

**ARGONNE NATIONAL LABORATORY-EAST
SITE ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1989**

by

N. W. Golchert and T. L. Duffy



ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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Preceding Report in This Series: ANL-89/8

TABLE OF CONTENTS

	<u>Page</u>
3.4. National Environmental Policy Act	40
3.5. Safe Drinking Water Act	42
3.5.1. Applicability to ANL	42
3.5.2. Monitoring Requirements	43
3.6. Federal Insecticide, Fungicide and Rodenticide Act	43
3.7. Comprehensive Environmental Response, Compensation and Liability Act	43
3.7.1. Federal Facilities Under CERCLA	44
3.7.2. Emergency Planning and Community Right to Know Act, SARA Title III	46
3.8. Toxic Substances Control Act	46
3.8.1. PCBs in Use at ANL	48
3.9. Environmental Permits, Assessments, and Audits	48
3.9.1. Permits	48
3.9.2. Assessments and Audits	51
3.10. Environmental Restoration and Waste Management Five Year Plan	52
4. ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION	53
4.1. Description of Monitoring Program	53
4.2. Air	56
4.3. Surface Water	62
4.4. Soil, Grass, and Bottom Sediment	71
4.5. Milk	73
4.6. External Penetrating Radiation	77
4.7. Estimates of Potential Radiation Doses	82
4.7.1. Airborne Pathway	82
4.7.2. Water Pathway	96
4.7.3. External Direct Radiation Pathway	97
4.7.4. Dose Summary	98
5. ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION	101
5.1. National Pollutant Discharge Elimination System	101

TABLE OF CONTENTS

	<u>Page</u>
5.1.1. Sample Collection	103
5.1.2. Results of Analyses	103
5.2. Waste Water Treatment Plant Effluent	109
5.2.1. Sample Collection	110
5.2.2. Results of Analyses	110
5.3. Sawmill Creek	110
5.3.1. Sample Collection	112
5.3.2. Results of Analyses	112
5.4. Des Plaines River	112
6. GROUNDWATER PROTECTION	114
6.1. Potable Water System	114
6.2. 317 and 319 Areas	119
6.2.1. Sample Collection	121
6.2.2. Results of Analyses	121
6.2.2.1. Inorganic Constituents	121
6.2.2.2. Organic Constituents	133
6.2.2.3. Radioactive Constituents	135
6.3. Sanitary Landfill	135
6.3.1. Sample Collection	138
6.3.2. Results of Analyses	139
6.3.2.1. Inorganic Constituents	139
6.3.2.2. Organic Constituents	139
6.3.2.3. Radioactive Constituents	139
7. QUALITY ASSURANCE	153
7.1. Radiochemical Analysis and Radioactivity Measurements	153
7.2. Chemical Analysis	156
8. APPENDIX	161
8.1. References	161
8.2. Acknowledgements	164

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.1	Population Distribution in the Vicinity of ANL, 1981	8
1.2	ANL Weather Summary, 1989	11
3.1	Description of NPDES Outfalls at ANL	26
3.2	NPDES Effluent Quality Summary, 1989	30
3.3	Hazardous Waste Treatment and Storage Facilities	36
3.4	List of Inactive Disposal Sites at ANL Described in Preliminary Assessment Reports	45
3.5	Compounds Reported Under SARA Title III	47
3.6	IEPA Environmental Permits in Effect at ANL	49
4.1	Detection Limits	54
4.2	Total Alpha and Beta Activities in Air-Filter Samples, 1989	58
4.3	Gamma-Ray Activity in Air-Filter Samples, 1989	59
4.4	Strontium, Thorium, Uranium, and Plutonium Concentrations in Air-Filter Samples, 1989	61
4.5	Summary of Airborne Radioactive Emissions from ANL Facilities, 1989	63
4.6	Tritiated Water Vapor in Air, 1989	64
4.7	Radionuclides in Sawmill Creek Water, 1989	66
4.8	Radionuclides in Des Plaines River Water, 1989	69
4.9	Radionuclides in Illinois River Water, 1989	70
4.10	Gamma-Ray Emitting Radionuclides in Soil, 1989	72
4.11	Transuranics in Soil, 1989	74
4.12	Radionuclides in Grass, 1989	75
4.13	Radionuclides in Bottom Sediment, 1989	76
4.14	Strontium-90 in Milk, 1989	78
4.15	Environmental Penetrating Radiation at Off-Site Locations, 1989	79
4.16	Environmental Penetrating Radiation at ANL, 1989	80
4.17	Radiological Airborne Releases from Buildings 200 and 211, 1989	84
4.18	Maximum Perimeter and Individual Doses from Buildings 200 and 211 Air Emissions, 1989	85

