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SITE SURVEILLANCE AND MAINTENANCE PROGRAM FOR PALOS PARK

Report for 1987

by

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SITE SURVEILLANCE AND MAINTENANCE PROGRAM FOR PALOS PARK

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Abstract

The results of the environmental monitoring program conducted at Site A/Plot M in the Palos Park Forest Preserve area for CY 1987 are presented. The monitoring program is the ongoing remedial action that resulted from the original radiological characterization of the site. This study had determined that hydrogen-3 (as tritiated water) migrated from the burial ground and was present in two nearby hand-pumped picnic wells. The current program consists of sample collection and analysis of air, surface and subsurface water, and bottom sediment. The results of the analyses are used to 1) determine the migration pathway of water from the burial ground (Plot M) to hand-pumped picnic wells, 2) establish if buried radionuclides other than hydrogen-3 have migrated, and 3) generally characterize the radiological environment of the area. The program was designed to study the migration of non-radiological hazardous waste constituents that may have been buried with the radioactive waste. This was done by analyzing borehole water samples for selected heavy metals and organic compounds and analyzing quarterly water samples from the Red Gate Woods picnic well for inorganic constituents. Hydrogen-3 in the Red Gate Woods picnic well continued to show the same pattern of elevated levels in the winter and low concentrations in the summer, but the magnitude of the current winter peak was significantly less than in earlier years. Tritiated water continues to be detected in a number of wells, boreholes, dolomite holes, and a surface stream. For many years it was the only radionuclide found to have migrated in measurable quantities. Recent measurements indicate the presence of strontium-90 and technetium-99 in borehole water next to Plot M. The present data does not allow a conclusion as to whether these nuclides represent recent migration or movement that occurred before the Plot was capped. However, the results of the program established that the radioactivity remaining at Site A/Plot M does not endanger the health or safety of the public visiting the site or those living in the vicinity.

1.0 Introduction

This report presents and discusses the monitoring data obtained during calendar year 1987. The program is the ongoing remedial action that resulted from the radiological characterization of the former site of Argonne National Laboratory and its predecessor, the University of Chicago's Metallurgical Laboratory, which was part of the World War II Manhattan Engineer District Project, in the Palos Park Forest Preserve southwest of Chicago, IL. The Laboratory used two locations in the Forest Preserve: Site A, a 19-acre area that contained experimental laboratory and nuclear reactor facilities; and Plot M, a 150 ft x 140 ft area used for the burial of radioactive waste. These locations are shown in Figures 1.1 and 1.2. To assist in understanding this report, reference should be made to the previous comprehensive reports on this subject,[1,2] which provide greater detail and illustrations on sampling locations and descriptive material and give the results through 1981, and to the annual reports for 1982,[3] 1983,[4] 1984,[5] 1985,[6] and 1986.[7] Earlier data will not be repeated in this progress report, but reference will be made to some of the results.

Operations at Site A began in 1943 and ceased in 1954. Among the research programs carried out at Site A were reactor physics studies, fission product separations, tritium recovery from irradiated lithium, and studies of the metabolism of radionuclides in laboratory animals. Radioactive waste and radioactively-contaminated laboratory articles from these studies were buried in Plot M. At the termination of the programs, the reactor fuel and heavy water, used for neutron moderation and reactor cooling, were removed and disposed of elsewhere. The containment shell and biological shield for the CP-2 and CP-3 reactors, together with various pipes, valves, and debris, were buried in place.

Burial of radioactive waste at Plot M began in 1943 or 1944 and was discontinued in 1949. Waste was buried in six-foot deep trenches and covered with soil until 1948, after which burial took place in steel bins. The steel bins were removed in 1949, but the waste buried in trenches was allowed to remain in place. Concrete sidewalls, eight feet deep, were poured around the perimeter of the burial area and a one-foot thick concrete

