Distribution Category:
Health and Safety (UC-11)

ANL-86-13

ANL--86-13

DE86 009453

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

1985 ANNUAL SITE ENVIRONMENTAL REPORT FOR ARGONNE NATIONAL LABORATORY

by

N. W. Golchert, T. L. Duffy, and J. Sedlet

Occupational Health and Safety Department

Laboratory Work Performed by

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

March 1986

Approved:
D. P. O'Neil
Department Manager

Preceding Report in This Series: ANL-85-17

TABLE OF CONTENTS

TABLE OF CONTENTS

Page

LIST OF TABLES

No. Title Page

LIST OF TABLES

LIST OF FIGURES

1985 ANNUAL SITE ENVIRONMENTAL REPORT FOR ARGONNE NATIONAL LABORATORY

by

N. W. Golchert, T. L. Duffy, and J. Sedlet

ABSTRACT

The results of the environmental monitoring program at Argonne National Laboratory (ANL) for 1985 are presented and discussed. To evaluate the effect of Argonne operations on the environment, measurements were made for a variety of radionuclides in air, surface water, ground water, soil, grass, bottom sediment, and milk; for a variety of chemical constituents in surface water, ground water, and Argonne effluent water; and of the environmental penetrating radiation dose. Sample collections and measurements were made on the site, at the site boundary, and off the Argonne site for comparison purposes. The potential radiation dose to off-site population groups is also estimated. The results of the program are interpreted in terms of the sources and origin of the radioactive and chemical substances (natural, fallout, Argonne, and other) and are compared with applicable environmental quality standards. A new U. S. Department of Energy (DOE) dose calculation methodology based on recent International Commission on Radiological Protection (ICRP) recommendations was required and used for the first time in this report. The average concentrations and total amounts of radioactive and chemical pollutants released by Argonne to the environment were all below appropriate standards.

I. INTRODUCTION

A. General

This report is prepared to provide DOE and the public with information on the levels of radioactive and chemical pollutants in the environment of

Argonne and on the amounts, if any, added to the environment as a result of Argonne operations. The report follows the guidelines given in DOE Draft Order 5484.1A, Chapter III.[1] The Laboratory conducts a continuous environmental monitoring program on and near the Argonne site with the primary purpose of determining the magnitude, origin, and identity of radioactive or chemical substances in the environment. Of special interest is the detection of any such materials released to the environment by Argonne. One important function of the program is to verify the adequacy of Argonne's pollution controls.

Argonne 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. Some of the energy-related research projects conducted during 1985 were 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), 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, and operation of the National Battery Test Laboratory. 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 acidic precipitation 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 Laboratory are a 200 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 60-inch cyclotron; several other charged particle 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 heavy metal target to produce the neutrons; cobalt-60 irradiation sources; chemical and metallurgical plutonium laboratories; and several hot cells and laboratories designed for work with multicurie quantities of the actinide elements and with irradiated reactor fuel elements. Two experiments, initiated in 1984, were continued in these facilities in 1985 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 not in operation during 1985. The CP-5 facility is awaiting decontamination and decommissioning (D&D), while The D&D work has been completed at the ZGS. The DOE New Brunswick Laboratory, a safeguards plutonium and uranium measurements and analytical chemistry laboratory is located on the ANL site. The principal non-nuclear activities at Argonne that may produce a measurable impact on the environment are a coalfired boiler (No. 5) and the closed-loop heat exchanger studies for waste heat recovery. The boiler is designed to burn high sulfur (3.5%) Illinois coal to produce export steam for Laboratory use. It is equipped with a slaked lime spray scrubber and bag collector to reduce sulfur dioxide and particulate emissions. The heat recovery studies use 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 is the accidental release due to equipment malfunction.

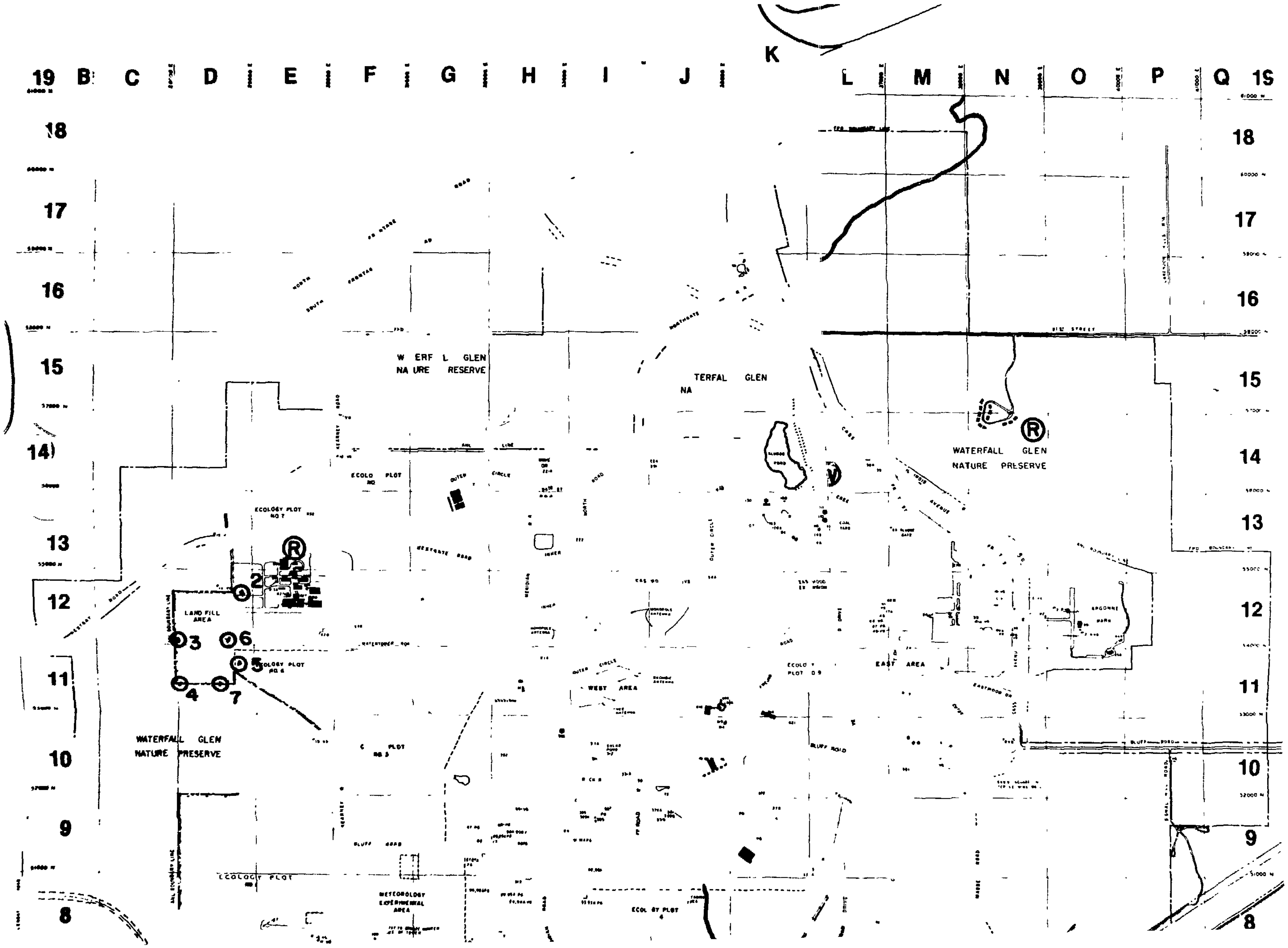
B. Description of Site

Argonne National Laboratory (Illinois site) occupies the central 688 hectares (1,700 acres) of a 1514-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 in the Des Plaines River Valley, south of Interstate Highway 55 and west of Illinois Highway 83. Figures 1 and 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 Argonne 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 the Laboratory 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 comprise 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) 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


19
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
18
17
16
15
14
13
12
11
10
9
8
W ERF L GLEN
NA URE RESERVE
TERFAL GLEN
NA
WATERFALL GLEN
NATURE PRESERVE
R
ECOLOGY PLOT
NO 7
LAND FILL
AREA
1
2
3
4
5
6
7
ECOLOGY PLOT
NO 6
WATERFALL GLEN
NATURE PRESERVE
ECOLOGY PLOT
METEOROLOGY
EXPERIMENTAL
AREA
WEST AREA
EAST AREA
ECOLO Y
PLOT O 9
ECOL GY PLOT
OUTER CIRCLE
WESTGATE ROAD
BLUFF ROAD
91ST STREET
ARGONNE
PARK
NORTH FRONTAGE
SOUTH FRONTAGE
KEARNEY ROAD
MERIDIAN
ECOLO PLOT
NO
C PLOT
NO 3
OUTER CIRCLE
EASTWOOD DR
BLUFF ROAD
RAIL LINE
FPD BOUNDARY LINE
ANL BOUNDARY LINE

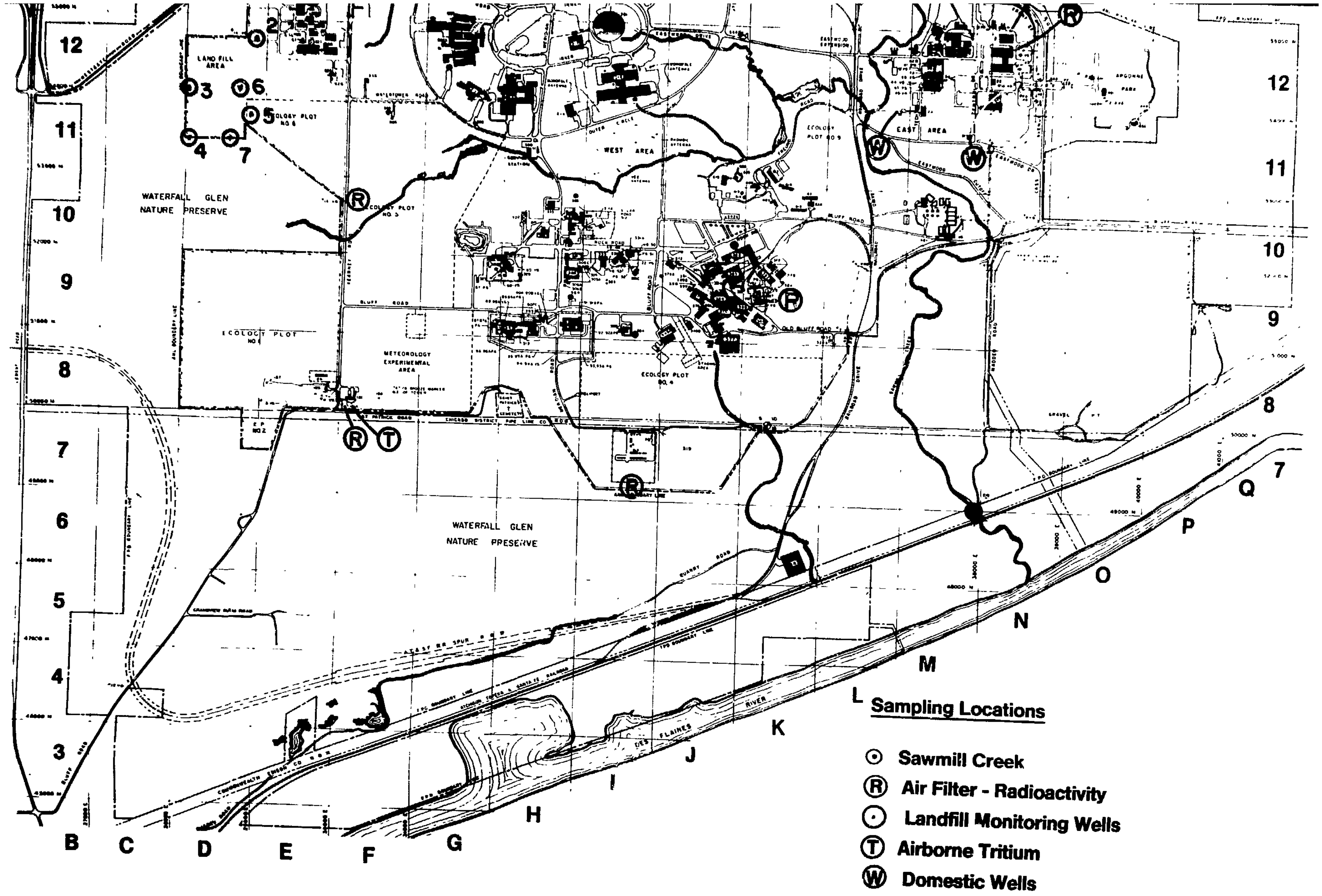


Fig. 1. Sampling Locations at Argonne National Laboratory

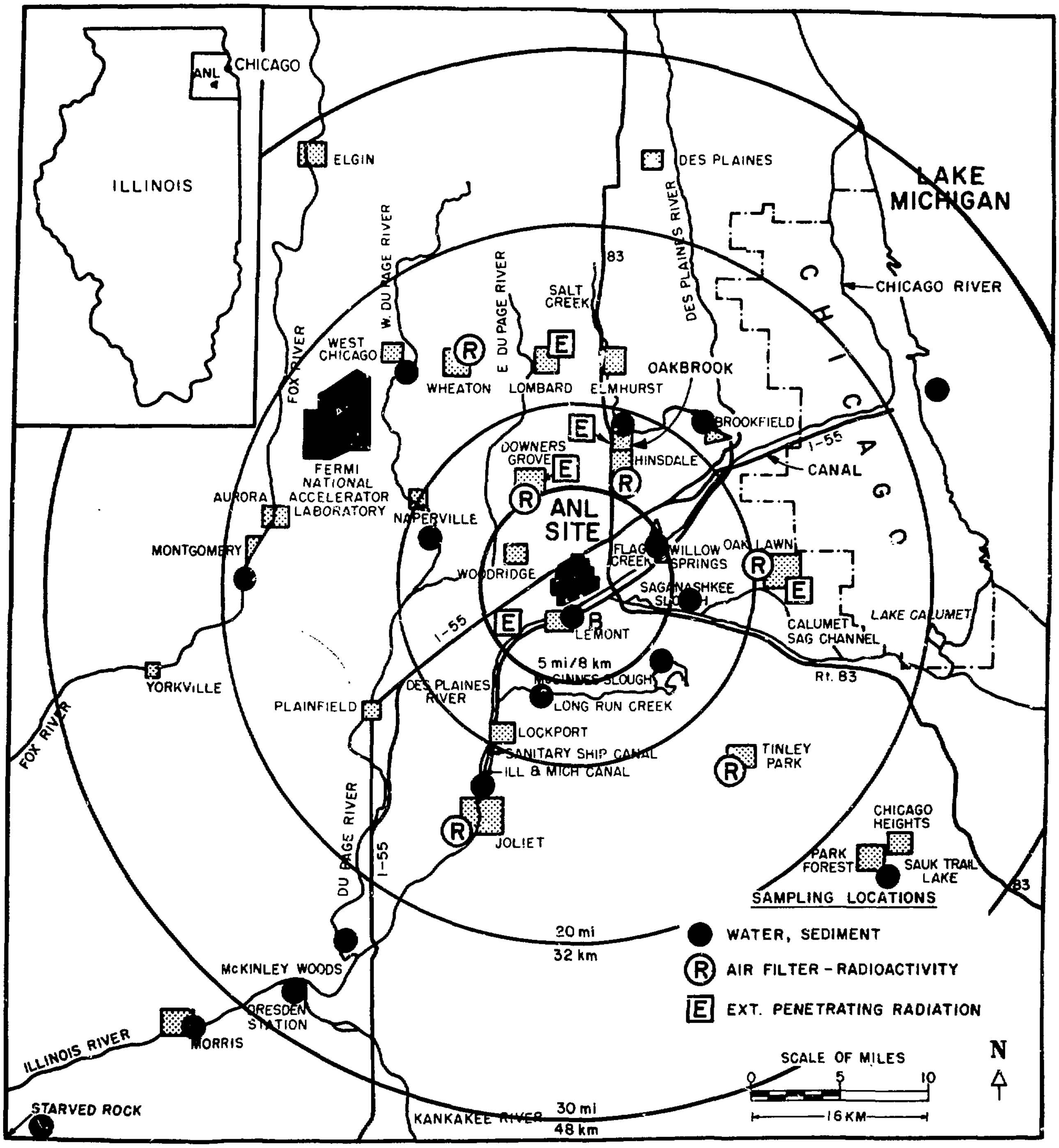


Fig. 2. Sampling Locations Near Argonne National Laboratory

Atchison, Topeka, and Santa Fe Railroad have rights-of-way. Additional information about the site is given in the Argonne Environmental Assessment.[2]

C. Population

The area around Argonne 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. The population distribution was obtained by modifying a distribution for 1981 prepared by Urban Decision Systems, Inc. and 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.

D. 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. Because on-site meteorological data are no longer available in suitable form, measurements taken in 1985 at the nearest U. S. Weather Bureau station, O'Hare Airport, 31 km (18 mi) north of Argonne, were used. The 1985 average monthly and annual wind roses are shown in Figure 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

TABLE 1

Incremental Population Data in the Vicinity of ANL, 1981

						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
<u>Direction</u>										
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

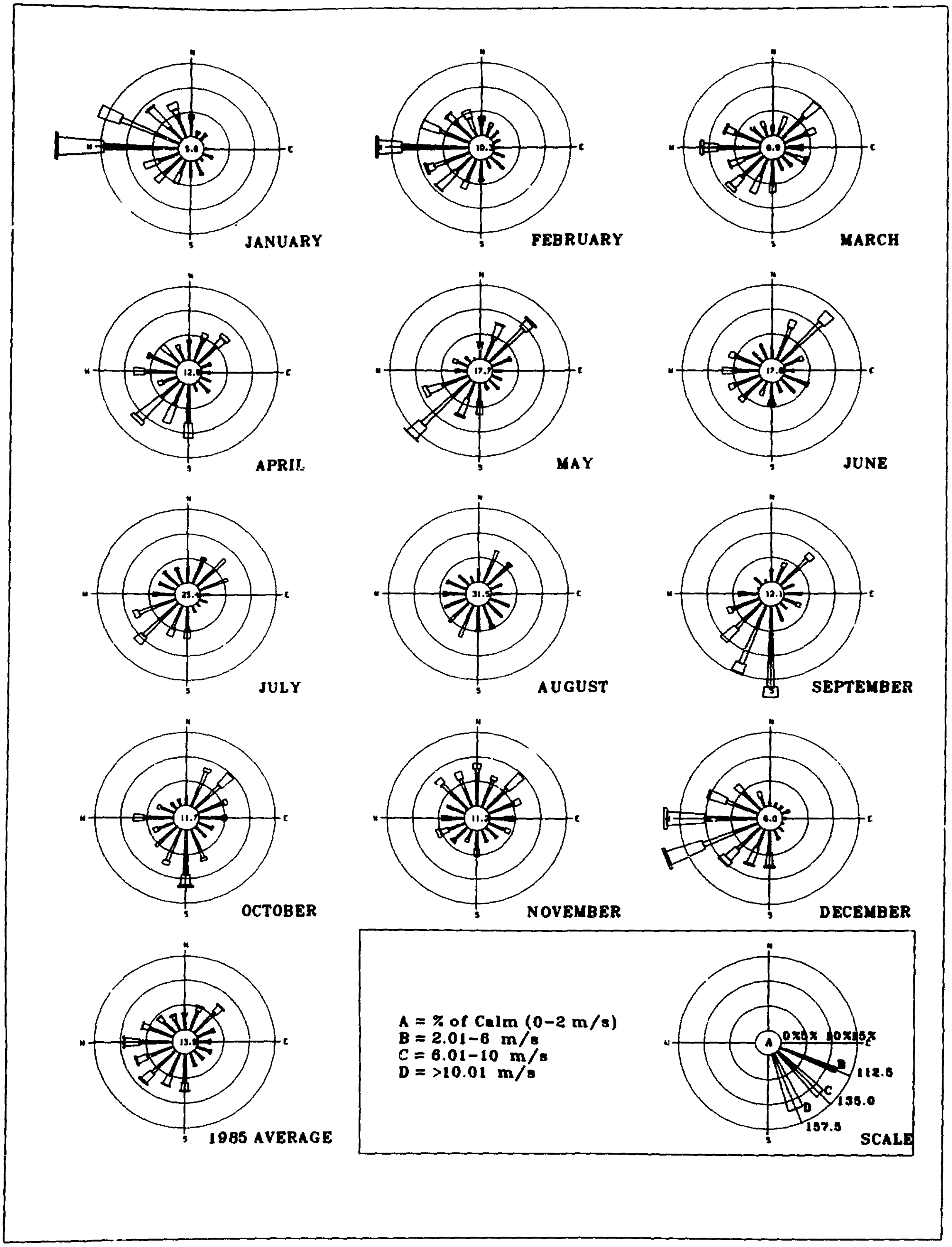


Fig. 3. Monthly and Annual Wind Roses Near Agonne National Laboratory, 1985

number in the center represents the percent of observations 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 sufficiently variable that monitoring for airborne releases must be carried out in all directions from the site. For example, the dominant wind direction in January is west while in June it is northeast. The annual average wind rose for 1985 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 1985 are shown in Table 2. The monthly precipitation data for 1985 was marked by large differences from the average. For example, February, March, October, and November were significantly above the average, while April, June, September, and December were well below normal. The annual total was about 15% higher than the average. The temperatures were about average, except for colder than normal January, February, June, and December.

