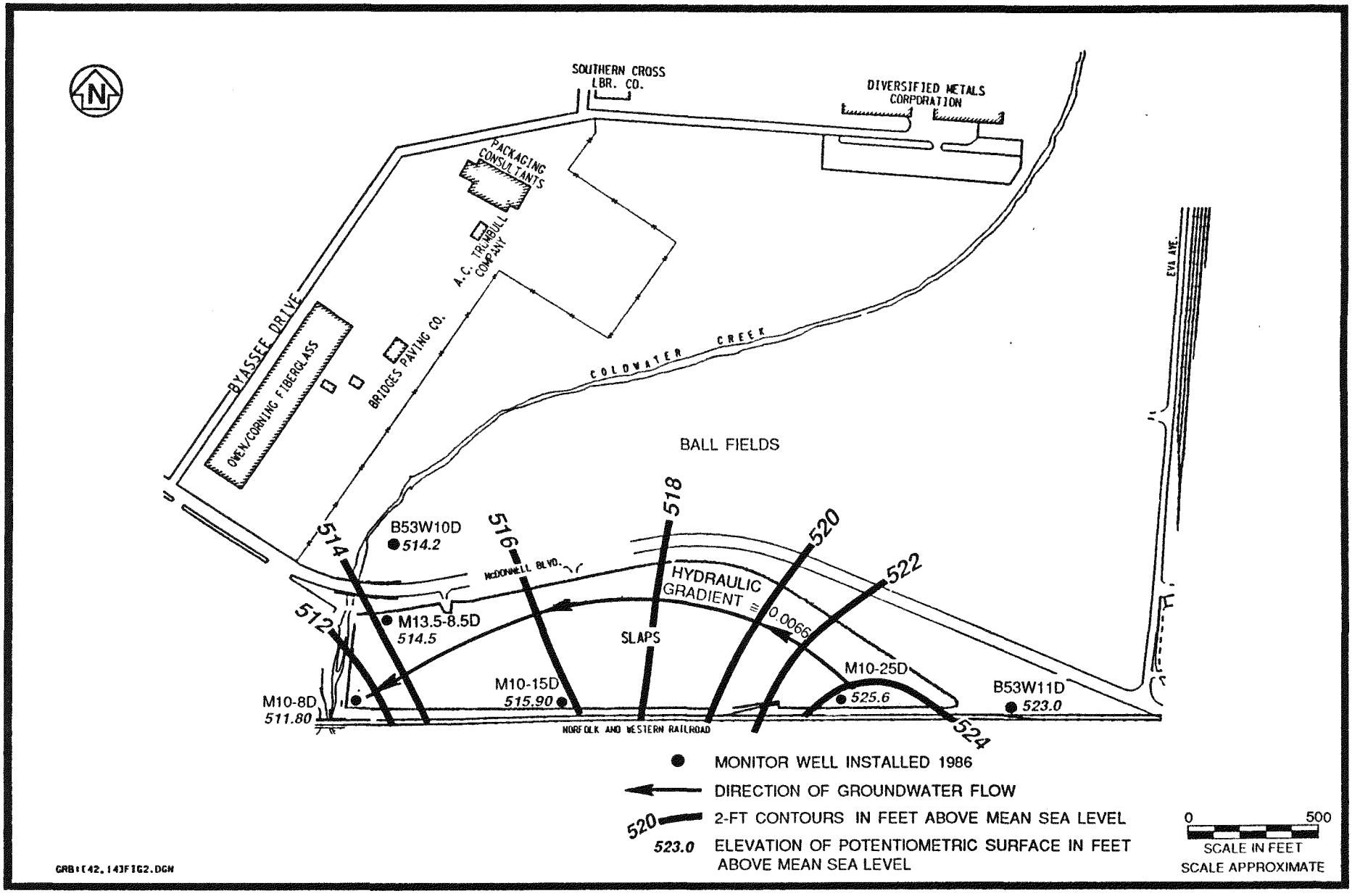


FIGURE 1-11 SLAPS LOWER GROUNDWATER SYSTEM POTENTIOMETRIC SURFACE (3/18/88)

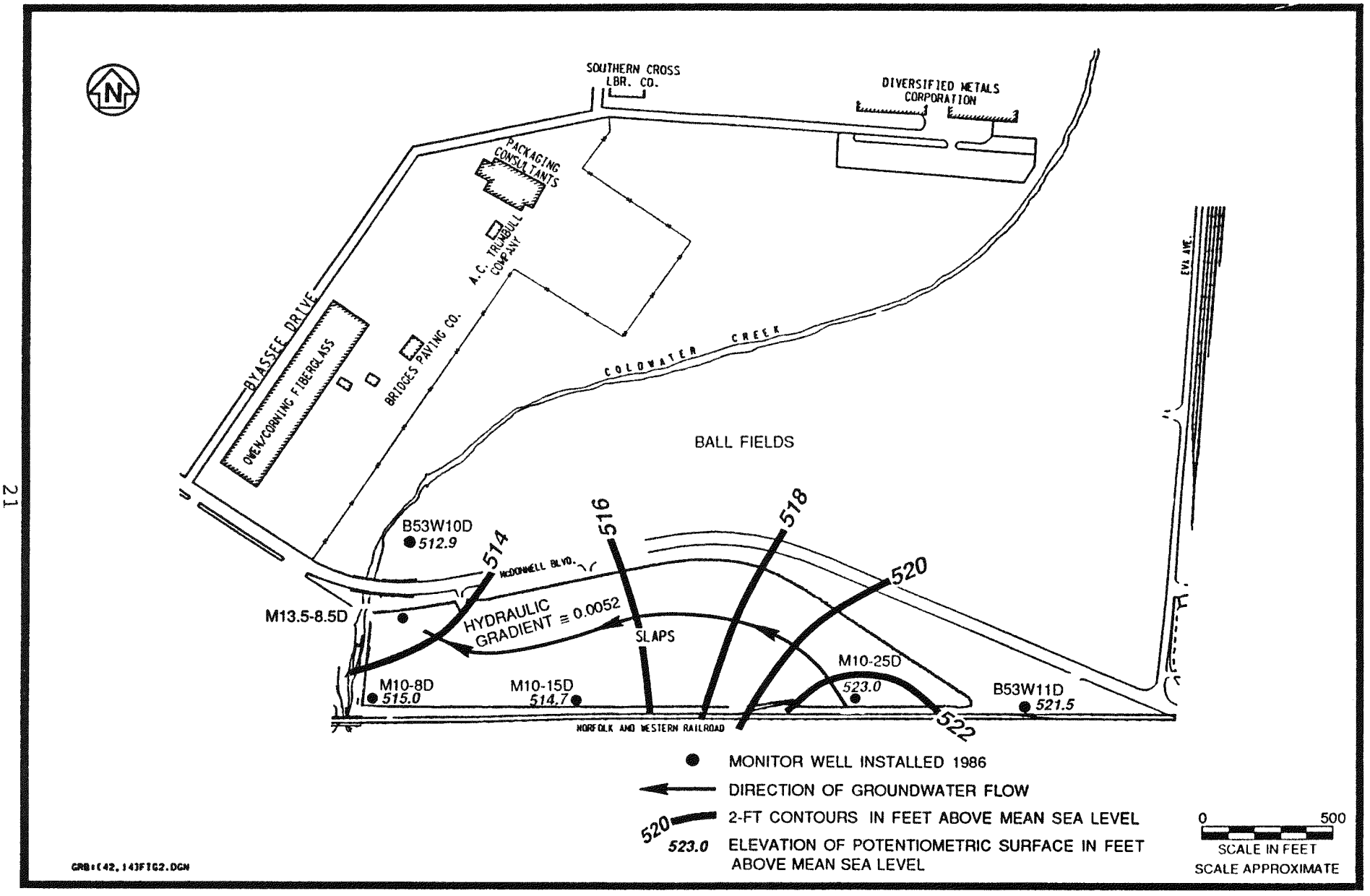


FIGURE 1-12 SLAPS LOWER GROUNDWATER SYSTEM
POTENTIOMETRIC SURFACE (11/11/88)

with a hydraulic gradient ranging from 0.0052 to 0.0066. The behavior of wells M10-8D and M13.5-8.5D discussed above has little effect on the gradient shown. On 3/18/88 the flow direction is toward M10-8D, and on 11/11/88 it is toward M13.5-8.5D.

