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1987 ANNUAL SITE ENVIRONMENTAL REPORT FOR ARGONNE NATIONAL LABORATORY

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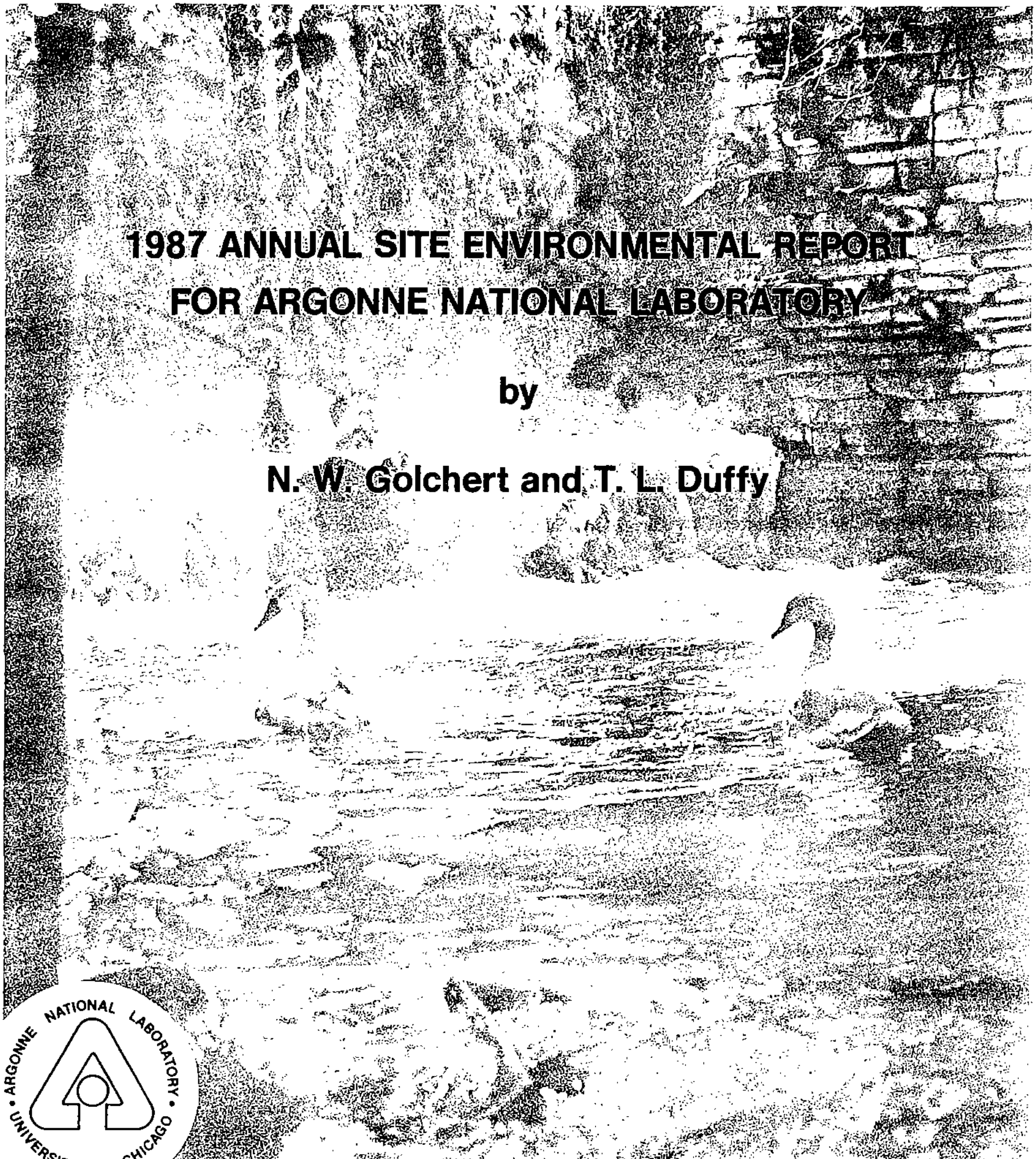
N. W. Golchert and T. L. Duffy



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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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N. W. Golchert and T. L. Duffy

Environment, Safety and Health Department

Laboratory Work Performed by

T. L. Duffy	D. M. Ray
N. W. Golchert	J. G. Riha
R. B. Kasper	H. C. Svoboda
N. D. Kretz	T. TenKate

April 1988

Approved: R.A. Wynveen
R. A. Wynveen
Acting Department Manager

Preceding Report in This Series: ANL-87-9

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ABSTRACT

The results of the environmental monitoring program at Argonne National Laboratory (ANL) for 1987 are presented and discussed. To evaluate the effect of ANL operations on the environment, sample collections were made on the site, at the site boundary, and off the ANL site for comparison purposes. Measurements were made for a variety of radionuclides in air, surface water, ground water, soil, grass, bottom sediment, and milk. Samples were also analyzed for a variety of chemical constituents in surface water, ground water, and ANL effluent water. Measurements of external penetrating radiation dose were also determined. The potential radiation dose to off-site population groups is estimated. The results of the program are interpreted in terms of the origin of the radioactive and chemical substances (natural, fallout, ANL, and other) and are compared with applicable environmental quality standards. A United States Department of Energy (DOE) dose calculation methodology, based on recent International Commission on Radiological Protection (ICRP) recommendations, is used in this report. The average concentrations and total amounts of radioactive and chemical pollutants released by ANL to the environment were all below appropriate standards.

1. INTRODUCTION

1.1. General

This report is prepared to provide DOE, environmental agencies, and the public with information on the levels of radioactive and chemical pollutants in ANL's environment and on the amounts, if any, added to the environment as a result of ANL operations. The report follows the guidelines given in DOE

Draft Order 5400.1.[1]. ANL conducts a continuous environmental monitoring program on and near the site with the primary purpose of determining the magnitude, origin, and identity of radioactive or toxic chemical substances in the environment. The detection of any such materials released to the environment by ANL is of special interest. One important function of the program is to verify the adequacy of ANL's pollution controls.

ANL is a DOE energy research and development laboratory with several principal objectives. It conducts a broad program of research in the basic energy and related sciences (physical, chemical, material, nuclear, biomedical, and environmental) and serves as an important engineering center for the study of nuclear and non-nuclear energy sources. Energy-related research projects conducted during 1987 included: safety studies for light water and breeder reactors; development of components and materials for fission and fusion reactors; improvements in the utilization of coal for power production (particularly high sulfur coal); development of electrochemical energy sources including fuel cells and batteries for vehicles and for energy storage; solar energy utilization; evaluation of heat exchangers for the recovery of waste heat from engines; operation of the National Battery Test Laboratory; and high-temperature super-conductor development.

Other areas of research are the use of superconducting magnets for improved nuclear particle accelerators, coal technology, fundamental coal chemistry studies, magnetic confinement fusion, the immobilization of radioactive waste products for safe disposal, medical radioisotope technology, carcinogenesis, and the biological effects of small amounts of radiation. Environmental research studies include biological activity of energy-related mutagens and carcinogens, chemistry of actinides in natural waters, characterization and monitoring of energy-related pollutants, and the effect of acid rain on vegetation, soil, and surface water quality. A significant portion of these laboratory studies requires the use of radioactive and chemically toxic substances.

The principal nuclear facilities at the ANL are a 185 kW light-water cooled and moderated biological research reactor (Janus), fueled with enriched uranium; the Argonne Thermal Source Reactor (ATSR), a 10 kW research reactor fueled with enriched uranium; a superconducting heavy ion linear accelerator (Argonne Tandem Linac Accelerating System, ATLAS); a 22 MeV pulsed electron Linac; a 60-inch cyclotron; several other charged parti-cle accelerators (principally of the Van de Graaff and Dynamitron type); a large fast neutron source (Intense Pulsed Neutron Source, IPNS) in which high-energy protons strike a uranium target to produce neutrons; cobalt-60 irradiation sources; chemical and metallurgical plutonium labora-tories; and several hot cells and laboratories designed for work with multi-curie quantities of the actinide elements and with irradiated reactor fuel materials. The DOE New Brunswick Laboratory, a safeguards plutonium and uranium measurements and analytical chemistry laboratory, is located on the ANL site.

Two experiments initiated in 1984 were continued in these facilities in 1987 and have some potential environmental impact: (1) proof-of-breeding in light-water reactors, which involves the dissolution and analysis of irradiated thorium and uranium-233 dioxide fuel elements and (2) recovery of tritium from reactor irradiated ceramic lithium compounds. Two major facilities, a 12.5 GeV proton accelerator (Zero Gradient Synchrotron, ZGS) and a 5-MW heavy water enriched uranium reactor (CP-5), were shut down years ago. The CP-5 facility is awaiting decontamination and decommissioning (D&D), whereas the D&D work has been completed at the ZGS.

The principal non-nuclear activities at ANL that may produce a measurable impact on the environment include the use of a coal-fired boiler (No. 5), the closed-loop heat exchanger studies for waste heat recovery, and work in the Fossil Energy Users Laboratory (FEUL). The boiler is designed to burn high sulfur (3.5%) Illinois coal to produce export steam for ANL use and is equipped with a slaked lime spray scrubber and bag collector to reduce sulfur dioxide and particulate emissions. In 1987, the closed-loop heat exchanger studies used moderately large quantities of toxic or flammable organic compounds, such as toluene, Freon, biphenyl oxides, methyl pyridine, and trifluoroethanol. The major environmental impact of these materials would be caused by their accidental release due to equipment malfunction.

1.2. Description of Site

Argonne National Laboratory (Illinois site) occupies the central 688 hectares (1,700 acres) of a 1,514-hectare (3,740-acre) tract in DuPage County, 43 km (27 mi) southwest of downtown Chicago, and 39 km (24 mi) due west of Lake Michigan. It lies north of the Des Plaines River Valley, south of Interstate Highway 55 and west of Illinois Highway 83. Figures 1.1 and 1.2 are maps of the site and of the surrounding area. The 826-hectare (2,040-acre) area surrounding the site (Waterfall Glen Forest Preserve) was formerly ANL property, but was deeded to the DuPage County Forest Preserve District in 1973 for their use as a public recreational area, nature preserve, and demonstration forest.

The terrain is gently rolling, partially wooded, former prairie and farmland. The grounds contain a number of small ponds and streams, the principal one being Sawmill Creek, which runs through the site in a southerly direction and enters the Des Plaines River about 2.1 km (1.3 mi) southeast of the center of the site. The land is drained primarily by Sawmill Creek, although the extreme southern portion drains directly into the Des Plaines River, which flows along the southern boundary of the forest preserve. This river flows southwest until it joins the Kankakee River about 48 km (30 mi) southwest of ANL to form the Illinois River.

The largest topographical feature is the Des Plaines River channel, about 1.6 km (1 mi) wide. This channel contains the river, the Chicago Sanitary and Ship Canal, and the Illinois and Michigan Canal. Their presence extends the uninhabited area about 1.6 km (1 mi) south of the site. The elevation of the channel surface is 180 m (590 ft) above sea level. Bluffs, which compose the south border of the site, rise from the channel at varying slope angles of 15° to 60°, reaching an average elevation of 200 m (650 ft) above sea level at the top. The land then slopes gradually upward reaching the average site elevation of 220 m (725 ft) above sea level at 940 m (3,000 ft) from the bluffs. Several large ravines oriented in a north-south direction are located in the southern portion of the site. The bluffs and ravines generally are forested with mature deciduous trees. The remaining portion of the site changes in elevation by no more than 7.6 m (25 ft)

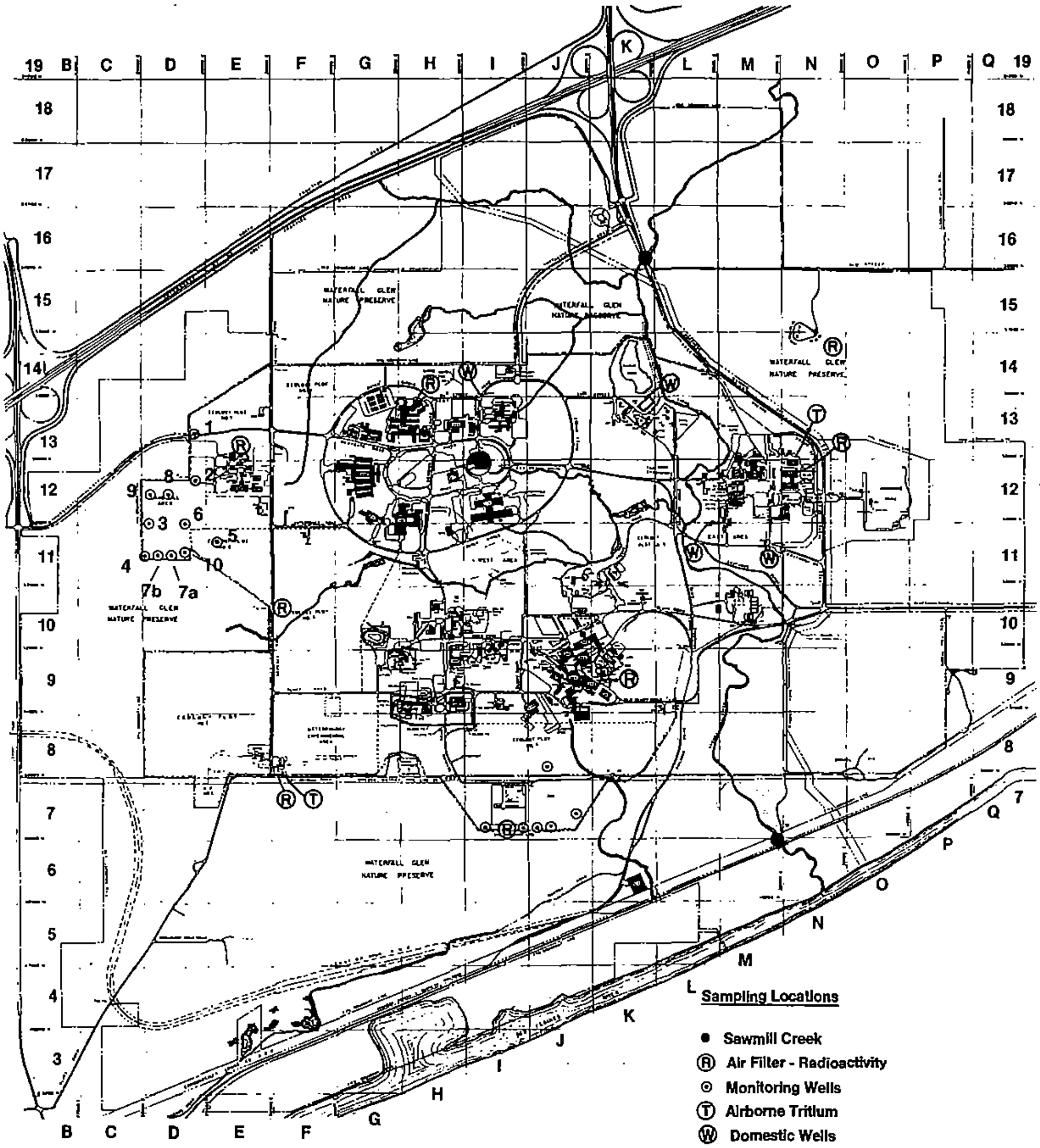

Fig. 1.1 Sampling Locations at Argonne National Laboratory

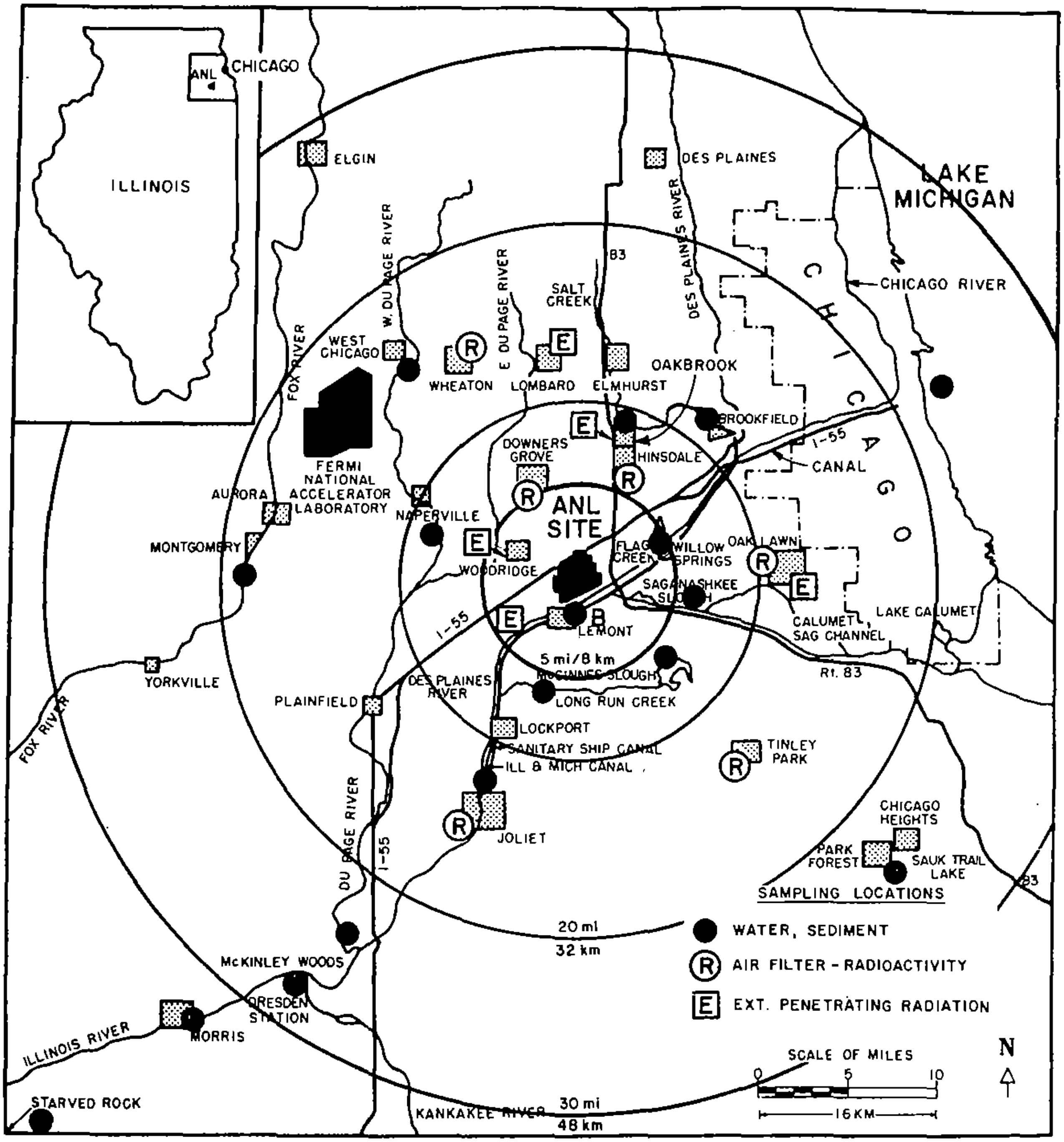

Fig. 1.2 Sampling Locations Near Argonne National Laboratory

in a distance of 150 horizontal m (500 ft). In the southern portion of the forest preserve, the Chicago District Pipe Line Co. and the Atchison, Topeka, and Santa Fe (AT&SF) have rights-of-way. Additional information about the site is given in the Argonne Environmental Assessment.[2]

1.3. Population

The area around ANL has exhibited a large population growth in the past 30 years. Large areas of farmland have been converted into housing. A directional and annular 80-km (50-mi) population distribution for the area, which is used for the population dose calculations later in this report, is shown in Table 1.1. The population distribution was obtained by modifying a distribution for 1981 prepared by Urban Decision Systems, Inc. which was based on the 1980 census. The values for distances within 8 km (5 mi) of the site were modified by using quarter-section population data supplied by the Northeastern Illinois Planning Commission, as adjusted on the basis of local observations.

1.4. Climatology

The climate of the area is that of the upper Mississippi Valley, as moderated by Lake Michigan. A summary of the meteorological data collected on the site from 1950 to 1964 is available[3] and provides a historical sample of the climate.

The most important meteorological parameters for the purposes of this report are wind direction, wind speed, temperature, and precipitation. The wind data are used to calculate radiation doses from air emissions and in selecting air sampling locations and distances. Temperature and precipitation data are useful in interpreting some of the environmental results. The 1987 meteorological data were obtained from the on-site ANL station. The 1987 average monthly and annual wind roses are shown in Figure 1.3. The wind roses are polar coordinate plots, in which the lengths of the radii represent the percentage frequency of wind speeds in classes of 2.01-6 m/s (4.5-13.4 mph), 6.01-10 m/s (13.4-22.4 mph), and greater than 10.01 m/s (22.4 mph). The number in the center represents the percent of observations

TABLE 1.1

Incremental Population Data in the Vicinity of ANL, 1981

If this is dist from center it's ok

						In Thousands				
Distance, miles	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5-10	10-20	20-30	30-40	40-50
Distance, km	0-1.6	1.6-3.2	3.2-4.8	4.8-6.4	6.4-8.0	8-16	16-32	32-48	48-64	64-80
Direction										
N	0	344	1504	863	4115	37.2	179.2	312.1	133.3	202.1
NNE	0	188	2086	14685	5882	38.8	290.7	493.4	95.9	0
NE	0	528	6544	1450	1219	44.0	710.1	940.7	0	0
ENE	0	2630	3640	1854	985	35.6	630.5	240.8	0	0
E	0	14	212	20	15	34.4	514.9	249.4	10.7	25.2
ESE	0	0	85	275	120	11.3	206.2	291.9	271.0	69.0
SE	0	5	155	225	68	29.0	69.5	119.2	24.4	13.3
SSE	0	44	2299	1422	120	1.9	21.7	9.3	9.2	20.0
S	0	100	574	2114	725	5.5	18.5	1.8	33.0	39.5
SSW	0	60	4407	1928	705	19.1	100.9	9.4	17.7	7.5
SW	0	620	1304	50	915	13.1	31.5	6.5	15.0	7.8
WSW	0	492	50	409	12261	3.3	7.1	2.1	6.3	9.4
W	0	2853	905	14000	16464	4.1	58.7	19.6	15.0	6.6
WNW	0	1007	140	5100	5960	39.8	85.5	8.7	7.7	50.3
NW	0	215	2032	3367	7741	28.5	65.2	87.2	10.5	16.6
NNW	0	323	987	2156	7710	41.1	151.2	167.1	107.7	79.5
Total	0	9423	26924	49918	65005	386.7	3141.4	2959.2	757.4	546.8
Cumulative Total	0	9423	36347	86265	151270	538.0	3679.4	6638.6	7396.0	7942.8

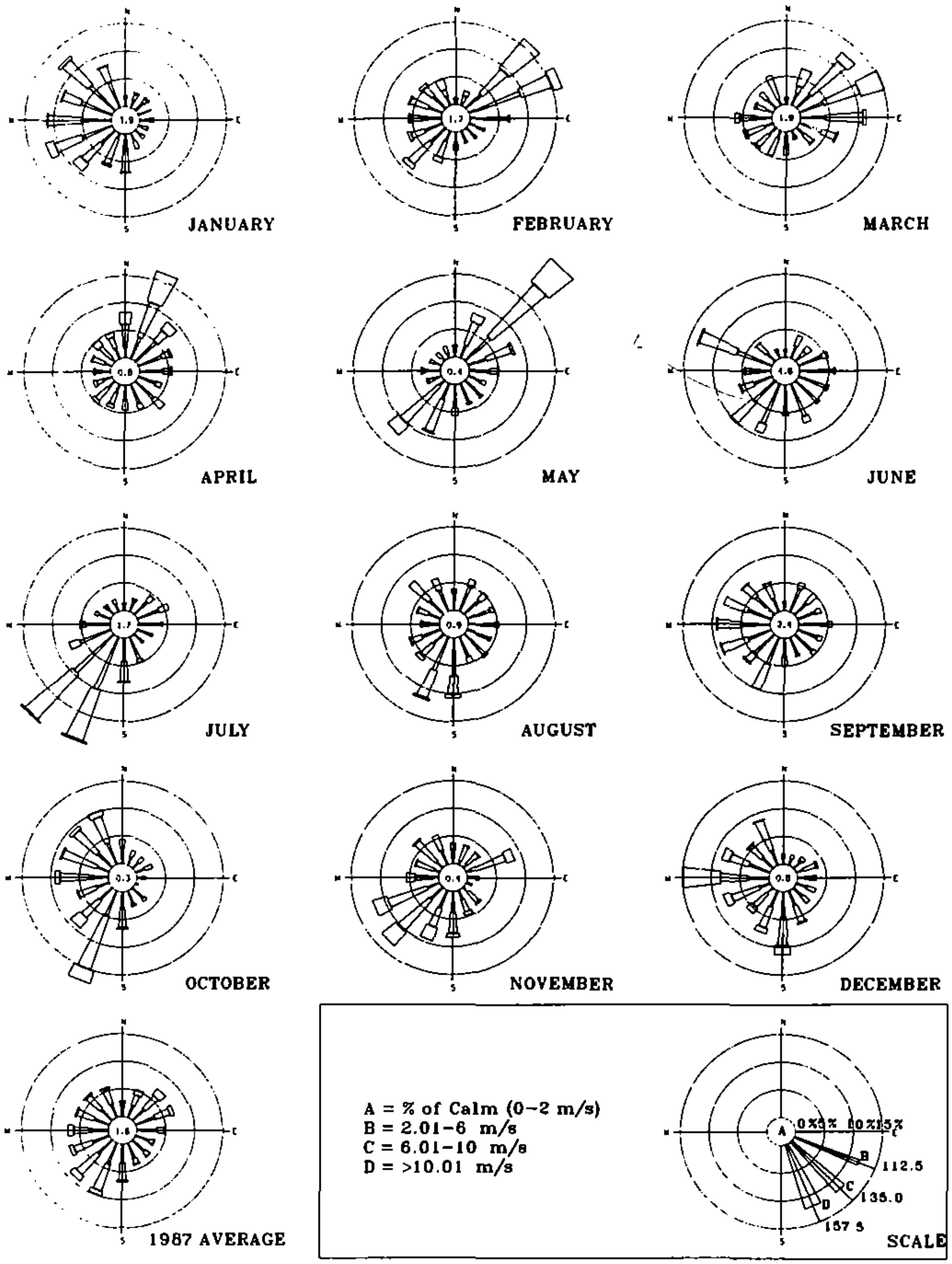

Fig. 1.3 Monthly and Annual Wind Roses Near Argonne National Laboratory, 1987

of wind speed less than 2 m/s (4.5 mph) in all directions. The direction of the radii from the center represents the direction from which the wind blows. Sixteen radii are shown on each plot at 22.5° intervals; each radius represents the average wind speed for the direction covering 11.25° on either side of the radius.