E. Geohydrology

The geology of the Laboratory area consists of about 30 m (100 ft) of glacial till overlying dolomite bedrock. The bedrock is the Niagaran and Alexandrian dolomite of 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 the Laboratory. The upper aquifer is the Niagaran-Alexandrian dolomite, which is about 60 m (200 ft) thick in the Laboratory 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 the Galesville sandstone, which lies between 150 and 450 m (490 and 1,500 ft) below the surface. The Maquoketa shale separates the upper dolomite aquifer from the underlying

TABLE 2

ANL Weather Summary, 1985*

	Precipitation (cm)		Temperature (°C)	
Month	Amount	Average	Monthly Average	Average
January	3.76	4.06	-9.8	-5.9
February	8.79	3.33	-6.4	-3.3
March	12.01	6.58	4.1	2.2
April	3.76	9.30	11.4	9.3
May	7.09	8.00	15.7	15.1
June	5.00	10.36	17.6	20.3
July	9.52	9.22	21.9	22.8
August	9.91	8.97	20.7	22.2
September	4.62	8.51	18.6	18.2
October	12.65	5.79	11.4	11.9
November	20.88	5.23	3.2	4.3
December	3.78	5.33	-8.3	-2.4
Total	101.78	84.68		

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

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

The four domestic water wells now in use 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 Laboratory pumping, dropping about 3.7 m (12 ft) between 1960 and 1980. The aquifer appears to be adequate for future Laboratory 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.

F. Water and Land Use

The principal stream that drains the site is Sawmill Creek. It carries effluent water continuously from a sewage treatment plant (Marion Brook Treatment Plant) located a few kilometers north of the site. The plant has an operating capacity of about 11.4 megaliters (3 million gallons) per day. In addition, the residential development in the area has resulted in the collection and channeling of additional runoff water into the Creek. Treated sanitary and laboratory waste water from Argonne are combined and discharged into Sawmill Creek at location 7M in Figure 1. This effluent averaged 3.0 megaliters (0.81 million gallons) per day, while the water flow in the Creek upstream of the waste-water outfall averaged about 38 megaliters (10 million gallons) per day during 1985. The combined Argonne effluent consisted of 50% laboratory waste water and 50% sanitary waste water.

Sawmill Creek and the Des Plaines River above Joliet, about 21 km (13 mi) southwest of Argonne, receive very little recreational or industrial use. A few people fish in these waters downstream from Argonne and some duck hunting takes place on the Des Plaines River. Water from the Chicago Sanitary and Ship Canal is used by Argonne 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 Argonne 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 Argonne. 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 use of water for drinking is an indirect one at Alton, on the Mississippi River about 710 km (370 mi) downstream from Argonne, where water is used to replenish ground water supplies by infiltration. In the vicinity of the Laboratory, only subsurface water (from both shallow and deep aquifers) and Lake Michigan water are used for drinking purposes.

The principal recreational area near Argonne is Waterfall Glen Forest Preserve, which surrounds the site as described in Section I.B. and is shown in Figure 1. The area is available for hiking, skiing, and equestrian sports. Sawmill Creek flows through the south 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 Argonne and the Des Plaines River. The preserves include the two sloughs shown in Figure 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 Argonne site (Location 12-O in Figure 1) is for the use of Argonne and Department of Energy employees only.

II. 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 Argonne operations. Included in this report are the results of measurements obtained in 1985 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 dose. The previous report in this series is ANL-85-17.[4]

The major airborne radionuclides released from the Laboratory were hydrogen-3, carbon-11, argon-41, krypton-85, and radon-220, all as gases. The maximum dose from these nuclides at the site boundary was 0.38 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 0.036 mrem/y, which is 0.036% of the DOE 100 mrem/y limit for prolonged exposures.* These releases constitute an insignificant addition to the dose received from the natural background radiation, which is about 76 mrem/y. The total 80-km population dose from these radionuclides was less than 3.1 man-rem for 1985, compared to approximately 6.0×10^5 man-rem from the natural background radiation.

Particulate radioactivity (total alpha and beta, fission and activation products, plutonium, thorium, and uranium) was measured in air-filter samples collected continuously at the site perimeter and off the site. No activity attributable to Argonne operations could be detected. These samples contained only radionuclides from natural sources and nuclear test detonations. Almost all of the radioactive materials injected into the air

---

*The hazard due to a given concentration of a 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. The method of calculating doses, and the dose limits are discussed in Section III.A. and III.A.7., and described in References 5 and 7.

by previous atmospheric nuclear tests have either decayed or have been deposited on the ground.

Argonne waste water is discharged into Sawmill Creek, and this stream was sampled above and below the site to evaluate the effect of Argonne operations on its radioactive content. The nuclides (for which analyses were made) added to the Creek in the waste water, and the ingestion dose from their net average Creek concentrations, were hydrogen-3, 0.022 mrem/y; strontium-90, 0.001 mrem/y; neptunium-237, 0.0010 mrem/y; plutonium-239,240, 0.0008 mrem/y; and americium-241, 0.0040 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 latter two streams were similar to those in other streams in the area, and the activity added to the Creek by Argonne 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 0.8×10^{-3} $\mu Ci/m^2$ at the site perimeter and 0.7×10^{-3} $\mu Ci/m^2$ off the site. The corresponding plutonium-238 averages were 0.03×10^{-3} $\mu Ci/m^2$ at both locations. The plutonium content of grass was similar to that found in previous years and was about a factor of 10^4 less 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 1×10^{-9} $\mu Ci/g$ to 20×10^{-9} $\mu Ci/g$ of plutonium-239,240, a range found in previous years to be normal for fallout plutonium in such materials. Concentrations five times normal were found in the sediment just below the Laboratory waste water outfall as a result of their presence in Argonne waste water, but they decreased to normal, or fallout, levels 50 meters downstream of the outfall.

Milk from a dairy farm near the Laboratory was analyzed for hydrogen-3 and strontium-90. Hydrogen-3 concentrations averaged < 100 x 10^{-9} µCi/mL. The strontium-90 concentration of 2.9 x 10^{-9} µCi/mL was similar to the 1984 result. These radionuclides resulted from nuclear test detonations, and are not related to Argonne operations.

Measurements of penetrating radiation were made at several locations at the site boundary and off the site. The off-site results averaged 76 ± 5 mrem/y, which is in the normal range for the area. At two site boundary locations, above-normal readings were recorded that were attributable to Argonne operations. At the south fence (grid 7I in Figure 1), the dose rate averaged about 865 mrem/y above normal 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 79 ± 4 mrem/y, which is within the normal range. Along the north side of the site, the dose at the fence at location 14I was 24 mrem/y above normal due to radiation from cobalt-60 sources in Building 202. Since all of these locations are unoccupied, 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 0.20 mrem/y, which is 0.2% 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 Argonne 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.

All the results obtained for the ANL waste water were below the State standards except for mercury, which exceeded the standard in 12% of the samples measured. The average mercury concentration was 60% of the State effluent standard. Efforts are continuing to lower these concentrations by *additional treatment of batches of waste water that contain elevated levels of mercury.*

The results for the NPDES permit effluent locations were in general compliance with the exception of the pH at Location 009 (Fig. 6). This remains above the limit, due to the basicity of water from the water softening process. This location is expected to be in compliance when this softening process is replaced in 1986. In any event, this effluent has no measurable effect on the receiving stream.

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 61% and 55% of the State standards, and individual values exceeded the standards 4% and 10% of the time, respectively. Copper and iron concentrations increased in the stream as a result of rainfall runoff. Elevated levels of these elements in the Creek are not due to their presence in waste water since the waste water is diluted by the Creek resulting in levels below the State stream standard. Mercury concentrations did not exceed the State standard, and the average concentration was 13% of the standard. The concentration of mercury in the Des Plaines River was not affected by the amounts in Argonne effluent water.

Samples from monitoring wells in the ANL sanitary landfill area were examined for selected inorganic and organic constituents. Levels of manganese were elevated in two of the wells, the pH in a third well, and arsenic in another. Similar results were obtained in the past, and there is no indication of migration since the concentrations have not changed with time. Organic compounds (ethylbenzene, benzene, perchloroethylene, toluene, trichloroethylene, and xylene) were not detected.

The average concentrations and total amounts of radioactive and chemical pollutants released by Argonne to the environment did not constitute a health hazard. Any individual discharges from the Laboratory that exceeded acceptable standards were temporary, and when they did occur, investigations were undertaken to identify the source and reduce their discharge.

III. MONITORING RESULTS

A. 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 results of radioactivity measurements are expressed in this report in terms of microcuries per milliliter (μCi/mL) for water, air, and milk and microcuries per gram (g) and/or square meter (m^2) for soil, bottom sediment, and vegetation. When a nuclide was not detected, the result is given as less than (<) the minimum amount detectable (detection limit) by the analytical method used. 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 picture of the average concentration at locations where the concentrations not only varied greatly, but were at times not detectable. Penetrating radiation measurements are reported in units of millirem (mrem) per year and population dose in man-rem.

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 interim guidance for dose equivalent calculations for members of the public based on ICRP-26 and ICRP-30.[5,7] 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.[6] 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 interim 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. 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 interim guidance.[7] *The numerical values of the EFF.D.E.s used in this report are given in Section III.A.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.*

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 and 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 Argonne site perimeter and at five locations off the site. 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 Argonne 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 3. 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. The gamma-ray detector is a shielded germanium diode calibrated for each gamma-ray emitting nuclide measured.

The alpha and beta activities, principally due to naturally occurring nuclides, averaged the same as the past several years and were in their normal range. The average perimeter beta activity for the year, 2.4×10^{-14} µCi/mL, was identical to 1982, 1983, and 1984 averages. The fission products from previous nuclear tests found and reported in the past were not detected in 1985 due to decay and/or deposition. The most recent atmospheric nuclear test took place on October 16, 1980, by the People's Republic of China. Beryllium-7 exhibits a spring increase in concentration, indicating its stratospheric origin. The lead-210 in air is due to the radioactive decay of gaseous radon-222 in air.

Samples for radiochemical analyses were collected at perimeter locations 12N and 7I (Figure 1) and off the site in Downers Grove (Figure 2). Collections were made on polystyrene filters. The total air volume filtered for the monthly samples was about 25,000 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.

TABLE 3

TOTAL ALPHA AND BETA ACTIVITIES IN AIR-FILTER SAMPLES, 1985*
(CONCENTRATIONS IN 1E-15 MICROCURIES/ML)

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	32	2.2	0.9	2.9	24	14	38
	OFF-SITE	20	1.7	1.0	2.8	20	13	30
FEBRUARY	PERIMETER	32	2.0	0.4	3.2	27	11	42
	OFF-SITE	18	1.8	0.5	4.9	24	8	60
MARCH	PERIMETER	38	1.8	0.8	5.8	18	10	34
	OFF-SITE	20	1.9	0.6	4.2	17	8	30
APRIL	PERIMETER	28	1.3	0.2	3.6	18	10	26
	OFF-SITE	23	2.2	0.4	4.4	22	5	64
MAY	PERIMETER	33	2.2	0.2	6.5	19	9	33
	OFF-SITE	18	2.2	0.7	4.9	17	10	26
JUNE	PERIMETER	29	2.6	1.4	6.0	19	5	30
	OFF-SITE	20	2.1	0.7	5.8	18	12	24
JULY	PERIMETER	27	2.8	0.8	9.4	24	13	34
	OFF-SITE	23	2.3	1.2	7.3	21	7	35
AUGUST	PERIMETER	30	2.2	0.9	3.8	24	8	35
	OFF-SITE	19	1.8	1.1	2.9	23	14	34
SEPTEMBER	PERIMETER	34	2.3	0.3	5.0	25	6	64
	OFF-SITE	20	1.9	1.0	4.0	21	11	30
OCTOBER	PERIMETER	29	1.5	0.3	3.8	21	14	28
	OFF-SITE	23	1.5	0.4	3.1	20	12	30
NOVEMBER	PERIMETER	35	1.5	0.2	3.4	22	8	40
	OFF-SITE	21	1.5	0.1	2.6	20	7	33
DECEMBER	PERIMETER	23	2.8	1.7	5.0	41	26	60
	OFF-SITE	20	2.3	0.2	4.1	30	11	51
ANNUAL SUMMARY	PERIMETER	370	2.1 ± 0.1	0.2	9.4	24 ± 1	5	64
	OFF-SITE	245	1.9 ± 0.1	0.1	7.3	21 ± 1	5	64

---

* 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.

NOTE: (1E-15 = 10^{-15})

TABLE 4

GAMMA RAY ACTIVITY IN AIR-FILTER SAMPLES, 1985 (CONCENTRATIONS IN 1E-15 MICROCURIES/ML)

MONTH	LOCATION	BE7	PB210
JANUARY	PERIMETER	60	34
	OFF-SITE	57	35
FEBRUARY	PERIMETER	79	41
	OFF-SITE	66	42
MARCH	PERIMETER	85	24
	OFF-SITE	81	32
APRIL	PERIMETER	102	25
	OFF-SITE	101	26
MAY	PERIMETER	108	20
	OFF-SITE	122	26
JUNE	PERIMETER	136	22
	OFF-SITE	140	25
JULY	PERIMETER	132	30
	OFF-SITE	111	24
AUGUST	PERIMETER	95	32
	OFF-SITE	108	36
SEPTEMBER	PERIMETER	114	28
	OFF-SITE	104	34
OCTOBER	PERIMETER	72	25
	OFF-SITE	81	31
NOVEMBER	PERIMETER	60	28
	OFF-SITE	58	29
DECEMBER	PERIMETER	75	56
	OFF-SITE	60	41
ANNUAL SUMMARY	PERIMETER	93 ± 16	30 ± 6
	OFF-SITE	91 ± 17	32 ± 4
DOSE(REM)	PERIMETER	(0.00021)	(0.033)
	OFF-SITE	(0.00021)	(0.035)

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-234, 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 5.

The average strontium-90 and plutonium-239 concentrations were similar to 1984 results. Strontium-89 was not observed above the detection limit of 1×10^{-16} µCi/mL. The plutonium-239 and strontium-90 concentrations at Location 12N are slightly elevated in November. The source of this activity is uncertain. It could result from a single fallout particle, particularly since strontium-90 is also elevated in this sample. If a hypothetical individual were exposed to plutonium-239 at this concentration for a whole year, the resulting dose would be 0.00003 mrem. This dose is significantly less than the standard of 100 mrem/y and less than fallout levels of plutonium-239 a few years ago.

Figure 4 shows the monthly plutonium-239 off-site air concentrations for the past 13 years. The arrows indicate the approximate dates of atmospheric nuclear tests. An examination of Figure 4 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 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 9% in

TABLE 5

STRONTIUM, THORIUM, URANIUM AND PLUTONIUM CONCENTRATIONS IN AIR-FILTER SAMPLES, 1985
(CONCENTRATIONS IN 1E-18 MICROCURIES/ML)