1.3.3 Conclusions

Both the upper and lower groundwater systems have a hydraulic gradient with a direction of flow from east to west. The upper system has a hydraulic gradient of approximately 0.009 and the lower system has a hydraulic gradient of approximately 0.006.

2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program at SLAPS, which began in 1984, continued in 1988; 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. 11). The potential radiation dose that might be received by a hypothetical maximally exposed individual was calculated to determine whether the site was in compliance with the DOE radiation protection standard.

Annual average radon concentrations (including background) ranged from 7×10^{-10} to 2.1×10^{-9} µCi/ml (0.7 to 2.1 pCi/l) (see Subsection 3.1). The average background level in 1988 ranged from 4×10^{-10} to 5×10^{-10} µCi/ml (0.4 to 0.5 pCi/l). Radon levels have risen steadily at only one location since the monitoring program began (see Subsection 3.6.1) (Refs. 12-15).

Average external gamma radiation levels measured at the SLAPS boundary ranged from 38 to 2,128 mR/yr above background, which was 73 mR/yr in 1988. 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 4×10^{-9}, 5×10^{-10}, and 3×10^{-10} µCi/ml (4, 0.5, and 0.3 pCi/l), respectively (see Subsection 3.3.1). These values are approximately the same as the background concentrations measured upstream of SLAPS. Measured concentrations of the radionuclides in surface water at SLAPS have remained relatively consistent since 1984 (see Subsection 3.6.3) (Refs. 12-15).

The highest annual average uranium concentration in groundwater was 5.59×10^{-6} µCi/ml (5,590 pCi/l). The highest average radium-226 concentration was 9×10^{-10} µCi/ml (0.9 pCi/l), and the highest average thorium-230 concentration was 5.2×10^{-8} µCi/ml (52 pCi/l) (see Subsection 3.3.2). The elevated uranium value

occurred in well B, and the elevated thorium-230 value was in well M11-21. Both wells are in an area of known contamination. Concentrations of radionuclides in surface water and most of the groundwater at SLAPS may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D. When compared with the lowest annual average uranium concentration in groundwater [$<3 \times 10^{-9}$ μCi/ml (<3 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 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 discharge to Coldwater Creek is monitored as part of the surface water monitoring program. Current indications are that this transport pathway has not resulted in degradation of surface water quality.

In sediments collected downstream from the site, the annual average concentration was 2.6 pCi/g for total uranium, 1.0 pCi/g for radium-226, and 5.4 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. As a point of reference, the observed concentrations may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

The potential radiological dose that could be received by a hypothetical maximally exposed individual was calculated. This hypothetical individual is one who is assumed to have been adjacent to the site and who walked the northern fence line of the site twice a day, five days a week. The maximum exposure for this individual would be 7.5 mR/yr above background. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 7.5 percent of the DOE radiation protection standard.

The cumulative dose to the population within an 80-km (50-mi) radius of SLAPS that would result from radioactive materials present at the

site is indistinguishable from the dose the same population receives from naturally occurring radioactive sources.

Analytical results for chemicals are summarized in Subsection 4.1. Currently, no environmental permits are required for the site.

Results of 1988 monitoring show that SLAPS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1988 environmental monitoring at SLAPS (Ref. 16). It also describes 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 that include minimum and maximum values recorded, number of data points collected, and average values. 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 statistical analyses 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 to be equal to the limit of sensitivity and the average value is reported without the "less than" notation. If more than one value is less than the limit of sensitivity, the "less than" notation is used.

During 1988, 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.

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 1988 to allow for comparisons of data and identification of trends in monitoring results.

3.1 RADON SAMPLING

Nine radon detectors are maintained along the site boundary, spaced so as to ensure adequate detection capability under most atmospheric conditions. The locations of the radon monitors are shown in Figure 3-1. Three background detectors are maintained off-site.

Radon concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which radon can diffuse. Radon will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, it will equilibrate with radon in the outside air. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. When returned to Terradex for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification, the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm^2) is related through calibration to the concentration of radon in air. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling location and return the exposed monitors to Terradex for analysis.

Table 3-1 reports the radon concentrations measured at the nine monitoring locations. The annual average concentrations ranged from 7×10^{-10} to 2.1×10^{-9} µCi/ml (0.7 to 2.1 pCi/l). Background concentrations ranged from 4×10^{-10} to 5×10^{-10} µCi/ml (0.4 to 0.5 pCi/l) and have not been subtracted. Based on measured radon concentrations at 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 1988, see Subsection 3.6.1.