A comparison of the monthly wind roses indicates that the winds are variable so that monitoring for airborne releases must be carried out in all directions from the site. For example, the dominant wind direction in May is northeast, while in July it is southwest. The annual average wind rose for 1987 is consistent with the long term average wind direction, which usually varies from the west to south, but with a significant northeast component. Precipitation and temperature data for 1987 are shown in Table 1.2. The monthly precipitation data for 1987 were marked by large differences from the average. For example, March, April, May, and June, along with September were significantly below the average, while August was a record high of almost five times above the average. The annual total was about 25% higher than the average, principally due to the August record rainfalls. The temperatures were slightly above the average throughout the year.

1.5. Geohydrology

The geology of the ANL area consists of about 30 m (100 ft) of glacial till overlying dolomite bedrock. The bedrock is Niagaran and Alexandrian dolomite from the Silurian age. These formations are underlain by Maquoketa shale of Ordovician age, and older dolomites and sandstones of Ordovician and Cambrian age. The beds are nearly horizontal.

Two principal aquifers are used as water supplies in the vicinity of ANL. The upper aquifer is Niagaran and Alexandrian dolomite, which is about 60 m (200 ft) thick in the ANL area, and has a piezometric surface between 15 and 30 m (50 and 100 ft) below the ground surface over much of the site. The lower aquifer is Galesville sandstone, which lies between 150 and 450 m (490 and 1,500 ft) below the surface. Maquoketa shale separates the upper

TABLE 1.2

ANL Weather Summary, 1987

Month	Precipitation (cm) Amount	Precipitation (cm) Historical Average*	Temperature (°C) Monthly Average	Temperature (°C) Historical Average*
January	4.24	4.06	-3.4	-5.9
February	2.51	3.33	1.1	-3.3
March	4.04	6.58	4.9	2.2
April	5.94	9.30	10.3	9.3
May	5.61	8.00	17.4	15.1
June	5.56	10.36	22.4	20.3
July	10.64	9.22	24.8	22.8
August	43.43	8.97	22.2	22.2
September	2.39	8.51	18.4	18.2
October	4.04	5.79	8.5	11.9
November	7.04	5.23	6.6	4.3
December	9.58	5.33	0.1	-2.4
Total	105.02	84.68		

*Data obtained from the National Oceanic and Atmospheric Administration (NOAA) for the weather station at O'Hare International Airport. The average is for the years 1951-1980.

dolomite aquifer from the underlying sandstone aquifer. This shale retards hydraulic connection between the upper and lower aquifers.

The four domestic water wells now in use (see Figure 1.1) are about 90 m (300 ft) deep in the Niagaran dolomite. One well, in the Galesville sandstone 490 m (1,600 ft) deep, is not used because the water table has dropped below the pumping level. The water level in the Niagaran dolomite has remained reasonably stable under ANL pumping, dropping about 3.7 m (12 ft) between 1960 and 1980. The aquifer appears to be adequate for future ANL use, but this ground water source is used throughout the area. There are also several monitoring wells and small capacity water wells used for laboratory experiments, fire protection, and sanitary facilities.

1.6. Water and Land Use

The principal stream that drains the site is Sawmill Creek. It carried effluent water continuously from a sewage treatment plant (Marion Brook Treatment Plant) located a few kilometers north of the site until October 27, 1986, when the plant was closed. The residential and commercial development in the area has resulted in the collection and channeling of runoff water into Sawmill Creek. Treated sanitary and laboratory waste water from ANL are combined and discharged into Sawmill Creek at location 7M in Figure 1.1. This effluent averaged 3.8 megaliters (1.04 million gallons) per day. The combined ANL effluent consisted of 56% laboratory waste water and 44% sanitary waste water. The water flow in Sawmill Creek upstream of the waste-water outfall averaged about 16 megaliters (4.3 million gallons) per day during 1987.

Sawmill Creek and the Des Plaines River above Joliet, about 21 km (13 mi) southwest of ANL, receive very little recreational or industrial use. A few people fish in these waters downstream of ANL and some duck hunting takes place on the Des Plaines River. Water from the Chicago Sanitary and Ship Canal is used by ANL for cooling towers and by others for industrial purposes, such as hydroelectric generators and condensers, and for irrigation at the state prison near Joliet. The ANL usage is about 0.4 megaliter (100,000 gallons) per day. The canal, which receives Chicago Metropolitan

Sanitary District effluent water, is used for industrial transportation and some recreational boating. Near Joliet, the river and canal are combined into one waterway, which continues until it joins the Kankakee River to form the Illinois River about 48 km (30 mi) southwest of ANL. The Dresden Nuclear Power Station complex is located at the confluence of the Kankakee, Des Plaines, and Illinois Rivers. This station uses water from the Kankakee River for cooling and discharges the water into the Illinois River. The first place where water is used for drinking is at Alton, on the Mississippi River about 710 km (370 mi) downstream from ANL and it is indirect use. There, water is used to replenish ground water supplies by infiltration. In the vicinity of ANL, only subsurface water (from both shallow and deep aquifers) and Lake Michigan water are used for drinking purposes.

The principal recreational area near ANL is Waterfall Glen Forest Preserve, which surrounds the site as described in Section 1.2 and is shown in Figure 1.1. The area is available for hiking, skiing, and equestrian sports. Sawmill Creek flows south through the eastern portion of the preserve on its way to the Des Plaines River. Several large forest preserves of the Cook County Forest Preserve District are located east and southeast of ANL and the Des Plaines River. The preserves include the two sloughs shown in Figure 1.2, McGinnis and Saganashkee, as well as other smaller lakes. These areas are used for picnicking, boating, fishing, and hiking. A small park located in the eastern portion of the ANL site (Location 12-O in Figure 1.1) is for the use of ANL and DOE employees only.

2. SUMMARY

This is one in a series of annual reports prepared to provide DOE, environmental agencies, and the public with information on the level of radioactive and chemical pollutants in the environment and on the amounts of such substances, if any, added to the environment as a result of ANL operations. Included in this report are the results of measurements obtained in 1987 for a number of radionuclides in air, surface water, ground water, soil, grass, bottom sediment, and milk; for a variety of chemical constituents in surface and subsurface water; and for the external penetrating radiation. The previous report in this series is ANL-87-9.[4]

The major airborne radionuclides released from ANL were hydrogen-3, carbon-11, argon-41, krypton-85, and radon-220 (plus daughters). The maximum dose from these nuclides at the site boundary was 0.45 mrem/y in the north direction, as calculated from an atmospheric dispersion model. The calculated dose to the closest full-time resident, who is located about 0.5 km (0.3 mi) north of the site boundary, was 0.34 mrem/y, which is 0.34% of the DOE 100 mrem/y limit for prolonged public exposures. The limit set by the United States Environmental Protection Agency (EPA) in the Clean Air Act is 25 mrem/y for atmospheric releases. These releases constitute an insignificant addition to the dose received from the natural external background radiation, which is about 90 mrem/y, based on the TLD measurements. The total 80-km population dose from these radionuclides was 44 man-rem for 1987, compared to approximately 7.1×10^5 man-rem from the natural background radiation. The hazard due to a given concentration of radionuclide or quantity of external radiation is assessed in this report by calculating the corresponding effective dose equivalent and comparing it to the DOE recommended dose limits discussed in Sections 4.1 and 4.1.7, and described in References 5 and 6.

Radioactivity in airborne particulates was measured in air-filter samples collected continuously at the site perimeter and off the site. The filters were analyzed for total alpha, total beta, fission and activation products, thorium, uranium, and plutonium. No activity attributable to ANL operations could be detected. These samples contained only radionuclides from natural sources and nuclear test detonations.

ANL waste water is discharged into Sawmill Creek, and this creek was sampled above and below the site to evaluate the effect of ANL operations on its radioactive content. The nuclides (for which analyses were made) added to the creek in the waste water, and the ingestion doses from their net average creek concentrations, if the creek water had been used as a potable water supply, were hydrogen-3, 0.006 mrem/y; strontium-90, 0.09 mrem/y; cesium-137, 0.06 mrem/y; neptunium-237, 0.0005 mrem/y; plutonium-239,240, 0.0025 mrem/y; and americium-241, 0.021 mrem/y. The concentrations and corresponding doses are all very low compared to the 100 mrem/y dose limit.

Sawmill Creek flows into the Des Plaines River, which in turn flows into the Illinois River. The radioactivity levels in the rivers were similar to those in other streams in the area, and the radionuclides added to the creek by ANL waste water had no measurable effect on the radioactive content of either the Des Plaines or Illinois Rivers.

Plutonium concentrations in soil showed the same general range and average at the site perimeter and off the site as in the past years. The average plutonium-239,240 content of the top 5 cm (2 in) of soil was 0.86 nCi/m^2 at the site perimeter and 0.87 nCi/m^2 off the site. The corresponding plutonium-238 averages were 0.04 nCi/m^2 at both locations. The plutonium content in grass was similar to that found in previous years and was about a factor of 10^4 lower than soil from the same locations. The results were within the range reported by other laboratories for fallout from test detonations, and the plutonium found in soil and grass is attributed to this source. The plutonium content of samples from beds of off-site streams and ponds ranged from 1 fCi/g to 11 fCi/g of plutonium-239,240, a range found in previous years to be normal for fallout plutonium in such materials. However, concentrations about ten times off-site levels were found in the sediment just below the ANL waste-water outfall as a result of their presence in ANL waste water.

Milk from a dairy farm located 10 km (6 mi) south of ANL was collected monthly and analyzed for hydrogen-3 and strontium-90. Hydrogen-3 concentrations averaged < 103 pCi/L. The strontium-90 concentration of 2.7 pCi/L was similar to the 1986 result. These radionuclides resulted from fallout from nuclear test detonations, and are not related to ANL operations.

Measurements of penetrating radiation were made at several locations at the site boundary and off the site. The off-site results averaged 90 $\pm$ 5 mrem/y, which is in the average background range for the area. At two site boundary locations, above-background readings were recorded that were attributable to ANL operations. At the south fence (grid 7I in Figure 1.1), the dose rate averaged about 368 mrem/y above background as a result of radiation from an on-site temporary storage facility for radioactive waste. About 300 m (0.2 mi) south of the fence, the measured dose rate decreased to 92 $\pm$ 7 mrem/y, which is within the background range. Along the north side of the site, the dose at the fence at location 14I was 22 mrem/y above background due to radiation from cobalt-60 sources in Building 202. Since there are no residences at these locations, there are no individuals receiving these measured doses. The calculated outdoor dose rate from these sources to the residents closest to the south boundary, about 1.6 km (1 mi) from the fence line, was about 0.08 mrem/y, which is 0.08% of the dose limit. Similarly, the dose rate to the residents closest to the north boundary, about 0.75 km (0.5 mi) from the fence, was about 0.11 mrem/y, which is 0.11% of the dose limit.

Concentrations of chemical constituents and other water quality parameters were measured in ANL waste and effluent water and in Sawmill Creek. The results were compared to the standards adopted by the State of Illinois as well as National Pollutant Discharge Elimination System (NPDES) permit limits.

Results obtained at the NPDES sampling locations were generally within permit limits with the exception of chloride and total dissolved solids at location 001 and iron and pH at location 001C. The chloride and total dissolved solids are generated by recharging the ion exchange treatment system for the domestic water supply. A treatment plant has been designed for their removal. Location 001C contains water from the coal pile storage area which has runoff flow only during precipitation and winter snow melt.

Four samples (12%) from the Waste Water Treatment Plant exceeded the 0.5 μg/L state standard for mercury but were well below the one time limit of 2.5 μg/L. All of the other constituents were below the state standards.

The average values in Sawmill Creek for dissolved oxygen and most chemical constituents were within the State of Illinois Water Quality Standards. The average levels of copper and iron were 85% and 70% of the state standards, and individual values exceeded the standards 25% and 15% of the time, respectively. The levels of iron in the stream increase during periods of storm runoff. The levels in the ANL effluent are not sufficient to materially affect background levels. The effluent levels of copper are only 4% of the state standard of 1 mg/L but these levels are sufficient to have a significant effect on the stream standard of 20 μg/L. Mercury concentrations exceeded the state standard on two occasions, and the average concentration was 47% of the standard. The concentration of mercury in the Des Plaines River was less than the detection limit of 0.1 μg/L and was not affected by the amounts in the ANL effluent water.

Additional monitoring wells were constructed at the sanitary landfill to expand and improve the coverage. Samples from these monitoring wells were examined for selected inorganic and organic constituents. Levels of manganese exceeded 1 mg/L in two of the wells, the pH was 11.4 in a third well, and arsenic was detected in another. Similar results were obtained in the past, and there is no indication of migration between wells since the relative concentrations have not changed with time. Samples were examined for volatile organic compounds and polychlorinated biphenyls and all concentrations were below the required detection limits.

The average concentrations and total amounts of radioactive and chemical pollutants released by ANL does not have a significant environmental impact. Any individual discharges from ANL that exceeded acceptable standards were temporary, and when they did occur, investigations were undertaken to identify the source and reduce the discharge.

3. COMPLIANCE REVIEW

It is the policy of ANL to conduct its operations so as to comply with all applicable environmental laws and regulations. The following is a review of those environmental requirements that are relevant to the functions at ANL.

3.1. Clean Water Act

3.1.1. Liquid Effluent Discharge Permits

The Clean Water Act established a National Pollutant Discharge Elimination System (NPDES)[7] as a mechanism to improve the nation's waters by controlling and eventually eliminating liquid discharges having an adverse effect on the waters of the nation. The Act establishes limits for discharges reflecting the contaminants likely to occur at each site. The permittee performs compliance monitoring and the results are reported to the state monthly and to the EPA quarterly. The permittee for ANL is The Department of Energy-Chicago Operations Office, which delegates the monitoring function to ANL. The permit currently in effect (IL-0034592) was modified effective June 28, 1987, and expires on March 1, 1989. It lists 13 discharge points, some of which are tributary to a final discharge point that is separately regulated. The sampling locations and frequency are specified in the permit. The analytical procedures are listed in 40 CFR 136[8] and are required for these samples. Participation in an annual EPA performance evaluation for the regulated constituents is required of major permittees. Deviations from NPDES permit limitations are reported to the Illinois Environmental Protection Agency (IEPA) within 24 hours, and the reasons for deviations are included in the monthly report. A summary of the NPDES results is given in Table 3.1. The permit locations are shown in Figure 4.4 and additional discussion occurs in Section 4.2.1.1 and earlier reports.[4]

There are two major areas of noncompliance. The first results from ion exchange reconditioning, which produces levels of chloride and total dissolved solids that frequently exceed the permit limits at location 001 and

TABLE 3.1

NPDES Effluent Quality Summary, 1987

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L 30 Day Average	Daily Max.	Number Exceeding Limit	*R Measured/Permit
001A	50	Flow	None		0	-
		BOD	30	60	0	-
		TSS	30	60	0	-
001B	50	Flow	None		0	-
		Chemical Oxygen Demand	-	-	0	-
		TSS	15	30	1	1.3
		Mercury	0.003	0.006	0	-
001C	4	Iron	2	4	3	5-40
		Lead	0.2	0.4	0	-
		Zinc	1	2	3	1.1-1.3
		Manganese	1	2	1	1.5
		Chromium (Total)	1	2	0	-
		Copper	0.5	1	0	-
		Oil & Grease	15	30	0	-
		TSS	15	30	3	1.5-2.4
		pH	6-9		3	3.1-3.3
001	50	pH	6-9		1	9.4
		Fecal Coliform	-	400 organisms/100 mL	2	3.3-10.5
		BOD	30	60	0	-
		TSS	30	60	0	-
002	6	Flow	None		0	-
		pH	6-9		1	10.8
		TSS	15	30	1	2.3
		Temperature	< 2.8°C Rise		0	-

No chloride or TDS limits?

TABLE 3.1 (Contd)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L 30 Day Average	Concentration Limits mg/L Daily Max.	Number Exceeding Limit	*R Measured/Permit
003	12	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	2	1.2-1.4
		Temperature	< 2.8°C Rise		0	-
004	12	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	2	2.0-6.9
		Temperature	< 2.8°C Rise		0	-
005	12	Flow	None.		0	-
		pH	6-9		0	-
		Temperature	< 2.8°C Rise		0	-
		Fats, Oil, & Grease	15	30	0	-
006	12	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	2	1.3
		Zinc	1.0	2.0	0	-
007	12	Flow	None		0	-
		pH	6-9		0	-
		Temperature	< 2.8°C Rise		0	-
008	12	Flow	None		0	-
		pH	6-9		0	-
009	0	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	0	-

*R is the range of the ratio of the values of the measurements exceeding the concentration limit to the concentration limit (except for pH, for which the actual values are given).

To who, when, what's status

Sawmill Creek. A proposal has been submitted for removal of these materials at the source, the domestic water treatment plant. The second area where violations occur is in regard to coal pile runoff effluents. Funding has been obtained for a treatment system that will remove these contaminants from the effluent. Occasional violations regarding total suspended solids have occurred at other locations, but this seems to be related more to soil resuspension by precipitation rather than resulting from ANL operations.

The EPA, in conjunction with IEPA, conducted an audit in February 1987. This was a comprehensive overview which included NPDES sample collection, analyses, and reporting. Minor procedural deficiencies were noted and these were quickly rectified.

3.1.2. Spill Prevention Control and Countermeasures (SPCC) Plan

An approved plan is in place that meets the requirements of 40 CFR 112 "Oil Pollution Prevention," 40 CFR 761 "Polychlorinated Biphenyls, Manufacturing, Process, Distribution in Commerce, and Use Prohibitions," and 40 CFR 264 Subject D "Continuing Plan and Emergency Procedures for the Hazardous Materials." The plan specifies responsibilities for emergency operational procedures and reporting in the event of spills of hazardous materials and oil. Areas for which a reasonable potential exists for the failure of pollution control equipment are identified.

3.2. Clean Air Act

3.2.1. National Emissions Standard for Hazardous Air Pollutants (NESHAPS)

This regulation sets reporting, emissions control, disposal, stack testing, and other requirements for operations involving hazardous air pollutants. ANL operations involving asbestos and radionuclides are the air pollutants currently regulated under NESHAPS.

The EPA has published regulations for control of airborne radionuclide releases from DOE facilities (40 CFR 61, Subpart H).[10] In 1985, DOE adopted

EPA's limits as the radiation protection standards for exposure via the air route. This subject is discussed in Section 4.1.7.1.

The notification, emissions control, and disposal requirements for asbestos are handled at ANL by completion of a form which documents the group doing the removal, the building information, the abatement information, and the disposal site. The form is required to be completed at least 18 days before the start of demolition or renovation involving the stripping or removal of at least 79 m (260 ft) of asbestos material on pipes, or at least 4.5 m^2 (160 ft^2) of asbestos material on ducts, boilers, tanks, reactors, turbines, furnaces, load supporting members, or non-supporting members. Notification is required only for work with friable asbestos (i.e., asbestos that can crumble or be reduced to powder by hard pressure when dry). Floor tile, coated roofing products, and asbestos cement board (transite) are exempt, although exposure precautions are required if dust can be generated when working with these materials.

During 1987, 3,049 m (10,029 ft) of asbestos material on pipe and 56 m^2 (1,977 ft^2) of other facility components were removed. Asbestos materials from these sources, as well as non-friable materials from other renovation or demolition products, were buried with proper packaging in the ANL sanitary landfill. A total of 143.5 m^3 (5,068 ft^3) was disposed in this manner.

3.3. Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA) of 1976 was enacted to regulate hazardous waste, and thus promote protection of the environment and public health by establishing various regulatory, technical assistance, and training programs. A major concern at all hazardous waste disposal sites was the possibility of contaminating underlying groundwater systems. The interim status hazardous waste and consolidated permit regulations were issued in May 1980 and required a minimum of four groundwater sampling wells at each location. The regulations stipulated the locations of such wells and specify the monitoring parameters.

In November 1984, the Hazardous and Solid Waste Amendments (HSWA) were promulgated. The main objectives were to reduce hazardous waste volume and toxicity and to minimize land disposal of hazardous waste. Among the more prominent aspects of the Amendments are the prohibition of placement of bulk liquids, even with adsorbents, in landfills, the prohibition of the disposal of certain waste, establishment of minimum technology requirements for underground tanks, the requirement that operators of landfills certify that a monitoring program is in place, and to seek a Part B permit which requires a health assessment. A waste is considered hazardous if it is listed in 40 CFR 261. A Part A application was revised and resubmitted in 1986 by ANL. Part B was submitted in September 1986 and is in interim status. Disposal of hazardous wastes in landfills was discontinued in 1979, and the only operating landfill at ANL is a sanitary landfill permitted by the State of Illinois.

A list of underground storage tanks was submitted on October 19, 1987, to the Fire Marshall's Office of the State of Illinois in accordance with HSWA. A total of 41 tanks may be regulated under RCRA. Leak testing was conducted on 27 tanks. In February 1987, a hazardous waste inspection was conducted jointly by the EPA and IEPA which included a review of the underground storage tank program.

3.4. National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) establishes a broad national policy to encourage productive and enjoyable harmony between persons and their environment and to ensure that consideration is given to environmental values and factors in federal decision making and actions. Responsibility and guidance documentation are specified under DOE Order 5440.1B.[9] This documentation appears in the ANL HEALTH AND SAFETY MANUAL (Chapter III-13). An environmental assessment for ANL,[2] was prepared to fulfill the requirements of this act.