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	18 ± 1	9 ± 1	20 ± 2	1.0 ± 0.7	16 ± 2	2.2 ± 0.6
	12N	< 10	16 ± 4	29 ± 2	15 ± 2	41 ± 3	2.1 ± 1.0	40 ± 3	1.8 ± 0.6
	OFF-SITE	11 ± 9	7 ± 3	15 ± 1	7 ± 1	14 ± 2	1.1 ± 0.9	12 ± 2	2.6 ± 0.7
FEBRUARY	7I	14 ± [illegible]	6 ± 1	13 ± 1	6 ± 1	14 ± 1	0.5 ± 0.5	13 ± 1	1.4 ± 0.5
	12N	14 ± 10	9 ± 2	21 ± 3	7 ± 2	21 ± 2	1.5 ± 0.7	18 ± 2	1.0 ± 0.6
	OFF-SITE	-	6 ± 1	7 ± 1	3 ± 1	9 ± 1	< 0.3	7 ± 1	0.8 ± 0.6
MARCH	7I	-	5 ± 1	11 ± 1	5 ± 1	16 ± 1	0.7 ± 0.6	16 ± 1	0.9 ± 0.5
	12N	17 ± 24	11 ± 1	28 ± 2	13 ± 1	31 ± 2	0.9 ± 0.7	25 ± 2	1.0 ± 0.7
	OFF-SITE	< 10	2 ± 2	5 ± 1	2 ± 1	6 ± 1	< 0.3	6 ± 1	0.9 ± 0.6
APRIL	7I	13 ± 7	5 ± 3	9 ± 1	4 ± 1	14 ± 1	< 0.3	15 ± 1	1.0 ± 0.5
	12N	11 ± 3	8 ± 4	16 ± 2	7 ± 1	22 ± 2	0.9 ± 0.4	15 ± 2	1.2 ± 0.6
	OFF-SITE	14 ± 7	9 ± 2	15 ± 1	8 ± 1	8 ± 2	< 0.3	8 ± 2	1.2 ± 0.5
MAY	7I	13 ± 4	16 ± 2	21 ± 1	14 ± 1	22 ± 1	< 0.3	20 ± 1	1.9 ± 0.5
	12N	< 10	17 ± 4	33 ± 2	17 ± 2	27 ± 2	< 0.3	28 ± 2	1.6 ± 0.5
	OFF-SITE	24 ± 3	14 ± 2	27 ± 2	16 ± 1	30 ± 2	< 0.3	22 ± 2	1.5 ± 0.5
JUNE	7I	22 ± 7	16 ± 4	27 ± 2	14 ± 1	20 ± 1	0.4 ± 0.2	18 ± 1	2.2 ± 0.6
	12N	18 ± 8	4 ± 2	13 ± 1	6 ± 1	21 ± 2	< 0.3	18 ± 1	0.7 ± 0.4
	OFF-SITE	31 ± 6	23 ± 2	26 ± 2	15 ± 1	24 ± 2	< 0.3	24 ± 2	1.3 ± 0.5
JULY	7I	15 ± 16	14 ± 2	15 ± 2	7 ± 1	12 ± 1	< 0.3	10 ± 1	2.0 ± 0.6
	12N	< 10	9 ± 2	20 ± 2	7 ± 1	10 ± 1	< 0.3	9 ± 1	0.7 ± 0.5
	OFF-SITE	< 10	9 ± 1	13 ± 1	4 ± 1	9 ± 1	< 0.3	8 ± 1	0.8 ± 0.4
AUGUST	7I	< 10	3 ± 5	6 ± 2	2 ± 1	5 ± 1	< 0.3	3 ± 1	1.0 ± 0.4
	12N	11 ± 17	5 ± 2	12 ± 1	5 ± 1	10 ± 1	< 0.3	9 ± 1	1.0 ± 0.4
	OFF-SITE	< 10	9 ± 1	13 ± 1	5 ± 1	11 ± 1	< 0.3	11 ± 1	0.8 ± 0.4
SEPTEMBER	7I	< 10	2 ± 1	7 ± 1	4 ± 1	11 ± 1	< 0.3	11 ± 1	0.3 ± 0.2
	12N	< 10	3 ± 3	5 ± 1	3 ± 1	8 ± 1	< 0.3	9 ± 1	1.1 ± 0.4
	OFF-SITE	< 10	1 ± 2	5 ± 1	2 ± 1	6 ± 1	< 0.3	6 ± 1	0.5 ± 0.3
OCTOBER	7I	31 ± 5	2 ± 1	8 ± 1	4 ± 1	10 ± 1	< 0.3	6 ± 1	0.7 ± 0.2
	12N	< 10	-	-	-	10 ± 1	< 0.3	10 ± 1	0.5 ± 0.2
	OFF-SITE	< 10	3 ± 1	6 ± 1	2 ± 1	4 ± 2	< 0.3	5 ± 1	0.3 ± 0.2
NOVEMBER	7I	< 10	4 ± 1	16 ± 4	4 ± 2	6 ± 2	< 0.3	8 ± 2	1.6 ± 1.4
	12N	45 ± 5	10 ± 1	21 ± 1	11 ± 1	22 ± 2	< 0.3	20 ± 2	11 ± 1.1
	OFF-SITE	19 ± 12	7 ± 1	8 ± 1	5 ± 1	8 ± 2	< 0.3	8 ± 1	0.8 ± 0.3
DECEMBER	7I	15 ± 11	10 ± 1	12 ± 1	8 ± 1	15 ± 2	< 0.3	14 ± 2	0.7 ± 0.3
	12N	19 ± 1	10 ± 1	15 ± 1	12 ± 1	52 ± 3	< 0.3	54 ± 3	0.4 ± 0.2
	OFF-SITE	< 10	3 ± 1	3 ± 1	2 ± 1	7 ± 1	< 0.3	5 ± 1	0.3 ± 0.2
ANNUAL	7I	10 ± 1	8 ± 3	13 ± 4	7 ± 2	14 ± 3	< 0.4	12 ± 3	1.3 ± 0.4
	12N	10 ± 10	9 ± 3	19 ± 5	9 ± 3	23 ± 8	< 0.6	21 ± 8	1.8 ± 1.8
SUMMARY	OFF-SITE	< 10	8 ± 4	12 ± 5	6 ± 3	11 ± 5	< 0.4	10 ± 4	1.0 ± 0.4
DOSE(MREM)	7I	11	(0.20)	(0.70)	(0.006)	(.15)	< 0.004	(0.13)	0.037
	12N	11	(0.24)	(1.00)	(0.009)	(.25)	< 0.007	(0.21)	0.051
(X 1E-5)	OFF-SITE	< 11	(0.20)	(0.62)	(0.006)	(.12)	< 0.004	(0.10)	0.027

---

[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 MICROCURIES/ML BY 2.96 X 10^{12} FOR URANIUM-238 AND BY 9 X 10^{12} FOR THORIUM-232. THE MASS OF THE OTHER THORIUM ISOTOPES IN COMPARISON TO THORIUM-232 AND THE OTHER URANIUM ISSOTOPES IN COMPARISON TO URANIUM-238 IS NEGLIGIBLE.

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

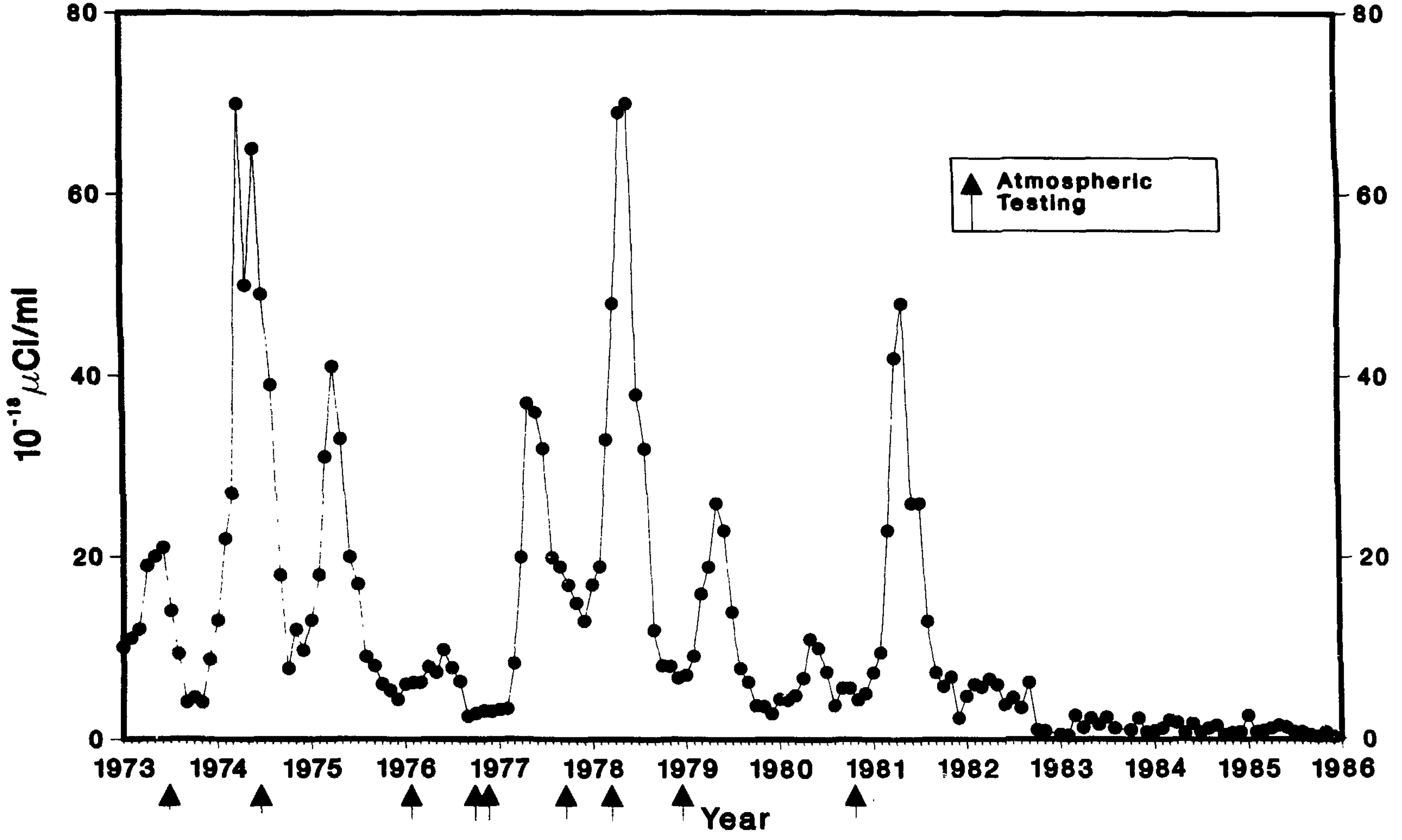


Figure 4.
Plutonium-239,240 in Air Concentrations, 1973-1985

Fig. 4. Plutonium-239,240 Air Concentrations, 1973-1985

January to 64% in December 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 1985 are listed in Table 6 by location. The increase from Building 200 is due to work on the "proof-of-breeding" program and the hydrogen-3 from Building 212 is from the tritium recovery studies. In addition to the nuclides listed in Table 6, several other fission products were also released in millicurie or smaller amounts. The quantities listed in Table 6 were measured by on-line stack monitors in the exhaust systems of the buildings.

Because the Laboratory is conducting a program that could result in the release of tritiated water vapor into the air, the air sampling program for determining tritium in air was carried out. Samples were collected at Locations 8F (at the southwest corner of the site) and at 12N (on the east perimeter of the site). The tritiated water vapor was collected by adsorption on silica gel and was measured by counting the desorbed water in a liquid scintillation spectrometer. The results are given in Table 7. Based on the data in Table 6, the principal source of the tritiated water vapor should be from Building 212, Location 12I. Because the winds are usually from the west to south, the tritium concentrations should be higher at Location 12N. However, the concentrations at 8F were four times higher than at 12N, but a factor of two to three less than when these measurements were last made in 1979[8] when the major source of tritiated water vapor was the CP-5 reactor at Location 9H. Another potential source of tritiated water vapor is this reactor, which although not operating, is discharging some residual tritium. Emissions from CP-5 were not measured in 1985. The highest measured tritium concentration was at Location 8F and occurred between August 12 and August 16. Most of this time period the wind was blowing from the north to northeast. The source of this measured tritium could have been Building 200, Building 212, or Building 330 (CP-5) since each was upwind of Location 8F at some time during this period.

TABLE 6

Summary of Airborne Radioactive Emissions, 1985
(Curies/Year)

Building	Nuclide	Half-Life	Amount Released
200	Hydrogen-3	12.3 y	7.7
	Krypton-85	10.7 y	127
	Radon-220	56 s	2788
202 (Janus)	Argon-41	1.8 h	2.6
212	Hydrogen-3	12.3 y	38.9
	Krypton-85	10.7 y	1.6
375 (IPNS)	Carbon-11	20 m	152

TABLE 7

Tritiated Water Vapor in Air, 1985
(Concentrations in 10^{-12} μCi/mL)

Month	Location*	No. of Samples	Avg.	Min.	Max.
January	8F	8	0.4	< 0.1	1.3
	12N	8	2.6	0.4	12.6
February	8F	8	0.7	0.1	2.0
	12N	7	1.2	0.1	3.1
March	8F	9	1.9	0.2	5.9
	12N	9	1.4	0.1	3.3
April	8F	8	4.0	0.4	13.3
	12N	8	0.8	0.1	2.3
May	8F	9	5.1	0.2	20.1
	12N	9	1.1	0.1	3.2
June	8F	9	5.6	0.4	19.0
	12N	9	1.5	0.1	4.5
July	8F	9	5.8	0.2	23.3
	12N	9	3.6	0.3	8.3
August	8F	8	35.7	1.5	199.2
	12N	8	3.6	0.2	10.6
September	8F	9	5.7	0.9	25.3
	12N	9	1.4	0.3	3.4
October	8F	9	3.1	< 0.1	10.1
	12N	9	0.9	0.1	2.5
November	8F	9	1.0	< 0.1	4.2
	12N	9	0.6	< 0.1	1.8
December	8F	5	0.4	< 0.1	1.2
	12N	5	0.9	0.3	1.3
Annual Summary	8F	100	5.8	< 0.1	199.2
	12N	99	1.6	< 0.1	12.6
Dose (mrem)	8F	-	0.0031	< 0.00005	0.105
	12N	-	0.0008	< 0.00005	0.0067

*Locations are given in terms of the grid coordinates in Figure 1.

The highest concentration is only 0.02% of the 500 mrem/y dose limit. Ambient tritium-in-air concentrations are about 1 x 10^{-12} µCi/mL, based on results obtained in previous years, so that concentrations above this value are considered to have originated at Argonne.

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 determined on a separate sample, and this activity does not appear in the total nonvolatile beta activity. Uranium was determined using a laser fluorometer, and the results 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 system. Analyses for transuranium nuclides were performed on 10-liter samples by chemical separation methods followed by alpha spectrometry.[9,10] 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.

Argonne waste water is discharged into Sawmill Creek, a small stream that runs through the Laboratory 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 Argonne site and downstream from the waste-water outfall to determine if radioactivity was added to the stream by Argonne waste water or surface drainage. The sampling locations are shown in Figure 1. Below the waste-water outfall, daily samples were collected by a continuous sampler, which operated about 89% 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 8. Comparison of the results, and 95% confidence levels of the averages, for the two sampling locations shows that the nuclides whose presence in the Creek water can be attributed to Argonne operations were hydrogen-3, neptunium-237, plutonium-239, americium-241, and occasionally strontium-90, plutonium-238, curium-242 and/or californium-252, and curium-244 and/or californium-249. The percentage of individual samples containing activity attributable to Argonne was 50% for hydrogen-3, 96% for neptunium-237, 80% for plutonium-239, and 80% 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 Argonne waste water, in terms of concentration, was hydrogen-3. The hydrogen-3 content has decreased over the past few years due to the cessation of the operation of the CP-5 reactor.

The hydrogen-3 in the Creek above the site was similar in concentration to levels found away from the Laboratory site and is characteristic of the current ambient level in surface water. During 1985, the hydrogen-3 content of 21 other lakes and streams ranged from $< 100 \times 10^{-9}$ µCi/mL to 483×10^{-9} µCi/mL and averaged 179×10^{-9} µCi/mL.

The total radioactive effluent discharged to the Creek in Argonne waste water can be estimated from the average net concentrations and the volume of water carried by the Creek. These totals are 7.4 Ci of hydrogen-3, < 0.1 mCi of strontium-90, 0.06 mCi of neptunium-237, 0.04 mCi of plutonium-239, 0.04 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 latter two

TABLE 8

RADIONUCLIDES IN SAWMILL CREEK WATER, 1985

TYPE OF ACTIVITY	LOCATION*	NO. OF SAMPLES	CONCENTRATION (1E-09 MICROCURIES/ML) AVG.	MIN.	MAX.	DOSE (MREM) AVG.	MIN.	MAX.
ALPHA (NONVOLATILE)	16K	12	5.3 ± 0.2	1.6	13	-	-	-
	7M	246	1.6 ± 0.2	0.8	3.5	-	-	-
BETA (NONVOLATILE)	16K	12	21 ± 1	5	34	-	-	-
	7M	246	17 ± 2	6	28	-	-	-
HYDROGEN-3	16K	12	< 122	< 100	288	< 0.0056	< 0.005	0.0133
	7M	246	614 ± 669	< 100	15120	0.0282	< 0.005	0.6955
STRONTIUM-90	16K	12	< 0.27	< 0.25	0.37	< 0.026	< 0.02	0.04
	7M	246	0.28 ± 0.05	< 0.25	0.97	0.027	< 0.02	0.09
RADIUM-226	7M	246	0.40 ± 0.10	0.18	2.52	(0.32)	(0.14)	(2.03)
URANIUM** (NATURAL)	16K	11	1.1 ± 0.2	0.5	1.5	(0.18)	(0.087)	(0.25)
	7M	246	1.0 ± 0.1	0.5	2.0	(0.17)	(0.089)	(0.34)
NEPTUNIUM-237	16K	12	-	-	< 0.001	-	-	< 0.00028
	7M	246	0.0047 ± 0.0013	< 0.001	0.021	0.0013	< 0.00028	0.0060
PLUTONIUM-238	16K	12	-	-	< 0.001	-	-	< 0.00028
	7M	246	< 0.0011	< 0.001	0.004	0.00032	< 0.00028	0.00107
PLUTONIUM-239	16K	12	-	-	< 0.001	-	-	< 0.00031
	7M	246	0.0034 ± 0.0008	< 0.001	0.0124	0.0011	< 0.00031	0.0039
AMERICIUM-241	16K	12	-	-	< 0.001	-	-	< 0.0016
	7M	232	0.0035 ± 0.0009	< 0.001	0.014	0.0056	< 0.0016	0.022
CURIUM-242 AND/OR CALIFORNIUM-252	16K	12	-	-	< 0.001	-	-	< 0.0003
	7M	232	< 0.0012	< 0.001	0.0056	< 0.0004	< 0.0003	0.0019
CURIUM-244 AND/OR CALIFORNIUM-249	16K	12	-	-	< 0.001	-	-	< 0.0017
	7M	232	< 0.0017	< 0.001	0.0078	< 0.0028	< 0.0017	0.0131

---

* 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 X 10^{9}.

streams is important in assessing the contribution of Argonne 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 activity in the River.

Annual summaries of the results obtained for these two locations are given in Table 9. 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 as such in the Des Plaines River. The average nonvolatile alpha and beta activities, 2.1×10^{-9} µCi/mL and 11×10^{-9} µCi/mL, respectively, of 21 off-site surface water samples collected this year (excluding the Des Plaines River) were similar to the levels found in previous years.

The radioactivity in samples of Illinois River water, shown in Table 10, was similar to those found previously at these same locations. No radioactivity originating at Argonne could be detected in the Des Plaines or Illinois Rivers.

A water sample was collected October 21, 1985, from the point where the surface drainage leaves the suspect landfill located at 7J in Figure 1. Material was buried in this area between January 1965 and October 1967 and consisted of items that did not show any radioactivity by survey, but could be contaminated in inaccessible areas, such as inside pipes. The sample was analyzed for tritiated water, strontium-90, and by gamma-ray spectrometry. No gamma-ray activities above ambient levels were detected. The tritium concentration at the site boundary was 2.8×10^{-5} µCi/mL and the strontium-90 was 6.4×10^{-9} µCi/mL. These concentrations, although approximately 150 and 20 times, respectively, greater than ambient levels, are all well below the DOE standards. The excess activity is evidently from the landfill. This area will be monitored regularly to establish trends. Most of the year this area was dry.

TABLE 9

RADIONUCLIDES IN DESPLAINES RIVER WATER, 1985

TYPE OF ACTIVITY	LOCATION*	NO. OF SAMPLES	CONCENTRATION (1E-09 MICROCURIES/ML) AVG.	MIN.	MAX.	DOSE (MREM) AVG.	MIN.	MAX.
ALPHA (NONVOLATILE)	A	12	1.7 ± 0.1	0.8	2.7	-	-	-
	B	24	1.7 ± 0.3	0.8	3.4	-	-	-
BETA (NONVOLATILE)	A	12	13 ± 1	5	22	-	-	-
	B	24	12 ± 2	4	25	-	-	-
HYDROGEN-3	A	12	< 129	< 100	280	< 0.0059	< 0.005	0.0129
	B	24	< 133	< 100	371	< 0.0061	< 0.005	0.0171
STRONTIUM-90	A	11	0.27 ± 0.06	< 0.25	0.37	0.03	< 0.02	0.04
	B	24	0.29 ± 0.07	< 0.25	0.76	0.03	< 0.02	0.07
URANIUM** (NATURAL)	A	11	1.3 ± 0.2	0.8	2.0	(0.21)	(0.143)	(0.34)
	B	23	1.2 ± 0.2	0.4	2.3	(0.21)	(0.064)	(0.38)
NEPTUNIUM-237	A	12	< 0.001	< 0.001	0.003	< 0.0003	< 0.00028	0.00072
	B	12	-	-	< 0.001	-	-	< 0.00028
PLUTONIUM-238	A	12	-	-	< 0.001	-	-	< 0.00028
	B	12	-	-	< 0.001	-	-	< 0.00028
PLUTONIUM-239	A	12	< 0.0013	< 0.001	0.004	< 0.0004	< 0.0003	0.0013
	B	12	-	-	< 0.001	-	-	< 0.0003
AMERICIUM-241	A	12	-	-	< 0.001	-	-	< 0.0016
	B	12	< 0.001	< 0.001	0.001	< 0.0016	< 0.0016	0.0018
CURIUM-242 AND/OR CALIFORNIUM-252	A	12	-	-	< 0.001	-	-	< 0.0003
	B	12	-	-	< 0.001	-	-	< 0.0003
CURIUM-244 AND/OR CALIFORNIUM-249	A	12	-	-	< 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 X 10^9.