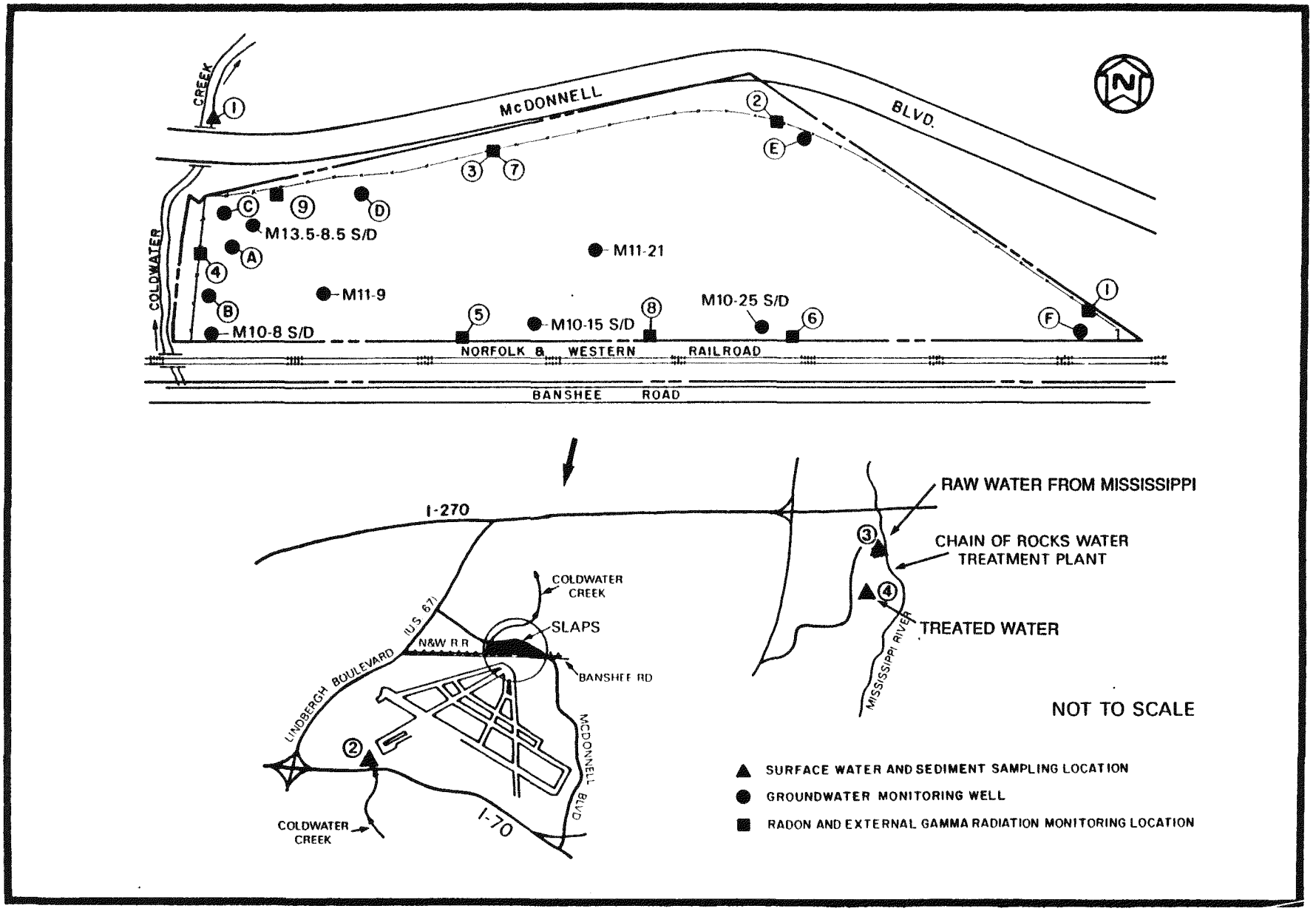


FIGURE 3-1 SLAPS ENVIRONMENTAL MONITORING LOCATIONS

TABLE 3-1

CONCENTRATIONS OF RADON-222 AT SLAPS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
1	4	0.3	2.9	1.1
2	4	0.5	1.7	1.2
3	4	0.7	1.5	1.0
4	4	0.6	1.2	1.0
5	4	0.7	4.6	2.1
6	4	0.5	1.0	0.8
7[d]	4	0.4	1.1	0.7
8	4	0.5	2.9	1.8
9	4	0.4	2.0	1.0
Background				
16[e]	4	0.3	0.6	0.4
17[f]	2	0.4	0.4	0.4
18[g]	2	0.3	0.7	0.5

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

[b]Background has not been subtracted. Note that some locations have radon concentrations below background.

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

[d]Location 7 is a quality control for Location 3.

[e]Located in Florissant, MO, 26 km (16 mi) northeast of SLAPS.

[f]Located at McDonnell Blvd., 0.8 km (0.5 mi) east of SLAPS. Established in April 1988.

[g]Located in St. Charles County, MO, approximately 32 km (20 mi) southwest of SLAPS. Established in April 1988.

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.

External gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs). Beginning in 1988, the system of measurement utilizes tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to the tissues of the body at a depth of 1 cm. This dosimetry system offers advantages in accuracy and sensitivity that were not available with the system used previously.

Each dosimetry station contains a minimum of four dosimeters, which are exchanged after one year of accumulated exposure. For example, a dosimeter placed in the station in October 1987 would be removed in October 1988. Each dosimeter contains five individual LiF chips (each group of which was preselected on the basis of having a reproducibility of ± 3 percent across a series of laboratory exposures), the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). The average value is then corrected for the shielding effect of the shelter housing (approximately 8 percent) and for the effect of fade.

Fade is the loss of dose information brought about by environmental effects, primarily high summer temperatures. Fade is determined by collocating dosimeters that have been exposed to a known level of radiation (called a spike) before they are placed at a minimum of two stations, generally on the eastern and western boundaries of a site. The fade factor can be determined by subtracting the station radiation value from the fade control dosimeter radiation value followed by dividing by the known spike level. The corrected value is then converted to milliroentgens per year by dividing by the number of days of exposure and subsequently multiplying by 365 days.

Some differences in external gamma radiation values may be noted in the 1988 data in comparison with the 1987 values. The current measurement system is more sensitive to low radiation levels and more accurate in its resolution than the system used previously. Therefore, some stations that previously demonstrated no measurable external gamma radiation value in excess of background now exhibit a small measurable value. Similarly, at some other stations values are higher or lower because of the improved method of measurement, not because of deterioration of site conditions or remedial action.

The results of the measurements for external gamma radiation are presented in Table 3-2. Annual radiation levels ranged from 38 to 2,128 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. The elevated level is due to this station's proximity to a ditch that is located between the site fence and McDonnell Boulevard (Ref. 7). 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 1988 was 129 mR/yr above background. The annual average background radiation level was 73 mR/yr. For comparisons of external radiation levels measured from 1984 through 1988, see Subsection 3.6.2.

The background external gamma radiation value for a given location is not a static constant. Because the background radiation value is a combination of both natural terrestrial sources and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil can affect the value measured. Independent of the placement of the detector at the Earth's surface are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 17).

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT SLAPS, 1988

Sampling Location[a]	Number of Measurements	Radiation Level (mR/yr)[b] Minimum	Maximum	Average
1	4	30	56	47
2	4	1898	2229	2128
3[c]	4	81	122	101
4	4	16	48	38
5	4	17	70	45
6	4	24	53	43
7[c]	4	77	167	129
8[d]	4	21	49	38
9	4	88	183	129
Background[e]				
16[f]	4	63	86	73

[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.

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

[d]Location 8 was moved in April 1987.

[e]In April 1988, background detectors were installed at McDonnell Blvd., 0.8 km (0.5 mi) east of SLAPS, and in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS. Because the instruments have been in place for less than 1 year, data will not be reported until 1989.

[f]Located in Florissant, MO, 26 km (16 mi) northeast of SLAPS.

Because of these factors, the background radiation level is not constant from one location to another even over a short time. Thus it is not abnormal for some stations at the boundary of a site to have an external gamma radiation value less than the background level measured some distance from the site.

In April 1988, additional background monitoring locations were established at the Federal Aviation Administration Building, located 0.5 mi east of SLAPS at McDonnell Blvd., and at St. Charles County Airport, located approximately 32 km (20 mi) southwest of SLAPS in St. Charles County. Because the 6 months of exposure time is not representative of the yearly fluctuations in background that occur because of seasonal weather variations, data from these locations will not be reported until 1989.

3.3 WATER SAMPLING

During 1988, 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 intersection of 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 and 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 sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.) Thorium-230 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

The results of analyses 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 SLAPS were nearly equal to the 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 1988, see Subsection 3.6.3.

3.3.2 Groundwater

During 1988, groundwater samples were collected quarterly from 16 on-site wells. Samples were collected by a hand bailer after the wells had been pumped dry or three well casing volumes had been removed and ample time had been allowed for well recharge. 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 thorium-230 using the methods applied to surface water analyses (see Subsection 3.3.1).