3.5. Safe Drinking Water Act (SDWA)

The 1986 amendments to the Safe Drinking Water Act (SDWA) recognize 83 contaminants for which regulations are to be developed by 1989. These consist of volatile organic chemicals, synthetic organic chemicals, inorganic chemicals, microbiological contaminants, and radionuclides. In addition, the IEPA adopted public water supply standards under Subpart C of Title 35. When these materials are regulated by both EPA and IEPA, the more stringent standard is applicable. ANL is defined as a non-transient non-community water system (NTNCWS) ~~and is required to~~ sample the treated water four times per year and the ground water annually.

Sampling and analysis for chemical contaminants began in September 1987 and were also performed in December 1987. All four domestic wells and treated water were sampled and analyzed and all constituents were either below regulatory limits or were not detected.

3.6. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) required registration of all pesticides and regulates their use and disposal. Work of this type at ANL is performed by subcontractors who are licensed. Quarterly reports of pesticide use by these contractors are submitted by ANL to the EPA.

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

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 required cleanup of toxic and hazardous waste at closed and abandoned waste sites. Under DOE Order 5480.14, a Phase I assessment report was submitted in July 1986. The purpose was to identify candidate, inactive hazardous waste sites which should be characterized. Seven sites were identified on the ANL-Illinois site and a pond in the Waterfall Glen Nature Preserve (formerly part of ANL) which is part of the DuPage County Forest Preserve was included. The sites identified for Phase II studies are the 319 Area landfill, 317 Area "French drain", and the 800 Area sanitary landfill "French drain".

In 1986, the Superfund Amendments and Reauthorization Act (SARA) was enacted. The major goals of SARA included accelerated cleanup of waste sites, reduction of waste volume and toxicity, and restriction of mobility. SARA also significantly expands the authority and responsibilities of the EPA.

3.8. Toxic Substance Control Act (TSCA)

The major impact of this Act on ANL is with regard to polychlorinated biphenyls (PCBs) covered in Part 761 of TSCA. This contains regulations which apply to the manufacture, processing, distribution, use, and disposal of PCB and PCB items. Most of the regulations apply to items that contain PCBs above a certain concentration. Storage and disposal regulations apply to concentrations of 50 ppm or above. A major source of the PCB inventory at ANL involves capacitators and transformers. An annual PCB report (40 CFR 761.180) was submitted in June 1987 which listed 44 electrical power transformers in service which contained > 60,000 ppm PCB, seven in the range of 501-60,000 ppm, and 37 in the range of 50-500 ppm. All out of service PCB articles are stored in compliance with pertinent regulations. All disposal of PCB materials is accomplished by licensed contractors.

3.9. Environmental Permits, Impact Statements, and Activities

The environmental permits in effect at ANL are shown in Table 3.2. As shown, all the permits have been issued by the IEPA. The compliance status of the NPDES permit is discussed in Section 3.1.1 and 4.1.1.1. The monitoring data obtained for the landfill are discussed in Section 4.2.2.2. The limits or standards are not specified in the permit to operate the landfill, but the number of monitoring wells and the types of measurements and results are within the IEPA guidelines.

For Boiler No. 5 operations, sulfur dioxide and particulates are

TABLE 3.2

IEPA Environmental Permits in Effect at ANL

Permit Type	Facility	Permit/ Application No.	Expires
Fossil Energy Users Laboratory (FEUL) Facility Air Emissions	FEUL-MHD Building 145	ID 043802AAA App. C8012024	9/13/87
Operating	Steam Plant - Boiler No. 5 Building 108	ID 043802AAA D/02 App. 79090047	8/1/88
Construct and Own	Water pollution control facility, coal-pile run-off containment area Building 108	1980-EB-1568	Covered by NPDES Permit 3/1/89
Construction Operation	Emco Wheaton coaxial recovery system for gas dispensing facilities - Building 827	HG490	5/30/90
NPDES	Laboratory Water Effluents	IL0034592	3/1/89
Sludge Drying Bed Replacement	Sanitary Plant Laboratory Plant Building 570	1981-EB-1776	Covered by NPDES Permit 3/1/89
Lift Station Construction	Boiler waste-water, coal-pile runoff overflow, lime pond and water pond overflow Building 108	1982-HB-0402	Operation covered by NPDES Permit 3/1/89
Operating	Landfill 800 Area	1981-20-OP	Special Conditions
RCRA Hazardous Waste Storage, Generation, and Treatment	Facilities 306, 317, 325A, 325C, and 329	IL3-890-008946	Interim
Methanol Storage Tank	Coaxial Vapor Control System Building 827	App. 86020043	2/7/91

measured in the exhaust stack and the results reported to the IEPA. The Boiler is operated in compliance with the permit.

The vapor recovery system for gasoline and alcohol vehicle fuel dispensing was constructed, and is operating, as designed in accordance with the permit.

The environmental effects of new constructions projects, modifications to facilities, and other activities that can have an environmental impact are evaluated before work is begun. During 1987, no final Environmental Impact Statements or Environmental Assessments were completed, and no significant pollution abatement projects were undertaken.

4. MONITORING RESULTS

4.1. Radiological

The radioactivity of the environment was determined by measuring the concentrations of radioactive nuclides in naturally occurring materials and by measuring the external penetrating radiation dose. Sample collections and measurements were made at the site perimeter and off the site principally for comparison purposes. Some on-site results are also reported when they are useful in interpreting perimeter and off-site results. Since radioactivity is usually transported by air and water, the sample collection program has concentrated on these media. In addition, soil, plants, foodstuffs, and materials from the beds of lakes and streams were also collected and analyzed. The program followed the guidance provided in the DOE Environmental[11] and Effluent[12] Surveillance Guides. About 1,600 samples were collected and approximately 4,000 analyses were performed. The results of radioactivity measurements are expressed in terms of picocuries per liter (pCi/L) for water and milk; femtocuries per cubic meter (fCi/m^3) and attocuries per cubic meter (aCi/m^3) for air; and picocuries per gram (pCi/g), femtocuries per gram (fCi/g), and/or nanocuries per square meter (nCi/m^2) for soil, bottom sediment, and vegetation. Penetrating radiation measurements are reported in units of millirem (mrem) per year and population dose in man-rem. Other units are defined in the text.

When a nuclide was not detected, the result is given as less than (<) the minimum amount detectable (detection limit) by the analytical method used. The detection limits were chosen so that the measurement uncertainty at the 95% confidence level is equal to the measured value. The air and water detection limits (minimum detectable amounts) for all radionuclides, and for those materials, for which measurements were made, are collected in Table 4.1. The relative error in a result decreases with increasing concentration. At a concentration equal to twice the detection limit, the error is about 50% of the measured value, and at ten times the detection limit, the error is about 10%.

TABLE 4.1

Detection Limits

Nuclide or Activity	Air (fCi/m^3)	Water (pCi/L)
Americium-241	-	0.001
Beryllium-7	5	-
Californium-249	-	0.001
Californium-252	-	0.001
Cesium-137	0.1	1
Curium-242	-	0.001
Curium-244	-	0.001
Hydrogen-3	100	100
Neptunium-237	-	0.001
Plutonium-238	0.0003	0.001
Plutonium-239	0.0003	0.001
Radium-226	-	0.1
Strontium-89	0.1	2
Strontium-90	0.01	0.25
Thorium-228	0.001	-
Thorium-230	0.001	-
Thorium-232	0.001	-
Uranium-234	0.0001	0.01
Uranium-235	0.0001	0.01
Uranium-238	0.0001	0.01
Uranium - natural	0.02	0.2
Alpha	0.2	0.2
Beta	0.5	1

Averages, including individual results that were less than the detection limit, were calculated by one of the following two methods. If a large fraction (usually 50% or more) of the individual results was less than the detection limit, the average was calculated with the assumption that such results were equal to the detection limit, and the resulting average value is expressed as less than (<) the computed average. If only a small fraction of the individual results was less than the detection limit, the average was calculated with the assumption that such results were actually one-half of the detection limit, and the average is given as a definite value. The former technique probably overestimates the average concentration in those samples below the detection limit and gives an upper limit for the average of all the samples in the group, since it is unlikely that all concentrations not detectable are at the detection limit. The latter method is based on the assumption that the values below the detection limit are distributed between zero and the detection limit with a frequency such that the average value is one-half of the detection limit. The averages that are obtained by using these two methods under the conditions indicated are believed to give an adequate representation of the average concentration at locations where the concentrations not only varied greatly, but were at times not detectable.

Average values are usually accompanied by a plus-or-minus (±) limit value. Unless otherwise stated, this value is the standard error at the 95% confidence level calculated from the standard deviation of the average and is a measure of the range in the concentrations encountered at that location. It does not represent the conventional uncertainty in the average of repeated measurements on the same or identical samples. Since many of the variations observed in environmental radioactivity are not random, but occur for specific reasons (e.g., seasonal variations), samples collected from the same location at different times are not replicates. The more random the variation in activity at a particular location, the closer the confidence limits will represent the actual distribution of values at that location. The averages and confidence limits should be interpreted with this in mind. When a plus-or-minus figure accompanies an individual result in this report, it represents the statistical counting error at the 95% confidence level.

DOE has provided draft guidance[6] for dose equivalent calculations for members of the public, based on ICRP-26 and ICRP-30. These procedures have been used in this report, and it is expected that this approach will replace the Concentration Guides (CGs) in DOE Order 5480.1A, Chapter XI, that have been used in the past to compare environmental radionuclide concentrations with DOE standards.[13] The new methodology requires three components to be calculated: (1) the committed dose equivalent from all sources of ingestion, (2) the committed dose equivalent from inhalation, and (3) direct dose equivalent from external radiation. These three components are summed for comparison with the new DOE dose equivalent limits for environmental exposure. The draft guidance requires that sufficient data be available on exposure to radionuclides and sources to assure that at least 90% of the total committed effective dose equivalent is accounted for. The primary radiation dose limit for members of the public is 500 mrem/y for occasional annual exposures and 100 mrem/y for prolonged exposures (greater than five years). The effective dose equivalents for members of the public from all routine DOE operations, natural background and medical exposures excluded, shall not exceed these values and shall be as far below these limits as is practical (ALARA). Routine DOE operations are normally planned operations, which exclude actual or potential accidental or unplanned releases.

The measured or calculated environmental radionuclide concentrations or radiation dose is converted to a 50-year committed effective dose equivalent with the use of the Effective Dose Equivalent Factors (EFF.D.E.) and compared to the annual dose limits for uncontrolled areas. The EFF.D.E.s and annual dose limits are both given in the draft guidance.[6] The numerical values of the EFF.D.E.s used in this report are given in Section 4.1.7. Although the EFF.D.E.s apply only to concentrations above natural levels, the calculated dose is sometimes given in this report for activities that are primarily of natural origin for comparison purposes. Such values are enclosed in parentheses to indicate this. Occasionally, other standards are used, and their source is identified in the text.

4.1.1. Air

The radioactive content of particulate matter was determined by collecting and analyzing air-filter samples. The sampling locations are shown in Figures 1.1 and 1.2. Separate collections were made for specific radiochemical analyses and for alpha, beta, and gamma counting. The latter measurements were made on samples collected continuously on laminated glass fiber filters, changed weekly at eight locations at the ANL site perimeter and at five off-site locations. The site perimeter samplers are placed at the nearest location to the site boundary fence that provides electrical power and shelter. Measurements were made at the perimeter because comparison between perimeter and off-site concentrations is necessary in evaluating and establishing the normal environmental concentration. If only off-site radioactivity were reported, their normality or origin could not be evaluated. Higher activities at the site perimeter may indicate radioactivity released by ANL, if the differences are greater than the error in sampling and measurement. Such results require investigation to determine the cause of the difference. The relative error is between 5% and 20% for most results, but approaches 100% at the detection limit.

The total alpha and beta activities in the individual weekly samples are summarized in Table 4.2. These measurements were made in low-background gas-flow proportional counters, and the counting efficiencies used to convert counting rates to disintegration rates were those measured for radon decay products on filter paper. The average concentrations of gamma-ray emitters, as determined by gamma-ray spectrometry performed on composite weekly samples are given in Table 4.3. The gamma-ray detector is a shielded germanium diode calibrated for each gamma-ray emitting nuclide measured.

The alpha activity, principally due to naturally occurring nuclides, averaged the same as in the past several years and was in its normal range. The perimeter beta activity averaged 25 fCi/m^3, which is the same as the average value for the past four years. The gamma-ray emitters listed in Table 4.3 are those that have been present in the air for the past few years and are of natural origin. The beryllium-7 exhibits a spring increase in concentration, indicating its stratospheric origin. The lead-210 in air is

TABLE 4.2

TOTAL ALPHA AND BETA ACTIVITIES IN AIR-FILTER SAMPLES, 1987*
(CONCENTRATIONS IN FEMTOCURIES/CUBIC METER)

MONTH	LOCATION	NO. OF SAMPLES	ALPHA ACTIVITY AV.	ALPHA ACTIVITY MIN.	ALPHA ACTIVITY MAX.	BETA ACTIVITY AV.	BETA ACTIVITY MIN.	BETA ACTIVITY MAX.
JANUARY	PERIMETER	25	1.8	0.4	3.5	27	5	40
	OFF-SITE	17	2.3	0.8	12	23	11	34
FEBRUARY	PERIMETER	31	1.9	1.2	3.1	24	17	30
	OFF-SITE	19	1.7	0.7	3.5	22	13	29
MARCH	PERIMETER	30	2.5	1.1	3.3	25	16	36
	OFF-SITE	15	2.2	1.1	3.7	22	11	38
APRIL	PERIMETER	40	2.0	0.8	3.7	21	13	42
	OFF-SITE	19	2.2	0.8	5.9	17	5	24
MAY	PERIMETER	28	2.4	0.4	4.1	22	12	34
	OFF-SITE	18	2.2	1.0	4.5	20	10	32
JUNE	PERIMETER	29	2.5	1.3	3.8	26	18	36
	OFF-SITE	8	2.2	0.8	3.0	24	14	32
JULY	PERIMETER	38	2.3	1.0	7.3	25	14	43
	OFF-SITE	15	1.7	0.7	3.3	26	16	46
AUGUST	PERIMETER	30	2.1	0.8	4.3	25	15	33
	OFF-SITE	18	1.6	0.4	3.7	24	2	40
SEPTEMBER	PERIMETER	37	2.0	0.7	3.8	28	13	98
	OFF-SITE	21	1.8	0.7	3.3	27	12	43
OCTOBER	PERIMETER	30	2.3	0.9	5.8	25	13	60
	OFF-SITE	12	2.7	0.4	9.3	24	7	41
NOVEMBER	PERIMETER	32	2.8	1.2	4.1	35	19	50
	OFF-SITE	17	2.2	0.3	3.5	30	1	51
DECEMBER	PERIMETER	33	1.4	0.4	2.8	21	7	31
	OFF-SITE	27	1.4	0.4	2.5	21	4	36
ANNUAL SUMMARY	PERIMETER	383	2.2 ± 0.1	0.4	7.3	25 ± 1	5	98
	OFF-SITE	206	2.0 ± 0.1	0.3	12	23 ± 1	1	51

* THESE RESULTS WERE OBTAINED BY MEASURING THE SAMPLES FOUR DAYS AFTER THEY WERE COLLECTED TO AVOID COUNTING THE NATURAL ACTIVITY DUE TO SHORT-LIVED RADON AND THORON DECAY PRODUCTS. THIS ACTIVITY IS NORMALLY PRESENT IN THE AIR AND DISAPPEARS WITHIN FOUR DAYS BY RADIOACTIVE DECAY.

TABLE 4.3

GAMMA RAY ACTIVITY IN AIR-FILTER SAMPLES, 1987
(CONCENTRATIONS IN FEMTOCURIES/CUBIC METER)

MONTH	LOCATION	BE7	PB210
JANUARY	PERIMETER	76	39
	OFF-SITE	51	31
FEBRUARY	PERIMETER	84	33
	OFF-SITE	87	29
MARCH	PERIMETER	121	24
	OFF-SITE	131	26
APRIL	PERIMETER	122	18
	OFF-SITE	120	18
MAY	PERIMETER	111	19
	OFF-SITE	122	24
JUNE	PERIMETER	179	24
	OFF-SITE	184	34
JULY	PERIMETER	116	29
	OFF-SITE	132	36
AUGUST	PERIMETER	83	31
	OFF-SITE	101	38
SEPTEMBER	PERIMETER	112	33
	OFF-SITE	76	33
OCTOBER	PERIMETER	85	30
	OFF-SITE	50	40
NOVEMBER	PERIMETER	90	49
	OFF-SITE	66	44
DECEMBER	PERIMETER	52	35
	OFF-SITE	43	33
ANNUAL SUMMARY	PERIMETER	103 ± 19	30 ± 5
	OFF-SITE	97 ± 26	32 ± 4
DOSE(REM)	PERIMETER	(0.00023)	(0.033)
	OFF-SITE	(0.00022)	(0.035)

due to the radioactive decay of gaseous radon-222. No airborne radionuclides from the accident at the Russian nuclear power facility near Chernobyl were measurable in 1987.

Samples for radiochemical analyses were collected at perimeter locations 12N and 7I (Figure 1.1) and off the site in Downers Grove (Figure 1.2). Collections were made on polystyrene filters. The total air volume filtered for the monthly samples was about 20,000 m^3. Samples were ignited at 600°C to remove organic matter and prepared for analysis by vigorous treatment with hot hydrochloric, hydrofluoric, and nitric acids.

Plutonium and thorium were separated on an anion exchange column and the uranium was extracted from the column effluent. Following the extraction, the aqueous phase was analyzed for radiostrontium by a standard radiochemical procedure. The separated plutonium, thorium, and uranium fractions were electrodeposited and measured by alpha spectrometry. The chemical recoveries were monitored by adding known amounts of plutonium-242, thorium-229, and uranium-232 tracers prior to ignition. Since alpha spectrometry cannot distinguish between plutonium-239 and plutonium-240, it should be understood that when plutonium-239 is mentioned in this report, the alpha activity due to the plutonium-240 isotope is also included. The results are given in Table 4.4.

The average strontium-90 and plutonium-239 concentrations were similar to the averages of the past few years, excluding the strontium-90 contribution from the Chernobyl accident in 1986. Strontium-89 was not observed above the detection limit of 100 aCi/m^3. Figure 4.1 shows the monthly plutonium-239 off-site air concentrations for the past 15 years. The arrows indicate the approximate dates of atmospheric nuclear tests. An examination of Figure 4.1 indicates that plutonium in air exhibits significant increases in concentration in the spring following an atmospheric nuclear test. The magnitude of the increase is related to the size of the test.

The thorium and uranium concentrations are in the same range found during the past several years and are considered to be of natural origin. The amounts of thorium and uranium in a sample were proportional to the mass of

TABLE 4.4

STRONTIUM, THORIUM, URANIUM AND PLUTONIUM CONCENTRATIONS IN AIR-FILTER SAMPLES, 1987
(CONCENTRATIONS IN ATTOCURIES/CUBIC METER)

MONTH	LOCATION[1]	SR-90	TH-228	TH-230	TH-232[2]	U-234	U-235	U-238[2]	PU-239[3]
JANUARY	7I	< 10	10 ± 3	17 ± 2	5 ± 1	13 ± 1	< 0.3	15 ± 1	0.6 ± 0.4
	12N	< 10	6 ± 3	14 ± 2	6 ± 1	16 ± 2	0.4 ± 0.3	17 ± 2	0.9 ± 0.5
	OFF-SITE	< 10	6 ± 3	7 ± 2	2 ± 1	8 ± 1	< 0.3	8 ± 1	0.9 ± 0.5
FEBRUARY	7I	18 ± 13	9 ± 3	24 ± 2	13 ± 2	11 ± 1	< 0.3	11 ± 1	0.8 ± 0.5
	12N	< 10	8 ± 2	15 ± 1	5 ± 1	13 ± 1	< 0.3	12 ± 1	0.4 ± 0.3
	OFF-SITE	-	4 ± 2	10 ± 1	3 ± 1	8 ± 1	< 0.3	6 ± 1	1.9 ± 1.1
MARCH	7I	53 ± 13	11 ± 3	15 ± 2	6 ± 1	20 ± 2	0.6 ± 0.3	12 ± 1	1.3 ± 0.6
	OFF-SITE	16 ± 8	6 ± 3	16 ± 2	3 ± 1	10 ± 1	< 0.3	8 ± 1	1.1 ± 0.6
APRIL	7I	12 ± 12	26 ± 4	36 ± 3	15 ± 2	19 ± 2	1.1 ± 0.3	11 ± 1	0.6 ± 0.4
	12N	< 10	17 ± 3	21 ± 2	6 ± 1	11 ± 2	< 0.3	12 ± 1	1.4 ± 0.5
	OFF-SITE	17 ± 13	7 ± 4	13 ± 2	2 ± 1	6 ± 1	< 0.3	5 ± 1	0.9 ± 0.5
MAY	7I	< 10	8 ± 2	14 ± 1	8 ± 1	13 ± 1	< 0.3	13 ± 1	1.4 ± 0.4
	12N	< 10	5 ± 4	12 ± 2	6 ± 2	13 ± 1	< 0.3	11 ± 1	0.4 ± 0.3
	OFF-SITE	19 ± 9	9 ± 5	9 ± 2	6 ± 2	9 ± 1	< 0.3	10 ± 1	1.0 ± 0.5
JUNE	7I	< 10	11 ± 7	44 ± 5	11 ± 3	19 ± 3	< 0.3	14 ± 3	2.0 ± 1.2
	12N	< 10	3 ± 1	8 ± 2	3 ± 1	8 ± 1	< 0.3	7 ± 1	0.6 ± 0.4
	OFF-SITE	< 10	6 ± 3	18 ± 2	4 ± 1	7 ± 1	< 0.3	8 ± 1	1.0 ± 0.5
JULY	7I	< 10	4 ± 4	12 ± 2	5 ± 1	10 ± 2	0.6 ± 0.6	10 ± 2	0.6 ± 0.4
	12N	12 ± 10	4 ± 3	14 ± 2	4 ± 1	8 ± 1	< 0.3	8 ± 1	0.3 ± 0.2
	OFF-SITE	< 10	9 ± 4	13 ± 2	10 ± 2	4 ± 1	< 0.3	7 ± 1	0.3 ± 0.3
AUGUST	7I	< 10	16 ± 4	14 ± 3	3 ± 1	7 ± 2	< 0.3	5 ± 2	0.4 ± 0.2
	12N	< 10	11 ± 3	22 ± 3	13 ± 1	6 ± 1	< 0.3	6 ± 1	0.2 ± 0.2
	OFF-SITE	< 10	10 ± 2	38 ± 3	12 ± 1	5 ± 1	< 0.3	5 ± 1	0.3 ± 0.2
SEPTEMBER	7I	< 10	7 ± 4	11 ± 2	2 ± 1	7 ± 1	< 0.3	7 ± 1	0.9 ± 0.4
	12N	< 10	4 ± 3	8 ± 1	2 ± 1	10 ± 3	< 0.3	7 ± 3	0.2 ± 0.2
	OFF-SITE	< 10	7 ± 1	11 ± 1	9 ± 3	4 ± 1	< 0.3	3 ± 1	0.9 ± 0.5
OCTOBER	7I	< 10	4 ± 4	6 ± 1	3 ± 1	6 ± 1	< 0.3	6 ± 1	0.5 ± 0.5
	12N	< 10	7 ± 2	8 ± 2	3 ± 1	8 ± 2	< 0.3	7 ± 2	0.4 ± 0.4
NOVEMBER	7I	< 10	6 ± 2	7 + 2	2 ± 1	6 ± 1	< 0.3	6 ± 1	0.9 ± 0.4
	12N	< 10	6 ± 3	7 ± 2	3 ± 1	8 ± 1	< 0.3	6 ± 1	0.4 ± 0.3
	OFF-SITE	< 10	6 ± 3	10 ± 1	5 ± 1	9 ± 1	< 0.3	5 ± 1	0.5 ± 0.5
DECEMBER	7I	< 10	3 ± 1	7 ± 2	3 ± 1	8 ± 4	< 0.3	6 ± 4	1.3 ± 0.5
	12N	< 10	4 ± 1	8 ± 1	4 ± 1	14 ± 4	< 0.3	11 ± 4	0.3 ± 0.2
	OFF-SITE	< 10	5 ± 3	6 ± 2	4 ± 1	10 ± 2	< 0.3	9 ± 2	0.5 ± 0.3
ANNUAL	7I	< 10	9 ± 4	17 ± 7	6 ± 3	12 ± 3	< 0.4	10 ± 2	0.9 ± 0.3
	12N	< 10	7 ± 2	12 ± 3	5 ± 2	10 ± 2	< 0.3	10 ± 2	0.5 ± 0.2
SUMMARY	OFF-SITE	< 10	7 ± 1	14 ± 5	6 ± 2	7 ± 1	< 0.3	7 ± 1	0.9 ± 0.3
DOSE(MREM)	7I	< 11	(0.25)	(0.89)	(0.006)	(.13)	(< 0.004)	(0.10)	0.026
	12N	< 11	(0.17)	(0.64)	(0.004)	(.11)	(< 0.003)	(0.10)	0.014
(X 1E-5)	OFF-SITE	< 11	(0.18)	(0.71)	(0.005)	(.08)	(< 0.003)	(0.07)	0.024

[1] PERIMETER LOCATIONS ARE GIVEN IN TERMS OF THE GRID COORDINATES IN FIGURE 1.