TABLE 10

Radionuclides in Illinois River Water, 1985
(Concentrations in 10^{-9} μCi/mL)

Date Collected	Location	Alpha*	Beta*	Hydrogen-3	Uranium** (natural)	Plutonium-239
May 23	McKinley Woods State Park	0.8 ± 0.4	9.8 ± 0.6	328 ± 96	0.5 ± 0.1	< 0.001
May 23	Below Dresden Power Station	2.3 ± 0.4	6.6 ± 0.4	297 ± 95	0.8 ± 0.1	< 0.001
May 23	Morris	1.3 ± 0.4	5.9 ± 0.5	< 100	0.6 ± 0.1	-
May 23	Starved Rock State Park	1.4 ± 0.4	7.7 ± 0.4	< 100	0.8 ± 0.1	-
October 8	McKinley Woods State Park	0.6 ± 0.2	8.0 ± 0.6	145 ± 92	0.4 ± 0.1	< 0.001
October 8	Below Dresden Power Station	0.9 ± 0.3	8.5 ± 0.6	< 100	0.4 ± 0.1	< 0.001
October 8	Morris	1.3 ± 0.4	7.7 ± 0.5	122 ± 92	0.4 ± 0.1	-
October 8	Starved Rock State Park	0.7 ± 0.2	6.0 ± 0.6	157 ± 93	0.4 ± 0.1	-

*Nonvolatile activity.

**Uranium concentrations in units of μg/L can be obtained by multiplying the concentration by 1.48 x 10^9.

3. Ground Water

The Laboratory domestic water is provided by four wells which are described in Section I.E. and the locations are shown in Figure 1. Samples from each well were collected quarterly at the well head and analyzed for several types of radioactivity. The 1985 results are in Table 11. In addition to the well water samples, one tap water sample was collected and the results are also in Table 11.

Since the Laboratory is a "non-community water system",[11] the EPA standards for this type of system apply. For the nuclides measured in Table 11, the following limits are established:

Gross alpha particle activity	15 pCi/L (10^{-9} µCi/mL)
Gross beta particle activity	15 pCi/L (10^{-9} µCi/mL)
Hydrogen-3	2 x 10^4 pCi/L (10^{-9} µCi/mL)
Strontium-90	8 pCi/L (10^{-9} µCi/mL)
Radium-226	5 pCi/L (10^{-9} µCi/mL)

The uranium results would be covered by the gross alpha standard. Inspection of Table 11 indicates that all measurements are well within the EPA drinking water standards. This program is being conducted to demonstrate the Laboratory'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 only 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) in the 1950's. 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 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. Two hydrogen-3 results from Well 3 were very

TABLE 11

Radioactivity in ANL Domestic Wells, 1985
(Concentrations in 10^{-9} μCi/mL)

Type of Activity	Location	No. of Samples	Avg.	Min.	Max.
Alpha (nonvolatile)	Well #1	4	4.1 ± 1.0	2.9	5.0
	Well #2	4	4.0 ± 1.1	2.8	5.2
	Well #3	4	3.0 ± 0.5	2.4	3.4
	Well #4	3	2.5 ± 1.3	1.8	3.6
	Tap	1	-	-	0.4
Beta (nonvolatile)	Well #1	4	7.8 ± 1.6	6.3	9.6
	Well #2	4	6.7 ± 0.9	5.6	7.6
	Well #3	4	6.4 ± 1.2	5.1	7.6
	Well #4	3	5.9 ± 2.2	4.1	7.1
	Tap	1	-	-	5.1
Hydrogen-3	Well #1	4	220 ± 41	181	257
	Well #2	4	161 ± 130	< 100	333
	Well #3	4	111 ± 15	< 100	125
	Well #4	3	-	-	< 100
	Tap	1	-	-	114
Strontium-90	Well #1	1	-	-	< 0.25
	Well #2	1	-	-	< 0.25
	Well #3	1	-	-	< 0.25
	Well #4	1	-	-	< 0.25
	Tap	1	-	-	< 0.25
Radium-226	Well #1	1	-	-	1.27
	Well #2	1	-	-	1.01
	Well #3	1	-	-	0.72
	Well #4	1	-	-	0.76
	Tap	1	-	-	0.12
Uranium-234	Well #1	1	-	-	0.23
	Well #2	1	-	-	0.18
	Well #3	1	-	-	0.26
	Well #4	1	-	-	0.12
	Tap	1	-	-	0.06
Uranium-238	Well #1	1	-	-	0.16
	Well #2	1	-	-	0.17
	Well #3	1	-	-	0.18
	Well #4	1	-	-	0.12
	Tap	1	-	-	0.15

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,[12] an unusual occurrence was reported which consisted of the loss from the Argonne Advanced Research Reactor (A^2R^2) excavation (Location 10G) of about 7.5 megaliters (2 million gallons) of ponded water containing about 26 mCi of tritiated water. Quarterly monitoring of wells and a seep likely to be in the subsurface flow path of this water continued during 1985 and the results are summarized in Table 12. The concentrations of tritiated water were in the normal range and none was detected that could be attributed to this release. In 1982, elevated concentrations, up to 1200 x 10^{-9} μCi/mL, were measured in Well 9 from this release. The concentration in the tritiated water that remains in the A^2R^2 excavation continued to decrease from the 2.2 x 10^{-6} μCi/mL in 1982 to 0.7 x 10^{-6} μCi/mL in 1985. The excavation is being filled with concrete, asphalt, and soil as these materials become available. Monitoring will continue in the wells and the excavation. The wells are used to measure water levels, and are not a source of drinking water.

TABLE 12

Tritium Content of Water Near A^2R^2 Excavation, 1985 (Concentrations in 10^{-9} μCi/mL)

Sample	Location*	No. of Samples	Avg.	Min.	Max.
Well #9	9F	3	108 ± 18	< 100	123
Well #10	11J	4	106 ± 12	< 100	122
Well D181	8F	4	-	-	< 100
Well D185	8E	4	-	-	< 100
Seep	4EF	4	107 ± 15	< 100	126
A^2R^2	10G	4	731 ± 81	656	825

*See Figure 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 Argonne is normal. For this purpose, the American Society for Testing and Materials (ASTM) site selection criteria, sample collection, and sample preparation techniques were used.[13] Sites were selected in several directions and at various distances from the Laboratory. 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 intervals. 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 Argonne environment has been established. By 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 III.A.1 for air-filter residues. The plutonium and americium were separated from the same 100 gram 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 13. Intermediate half-life fission products reported previously have decayed to below their detection limits. 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

TABLE 13

Gamma-Ray Emitting Radionuclides in Soil, 1985
(Concentrations in 10^{-6} μCi/g)

Date Collected	Location	Potassium-40	Cesium-137	Radium-226 (Bismuth-214)	Thorium-228 (Lead-212)	Thorium-232 (Actinium-228)
	Perimeter*					
May 24	7J	17.16 ± 0.60	1.11 ± 0.04	1.16 ± 0.06	0.87 ± 0.03	0.91 ± 0.09
May 24	10N	20.39 ± 0.76	0.88 ± 0.04	1.68 ± 0.07	1.10 ± 0.04	0.91 ± 0.09
May 24	9N	17.57 ± 0.58	0.61 ± 0.03	1.12 ± 0.06	0.86 ± 0.03	0.81 ± 0.08
May 24	14I	18.17 ± 0.72	0.92 ± 0.04	1.35 ± 0.07	1.17 ± 0.04	0.89 ± 0.09
May 24	10E	15.06 ± 0.53	1.05 ± 0.04	0.98 ± 0.06	0.79 ± 0.03	0.79 ± 0.08
November 6	14E	15.60 ± 0.53	0.66 ± 0.03	1.05 ± 0.05	0.90 ± 0.03	0.86 ± 0.08
November 6	14N	16.08 ± 0.58	0.61 ± 0.03	1.06 ± 0.06	0.92 ± 0.03	0.78 ± 0.08
November 6	10P	17.70 ± 0.59	0.81 ± 0.03	1.02 ± 0.06	0.84 ± 0.03	0.76 ± 0.08
November 6	7E/F	18.86 ± 0.60	0.35 ± 0.02	1.16 ± 0.06	0.84 ± 0.03	0.74 ± 0.08
November 15	4E/F	16.21 ± 0.56	1.11 ± 0.04	1.22 ± 0.06	0.85 ± 0.03	0.76 ± 0.08
	Average	17.28 ± 1.02	0.81 ± 0.16	1.18 ± 0.13	0.91 ± 0.08	0.82 ± 0.04
	Off-Site					
May 22	Bemis Woods, Western Springs, IL	19.47 ± 0.61	0.64 ± 0.03	1.71 ± 0.07	0.95 ± 0.03	0.83 ± 0.08
May 22	McCormick Woods, Brookfield, IL	23.13 ± 0.79	0.81 ± 0.04	1.60 ± 0.07	1.15 ± 0.04	0.98 ± 0.09
May 23	McKinley Woods State Park, IL	18.63 ± 0.77	0.54 ± 0.03	1.38 ± 0.07	0.99 ± 0.04	0.79 ± 0.09
May 23	Starved Rock State Park, IL	13.16 ± 0.53	0.76 ± 0.03	0.95 ± 0.06	0.70 ± 0.03	0.66 ± 0.08
May 23	Dresden Lock & Dam, IL	16.21 ± 0.58	1.09 ± 0.04	0.89 ± 0.06	0.79 ± 0.03	0.79 ± 0.08
October 8	Morris, IL	14.65 ± 0.59	0.18 ± 0.02	1.11 ± 0.06	0.66 ± 0.03	0.57 ± 0.08
October 8	Channahon, IL	14.45 ± 0.56	0.71 ± 0.03	0.92 ± 0.06	0.73 ± 0.03	0.60 ± 0.08
October 9	Saganashkee Slough, IL	20.28 ± 0.62	0.48 ± 0.03	1.50 ± 0.06	0.97 ± 0.03	0.97 ± 0.08
October 9	McGinnis Slough, IL	18.11 ± 0.37	0.66 ± 0.02	1.63 ± 0.04	0.86 ± 0.02	0.79 ± 0.05
October 9	Woodridge, IL	17.64 ± 0.58	0.85 ± 0.03	1.22 ± 0.06	0.98 ± 0.03	0.86 ± 0.08
	Average	17.57 ± 1.92	0.67 ± 0.15	1.29 ± 0.20	0.88 ± 0.10	0.78 ± 0.09

*The perimeter locations are given in terms of the grid coordinates in Figure 1.

concentrations for the perimeter and off-site samples are similar. The plutonium and americium concentrations are given in Table 14. The ranges and concentrations of plutonium and americium in soil are similar at both perimeter and off-site locations. 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.[14] The measured deposition of americium-241 and the americium-241/plutonium-239 ratio is consistent with reported values.[14]

As part of a characterization of the suspect landfill located at 7J and discussed in Section III.A.2., 17 soil samples were collected in August 1985 from shallow soil borings within and outside the burial area. The soil moisture was analyzed for tritiated water and the dried soil measured for gamma-ray emitting radionuclides. The gamma-ray results were normal and similar to the surface soil results in Table 13. No tritiated water above the detection limit of 2×10^{-7} µCi/mL was found outside the burial area. Four of 12 samples collected within the burial area had elevated tritiated water concentrations that ranged from 1.2×10^{-6} µCi/mL to 3.0×10^{-6} µCi/mL of soil water. These were all collected several feet below the surface. One sample from the burial area contained 4.2×10^{-6} µCi/g of plutonium-239 and 1.8×10^{-6} µCi/g of americium-241 about 300 and 500 times, respectively, greater than ambient levels. All these samples were collected from the subsurface and are within the Laboratory security area.

The results of radionuclide concentrations measured in grass are given in Table 15. The annual averages and concentration ranges were similar at the perimeter and off-site locations as well as similar to previous years, indicating no contribution from ANL operations. In terms of 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 16. The annual off-site averages are in the same range found in off-site samples collected in previous years. Plutonium results vary widely between locations and are strongly dependent

TABLE 14

Transuranics in Soil, 1985

Date Collected	Location	Plutonium-238		Plutonium-239			Americium-241		
		10^{-9} µCi/g	10^{-3} µCi/m^2	10^{-9} µCi/g	10^{-3} µCi/m^2	^{238}Pu/^{239}Pu	10^{-9} µCi/g	10^{-3} µCi/m^2	^{241}Am/^{239}Pu
	Perimeter*								
May 24	7J	1.3 ± 0.2	0.064 ± 0.012	42.5 ± 1.4	2.100 ± 0.067	0.030	8.6 ± 0.9	0.425 ± 0.044	0.20
May 24	10N	0.7 ± 0.2	0.025 ± 0.007	15.0 ± 0.8	0.571 ± 0.029	0.045	3.6 ± 0.3	0.136 ± 0.011	0.24
May 24	9N	0.6 ± 0.2	0.027 ± 0.007	11.6 ± 0.7	0.483 ± 0.028	0.055	2.2 ± 0.2	0.094 ± 0.009	0.19
May 24	14I	0.8 ± 0.1	0.037 ± 0.006	17.2 ± 0.5	0.761 ± 0.024	0.049	5.5 ± 0.4	0.243 ± 0.020	0.32
May 24	10E	0.8 ± 0.1	0.029 ± 0.004	18.7 ± 0.5	0.716 ± 0.019	0.040	4.8 ± 0.3	0.182 ± 0.012	0.25
November 6	14E	0.7 ± 0.2	0.032 ± 0.009	13.8 ± 0.8	0.656 ± 0.040	0.048	-	-	-
November 6	14N	0.5 ± 0.2	0.019 ± 0.006	12.9 ± 0.8	0.516 ± 0.033	0.036	-	-	-
November 6	10P	0.7 ± 0.2	0.031 ± 0.008	10.1 ± 0.7	0.429 ± 0.031	0.071	-	-	-
November 6	7E/F	0.5 ± 0.2	0.025 ± 0.008	7.9 ± 0.6	0.381 ± 0.031	0.067	-	-	-
November 15	4E/F	0.9 ± 0.3	0.044 ± 0.013	21.4 ± 1.3	1.025 ± 0.060	0.043	-	-	-
	Average	0.8 ± 0.1	0.033 ± 0.008	17.1 ± 6.2	0.764 ± 0.320	0.048	4.9 ± 2.1	0.216 ± 0.116	0.24
	Off-Site								
May 22	Bemis Woods, Western Springs, IL	0.7 ± 0.2	0.033 ± 0.007	12.2 ± 0.6	0.563 ± 0.029	0.058	2.9 ± 0.7	0.135 ± 0.032	0.24
May 22	McCormick Woods, Brookfield, IL	0.7 ± 0.2	0.029 ± 0.008	14.7 ± 0.8	0.583 ± 0.034	0.050	3.1 ± 0.5	0.122 ± 0.018	0.21
May 23	McKinley Woods State Park, IL	0.7 ± 0.2	0.035 ± 0.009	11.7 ± 0.7	0.599 ± 0.035	0.059	3.9 ± 0.4	0.200 ± 0.022	0.33
May 23	Starved Rock State Park, IL	0.6 ± 0.2	0.028 ± 0.008	13.9 ± 0.8	0.702 ± 0.039	0.040	3.8 ± 0.3	0.190 ± 0.015	0.27
May 23	Dresden Lock and Dam, IL	1.0 ± 0.2	0.045 ± 0.009	21.7 ± 0.9	1.007 ± 0.042	0.045	2.5 ± 0.2	0.115 ± 0.011	0.11
October 8	Morris, IL	0.2 ± 0.1	0.011 ± 0.007	4.6 ± 0.5	0.289 ± 0.029	0.038	1.7 ± 0.3	0.107 ± 0.021	0.37
October 8	Channahon, IL	0.7 ± 0.2	0.044 ± 0.012	16.5 ± 0.9	0.984 ± 0.055	0.045	4.7 ± 1.6	0.281 ± 0.092	0.29
October 9	Saganashkee Slough, IL	0.3 ± 0.1	0.014 ± 0.005	10.3 ± 0.7	0.406 ± 0.026	0.034	2.4 ± 0.8	0.095 ± 0.030	0.23
October 9	McGinnis Slough, IL	0.4 ± 0.1	0.019 ± 0.007	14.0 ± 0.8	0.659 ± 0.038	0.029	-	-	-
October 9	Woodridge, IL	0.7 ± 0.2	0.028 ± 0.008	16.8 ± 0.9	0.722 ± 0.037	0.039	-	-	-
	Average	0.6 ± 0.2	0.029 ± 0.007	13.6 ± 2.9	0.651 ± 0.142	0.044	3.1 ± 1.0	0.156 ± 0.063	0.26

---

*The perimeter locations are given in terms of the grid coordinates in Figure 1.

TABLE 15

Radionuclides in Grass, 1985

Date Collected	Location	(Concentrations in 10^{-9} μCi/g) Cesium-137	Plutonium-239	(10^{-6} μCi/m^2) Deposition of Plutonium-239
	<u>Perimeter</u>*			
May 24	7S	< 10	0.5 ± 0.1	0.07 ± 0.01
May 24	10N	< 10	< 0.1	< 0.01
May 24	9N	< 10	0.3 ± 0.1	0.03 ± 0.01
May 24	14I	18 ± 22	< 0.1	< 0.01
May 24	10E	< 10	< 0.1	< 0.01
November 6	14E	14 ± 12	< 0.1	< 0.01
November 6	14N	16 ± 13	< 0.1	< 0.01
November 6	10P	16 ± 24	< 0.1	< 0.01
November 6	7E/F	14 ± 25	< 0.1	< 0.01
November 15	4E/F	26 ± 19	0.1 ± 0.1	0.01 ± 0.01
	Average	12 ± 5	< 0.2	< 0.02
	<u>Off-Site</u>			
May 22	Bemis Woods, Western Springs, IL	< 10	< 0.1	< 0.01
May 22	McCormick Woods, Brookfield, IL	< 10	< 0.1	< 0.01
May 23	McKinley Woods State Park, IL	< 10	< 0.1	< 0.01
May 23	Starved Rock State Park, IL	29 ± 16	0.2 ± 0.1	0.03 ± 0.01
May 23	Dresden Lock and Dam, IL	21 ± 13	< 0.1	< 0.01
October 8	Morris, IL	< 10	< 0.1	< 0.01
October 8	Channahon, IL	13 ± 22	0.1 ± 0.1	0.02 ± 0.01
October 9	Saganashkee Slough, IL	< 10	< 0.1	< 0.01
October 9	McGinnis Slough, IL	< 10	0.1 ± 0.1	0.01 ± 0.01
October 9	Woodridge, IL	< 10	< 0.1	< 0.01
	Average	< 13	< 0.1	< 0.01

---

*The perimeter locations are given in terms of the grid coordinates in Figure 1.