Results of analyses for concentrations of total uranium, radium, and thorium in groundwater are presented in Table 3-4. Averages for radium-226 ranged from 3×10^{-10} to 9×10^{-10} μCi/ml (0.3 to 0.9 pCi/l). For thorium-230, averages ranged from

TABLE 3-3

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SURFACE WATER IN THE VICINITY OF SLAPS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
1	4	<3	5	4
2[d]	4	<3	5	4
3	3[e]	3	5	4
4	3[e]	3	3	3
Radium-226				
1	4	0.2	0.4	0.3
2[d]	4	0.2	1.3	0.5
3	3[e]	0.1	0.4	0.3
4	3[e]	0.1	0.3	0.2
Thorium-230				
1	4	0.1	0.5	0.3
2[d]	4	<0.1	0.2	0.1
3	3[e]	0.3	0.4	0.3
4	3[e]	<0.1	0.1	<0.1

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

[b]1 x 10^{-9} µCi/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]Location is upstream of the site and acts as background. Background values have not been subtracted.

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

TABLE 3-4

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN GROUNDWATER AT SLAPS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Total Uranium				
Well A	4	1535	1870	1700
Well B	4	5340	6670	5590
Well C	4	11	24	18
Well D	4	62	800	475
Well E	4	127	293	197
Well F	4	160	367	265
Well M10-25S	4	12	63	39
Well M10-25D	4	<3	5	4
Well M11-21	4	61	100	73
Well M10-15S	4	8	11	9
Well M10-15D	4	3	6	5
Well M10-8S	4	10	27	19
Well M10-8D	4	<3	5	4
Well M11-9	4	4135	5000	4620
Well M13.5-8.5S	4	<3	5	4
Well M13.5-8.5D	4	<3	<3	<3
Background				
Well B53W01S	2[d]	<3	4	3
Well B53W01D	2[d]	<3	5	4
Radium-226				
Well A	4	0.2	0.8	0.4
Well B	4	0.4	0.8	0.6
Well C	4	0.4	0.6	0.5
Well D	4	0.2	0.4	0.3
Well E	4	0.2	1.1	0.6
Well F	4	0.4	0.7	0.6
Well M10-25S	4	0.2	0.7	0.6
Well M10-25D	4	0.2	0.6	0.4
Well M11-21	4	0.5	1.1	0.7
Well M10-15S	4	0.3	1.3	0.8
Well M10-15D	4	0.6	1.1	0.9
Well M10-8S	4	0.3	0.9	0.5
Well M10-8D	4	0.3	0.8	0.6
Well M11-9	4	0.4	1.2	0.8
Well M13.5-8.5S	4	0.5	1.4	0.8
Well M13.5-8.5D	4	0.4	0.7	0.6

TABLE 3-4

(continued)

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Radium-226 (continued)				
Background				
Well B53W01S	2[d]	0.3	0.8	0.6
Well B53W01D	2[d]	1.0	1.1	1.1
Thorium-230				
Well A	4	1.1	4.9	2.8
Well B	4	1.3	3.2	2.0
Well C	4	<0.1	0.4	0.3
Well D	4	0.4	1.3	0.9
Well E	4	0.2	14.0	4.8
Well F	4	1.1	3.0	2.0
Well M10-25S	4	0.2	0.6	0.4
Well M10-25D	4	0.2	0.9	0.5
Well M11-21	4	8.0	130.0	52.0
Well M10-15S	4	1.3	17.0	5.3
Well M10-15D	4	0.1	4.5	1.3
Well M10-8S	4	0.2	1.1	0.5
Well M10-8D	4	0.1	0.6	0.3
Well M11-9	4	0.3	2.6	1.0
Well M13.5-8.5S	4	0.2	1.1	0.7
Well M13.5-8.5D	4	0.2	0.9	0.7
Background				
Well B53W01S	2[d]	0.1	0.2	0.2
Well B53W01D	2[d]	0.2	0.2	0.2

[a]Sampling locations are shown in Figure 3-1. Background locations are shown in Figure 1-5 as W01D and W01S.

[b]1 x 10^{-9} µCi/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]New wells; first sampled in July 1988. Located at Byassee Drive, approximately 0.8 km (0.5 mi) northwest of SLAPS.

3×10^{-10} to 5.2×10^{-8} μCi/ml (0.3 to 52 pCi/l). Averages for total uranium in groundwater ranged from $<3.0 \times 10^{-9}$ to 5.59×10^{-6} μCi/ml (<3 to 5,590 pCi/l).

Concentrations of total uranium in several of the shallow wells at SLAPS are high because the wells are located in areas of known subsurface contamination. However, because 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 discharge to Coldwater Creek is monitored as part of the surface water monitoring program. Current indications are that this potential transport pathway 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.

For a discussion of the comparisons of radionuclide concentrations in groundwater measured from 1984 through 1988, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

During 1988, samples consisting of approximately 500 g of sediment (1.1 lb) were collected off-site at surface water sampling Locations 1 and 2 (Figure 3-1). TMA/E analyzed the samples for total uranium, radium-226, and thorium-230. Total uranium concentrations were 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-226, and thorium-230 (based on dry weight) are presented in Table 3-5. The annual average concentration of total uranium, radium-226, and thorium-230 at the downstream sampling location was 2.6, 1.0, and 5.4 pCi/g, respectively. These concentrations of radium-226 are lower than background concentrations measured at upstream Location 2. Total

TABLE 3-5

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SEDIMENT IN THE VICINITY OF SLAPS, 1988

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Radium-226				
1	4	0.9	1.1	1.0
2	4	1.0	1.9	1.5
Thorium-230				
1	4	2.7	8.0	5.4
2	4	0.4	3.3	1.3
Uranium-234				
1	4	1.1	1.3	1.2
2	4	0.8	1.0	0.9
Uranium-235				
1	4	<0.1	0.1	<0.1
2	4	<0.1	<0.1	<0.1
Uranium-238				
1	4	1.2	1.3	1.3
2	4	0.6	0.8	0.7
Total Uranium[b]				
1	4	2.4	2.7	2.6
2	4	1.5	1.9	1.7

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

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

uranium concentrations at Location 2 are slightly higher than at downstream Location 1. The average thorium-230 concentration at Location 1 is higher than that at Location 2. For reference, these concentrations may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

3.5 RADIATION DOSE

To assess the environmental significance of possible release of radioactivity from materials stored at SLAPS, radiological exposure pathways were evaluated to calculate the potential dose to a hypothetical maximally exposed individual. This individual is one who is assumed to be adjacent to the site and who, when all potential routes of exposure are considered, receives the greatest dose. An appraisal of potential pathways (exposure to external radiation, ingestion of water, and inhalation of radon) suggested that external gamma radiation was the only plausibly significant exposure mode.

The dose from ingesting groundwater or surface water from sources on SLAPS property was not calculated because it was considered unrealistic that ingestion of this water could occur. 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. To consume groundwater from a well at SLAPS, the trespasser would have to be equipped with a means of removing the well cap (which is locked), 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 the Maximally Exposed Individual

To identify the individual in the vicinity of 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 to the public. From these calculations, it was determined that the highest overall dose would be received by an individual who walked daily along the northern site boundary. Because the area adjacent to 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 walked at a rate of 4.8 km/h (3 mph) along the 0.8-km (0.5-mi) northern site boundary and during this period was exposed to an average of the annual exposure rates observed at Locations 1, 2, and 3.

The external exposure to this individual would be 7.5 mR/yr above background. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 7.5 percent of the DOE radiation protection standard of 100 mrem/yr and is approximately equal to the exposure a person would receive during two round-trip flights from Los Angeles to New York as a result of the greater amounts of cosmic radiation at higher altitudes (see Appendix D). This scenario is highly conservative in that it is unlikely that any individual would spend so much time at this location. A more realistic assessment of the use of the site would demonstrate that the incremental dose is less than 1 mrem/yr.