[2] THE CONCENTRATIONS IN UNITS OF MICROGRAMS/CUBIC METER CAN BE OBTAINED BY MULTIPLYING THE VALUE IN ATTOCURIES/CUBIC METER BY 2.96×10^{-6} FOR URANIUM-238 AND BY 9×10^{-6} FOR THORIUM-232. THE MASS OF THE OTHER THORIUM ISOTOPES IN COMPARISON TO THORIUM-232 AND THE OTHER URANIUM ISOTOPES IN COMPARISON TO URANIUM-238 IS NEGLIGIBLE.

[3] PLUTONIUM-240 IS INCLUDED (SEE TEXT).

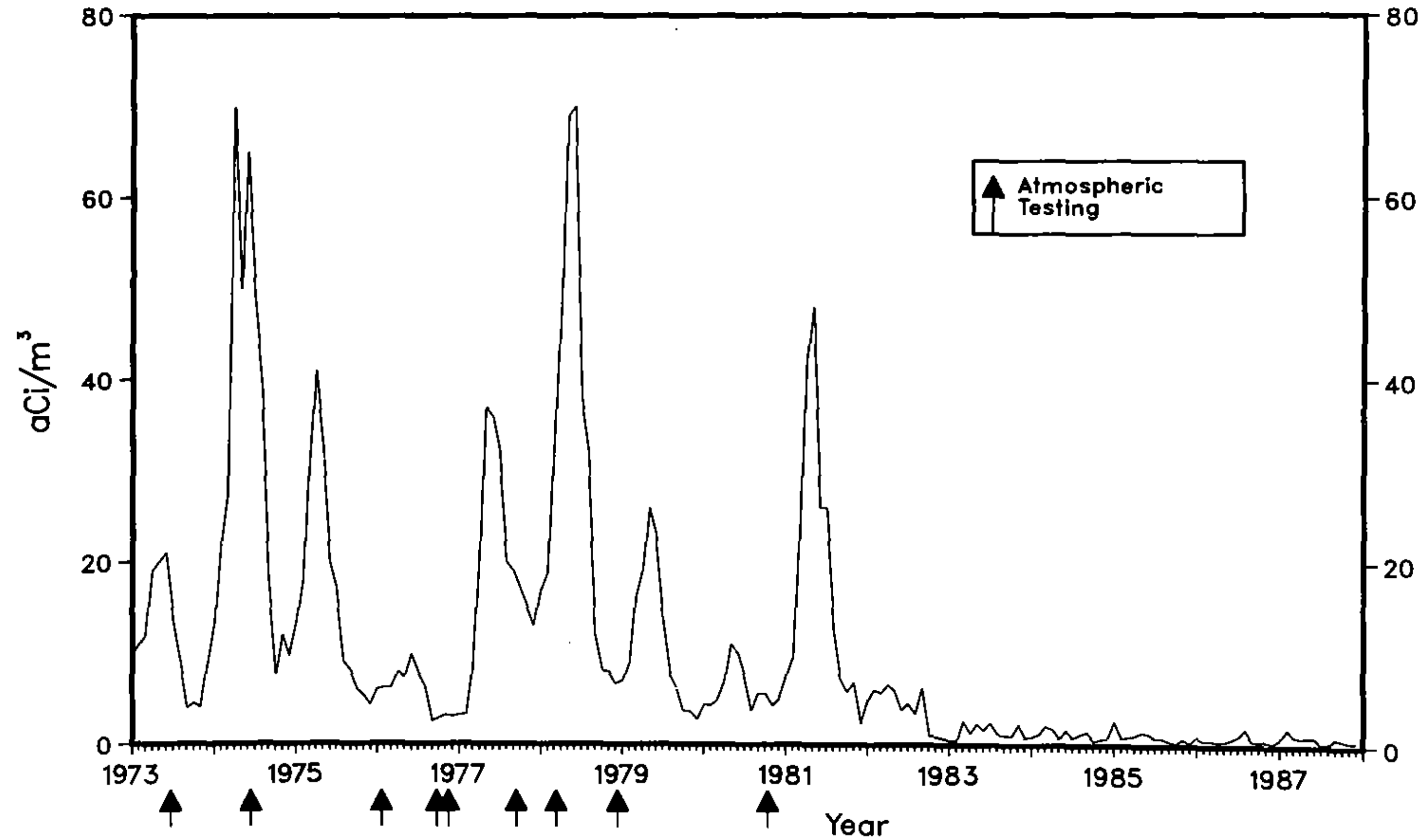

Fig. 4.1 Plutonium-239,240 Air Concentrations, 1973-1987

inorganic material collected on the filter paper. The bulk of these elements in the air was due to resuspension of soil. In contrast, the amount of plutonium in the air samples contributed by soil ranged from about 3% to 51% and averaged 21% of the total plutonium in the samples. This assumes that the resuspended soil has the same plutonium concentration as the first centimeter on the ground. The remainder of the plutonium-239 is due to world-wide fallout.

The major airborne effluents released during 1987 are listed by location in Table 4.5. The radon-220 from Building 200 is due to stored waste from the "proof-of-breeding" program and nuclear medicine studies. The hydrogen-3 from Building 212 is from the tritium recovery studies. In addition to the nuclides listed in Table 4.5, several other fission products were also released in millicurie or smaller amounts. The quantities listed in Table 4.5 were measured by on-line stack monitors in the exhaust systems of the buildings.

TABLE 4.5

Summary of Airborne Radioactive Emissions, 1987

Building	Nuclide	Half-Life	Amount Released (curies/y)
200	Hydrogen-3	12.3 y	0.3
	Radon-220	56 s	6377
202 (Janus)	Argon-41	1.8 h	1.7
212	Hydrogen-3	12.3 y	12.2
	Krypton-85	10.7 y	4.0
	Radon-220	56 s	2.3
330 (CP-5)	Hydrogen-3	12.3 y	30
375 (IPNS)	Carbon-11	20 m	202

An air sampling program for measuring tritium concentrations in air was carried out because ANL conducted a program that could release tritiated water vapor into the air. Samples were collected at perimeter locations, 8F (at the southwest corner of the site) and 12N (on the east perimeter of the site), and off the site in Woodridge, Illinois. The water vapor was collected by adsorption on silica gel and the tritium concentration was measured by counting the desorbed water in a liquid scintillation spectrometer. The results are given in Table 4.6. Based on the data in Table 4.5, the principal sources of the tritiated water vapor should be from Building 212, Location 12I, and Building 330, Location 9H (CP-5). Because the winds are usually from the west to south, the tritium concentrations should be higher at equal distances east and north of the release points. However, the concentrations at 8F were similar to 12N, because this location is closer to the principal source (CP-5). At all sampling locations, the doses were very low compared to applicable standards.

4.1.2. Surface Water

Total (nonvolatile) alpha and beta activities were determined by counting the residue remaining after evaporation of the water, and applying counting efficiency corrections determined for uranium-233 (for alpha activity) and thallium-204 (for beta activity) to obtain disintegration rates. Hydrogen-3 was measured on a separate sample, and this activity does not appear in the total nonvolatile beta activity. Uranium was measured using a laser fluorometer, and the results were calculated in terms of activity, with the assumption that the isotopic composition was that of natural uranium. Analyses for other radionuclides were performed by specific radiochemical separations followed by appropriate counting. One liter aliquots were used for all analyses except hydrogen-3 and the transuranium nuclides. Hydrogen-3 analyses were performed by liquid scintillation counting of 10 mL in a gel medium. Analyses for transuranium nuclides were performed on 10-liter samples using chemical separation methods followed by alpha spectrometry.[14,15] Plutonium-236 was used to determine the yields of plutonium and neptunium, which were separated together. A group separation of a fraction containing the transplutonium elements was monitored for recovery with americium-243 tracer.

TABLE 4.6

Tritiated Water Vapor in Air, 1987
(Concentrations in pCi/m^3)

Month	Location*	No. of Samples	Avg.	Min.	Max.
January	8F	7	0.33	< 0.1	1.41
	12N	7	0.55	< 0.1	1.47
	Off-Site	2	0.33	0.27	0.39
February	8F	9	0.88	0.15	3.10
	12N	9	0.60	0.19	1.16
	Off-Site	2	0.55	0.26	0.84
March	8F	8	1.46	0.48	3.59
	12N	8	0.89	0.29	2.15
	Off-Site	2	0.57	0.52	0.62
April	8F	9	1.18	0.26	2.16
	12N	9	0.96	0.27	2.71
	Off-Site	2	0.66	0.33	0.98
May	8F	9	1.18	0.11	3.25
	12N	8	0.84	0.10	2.34
	Off-Site	2	0.62	0.47	0.78
June	8F	9	1.39	0.18	4.09
	12N	9	1.15	0.38	2.18
	Off-Site	2	0.44	0.28	0.59
July	8F	8	1.94	0.17	8.86
	12N	8	1.41	0.68	2.23
	Off-Site	2	0.41	0.15	0.67
August	8F	9	1.61	0.19	2.57
	12N	9	1.49	0.33	3.31
	Off-Site	0	-	-	-
September	8F	9	2.19	0.38	4.91
	12N	9	1.39	0.53	2.59
	Off-Site	2	0.72	< 0.1	1.35
October	8F	9	0.37	< 0.1	0.60
	12N	9	0.39	< 0.1	1.03
	Off-Site	2	0.28	0.15	0.41
November	8F	8	0.30	< 0.1	0.61
	12N	8	0.54	< 0.1	1.58
	Off-Site	2	0.21	0.18	0.24
December	8F	7	0.20	< 0.1	0.59
	12N	7	0.94	0.16	4.56
	Off-Site	2	0.12	< 0.1	0.18
Annual Summary	8F	101	1.09	< 0.1	8.86
	12N	100	0.93	< 0.1	4.56
	Off-Site	22	0.45	< 0.1	1.35
Dose (mrem)	8F	-	0.00057	< 0.00005	0.0047
	12N	-	0.00049	< 0.00005	0.0024
	Off-Site	-	0.00024	< 0.00005	0.00071

*Locations are given in terms of the grid coordinates in Figure 1.1.

ANL waste water is discharged into Sawmill Creek, which runs through the ANL grounds, drains surface water from much of the site, and flows into the Des Plaines River about 500 m (0.3 mi) downstream from the waste-water outfall. Sawmill Creek was sampled upstream from the ANL site and downstream from the waste-water outfall to determine if radioactivity was added to the stream by ANL waste water or surface drainage. The sampling locations are shown in Figure 1.1. Below the waste-water outfall, daily samples were collected by a continuous sampler, which operated about 77% of the year. When the continuous sampling device was not functioning, a grab sample was collected each working day. Equal portions of the daily samples collected each week were combined and analyzed to obtain an average weekly concentration. Above the site, samples were collected once a month and were analyzed for the same radionuclides as the below-outfall samples.

Annual summaries of the results obtained for Sawmill Creek are given in Table 4.7. Comparison of the results and 95% confidence levels of the averages for the two sampling locations shows the nuclides found in the creek water that can be attributed to ANL operations were hydrogen-3, strontium-90, cesium-137, neptunium-237, plutonium-239, americium-241, and occasionally plutonium-238, curium-242 and/or californium-252, and curium-244 and/or californium-249. The percentage of individual samples containing activity attributable to ANL was 78% for hydrogen-3, 96% for strontium-90, 80% for cesium-137, 86% for neptunium-237, 100% for plutonium-239, and 100% for americium-241. The concentrations of all these nuclides were low and resulted in very small potential doses. The total concentration, regardless of source, must be used in assessing the hazard of a radionuclide not naturally present. The principal radionuclide added to the creek by ANL waste water, in terms of concentration, was hydrogen-3.

The total alpha activity is similar above and below the site and in the range of concentrations found in the past. However, the total beta activity at 16K was down by a factor of three compared to 1986. It was noted last year that after the Marion Brook waste water treatment plant closed on October 27, 1986, the beta activity decreased by a factor of three in the creek above the site, and this reduction is assumed to be due to the absence of natural radioactivities in human excretions processed and discharged by

TABLE 4.7

RADIONUCLIDES IN SAWMILL CREEK WATER, 1987

TYPE OF ACTIVITY	LOCATION*	NO. OF SAMPLES	CONCENTRATION (PICOCURIES/LITER) AVG.	MIN.	MAX.	DOSE (MREM) AVG.	MIN.	MAX.
ALPHA (NONVOLATILE)	16K	12	1.9 ± 0.1	0.8	2.4	-	-	-
	7M	248	2.2 ± 0.2	1.3	4.5	-	-	-
BETA (NONVOLATILE)	16K	12	7 ± 1	4	9	-	-	-
	7M	248	20 ± 3	8	58	-	-	-
HYDROGEN-3	16K	12	< 138	< 100	321	< 0.0064	< 0.005	0.0148
	7M	248	263 ± 82	< 100	1619	0.0121	< 0.005	0.0745
STRONTIUM-90	16K	12	0.31 ± 0.01	< 0.25	0.48	0.029	< 0.02	0.05
	7M	248	1.27 ± 0.37	< 0.25	6.78	0.120	< 0.02	0.64
CESIUM-137	16K	10	-	-	< 1.0	-	-	< 0.03
	7M	217	2.7 ± 1.3	< 1.0	26.0	0.09	< 0.03	0.87
URANIUM** (NATURAL)	16K	12	2.0 ± 0.1	0.8	3.2	(0.34)	(0.129)	(0.53)
	7M	248	1.5 ± 0.3	0.6	5.2	(0.25)	(0.097)	(0.87)
NEPTUNIUM-237	16K	11	-	-	< 0.001	-	-	< 0.00028
	7M	243	0.0029 ± 0.0008	< 0.001	0.018	0.0008	< 0.00028	0.0051
PLUTONIUM-238	16K	12	-	-	< 0.001	-	-	< 0.00028
	7M	248	0.0022 ± 0.0009	< 0.001	0.022	0.00062	< 0.00028	0.0060
PLUTONIUM-239	16K	12	-	-	< 0.001	-	-	< 0.00031
	7M	248	0.0088 ± 0.0023	0.002	0.048	0.0028	0.00048	0.0151
AMERICIUM-241	16K	12	< 0.001	< 0.001	0.001	< 0.00165	< 0.0016	0.002
	7M	238	0.0146 ± 0.0035	0.003	0.070	0.0234	0.0042	0.113
CURIUM-242 AND/OR CALIFORNIUM-252	16K	12	-	-	< 0.001	-	-	< 0.0003
	7M	238	< 0.0012	< 0.001	0.0035	< 0.0004	< 0.0003	0.0012
CURIUM-244 AND/OR CALIFORNIUM-249	16K	12	-	-	< 0.001	-	-	< 0.0017
	7M	238	0.0027 ± 0.0005	< 0.001	0.0086	0.0045	< 0.0017	0.014

*LOCATION 16K IS UPSTREAM FROM THE ARGONNE SITE AND LOCATION 7M IS DOWNSTREAM FROM THE ARGONNE WASTE-WATER OUTFALL.

**URANIUM CONCENTRATIONS IN UNITS OF MICROGRAMS/L CAN BE OBTAINED BY MULTIPLYING THE CONCENTRATION GIVEN BY 1.48.

the treatment plant. This reduction of about 12 pCi/L is also apparent in the total beta activity below the site.

Elevated annual average concentrations of strontium-90 and cesium-137 are the result of the residual effects of an inadvertent release of these constituents in the summer of 1986. Low, but measurable, concentrations of these radionuclides continued to be observed in Sawmill Creek water from August of 1986 until early in 1987. During most of 1987, these activities were at their normal or ambient levels. The other radionuclides, hydrogen-3 and the transuranics, are at the normal discharge levels as measured over the past few years.

The total radioactive effluent discharged to the creek in ANL waste water can be estimated from the average net concentrations and the volume of water carried by the creek. These totals are 0.9 Ci of hydrogen-3, 0.007 Ci of strontium-90, 0.012 Ci of cesium-137, 0.01 mCi of neptunium-237, 0.06 mCi of plutonium-239, 0.10 mCi of americium-241, and <0.01 mCi of curium and californium nuclides.

Because Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the two rivers is important in assessing the contribution of ANL waste water to the environmental radioactivity. The Des Plaines River was sampled twice a month below, and monthly above, the mouth of Sawmill Creek to determine if the radioactivity in the creek had any effect on the river.

Annual summaries of the results obtained for these two locations are given in Table 4.8. The average nonvolatile alpha, beta, and uranium concentrations in the river were very similar to past averages and remained in the normal range. Results were quite similar above and below the creek for all radionuclides, since the activity in Sawmill Creek was reduced by dilution, so that it was not detectable in the Des Plaines River. The average nonvolatile alpha and beta activities, 1.4 pCi/L and 8.2 pCi/L, respectively, of 20 off-site surface water samples collected this year were similar to the levels found in previous years. The hydrogen-3 concentration in these surface water samples averaged 186 pCi/L.

TABLE 4.8

RADIONUCLIDES IN DESPLAINES RIVER WATER, 1987

TYPE OF ACTIVITY	LOCATION *	NO. OF SAMPLES	CONCENTRATION (PICOCURIES/LITER) AVG.	MIN.	MAX.	DOSE (MREM) AVG.	MIN.	MAX.
ALPHA (NONVOLATILE)	A	11	1.7 ± 0.2	1.3	2.4	-	-	-
	B	24	1.4 ± 0.2	0.3	1.9	-	-	-
BETA (NONVOLATILE)	A	11	12 ± 3	8	19	-	-	-
	B	24	12 ± 1	7	18	-	-	-
HYDROGEN-3	A	11	< 132	< 100	247	< 0.0061	< 0.005	0.0114
	B	24	141 ± 35	< 100	361	0.0065	< 0.005	0.0166
STRONTIUM-90	A	11	0.29 ± 0.07	< 0.25	0.43	0.03	< 0.02	0.04
	B	24	0.26 ± 0.04	< 0.25	0.50	0.02	< 0.02	0.05
URANIUM ** (NATURAL)	A	11	1.3 ± 0.4	0.3	2.5	(0.21)	(0.052)	(0.41)
	B	24	1.3 ± 0.3	0.3	3.4	(0.22)	(0.059)	(0.57)
NEPTUNIUM-237	A	10	-	-	< 0.001	-	-	< 0.00028
	B	11	-	-	< 0.001	-	-	< 0.00028
PLUTONIUM-238	A	11	-	-	< 0.001	-	-	< 0.00028
	B	12	-	-	< 0.001	-	-	< 0.00028
PLUTONIUM-239	A	11	-	-	< 0.001	-	-	< 0.0003
	B	12	-	-	< 0.001	-	-	< 0.0003
AMERICIUM-241	A	11	-	-	< 0.001	-	-	< 0.0016
	B	12	< 0.001	< 0.001	0.001	< 0.0017	< 0.0016	0.0024
CURIUM-242 AND/OR CALIFORNIUM-252	A	11	-	-	< 0.001	-	-	< 0.0003
	B	12	-	-	< 0.001	-	-	< 0.0003
CURIUM-244 AND/OR CALIFORNIUM-249	A	11	-	-	< 0.001	-	-	< 0.0017
	B	12	-	-	< 0.001	-	-	< 0.0017

* LOCATION A, NEAR WILLOW SPRINGS, IS UPSTREAM AND LOCATION B, NEAR LEMONT, IS DOWNSTREAM FROM THE MOUTH OF SAWMILL CREEK. SEE FIGURE 2.

** URANIUM CONCENTRATIONS IN UNITS OF MICROGRAMS/L CAN BE OBTAINED BY MULTIPLYING THE CONCENTRATION GIVEN BY 1.48

The radioactivity levels in samples of Illinois River water, shown in Table 4.9, were similar to those found previously at these same locations. No radioactivity originating at ANL could be detected in the Des Plaines or Illinois Rivers.

4.1.3. Ground Water

The ANL domestic water is provided by four wells which are described in Section 1.5 and the locations are shown in Figure 1.1. Samples from each well were collected quarterly at the well head and analyzed for several types of radioactivity. The results are shown in Table 4.10. In addition to the well water samples, one tap water sample was collected, and the results are also in Table 4.10.

Since ANL is a "non-community water system",[16] the EPA standards for this type of system apply. For the nuclides measured in Table 4.10, the following EPA limits are established:

Gross alpha particle activity	15 pCi/L
Gross beta particle activity	50 pCi/L
Hydrogen-3	2×10^4 pCi/L
Strontium-90	8 pCi/L
Radium-226	5 pCi/L

The uranium results would be covered by the gross alpha standard. Inspection of Table 4.10 indicates that all measurements are well within the EPA drinking water standards. This program is being conducted to demonstrate ANL's compliance with the EPA drinking water regulations.

Wells #1 and #2 had measurable levels of hydrogen-3 at various times during the year, although the average concentration was about 1% of the EPA standard. It is speculated that the source of the hydrogen-3 was from liquid wastes that were placed in holding ponds in the sewage treatment area (Location 10M in Figure 1.1) in the 1950s. The tritiated water migrated down through the soil to the dolomite and was drawn into the wells. Well #1, which is about 200 m north of the treatment area, had higher hydrogen-3

TABLE 4.9

Radionuclides in Illinois River Water, 1987

(Concentrations in pCi/L)

Date Collected	Location	Alpha*	Beta*	Hydrogen-3	Uranium** (natural)	Plutonium-239
May 19	McKinley Woods State Park	0.9 ± 0.3	9.5 ± 0.4	138 ± 96	0.6 ± 0.1	< 0.001
May 19	Below Dresden Power Station	1.4 ± 0.2	3.4 ± 0.2	< 100	1.4 ± 0.1	< 0.001
May 19	Morris	2.1 ± 0.3	7.5 ± 0.3	156 ± 97	0.9 ± 0.1	-
May 19	Starved Rock State Park	1.4 ± 0.3	6.7 ± 0.3	112 ± 96	0.9 ± 0.1	-
October 1	McKinley Woods State Park	0.5 ± 0.2	7.7 ± 0.3	229 ± 74	0.5 ± 0.1	< 0.001
October 1	Below Dresden Power Station	0.7 ± 0.2	6.4 ± 0.3	231 ± 74	0.8 ± 0.1	< 0.001
October 1	Morris	0.6 ± 0.1	6.0 ± 0.3	181 ± 73	0.5 ± 0.1	-
October 1	Starved Rock State Park	1.0 ± 0.2	7.4 ± 0.3	182 ± 73	0.7 ± 0.1	-

*Nonvolatile activity.