TABLE 16

Radionuclides in Bottom Sediment, 1985

Date Collected	Location	Concentrations in 10^{-6} µCi/g					Concentrations in 10^{-9} µCi/g		
		Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232	Plutonium-238	Plutonium-239	Americium-241
	Perimeter*[*]								
June 17	50 m Above ANL Outfall	10.40 ± 0.40	0.07 ± 0.01	1.25 ± 0.04	0.59 ± 0.02	0.62 ± 0.05	0.8 ± 0.2	3.7 ± 0.5	-
June 17	ANL Outfall	10.99 ± 0.55	4.78 ± 0.09	0.77 ± 0.06	0.49 ± 0.03	0.48 ± 0.08	12.6 ± 0.6	136.8 ± 2.1	6.6 ± 1.1
June 17	50 m Below ANL Outfall	8.75 ± 0.43	0.17 ± 0.02	0.83 ± 0.06	0.44 ± 0.03	0.50 ± 0.08	0.4 ± 0.2	6.6 ± 0.6	0.7 ± 0.5
June 17	100 m Below ANL Outfall	10.24 ± 0.44	1.19 ± 0.04	1.20 ± 0.06	0.53 ± 0.03	0.67 ± 0.08	2.4 ± 0.3	20.8 ± 0.9	2.1 ± 1.0
June 17	500 m Below ANL Outfall	11.94 ± 0.50	1.43 ± 0.04	1.35 ± 0.06	0.73 ± 0.03	0.86 ± 0.08	1.9 ± 0.3	18.9 ± 0.8	1.8 ± 0.7
	Off-Site								
May 22	Salt Creek, Western Springs, IL	16.06 ± 0.71	0.08 ± 0.03	2.51 ± 0.08	1.01 ± 0.04	1.03 ± 0.10	< 0.1	1.6 ± 0.2	0.4 ± 0.6
May 22	Des Plaines River, Brookfield, IL	19.39 ± 0.74	0.51 ± 0.03	1.66 ± 0.07	0.96 ± 0.04	0.92 ± 0.09	0.7 ± 0.2	8.4 ± 0.6	< 0.1
May 23	Illinois River, McKinley Woods, IL	9.97 ± 0.56	0.15 ± 0.02	2.47 ± 0.09	1.05 ± 0.04	1.31 ± 0.12	< 0.1	6.0 ± 0.6	1.5 ± 1.5
May 23	Illinois River, Morris, IL	9.29 ± 0.43	0.04 ± 0.01	0.59 ± 0.04	0.45 ± 0.03	0.41 ± 0.06	< 0.1	0.7 ± 0.2	< 0.1
May 23	Illinois River, Dresden, IL	14.08 ± 0.49	0.60 ± 0.03	0.99 ± 0.05	0.48 ± 0.03	0.32 ± 0.05	< 0.1	1.6 ± 0.3	-
October 8	Illinois River, Starved Rock State Park, IL	7.33 ± 0.41	0.32 ± 0.02	0.63 ± 0.05	0.38 ± 0.02	0.36 ± 0.06	0.2 ± 0.1	2.1 ± 0.3	0.8 ± 0.2
October 8	DuPage River, Channahon, IL	12.96 ± 0.53	0.40 ± 0.03	1.17 ± 0.06	1.05 ± 0.03	1.10 ± 0.09	0.3 ± 0.1	9.1 ± 0.6	2.9 ± 0.6
October 9	Saganashkee Slough, IL	24.24 ± 0.81	0.08 ± 0.02	1.58 ± 0.08	1.17 ± 0.04	1.01 ± 0.10	0.9 ± 0.2	20.0 ± 0.9	0.7 ± 0.4
October 9	McGinnis Slough, IL	22.78 ± 0.94	1.12 ± 0.05	1.50 ± 0.09	1.00 ± 0.05	0.76 ± 0.11	0.6 ± 0.2	1.5 ± 0.2	0.7 ± 0.4
October 9	Des Plaines River, Romeoville, IL	8.95 ± 0.54	0.38 ± 0.03	1.69 ± 0.08	0.93 ± 0.04	0.95 ± 0.10	0.6 ± 0.2	12.4 ± 0.7	-
	Average	14.51 ± 3.78	0.37 ± 0.21	1.48 ± 0.42	0.85 ± 0.18	0.82 ± 0.22	0.4 ± 0.2	6.3 ± 4.0	0.9 ± 0.7

---

[*] The perimeter locations are given in terms of the grid coordinates in Figure 1.

on the retentiveness of the bottom material. A set of samples was collected on June 17, 1985, from the Sawmill Creek bed, above, at, and at several locations below, the point at which the Laboratory discharges its treated waste water (Location 7M in Figure 1). The results are listed in Table 16 and indicate that the sample above the 7M outfall is similar to the off-site samples. The plutonium and americium concentrations are the highest at the outfall and decrease rapidly with distance, indicating their origin is in Argonne waste water. Similar sets of samples were collected on 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 farther downstream, while the 1980, 1983, and 1984 results were more like the 1985 set. The changes in concentrations of the various nuclides with time indicates the dynamic nature of the sediment material in this area.

5. Milk

Raw 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 17. The average strontium-90 concentration was similar to the 1984 results. These nuclides are fission products from nuclear tests and their presence in milk is not related to Argonne operations.

The concentrations given in Table 17 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 0.7 mrem/y for strontium-90 and < 0.25 mrem/y for hydrogen-3.

TABLE 17

Radionuclides in Milk, 1985
(Concentrations in 10^{-9} μCi/mL)

Date Collected	Hydrogen-3	Strontium-90
January 2	< 100	3.2 ± 1.5
February 6	< 100	3.3 ± 2.3
March 6	< 100	3.1 ± 0.4
April 3	< 100	2.0 ± 0.1
May 1	< 100	3.0 ± 1.2
June 5	< 100	3.8 ± 0.3
July 3	< 100	3.3 ± 0.4
August 7	< 100	2.8 ± 0.9
September 4	< 100	2.8 ± 0.6
October 2	< 100	2.4 ± 0.3
November 6	< 100	2.2 ± 0.6
December 4	< 100	2.7 ± 0.7
Average	< 100	2.9 ± 0.3

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. Except for the packets set out during the first quarter of 1985, 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 values for the first quarter of 1985 were corrected for over-response at low energies by exposing both bare and shielded calcium fluoride and bare lithium fluoride at the same locations during the second quarter, and applying the ratios to the first quarter results. 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 exposed 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 2.

The results are summarized in Tables 18 and 19, and the site boundary and on-site readings are also shown in Figure 5. 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.

TABLE 18

Environmental Penetrating Radiation at Off-Site Locations, 1985

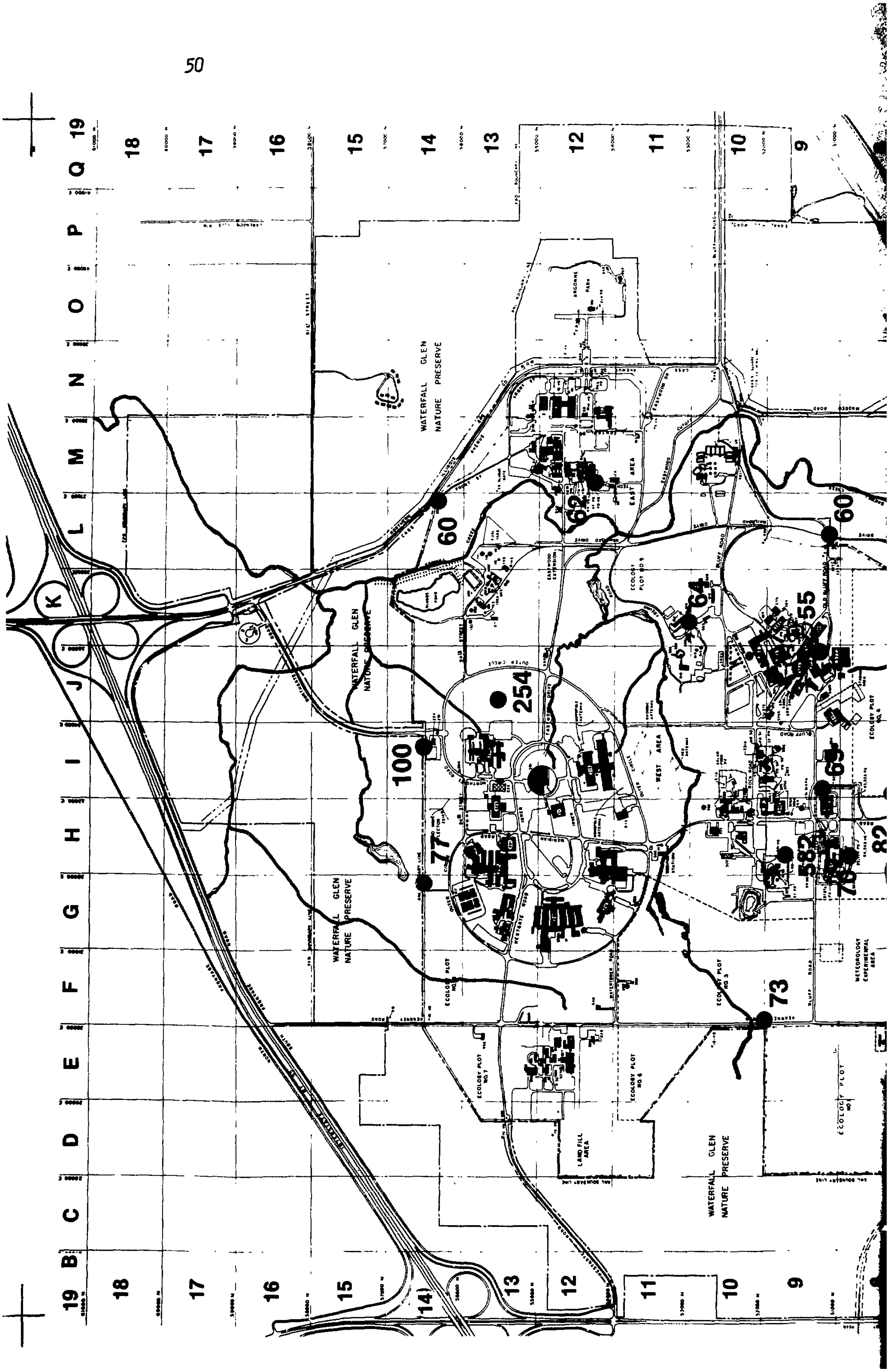
	Dose Rate (mrem/year)				
		Period of Measurement			
Location	1/8-4/9	4/9-7/17	7/17-10/6	10/6-1/9	Average
Downers Grove	75	77	87	74	78 ± 9
Lemont	74	78	83	75	78 ± 6
Lombard	74	65	83	73	74 ± 12
Oak Brook	83	75	80	79	79 ± 5
Oak Lawn	65	76	68	68	69 ± 8
Average	74 ± 8	74 ± 7	80 ± 9	74 ± 5	76 ± 5

The off-site results averaged 76 ± 5 mrem/y and are about 10 to 15 mrem/y lower than in previous years and is due to the use of the copper shielding this year. 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 76 ± 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 6.0 mrem/y, so that individual results in the range of 76 ± 12

TABLE 19

Environmental Penetrating Radiation at ANL, 1985

Location	Dose Rate (mrem/year) Period of Measurement 1/8-4/9	4/9-7/17	7/17-10/16	10/16-1/9	Average
14L - Boundary	64	50	66	61	60 ± 1
14I - Boundary	103	-	-	96	100 ± 44
14G - Boundary	73	75	79	83	77 ± 7
9/10EF - Boundary	69	74	77	72	73 ± 5
8H - Boundary	88	73	79	75	79 ± 11
8H - Boundary, Center, St. Patrick's Cemetery	87	81	84	77	82 ± 7
7I - Boundary	1060	1060	1060	584	941 ± 379
6I - 200 m N of Quarry Road	80	76	82	77	79 ± 4
9L - Boundary	60	-	-	-	60
9H - 50 m SE of CP-5	664	529	538	598	582 ± 99
8H - 65 m S of Building 316	79	62	74	66	70 ± 12
8H/I - 200 m NW of Waste Storage Area Building 317	153	83	105	85	106 ± 52
7I - Center, Waste Storage Area Building 317	7900	8050	7960	6500	7600 ± 1170
10/11K - Lodging Facilities	60	63	67	64	64 ± 5
9J - Between ZGS Condenser and Building 370	55	-	-	-	55
13J - 135 m E of Building 202	254	-	-	-	254
12M - 30 m W of Building 55	62	-	-	-	62
9I - 65 m NE of Building 350, 230 m NE of Building 316	74	66	68	68	69 ± 6


B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
19
18
17
16
15
14
13
12
11
10
9
60
62
64
55
254
100
77
73
582
76
65
82
WATERFALL GLEN NATURE PRESERVE
EAST AREA
WEST AREA
ARGONNE PARK
ECOLOGY PLOT NO 5
ECOLOGY PLOT NO 4
ECOLOGY PLOT NO 3
ECOLOGY PLOT NO 6
ECOLOGY PLOT NO 7
ECOLOGY PLOT NO 1
LAND FILL AREA
METEOROLOGY EXPERIMENTAL AREA
OUTER CIRCLE
INNER CIRCLE
BLUFF ROAD
KEARNEY ROAD
WESTGATE ROAD
EASTWOOD DRIVE

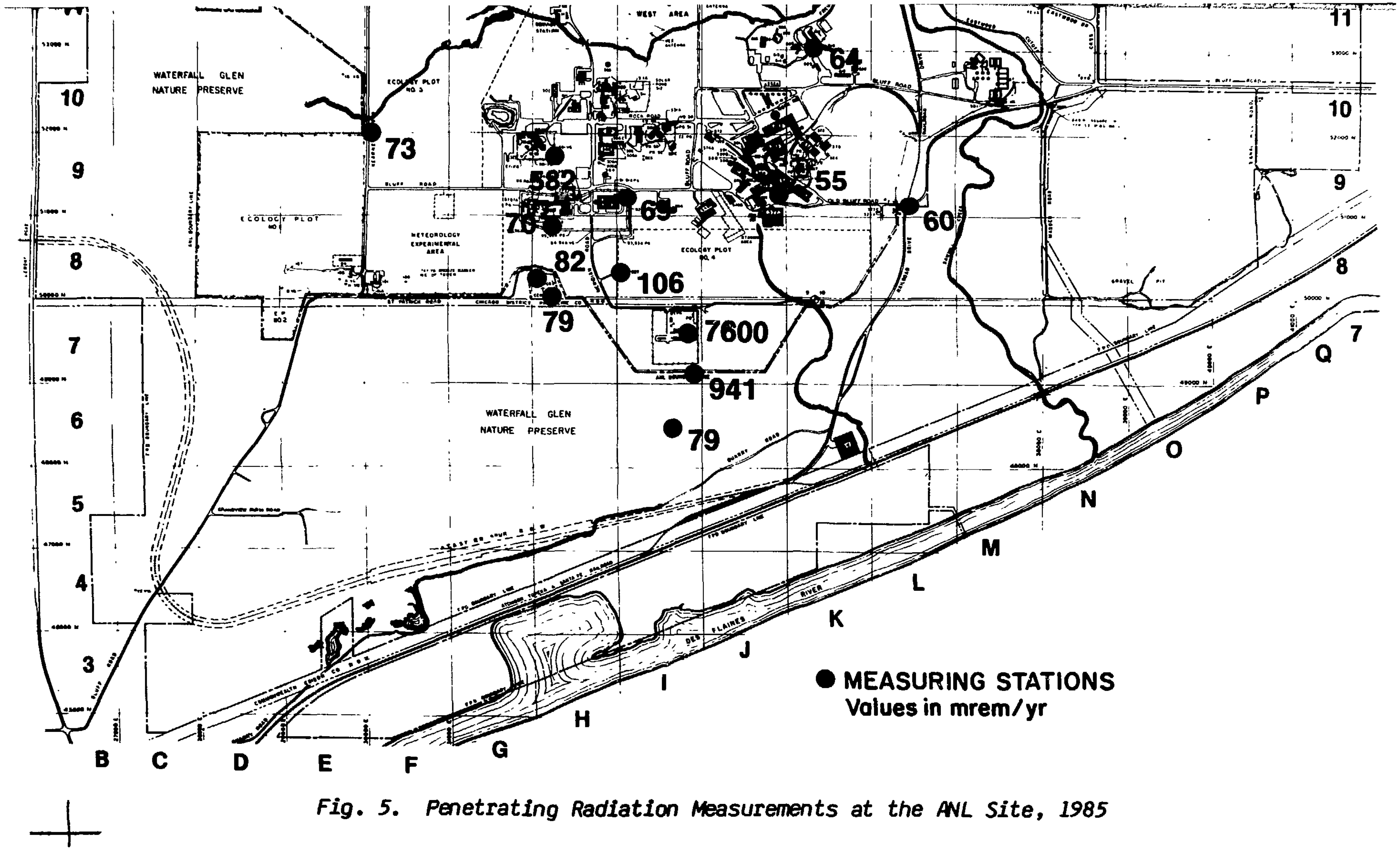


Fig. 5. Penetrating Radiation Measurements at the ANL Site, 1985

mrem/y may be considered normal 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 normal range. At 7I this was due to radiation from a Radioactive Waste Storage Facility 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-normal dose at this location was about 865 mrem/y, about twice the 1984 average. This increase resulted from an unusually large amount of repackaging of waste in this area. In previous years, this value has ranged from 560 mrem/y in 1980 to 114 mrem/y in 1977. About 300 m (0.2 mi) south of the fence in grid 6I, the measured dose dropped to 79 ± 4 mrem/y, within the normal range. The above-normal dose at the 8H/I Location, 200 m NW of the Waste Storage Area, about 24 mrem/y, is also due to the Storage Area, as discussed in the 1982 report.[12] At Location 14I, at the north boundary, the dose rate was 24 mrem/y above normal, about 25% higher than in 1984. This dose is due to the use of cobalt-60 irradiation sources in Building 202.

The dose in the south portion of grid 8H is of interest. This area includes St. Patrick's Cemetery, which was in use before Argonne was constructed and is open to visitors. In 1985, as in previous years, this dose is 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 normal 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.

7. Potential Radiation Dose Estimates

The radiation doses at the site boundary and off the site that could have been received by the public from radioactive materials and radiation leaving the site were calculated. These calculations are made for four exposure pathways; submersion, inhalation, ingestion, and direct radiation from external sources. DOE interim guidance[7] requires the use of the EPA-AIRDOSE/RADRISK model and computer program[15] for the calculation of the submersion dose for radionuclides released to the air. The inhalation and ingestion pathway calculations require the use of the DOE interim 50-year Committed Dose Equivalent Factors.[7]

a. Submersion Pathway

The EPA-AIRDOSE/RADRISK computer code uses a modified Gaussian plume equation to estimate both horizontal and vertical dispersion of radionuclides released to the air from stacks or area sources. For 1985, submersion dose calculations were carried out for carbon-11, argon-41, krypton-85, and radon-220. The annual release rates are those listed in Table 6. The wind speed and direction data shown in Figure 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 distant increments given in Table 1. The dose rate was calculated at the midpoint of each interval and integrated over the entire area to give the annual cumulative dose.

The highest perimeter dose rates are in the north to east sectors. 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 results are summarized in Table 20. The applicable DOE dose limits to members of the public are 500 mrem/y for occasional annual exposure (less than five years) and 100 mrem/y (more than five years) for continuous exposure.

The population data in Table 1 was used to calculate the cumulative population dose from gaseous radioactive effluents. The results are given in Table 21, 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 20

Submersion Dose From Airborne Emissions, 1985
(Millirems)

Nuclide	Quantity Released (Ci)	Maximum Perimeter	Maximum Individual
		50-Year	50-Year
Carbon-11	152	0.040	0.010
Argon-41	2.6	0.0010	0.0003
Krypton-85	127.6	0.0083	0.0028
Radon-220	2788	0.284	0.0088

TABLE 21

80 km Population Dose, 1985

Source	Man-Rems
	50-Year
Carbon-11	0.36
Argon-41	0.03
Krypton-85	0.53
Radon-220	0.07
Natural	6.00×10^5

b. Inhalation Pathway

The potential radiation exposures by the inhalation pathways were calculated by the methodology specified in the interim guidance.[7] The total quantity for each radionuclide inhaled, in μCi, is calculated by multiplying the annual average air concentrations by the general public breathing rate of 8400 m^3/y.[16] 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. are in units of Rem/μCi, this calculation gives the 50-year committed effective dose equivalent directly. The applicable EFF.D.E.s are collected in Table 22.