3.5.2 Dose to the Population in the Vicinity of SLAPS

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 SLAPS, these pathways are direct exposure to gamma radiation, inhalation of radon, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be measured because gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma exposure rate at a distance of 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) would be indistinguishable from naturally occurring background radiation. Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 18). 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.

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

3.6 TRENDS

The environmental monitoring program at 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 to permit detection of trends. In the following subsections, 1988 annual averages for each monitoring location for radon,

external gamma radiation, surface water, and groundwater are compared with results for 1984 through 1987 (Refs. 12-15). As the environmental monitoring program at SLAPS continues and more data are collected, comparisons and analyses of trends will become more meaningful.

3.6.1 Radon

As shown in Table 3-6, overall radon levels remained relatively constant as compared with 1987 levels. 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. In 1988, dry weather conditions moderated slightly, and the ditch contained some standing water throughout the year. This may account for the slight decrease in radon levels.

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 began in 1984. Overall, the 1988 external gamma radiation levels remained stable as compared with the 1987 values.

3.6.3 Surface Water

Measured concentrations of radionuclides in surface water at SLAPS have remained relatively stable since 1984 and remain about equal to the upstream values. Surface water data for the 1984-1988 period are given in Table 3-8.

3.6.4 Groundwater

Ten new wells installed in 1986 were added to the groundwater monitoring program in April 1987. Uranium, radium-226, and thorium-230 values for 1987 and 1988 in these new wells are presented in Table 3-9. Statistical comparisons are made only on

TABLE 3-6

ANNUAL AVERAGE CONCENTRATIONS OF RADON-222 AT SLAPS, 1984-1988[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c,d]				
	1984	1985	1986	1987	1988
1	0.1	0.5	0.4	1.6	1.1
2	0.5	1.2	3.5	3.6	1.2
3	0.3	0.8	0.8	0.7	1.0
4	0.6	0.4	0.9	0.8	1.0
5	-[e]	0.8	0.6	2.1	2.1
6	0.4	0.5	0.6	0.5	0.8
7	-[e]	0.5	0.7	0.8	0.7
8	-[e]	1.0	0.7	1.3	1.8
9	-[f]	-[f]	-[f]	3.1	1.0
Background					
16[g]	-[g]	0.5	0.3	0.4	0.4
17[h]	-[h]	-[h]	-[h]	-[h]	0.4
18[i]	-[i]	-[i]	-[i]	-[i]	0.5

[a]Data sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

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

[c]Background has not been subtracted.

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

[e]Detector installed in 1985.

[f]Detector installed in April 1987.

[g]Background detector installed in 1985 in Florissant, MO, approximately 24 km (15 mi) northeast of SLAPS.

[h]Background detector installed in April 1988 at McDonnell Blvd., approximately 0.8 km (0.5 mi) east of SLAPS.

[i]Background detector installed in April 1988 in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS.

TABLE 3-7

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT SLAPS, 1984-1988[a]

Sampling Location[b]	Radiation Level (mR/yr)[c] 1984	1985	1986	1987	1988
1	59[d]	46	14	34	47
2	2157[d]	2087	1363	1557	2128
3	115[d]	116	67	87	101
4	51[d]	57	21	38	38
5	-[e]	3	81	67	45
6	28[d]	41	10	35	43
7[f]	-[e]	93	43	58	129
8	-[e]	12	17	25	38
9	-[g]	-[g]	-[g]	110	129
Background[h]					
16[i]	-[i]	99	97	77	73

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 12-15).

[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.

[d]Sampling location installed in late 1984; data are for fourth quarter only.

[e]Sampling location established in early 1985.

[f]Location 7 is a quality control for Location 3.

[g]Location 9 was established in April 1987.

TABLE 3-7

(continued)

[h]Background detector installed at McDonnell Blvd., approximately 0.8 km (0.5 mi) east of SLAPS, and in St. Charles County, approximately 32 km (20 mi) southwest of SLAPS. Because the instruments have been in place for less than 1 year, data will not be reported until 1989.

[i]Background detectors installed in April 1985. Located in Florissant, MO, approximately 24 km (16 mi) northeast of SLAPS.

TABLE 3-8

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-230 IN SURFACE WATER IN THE VICINITY OF SLAPS, 1984-1988[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c]				
	1984	1985	1986	1987	1988
Total Uranium					
1	14.0	3.4	4.3	4.2	4.0
2[d]	4.0	<3.0	<3.0	<3.0	4.0
3	-[e]	<3.0	<3.0	<4.0	4.0
4	-[e]	<3.0	3.5	<4.0	3.0
Radium-226					
1	0.2	0.2	0.2	0.4	0.3
2[d]	0.1	0.1	0.3	0.3	0.5
3	-[e]	0.2	0.2	0.3	0.3
4	-[e]	0.1	0.2	0.3	0.2
Thorium-230					
1	0.1	0.4	<0.2	0.4	0.3
2[d]	0.36	<0.4	<0.2	0.2	0.1
3	-[e]	<0.5	0.3	0.3	0.3
4	-[e]	<0.4	<0.2	<0.2	<0.1

[a]Data sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

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

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

[d]Location is upstream of the site and acts as background. Background values have not been subtracted.

[e]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 SLAPS, 1984-1988[a]

Sampling Location[b,c]	Concentration (10^{-9} µCi/ml)[d] 1984	1985	1986	1987	1988
Total Uranium					
Well A	1287	2375	1184	1139	1700
Well B	5700	4735	6570	5829	5590
Well C	40	36	16	13	18
Well D	233	474	802	637	475
Well E	129	114	540	576	197
Well F[e]	141	177	146	106	265
Well M10-25S	--	--	--	25	39
Well M10-25D	--	--	--	4	4
Well M11-21	--	--	--	45	73
Well M10-15S	--	--	--	11	9
Well M10-15D	--	--	--	9	5
Well M10-8S	--	--	--	32	19
Well M10-8D	--	--	--	5	4
Well M11-9	--	--	--	4578	4620
Well M13.5-8.5S	--	--	--	4	4
Well M13.5-8.5D	--	--	--	<3	<3
Background[f]					
Well B53W01S	--	--	--	--	3
Well B53W01D	--	--	--	--	4
Radium-226					
Well A	0.3	0.2	0.3	0.3	0.4
Well B	0.3	0.2	0.3	0.3	0.6
Well C	0.3	0.2	0.3	0.4	0.5
Well D	0.2	0.1	0.3	0.1	0.3
Well E	0.6	0.2	0.5	0.3	0.6
Well F[e]	0.2	0.1	0.2	0.3	0.6
Well M10-25S	--	--	--	0.2	0.6
Well M10-25D	--	--	--	0.2	0.4
Well M11-21	--	--	--	0.5	0.7
Well M10-15S	--	--	--	0.3	0.8
Well M10-15D	--	--	--	0.4	0.9
Well M10-8S	--	--	--	0.4	0.5
Well M10-8D	--	--	--	0.3	0.6
Well M11-9	--	--	--	0.5	0.8
Well M13.5-8.5S	--	--	--	0.5	0.8
Well M13.5-8.5D	--	--	--	0.5	0.6

TABLE 3-9

(continued)