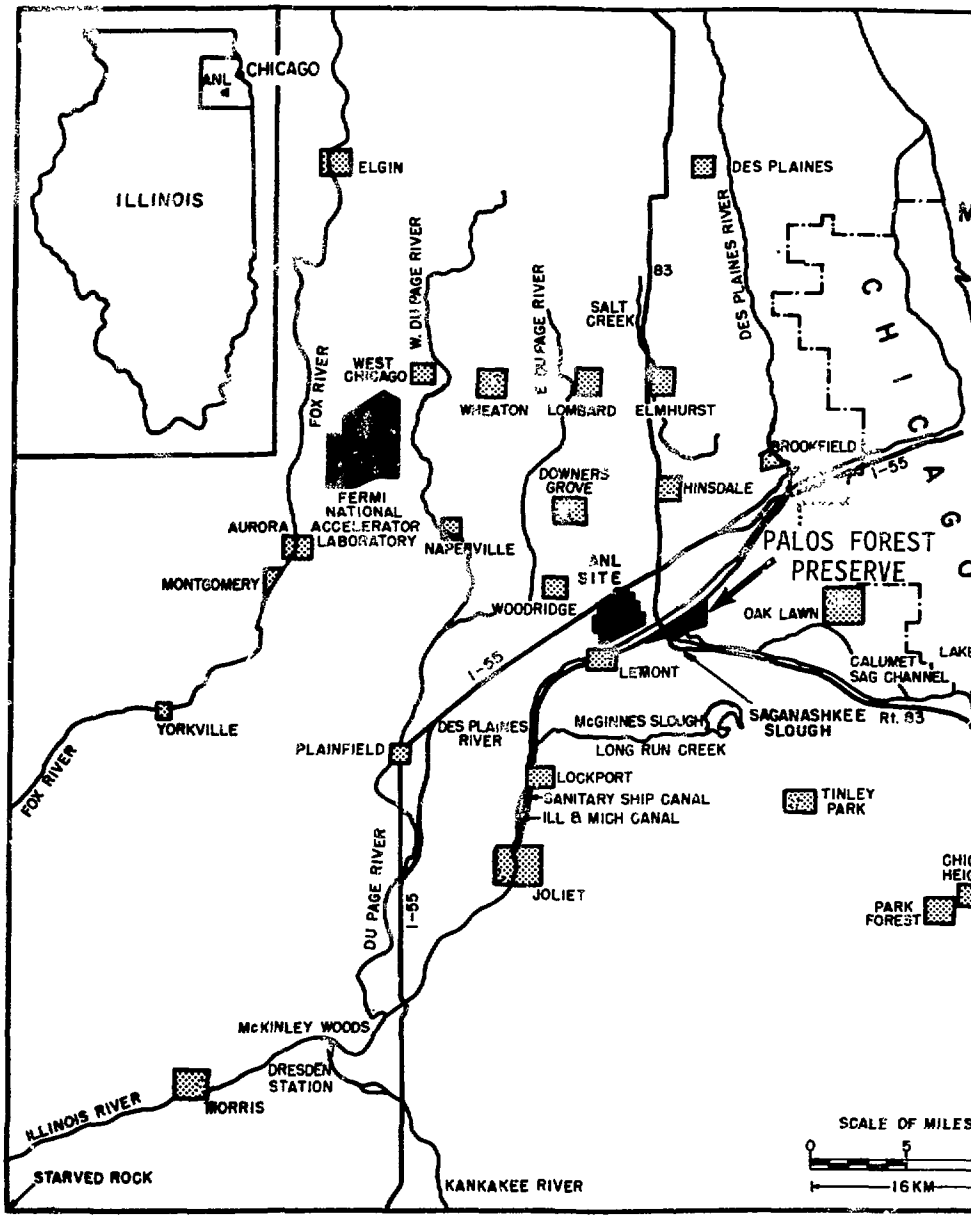

Figure 1.1 Location of Palos Forest Preserve on Chicago-Area

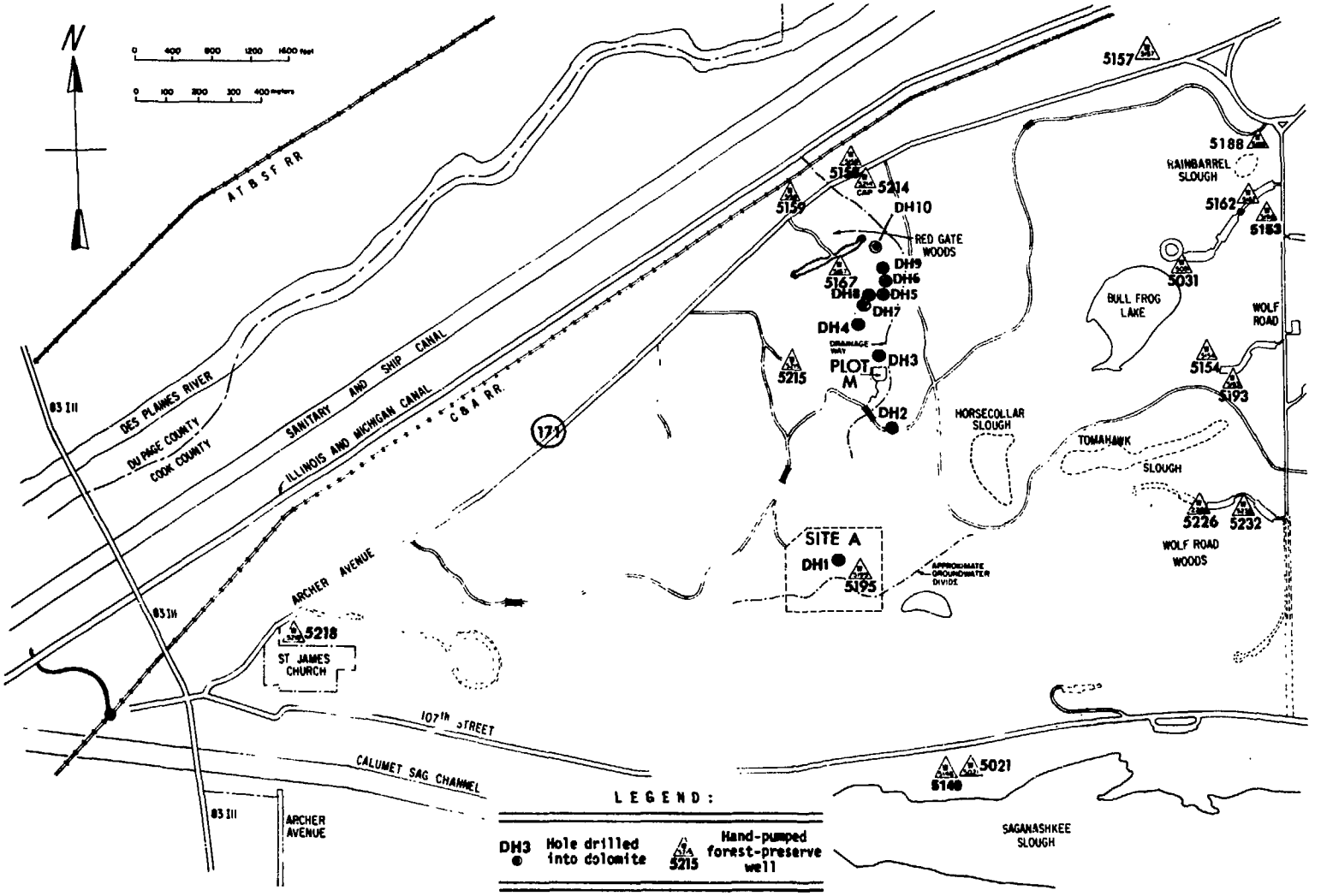

Figure 1.2 Palos Forest Preserve Showing Location of Site A/Plot M Dolomite Holes and Picnic Wells

slab was poured over the top. The concrete slab was covered with soil and seeded with grass. Both the Site A and Plot M areas were decommissioned in 1956. In 1973, elevated levels of hydrogen-3 (as water) were detected in two nearby hand-pumped picnic wells and found to be migrating from the burial plot into the surrounding soil and aquifers. As a result, an extensive radiological survey of the entire Palos Park site was conducted.

Geologically, Plot M is constructed on a moraine upland which is dissected by two valleys, the Des Plaines River valley to the north and the Sag Valley to the south. The upland is characterized by rolling terrain with poorly developed drainage. Streams are intermittent and drain internally or flow to one of the valleys. The area is underlain by glacial till or drift, dolomite, and sedimentary rocks. The uppermost bedrock is Silurian dolomite, into which both the picnic wells and some of the monitoring wells are placed, and sampled as described in the text. The dolomite bedrock is about 200 feet thick. The overlying glacial till has a thickness that ranges from 165 feet at Site A to zero at the Des Plaines and Calumet Sag Channel, and some of the monitoring wells terminate in this layer. The depth to bedrock at Plot M is about 130 feet. Hydrologically, the surface water consists of swamps, ponds, and intermittent streams. The intermittent stream that drains Plot M flows from the highest point near Site A, past Plot M, then continues near the Red Gate Woods well (Fig. 1.2) and discharges, when there is sufficient water, into the Illinois and Michigan Canal. The ground water in the glacial till and dolomite forms two distinct flow systems. The flow in the drift is controlled principally by topography. The flow in the dolomite is controlled by two discharge areas, the Des Plaines River to the north and the Calumet Sag Channel to the south. Water usage at the site is confined to the hand-pumped picnic wells, which are used principally in the warmer seasons.

The climate is that of the upper Mississippi Valley, as moderated by Lake Michigan, and is characterized by cold winters and hot summers. Precipitation averages about 33 inches annually. The largest rainfalls occur between April and September. The average monthly temperature ranges from 21°F in January to 73°F in July. Approximately 7.9 million people reside within 50 miles of the site; the population within a five-mile radius is

about 150,000. The only portion of the Forest Preserve in the immediate area of Plot M and Site A that is developed for public use is the Red Gate Woods picnic area (Fig. 1.2), although small numbers of individuals use the more remote areas of the Preserve.

The terminology used in previous reports is continued. A hole drilled and completed into the glacial till is called a borehole. The soil samples obtained from the borehole are called soil cores. Some boreholes have been cased and screened to form monitoring wells. Water from such wells is called borehole water. Test wells drilled into the dolomite bedrock are called dolomite holes or deep holes. Water from such wells is called dolomite water. The hand-pumped picnic wells, which are completed into or close to the dolomite bedrock, are called wells or picnic wells. They are identified by a location name or well number. These were in existence before this radiological and hydrological study of the area was begun.

The results of radioactivity measurements are expressed in this report in terms of picocuries per liter (pCi/L) and nanocuries per liter (nCi/L)for water, picocuries per cubic meter (pCi/m^3) for air, and picocuries per gram (pCi/g) for soil and sediment samples. Radiation dose calculations are reported in units of millirem (mrem) or millirem per year (mrem/y). Other abbreviation of units are defined in the text.

2.0 Summary

The results of the ongoing environmental monitoring and surveillance program at the Palos Park site for calendar year 1987 are presented in this report. Sample collection and analyses were conducted on air, surface and subsurface water, and bottom sediment. Water vapor samples were collected over the stream bed upstream and downstream of the waste burial Plot and analyzed for tritium. Above ambient concentrations were found downstream of the Plot and are attributed to tritiated water leaching from the Plot and evaporating from the surface stream and possible transpiration from plants. The maximum dose from tritium in air to a hypothetical individual who spends all of his time at the downstream location would be

0.006 mrem/y, or 0.006% of the applicable U. S. Department of Energy (DOE) Radiation Protection Standard of 100 mrem/y.

Surface water samples collected from the stream that flows around Plot M showed the same tritiated water concentration pattern as was observed in the past. Concentrations were at the ambient level (< 0.2 nCi/L) upstream of the Plot, increased to 50-400 nCi/L adjacent to the Plot, then decreased to 10-30 nCi/L further downstream. Other radiochemical analyses of water and stream-bed sediment collected above and below Plot M indicated that there are slightly higher concentrations of strontium-90 (in water only), uranium (in water only), and plutonium-239 (in sediment only) downstream. For both the water and sediment samples, the concentrations were very low.

The tritiated water concentrations in the borehole and dolomite hole water were consistent with those observed in the past. Water from eight of 16 boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L, which is considered the normal or ambient level. Technetium-99 was identified above the detection limit of 0.5 pCi/L in six of the 15 boreholes analyzed. The elevated strontium-90 levels found in some boreholes are probably from the Plot, since concentrations above 0.25 pCi/L have not been observed in the water from atmospheric fallout from previous nuclear weapons testing, and no other source is known. Both strontium-90 and technetium 99 are relatively mobile species and their presence in the borehole water is not unexpected. It is unclear whether this is current migration or movement that occurred before the Plot was capped.

Sampling of the five Forest Preserve picnic wells continued. Although the pattern of high tritium concentrations in the winter and low concentrations (less than the detection limit of 0.2 nCi/L) in the summer continued, the magnitude of the winter peak (3.3 nCi/L) and the annual average (1.6 nCi/L) in the Red Gate Woods well are significantly less than in earlier years. The corresponding values for the peak and average concentrations were 9.2 nCi/L and 4.8 nCi/L in 1982, 3.0 nCi/L and 2.2 nCi/L in 1983, 2.7 nCi/L and 1.2 nCi/L in 1984, 2.5 nCi/L and 1.0 nCi/L in 1985 and 3.4 nCi/L and 1.3 nCi/L in 1986. The well opposite Red Gate Woods showed the same pattern as in past years with maximum and minimum concentrations of 0.9

nCi/L and less than 0.2 nCi/L, respectively. The other wells were only occasionally greater than 0.2 nCi/L. If water equal to the Red Gate Woods well average concentration of 1.6 nCi/L were the sole source of water for an individual, the annual dose from tritium would be 0.32 mrem, compared to the U. S. Environmental Protection Agency (EPA) drinking water limit of 20 nCi/L and the corresponding annual dose of 4 mrem.[8] This is 8% of the annual dose limit. Consumption of one liter of this water would produce a dose of 0.0004 mrem.