TABLE 22

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
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	-

The calculated doses in Tables 4, 5, and 7 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 interim guidance does not provide EFF.D.E.s for such measurements.

The other source of inhalation exposure is from the tritiated water vapor discharged from the stacks. The annual release rates and locations are given in Table 6. The concentrations at various distances and doses were calculated by a computer program based on an atmospheric dispersion model[17,18] and the hydrogen-3 EFF.D.E. from Table 22. The doses were calculated on the same basis as for the submersion pathway and are collected in Table 23.

TABLE 23

Hydrogen-3 Inhalation Dose, 1985

Maximum Perimeter	0.043 mrem
Maximum Individual	0.014 mrem
80 km Population Dose	2.14 man-rem

c. Ingestion Pathway

Similarly, following the methodology outlined in the interim guidance, the ingestion annual intake, in µCi, is obtained by multiplying the concentration (µCi/mL) by the annual water consumption by 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 22) 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 Argonne operations could be found in off-site water was Sawmill Creek below the wastewater 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 nuclides added to Sawmill Creek by Argonne waste water, their net concentrations in the Creek and the corresponding dose rates, if water at these concentrations were used as the sole water supply by an individual, are given in Table 24. The dose 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.

TABLE 24

Radionuclide Concentrations and Dose Estimates
for Sawmill Creek Water, 1985

Nuclide	Total Released (Millicuries)	Net Avg. Conc. (10^{-9} µCi/mL)	Dose (mrem/year)
Hydrogen-3	7400	490	0.0225
Strontium-90	0.1	0.01	0.00095
Neptunium-237	0.06	0.0037	0.00105
Plutonium-239	0.04	0.0024	0.00075
Americium-241	0.04	0.0025	0.00402
Sum			0.0293

As indicated in Table 8, 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 due to an individual consuming water at these concentrations can be calculated as was done 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.[11] For hydrogen-3, the EPA standard is 2×10^{-5} µCi/mL and for strontium-90, it is 8×10^{-9} µCi/mL. The concentrations in Table 24 correspond to 2.4% (hydrogen-3) and 0.1% (strontium-90) of the EPA standards. No specific EPA standards exist for the transuranic nuclides.

d. External Direct Radiation Pathway

The TLD results in Section III.A.6. are used to calculate the radiation dose from external sources. Above-normal fenceline doses attributable to Argonne 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 Argonne was about 865 mrem/y. Approximately 300 m (0.3 mi) south of the fenceline (grid 6I), the measured dose was 79 ± 4 mrem/y, well within the normal range of the off-site average (76 ± 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 Area is about 0.04 mrem/y, if the energy of the radiation were the cesium-137 0.66 MeV gamma-ray and about 0.2 mrem/y if the energy were 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 24 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 dwelling some of the time.

e. Dose Summary

The total dose received by off-site residents was a combination of the separate pathways that contribute to this total: carbon-11, argon-41, krypton-85, and radon-220 submersion dose; hydrogen-3 inhalation dose; and cobalt-60 external radiation dose. The highest dose was about 0.15 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 3.1 man-rem.

B. Chemical Constituents

1. Surface Water

The environmental water data contained in this section were collected to ascertain the effectiveness of Argonne's effluent pollution controls and determine compliance with State regulations and National Pollutant Discharge Elimination System (NPDES) permits. The appropriate stream and effluent standards are listed in the STATE OF ILLINOIS RULES AND REGULATIONS, Title 35, Subtitle C, Chapter I.[19] Stream Quality Standards appear in Part 302, Subpart B and Effluent Quality Standards appear in Part 304, Subpart A of that document. All of the results are compared to the State standards, which are listed in Table 25. Minimum detectable amounts are included for comparison. The detection limits for atomic absorption methods represent twice the background variation, which is commonly used for this purpose. Detection limits for ion selective methods are those listed by the manufacturer. The lower limit of detection for x-ray fluorescence is based on the appropriate counting statistics.

The analytical methods have been described in previous reports in this series. The results of measurements for chemical constituents are expressed as milligrams (mg) or micrograms (μg) per liter (L). Averages were calculated as described in Section III.A. Yearly averages are reported with a (±) limit value. This value is the standard error at the 95% confidence limit and is calculated from the standard deviation of the yearly average. Only when sample concentrations are random does this value represent the actual distribution occurring at the sampling location. As in the past, emphasis has been placed on Sawmill Creek, since this is the principal route for waste water leaving the Argonne site, and on the NPDES permit locations.

TABLE 25

Water Quality Standards and Detection Limits
(Concentrations in mg/L)

Constituent	State Standard Stream	 Effluent	Detection Limit
Ammonia Nitrogen (as N)	1.5	2.5 (Apr.-Oct.) 4.0 (Nov.-Mar.)	0.1
Arsenic	1.0	0.25	0.005
Barium	5.0	2.0	0.002
Cadmium	0.05	0.15	0.0002
Chloride	500	-	1.0
Chromium	1.0	1.0	0.001
Copper	0.02	1.0	0.0008
Cyanide	0.025	0.025	0.020
Fluoride	1.4	15	0.02
Iron	1.0	2.0	0.10
Lead	0.1	0.1	0.002
Manganese	1.0	1.0	0.001
Mercury	0.0005	0.0005	0.0001
Nickel	1.0	1.0	0.003
pH	6.5-9.0	6.0-9.0	-
Selenium	1.0	-	0.005
Silver	0.005	0.1	0.0002
Sulfate	500	-	1.0
Total Dissolved Solids	1000	-	-
Zinc	1.0	1.0	0.01

a. Waste Treatment Plant Effluent Water

The major discharge of waste water from Argonne operations is by way of the waste treatment plant. The water volume from this source was approximately 3.0 megaliters (0.81 million gallons) per day in 1985 and was comprised of 50% sanitary waste water and 50% water from laboratory operations. Laboratory waste is directed to a large holding pond with an overflow which controls the flow to about 1300 liters/minute (350 gallons/minute). The discharge occurs over a 24-hour period. Since the sanitary system is fairly constant, the overall output is constant.

Water from the waste treatment plant is collected on a continuous basis during the work week. A flow proportional 24-hour sample of the combined sanitary and laboratory effluent is obtained each day and analyzed for constituents of interest.

Past experience has shown that levels of arsenic, barium, beryllium, cadmium, lead, nickel, selenium, silver, and zinc in the effluent were normally 5% or less than the State limits. In addition, the analytical sensitivity is such that very low levels of these constituents can be determined. On this basis, effluent samples to be analyzed for these constituents were composited on a monthly basis. If results approached the State limit, the individual samples could be analyzed to determine if the value of any sample was equal to the limit.

The results obtained for chemical constituents in the effluent water from the treatment plant are shown in Table 26. All of the average concentrations were below the State standards. The average value for mercury was 60% of the State standard and 12% of the samples exceeded this value. The corresponding values for 1984 were 88% and 31%. Efforts are continuing to lower mercury levels by monitoring the waste water retention tanks most likely to contain mercury, and treating those tanks containing elevated concentrations. This year's results indicate a substantial improvement over previous years. Concentrations of all the other constituents are similar to last year's values and are not due to Argonne operations.

TABLE 26
CHEMICAL CONSTITUENTS IN EFFLUENTS FROM ANL TREATMENT PLANT, 1985
(CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	CONCENTRATION AVG.	CONCENTRATION MIN.	CONCENTRATION MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	12	-	-	< 5	< 2.0	0
BARIUM	22	18 ± 4	2	36	0.9	0
BERYLLIUM	12	0.04 ± 0.01	0.01	0.08	-	-
CADMIUM	22	0.6 ± 0.1	< 0.2	1.4	0.4	0
CHROMIUM	50	7.6 ± 0.9	2	20	-	-
COPPER	51	21 ± 1	13	33	2.1	0
FLUORIDE	22	367 ± 78	236	980	2.4	0
IRON	51	212 ± 29	118	858	11	0
LEAD	22	2.3 ± 0.5	< 2.0	5.2	2.3	0
MANGANESE	51	34 ± 6	9	123	3.4	0
MERCURY	51	0.30 ± 0.08	0.05	1.72	60	12
NICKEL	22	8 ± 3	3	24	0.8	0
PH	244	-	6.9	8.1	-	0
SELENIUM	12	-	-	< 5	< 0.5	0
SILVER	22	2.1 ± 0.4	0.4	3.4	2.1	0
ZINC	22	82 ± 78	26	870	8.2	0

b. National Pollutant Discharge Elimination System (NPDES)

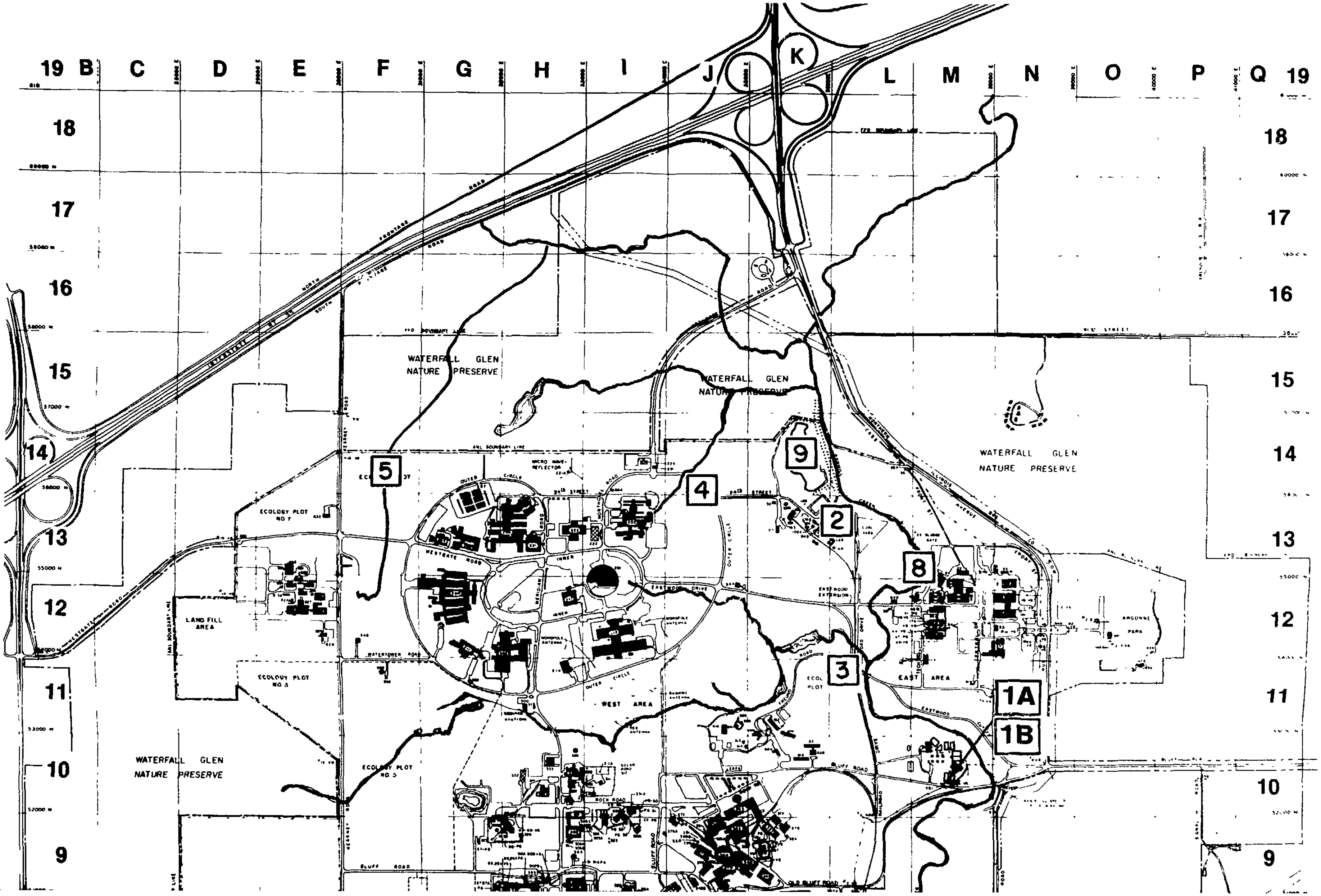
The Laboratory discharges are regulated by NPDES Permit #IL 0034592. This permit is subject to renewal about every three to five years. Effective October 1984, this permit was renewed to March 1, 1989, and several revisions of requirements have occurred. The locations previously described[4] and shown in Figure 6 remain the same. For purposes of clarity, the location numbers in the figure are given without the zeros. Thus, permit Location 001 is shown in the figure as 1. The location formerly denoted as 001 (waste treatment plant) has been divided into 001A (sanitary waste) and 001B (laboratory waste). Requirements for the combined effluent are still listed under Location 001.

Requirements for total dissolved solids and residual chlorine have been eliminated. Measurement of fats, oil, and greases (FOG) were added to all locations except 001, 007, and 008. In October 1985, this requirement was removed and only Location 005 was tested for FOG. Chemical oxygen demand has been added to Location 001B (laboratory waste) and zinc has been added to Location 006. The limit for mercury has been changed from an overall limit of 0.5 µg/L to a 30-day average of 3 µg/L and a daily maximum of 6 µg/L.

All samples collected at Locations 001A, 001B, and 001 were collected weekly. All other samples were collected monthly. Results for 1985 are in Table 27. Total suspended solids occasionally exceeded the permit levels at several locations, usually when excessive rainfall occurred. The levels at Location 004 exceeded the limit on four occasions due to nearby construction activities. One sample exceeded the limit for fecal coliform, presumably due to low chlorine levels. The water that is discharged at Location 009 always has a pH greater than the limit of 9.0 because it contains water treatment chemicals. The limit for mercury was exceeded on one occasion.

c. Sawmill Creek

Samples collected for evaluation of the effect of the sanitary waste on stream quality were obtained once per week using specially constructed


19 B C D E F G H I J K L M N O P Q 19
18
17
16
15
14
13
12
11
10
9
1A
1B
2
3
4
5
8
9
(14)
WATERFALL GLEN NATURE PRESERVE
WATERFALL GLEN NATURE PRESERVE
WATERFALL GLEN NATURE PRESERVE
WATERFALL GLEN NATURE PRESERVE
ECOLOGY PLOT NO 7
ECOLOGY PLOT NO 3
ECOLOGY PLOT NO 5
ECOL PLOT
LAND FILL AREA
ANL BOUNDARY LINE
WEST AREA
EAST AREA
ARGONNE PARK
OUTER CIRCLE
INNER CIRCLE
WESTGATE ROAD
EASTWOOD DRIVE
EASTWOOD EXTENSION
BLUFF ROAD
OLD BLUFF ROAD
ROCK ROAD
WATERTOWER ROAD
MICRO WAVE REFLECTOR
NORTHGATE ROAD
NORTH FRONTAGE ROAD
SOUTH FRONTAGE ROAD
91st STREET
EASTWOOD

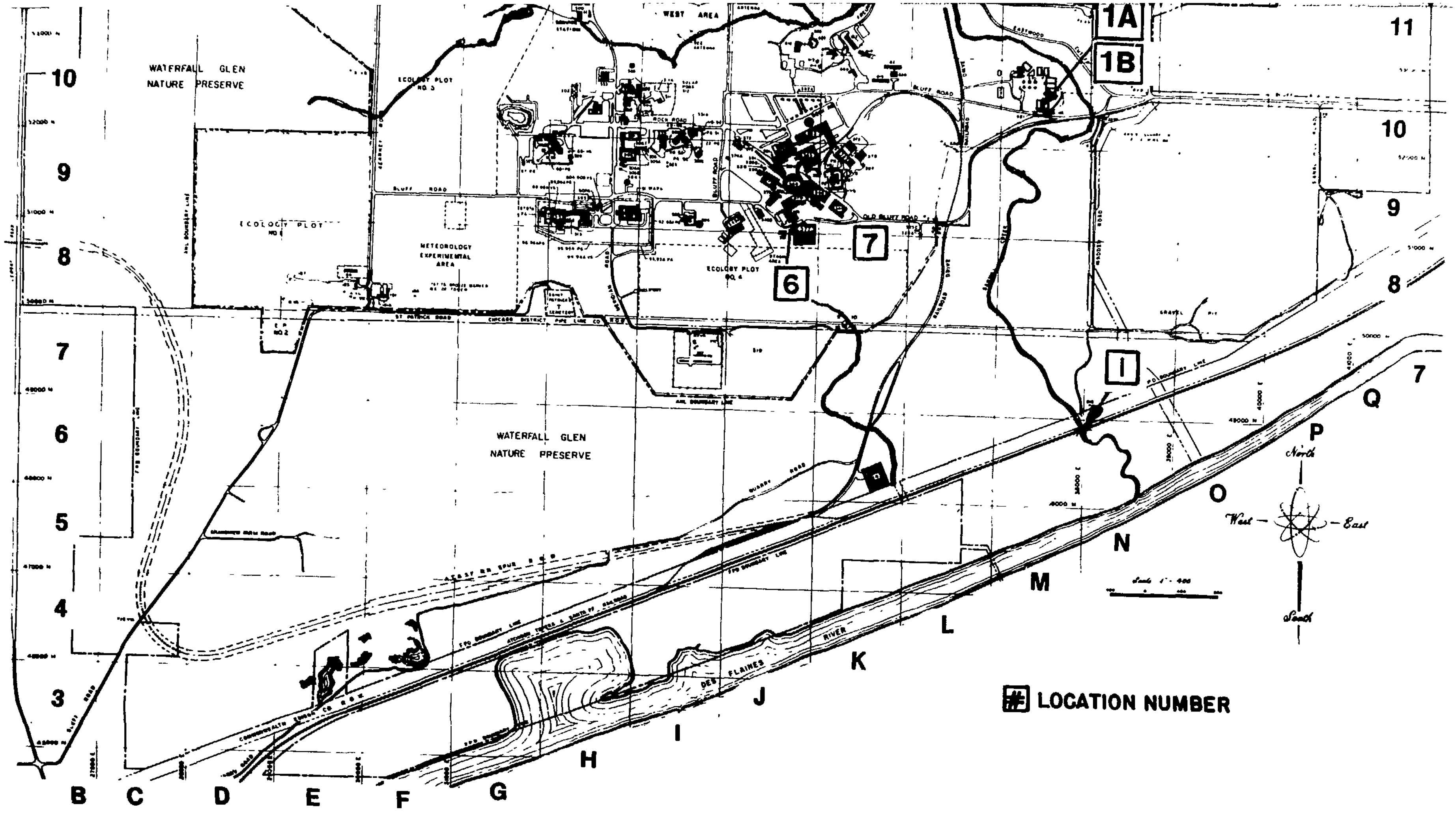


Fig. 6. NPDES Permit Locations

TABLE 27

NPDES Effluent Quality Summary, 1985

Discharge Location	Permit Constituent	Concentration Limits mg/L 30 Day Average	Daily Max.	Number Exceeding Limit	$*_R$ $\frac{\text{Measured}}{\text{Permit}}$
001A	Flow	None		0	-
	BOD	30	60	0	-
	TSS	30	60	0	-
001B	Flow	None		0	-
	Chemical Oxygen Demand	-	-	0	-
	TSS	15	30	2	1.6-2.3
	Mercury	0.003	0.006	1	1.2
001	pH	6-9		0	-
	Fecal Coliform	-	$\frac{400\ \text{organisms}}{100\ \text{mL}}$	1	83.5
	BOD	30	60	0	-
	TSS	30	60	0	-
002	Flow	None		0	-
	pH	6-9		0	-
	TSS	15	30	0	-
	Temperature	< 2.8°C Rise		0	-
	FOG	-	-	0	-
003	Flow	None		0	-
	pH	6-9		0	-
	TSS	15	30	1	1.3
	Temperature	< 2.8°C Rise		0	-
	FOG	-	-	0	-

TABLE 27 (contd)

Discharge Location	Permit Constituent	Concentration Limits mg/L 30 Day Average	Concentration Limits mg/L Daily Max.	Number Exceeding Limit	*R Measured/Permit
004	Flow	None		0	-
	pH	6-9		0	-
	TSS	15	30	4	1.0-3.6
	Temperature	< 2.8°C Rise		0	-
	FOG	-	-	0	-
005	Flow	None		0	-
	pH	6-9		0	-
	Temperature	< 2.8°C Rise		0	-
	FOG	15	30	0	-
006	Flow	None		0	-
	pH	6-9		1	9.7
	TSS	15	30	4	1.1-1.2
	Zinc	1.0	2.0	0	-
	FOG	-	-	0	-
007	Flow	None		0	-
	pH	6-9		1	9.1
	Temperature	< 2.8°C Rise		0	-
008	Flow	None		0	-
	pH	6-9		0	-
	FOG	-	-	0	-
009	Flow	None		0	-
	pH	6-9		12	All > 9
	TSS	15	30	3	1.3-3.8
	FOG	-	-	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).

sampling bottles. The sampling bottles were designed to provide temperature measurements as well as to minimize changes in oxygen content during collection. These samples were collected 15 m (50 ft) upstream of the Argonne wastewater outfall [7M (up)] and 100 m (310 ft) downstream of the outfall [7M (down)].