Sampling Location[b,c]	Concentration (10^{-9} µCi/ml)[d] 1984	1985	1986	1987	1988
Radium-226 (continued)					
Background[f]					
Well B53W01S	--	--	--	--	0.6
Well B53W01D	--	--	--	--	1.1
Thorium-230					
Well A	9.5	2.3	<0.4	0.8	2.8
Well B	0.3	0.3	1.2	1.4	2.0
Well C	0.2	0.2	0.2	0.9	0.3
Well D	0.9	1.3	0.3	0.9	0.9
Well E	0.3	1.0	0.4	0.9	4.8
Well F[e]	0.4	1.1	0.2	1.7	2.0
Well M10-25S	--	--	--	0.2	0.4
Well M10-25D	--	--	--	<0.8	0.5
Well M11-21	--	--	--	15.2	52.0
Well M10-15S	--	--	--	1.8	5.3
Well M10-15D	--	--	--	0.4	1.3
Well M10-8S	--	--	--	0.2	0.5
Well M10-8D	--	--	--	<0.1	0.3
Well M11-9	--	--	--	0.3	1.0
Well M13.5-8.5S	--	--	--	0.4	0.7
Well M13.5-8.5D	--	--	--	<0.1	0.7
Background[f]					
Well B53W01S	--	--	--	--	0.2
Well B53W01D	--	--	--	--	0.2

[a]Data sources for 1984-1987 are the annual site environmental reports for those years (Refs. 12-15).

[b]Sampling locations are shown in Figure 3-1, and background locations are shown in Figure 1-5.

[c]The "M" wells were added to the environmental monitoring program in April 1987.

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

[e]Upgradient well.

[f]Wells established for background in July 1988.

the A-F wells because there are insufficient data for analyses of the M wells (Figure 3-1). As shown in Table 3-9, concentrations of total uranium in groundwater have remained consistently high in wells A and B; in 11-9, which is located approximately 15.2 m (50 ft) east of well B; and in M13.5-8.5S. Uranium concentrations in well C remained low over the period 1984-1988. These five wells are located on the western end of the site.

Levels of radium-226 and thorium-230 have been generally stable at low levels. An insignificant increase in levels of radium-226 and thorium-230 was observed in 1988.

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. Uranium concentrations observed in certain wells (F and A) increased from those measured in 1987.

Though these increases cannot be definitively explained, it is known that wells D and E are located adjacent to buried radioactive materials. Because 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 analytical results for surface water and hydrogeological studies concerning discharge of groundwater into Coldwater Creek, there is no evidence that surface water downstream of the site has been degraded. Therefore, 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 April 1987, monitoring of the groundwater for chemical indicator parameters began at SLAPS. These parameters include pH, specific-conductance, total organic carbon (TOC), and total organic halide (TOX). These parameters are indicators of changes in the inorganic and organic composition of the groundwater.

Specific conductance and pH measure changes in the inorganic composition of the groundwater. Acidity and basicity are measured by pH. A change in pH affects the solubility and mobility of chemical contaminants in groundwater. Specific conductance measures the capacity of water to conduct an electrical current. Conductivity generally increases with elevated concentrations of dissolved solids. Waters with high salinities or high total dissolved solids exhibit high conductivities.

Groundwater is analyzed for TOC and TOX to determine the organic content of the water. TOC measures the total organic carbon content of water but is not specific to a given contaminant. TOX measures organic compounds containing halogens, which are organic compounds containing fluorine, chlorine, bromine, and iodine.

Table 4-1 lists the ranges of observed concentrations of the four indicator parameters. Except for specific conductance and the TOX values, all other parameter levels are within the range of the background wells (B53W01S and B53W01D).

The elevated TOX values occurred in wells B, D, and M11-9. No explanation for these elevated levels is currently available. However, investigations will be conducted in 1989 to determine the possible cause.

TABLE 4-1

CONCENTRATIONS OF INDICATOR PARAMETERS IN GROUNDWATER AT SLAPS, 1988

Sampling Location (Well No.)[a]	Parameter: pH (Standard Units)	Total Organic Carbon (mg/l)	Total Organic Halide (µg/l)[b]	Specific Conductance (µmhos/cm)
A	6.7 - 6.9	5.0 - 16.2	38 - 88	1310 - 1440
B	6.6 - 7.5	6.7 - 20.0	100 - 270	6870 - 7620
C	6.7 - 7.0	4.4 - 20.6	19 - 73	1580 - 1700
D	6.7 - 7.8	6.9 - 20.6	82 - 120	2150 - 2370
E	6.7 - 7.0	2.7 - 9.0	ND - 58	3200 - 6220
F[c]	7.1 - 7.3	1.5 - 7.0	13 - 82	671 - 695
M10-8S	6.8 - 7.1	5.1 - 11.4	ND - 41	1360 - 1860
M10-8D	7.2 - 7.5	4.4 - 9.6	ND - 27	772 - 891
M10-15S	6.9 - 7.1	1.5 - 6.9	ND - 11	2320 - 2820
M10-15D	7.1 - 7.4	3.9 - 15.5	ND - 39	842 - 963
M10-25S	7.1 - 7.3	1.5 - 9.0	ND - 36	700 - 781
M10-25D	6.9 - 7.6	2.5 - 11.5	ND - 70	687 - 1090
M11-9	6.5 - 6.7	7.6 - 27.3	36 - 370	7930 - 8560
M11-21	6.9 - 7.1	4.5 - 16.8	ND - 25	2360 - 2950
M13.5-8.5S	7.0 - 7.4	5.9 - 9.8	ND - 76	796 - 1570
M13.5-8.5D	6.9 - 7.1	5.8 - 8.8	ND - 31	876 - 1660
Background				
B53W01S[d,e]	7.1	2.7	23	1010
B53W01D[d]	6.8 - 7.0	7.1 - 34.2	ND - 35	932 - 1010

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

[b]ND - no detectable concentration.

[c]Upgradient well.

[d]Background well added to the monitoring program in July 1988.

[e]Label error for samples taken in October 1988; no analyses performed.

Specific conductance levels indicate that many of the wells show levels several times greater than background of total dissolved solids; thus the groundwater is 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 (wells M10-8S/D and M13.5-8.5 S/D). Wells with historically high levels of uranium (B, D, E, M11-9, and M11-21) exhibit elevated specific conductance values.

4.2 SPECIAL STUDIES

No special studies were performed at SLAPS during 1988.

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APPENDIX A
QUALITY ASSURANCE

APPENDIX A
QUALITY ASSURANCE

A comprehensive quality assurance (QA) program was maintained to ensure that the data collected were representative of actual concentrations in the environment. First, extensive environmental data were obtained to prevent reliance on only a few results that 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 (QC), participating in interlaboratory cross-checks, performing replicate analyses, and splitting samples with other recognized laboratories. 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 were performed under subcontract by TMA/E, Albuquerque, New Mexico. This laboratory maintained an internal quality assurance program that involved routine calibration of counting instruments, source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide determination was 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 DOE, the Nuclear Regulatory Commission, and the EPA. Table A-1 summarizes results of the EPA comparison studies for water samples.

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.