The results of this program show that the radioactivity remaining at Palos Park does not endanger the health or safety of the public visiting the site or those living in the vicinity. The potential radiation doses are very low relative to the applicable standards.

3.0 Monitoring Program

The program is designed to monitor the elevated hydrogen-3 (as tritiated water) concentrations in some of the picnic wells in the Forest Preserve, determine the migration pathway of water from the burial ground to the wells, establish if other buried radionuclides or waste constituents have migrated, and characterize the radiological and non-radiological pollutant environment of the area. This is accomplished by analyses of water vapor samples and of water from wells, deep holes, boreholes, and surface streams in the area. Samples are collected from biweekly to annually, depending on past results and proximity to Plot M. During CY 1987, 354 samples were collected and 470 radiochemical analyses were performed. For the most part, individual results are presented in the tables, and compared to control, off-site, or upstream results. Where applicable, results are compared to appropriate standards such as the EPA drinking water standard[8] or the U. S. Department of Energy Radiation Protection Standard of 100 mrem/y.[9] The Site A/Plot M program follows the guidance for monitoring at DOE facilities.[10]

The uncertainties associated with individual concentrations given in the tables are the statistical counting errors at the 95% confidence level. A few tables of tritium data do not contain these uncertainties, because they

were not carried in the data base that was used to prepare the computer-generated tables. In such cases, the following uncertainties apply:

Concentration (nCi/L)	Uncertainty (% of Conc.)
0.2-1.0	25-5%
1-10	5-1%
> 10	1%

3.1 Air

Water vapor samples were collected over the surface stream bed next to Plot M, since this stream drains tritiated water leached from the Plot, and analyzed for tritium to estimate the potential exposure from the atmospheric pathway. Samples were collected above and below Plot M and the results are given in Table 3.1. The concentrations were higher below Plot M than above, where the levels were similar to ambient tritium-in-air concentrations.[11] During some of the sampling periods, water was not flowing in the stream, but above-ambient tritiated water vapor concentrations were observed below the Plot. As was also observed last year, the downstream concentrations in the fall were substantially lower than the spring values and may be due to generally higher tritium stream concentrations in the spring. The dose to a hypothetical individual who breathed air continuously for one year at the maximum concentration of 10.8 pCi/m^3 would be 0.006 mrem or 0.006% of the applicable DOE environmental dose limit of 100 mrem/y. This dose was calculated using the methodology specified in the DOE Draft Order[9] for determining radiation exposures to members of the public in uncontrolled areas. The total quantity of radionuclide inhaled, in microcuries (μCi), is obtained by multiplying the air concentration by the general public breathing rate of 8400 m^3/y.[12] This annual intake is then multiplied by the 50-year Effective Dose Equivalent Factor (EFF.D.E.) to obtain the dose. The EFF.D.E. for tritiated water vapor is 6.3×10^{-5} rem/μCi (rem per microcurie).

TABLE 3.1

Concentration of Tritiated Water Vapor Next to Plot M, 1987
(Concentrations in pCi/m^3)

Sampling Period	Location #1* (Upstream)	Location #9* (Downstream)
April 21 to April 24	0.6 ± 0.6	1.2 ± 0.6
April 28 to May 1	0.3 ± 0.5	5.5 ± 0.7
May 4 to May 7	0.6 ± 0.6	4.8 ± 0.9
May 11 to May 14	2.0 ± 0.7	10.8 ± 0.8
May 18 to May 21	0.5 ± 0.5	6.1 ± 1.2
Spring Average	0.8 ± 0.6	5.7 ± 2.7
September 21 to September 24	1.2 ± 0.8	2.5 ± 0.8
September 28 to October 1	1.1 ± 0.7	2.5 ± 0.7
October 5 to October 8	0.8 ± 0.4	1.5 ± 0.4
October 13 to October 16	0.8 ± 0.4	2.5 ± 0.5
October 19 to October 22	0.6 ± 0.4	0.4 ± 0.4
Fall Average	0.9 ± 0.7	1.9 ± 1.0

*See Figure 3.1.

3.2 Surface Water

Four sets of samples were collected from the stream that flows around Plot M. The sampling locations are shown in Figure 3.1. The samples were analyzed for tritiated water and the results are in Table 3.2. The same concentration pattern in the water flowing around Plot M was observed this year as in the past. Concentrations were low upstream of the Plot, increased as the stream flowed past the Plot, where it received tritiated water leaching out of the burial site, then decreased downstream due to dilution. The concentrations in the stream remained essentially the same as in recent years.

Using the methodology prescribed in the DOE guidance,[9] the committed dose equivalent for consumption of water can be calculated. If a hypothetical individual used water from the seep (Location #6) as his sole source of water, the annual dose based on the maximum 1987 concentration of 352 nCi/L would be about 16 mrem/y and a dose of 14 mrem/y based on the annual average seep concentration of 312 nCi/L. Using the same calculations for concentrations at Location #9, the maximum concentration of 103 nCi/L would produce 4.8 mrem/y and the 1987 average concentration of 70 nCi/L would give a dose of 3.2 mrem/y. Consumption of one liter would produce a dose of 0.004 mrem/y.

Large volume (20 liter) water samples were collected on April 28, 1987, from this stream above Plot M at Location #1 and from below Plot M at Location #9. No fall sample was collected because of a lack of surface flow during the late summer and fall as a result of low precipitation. These samples were analyzed for very low concentrations of radionuclides to determine if any had migrated out of Plot M and entered this surface stream. The results are given in Table 3.3. In addition to hydrogen-3, there may be elevated concentrations of strontium-90 and uranium at the downstream location. Strontium-90 has been found in the past in Borehole #6 in Figure 3.2, between Plot M and the stream, and its presence in the stream would be another indicator of possible migration of these radionuclides.

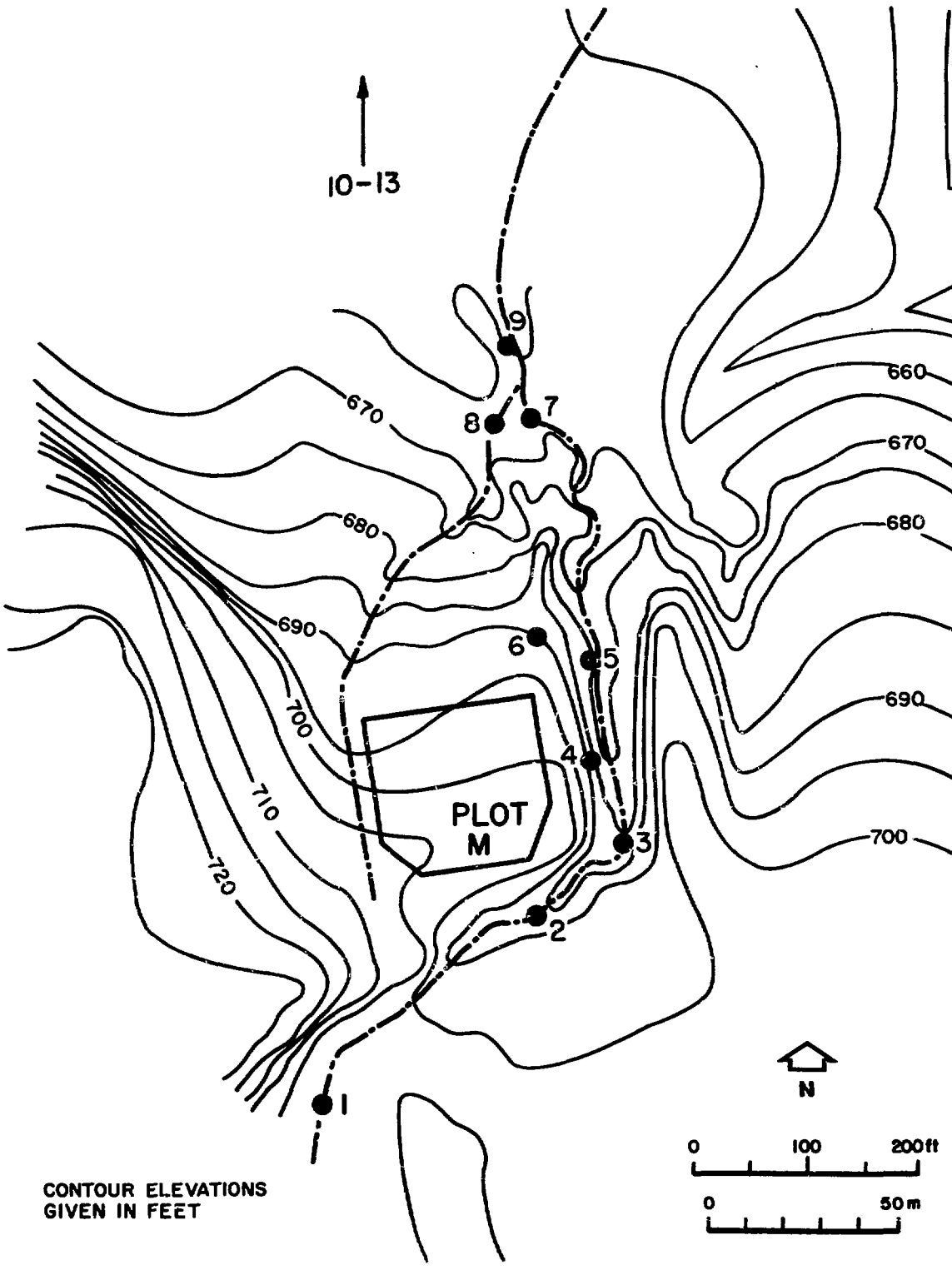

Figure 3.1 Surface Water Sampling Locations Near Plot M

TABLE 3.2

Tritiated Water Content of Surface Stream
Next to Plot M, 1987

(Concentrations in nCi/L)