**Uranium concentrations in units of µg/L can be obtained by multiplying the concentration by 1.48.

TABLE 4.10

Radioactivity in ANL Domestic Wells, 1987

(Concentrations in pCi/L)

Type of Activity	Location	No. of Samples	Avg.	Min.	Max.
Alpha (nonvolatile)	Well #1	2	3.5	3.4	3.6
	Well #2	4	5.0	3.8	5.5
	Well #3	4	3.4	3.0	4.0
	Well #4	4	2.8	2.5	3.4
	Tap	1	-	-	0.5
Beta (nonvolatile)	Well #1	2	7.4	7.3	7.4
	Well #2	4	8.3	6.8	9.6
	Well #3	4	7.4	7.0	7.7
	Well #4	4	6.5	5.7	7.4
	Tap	1	-	-	3.5
Hydrogen-3	Well #1	2	217	204	230
	Well #2	4	141	< 100	174
	Well #3	4	122	< 100	190
	Well #4	4	110	< 100	142
	Tap	1	-	-	< 100
Strontium-90	Well #2	1	-	-	< 0.25
	Well #3	1	-	-	< 0.25
	Well #4	1	-	-	< 0.25
	Tap	1	-	-	< 0.25
Radium-226	Well #2	1	-	-	0.94
	Well #3	1	-	-	0.64
	Well #4	1	-	-	0.72
	Tap	1	-	-	0.15
Uranium (natural)	Well #2	1	-	-	0.32
	Well #3	1	-	-	0.47
	Well #4	1	-	-	0.25
	Tap	1	-	-	0.31

concentrations than Well #2, which is about 300 m from the treatment area. Although the normal subsurface water flow gradient is in the south direction, the cone of depression created by the pumping on these wells would overpower the normal pattern. The holding ponds have not been used for a number of years. One hydrogen-3 result from Well #3 and one from Well #4 were slightly above the detection limit, but these are considered to be within the normal fluctuation range for the measurement of hydrogen-3 in water.

In the 1982 monitoring report,[17] an unusual occurrence was reported which consisted of the loss of about 7.5 megaliters (2 million gallons) of ponded water containing about 26 mCi of tritiated water from the Argonne Advanced Research Reactor (A^2R^2) excavation (Location 10G). The concentration of the tritiated water that remains in the A^2R^2 excavation continued to decrease from 2,900 pCi/L in 1982, to 1,200 pCi/L in 1983, to 910 pCi/L in 1984, to 730 pCi/L in 1985, to 590 pCi/L in 1986, and to 490 pCi/L in 1987. The excavation is being filled with concrete, asphalt, and soil as these materials become available.

Six monitoring wells were recently installed around the 317/319 Areas to determine if any radionuclides from operations in these areas were moving through the soil column. The 317 Area is a temporary storage area for radioactive waste before it is shipped off-site for permanent disposal. The 319 Area is a landfill that was used during the 1950s for the disposal of debris and equipment in which radioactive contamination could not be detected. When the complete absence of contamination could not be guaranteed, such as the inside of small pipes, the material was disposed of in this Area. The locations of the monitoring wells are shown in Figure 4.2. The general groundwater flow is to the south, so that MW-1 is a control well. All the monitoring wells are 40 feet deep into the glacial till and screened at the bottom. Prior measurements were discussed in last year's report.[4]

Samples were collected quarterly from these monitoring wells and analyzed for hydrogen-3, strontium-90, and gamma-ray emitters. The results are collected in Table 4.11. The only evidence of possible migration is low concentrations of hydrogen-3 and strontium-90 in MW-3. This monitoring well

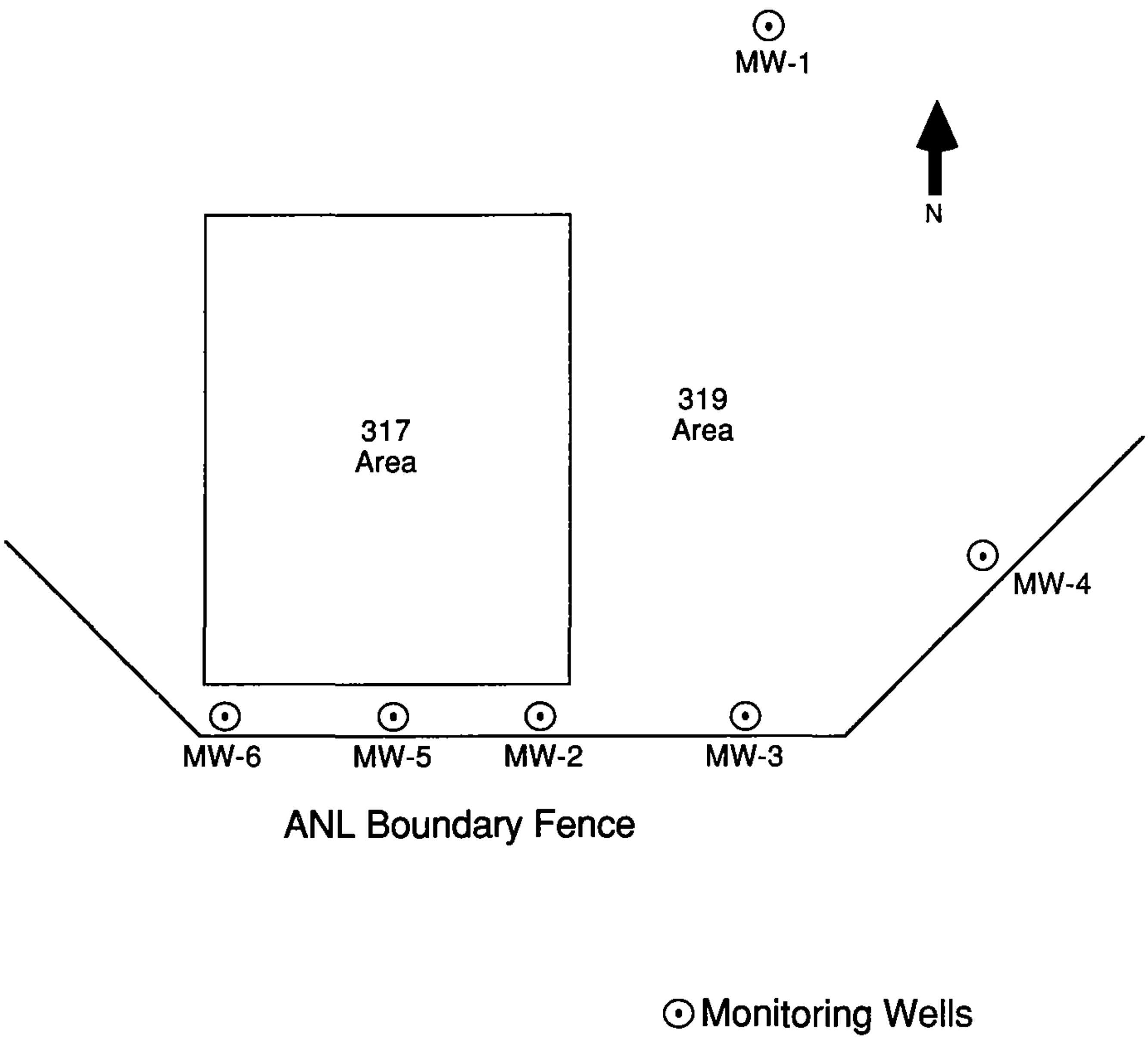

Fig. 4.2 Monitoring Well Locations in 317/319 Areas, 1987

TABLE 4.11

Radionuclides in 317/319 Area Monitoring Wells, 1987
(Concentrations in pCi/L)

Type of Activity	Location*	No. of Samples	Avg.	Min.	Max.
Hydrogen-3	MW-1	4	296	277	336
	MW-2	4	346	< 100	451
	MW-3	2	2426	2228	2625
	MW-4	Dry	-	-	-
	MW-5	Dry	-	-	-
	MW-6	2	254	214	294
Strontium-90	MW-1	4	-	-	< 0.25
	MW-2	4	-	-	< 0.25
	MW-3	2	0.7	0.6	0.7
	MW-4	Dry	-	-	-
	MW-5	Dry	-	-	-
	MW-6	2	0.3	< 0.25	0.4
Cesium-137	MW-1	4	-	-	< 1
	MW-2	4	-	-	< 1
	MW-3	2	-	-	< 1
	MW-4	Dry	-	-	-
	MW-5	Dry	-	-	-
	MW-6	2	-	-	< 1

*See Figure 4.2.

is directly below a small drainage swale that has contained water intermittently with measurable concentrations of hydrogen-3 and strontium-90 from the 319 Area. All concentrations are well below any applicable standard.

Samples collected from the 800 Area sanitary landfill monitoring wells on March 11, 1987, and on October 15, 1987, for chemical analysis were also analyzed for tritiated water. The results are shown in Table 4.12. Although the disposal of radioactive material is prohibited in the sanitary landfill, very low concentrations of tritiated water were detected, probably due to their inadvertent disposal with ANL trash. However, the presence of the tritiated water allows information to be obtained on the subsurface water flow pathway in the sanitary landfill area. The data indicate that the principal direction of subsurface water flow is to the south-southeast, with a small component to the northwest. This is consistent with estimates based on water level measurements and general flow patterns in the area.

4.1.4. Soil, Grass, and Bottom Sediment

The radioactive content of soil, grass, and bottom sediment was measured at the site perimeter and off the site. The purpose of the off-site sampling was to measure deposition for comparison with perimeter samples, and with results obtained by other organizations for samples collected at large distances from nuclear installations. Such comparisons are useful in determining if the soil activity near ANL is normal. For this purpose, the American Society for Testing and Materials (ASTM) site selection criteria, sample collection, and sample preparation techniques were used.[18] Sites were selected in several directions and at various distances from ANL. Each site was selected on the basis that the soil appeared, or was known to have been, undisturbed for a number of years. Attempts were made to select open, level, grassy areas that were mowed at reasonable interval. Public parks were selected when available.

Each soil sample consisted of ten cores, totaling 864 cm^2 in area by 5 cm deep. Through 1976, samples had been collected down to 30 cm to measure total deposition, and as a result of five years of sample collection at this depth, the total deposition in the ANL environment has been established. By

TABLE 4.12

Hydrogen-3 Content of Water From Sanitary Landfill Wells, 1987
(Concentrations in pCi/L)

Location*	Date Collected March 11, 1987	October 15, 1987
Well 1-2	189 ± 82	-
Well 2-2	268 ± 83	-
Well 3	< 100	< 100
Well 4-2	< 100	-
Well 5	622 ± 89	-
Well 6	490 ± 87	393 ± 77
Well 7a	593 ± 88	906 ± 86
Well 8	399 ± 85	191 ± 74
Well 9	792 ± 92	638 ± 81
Well 10	140 ± 81	< 100

*See Figure 4.5.

reducing the sampling depth to 5 cm, the analysis will be more sensitive to changes in current deposition. The grass samples were obtained by collecting the grass from a 1 m^2 area in the immediate vicinity of a soil sample. A grab sample technique was used to obtain bottom sediment. After drying, grinding, and mixing, 100 g portions of soil, bottom sediment, and grass were analyzed by the same methods described in Section 4.1.1 for air-filter residues. The plutonium and americium were separated from the same 100 g aliquot of soil. Results are given in terms of the oven-dried (110°C) weight.

The results for the gamma-ray emitting nuclides in soil are presented in Table 4.13. Intermediate half-life fission products reported previously have decayed to below their detection limits and no evidence of Chernobyl fallout is apparent. The cesium-137 levels are similar to those found over the past several years, and represent an accumulation from nuclear tests over a period of many years. The annual average concentrations for the perimeter and off-site samples are similar. The plutonium and americium concentrations are given in Table 4.14. The two samples collected at Location 7I, south of the 317 Area, are an extension of the characterization of this general area started several years ago. Samples collected in 1986 south of the 319 Area at Location 7J contained elevated plutonium-239 up to 80 fCi/g. In contrast, the samples collected this year were in the normal range of the plutonium-239 concentration for surface soil. The elevated plutonium-239 concentrations appear to be limited to the perimeter soil south of the 319 Area. The range and average concentrations of plutonium and americium in soil at all other locations are similar at both perimeter and off-site sampling points. For fallout americium-241 in soil, about 10% is due to direct deposition, while about 90% is from the decay of the previously deposited plutonium-241.[19] The measured deposition of americium-241 and the americium-241/plutonium-239 ratio is consistent with reported values.[19]

The results of radionuclide concentrations measured in grass are given in Table 4.15. The annual averages and concentration ranges were similar at the perimeter and off-site locations, as well as similar to those of previous years, indicating no contribution from ANL operations. In terms of

TABLE 4.13

Gamma-Ray Emitting Radionuclides in Soil, 1987
(Concentrations in pCi/g)

Date Collected	Location	Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232
	Perimeter*					
April 21	7I	19.98 ± 0.79	0.84 ± 0.04	1.18 ± 0.07	1.12 ± 0.04	0.93 ± 0.09
April 21	7I	20.68 ± 0.48	0.82 ± 0.02	1.24 ± 0.04	1.15 ± 0.03	1.01 ± 0.06
June 4	14E	21.37 ± 0.64	0.97 ± 0.04	1.59 ± 0.07	1.03 ± 0.04	0.91 ± 0.09
June 4	14N	17.37 ± 0.59	0.67 ± 0.03	1.29 ± 0.06	1.03 ± 0.04	0.86 ± 0.09
June 4	10P	16.75 ± 0.60	0.84 ± 0.04	1.22 ± 0.06	0.99 ± 0.04	0.84 ± 0.09
June 4	7E/F	16.20 ± 0.57	1.40 ± 0.04	1.22 ± 0.06	0.93 ± 0.03	0.83 ± 0.09
June 4	4E/F	17.37 ± 0.59	0.49 ± 0.03	1.20 ± 0.06	0.86 ± 0.03	0.64 ± 0.08
October 2	7M	16.14 ± 0.81	0.98 ± 0.04	0.91 ± 0.06	0.55 ± 0.03	0.53 ± 0.09
October 2	8G	24.35 ± 0.90	1.29 ± 0.04	1.41 ± 0.07	1.00 ± 0.04	0.92 ± 0.10
October 5	15H	21.23 ± 0.90	0.33 ± 0.03	1.39 ± 0.07	1.15 ± 0.04	0.98 ± 0.10
October 5	13N	22.59 ± 0.88	0.66 ± 0.03	1.49 ± 0.07	1.18 ± 0.04	1.05 ± 0.09
October 5	13D	22.38 ± 0.88	0.79 ± 0.04	1.57 ± 0.07	1.23 ± 0.04	1.08 ± 0.10
	Average	19.70 ± 1.63	0.84 ± 0.17	1.31 ± 0.11	1.02 ± 0.11	0.88 ± 0.09
	Off-Site					
May 19	McKinley Wood State Park, IL	23.83 ± 0.80	0.74 ± 0.04	1.53 ± 0.07	1.10 ± 0.04	0.92 ± 0.09
May 19	Morris, IL	13.38 ± 0.72	1.54 ± 0.05	1.07 ± 0.06	0.74 ± 0.04	0.76 ± 0.09
May 19	Dresden Lock and Dam, IL	20.56 ± 0.80	1.13 ± 0.04	1.18 ± 0.07	0.99 ± 0.04	0.88 ± 0.10
May 28	Saganashkee Slough, IL	16.27 ± 0.55	0.70 ± 0.03	1.23 ± 0.06	0.75 ± 0.03	0.67 ± 0.08
May 28	McGinnis Slough, IL	19.71 ± 0.65	0.94 ± 0.04	1.45 ± 0.07	0.88 ± 0.04	0.83 ± 0.09
September 29	Pioneer Park, Naperville, IL	15.53 ± 0.81	0.23 ± 0.03	1.40 ± 0.07	1.84 ± 0.05	1.62 ± 0.11
September 29	Romeoville, IL	19.81 ± 0.85	0.60 ± 0.03	1.94 ± 0.08	1.10 ± 0.04	0.93 ± 0.09
September 29	Lemont, IL	22.45 ± 0.88	0.72 ± 0.04	1.81 ± 0.07	0.92 ± 0.04	0.82 ± 0.09
October 1	Channahon, IL	20.28 ± 0.86	1.12 ± 0.04	1.24 ± 0.07	0.88 ± 0.04	0.82 ± 0.09
October 1	Starved Rock State Park, IL	21.03 ± 0.86	1.05 ± 0.04	1.39 ± 0.07	0.89 ± 0.04	0.83 ± 0.09
	Average	19.23 ± 2.05	0.888 ± 0.23	1.42 ± 0.17	1.01 ± 0.20	0.91 ± 0.17

*The perimeter locations are given in terms of the grid coordinates in Figure 1.1.

TABLE 4.14

Transuranics in Soil, 1987

Date Collected	Location	Plutonium-238 fCi/g	Plutonium-238 nCi/m^2	Plutonium-239 fCi/g	Plutonium-239 nCi/m^2	^{238}Pu/^{239}Pu	Americium-241 fCi/g	Americium-241 nCi/m^2	^{241}Am/^{239}Pu
	Perimeter*								
April 21	7I	0.7 ± 0.2	0.036 ± 0.011	18.2 ± 1.3	0.982 ± 0.069	0.037	5.1 ± 2.0	0.274 ± 0.108	0.28
April 21	7I	0.7 ± 0.2	0.039 ± 0.011	17.4 ± 1.2	1.006 ± 0.066	0.039	3.8 ± 1.1	0.220 ± 0.065	0.22
June 4	14E	0.9 ± 0.3	0.043 ± 0.012	8.1 ± 0.7	0.372 ± 0.032	0.034	5.1 ± 0.6	0.236 ± 0.029	0.64
June 4	14N	0.6 ± 0.2	0.023 ± 0.007	14.4 ± 1.0	0.586 ± 0.040	0.040	2.8 ± 0.5	0.116 ± 0.020	0.20
June 4	10P	0.7 ± 0.2	0.032 ± 0.010	17.7 ± 1.3	0.816 ± 0.062	0.039	4.1 ± 0.8	0.188 ± 0.038	0.23
June 4	7E/F	0.4 ± 0.2	0.021 ± 0.010	12.9 ± 1.2	0.712 ± 0.066	0.029	3.1 ± 0.6	0.169 ± 0.035	0.24
June 4	4E/F	1.3 ± 0.3	0.050 ± 0.011	30.1 ± 1.9	1.160 ± 0.072	0.043	6.9 ± 1.0	0.267 ± 0.040	0.23
October 2	7M	1.0 ± 0.2	0.054 ± 0.010	30.3 ± 0.9	1.593 ± 0.050	0.034	-	-	-
October 2	8G	1.0 ± 0.2	0.056 ± 0.012	26.5 ± 1.5	1.467 ± 0.081	0.038	-	-	-
October 5	15H	0.5 ± 0.2	0.025 ± 0.010	5.7 ± 0.7	0.294 ± 0.037	0.085	-	-	-
October 5	13N	0.5 ± 0.2	0.023 ± 0.008	17.1 ± 1.2	0.722 ± 0.052	0.031	-	-	-
October 5	13D	0.7 ± 0.2	0.030 ± 0.009	14.3 ± 1.1	0.655 ± 0.049	0.047	-	-	-
	Average	0.8 ± 0.1	0.036 ± 0.007	17.7 ± 4.5	0.864 ± 0.230	0.041	4.4 ± 1.1	0.210 ± 0.043	0.29
	Off-Site								
May 19	McKinley Woods State Park, IL	0.6 ± 0.2	0.034 ± 0.011	15.9 ± 0.9	0.898 ± 0.048	0.037	4.0 ± 2.1	0.228 ± 0.119	0.25
May 19	Morris, IL	1.2 ± 0.2	0.069 ± 0.014	25.4 ± 1.0	1.525 ± 0.063	0.045	7.7 ± 1.0	0.461 ± 0.061	0.30
May 19	Dresden Lock and Dam, IL	2.1 ± 0.3	0.102 ± 0.015	28.5 ± 1.1	1.382 ± 0.054	0.074	13.7 ± 1.9	0.666 ± 0.093	0.48
May 28	Saganashkee Slough, IL	0.6 ± 0.3	0.029 ± 0.013	16.5 ± 1.6	0.764 ± 0.074	0.038	3.4 ± 0.9	0.158 ± 0.041	0.21
May 28	McGinnis Slough, IL	0.5 ± 0.2	0.026 ± 0.011	13.9 ± 0.9	0.691 ± 0.046	0.038	3.3 ± 0.6	0.163 ± 0.030	0.24
September 29	Pioneer Park, Naperville, IL	0.3 ± 0.1	0.015 ± 0.007	5.6 ± 0.6	0.295 ± 0.034	0.049	-	-	-
September 29	Romeoville, IL	0.5 ± 0.2	0.014 ± 0.005	13.4 ± 1.0	0.401 ± 0.030	0.036	-	-	-
September 29	Lemont, IL	0.5 ± 0.2	0.026 ± 0.008	14.1 ± 1.0	0.732 ± 0.049	0.036	-	-	-
October 1	Channahon, IL	0.7 ± 0.2	0.035 ± 0.009	22.0 ± 1.3	1.121 ± 0.064	0.031	-	-	-
October 1	Starved Rock State Park, IL	0.8 ± 0.2	0.028 ± 0.008	22.8 ± 1.4	0.840 ± 0.052	0.034	-	-	-
	Average	0.8 ± 0.1	0.038 ± 0.007	17.8 ± 4.6	0.865 ± 0.240	0.042	6.4 ± 4.0	0.335 ± 0.199	0.30

*The perimeter locations are given in terms of the grid coordinates in Figure 1.1.

TABLE 4.15

Radionuclides in Grass, 1987

Date Collected	Location	Potassium-40 (pCi/g)	Cesium-137 (fCi/g)	Plutonium-239 (fCi/g)	Deposited Plutonium-239 (nCi/m^2)
	Perimeter*				
June 4	14E	19.42 ± 0.63	26 ± 14	< 0.1	< 0.01
June 4	14N	26.05 ± 0.71	10 ± 12	< 0.1	< 0.01
June 4	10P	24.91 ± 0.81	< 10	0.3 ± 0.1	0.03 ± 0.0
June 4	7E/F	16.18 ± 0.75	17 ± 17	< 0.1	< 0.01
June 4	4E/F	15.21 ± 0.64	< 10	< 0.1	< 0.01
October 2	7M	11.74 ± 0.53	23 ± 14	< 0.1	< 0.01
October 2	8G	8.19 ± 0.86	18 ± 32	0.2 ± 0.1	0.05 ± 0.02
October 5	15H	17.71 ± 0.70	15 ± 15	0.2 ± 0.1	0.05 ± 0.02
October 5	13N	13.40 ± 0.85	< 10	0.1 ± 0.1	0.06 ± 0.03
October 5	13D	3.06 ± 0.54	20 ± 20	< 0.1	< 0.01
	Average	15.59 ± 4.46	13 ± 5	< 0.2	< 0.03
	Off-Site				
May 19	McKinley Wood State Park, IL	20.51 ± 0.80	25 ± 19	-	-
May 19	Morris, IL	26.05 ± 0.71	18 ± 15	-	-
May 19	Dresden Lock and Dam, IL	13.41 ± 0.54	69 ± 16	< 0.1	< 0.01
May 28	Saganashkee Slough, IL	23.30 ± 0.69	11 ± 12	-	-
May 28	McGinnis Slough, IL	19.06 ± 0.62	< 10	< 0.1	< 0.01
September 29	Naperville, IL	14.92 ± 0.59	59 ± 16	0.1 ± 0.1	0.01 ± 0.01
September 29	Romeoville, IL	6.68 ± 0.88	60 ± 24	0.1 ± 0.1	0.01 ± 0.01
September 29	Lemont, IL	11.04 ± 0.75	26 ± 18	< 0.1	< 0.01
October 1	Channahon, IL	2.62 ± 0.31	17 ± 11	< 0.1	< 0.01
October 1	Starved Rock State Park, IL	12.73 ± 0.86	18 ± 19	0.4 ± 0.3	0.09 ± 0.07
	Average	15.03 ± 4.64	31 ± 14	< 0.2	< 0.02

*The perimeter locations are given in terms of the grid coordinates in Figure 1.1.

deposition, the plutonium-239 concentration was a factor of about 10^4 less in the grass than in the soil from the same location.