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

For inorganic analyses, the program includes:

- Initial calibration and calibration verification
- Continuing calibration verification
- Reagent blank analyses
- Matrix spike analyses
- Duplicate sample analyses
- Laboratory control sample analyses

TABLE A-1

SUMMARY COMPARISON OF WATER SAMPLE RESULTS

(EPA and TMA/E)

Analysis and Sample Date	Value (pCi/l) EPA	Value (pCi/l) TMA/E	Ratio (TMA/E:EPA)
Alpha			
1/88	28.0 ± 7.0	40.0 ± 2.0	1.43
2/88	4.00 ± 5.00	3.33 ± 0.60	0.83
5/88	6.0 ± 5.0	5.3 ± 0.6	0.88
7/88	46.0 ± 11.0	53.3 ± 2.9	1.16
8/88	15.0 ± 5.0	12.7 ± 0.6	0.85
11/88	8.00 ± 5.00	7.00 ± 1.00	0.88
Beta			
1/88	72.0 ± 5.0	90.0 ± 4.0	1.25
2/88	8.00 ± 5.00	9.30 ± 0.6	1.16
5/88	13.0 ± 5.0	16.3 ± 0.6	1.25
7/88	57.0 ± 5.0	69.7 ± 2.9	1.22
8/88	4.0 ± 5.0	5.0 ± 1.0	1.25
11/88	10.00 ± 5.00	10.00 ± 1.00	1.00
Ra-226			
1/88	4.80 ± 0.72	4.70 ± 0.26	0.98
1/88	4.80 ± 0.72	4.53 ± 0.15	0.94
5/88	7.60 ± 1.14	7.27 ± 0.25	0.96
7/88	6.40 ± 0.96	6.37 ± 0.59	1.00
8/88	10.0 ± 1.51	9.90 ± 0.53	0.99
11/88	8.40 ± 1.30	8.53 ± 0.15	1.02
Ra-228			
1/88	5.30 ± 0.80	4.35 ± 1.4	0.82
1/88	3.60 ± 0.54	4.60 ± 0.95	1.28
5/88	7.70 ± 1.16	8.73 ± 0.5	1.13
7/88	5.60 ± 0.84	6.50 ± 0.10	1.16
8/88	12.40 ± 1.86	14.80 ± 0.72	1.19
11/88	5.40 ± 0.80	5.33 ± 0.35	0.99
U (Natural)			
1/88	3.0 ± 6.0	3.33 ± 0.58	1.11
4/88	3.0 ± 6.0	3.7 ± 0.6	1.23
7/88	6.00 ± 6.00	6.33 ± 0.58	1.06
10/88	6.0 ± 6.0	7.0 ± 0.0	1.17

The laboratory for organic analyses conforms to QC procedures for the following:

- o GC/MS instrumentation for both volatile and semivolatile compound analysis
- o Initial multilevel calibration for each hazardous substance list (HSL) compound
- o Continuing calibration for each HSL compound
- o Addition of surrogate compounds to each sample and blanks for determining percent recovery information
- o Matrix spike analyses
- o Reagent blank analyses

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

They participate in water studies to demonstrate technical competence for state drinking water certification programs. They also participate in water pollution studies to demonstrate technical competence for state wastewater certification programs. Currently, they participate in drinking water, wastewater, and/or hazardous waste certification programs. They are certified (or pending) in 35 such state programs. Continued certification hinges upon Weston's ability to pass the performance evaluation testing, and many of these tests are conducted semiannually.

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

The FUSRAP sampling program was designed to provide for spikes, blanks, and QC duplicate sampling. Samples are tracked by chain-of-custody procecdures to maintain traceability.

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. 11). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represent actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Use of such assumptions will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1

CONVERSION FACTORS

1 yr	=	8,760 h
1 liter	=	1,000 ml
1 mR	=	1 mrem
1 mrem	=	1,000 μR
100 mrem/yr	=	11.4 μR/h (assuming 8,760 hours of exposure per year)
1 μCi	=	1,000,000 pCi
1 pCi	=	0.000001 μCi
1 pCi/l	=	10^{-9} μCi/ml
1 pCi/l	=	0.000000001 μCi/ml
1 μCi/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

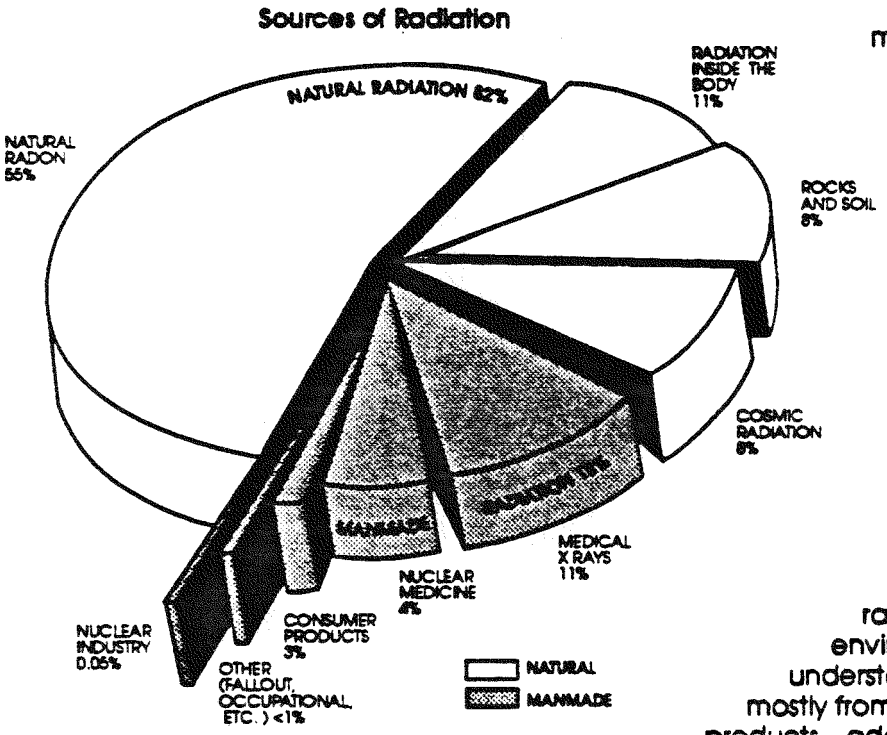
cm	centimeter
cm/sec	centimeters per second
ft	foot
ft msl	feet above mean sea level
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
l	liter
lb	pound
m	meter
m^3	cubic meter
mg	milligram
mg/l	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mR	milliroentgen
mrem	millirem
mR/yr	milliroentgens per year
mrem/yr	millirem per year
µCi/ml	microcuries per milliliter
µg/l	microgram per liter
µR/h	microroentgens per hour
pCi	picocurie
pCi/g	picocuries per gram
pCi/l	picocuries per liter
yd^3	cubic yard
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.