Location Number*	Date Collected			
	February 24	April 28	June 23	December 10
1	< 0.2	< 0.2	< 0.2	< 0.2
2	3.0 ± 0.3	117.6 ± 0.3	3.8 ± 0.3	0.2 ± 0.2
3	115.7 ± 0.8	141.8 ± 0.8	161.9 ± 0.9	174.4 ± 0.4
4	138.0 ± 0.8	134.8 ± 0.8	162.7 ± 0.6	180.0 ± 0.4
5	122.6 ± 0.8	106.7 ± 0.7	-	167.6 ± 0.4
6 (Seep)	319.1 ± 1.2	352.0 ± 1.2	-	265.9 ± 1.4
7	98.8 ± 0.7	79.2 ± 0.6	86.1 ± 0.7	23.3 ± 0.5
8	163.6 ± 0.9	118.6 ± 0.7	-	36.4 ± 0.6
9	103.3 ± 0.7	73.3 ± 0.6	76.5 ± 0.6	25.4 ± 0.5
10	54.8 ± 0.6	46.3 ± 0.5	24.7 ± 0.4	17.5 ± 0.5
11	29.5 ± 0.4	24.8 ± 0.4	14.3 ± 0.4	12.6 ± 0.4

*See Figure 3.1.

TABLE 3.3

Radioactivity Content of Stream Next to Plot M, 1987
Samples Collected April 28, 1987

(Concentrations in pCi/L)

Constituent	Location #1* (Upstream)	Location #9* (Downstream)
Total Alpha**	0.9 ± 0.2	2.1 ± 0.3
Total Beta**	6.7 ± 0.3	8.3 ± 0.3
Hydrogen-3	< 200	7.33×10^4 ± 600
Strontium-90	1.26 ± 0.13	1.75 ± 0.23
Uranium-234	0.39 ± 0.07	1.01 ± 0.10
Uranium-235	0.02 ± 0.02	0.03 ± 0.02
Uranium-238	0.41 ± 0.07	1.14 ± 0.11
Neptunium-237	< 0.001	< 0.001
Plutonium-238	< 0.001	< 0.001
Plutonium-239	< 0.001	< 0.001
Americium-241	< 0.001	< 0.001
Curium-242 and/or Californium-252	< 0.001	< 0.001
Curium-244 and/or Californium-249	< 0.001	< 0.001

*See Figure 3.1.

**Non-volatile.

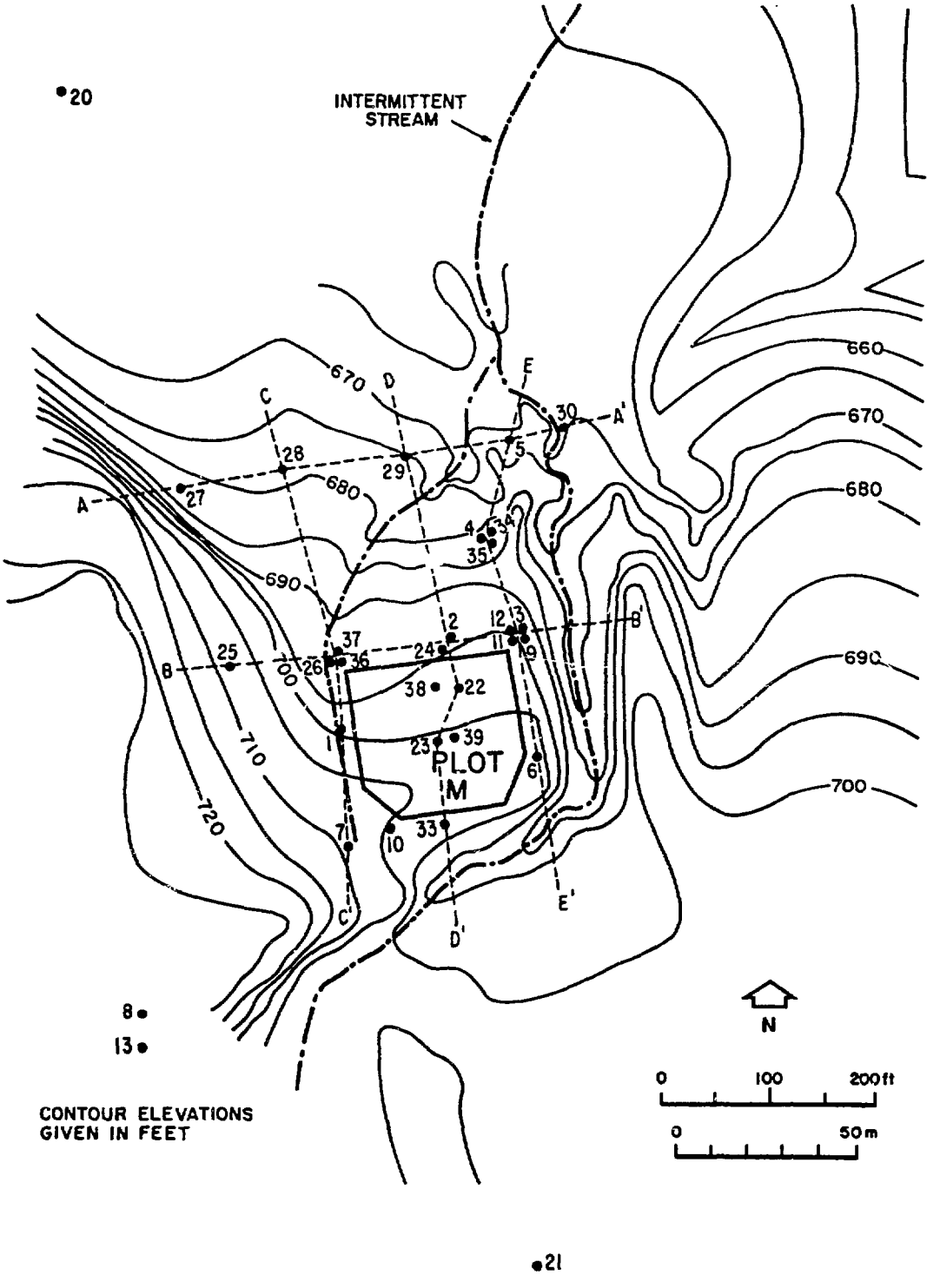

Figure 3.2 Map of Plot M Palos Site Showing Topography, Intermittent Stream, and Borehole Locations

3.3 Subsurface Water

3.3.1 Borehole Water

A number of the boreholes drilled in the Plot M area (Fig. 3.2) were cased with plastic pipe and screens installed (piezometers) to serve as sampling points within the till. Water samples were collected and water level measurements were made in these boreholes approximately bimonthly, weather permitting. The shallow boreholes responded to the spring precipitation as indicated by an increase in water levels followed by a drop during summer and fall when moisture was used for plant growth. The water levels in the deeper boreholes (> 100 ft) were relatively constant throughout the year. Some boreholes were occasionally dry. All the water samples were analyzed for tritiated water and the results are collected in Table 3.4. Borehole #11 contains a nest of piezometers at three depths, 39 feet, 68 feet, and 124 feet. The piezometer at 68 feet was dry all year. The principal purpose of this arrangement is to obtain water level measurements at different depths to determine the vertical gradient of the hydraulic head.

The tritium concentrations varied more widely than in past years with no identifiable pattern or trends. Some borehole water tritium concentrations, e.g., Borehole #24, changed by a factor of ten within one month. However, the average concentrations were similar to those observed in past years.

In the 40-foot deep boreholes, low tritium concentrations correlate with high water levels, apparently a dilution phenomenon. The measured water levels in the boreholes are in Table 3.5. Since the measurement of the water levels is made relative to a benchmark at the top of the well casing, a decrease in numerical value indicates a rise in water level and dilution of the tritiated water. Higher tritiated water concentrations correlate with higher tritium concentrations in the soil cores obtained when the boreholes were constructed.