Results of analyses of bottom sediment samples for gamma-ray emitters and transuranics are given in Table 4.16. The annual off-site averages are in the same range found in off-site samples collected in previous years. The pond at Location 15H contains above-average concentrations of plutonium-239, but higher concentrations have been observed in this and similar off-site ponds in past samplings. Plutonium results vary widely between locations and are strongly dependent on the retentiveness of the bottom material.

A set of samples was collected on August 12, 1987, from the Sawmill Creek bed, above, at, and at several locations below the point at which ANL discharges its treated waste water (Location 7M in Figure 1.1). The results are listed in Table 4.16 and show that the results of the sample above the 7M outfall are similar to those of the off-site samples. The plutonium and americium concentrations are elevated below the outfall, indicating their origin is in ANL waste water. Similar sets of samples were collected on June 24, 1986, June 17, 1985, July 27, 1984, August 11, 1983, September 15, 1982, and September 24, 1980. Comparison of plutonium concentrations indicates that the 1982 results were an order of magnitude higher at the outfall, but similar further downstream, while the 1980, 1983, 1984, 1985, and 1986 results were more like the 1987 set at the same locations. The changes in concentrations of the various nuclides with time indicates the dynamic nature of the sediment material in this area.

The 1986 report[4] discussed the discovery of a pipe discharging water containing above-background concentrations of radionuclides into the Waterfall Glen Nature Preserve about 200 feet south of the 317 Facility fence, Location 6I/J (see Section 4.1.3 and Figure 1.1). As part of the characterization of the 317 Area, a set of sediment samples were collected on January 6, 1987, from the drainage pathway south of the 317 Area beginning at the pipe outfall. All the samples were analyzed by gamma-ray spectrometry and the first four were also analyzed radiochemically for strontium-90. The results are shown in Table 4.17. The cesium-137 concentrations in

TABLE 4.16

Radionuclides in Bottom Sediment, 1987

Date Collected	Location	Concentrations in 10^{-6} pCi/g					Concentrations in 10^{-9} fCi/g		
		Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232	Plutonium-238	Plutonium-239	Americium-241
	<u>Perimeter</u>*								
August 11	4EF Quarry	20.69 ± 0.54	0.55 ± 0.02	1.59 ± 0.04	1.08 ± 0.03	0.80 ± 0.06	-	-	-
August 12	Sawmill Creek - 25 m Above Outfall	12.35 ± 0.79	0.13 ± 0.03	1.14 ± 0.07	0.60 ± 0.04	0.59 ± 0.08	0.2 ± 0.1	5.3 ± 0.6	1.3 ± 0.2
August 12	Sawmill Creek - At Outfall	11.26 ± 0.76	0.54 ± 0.03	1.07 ± 0.06	0.48 ± 0.03	0.65 ± 0.09	3.8 ± 0.5	25.0 ± 1.6	1.4 ± 0.6
August 12	Sawmill Creek - 50 m Below Outfall	11.03 ± 0.49	1.88 ± 0.05	1.17 ± 0.06	0.59 ± 0.03	0.74 ± 0.08	8.3 ± 0.9	53.2 ± 3.2	28.6 ± 1.8
August 12	Sawmill Creek - 150 m Below Outfall	10.55 ± 0.49	2.50 ± 0.06	0.93 ± 0.06	0.55 ± 0.03	0.67 ± 0.09	7.9 ± 0.7	55.6 ± 2.8	45.7 ± 1.7
August 12	Sawmill Creek - At Des Plaines River	12.55 ± 0.52	2.68 ± 0.06	1.23 ± 0.06	0.68 ± 0.03	0.79 ± 0.09	3.8 ± 0.5	40.2 ± 2.4	24.5 ± 0.6
October 5	15H Pond	10.99 ± 0.76	2.39 ± 0.05	0.97 ± 0.06	0.65 ± 0.04	0.49 ± 0.08	1.9 ± 0.5	49.8 ± 3.4	-
	<u>Off-Site</u>								
May 19	Illinois River, McKinley State Park, IL	12.48 ± 0.77	0.03 ± 0.03	0.61 ± 0.06	0.43 ± 0.03	0.40 ± 0.08	< 0.1	0.7 ± 0.2	0.4 ± 0.2
May 19	Illinois River, Morris, IL	16.08 ± 0.81	0.10 ± 0.02	0.85 ± 0.06	0.53 ± 0.03	0.49 ± 0.08	< 0.1	1.8 ± 0.3	0.9 ± 0.2
May 19	Illinois River, Dresden Lock and Dam, IL	20.08 ± 0.85	0.12 ± 0.03	0.89 ± 0.06	0.72 ± 0.04	0.62 ± 0.08	< 0.1	1.4 ± 0.3	0.4 ± 0.9
May 28	Saganashkee Slough, IL	21.44 ± 0.90	0.06 ± 0.03	0.48 ± 0.06	0.42 ± 0.03	0.42 ± 0.09	< 0.1	1.2 ± 0.2	0.8 ± 0.1
May 28	McGinnis Slough, IL	26.86 ± 0.58	0.07 ± 0.01	1.45 ± 0.04	0.94 ± 0.02	0.83 ± 0.06	0.1 ± 0.1	1.2 ± 0.3	0.2 ± 0.3
September 29	DuPage River, Naperville, IL	20.35 ± 0.86	0.04 ± 0.02	1.36 ± 0.07	1.12 ± 0.04	1.05 ± 0.10	0.5 ± 0.5	2.4 ± 0.8	0.5 ± 0.4
September 29	Des Plaines River, Romeoville, IL	14.24 ± 0.80	0.46 ± 0.03	1.39 ± 0.07	0.94 ± 0.04	0.83 ± 0.09	0.7 ± 0.2	11.0 ± 0.9	2.4 ± 0.3
September 29	Long Run Creek, Lemont, IL	20.96 ± 0.89	0.13 ± 0.02	1.43 ± 0.07	0.91 ± 0.04	0.80 ± 0.10	0.2 ± 0.1	4.2 ± 0.5	-
October 1	DuPage River, Channahon, IL	16.42 ± 0.82	0.26 ± 0.03	1.57 ± 0.07	1.19 ± 0.04	1.05 ± 0.10	0.1 ± 0.2	4.7 ± 1.2	-
October 1	Illinois River, Starved Rock State Park, IL	5.16 ± 0.69	0.01 ± 0.02	1.02 ± 0.06	0.28 ± 0.03	0.26 ± 0.07	0.1 ± 0.2	0.6 ± 0.3	-
	Average	17.41 ± 3.78	0.13 ± 0.09	1.11 ± 0.20	0.75 ± 0.17	0.68 ± 0.18	0.2 ± 0.1	2.9 ± 2.0	0.8 ± 0.6

*The perimeter locations are given in terms of the grid coordinates in Figure 1.1.

TABLE 4.17

Sediment Samples Collected January 6, 1987, to Radiologically Characterize the Drainage South of the 317 Area

(Concentrations in pCi/g)

Location	Cobalt-60	Strontium-90	Cesium-137
20′ Downstream of Pipe Outfall	0.45 ± 0.04	1.08 ± 0.08	107.80 ± 0.42
100′ Downstream of Pipe Outfall	0.25 ± 0.03	0.90 ± 0.05	25.03 ± 0.17
200′ Downstream of Pipe Outfall	0.18 ± 0.03	0.53 ± 0.11	15.51 ± 0.14
300′ Downstream of Pipe Outfall	0.16 ± 0.03	0.96 ± 0.07	10.23 ± 0.11
400′ Downstream of Pipe Outfall	0.11 ± 0.03	-	6.54 ± 0.09
500′ Downstream of Pipe Outfall	0.08 ± 0.02	-	9.88 ± 0.11
800′ Downstream of Pipe Outfall	0.07 ± 0.03	-	7.86 ± 0.09
1100′ Downstream of Pipe Outfall Just Above Confluence With 319 Drain	0.05 ± 0.02	-	5.26 ± 0.08
1400′ Downstream of Pipe Outfall at Quarry Road	< 0.05	-	0.38 ± 0.03
1700′ Downstream of Pipe Outfall	< 0.05	-	0.73 ± 0.03
North Side of Culvert Under Railroad Spur	< 0.05	-	1.86 ± 0.06
North Side of Culvert Under AT&SF Railroad Tracks	< 0.05	-	1.56 ± 0.06
50′ South of AT&SF Tracks in Wetlands	< 0.05	-	1.87 ± 0.05

samples collected downstream to 1,100 feet below the pipe outfall should be considered elevated compared to the concentrations found in off-site sediment samples. The balance of the cesium-137, the cobalt-60, and the strontium-90 results may be slightly above ambient concentrations, but are still very low. Subsequent cleanup of this drainage area reduced the radionuclide concentrations in sediment to well below the 50 pCi/g specified in draft DOE Order 5480.XX.[6]

4.1.5. Milk

Fresh milk was collected monthly from a local dairy farm south of Lemont and analyzed for several radionuclides. The water was separated from the milk by low-temperature vacuum evaporation and the hydrogen-3 determined by liquid scintillation spectrometry. The strontium-90 was analyzed by the same method used for water and with the same detection limit. The results are given in Table 4.18. The average strontium-90 concentration was similar to the 1986 concentration. These nuclides are fission products from nuclear tests and their presence in milk is not related to ANL operations.

The concentrations given in Table 4.18 may be compared to the EPA drinking water limits. The consumption of one liter of milk per day would result in an average dose of 0.6 mrem/y for strontium-90 and $<$ 0.25 mrem/y for hydrogen-3.

4.1.6. External Penetrating Radiation

Measurements were made with calcium fluoride and lithium fluoride thermoluminescent dosimeter (TLD) chips. Each measurement was the average of four chips exposed in the same packet. All calcium fluoride packets were shielded with 1.6 mm (1/16 in) copper foil to reduce or eliminate the beta and low-energy X-ray components. The response of the chips was determined with a U. S. National Bureau of Standards (NBS) standard radium-226 source, and the results were calculated in terms of air dose. Dosimeters were exposeded at a number of locations at the site boundary and on the site. Readings were also taken at five off-site locations for comparison purposes. These locations are shown in Figure 1.2.

TABLE 4.18

Radionuclides in Milk, 1987
(Concentrations in pCi/L)

Date Collected	Hydrogen-3	Strontium-90
January 7	< 100	2.3 ± 0.2
February 6	< 100	2.4 ± 0.1
March 4	< 100	2.6 ± 0.8
April 1	< 100	2.8 ± 0.6
May 6	< 100	2.2 ± 0.1
June 3	< 100	4.1 ± 0.2
July 1	< 100	3.7 ± 1.7
August 5	< 100	2.4 ± 0.3
September 2	135 ± 75	2.8 ± 0.3
October 7	< 100	2.4 ± 0.2
November 4	< 100	2.4 ± 0.3
December 2	< 100	2.3 ± 0.5
Average	< 103	2.7 ± 0.3

The results are summarized in Tables 4.19 and 4.20, and the site boundary and on-site readings are also shown in Figure 4.3. Measurements were made for the four successive exposure periods shown in the tables and the results were calculated in terms of annual dose, for ease in comparing measurements made for different elapsed times. The uncertainty given in the tables for an average is the 95% confidence limit calculated from the standard deviation of the average.

The off-site results averaged 90 ± 5 mrem/y and are higher than last year's off-site average of 78 ± 5 mrem/y. If the off-site locations are an accurate sample of the radiation background in the area, then annual averages at the site in the range of 90 ± 5 mrem/y may be considered normal with a 95% probability. To compare boundary results for individual sampling periods, the standard deviation of the 20 individual off-site results is useful. This value is 6.2 mrem/y, so that individual results in the range of 90 ± 12 mrem/y may be considered to be the average natural background with a 95% probability, unless there are known reasons to the contrary.

At two site boundary locations, 7I (south) and 14I (north), the dose rates were consistently above the average background. At 7I this was due to radiation from a Radioactive Waste Storage Facility (317) in the northern half of grid 7I. Waste is packaged and temporarily kept in this area prior to removal for permanent storage elsewhere. The net above-background dose at this location was about 368 mrem/y, the same as the 1986 average. In previous years, this value has ranged from 865 mrem/y in 1985 to 114 mrem/y in 1977. About 300 m (0.2 mi) south of the fence in grid 6I, the measured dose dropped to 92 ± 7 mrem/y, within the normal range. The above-background dose at the 8H/I Location, 200 m northwest of the Waste Storage Facility, about 13 mrem/y, is also due to the Storage Area, as discussed in the 1982 report.[17] At Location 14I, at the north boundary, the dose rate was 22 mrem/y above background, about the same as in 1986. This dose is due to the use of cobalt-60 irradiation sources in Building 202.

A dramatic reduction in dose between the third and fourth quarters of 1987 at location 7I is obvious. To verify that the fourth quarter values were accurate, additional measurements were made with a Reuter-Stokes

TABLE 4.19

Environmental Penetrating Radiation at Off-Site Locations, 1987

Location	Dose Rate (mrem/year)				
	Period of Measurement				
	1/5-4/9	4/9-7/16	7/16-10/15	10/15-1/17	Average
Lemont	85	90	98	88	90 ± 6
Lombard	87	92	101	92	93 ± 6
Oak Brook	88	95	99	90	93 ± 5
Oak Lawn	78	82	84	80	81 ± 3
Woodridge	87	93	95	89	91 ± 4
Average	85 ± 4	90 ± 5	95 ± 7	88 ± 5	90 ± 5

TABLE 4.20

Environmental Penetrating Radiation at ANL, 1987

Location*	Dose Rate (mrem/year)				
	Period of Measurement				
	1/5-4/9	4/9-7/16	7/16-10/15	10/15-1/8	Average
14L - Boundary	78	80	82	74	78 ± 3
14I - Boundary	105	113	118	113	112 ± 5
14G - Boundary	88	91	101	89	92 ± 6
9/10EF - Boundary	85	91	92	83	88 ± 4
8H - Boundary	81	97	98	86	90 ± 8
8H - Boundary, Center, St. Patrick's Cemetery	90	98	99	89	94 ± 5
7I - Boundary	589	633	506	105	458 ± 241
6I - 200 m N of Quarry Road	-	91	100	86	92 ± 7
9H - 50 m SE of CP-5	377	368	526	1160	608 ± 375
8H - 65 m S of Building 316	80	175	93	79	107 ± 46
8H/I - 200 m NW of Waste Storage Area (Heliport)	101	106	114	90	103 ± 10
7I - Center, Waste Storage Area Facility 317	7710	8700	11300	283	7000 ± 4730
10/11K - Lodging Facilities	76	81	81	73	78 ± 4
9I - 65 m NE of Building 350, 230 m NE of Building 316	84	84	87	78	83 ± 4

*See Figure 1.1.

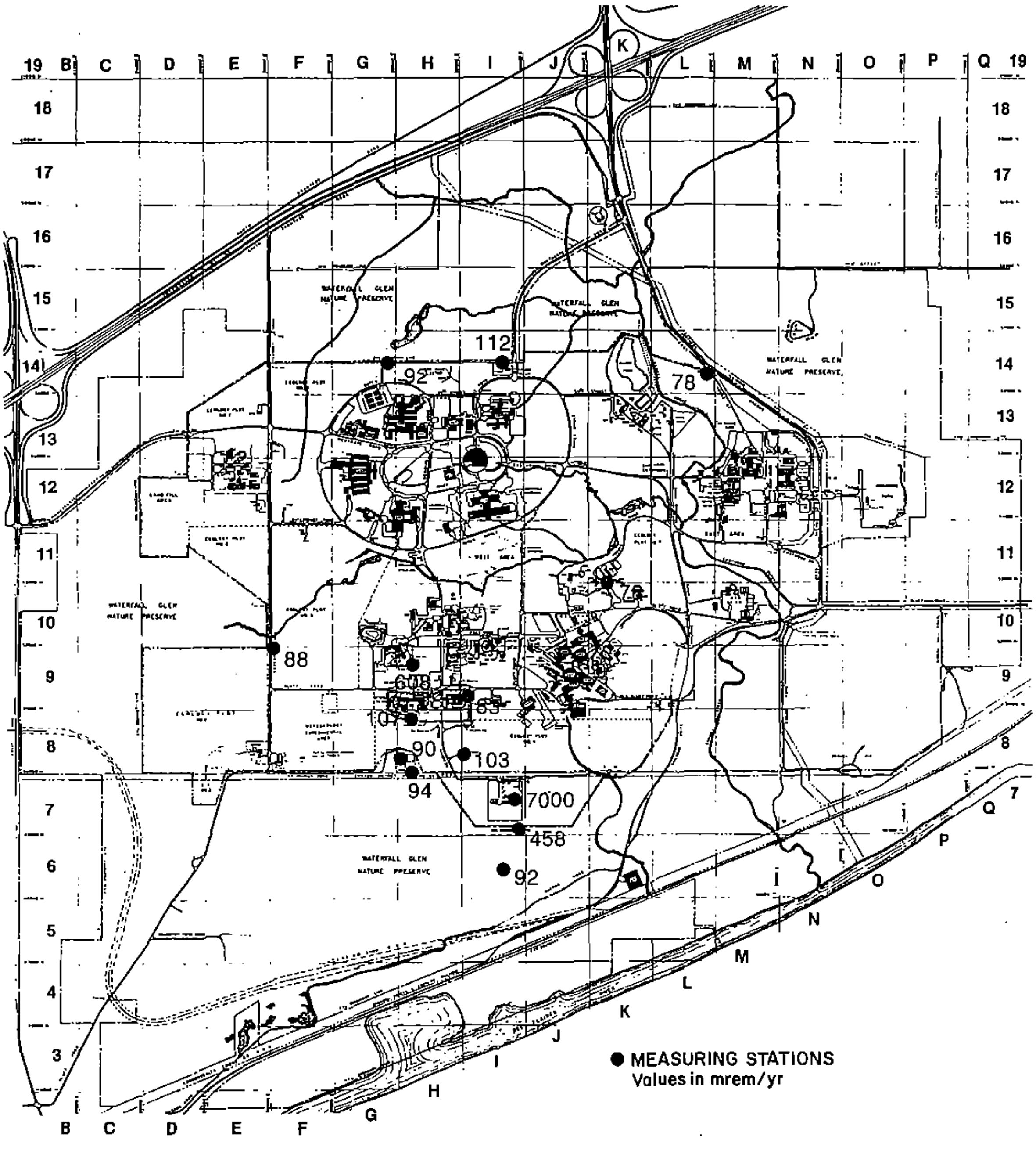

Fig. 4.3 Penetrating Radiation Measurements at the ANL Site, 1987

environmental radiation monitor. The results of the measurements at three different locations, 7I Center, 7I Boundary, and 9H, agree well with the TLD values in Table 4.20. Subsequent discussion with operating personnel at the Waste Storage Facility indicated that radioactive waste had been shipped off-site for disposal in the late summer and early fall, and very little material was stored in this area for the remainder of the year.

The dose in the south portion of grid 8H is of interest. This area includes St. Patrick's Cemetery, which was in use before ANL was constructed and is open to visitors. In 1987, as in previous years, this dose was estimated to be 5 to 10 mrem/y above the off-site average. Possible explanations are that the 8H dose rates are natural since the differences between the off-site and 8H averages are not statistically significant at the 95% confidence level, or that the monument stones in the cemetery produce the elevated rates because above-background dose rates were obtained from one of the large red granite stones, and granite is known to contain above average levels of natural thorium and its decay products.

4.1.7. Potential Radiation Dose Estimates

The radiation doses at the site boundary and off the site, which could have been received by the public from radioactive materials and radiation leaving the site, were calculated. These calculations were made for three exposure pathways, including airborne, water, and direct radiation from external sources. DOE draft guidance[6] requires the use of the EPA-AIRDOSE/RADRISK model and computer program[20] for the calculation of the submersion dose for radionuclides released to the air.

4.1.7.1. Airborne Pathway

DOE facilities with airborne releases are subject to 40 CFR Part 61, Subpart H,[10] which requires the use of the EPA-AIRDOSE/RADRISK code to demonstrate compliance with this regulation. The dose limits for the air pathway are 25 mrem/y to the whole body and 75 mrem/y to any organ. The EPA-AIRDOSE/RADRISK computer code uses a modified Gaussian plume equation to estimate both horizontal and vertical dispersion of radionuclides released the air from stacks or area sources. For 1987, dose calculations were carried out for hydrogen-3, carbon-11, argon-41, krypton-85, and radon-220 plus daughters. The annual release rates are those listed in Table 4.5. The wind speed and direction data shown in Figure 1.3 are the meteorological data needed for these calculations. The calculations were carried out to 80 km (50 mi) using the population distribution of 16 segments and ten distance increments given in Table 1.1. The dose rate was calculated at the midpoint of each interval and integrated over the entire area to give the annual population cumulative dose.

The highest perimeter dose rates are in the north to east sectors. The results of the above calculations for the perimeter location with the highest dose are due north of ANL and are given in Table 4.21. Dose is calculated in the code for all reasonable airborne pathways and the major contributors to the dose, immersion, inhalation, and ingestion, are listed in the table. Each radionuclide/pathway value is the sum of the doses to the individual organs for that combination. Inspection of Table 4.21 indicates that the dominant dose contributor is inhalation of lead-212 and that the organ receiving the greatest exposure is the lung. Through an oversight, the dose from the radon-220 daughters was not calculated in the past.

The closest full-time resident, who would receive the largest dose, is located approximately 0.5 km (0.3 mi) north of the site boundary. The EPA-AIRDOSE/RADRISK program was also used to calculate the doses at this location. The results are shown in Table 4.22. Again, the major contributor is the inhalation dose from lead-212, but it is smaller in magnitude because of the greater distance from the source.

The population data in Table 1.1 were used to calculate the cumulative population dose from gaseous radioactive effluents. The results are given in Table 4.23, together with the natural external radiation dose. The natural radiation dose was that measured at the off-site TLD locations, and it is assumed that this dose is representative of the entire area within an 80 km (50 mi) radius.

TABLE 4.21

Maximum Perimeter Dose From Airborne Emissions, 1987
(Millirem per year)

		Pathway	
Radionuclide	Immersion	Inhalation	Ingestion
Hydrogen-3	< 0.0001	0.0007	< 0.0002
Carbon-11	0.013	0.0011	< 0.0001
Argon-41	0.0002	< 0.0001	< 0.0001
Krypton-85	< 0.0001	< 0.0001	< 0.0001
Radon-220	< 0.0001	0.031	< 0.0001
Polonium-216	< 0.0001	< 0.0001	< 0.0001
Lead-212	< 0.0001	0.356	< 0.0001
Bismuth-212	0.0001	0.052	< 0.0001
Thallium-208	0.0010	< 0.0001	< 0.0001
Total	0.014	0.441	0.0002

TABLE 4.22

Maximum Individual Dose From Airborne Emissions, 1987
(Millirem per year)

		Pathway	
Radionuclide	Immersion	Inhalation	Ingestion
Hydrogen-3	< 0.0001	0.0004	0.0001
Carbon-11	0.0062	0.0006	< 0.0001
Argon-41	< 0.0001	< 0.0001	< 0.0001
Krypton-85	< 0.0001	< 0.0001	< 0.0001
Radon-220	< 0.0001	0.0040	< 0.0001
Polonium-216	< 0.0001	< 0.0001	< 0.0001
Lead-212	< 0.0001	0.195	< 0.0001
Bismuth-212	< 0.0001	0.028	< 0.0001
Thallium-208	0.0003	< 0.0001	< 0.0001
Total	0.0067	0.227	0.0001

TABLE 4.23

80 km Population Dose, 1987
(man-rems)

Radionuclide	Dose
Hydrogen-3	0.11
Carbon-11	0.32
Argon-41	0.013
Krypton-85	0.18
Radon-220	0.020
Polonium-216	< 0.01
Lead-212	40.5
Bismuth-212	2.88
Thallium-208	0.003
Total	44.0
Natural	7.1×10^5

The potential radiation exposures by the inhalation pathways were also calculated by the methodology specified in the draft guidance.[6] The total quantity for each radionuclide inhaled, in microcuries (μCi), is calculated by multiplying the annual average air concentrations by the general public breathing rate of 8,400 m^3/y.[21] This annual intake is then multiplied by the EFF.D.E. for the appropriate lung retention class (D, W, or Y). Because the EFF.D.E.s are in units of Rem per microcurie (Rem/μCi), this calculation gives the 50-year committed effective dose equivalent. The applicable EFF.D.E.s are collected in Table 4.24.