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



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

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

TYPES OF IONIZING RADIATION

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

Alpha

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

Beta

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

Gamma

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

Units of Measure

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

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

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

RADIATION IN THE ENVIRONMENT

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

mrem = millirem
pCi = picocurie

Cosmic Radiation

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

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

Terrestrial Radiation

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

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

Buildings

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

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

Radon

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

Average Indoor Radon Level ..... 1.5 pCi/liter
Occupational Working Limit ..... 200.0 pCi/liter

Food

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

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

Medical Treatment

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

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

Consumer Goods

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

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

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

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

International Nuclear Weapons Test Fallout from pre-1980 atmospheric tests (average for a U.S. citizen) ..... 1 mrem/year

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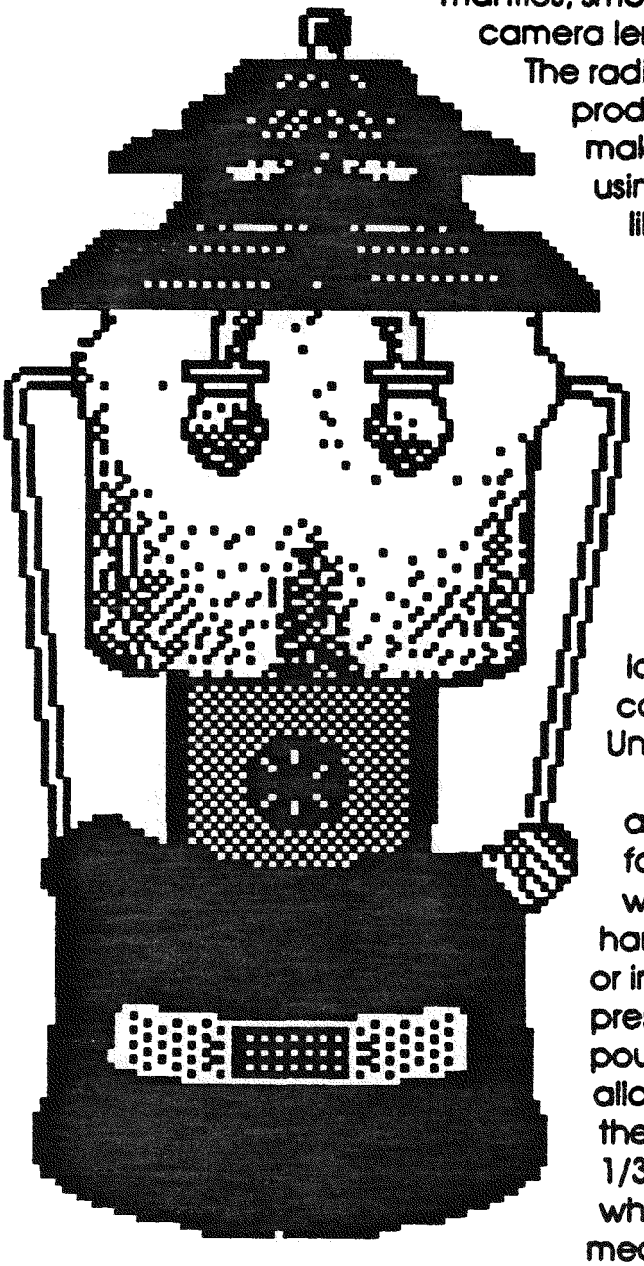
PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

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



Lanterns: In a New Light

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

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

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

PERSPECTIVE: How Big is a Picocurie?

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

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

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

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

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

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

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

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

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

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

Chart provided by W.L. Beck, Bechtel National, Inc.

APPENDIX E

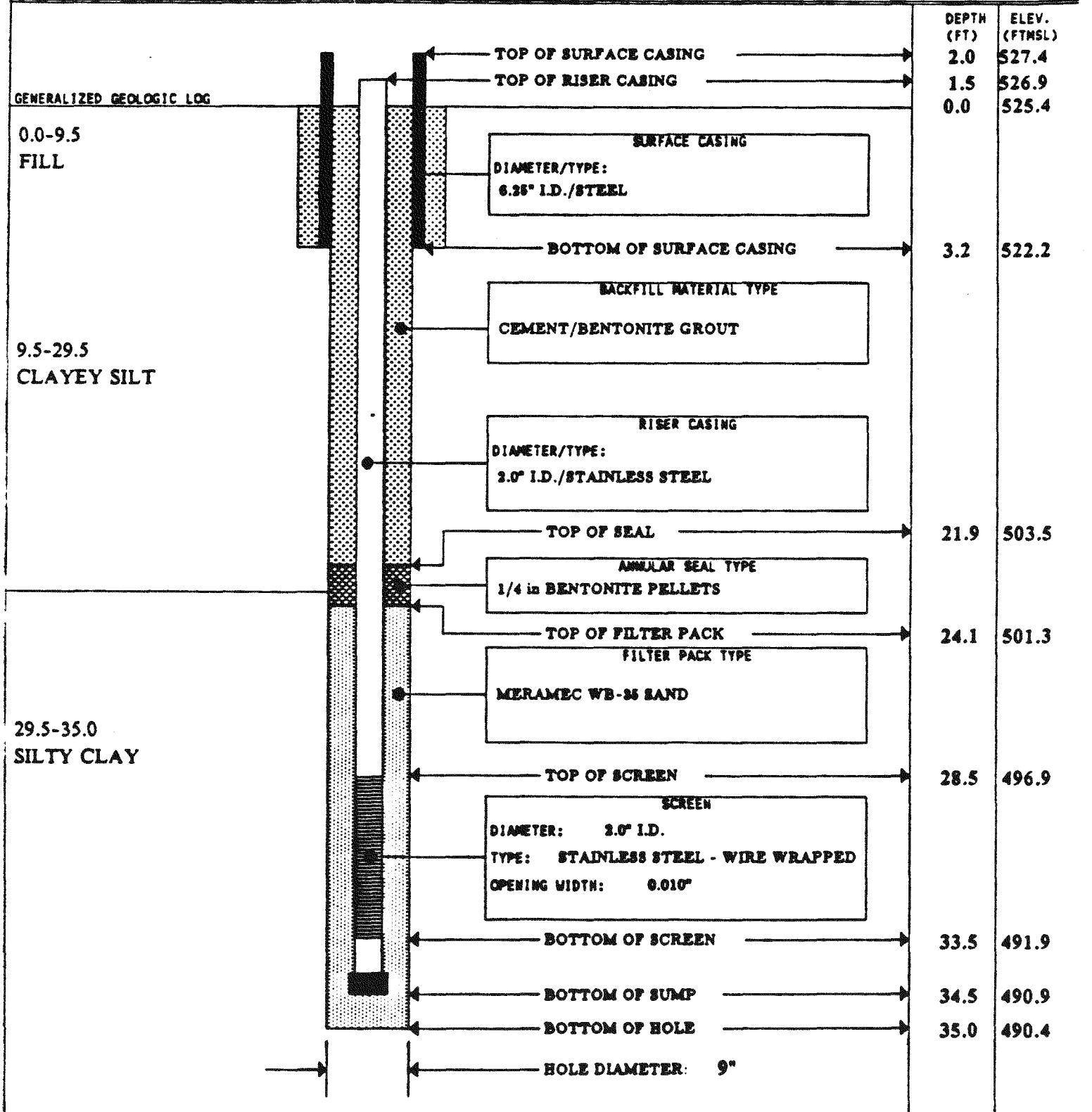
SAMPLE WELL CONSTRUCTION DETAILS

MONITORING WELL

PROJECT	WELL NO.
ST LOUIS AIRPORT SITE	B53W12S

JOB NO.	SITE	COORDINATES
14501	Ballfield Area	N 1566 E 927

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
1-19-88	1-19-88	G. CHERRY	TOP OF 2' RISER PIPE.



	DEPTH (FT)	ELEV. (FTMSL)
TOP OF SURFACE CASING	2.0	527.4
TOP OF RISER CASING	1.5	526.9
	0.0	525.4
BOTTOM OF SURFACE CASING	3.2	522.2
TOP OF SEAL	21.9	503.5
TOP OF FILTER PACK	24.1	501.3
TOP OF SCREEN	28.5	496.9
BOTTOM OF SCREEN	33.5	491.9
BOTTOM OF SUMP	34.5	490.9
BOTTOM OF HOLE	35.0	490.4

APPENDIX F

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