As part of a search for radionuclides other than tritium in the borehole monitoring wells, sets of large volume water samples were collected to obtain greater sensitivity in the analysis. One set of samples was collected

TABLE 3.4

Tritiated Water Content of Boreholes Near Plot M, 1987
(Concentrations in nCi/L)

Borehole	Depth (ft)	Date Collected						
		February 24	April 29	June 17	August 12	September 11	October 23	December 10
1	40	1380	1535	1600	1635	1725	991	911
2	40	326	326	391	399	403	499	546
3	40	3651	3747	3908	4528	4222	4429	4129
4	40	553	520	515	480	499	575	492
5	40	103	97.4	108	114	114	110	117
6	40	31.8	36.6	71.6	100	87.6	380	40.7
8	40	-	-	-	-	-	0.52	-
9	40*	2196	2604	2888	3569	1933	1.94×10^4	1713
10	40*	9903	5297	9808	1.72×10^4	1.98×10^4	-	2.11×10^4
11	39	-	-	-	-	-	929	1728
11	124	68.4	35.4	25.5	72.1	35.1	58.3	49.9
24	126	218	181	31.2	240	4.6	338	36.9
26	60	1662	378	112	1681	1725	1557	1391
28	60	308	326	325	295	296	335	270
35	110	2025	1889	1311	1516	1611	1413	865
36	127	550	653	788	1741	954	1070	1045

*Slant hole drilled at 45° to a depth of 40 ft below the surface.

TABLE 3.5

Water Level Measurements in Boreholes Near Plot M, 1987
(Units of feet below the benchmark at the top of the well)

Borehole	Depth (ft)	Date Measured						
		February 24	April 29	June 24	August 12	September 11	October 23	December 12
1	40	37.85	36.63	35.70	36.70	35.58	37.06	38.80
2	40	24.70	22.14	24.96	28.23	25.75	29.68	23.89
3	40	31.77	30.09	31.60	31.82	31.59	32.28	38.30
4	40	14.88	13.40	14.76	18.37	15.95	19.35	18.11
5	40	21.70	20.44	21.31	22.66	22.64	23.20	23.89
6	40	13.04	10.52	21.38	31.37	30.51	33.67	11.45
8	40	-	34.89	-	-	-	36.13	-
11	39	-	-	-	-	-	28.61	20.70
11	124	104.77	104.19	104.40	104.60	104.23	104.59	104.29
24	125	91.14	89.95	94.24	94.69	88.50	89.03	93.11
26	60	46.52	44.27	43.99	46.00	47.13	47.77	48.79
28	60	53.14	49.91	52.90	51.12	50.42	49.56	55.02
35	110	93.78	92.91	91.31	93.40	93.27	93.61	93.28
36	127	104.27	103.88	103.94	103.71	104.29	104.56	104.44

in spring on April 29, 1987, and the fall set on October 23 and 26, 1987. Samples were collected from all boreholes that yielded sufficient water for analysis. All samples were analyzed for strontium-90 and selected samples for technetium-99. The results are collected in Table 3.6. Strontium-90 concentrations greater than the detection limit of 0.25 pCi/L were found in eight of the 16 sampled boreholes. Levels above 0.25 pCi/L would not be expected in this water from fallout, and no other source is known. It should be noted that the borehole with one of the highest strontium-90 concentrations (Borehole #6) is between the buried waste and the stream that flows around Plot M. As seen in Table 3.3, measurable strontium-90 concentrations were also found in the stream water below the Plot.

Selected samples of borehole water were analyzed for the first time for technetium-99. Technetium is known to form very mobile anionic species that are poorly retarded by the soils. Technetium-99 concentrations greater than the detection limit of 0.5 pCi/L were found in six of the 15 boreholes analyzed. Concentrations are all very low and a small fraction of the most restrictive limit; the USEPA drinking water limit of 3000 pCi/L.[8] In general, the technetium-99 results do not correlate well with the strontium-90 concentrations. For example, Borehole #6 has one of the highest strontium-90 concentrations, but no technetium-99 was detected. The positive technetium-99 concentrations are north of Plot M, which is in the normal subsurface water flow direction. It is not known if any technetium-99 had been buried at Plot M, but fission product mixtures were used at the site and some were probably buried.

DOE Order 5480.14[13] requires the identification and characterization of any disposal site where chemically-hazardous waste may have been buried. Since various chemical wastes may have been buried along with the radioactive waste at Plot M, a program was established to determine if any such waste constituents were migrating from Plot M. Borehole water samples were collected on April 29, 1987, from six locations around Plot M. Samples were collected using a Teflon bailer and were iced from time of collection to analysis. The samples were collected and analyzed within 14 days as required by EPA protocols. Five water samples were collected from boreholes on the perimeter of the Plot, Boreholes #1, #2, #3, #6, and #26, and from

TABLE 3.6

Radiochemical Analyses of Borehole Water Samples Near Plot M, 1987
(Concentrations in pCi/L)

Borehole	Date Collected	Strontium-90	Technetium-99
1 (40')	April 29	0.64 ± 0.35	< 0.5
	October 26	0.47 ± 0.06	-
2 (40')	April 29	0.52 ± 0.24	< 0.5
	October 26	0.48 ± 0.28	-
3 (40')	April 29	< 0.25	0.8 ± 0.1
	October 23	< 0.25	2.0 ± 0.2
4 (40')	April 29	< 0.25	< 0.5
	October 23	< 0.25	-
5 (40')	April 29	< 0.25	< 0.5
	October 23	< 0.25	-
6 (40')	April 29	6.40 ± 0.47	< 0.5
	October 26	5.94 ± 0.82	-
8 (40')	April 29	< 0.25	< 0.5
	October 23	< 0.25	-
9 (40')	April 29	6.32 ± 0.79	3.1 ± 0.3
	October 23	6.34 ± 0.34	6.5 ± 0.7
10 (40')	April 29	< 0.25	< 0.5
11 (39')	October 26	3.83 ± 0.85	-
11 (124')	April 29	< 0.25	< 0.5
	October 23	0.82 ± 0.23	-
24 (125')	April 29	< 0.25	< 0.5
	October 26	< 0.25	-
26 (60')	April 29	1.63 ± 0.30	3.0 ± 0.3
	October 26	0.53 ± 0.23	< 0.5
28 (60')	April 29	< 0.25	4.9 ± 0.5
	October 26	< 0.25	< 0.5
35 (110')	April 29	< 0.25	1.3 ± 0.1
	October 23	0.64 ± 0.13	1.5 ± 0.1
36 (127')	April 29	< 0.25	1.0 ± 0.1
	October 26	< 0.25	2.3 ± 0.2

Borehole #8 which would serve as a control. The inorganic constituents in these samples were determined by either flameless atomic absorption using pyrolytic graphite, flame atomic absorption, or ion chromatography and the volatile organic constituents (VOA) were determined by purge and trap gas chromatography. The results of the measurements for selected inorganic constituents are in Table 3.7. Samples analyzed for the volatile organic constituents listed in Table 3.8 were all less than the detection limit of 5 µg/L.

Analyses were performed for a number of toxic metals and organic compounds that might be expected to be present in Plot M and the results were compared to the indicated limits. The results obtained for the inorganic constituents were below the drinking water limits[15] with the exception of sulfate in Boreholes #1, #2, #8, and #26 and the pH in Borehole #26. These results are similar to those previously reported. The sulfate appears to be a natural constituent in the area. The high pH could be related to grout in the borehole or locally high levels of basic materials. In addition, some other constituents were included in the table for which no limits have been established. These are either constituents that are frequently found in chemical waste or were identified by the analytical method that was employed for the other materials. The concentration of all the organic compounds thought likely to be present were less than the specified detection limit. Based on the sampling and analyses conducted on those samples, no hazardous waste constituents have been observed to be migrating from Plot M.

3.3.2 Dolomite Hole Water

At the present time, 17 wells are cased into the dolomite zone to monitor the movement of any radionuclides in this aquifer. Most of the dolomite holes are located north of Plot M and east of the Red Gate Woods well (#5167), as shown in Figures 1.2 and/or 3.3. Four dolomite holes, DH 11 to DH 14, were installed in fall of 1985 and three, DH 15 to DH 17 in the fall of 1986 by the U. S. Geological Survey (USGS), as part of a cooperative study of this site. Water was collected from the dolomite holes on the same schedule as the boreholes. All samples were analyzed for tritiated water and the results are in Table 3.9. Water levels were also measured in

TABLE 3.7

Inorganic Constituents in Borehole Water, 1987
(Concentrations in mg/L)

Inorganic Constituent	Borehole Number* 1	2	3	6	8	26	Limit**
Barium	0.03	0.02	0.02	< 0.01	0.02	0.13	100
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.0
Chloride	34	13	11	4	55	10	250
Chromium	0.02	< 0.01	0.01	< 0.01	0.02	< 0.01	5.0
Copper	0.08	0.07	0.03	0.01	0.04	0.05	-
Fluoride	0.24	0.19	0.18	0.29	0.25	0.17	2.0
Iron	0.10	< 0.1	< 0.1	< 0.1	2.10	< 0.1	-
Lead	0.03	< 0.01	< 0.01	< 0.01	0.03	< 0.01	5.0
Manganese	0.39	0.02	0.23	0.02	1.63	< 0.01	15
Mercury***	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	200***
Nickel	0.15	0.06	< 0.05	< 0.05	0.10	< 0.05	-
pH	6.8	7.0	7.0	7.2	6.9	11.5	-
Silver	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	5.0
Sulfate	3601	1119	247	74	2455	438	250
Zinc	0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	-