The data from these studies are in Table 28. Average levels for ammonia nitrogen were below the State limit at both locations for the third year after having always exceeded this limit in the past. The dissolved oxygen levels obtained during 1985 were all above the State minimum of 5 mg/L. The total dissolved solids above the outfall exceeded the State standard in 61% of the samples, and produced elevated dissolved solids levels downstream. Chloride levels were 65% of the State limit upstream and 60% downstream. All samples exceeding the limit downstream could be related to upstream levels.

Samples to evaluate the effect of combined sanitary and laboratory waste on the concentrations of chemical constituents in Sawmill Creek were collected by a continuous sampler in the Creek five times per week. These were the same samples taken for radioactivity analyses. The results are summarized in Table 29.

None of the individual samples for arsenic, barium, cadmium, chromium, fluoride, lead, manganese, mercury, nickel, selenium, silver, and zinc exceeded the State stream standards. As in the past, high iron levels reflect high turbidity conditions and are not related to Argonne releases. The level of copper exceeded State stream quality limits in 4% of the samples, but this is not due to ANL operations because the average stream and effluent copper concentrations differ by a factor of two, but the effluent water is diluted by about a factor of ten with stream water. The copper is believed to be of natural origin.

d. Des Plaines River

The effect of Sawmill Creek on the Des Plaines River was evaluated by collecting samples at Willow Springs (upstream of Argonne) and at Lemont

TABLE 28

SAWMILL CREEK - EFFECT OF SANITARY WASTE, 1985

CONSTITUENT	* LOCATION	NO. OF SAMPLES	CONCENTRATION (MG/L) AVG.	MIN.	MAX.	AVG. PERCENT OF STANDARD	PERCENT EXCEEDING STATE STANDARD
AMMONIA NITROGEN	7M (UP)	48	0.3 ± 0.1	0.1	1.1	19	0
	7M (DOWN)	48	0.3 ± 0.1	0.1	1.3	23	0
CHLORIDE	7M (UP)	48	324 ± 40	72	649	65	10
	7M (DOWN)	48	299 ± 36	79	645	60	8
CYANIDE	7M (DOWN)	48	-	-	< 0.02	45	0
DISSOLVED OXYGEN	7M (UP)	48	10.9 ± 0.6	7.8	15.8	-	0
	7M (DOWN)	48	10.7 ± 0.5	7.8	15.6	-	0
DISSOLVED SOLIDS	7M (UP)	46	1120 ± 110	420	1730	112	61
	7M (DOWN)	46	1020 ± 97	410	1690	102	57
** PH	7M (UP)	48	-	7.5	8.7	-	0
	7M (DOWN)	48	-	7.6	8.6	-	0
SULFATE	7M (UP)	48	149 ± 15	47	267	30	0
	7M (DOWN)	48	157 ± 15	47	307	31	0
TEMPERATURE ***	7M (UP)	48	14.1 ± 2.1	0.0	25.7	-	-
	7M (DOWN)	48	14.3 ± 2.1	0.3	25.3	-	-

---

* 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 29

CHEMICAL CONSTITUENTS IN SAWMILL CREEK LOCATION 7M,* 1985
(CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	CONCENTRATION AVG.	MIN.	MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	12	-	-	< 5	< 0.5	0
BARIUM	22	70 ± 11	37	130	1.4	0
BERYLLIUM	12	0.05 ± 0.02	0.02	0.13	-	-
CADMIUM	22	0.8 ± 0.2	0.1	1.8	1.7	0
CHROMIUM	51	6 ± 1	2	14	-	-
COPPER	51	12 ± 1	6	33	61	4
FLUORIDE	21	512 ± 67	260	714	37	0
IRON	51	550 ± 126	150	2430	55	10
LEAD	22	5 ± 2	2	22	5.3	0
MANGANESE	51	48 ± 10	10	234	4.8	0
MERCURY	51	0.06 ± 0.01	< 0.05	0.26	13	0
NICKEL	22	24 ± 12	3	118	2.4	0
PH	244	-	7.3	8.6	-	0
SELENIUM	12	-	-	< 5	< 0.5	0
SILVER	51	1.4 ± 0.2	0.3	3.3	28	0
ZINC	22	34 ± 6	15	74	3.4	0

---

* LOCATION 7M IS 60 M (200 FT) DOWNSTREAM FROM THE WASTE-WATER OUTFALL.

(downstream of Argonne). These samples were analyzed for total mercury, total iron, and total zinc until April 1985, after which time only mercury was determined. The results are in Table 30. In no case was there any indication that mercury levels were affected by the Argonne effluent.

2. Ground Water

A sanitary landfill for non-radioactive waste is located on the western edge of the Argonne site (Figures 1 and 7). This landfill operates under Illinois EPA permit No. 1981-29-OP and is further described in Reference 12. Operation of the ANL landfill began in July, 1966. During the period 1969-1978, substantial quantities of liquid organic and inorganic waste were disposed of on-site by adding them to an open "French drain" located in the northeast sector of the landfill.[2] This practice was discontinued several years ago.

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. 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 in the landfill itself. In April, 1980,[20] a more comprehensive study was initiated. Three additional test wells were placed in 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 southeasterly direction. Wells 7a and 7b were nested and were installed to measure vertical water movement as well as to provide monitoring of water from two depths. Test borings were also made in the fill area to determine soil conditions where refuse had been added.

The study established the following important characteristics. There is a lateral perched water condition at a depth 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 which permit lateral flow. Additionally, regional groundwater flow patterns confirm that the flow is generally southerly.

TABLE 30

CHEMICAL CONSTITUTENTS IN THE DES PLAINES RIVER, 1985

CONSTITUENT	LOCATION*	NO. OF SAMPLES	CONCENTRATION(MICROGRAM/LITER) AVG.	MIN.	MAX.
IRON	A	3	761 ± 893	280	1250
	B	6	594 ± 428	155	1220
MERCURY	A	12	-	-	< 0.05
	B	23	-	-	< 0.05
ZINC	A	3	31 ± 2	30	32
	B	6	30 ± 7	22	38

---

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

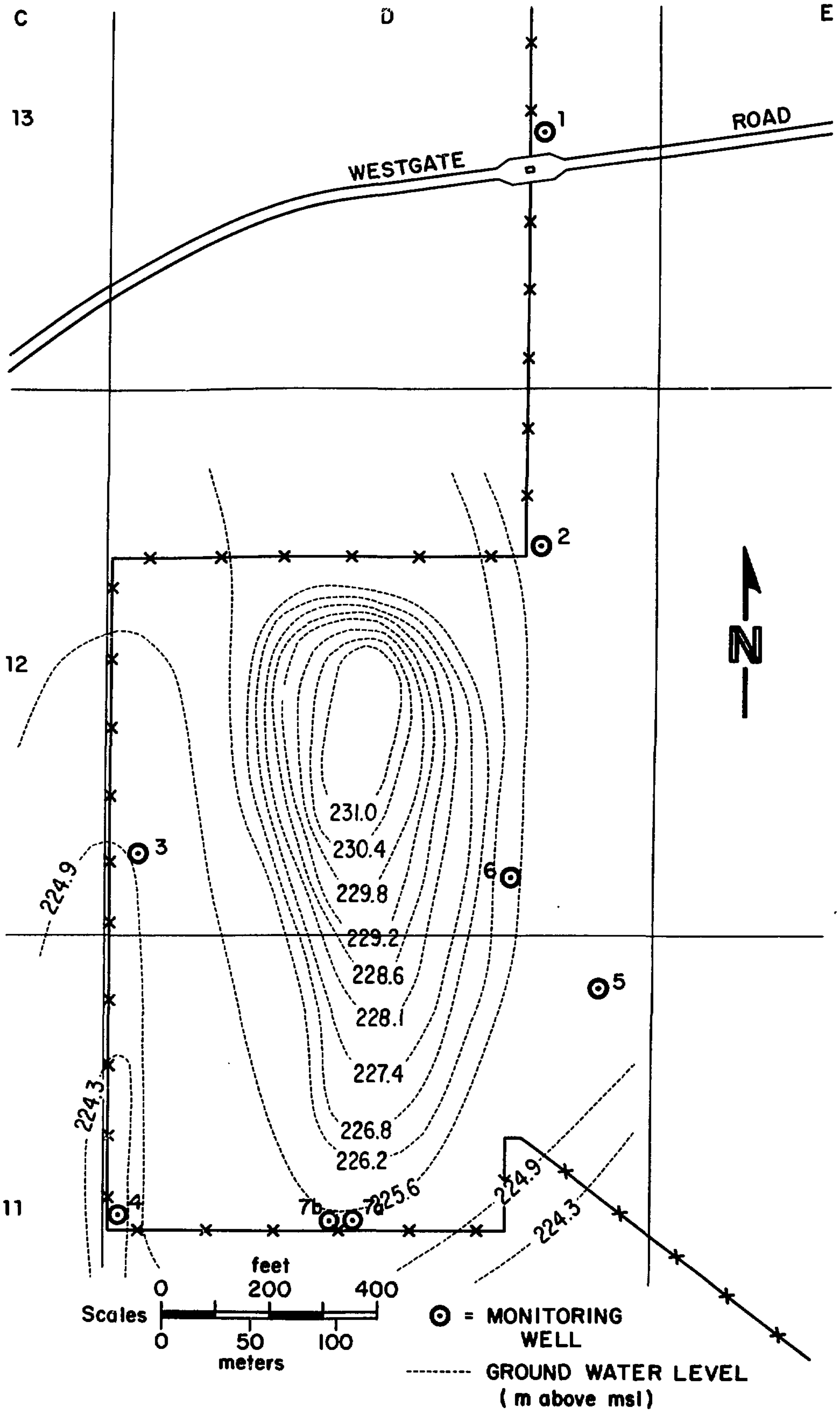


Fig. 7. Monitoring Well Locations for Landfill

These 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 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 little downward movement is occurring. If this movement were occurring, this stratum would be saturated.

All of the wells have been studied from 1979 until the present to determine constancy of water levels, recharge rates, and chemical characteristics. The water levels, measured quarterly, for 1985 are shown in Table 31. In addition, the precipitation for a 30-day period prior to sampling and the average levels for 1980-1984 are shown. The average water levels for Wells 1-4 were similar in 1985 to the 1980-1984 average . The average water levels in Wells 6 and 7a were much higher in 1985 than the 1980-1984 average. However, little change in water levels of Wells 6 and 7a occurred between 1984 and 1985. Wells 6 and 7a are believed to be better prepared and sealed than the other wells and are more accurate measures of the condition of the ground water. Water level measurements obtained in the third quarter, which was preceded by a low precipitation level of 46.2 mm, showed a moderate drop in water levels in Wells 1-4. Wells 6 and 7a showed a large decrease (about 3 m each).

Sampling was performed by removing one well volume of water and discarding it. The sample for analysis was obtained after water levels had re-established. This required up to 24 hours to occur. A submersible pump was used to obtain these samples.

On the basis of past data, selected elements were studied in all wells in 1985. Well 1 (Table 32) has persistently high chloride and total dissolved solid levels. The proximity of this well to Westgate Road and its rapid recharge rate indicates that surface runoff has free access to this well and that the chloride comes from salt used for deicing.

TABLE 31

Well Point and Water Level Elevations(1) of Monitoring Sites at the ANL Landfill

Well No.	Ground Surface Elevation	Well Point Elevation	Quarterly Measurements				Average	
			1st	2nd	3rd	4th	1985	1980-84
1	227.53	218.23	227.17	226.07	225.03	226.86	226.28	226.49
2	230.58	220.83	226.04	225.31	224.39	225.61	225.34	225.65
3	226.77	218.08	224.67	224.27	223.33	224.24	224.13	224.39
4	227.23	221.13	225.37	225.19	224.42	225.31	225.07	225.08
5	227.53	215.34	*	*	**	*	-	220.64
6	229.91	215.13	223.81	224.15	220.80	224.70	223.37	220.56
7a	227.81	220.19	226.28	225.77	222.78	226.50	225.33	222.82
7b	227.81	214.09	**	**	**	**	**	**
(2)	-	-	127.8	63.5	46.2	89.9	81.9	61.5

*Not measured.

**Dry.

Notes: (1) All measurements are in meters above mean sea level.

(2) Precipitation in millimeters for 30 day period prior to measurements.

TABLE 32

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 1
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	217 ± 150	134	375
CHLORIDE*	4	998 ± 243	848	1210
DISSOLVED SOLIDS*	4	2290 ± 690	1820	2910
FLUORIDE	4	150 ± 14	138	160
IRON	4	637 ± 920	160	1610
MANGANESE	4	218 ± 51	177	266
MERCURY	4	-	-	< 0.05
PH	4	-	7.0	7.1
SELENIUM	4	-	-	< 5
SULFATE*	4	147 ± 62	105	191
TEMPERATURE**	4	12.6	10.0	14.7

---

* CONCENTRATION IN MILLIGRAM/LITER.

** DEGREES CENTIGRADE

Well 2 (Table 33) has had a pH of 11 or greater from the beginning of sampling until the last two years. This was presumably due to the nearby disposal of carbonate-type water softening materials. The high pH water was confined to this area since no other wells have had elevated, or even changing pH values. The pH of samples obtained in 1985 were successively 8.5, 8.8, 7.6, and 8.7. This indicates the continued depletion of the source of basicity.

Well 3 (Table 34) is characterized by the presence of arsenic but at much lower levels than in previous years. The levels have changed regularly from a high of 35 µg/L in 1983 to current levels of about 5 µg/L, which is near the detection limit. The levels of iron and manganese are lower than in past years. Chloride and sulfate levels are very low. The source of the arsenic is probably buried waste and the results indicate depletion is occurring by dilution. Arsenic has not been found in any other well, indicating little hydraulic connection between them.

Well 4 (Table 35) continues to show high levels of manganese but relatively low iron levels. In addition, high levels of sulfate were found. This well has a fast recharge rate and is located close to a ditch which drains a marshy area. This ditch was sampled in 1984 and once in 1985. No unusual values were seen with the exception of an elevated chloride level which could be related to runoff from the road. Both manganese and sulfate levels are low. This would indicate little or no connection between the ditch and Well 4.

Well 6 (Table 36) contains very high levels of iron and manganese and moderate to high levels of chloride and sulfate. The elevated concentrations are probably due to manganese sulfate and ferric chloride disposed of in the landfill during previous years. Results from Well 7a (Table 37) are about the same as in past years with no outstanding characteristics.

The most characteristic factor in the results is the constancy of the pH values at each well. With the exception of Well 2, which was previously discussed, the pH values of each well tested in 1985 are the same as

TABLE 33

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 2
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	187 ± 91	111	243
CHLORIDE*	4	23 ± 3	21	25
DISSOLVED* SOLIDS	4	284 ± 66	252	353
FLUORIDE	4	122 ± 13	112	132
IRON	4	-	-	< 100
MANGANESE	4	14 ± 14	6	28
MERCURY	4	0.06 ± 0.03	< 0.05	0.10
PH	4	-	7.6	8.8
SELENIUM	4	-	-	< 5
SULFATE*	4	80 ± 9	71	86
TEMPERATURE**	4	11.6	9.9	13.2

---

* CONCENTRATION IN MILLIGRAM/LITER.

** DEGREES CENTIGRADE

TABLE 34

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 3
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	7 ± 3	< 5	10.0
BARIUM	4	308 ± 77	229	353
CHLORIDE*	4	3 ± 3	1	6
DISSOLVED SOLIDS*	4	753 ± 47	721	784
FLUORIDE	4	128 ± 22	106	144
IRON	4	742 ± 856	128	1600
MANGANESE	4	176 ± 18	168	196
MERCURY	4	-	-	< 0.05
PH	4	-	6.7	6.9
SELENIUM	4	-	-	< 5
SULFATE*	4	37 ± 12	28	48
TEMPERATURE**	4	11.0	9.9	13.0

---

*CONCENTRATION IN MILLIGRAM/LITER.

**DEGREES CENTIGRADE

TABLE 35

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 4
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	206 ± 148	86	301
CADMIUM	1	-	-	0.80
CHLORIDE*	4	297 ± 240	129	533
COPPER	1	-	-	8
DISSOLVED SOLIDS*	4	1410 ± 770	910	2190
FLUORIDE	4	190 ± 22	168	206
IRON	4	266 ± 229	100	493
LEAD	1	-	-	2
MANGANESE	4	991 ± 338	653	1200
MERCURY	4	-	-	< 0.05
NICKEL	1	-	-	11
PH	4	-	6.7	6.9
SELENIUM	4	-	-	< 5
SILVER	1	-	-	0.30
SULFATE*	4	386 ± 324	219	722
TEMPERATURE**	4	10.9	8.7	15.2
ZINC	1	-	-	20

---

* CONCENTRATION IN MILLIGRAM/LITER.

** DEGREES CENTIGRADE

TABLE 36

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 6
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	CONCENTRATION AVG.	MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	196 ± 119	149	324
CHLORIDE*	4	169 ± 55	134	204
DISSOLVED SOLIDS*	4	1230 ± 150	1080	1320
FLUORIDE	4	117 ± 20	100	130
IRON	4	11100 ± 7920	4150	17900
MANGANESE	4	3700 ± 1740	2880	5570
MERCURY	4	-	-	< 0.05
PH	4	-	6.5	6.6
SELENIUM	4	-	-	< 5
SULFATE*	4	156 ± 65	123	225
TEMPERATURE**	4	11.7	10.4	12.8

---

* CONCENTRATION IN MILLIGRAM/LITER.