The calculated doses in Tables 4.3, 4.4, and 4.6 were obtained using this procedure. Because they are all essentially perimeter locations, these doses represent the fenceline values for those radionuclides measured. In almost all cases, these doses also are the same as the off-site measurements and represent the ambient dose for the area from these nuclides. No doses are calculated for the total alpha and total beta measurements since the draft guidance does not provide EFF.D.E.s for such measurements.

4.1.7.2. Water Pathway

Similarly, following the methodology outlined in the draft guidance, the ingestion annual intake, in μCi, is obtained by multiplying the concentration in microcuries per milliliter (μCi/mL) by the annual water consumption of a member of the general public (7.3×10^5 mL). This annual intake is then multiplied by the EFF.D.E. for ingestion (Table 4.24) to obtain the dose. This is carried out for all radionuclides and summed to obtain the total ingestion dose.

The only location where radionuclides attributable to ANL operations could be found in off-site water was Sawmill Creek below the waste-water outfall. Although this water is not used for drinking purposes, the 50-year effective dose equivalent was calculated for a hypothetical individual ingesting water at the concentrations found. Those radionuclides added to Sawmill Creek by ANL waste water, their net concentrations in the creek and the corresponding dose rates, if water at these concentrations was used as the sole water supply by an individual, are given in Table 4.25. The dose

TABLE 4.24

50-Year Committed Dose Equivalent Factors - EFF.D.E.
(Rem/μCi)

Nuclide	Ingestion	Inhalation
Hydrogen-3	6.3×10^{-5}	6.3×10^{-5}
Beryllium-7	-	2.7×10^{-4}
Carbon-11	-	8.0×10^{-6}
Strontium-90	0.13	1.3
Cesium-137	0.05	0.032
Lead-210	-	0.13
Radium-226	1.1	-
Thorium-228	-	0.031
Thorium-230	-	0.062
Thorium-232	-	0.0011
Uranium-234	0.26	0.013
Uranium-235	0.25	0.012
Uranium-238	0.23	0.012
Neptunium-237	0.39	-
Plutonium-238	0.38	-
Plutonium-239	0.43	0.033
Americium-241	2.2	-
Curium-242	0.065	-
Curium-244	1.1	-
Californium-249	2.3	-
Californium-252	0.48	-

TABLE 4.25

Radionuclide Concentrations and Dose Estimates
for Sawmill Creek Water, 1987

Nuclide	Total Released (Millicuries)	Net Avg. Conc. (pCi/L)	Dose (mrem/y)
Hydrogen-3	916	128	0.006
Strontium-90	6.9	0.96	0.091
Cesium-137	12.3	1.7	0.062
Neptunium-237	0.01	0.0019	0.0005
Plutonium-239	0.06	0.0078	0.002
Americium-241	0.10	0.0136	0.022
Sum			0.184

rates were all well below the standards for the general population. It should be emphasized that Sawmill Creek is not used for drinking, swimming, or boating. Inspection of the area shows there are few fish in the stream, and they do not constitute a significant source of food for any individual.

As indicated in Table 4.7, occasional Sawmill Creek samples (less than 10) contained traces of plutonium-238, curium-242,244, or californium-249,252, but the averages were only slightly greater than the detection limit. The annual dose to an individual consuming water at these concentrations can be calculated using the same method that was used for those radionuclides more commonly found in creek water, but the method of averaging probably overestimates the true concentration. These annual doses range from 3×10^{-3} to 6×10^{-5} mrem/y for these radionuclides.

The U. S. Environmental Protection Agency (EPA) has established drinking water standards based on a dose of 4 mrem/y for man-made beta particle and photon-emitting radionuclides.[16] The EPA standard is 2×10^4 pCi/L for hydrogen-3, 8 pCi/L for strontium-90, and 200 pCi/L for cesium-137. The concentrations in Table 4.25 correspond to 0.6% (hydrogen-3), 12% (strontium-90), and 1.1% (cesium-137) of the EPA standards. No specific EPA standards exist for the transuranic nuclides.

4.1.7.3. External Direct Radiation Pathway

The TLD results in Section 4.1.6 are used to calculate the radiation dose from external sources. Above-normal fenceline doses attributable to ANL operations were found at the south boundary near the Waste Storage Facility (Location 7I) and at the north boundary near Building 202 (Location 14I).

At Location 7I, the fenceline dose from ANL was about 368 mrem/y. Approximately 300 m (0.3 mi) south of the fenceline (grid 6I), the measured dose was 92 ± 7 mrem/y, well within the normal range of the off-site average (90 ± 5 mrem/y). There are no individuals living in this area. The closest residents are about 1.6 km (1 mi) south of the fenceline. At this distance, the calculated dose rate from the Waste Storage Facility is about

0.02 mrem/y, if the energy of the radiation was the 0.66 MeV cesium-137 gamma-ray and about 0.08 mrem/y if the energy was the 1.33 MeV cobalt-60 gamma-ray. In the area north of the site, the fenceline radiation dose from the cobalt-60 sources in Building 202 was measured at 22 mrem/y. The nearest residents are 750 m (0.47 mi) to the north-northwest. The calculated dose at that location was about 0.11 mrem/y.

At the fenceline, where higher doses were measured, the land is wooded and unoccupied. All of these dose calculations are based on full-time, outdoor exposure. Actual exposures to individuals are substantially less, since they are inside (which provides shielding) or away from their dwellings some of the time.

4.1.7.4. Dose Summary

The total dose received by off-site residents was a combination of the separate pathways that contribute to this total: hydrogen-3, carbon-11, argon-41, krypton-85, and radon-220 (plus daughters), by the airborne pathway and cobalt-60 external radiation dose. The highest dose was about 0.34 mrem/y to individuals living north of the site if they were outdoors at that location during the entire year. The total annual population dose to the entire area within an 80 km (50 mi) radius is 44 man-rem.

In order to put the maximum individual dose of 0.34 mrem/y into perspective, comparisons can be made to annual average doses received by the public from natural or accepted sources of radiation. These are listed in Table 4.26. It is obvious that the magnitude of the doses received from ANL operations is insignificant compared to these sources. Therefore, the monitoring program results establish that the radioactive emissions from ANL are very low and do not endanger the health or safety of those living in the vicinity of the site.

TABLE 4.26

Annual Average Dose Equivalent in the U. S. Population*

Source	(mrem)
Natural Sources	
Radon	200
Internal (^{40}K and ^{226}Ra)	39
Cosmic	28
Terrestial	28
Medical	
Diagnostic X-rays	39
Nuclear Medicine	14
Consumer Products	
Tobacco	16
Domestic Water Supplies, Building Materials, etc.	10
Occupational (medical radiology, industrial radiography, research, etc.)	1
Nuclear Fuel Cycle	< 1
Fallout	< 1
Other Miscellaneous Sources	< 1
Total - non-smoker	~360
Total - smoker	~376

*NCRP Report No. 93.[22]

4.2. Chemical Constituents

4.2.1. Surface Water

The major discharge of waste water from ANL operations is by way of the Waste Water Treatment Plant. The Plant is composed of a conventional sanitary treatment plant and a system for handling waste water from ANL operations. The two effluents are combined and the water enters Sawmill Creek at location 7M (see Figure 1.1). There are nine other discharges that can or do enter the creek independent of the Treatment Plant. All of the effluents are regulated to, some degree by the National Pollutant Discharge Elimination System (NPDES) permits. Requirements for sampling, analysis, and reporting are specified in the permit. The combined effluent is additionally studied and results are compared to effluent standards listed in the STATE OF ILLINOIS RULES AND REGULATIONS, Title 35, Subtitle C, Chapter I.[23] Specific requirements relative to effluents are found in Part 304, Subpart A. The impact of all of the effluents on the stream quality is studied and compared to stream standards listed in Part 302, Subpart B, of the above document. All of the results obtained are compared to state standards listed in Table 4.27.

4.2.1.1. National Pollutant Discharge Elimination System (NPDES)

ANL discharges are regulated by NPDES Permit No. IL 0034592. This permit was renewed on September 28, 1984, and the final modification took effect on June 28, 1987. The modification consisted primarily of sampling requirements for coal pile runoff (001C). A system designed to handle excess runoff water resulting from heavy precipitation or pump failure was sampled at 010.

The NPDES locations are shown in Figure 4.4. For purposes of clarity, the location numbers in the figure are given without the zeroes. Thus, permit location 001 is given as 1. Locations 1A, 1B, and 1C are tributary to location 1, ANL's major outfall. Samples at locations 1A, 1B, and 1 are collected weekly, while most of the other samples are collected monthly.

TABLE 4.27

Water Quality Standards
(Concentrations in mg/L)

Constituent	State Standard Stream	Effluent
Ammonia Nitrogen (as N)	1.5	2.5 (Apr.-Oct.) 4.0 (Nov.-Mar.)
Arsenic	1.0	0.25
Barium	5.0	2.0
Cadmium	0.05	0.15
Chloride	500	-
Chromium	1.0	1.0
Copper	0.02	1.0
Cyanide	0.025	0.025
Fluoride	1.4	15
Iron	1.0	2.0
Lead	0.1	0.1
Manganese	1.0	1.0
Mercury	0.0005	0.0005
Nickel	1.0	1.0
pH	6.5-9.0	6.0-9.0
Selenium	1.0	-
Silver	0.005	0.1
Sulfate	500	-
Total Dissolved Solids	1000	-
Zinc	1.0	1.0

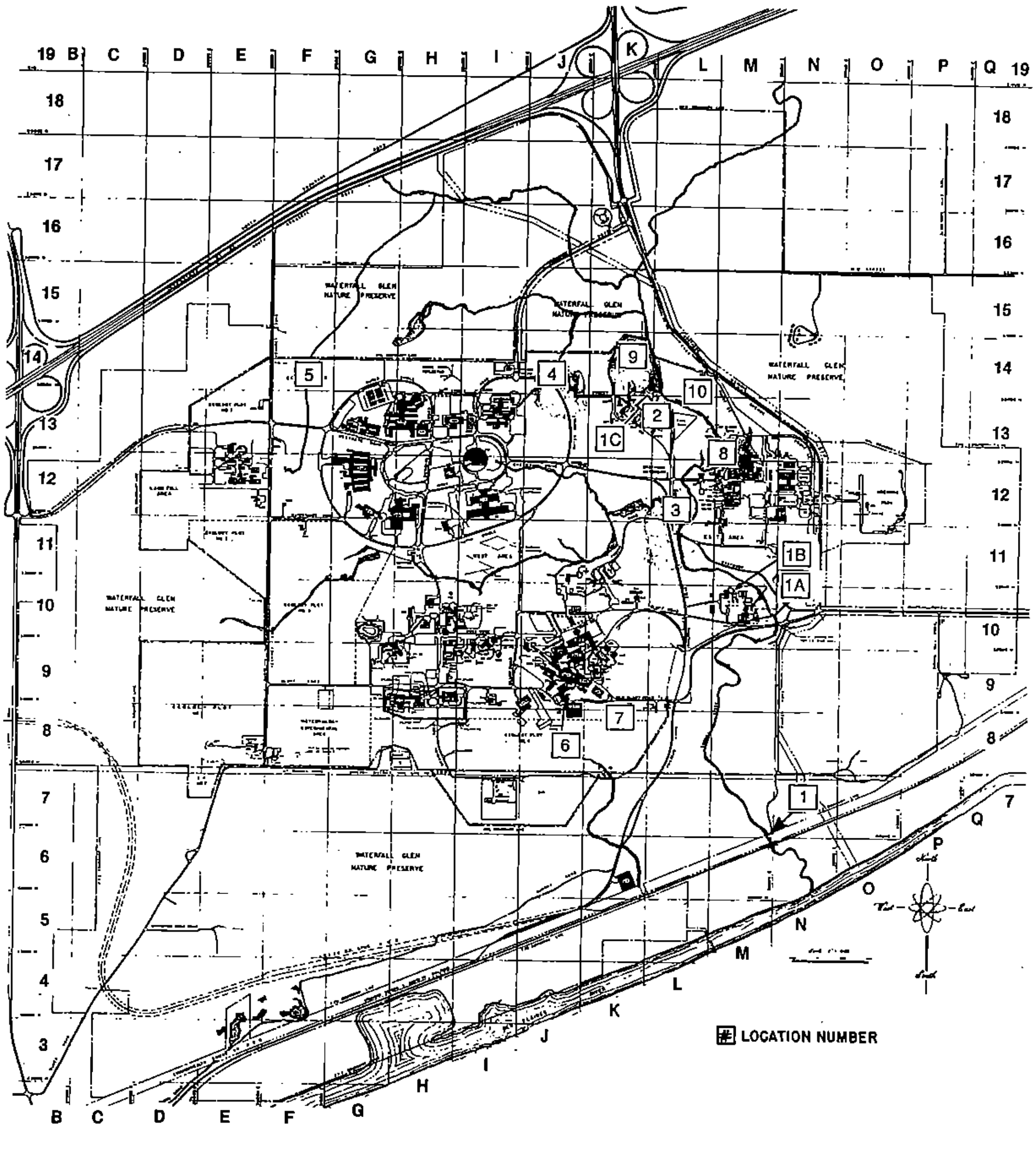

Fig. 4.4 NPDES Permit Locations

Special conditions exist for Sawmill Creek. The domestic water at ANL is now softened using ion-exchange resins and the backwash solution is routed through the ANL waste system (1B) and enters Sawmill Creek at 7M. The permit requires that grab samples be collected semi-monthly upstream and downstream of the outfall. A 24-hour sample, encompassing the time period of the grab samples, is collected at location 1. The limits for the downstream grab sample for chloride, sulfate, and total dissolved solids are not to be exceeded. The 24-hour sample at location 1 may exceed the permit limit if it does not cause the downstream grab sample to exceed the limit.

The collection of coal pile runoff has special sampling requirements. The leachate from the coal storage is initially collected in a pit and flows by gravity to a lift station. The liquid is then pumped to a small settling pond (this pond also contains effluent from the ANL water purification process). The water drains into a second lift station, where sampling for location 1C occurs. This sampling point, 1C, also samples water from location 2. Samples collected at location 2 contained water from the boiler house blowdown and coal pile runoff until this channel was permanently closed in mid-1987.

The system at location 10, which leads directly to Sawmill Creek, serves as an emergency overflow and must be sampled once per month when flowing. No flow was recorded from September through December 1987.

Sampling of the lime pond effluent at location 9 is required only when overflow occurs. Sufficient solids were removed from the lime pond bottom so that the water level in the pond is well below the outfall pipe. No overflow occurred in 1987.

Samples were collected in accordance with EPA requirements using the proper preservatives and holding times. Analyses were performed using test procedures listed in 40 CFR Part 136[8], except for chloride and sulfate, which used EPA Method 300.0.[24]

The results for chloride, sulfate, and total dissolved solids are shown in Table 4.28 for samples collected at location 1 and upstream and downstream of location 1 in Sawmill Creek.

TABLE 4.28

Impact of Effluent Water on Sawmill Creek, 1987
(Concentrations in mg/L)

Constituent	Upstream	Effluent	Downstream	Limit
Chloride	147 ± 43	514 ± 41	471 ± 95	500
Sulfate	90 ± 30	245 ± 30	140 ± 18	500
TDS	586 ± 97	1607 ± 81	1328 ± 191	1000

The downstream levels are used to measure compliance. Levels for chloride exceeded the limit 46% of the time, all in the first eight months of 1987. The total dissolved solids exceeded the limit 71% of the time, primarily through the first nine months. Sulfate has been below the limit in every sample. Domestic water is treated by ion exchange and the regeneration solutions are disposed of in the ANL sanitary waste water system. The chloride and TDS are elevated by this process. A system has been designed to reduce these constituents.

Samples have been obtained at the coal pile runoff at location 1C since September 1987, the effective date of the permit. A summary of all NPDES results appears in Table 3.1. The first sample obtained was within all of the limits, but all three samples since then have exceeded the limits for iron, zinc, suspended solids, and pH and for manganese in one sample. The pH of these samples was in the range of 3.1-3.3 and iron values ranged from 20 mg/L to 160 mg/L. Zinc and manganese values were slightly above the limit. Levels of suspended solids ranged from 8 mg/L to 72 mg/L. Funding has been obtained to treat coal pile runoff at its source.

Two samples at location 1 exceeded the limit for fecal coliform. In one instance the chlorinator was inoperative for one hour. The second case is believed to have been caused by upstream contamination since the upstream fecal coliform levels were comparable and high water flow probably washed creek water into the outfall sewer at location 7M. The residual chlorine of the effluent was 0.8 ppm and should been more than enough to reduce bacterial levels.

One sample at location 2 had a high pH and a high level of suspended solids. This location has since been closed and no flow has been observed since July. Occasional violations of suspended solids levels at locations 3, 4 and 6 have been observed. These can usually be related to high storm flows except for one sample at location 4 which is probably related to steam line maintenance. Some samples at location 1B have had elevated levels of suspended solids, probably due to an inoperative pump.

4.2.1.2. Waste Water Treatment Plant Effluent

The water volume from the Waste Water Treatment Plant averaged 1.04 million gallons per day and was comprised of 44% sanitary waste water and 56% laboratory process water. Laboratory process water is normally collected in 69,000 gallon tanks, and they are then pumped into a large holding pond. The pond is discharged at a constant rate by means of an overflow weir which regulates the release rate. This results in a constant flow over a 24-hour period. For a good portion of 1987, the pumps were inoperative, and the water was released by gravity through a gate valve over an eight-hour period.

Samples from the Waste Water Treatment Plant are collected in a 24-hour flow proportional sampler and are then transferred to specially cleaned bottles and are security sealed. The samples are analyzed within the required holding period and analyses are performed using EPA methods.[24]

The results obtained are shown in Table 4.29. All of the average concentrations were below state standards and similar to last year's values. The average value for mercury was 49% of the state standard of 0.5 µg/L and this was exceeded in six samples (12%). This standard must be viewed in terms of the mercury limit in the NPDES permit. The mercury concentration

TABLE 4.29
CHEMICAL CONSTITUENTS IN EFFLUENTS FROM ANL TREATMENT PLANT, 1987
(CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	3	-	-	< 5	< 2.0	0
BARIUM	12	49 ± 10	31	81	2.4	0
BERYLLIUM	12	0.06 ± 0.01	0.03	0.08	-	-
CADMIUM	12	0.9 ± 0.3	< 0.2	1.7	0.6	0
CHLORIDE*	24	515 ± 41	267	689	-	-
CHROMIUM	51	12 ± 2	5	35	-	-
COPPER	51	42 ± 5	15	103	4.2	0
DISSOLVED SOLIDS*	24	1610 ± 81	1030	2080	-	-
FLUORIDE	12	449 ± 43	340	536	3.0	0
IRON	51	270 ± 24	72	474	14	0
LEAD	12	3.4 ± 1.1	< 2.0	7.3	3.4	0
MANGANESE	51	55 ± 14	13	390	5.5	0
MERCURY	51	0.25 ± 0.05	0.10	0.75	49	12
NICKEL	12	28 ± 12	7	54	2.8	0
PH**	245	-	7.5	9.2	-	0
SELENIUM	3	-	-	< 5	< 0.5	0
SILVER	12	3.0 ± 0.7	1.1	5.3	3.0	0
SULFATE*	24	246 ± 30	151	373	-	-
ZINC	12	80 ± 11	44	107	8.0	0

* CONCENTRATION IN MILLIGRAM/LITER.

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is restricted by the permit to 6 μg/L for any sample and to a monthly average of 3 μg/L. The state regulation allows a single sample to be five times the state standard if the monthly average is not exceeded. In the case of mercury, a single result could be up to 2.5 μg/L. The maximum value found was 0.75 μg/L.

4.2.1.3. Sawmill Creek

The major portion of the water in Sawmill Creek has, in the past, originated from the DuPage County Marion Brook Treatment Plant, located upstream of ANL. This facility ceased operation on October 26, 1986, and the flow upstream of ANL decreased by 50%. The net effect is to increase the impact of ANL discharges on the creek quality compared to prior years. A substantial contribution of stream degradation from upstream sources still exists since positive fecal coliform results are frequently found.

Samples were obtained semi-monthly to evaluate the effect of sanitary waste on the creek using sampling bottles designed to minimize aeration. The samples were analyzed for ammonia nitrogen, dissolved oxygen, pH, and temperature. Results are shown in Table 4.30. Results downstream are not significantly different from upstream results, but no major effect is observed. The results for chlorine, sulfate, and total dissolved solids are included for comparison.

Samples were also collected to evaluate the effect of ANL discharges on levels of inorganic constituents in the creek. The results are shown in Table 4.31. Results for copper were above the state limit of 20 μg/L, and the standard was exceeded 69% of the time. This result is about twice the value of that found in 1986 and reflects lower water flow in Sawmill Creek. There is no known source of copper in ANL processes and the constancy of values over the years indicates that the source may be from copper pipes. The elevated levels of iron in the creek result from a variety of natural sources, but a portion may be due to iron from the coal pile as well as from the ion exchange water treatment.

TABLE 4.30

SAWMILL CREEK - EFFECT OF SANITARY WASTE, 1987

CONSTITUENT	LOCATION *	NO. OF SAMPLES	CONCENTRATION (MG/L) AVG.	MIN.	MAX.	AVG. PERCENT OF STANDARD	PERCENT EXCEEDING STATE STANDARD
AMMONIA NITROGEN	7M (UP)	24	0.1 ± 0.0	0.1	0.1	7	0
	7M (DOWN)	24	0.2 ± 0.1	0.1	0.6	14	0
CHLORIDE	7M (UP)	24	148 ± 41	44	443	-	-
	7M (DOWN)	24	482 ± 93	111	968	-	-
DISSOLVED OXYGEN	7M (UP)	24	10.8 ± 1.0	6.7	15.5	-	0
	7M (DOWN)	24	10.5 ± 0.8	8.2	13.6	-	0
DISSOLVED SOLIDS	7M (UP)	24	592 ± 93	336	1110	-	-
	7M (DOWN)	24	1350 ± 190	510	2250	-	-
PH **	7M (UP)	24	-	7.8	8.9	-	0
	7M (DOWN)	24	-	7.6	8.4	-	0
SULFATE ***	7M (UP)	24	92 ± 13	48	140	-	-
	7M (DOWN)	24	141 ± 17	66	201	-	-
TEMPERATURE ***	7M (UP)	24	14.1 ± 3.4	0.3	28.1	-	-
	7M (DOWN)	24	15.3 ± 2.7	3.3	25.1	-	-

* LOCATION 7M (UP) IS 15 M (50 FT) UPSTREAM FROM THE WASTE-WATER OUTFALL. ALL OTHER SAMPLES WERE COLLECTED 60 M (200 FT) DOWNSTREAM FROM THE OUTFALL.

** UNIT

*** DEGREES CENTIGRADE

TABLE 4.31

CHEMICAL CONSTITUENTS IN SAWMILL CREEK LOCATION 7M,* 1987
(CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	3	-	-	< 5	< 0.5	0
BARIUM	12	44 ± 11	20	77	0.9	0
BERYLLIUM	12	0.06 ± 0.02	0.03	0.10	-	-
CADMIUM	12	1.7 ± 0.4	1.0	2.8	3.4	0
CHROMIUM	51	13 ± 2	5	44	-	-
COPPER	51	30 ± 6	8	159	150	69
FLUORIDE	12	325 ± 72	38	444	23	0
IRON	51	916 ± 300	299	6980	92	22
LEAD	12	4 ± 2	1	9	4.1	0
MANGANESE	51	87 ± 20	30	462	8.7	0
MERCURY	51	0.24 ± 0.05	0.06	1.09	47	4
NICKEL	12	26 ± 12	1	50	2.6	0
PH	248	-	7.3	8.8	-	0
SELENIUM	3	-	-	< 5	< 0.5	0
SILVER	51	2.2 ± 0.4	0.2	7.0	44	2
ZINC	12	52 ± 11	32	85	5.2	0

* LOCATION 7M IS 15 M (50 FT) DOWNSTREAM FROM THE WASTE-WATER OUTFALL.