*See Figure 3.2

**Based on 40 CFR Parts 261, 271, and 302[14]

***Concentrations in µg/L

TABLE 3.8

Volatile Organic Constituents in Borehole Water, 1987
1,1-Dichloroethene
1,1-Dichloroethane
Trans-1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon Tetrachloride
Bromodichloromethane
1,2-Dichloropropane
Trans-1,3-Dichloropropene
Trichloroethene
Benzene
Dibromochloromethane
1,1,2-Trichloroethane
cis-1,3-Dichloropropene
2-Chloroethylvinyl Ether
Bromoform
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl Benzene
1,3-Dichlorobenzene
1,2-Dichlorobenzene
1,4-Dichlorobenzene

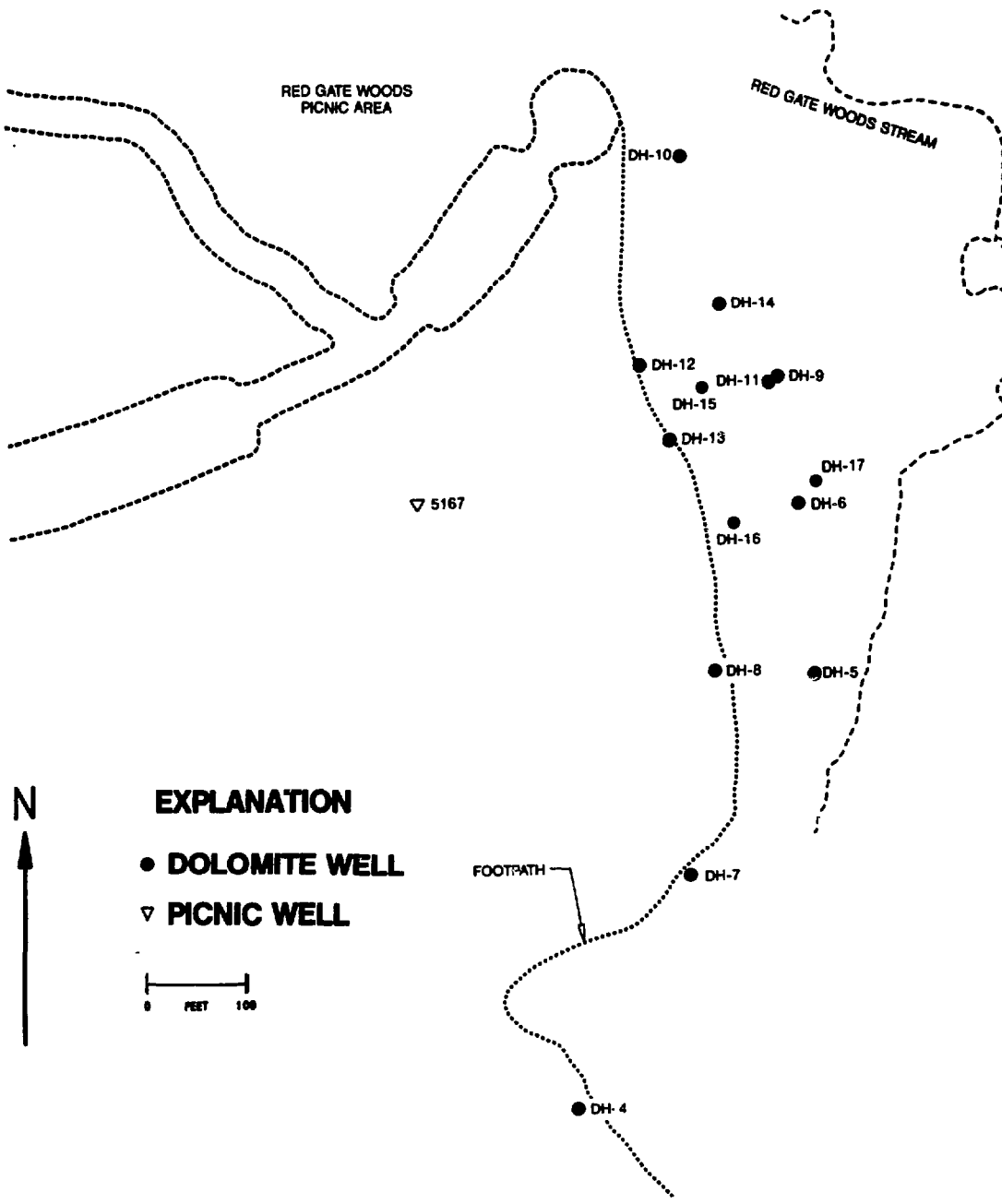

Figure 3.3 Locations of Dolomite HOles North of Plot M

TABLE 3.9

Tritiated Water Content of Dolomite Holes, 1987
(Concentrations in nCi/L)

Dolomite Hole	Date Collected							
	February 24	March 24	April 28	June 23	July 29	September 10	October 23	November 23
1	-	< 0.2	-	< 0.2	-	< 0.2	-	-
2	-	< 0.2	-	< 0.2	-	< 0.2	-	-
3	-	1.8 ± 0.1	1.7 ± 0.1	1.9 ± 0.1	-	1.4 ± 0.3	-	-
4	-	0.2 ± 0.1	-	< 0.2	-	0.3 ± 0.3	-	-
5	-	0.4 ± 0.1	-	< 0.2	-	0.3 ± 0.3	-	-
6	0.6 ± 0.1	1.0 ± 0.1	-	1.4 ± 0.1	1.4 ± 0.1	3.0 ± 0.3	2.5 ± 0.3	3.1 ± 0.3
7	-	< 0.2	-	< 0.2	-	0.5 ± 0.3	-	-
8	-	< 0.2	-	< 0.2	-	< 0.2	-	-
9	21.8 ± 0.2	23.4 ± 0.2	22.0 ± 0.2	20.7 ± 0.6	21.7 ± 0.4	22.3 ± 0.4	22.3 ± 0.5	25.0 ± 0.5
10	7.7 ± 0.2	7.9 ± 0.2	7.3 ± 0.1	7.5 ± 0.3	7.0 ± 0.3	7.5 ± 0.3	7.0 ± 0.4	9.0 ± 0.4
11	9.8 ± 0.2	9.6 ± 0.2	9.2 ± 0.2	9.3 ± 0.4	9.0 ± 0.3	8.9 ± 0.3	9.1 ± 0.4	9.9 ± 0.4
12	-	-	7.8 ± 0.2	8.4 ± 0.4	7.9 ± 0.3	9.1 ± 0.3	8.8 ± 0.4	9.0 ± 0.3
13	5.8 ± 0.1	5.8 ± 0.1	-	-	-	4.4 ± 0.3	4.9 ± 0.3	5.5 ± 0.3
14	12.0 ± 0.2	11.6 ± 0.2	11.1 ± 0.2	10.1 ± 0.4	11.0 ± 0.3	9.2 ± 0.3	9.4 ± 0.4	11.4 ± 0.4
15	0.8 ± 0.1	4.4 ± 0.1	5.3 ± 0.1	4.5 ± 0.3	4.0 ± 0.3	3.9 ± 0.3	3.0 ± 0.3	3.6 ± 0.3
16	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
17	0.7 ± 0.1	0.7 ± 0.1	1.3 ± 0.1	1.2 ± 0.3	1.2 ± 0.3	1.6 ± 0.3	1.7 ± 0.3	1.9 ± 0.3

the dolomite holes and these measurements are in Table 3.10. Since the four wells installed in the fall of 1985 are located close to each other, the water level was only measured in DH 11 and assumed to be representative of the four.

The results of the tritiated water analysis of the first 14 dolomite holes are consistent with concentrations measured in the past. The measured concentrations in DH 15 and DH 17 are consistent with their location relative to the other dolomite holes. In all, ten of the dolomite holes had elevated tritiated water concentrations. The highest tritium levels are in the eight dolomite holes, DH 9 to DH 15 and DH 17, which are the furthest north and near the surface stream that flows next to Plot M (see Section 3.2). The distribution of tritium in these wells is consistent with the USGS interpretation that a large tritium plume underlies the stream. Loss of water through the stream bottom has forced the tritium plume downward and outward resulting in the current configuration of the plume in the dolomite.

DH 9 and DH 11 are located about ten feet apart, but have significantly different tritiated water concentrations. When the USGS drilled DH 11, they collected soil cores down to the dolomite and as a result found that DH 9 is not open to the dolomite. Tritium concentrations in DH 11 cores from the same depth as the bottom of DH 9 were between 20 and 30 nCi/L, which is similar to those in DH 9. Several of the USGS holes had collapsed similar to that in DH 9 and water levels in them indicate they are open to glacial drift, not dolomite. These wells, which should not be considered as dolomite holes are: DH 6, DH 7, DH 8, and DH 9. However, DH 6 and DH 9 do provide useful tritium concentration data for the glacial drift just above the dolomite contact. The other dolomite hole with elevated tritium is DH 3, which is immediately downgradient from Plot M. Previous analyses of soil core samples indicated the presence of tritium down to the till-dolomite interface.