** DEGREES CENTIGRADE

TABLE 37

CHEMICAL CONSTITUENTS AT ANL LANDFILL
WELL 7A
(CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	154 ± 57	115	203
CHLORIDE*	4	17 ± 17	6	30
DISSOLVED SOLIDS*	4	526 ± 104	462	620
FLUORIDE	4	129 ± 11	120	138
IRON	4	-	-	< 100
MANGANESE	4	324 ± 75	247	372
MERCURY	4	-	-	< 0.05
PH	4	-	7.2	7.3
SELENIUM	4	-	-	< 5
SULFATE*	4	120 ± 38	93	150
TEMPERATURE**	4	10.4	8.8	12.6

---

* CONCENTRATION IN MILLIGRAM/LITER.

** DEGREES CENTIGRADE.

1984 values within 0.1 pH unit, although different from each other. It appears that some buffering system is available in each which maintains the pH. In addition, arsenic is found in only Well 3 at about the same level, and manganese in Wells 4 and 6 is high and fairly constant. It does not appear that water is moving from one well site to another and some type of equilibrium exists in each well.

Samples for organic analyses were collected in serum bottles which were immediately sealed with teflon septa using a crimping tool. The samples were refrigerated until analysis. The samples were extracted with n-pentane and analyzed by gas chromatography with mass spectrophotometric detection. The mass spectra were acquired using the pre-selected masses which increases sensitivity and provides for scanning of compound groups such as halogenated hydrocarbons and benzene derivatives. Results indicated concentrations of benzene, toluene, ethylbenzene, and xylene of less than 10 μg/L. Levels for trichloroethylene and perchloroethylene were less than 20 μg/L. These studies will continue using this sensitive and selective detection method.

IV. APPENDIX

A. References

1. U. S. Department of Energy, EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM REQUIREMENTS, DOE DRAFT ORDER 5484.1A, CHAPTER III (1984).

2. ENVIRONMENTAL ASSESSMENT RELATED TO THE OPERATION OF ARGONNE NATIONAL LABORATORY, Argonne National Laboratory, Argonne, Illinois, DOE/EA-0181, August 1982.

3. H. Moses and M. A. Bogner, "Fifteen-Year Climatological Summary, Jan. 1, 1950-Dec. 31, 1964." U.S.A.E.C. Report ANL-7084 (September, 1967); H. Moses and J. H. Willett, "Five-Year Climatological Summary, July 1949-June 1954," U.S.A.E.C. Report ANL-5592.

4. N. W. Golchert, T. L. Duffy, and J. Sedlet, "Environmental Monitoring at Argonne National Laboratory, Annual Report for 1984," U.S.D.O.E. Report ANL-85-17 (March 1985).

5. ICRP Publication 26, "Recommendations of the International Commission on Radiological Protection," ANNALS OF THE ICRP, Vol. 1, No. 3, Pergamon Press (1977); ICRP Publication 30, "Limits for Intakes of Radionuclides by Workers," Ibid (1978, et seq).

6. U. S. Department of Energy, REQUIREMENTS FOR RADIATION PROTECTION, DOE Order 5480.1, Chapter XI (1981).

7. J. P. Corley (Ed.), COMMITTED DOSE EQUIVALENT TABLES FOR U. S. DEPARTMENT OF ENERGY POPULATION DOSE CALCULATIONS, prepared for the U. S. Department of Energy - Office of Operational Safety by Pacific Northwest Laboratory, Richland, WA, DOE/EH, 1985.

8. N. W. Golchert, T. L. Duffy, and J. Sedlet, "Environmental Monitoring at Argonne National Laboratory, Annual Report for 1979," U.S.D.O.E. Report ANL-80-29 (March 1980).

9. N. W. Golchert and J. Sedlet, "Radiochemical Determination of Plutonium in Environmental Water Samples," RADIOCHEM. RADIOANAL. LETTERS, 12, 215 (1972).

10. N. W. Golchert and J. Sedlet, "Determination of Transuranics in Environmental Water," in M. H. Campbell (Ed.), HIGH-LEVEL RADIOACTIVE WASTE MANAGEMENT (Proceedings of a Symposium, American Chemical Society, April 1-2, 1974), American Chemical Society, Washington, DC, 1976, p. 152.

11. "National Interim Primary Drinking Water Regulations," Report EPA-570/9-76-003, Environmental Protection Agency, Office of Water Supply, U. S. Government Printing Office, Washington, DC.

12. N. W. Golchert, T. L. Duffy, and J. Sedlet, "Environmental Monitoring at Argonne National Laboratory, Annual Report for 1982," U.S.D.O.E. Report ANL-83-26 (March 1983).

13. "Sampling Surface Soil for Radionuclides, C-998-83," 1983 ANNUAL BOOK OF ASTM STANDARDS, Vol. 12.01, p. 792. "Soil Sample Preparation for the Determination of Radionuclides, C-999-83," IBID, p. 796.

14. B. G. Bennett, "Environmental Aspects of Americium," U.S.D.O.E. Report EML-348, December, 1978.

15. R. E. Moore, C. F. Baes, III, L. M. McDowell-Boyer, A. P. Watson, F. O. Hoffman, J. C. Pleasant, and C. W. Miller, "AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides," Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-5532, June 1979.

16. ICRP Publication 23, "Reference Man: Anatomical, Physiological, and Metabolic Characteristics," International Commission on Radiological Protection, Pergamon Press, New York (1975).

17. J. F. Sagendorf and J. T. Goll, "XOQDOQ Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," U. S. Nuclear Regulatory Commission, NUREG-0324 (September 1977).

18. K. F. Eckerman, F. J. Congel, A. K. Roecklein, and W. J. Pasciak, "User's Guide to GASPAR Code," U. S. Nuclear Regulatory Commission, NUREG-0597 (June 1980).

19. State of Illinois, RULES AND REGULATIONS, Title 35; Environmental Protection Subtitle C; Water Pollution, Chapter 1, March 22, 1985.

20. APPLICATION FOR PERMIT TO DEVELOP AND/OR OPERATE A SOLID WASTE MANAGEMENT SITE, Soil Testing Services, Inc., Northbrook, IL, for Argonne National Laboratory, STS Job No. 14236-P, June 30, 1980.

B. Environmental Permits, Impact Statements, and Activities

The environmental permits in effect at ANL are shown in Table 38. As shown, all the permits have been issued by the Illinois Environmental Protection Agency (IEPA). The compliance status of the NPDES permit is discussed in Section III.B.1. The monitoring data obtained for the landfill are discussed in Section III.B.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 measured in the exhaust stack and the results reported to the IEPA. The Boiler is operating in compliance with the permit. The vapor recovery system for gas dispensing facilities was constructed, and is operating, as designed and satisfies its permit.

The environmental effects of new construction projects, modifications to facilities, and other activities that can have an environmental impact are evaluated before work is begun. During 1985, no draft or final Environmental Impact Statements or Environmental Assessments were completed, and

TABLE 38

Environmental Permits in Effect at ANL

Permit Type	Facility	Application/ Permit No.	Agency	Expires
Fossil Energy Users Laboratory (FEUL) Facility Air Emissions Permit	FEUL-MHD Building 145	ID 43802AAA App. C8012024	IEPA	9/13/86
Operating	ANL Steam Plant-ANL Boiler No. 5	ID 043802AAA D/02 App. 79090047	IEPA	7/23/86
Construct and Own	Water Pollution Control Facility Coal-Pile Runoff Containment Area	1980-EB-1568	IEPA	Covered by NPDES Permit 3/1/89
Construction Operation	Emco Wheaton coaxial vapor recovery system for gas dispensing facilities	HG490	IEPA	6/24/85
NPDES	Laboratory Water Effluents	IL0034592	IEPA	3/1/89
Sludge Drying Bed Replacement	Sanitary Plant Laboratory Plant	1981-EB-1776	IEPA	Covered by NPDES Permit 3/1/89
Lift Station Construction	For Boiler waste-water, coal-pile runoff overflow lime pond and water pond overflow	1982-HB-0402	IEPA	Operation covered by NPDES Permit 3/1/89
Operating	Landfill	1981-20-OP	IEPA	Special Conditions
Hazardous Waste Storage Facility-Operation RCRA	Buildings 325C and 306	IL3-890-008946	IEPA	Interim

no significant environmental activities or pollution abatement projects were undertaken.

C. Environmental Quality Standards, Detection Limits, Analytical Errors, and Quality Assurance

1. Standards

All of the standards and detection limits for chemical constituents, and some of those for radionuclides and external radiation, are given in the main body of the report. The standards used in this report for determining the population exposure are the EFF.D.E. factors provided in the DOE interim guidance.[7] The applicable EFF.D.E.s for calculating the committed dose due to inhalation and ingestion exposure are given in Table 22, Section III.A.7. Except for gaseous emissions, where the chemical form was generally known, the most restrictive EFF.D.E. was selected when more than one choice was available.

2. Detection Limits

The detection limits were chosen so that the measurement uncertainty at the 95% confidence level is equal to the measured value. In Table 39 are collected air and water detection limits (minimum detectable amounts) for all radionuclides, and for those materials, for which measurements were made. 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 10 times the detection limit, the error is about 10%.

3. Quality Assurance Program

a. Radiochemical Analysis and Radioactivity Measurements

All nuclear instrumentation is calibrated with standard sources obtained from the NBS, if possible. If NBS standards were not available for particular nuclides, standards from the Amersham Corporation were used.

TABLE 39

Detection Limits
(μCi/mL)

Nuclide or Activity	Detection Limit Water	Air
Americium-241	1×10^{-12}	-
Beryllium-7	-	5×10^{-15}
Californium-249	1×10^{-12}	-
Californium-252	1×10^{-12}	-
Cesium-137	-	1×10^{-16}
Curium-242	1×10^{-12}	-
Curium-244	1×10^{-12}	-
Hydrogen-3	1×10^{-7}	-
Neptunium-237	1×10^{-12}	-
Plutonium-238	1×10^{-12}	3×10^{-19}
Plutonium-239	1×10^{-12}	3×10^{-19}
Radium-226	1×10^{-10}	-
Strontium-89	2×10^{-9}	1×10^{-16}
Strontium-90	2.5×10^{-10}	1×10^{-17}
Thorium-228	-	1×10^{-18}
Thorium-230	-	1×10^{-18}
Thorium-232	-	1×10^{-18}
Uranium-234	-	1×10^{-19}
Uranium-235	-	1×10^{-19}
Uranium-238	-	1×10^{-19}
Uranium - natural	2×10^{-10}	2×10^{-17}
Alpha	2×10^{-10}	2×10^{-16}
Beta	1×10^{-9}	5×10^{-16}

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 1985 are given in Table 40. 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. To assist in judging the quality of the results, typical errors for our analyses are 2% to 50% depending on the concentration and the nuclide, and the errors 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. Results for 1985 are collected in Table 41. In the table, the comparison is made between the EML value, which is the result of replicate determinations by that Laboratory, and the value obtained in our laboratory. To assist in judging the quality of the results, typical errors for our analyses are 2% to 50% and the errors 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.

b. Penetrating Radiation

Our laboratory participated in the Seventh International Environmental Dosimeter Intercomparison Project conducted by the DOE Radiological and Environmental Sciences Laboratory in Idaho FAlls, Idaho, and the DOE Environmental Measurements Laboratory (EML) in New York, New York. Participants supplied four sets of each type of dosimeter they wished to evaluate. One set was exposed in the field to a mixture of natural and man-made gamma radiation at the Idaho National Engineering Laboratory; two sets were

TABLE 40

Summary of EPA-QA Samples, 1985

Type of Sample	Analysis	Number Analyzed	Average Difference from Added
Air Filter	Total Alpha	2	37%
	Total Beta	2	1%
	Strontium-90	2	5%
	Cesium-137	2	46%
Milk	Potassium-40	1	2%
	Strontium-89	1	1%
	Strontium-90	1	2%
	Iodine-131	1	17%
	Cesium-137	1	7%
Water	Total Alpha	1	2%
	Total Beta	1	1%
	Hydrogen-3	2	5%
	Chromium-51	3	8%
	Cobalt-60	4	3%
	Zinc-65	3	4%
	Strontium-89	3	9%
	Strontium-90	3	6%
	Ruthenium-106	3	8%
	Iodine-131	1	7%
	Cesium-134	4	3%
	Cesium-137	3	12%
	Radium-226	2	22%
	Radium-228	2	8%
	Total Uranium	3	4%
	Plutonium-239	2	11%

TABLE 41

Summary of DOE-EML-QAP Samples, 1985

	Average Difference From EML Value				
	Air Filters	Water	Soil	Tissue	Vegetation
Hydrogen-3	-	4% (2)	-	-	-
Beryllium-7	6% (2)	-	-	-	-
Potassium-40	-	-	11% (2)	10% (2)	7% (2)
Manganese-54	7% (2)	3% (2)	-	-	-
Iron-59	-	5% (1)	-	-	-
Cobalt-60	6% (2)	4% (2)	-	-	3% (1)
Strontium-90	12% (2)	11% (2)	58% (2)	31% (1)	14% (2)
Antimony-125	9% (2)	-	-	-	-
Cesium-137	4% (2)	6% (2)	13% (2)	3% (2)	2% (2)
Cerium-141	-	8% (1)	-	-	-
Cerium-144	-	3% (1)	-	-	-
Radium-226	-	-	8% (2)	9% (2)	3% (1)
Uranium-234	3% (2)	6% (2)	10% (2)	-	-
Uranium-238	12% (2)	2% (2)	6% (2)	-	-
Plutonium-239	1% (2)	17% (2)	1% (2)	22% (2)	17% (2)
Americium-241	6% (2)	11% (2)	-	-	-

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

exposed in the laboratory to a known (but unrevealed) quantity of radiation, one set to a cesium-137 source and one set to a cobalt-60 source. The fourth set served as a control. After exposure, the dosimeters were returned to the participant for measurement. The field exposure was measured by an EML high-pressure ion chamber for comparison. The results, in milliroentgens (mR), were:

	Field Exposure	Laboratory Exposure	
		Co-60	Cs-137
Delivered Dose	76 ± 6	80 ± 4	75 ± 4
ANL Value			
calcium fluoride	84 ± 11	80 ± 11	88 ± 11
lithium fluoride	86 ± 12	92 ± 12	83 ± 12

The uncertainties listed are the standard deviations as estimated by the sponsors for their values and by us for our results. All results agree with the delivered dose within the measurement error at the 95% confidence levels. The most important comparison is for the field exposures. Here the differences between the ion chamber result and our results were 8.0 mR ± 12.5 mR for calcium fluoride and 10.0 mR ± 13.0 mR for lithium fluoride. The standard deviations for our results are relatively large because the transit and storage dose, as measured with the control dosimeters, is significant and must be subtracted from the total dose.

c. Chemical Analyses

Since July 1, 1985, all work has been performed in accordance with the Quality Assurance Plan (QAP) for the Industrial Hygiene Chemistry Laboratory. This QAP specifies quality-related activities that are necessary to obtain the required results with the required accuracy and precision.

All instrumentation is calibrated with NBS standard sources when available. Samples from the EPA are also used for these purposes. Duplicate analyses are performed frequently to check precision. Known amounts of standard materials are also routinely analyzed to measure accuracy.

The laboratory participates in the National Institute of Occupational Safety and Health (NIOSH) Proficiency Testing Program (PAT) which requires analyses of many materials of environmental interest. Results are in good agreement with the NIOSH values and are listed in Table 42.

TABLE 42

Summary of NIOSH-PAT Program Samples, 1985

Constituent	Average Difference From Reference Value
Cadmium	4% (16)
Lead	5% (16)
Zinc	7% (16)
Benzene	2% (4)
Carbon Tetrachloride	3% (4)
Chloroform	5% (4)
Dichloroethane	7% (8)
p-Dioxane	6% (4)
Toluene	3% (4)
Trichloroethylene	2% (4)
O-xylene	4% (8)

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

The laboratory also participated in the semi-annual DOE-EML-QAP Program. Results are in good agreement and are listed in Table 43.

TABLE 43

Summary of DOE-EML-QAP Non-Radiological Samples, 1985

Constituent	Average Difference From Reference Value
Cadmium	5% (4)
Lead	5% (4)
Manganese	4% (4)
Zinc	2% (4)

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

Finally, the laboratory participates in the U. S. Environmental Protection Agency Discharge Monitoring Report Quality Assurance Program (EPA-DMR-QAP). Results were rated acceptable by the EPA and appear in Table 44.

TABLE 44

Summary of EPA-DMR-QAP Non-Radiological Samples, 1985

Constituent	*Average Difference From Reference Value*
Mercury	*17%*
Zinc	*3%*
pH	*0*
Total Suspended Solids	*26%*
Oil and Grease	*10%*
Chemical Oxygen Demand	*0*

d. Sampling, Sample Storage, Other

Many factors enter into an overall quality assurance program other than the analytical quality control discussed above. Representative sampling is of prime importance. The continuous water sampler in Sawmill Creek provides a representative sample for a critical sampling location since the concentration of pollutants in the waste water may vary appreciably during each 24-hour period.

The accuracy of the flowmeters in the air sampling equipment is verified periodically with a calibrated rotameter, as well as by comparison to a Roots meter primary standard.

Samples are pre-treated in a manner designed to maintain the integrity of the constituent sought. For example, samples for trace radionuclide analysis are acidified immediately after collection to prevent hydrolytic loss of metal ions.

C. Distribution List

Argonne National Laboratory	No. of Copies
ANL Contract Copy	1
ANL Libraries	2
ANL Patent Dept.	1
C. L. Cheever	1
T. L. Duffy	10
A. J. Dvorak	1
N. W. Golchert	25
P. F. Gustafson	1
R. L. Herriford	1
R. B. Kasper	1
N. D. Kretz	1
F. P. Marchetti	1
D. P. O'Neil	1
OTD File #30.6	1
E. G. Pewitt	1
D. M. Ray	1
J. G. Riha	1
J. Sedlet	1
A. F. Stehney	1
H. C. Svoboda	1
T. TenKate	1
TIS Files	6
J. P. Unik	1
M. A. Wahlgren	1
R. A. Wynveen	1

External	*No. of Copies*
DOE Technical Information Center for distribution per UC-11	*203*
DOE-AAO Manager, Argonne Area Office	*7*
DOE-HQ Office of Environmental Audit and Compliance, EH-24	*10*
Manager, DOE-CH	*1*
Samuel Baker, Fermilab	*1*
Robert Buddemeier, Lawrence Livermore Laboratory	*1*
DuPage County Forest Preserve District	*1*
DuPage County (IL) Health Department	*1*
David Edgington, University of Wisconsin at Milwaukee	*1*
Billy M. Farmer, Mound Laboratory	*1*
Thomas C. Gunderson, Los Alamos National Laboratory	*1*
Andrew P. Hull, Brookhaven National Laboratory	*1*
Illinois Department of Public Health, Springfield, IL	*1*
Illinois Environmental Protection Agency, Springfield, IL	*1*
Terry Lash, Illinois Department of Nuclear Safety, Springfield, IL	*1*
J. B. McCaslin, Lawrence Berkeley Laboratory	*1*
Tom Oakes, Oak Ridge National Laboratory	*1*
Les Johnson, U. S. Environmental Protection Agency, Region 5, Chicago, IL	*1*
H. L. Volchok, DOE-EML, New York	*1*

D. Acknowledgements

We are indebted to C. L. Cheever of the ANL Plant Facilities and Services Division, who provided some of the NPDES data in Section III.B.2 b. and the environmental permit information in Section V.B., and to the ANL-OHS Health Physics Section, who provided some of the radioactive gaseous effluent data. J. J. Nelsen (DOE-CH), B. Fritz (DOE-CH), C. L. Cheever (ANL), R. A. Wynveen (ANL), and M. J. Robinet (ANL) reviewed the draft manuscript, and made a number of constructive comments for which we are grateful. The dedicated effort of Rita M. Beaver (ANL), who typed and prepared the manuscript and performed numerous other tasks needed to complete the report, is greatly appreciated.