Two samples analyzed for mercury exceeded the limit of 0.5 μg/L. In no case did the value approach the 2.5 μg/L single sample standard. Two samples analyzed for silver exceeded the standard of 5 μg/L and effluent levels (see Table 4.29) indicate ANL could be the source. Average and individual results for barium, beryllium, cadmium, chromium, fluoride, lead, manganese, nickel, and zinc were below the state standards.

4.2.1.3. Des Plaines River

The effect of Sawmill Creek on the levels of mercury in the Des Plaines River was evaluated by collecting samples in the river at Willow Springs (upstream of ANL) and at Lemont (downstream of ANL). The samples were analyzed for total mercury and the results were all less than the detection limit of 0.1 μg/L.

4.2.2. Ground Water

The ground water system was studied by sampling the wells used for the ANL domestic water supply and the monitoring wells in the landfill areas. The 1986 amendments to the Safe Drinking Water Act recognized 83 constituents for which drinking water regulations must be developed by the EPA by June 1989. Of these, 22 are currently implemented as interim primary drinking water regulations. Final maximum contaminant levels (MCL) were established for eight volatile organic compounds in July 1987. Studies were performed by Plant Facilities and Services (PFS) to screen for all constituents.

The sanitary landfill has been studied extensively[4] to determine whether materials disposed of in past years have begun to migrate. Sampling has also been performed to characterize the ground water.

4.2.2.1. Domestic Water

The domestic water is provided by four wells (see Section 1.5), and the locations are seen in Figure 1.1. Samples of raw water from each well and two combined treated water samples were analyzed for volatile organic compounds, pesticides, polychlorinated biphenyls, herbicides, metals, and semi-volatile organics. Quarterly samples are to be analyzed for volatile organic compounds and total dissolved solids. All others will be analyzed for the other constituents annually. Table 4.32 lists the volatile and semi-volatile organics, pesticides, PCBs, and herbicides for which analyses were conducted.

All results for volatile organics were below the required detection limit. One sample from Well #2 in September indicated 2 μg/L of chloroform which is 40% of the required detection limit. A sample collected from the same well in December indicated no detectable chloroform. The September sample from Well #2 also identified methylene chloride and acetone. Acetone was also tentatively identified in Well #3 and the blank.

Samples were collected in December from each of the four wells and from treated water. A sample from Well #3 indicated 1,1,1-trichloroethane at 6 μg/L (detection limit = 5 μg/L) and at 4 μg/L in Well #4. A maximum contaminant level of 200 μg/L has been established for 1,1,1-trichloroethane and the concentration in Well #3 is about 3% of the drinking water level.

Samples were collected on September 4 and 11, 1987, from the four wells and treated water and analyzed for semi-volatile organic compounds. Results for all semi-volatiles were below detection limits except for bis(2-ethylhexyl)-phthalate in all of the wells and in the treated water at levels from 1-5 μg/L. Additionally, Di-n-butylphthalate and butylbenzyl-phthalate were found in Wells #2 and #3 at levels of 1 μg/L. The samples were also analyzed for PCBs, pesticides, and herbicides, and none were found at the detection limits.

Samples from the wells and treated water were analyzed for the inorganic constituents listed in Table 4.33. The results are similar to those obtained in the past and are levels normally found, except for the copper concentration of 83 μg/L in Well #1. However, this is below the value of 1,300 μg/L proposed by the EPA.

TABLE 4.32

Regulated Organic Constituents

Volatile

1,1-Dichloroethene
1,1-Dichloroethane
Trans-1,2-Dichloroethane
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
Styrene
1,3-Dichlorobenzene
1,2-Dichlorobenzene
1,4-Dichlorobenzene
Xylene (total)

Semi-Volatile

2-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethyl Phthalate
Acenaphthylene
Nitrobenzene
Isophorone
Pentachlorophenol
2-6-Dinitrotoluene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
Diethylphthalate
Phenol
bis(-2-Chloroethyl)Ether
2-Chlorophenol
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-Methylphenol
Phenanthrene
Anthracene
Di-n-Butylphthalate
Fluoranthene
Pyrene
Butylbenzylphthalate
3,3'-Dichlorobenzidine
Benz(α)Anthracene
Chrysene
Di-n-Octylphthalate
Benzo(b)Fluoranthene
Benzo(k)Fluoranthene
Benz(α)Pyrene
Indeno(1,2,3-cd)Pyrene
Dibenz(a,h)Anthracene
Benzo(g,h,i)Perylene

TABLE 4.32 (contd)

1,3-Dichlorobenzene	bis(2-Ethylhexyl)Phthalate
1,4-Dichlorobenzene	4-Chlorophenyl-phenylether
Benzyl Alcohol	Fluorene
1,2-Dichlorobenzene	4-Nitroaniline
2-Methylphenol	4,6-Dinotro-2-Methylphenol
bis(2-chloroisopropyl)Ether	N-Nitrosodiphenylamine
4-Methylphenol	4-Bromophenyl-phenylether
N-Nitroso-Di-n-Proplylamine	Hexachlorobenzene
Hexachloroethane	

Pesticides and Herbicides

Alpha BHC	Endrin
Beta BHC	Endrin Ketone
Delta BHC	Endosulfan I
Lindane	Endosulfan II
Methoxychlor	Endosulfan Sulfate
Heptachlor	Alpha Chlordane
Heptachlor Epoxide	Gamma Chlordane
Aldrin	Toxaphene
pp' DDD	Alachlor
pp' DDE	Epichlorohydrin
pp' DDT	Adipates
Dieldrin	2,3,7,8-TCDD (Dioxin)

PCBs

PCBs Total	Aroclor 1248
Aroclor 1016	Aroclor 1254
Aroclor 1221	Aroclor 1260
Aroclor 1242	

TABLE 4.33

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

Inorganic Constituent	Well Number 1	2	3	4	Treated Water
Aluminum	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Antimony	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Arsenic	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Barium	0.094	0.081	0.052	0.050	0.050
Beryllium	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Chromium	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Copper	0.083	< 0.02	< 0.022	< 0.02	< 0.02
Lead	< 0.01	< 0.01	< 0.01	0.12	< 0.004
Manganese	0.035	0.019	0.016	0.014	< 0.01
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Molybdenum	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nickel	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Selenium	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Silver	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Sodium	36.9	24.4	22.4	21.1	21.7
Thallium	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Vanadium	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Zinc	< 0.02	0.027	0.016	0.011	0.011
Chlorides	79	55	49	42	58
Fluorides	0.24	0.29	0.30	0.33	0.3
Sulfates	140	130	100	140	150
Turbidity (NTU)	11.4	6.4	7.2	7.1	1.9

4.2.2.2. Sanitary Landfill

A sanitary landfill for non-radioactive waste is located on the western edge of the ANL site. This landfill operates under Illinois EPA Permit No. 1981-29-OP and is further described in Reference 25. Operation of the ANL landfill began in July 1966. During the period from 1969 through 1978, substantial quantities of liquid organic and inorganic wastes were disposed of on-site by adding them to an open "French drain" located in the northeast sector of the landfill.[2] A log of materials disposed of is available.

In 1979, an investigation was begun to determine the subsoil characteristics of the site and to place ground-water monitoring wells at appropriate points in and around the landfill (see Figure 4.5). Because the topography suggested a southerly water flow, Wells #1 and #5 were located outside the landfill and were meant to measure water entering and leaving the landfill. Wells #2, #3, and #4 were placed at the perimeter of the landfill. In April 1980, a more comprehensive study was initiated[25] to develop information required for the Illinois State operating permit. Three additional test wells were placed at the perimeter of the landfill at previously untested locations. Well #6 was placed in the east section to sample any water flowing out of the landfill in the south easterly direction. Wells #7a and #7b were located along the south side and were nested. These were installed to measure vertical water movement as well as to provide monitoring of water from two depths.

The permit study established several important characteristics. There is a perched water condition at depths varying from about 6 m (20 ft) on the north to about 7.6 m (25 ft) on the south. This is caused by the relatively impermeable condition of the underlying clay, which restricts downward water flow. There are several granular seams in the soil above the clay that permit lateral flow. Additionally, regional ground-water flow patterns confirm that the flow is generally southerly.

The above-stated facts indicate that water in the test wells is from surface infiltration and that it moves horizontally approximately 7.6 m (25 ft) below the surface. Penetration to the dolomite aquifer used for water

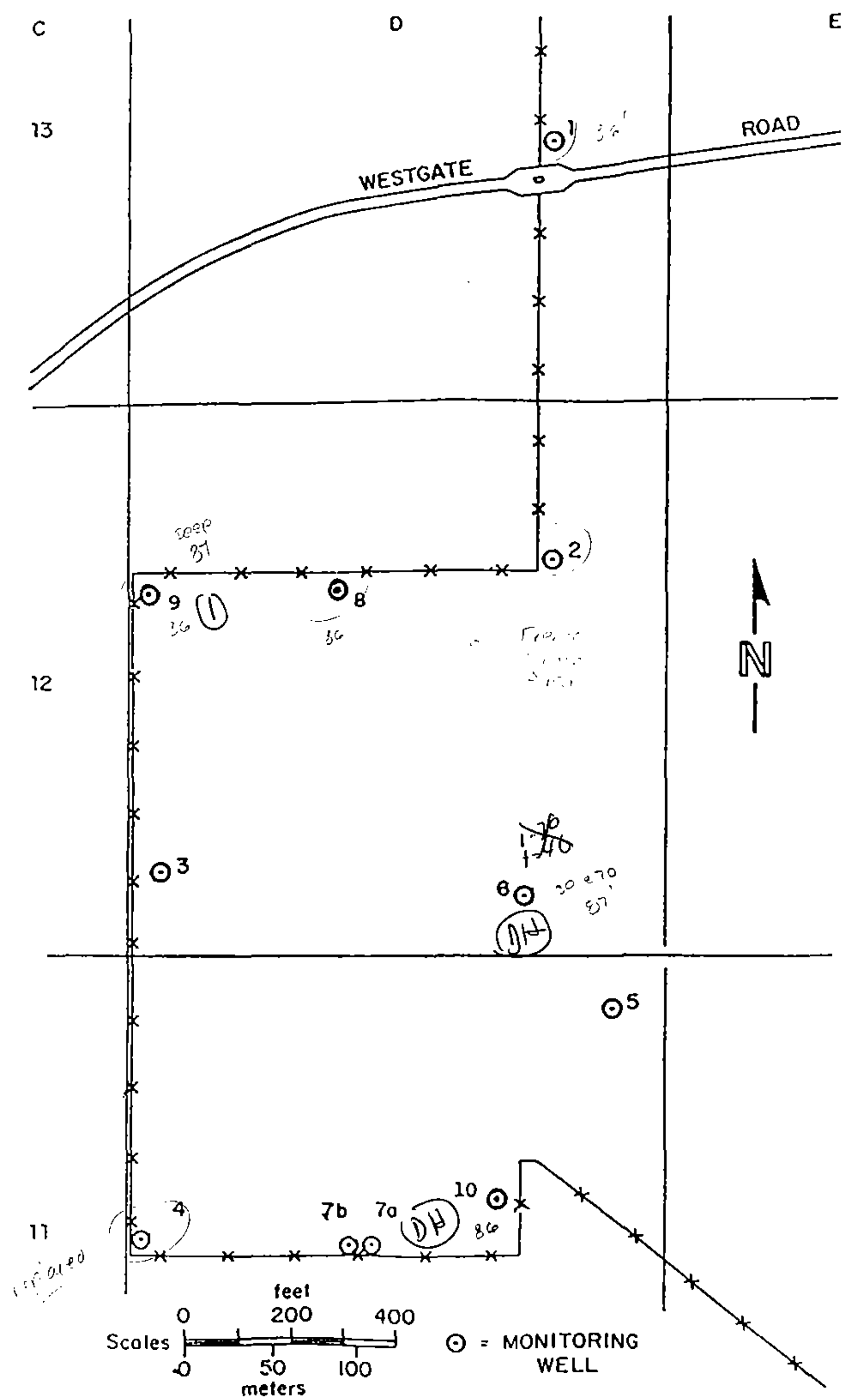

Fig. 4.5 Monitoring Well Locations for Landfill

supplies, 15-30 m (50-100 ft) below the surface, is very slow. Indeed, core samples obtained at 11-12 m (35-40 ft) below the surface were only moist, indicating that the aquifer is below this level and that little downward movement is occurring. If movement was occurring, this stratum would be nearly saturated. In September 1986, six new wells were constructed. Wells #1, #2, and #4 were suspected of being poorly sealed and replacement wells were drilled within five feet of the originals. Additional wells, #8, #9, and #10 (see Fig. 4.5) were constructed to improve the peripheral coverage. In November 1987, additional wells were constructed at #9 (70 ft) and at #6 (30 ft and 70 ft).

The wells have been studied from 1979 until the present to determine consistency of water levels, recharge rates, and chemical characteristics. The wells constructed in November have been sampled, but results are not yet available.

The water levels obtained in 1987 are very similar to previous results.[4] Sampling of these wells was changed in 1987 to follow the protocol in the Technical Enforcement Guidance Document[26] of the Resource, Conservation and Recovery Act. As before, the wells were emptied using a small diameter submersible pump. After recovery, which could take up to a week for some wells, samples were removed using a one liter Teflon bailer attached to a monofilament line. Cleaning between sampling and proper preservation of the sample was performed at the sampling site.

As previously mentioned, an inventory of materials disposed of in the landfill exists. The organic component is comprised primarily of volatile organic constituents and polychlorinated biphenyls.

All of the wells were sampled in the spring and analyzed for volatile organic compounds using purge and trap procedures capable of detecting these compounds at the required limits.[27] In the late summer, six wells were selected based on the highest tritium levels found (see Table 4.10), since it was deemed probable that tritium was moving from the landfill and that this could serve as an indicator of flow. Finally, samples were collected in January 1988 for PCB analysis as well as volatile organic analysis. The same selection criteria were used. In all of these measurements, no volatile organic compounds or PCBs were present above the detection limits.

All of the above landfill samples were also analyzed for inorganic constituents. Results for inorganic analyses were similar to previous years.[4] Well #1 was high in dissolved solids and chloride. This is probably related to the use of salt on nearby roads. Well #2 had a high pH (11.4) and Well #3 had elevated iron and dissolved solids, but arsenic was not detected. In the past several years, arsenic was detected in Well #3. Well #6 had high levels of iron and manganese as well as high levels of chloride. Well #8 had elevated levels of chloride and dissolved solids. Well #9 had high levels of chloride, iron, and manganese. Wells #4, #5, #7a, and #10 showed results within the expected ranges.

5. UNUSUAL OCCURRENCE

5.1. Oil Spill

On December 14, 1987, at about 4:45 p.m., a fiberglass diesel fuel tank for the Building 201 emergency generator was damaged during core drilling. The gash in the west end of the 550-gallon tank started about five inches below the top and was six inches wide and 20 inches long.

Upon noticing an odor of diesel fuel and observing fiberglass shards on the split-spoon sampler, the contractor representative went immediately to Building 214 to report it to his Facilities Engineering contact. The hole was plugged with styrofoam disks, and stiff plastic sheet material was placed over the hole to avoid water intrusion.

On Tuesday morning, December 15, 1987, the incident was report to the ANL Environmental Coordinator who notified DOE-CH and the Illinois Emergency Dispatcher's office. Petrochem Corporation was contacted for assistance and pumped out about 125 gallons of the remaining diesel fuel from the tank. From records on tank filling, the running time and rate of fuel consumption of the emergency generator, and the amount of remaining fuel pumped out of the tank, it was calculated that about 200 gallons were spilled.

The ANL Grounds Department dug out the tank on December 17, 1987, and contaminated pea-gravel and sand from the hole were placed in 55-gallon drums. Contaminated water was pumped out of the hole into 55-gallon drums. Oil Dri absorbent was poured into the hole and then dug out and placed into 55-gallon drums. All contaminated materials were delivered to Waste Management Operations for proper disposal.

The Building 201 footing drains connect to a sump within the mechanical equipment room that discharges into the Building 201 lined reflecting pond. Oil that entered this sump was absorbed in oil-absorbent pillows. A visible amount of oil was discharged into the pond. An oil-absorbent boom was installed across the outfall of the pond as a precaution, even though there was no discharge flow.

The Building 201 underground chilled-water tanks to the south of the incident location have a manhole drainage system that discharges to the sanitary sewer system. This manhole collected oil which was bailed or pumped out, or collected on absorbent pillows. Samples were collected from the open drainage course east of Building 201 at location 12I and analysis indicated no fuel oil was detected above the detection limit of 2.5 mg/L.

A letter was received from the IEPA listing a number of generic actions to be taken. ANL replied to this letter with a description of actions taken and an invitation to have an IEPA inspection of the incident location. Studies of the impact of this oil spill on the environmental are continuing.

6. QUALITY ASSURANCE

Quality Assurance Plans are in place for both the radiological (H 0030-0003-QA-00) and non-radiological analysis (H 0030-0002-QA-00). Both documents were prepared in accordance with ANSI/ASMC NQA-1 and meet the requirements of ANL QA documents.[28] It is anticipated that minor revisions in the above plans will be necessary to conform to the recently released ANL-EAST QUALITY ASSURANCE MANUAL.[29] The plans discuss responsibilities and auditability. Both documents are supplemented by operating manuals.

6.1. Radiochemical Analysis and Radioactivity Measurements

All nuclear instrumentation is calibrated with standard sources obtained from the National Bureau of Standards (NBS), if possible. If NBS standards were not available for particular nuclides, NBS traceable 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. In addition, standard and intercomparison samples distributed by the Quality Assurance Branch of the U. S. Environmental Protection Agency (EPA-QA) are analyzed regularly. Results of our participation in the EPA-QA program during 1987 are given in Table 6.1. In the table, the comparison is made between the EPA-QA value, which is the quantity added to the sample by that laboratory, and the value obtained in our laboratory. Certain information may assist in judging the quality of the results, including the fact that typical uncertainties for our analyses are 2% to 50% depending on the concentration and the nuclide, and the uncertainties in the EPA-QA results are 2% to 5% (our estimate).

In addition, participation continued in the DOE Environmental Measurements Laboratory Quality Assurance Program (DOE-EML-QAP), a semi-annual distribution of four or five different sample matrices containing various combinations of radionuclides that are analyzed. Results for 1987 are summarized in Table 6.2. In the table, the comparison is made between the EML value, which is the result of replicate determinations by that laboratory,

TABLE 6.1

Summary of EPA-QA Samples, 1987

Type of Sample	Analysis	Number Analyzed	Average Difference from Added
Air Filter	Total Alpha	2	27%
	Total Beta	2	5%
	Strontium-90	2	11%
	Cesium-137	2	30%
Milk	Potassium-40	1	2%
	Strontium-89	1	5%
	Strontium-90	1	10%
	Iodine-131	2	7%
	Cesium-137	1	1%
Water	Total Alpha	1	45%
	Total Beta	1	14%
	Hydrogen-3	3	3%
	Chromium-51	2	23%
	Cobalt-60	4	2%
	Zinc-65	3	1%
	Strontium-89	3	7%
	Strontium-90	3	4%
	Ruthenium-106	3	9%
	Iodine-131	3	6%
	Cesium-134	4	9%
	Cesium-137	4	5%
	Radium-226	2	6%
	Radium-228	2	10%
	Total Uranium	3	8%
	Plutonium-239	2	4%

TABLE 6.2

Summary of DOE-EML-QAP Samples, 1987

	Difference From EML Value				
	Air Filters	Water	Soil	Tissue	Vegetation
Hydrogen-3	-	10% (2)	-	-	-
Beryllium-7	5% (2)	-	-	-	-
Potassium-40	-	-	10% (2)	35% (2)	28% (2)
Manganese-54	2% (1)	8% (2)	-	-	-
Cobalt-57	-	1% (1)	-	-	-
Cobalt-60	3% (1)	4% (2)	-	-	19% (1)
Strontium-89	4% (1)	-	-	-	-
Strontium-90	8% (2)	7% (2)	19% (2)	-	15% (2)
Zirconium-95	4% (1)	-	-	-	-
Ruthenium-106	39% (1)	-	-	-	-
Antimony-125	41% (1)	-	-	-	-
Cesium-137	3% (2)	7% (2)	20% (2)	11% (1)	14% (2)
Cerium-144	1% (1)	-	-	-	-
Radium-226	-	-	14% (2)	16% (2)	12% (1)
Uranium-234	11% (2)	17% (2)	1% (1)	-	-
Uranium-238	13% (2)	12% (2)	18% (1)	-	-
Plutonium-239	7% (2)	46% (2)	14% (2)	-	4% (1)
Americium-241	16% (2)	18% (2)	-	-	22% (1)

Note: The figure in parentheses is the number of samples.

and the value obtained in our laboratory. Information that will assist in judging the quality of the results includes the fact that typical uncertainties for our analyses are 2% to 50% and that the uncertainties in the EML results are 1% to 30% (depending on the nuclide and the amount present). For most analyses for which the differences are large (> 20%), the concentrations were quite low and the differences were within the measurement uncertainties.

6.2. Chemical Analysis

The documentation for non-radiological operations is contained in an INDUSTRIAL HYGIENE OPERATING MANUAL (IHOM) and is composed of a sampling and analysis plan, as well as of individual analytical and collection procedures. All samples for NPDES and ground water are collected and analyzed in accordance with EPA regulations and are found in EPA-600/4-84-017[24] and SW-846.[27]

Standard Reference Materials (SRM) traceable to the NBS exist for most inorganic analyses (see Table 6.3). All standards are compared annually to the NBS values.

Detection limits are determined using techniques listed in SW-846.[27] In general, it is the measure of the variability of a standard material measurement at 5-10 times the instrumental detection limit as measured over an extended time period.

Recovery of inorganic metals, as determined by "spiking" unknown solutions, must be in the range of 75% to 125%. The precision, as determined by analysis of duplicate samples, must be within 20%. These measurements must be made on at least 10% of the samples.

Comparison samples for organic constituents are available from the EPA, and many are used in this work. An average value, with given confidence limits, is provided.

TABLE 6.3

NBS-SRM Used for Inorganic Analysis

NBS-SRM	Contents
3133	Mercury
3105	Beryllium
3104	Barium
3183	Fluoride
3182	Chloride
3181	Sulfate
2124	Cobalt Copper Iron Nickel
2125	Boron Chromium Manganese Molybdenum
2121	Cadmium Lead Silver Zinc

The requirement[27] for organic analyses is dependent upon the compounds studied. Requirements include analysis of a matrix spike, specified internal standards, recovery, and relative retention times are stipulated.

The laboratory participates in the National Institute of Occupational Safety and Health (NIOSH) proficiency testing program which requires analyses of many materials of environmental interest. Results are in agreement with the NIOSH values and are listed in Table 6.4. Our laboratory also participates in the U. S. Environmental Protection Agency Discharge Monitoring Report Quality Assurance Program (EPA-DMR-QAP). Results are rated acceptable by the EPA and appear in Table 6.5.

TABLE 6.4

Summary of NIOSH Program Samples, 1987

Constituent	Average Difference From Reference Value
Cadmium	1.7% (16)
Lead	2.6% (16)
Zinc	6.9% (16)
Benzene	2.7% (4)
Carbon Tetrachloride	7.5% (8)
Cellosolve Acetate	3.9% (4)
Chloroform	7.6% (4)
Dichloroethane	6.1% (8)
Toluene	2.6% (8)
Trichloroethylene	4.3% (4)
O-xylene	3.2% (8)

Note: The figures in parentheses are the number of samples analyzed.

TABLE 6.5

Summary of EPA-DMR-QAP Non-Radiological Samples, 1987

Constituent	Average Difference From Reference Value
Mercury	+17%
Zinc	0
pH	0
Total Suspended Solids	-13%
Oil and Grease	+2%
Chemical Oxygen Demand	-12%

7. APPENDIX

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