3.3.3 Well Water

Sampling was conducted throughout the year at the five Forest Preserve picnic wells located north of Plot M and shown in Figure 1.2. These wells

TABLE 3.10

Water Level Measurements in Dolomite Holes, 1987
(Units of feet below the benchmark at the top of the well)

Dolomite Hole	Date Measured							
	February 24	March 24	April 28	June 23	July 29	September 10	October 23	November 23
DH 1	-	160.62	-	161.03	-	160.64	-	-
DH 2	-	138.94	-	139.32	-	138.87	-	-
DH 3	-	97.50	-	97.75	-	97.48	-	-
DH 4	-	92.70	-	93.01	-	92.60	-	-
DH 5	-	77.72	-	77.95	-	77.54	-	-
DH 6	75.00	74.80	74.32	75.01	75.52	74.52	75.33	75.27
DH 7	-	82.21	-	81.97	-	81.83	-	-
DH 8	-	78.18	-	74.20	-	74.21	-	-
DH 9	73.98	72.96	73.08	72.95	73.27	73.02	73.86	73.68
DH 10	64.70	64.11	63.86	64.48	64.97	63.99	64.86	64.73
DH 11	75.84	75.17	75.04	75.62	76.12	75.13	76.02	75.87
DH 15	79.65	79.07	-	79.44	79.92	78.93	79.80	79.64
DH 16	75.82	75.24	75.00	75.57	76.10	75.12	75.97	75.82
DH 17	74.89	74.24	74.06	74.60	75.15	74.15	75.01	74.82

are located in the same dolomite rock zone as the previously discussed dolomite holes. All the samples were analyzed for tritiated water and the results are listed in Table 3.11. The Red Gate Woods well (#5167) continues to reach a maximum in the fall and winter and a minimum in the summer, while the well opposite Red Gate Woods (#5159) shows a maximum in the spring and a minimum in the fall. However, the magnitude of the winter peak in the Red Gate Woods well (#5167) is significantly less than in earlier years and has been trending downward over the last few years. This is illustrated in Figure 3.4 which shows a plot of the individual results for the past six years. The other wells, although also downgradient from Plot M, are evidently too far from the Plot to show consistently elevated tritium concentrations, although occasional results are above the detection limit. Three of the picnic wells, #5159, #5157, and #5158 were not available to the public during the year because the Cook County Forest Preserve District removed the pump handles due to high fecal coliform results. A set of picnic well water samples was collected on October 9, 1987, from the wells on the east and south sides of the Palos Forest Preserve. The sampled wells were #5162, #5031, #5188, #5153, #5193, #5154, #5226, #5021, and #5149 in Figure 1.2. All the tritium results were less than the detection limit of 0.2 nCi/L.

The tritium concentrations in the Red Gate Woods well (#5167) did not exhibit the normal pattern in the fall of 1987. After an initial increase in concentration in August, the tritium decreased to less than the detection limit in October and then gradually increased to the end of the year. This unusual decrease is consistent with the interpretation that recharging water from the drift dilutes tritium concentrations in well #5167.[16] A record 17 inches of precipitation was measured in August.

The Red Gate Woods well (#5167) is the location that provides the greatest potential radiation exposure to the public. If water equal to the Red Gate Woods well average concentration of 1.6 nCi/L were the sole source of water for an individual, the annual dose from the tritium would be 0.32 mrem. This is based on the EPA drinking water limit of a dose of 4 mrem/y, which results from the consumption of two liters of water per day at a concentration of 20 nCi/L.[8] If an individual consumed one liter of this water, the dose would be 0.0004 mrem. These doses are very low compared to

TABLE 3.11

TRITIATED WATER CONTENT IN WELLS NEAR SITE A /PLOT M, 1987
(CONCENTRATIONS IN NANOCURIES/L)

DATE COLLECTED	WELL NUMBER				
	5167	5159	5158	5157	5215
JANUARY 7, 1987	3.0	-	< 0.2	< 0.2	-
JANUARY 21, 1987	2.8	0.63	-	-	-
FEBRUARY 4, 1987	2.7	0.49	< 0.2	< 0.2	-
FEBRUARY 18, 1987	3.0	0.33	-	-	-
MARCH 4, 1987	3.0	-	0.29	< 0.2	< 0.2
MARCH 18, 1987	3.2	0.38	-	-	-
APRIL 1, 1987	1.8	< 0.2	< 0.2	< 0.2	< 0.2
APRIL 15, 1987	2.0	0.23	-	-	-
MAY 6, 1987	0.52	0.42	< 0.2	< 0.2	0.27
MAY 20, 1987	0.45	0.53	-	-	-
JUNE 3, 1987	-	0.39	< 0.2	< 0.2	< 0.2
JUNE 17, 1987	0.98	0.56	-	-	-
JULY 1, 1987	-	0.59	< 0.2	< 0.2	< 0.2
JULY 15, 1987	-	0.64	-	-	-
AUGUST 5, 1987	-	0.73	< 0.2	< 0.2	< 0.2
AUGUST 28, 1987	3.0	0.67	-	-	-
SEPTEMBER 2, 1987	3.3	0.62	0.30	-	< 0.2
SEPTEMBER 16, 1987	0.21	0.65	-	-	-
OCTOBER 7, 1987	< 0.2	0.64	< 0.2	< 0.2	< 0.2
OCTOBER 9, 1987	-	0.53	-	-	-
OCTOBER 21, 1987	< 0.2	-	-	-	-
NOVEMBER 4, 1987	0.32	0.68	< 0.2	< 0.2	< 0.2
NOVEMBER 18, 1987	0.54	0.73	-	-	-
DECEMBER 2, 1987	0.79	0.61	< 0.2	< 0.2	< 0.2
DECEMBER 18, 1987	1.2	0.61	-	-	-

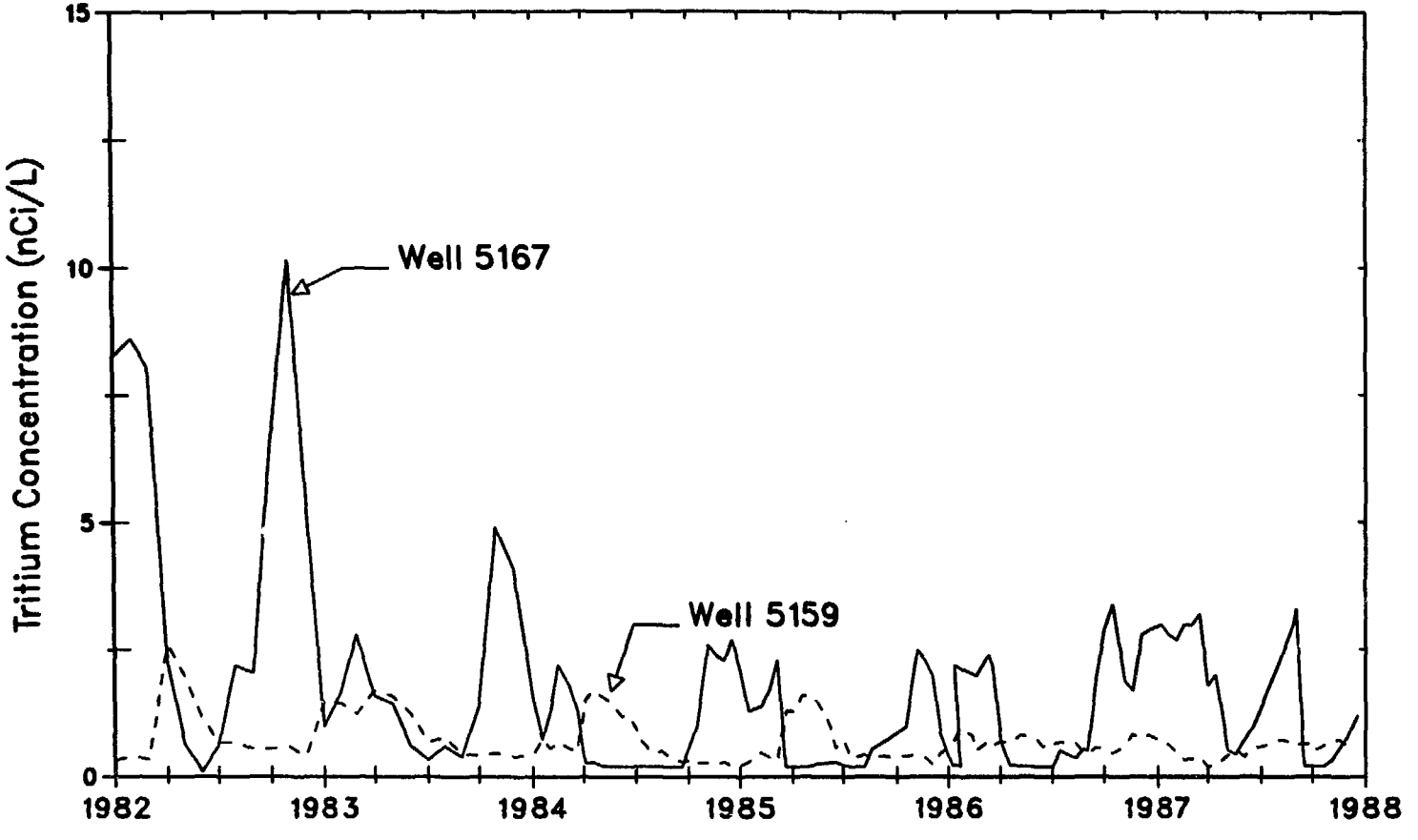

Figure 3.4 Tritiated Water Concentrations in Red Gate Woods Well (#5167) and Opposite Red Gates Woods (#5159) From 1982 to 1987

the current EPA limit. The well opposite Red Gate Woods (#5159) had tritium concentrations that ranged from 0.2 nCi/L to 0.73 nCi/L and averaged 0.54 nCi/L.

In addition to tritiated water measurements, one set of water samples from the five north wells were analyzed for isotopic uranium, total alpha, total beta, strontium-90, and the transuranic nuclides. The total alpha and total beta activities were in the normal range of concentrations found in other wells completed into the dolomite, the strontium-90 results were all less than the detection limit of 0.25 pCi/L and the transuranic nuclides were all less than the detection limit of 0.001 pCi/L. The uranium results are presented in Table 3.12. The range of concentrations is similar to that found previously.

Samples were collected quarterly from the Red Gate Woods well (#5167) and analyzed for the same inorganic constituents discussed in Section 3.3.1. The results are found in Table 3.13. Because the picnic wells are used as a drinking water supply, the limits used were the State of Illinois concentrations of chemical constituents in drinking water.[15] As discussed earlier, the constituents in Table 3.13 that do not have a specific limit are provided for completeness. Although the limits are occasionally exceeded for sulfate, this is probably due to natural causes. These concentrations are not unusual for dolomite water in northeast Illinois. Elevated levels of iron, zinc, and some trace metals can sometimes be related to the decomposition of the well pump materials. There is no evidence that the source of the elevated inorganic constituents is from Plot M.

3.4 Bottom Sediment

Bottom sediment samples were collected from the stream next to Plot M at Location #1 and at Location #9 on April 28, 1987, and at Location #1, Location #6 (Seep), and Location #9 on October 22, 1987. These samples were taken at the same times and locations as the water samples discussed in Table 3.3. Various radiochemical analyses were performed on these samples and the results are found in Table 3.14. The results are similar at all locations except that the plutonium-239 is slightly elevated downstream.

TABLE 3.12

Uranium Content of Well Water Near Plot M, 1987

(Concentrations in pCi/L)

Well Number*	Location	Date Collected			
		February 4	May 6	August 28	November 4
5167	Red Gate Woods	0.67 ± 0.16	0.54 ± 0.15	0.69 ± 0.17	0.44 ± 0.11
5159	Opposite Entrance to Red Gate Woods	0.56 ± 0.15	0.54 ± 0.16	0.19 ± 0.10	0.07 ± 0.05
5158	300 yds NE of Entrance to Red Gate Woods	0.32 ± 0.12	-	-	-
5157	95th & Archer	1.46 ± 0.23	-	-	-
5215	Guard Post	0.13 ± 0.06	-	-	-

*See Figure 1.2.

TABLE 3.13

Inorganic Constituents in Red Gate Woods Well Water, 1987
(Concentrations in mg/L)

Inorganic Constituent	February	May	August	November	Limit**
Barium	0.02	0.03	0.02	0.04	1.0
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Chloride	7	4	3	5	250
Chromium	< 0.01	< 0.01	0.01	< 0.01	0.05
Copper	0.02	0.07	0.05	0.02	-
Fluoride	0.13	0.11	0.11	0.26	-
Iron	15.0	3.0	26.7	10.0	-
Lead	0.02	< 0.01	< 0.01	0.01	0.05
Manganese	0.12	0.05	0.16	0.04	0.15
Mercury*	< 0.1	< 0.1	< 0.1	< 0.1	2.0*
Nickel	< 0.05	< 0.05	0.02	0.04	-
pH	7.2	7.0	7.1	7.0	-
Silver	< 0.01	< 0.01	< 0.01	< 0.01	0.05
Sulfate	299	293	327	371	250
Zinc	9.69	6.07	10.24	13.24	-

*Concentrations in µg/L.

**State of Illinois concentrations of chemical constituents in drinking water.[15]

TABLE 3.14

Radioactivity Content of Stream Bed Next to Plot M, 1987

(Concentrations in pCi/g)

Radionuclide	Date Collected	Location #1* (Upstream)	Location #6* (Seep)	Location #9* (Downstream)
Potassium-40	April 28	25.00 ± 1.00	-	22.72 ± 0.98
	October 22	23.74 ± 0.89	23.33 ± 0.88	24.15 ± 0.93
Strontium-90	April 28	0.17 ± 0.10	-	0.16 ± 0.14
	October 22	0.07 ± 0.10	0.11 ± 0.03	0.06 ± 0.07
Cesium-137	April 28	0.24 ± 0.03	-	0.27 ± 0.03
	October 22	0.30 ± 0.03	0.41 ± 0.03	0.32 ± 0.03
Radium-226	April 28	2.82 ± 0.10	-	3.14 ± 0.11
	October 22	2.58 ± 0.08	1.51 ± 0.07	1.64 ± 0.07
Thorium-228	April 28	1.42 ± 0.06	-	1.39 ± 0.05
	October 22	1.25 ± 0.04	0.97 ± 0.04	1.18 ± 0.05
Thorium-232	April 28	1.22 ± 0.13	-	1.21 ± 0.13
	October 22	1.06 ± 0.10	0.78 ± 0.09	0.82 ± 0.10
Uranium-234	April 28	1.31 ± 0.07	-	1.23 ± 0.07
	October 22	1.07 ± 0.07	0.92 ± 0.06	1.23 ± 0.09
Uranium-235	April 28	0.02 ± 0.01	-	0.02 ± 0.01
	October 22	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Uranium-238	April 28	1.64 ± 0.08	-	1.36 ± 0.07
	October 22	1.20 ± 0.08	1.06 ± 0.06	1.46 ± 0.10
Plutonium-238	April 28	0.0003 ± 0.0002	-	0.0005 ± 0.0001
	October 22	0.0005 ± 0.0002	0.0005 ± 0.0002	0.0004 ± 0.0002
Plutonium-239	April 28	0.0084 ± 0.0010	-	0.0216 ± 0.0007
	October 22	0.0088 ± 0.0009	0.0214 ± 0.0015	0.0278 ± 0.0018
Americium-241	April 28	0.0005 ± 0.0012	-	0.0013 ± 0.0008
	October 22	0.0035 ± 0.0008	0.0025 ± 0.0004	0.0049 ± 0.0007

*See Figure 3.1.

However, the plutonium-239 concentration of 0.028 pCi/g, is similar to the fallout level. The concentrations are very low and may reflect differences in the retentiveness of the bottom material.

4.0 References

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5.0 Appendices

5.1 Quality Assurance Program

All nuclear instrumentation is calibrated with standard sources obtained from the U. S. National Bureau of Standards (NBS), if possible. If NBS standards were not available for particular nuclides, standards from the Amersham Corporation were used. The equipment is usually checked on a daily basis with secondary counting standards to insure proper operation. Samples were periodically analyzed in duplicate or with the addition of known amounts of a radionuclide to check precision and accuracy. Intercomparison samples distributed by the Quality Assurance Branch of the EPA are analyzed regularly. In addition, our laboratory participates in the DOE Environmental Measurements Laboratory Quality Assurance Program, a semi-annual distribution of four or five different sample matrices containing various combinations of radionuclides. The results of our participation in both programs for 1987 are published in ANL-88-13.[11]

Many factors enter into an overall quality assurance program other than the analytical quality control discussed above. Representative sampling is of prime importance. Appropriate sampling protocols are followed for each type of sampling being conducted. Water samples are pre-treated in a manner designed to maintain the integrity of the constituent sought. For example, samples for trace radionuclide analyses are acidified immediately after collection to prevent hydrolytic loss of metal ions.

5.2 Applicable Standards

The principle standard that is applicable to this study is the EPA drinking water standard as applied to the Forest Preserve wells. All other water samples; surface stream, deep holes, and boreholes, are not drinking water supplies and therefore this standard does not apply. Since tritiated water is the only radionuclide identified in the Forest Preserve wells, the EPA limit of 20 nCi/L, which would result in an annual dose of 4 mrem, applies. The DOE draft Order[9] is applied to the other measurements. These EFF.D.E.s are based on a radiation protection standard of 100 mrem/y.

5.3 Analytical Methods

The analytical methods used to obtain the data in this report are the same as those described in ANL-88-13.[11]

5.4 Acknowledgements

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