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
4.19	Radiological Airborne Releases from Building 202 (JANUS), 1989	86
4.20	Maximum Perimeter and Individual Doses from Building 202 (JANUS) Air Emissions, 1989	87
4.21	Radiological Airborne Releases from Building 212, 1989	88
4.22	Maximum Perimeter and Individual Doses from Building 212 Air Emissions, 1989	89
4.23	Radiological Airborne Releases from Building 330 (CP-5), 1989	90
4.24	Maximum Perimeter and Individual Doses from Building 330 (CP-5) Air Emissions, 1989	91
4.25	Radiological Airborne Releases from Building 375 (IPNS), 1989	92
4.26	Maximum Perimeter and Individual Doses from Building 375 (IPNS) Air Emissions, 1989	93
4.27	80-km Population Dose, 1989	94
4.28	50-Year Committed Effective Dose Equivalent Factors - EDEF	95
4.29	Radionuclide Concentrations and Dose Estimates for Sawmill Creek Water, 1989	97
4.30	Annual Average Dose Equivalent in the U. S. Population	99
5.1	Illinois Water Quality Standards	102
5.2	Effects of ANL Ion Exchange Effluents on Sawmill Creek Water Quality, 1989	105
5.3	NPDES Effluent Quality Summary, 1989	106
5.4	Chemical Constituents in Effluents from ANL Wastewater Treatment Plant, 1989	111
5.5	Chemical Constituents in Sawmill Creek, Location 7M, 1989	113
6.1	Target Compound List	115
6.2	Radioactivity in ANL Domestic Wells, 1989	117
6.3	Chemical Constituents at 317 and 319 Areas, Well 300010, 1989	122
6.4	Chemical Constituents at 317 and 319 Areas, Well 300020, 1989	123
6.5	Chemical Constituents at 317 and 319 Areas, Well 300031, 1989	124

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
6.6	Chemical Constituents at 317 and 319 Areas, Well 300052, 1989	125
6.7	Chemical Constituents at 317 and 319 Areas, Well 300060, 1989	126
6.8	Chemical Constituents at 317 and 319 Areas, Well 300100, 1989	127
6.9	Chemical Constituents at 317 and 319 Areas, Well 300110, 1989	128
6.10	Chemical Constituents at 317 and 319 Areas, Well 300120, 1989	129
6.11	Chemical Constituents at 317 and 319 Areas, Well 300130, 1989	130
6.12	Chemical Constituents at 317 and 319 Areas, Well 300D03 (D3), 1989	131
6.13	Chemical Constituents at 317 and 319 Areas, Well 300D04 (D4), 1989	132
6.14	Organic Content of Monitoring Wells in the 317 and 319 Areas, 1989	134
6.15	Radionuclides in the 317 and 319 Area Monitoring Wells, 1989	136
6.16	Chemical Constituents at ANL 800 Area Landfill, Well 800012, 1989	140
6.17	Chemical Constituents at ANL 800 Area Landfill, Well 800022, 1989	141
6.18	Chemical Constituents at ANL 800 Area Landfill, Well 800030, 1989	142
6.19	Chemical Constituents at ANL 800 Area Landfill, Well 800042, 1989	143
6.20	Chemical Constituents at ANL 800 Area Landfill, Well 800050, 1989	144
6.21	Chemical Constituents at ANL 800 Area Landfill, Well 800060, 1989	145
6.22	Chemical Constituents at ANL 800 Area Landfill, Well 800071, 1989	146
6.23	Chemical Constituents at ANL 800 Area Landfill, Well 800080, 1989	147
6.24	Chemical Constituents at ANL 800 Area Landfill, Well 800090, 1989	148

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
6.25	Chemical Constituents at ANL 800 Area Landfill, Well 800100, 1989	149
6.26	Chemical Constituents at ANL 800 Area Landfill, Well 800130, 1989	150
6.27	Hydrogen-3 Content of Water from 800 Area Landfill Wells, 1989	151
7.1	Summary of EPA-QA Samples, 1989	154
7.2	Summary of DOE-EML-QAP Samples, 1989	155
7.3	NIST-SRM Used for Inorganic Analysis	157
7.4	USEPA Quality Check Sample Results, 1989	158
7.5	Summary of EPA-DMR-QAP Nonradiological Samples, 1989	159

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.1	Sampling Locations at Argonne National Laboratory	5
1.2	Sampling Locations Near Argonne National Laboratory	6
1.3	Monthly and Annual Wind Roses at Argonne National Laboratory, 1989	10
4.1	Penetrating Radiation Measurements at the ANL Site, 1989 . . .	81
5.1	NPDES Permit Locations	104
6.1	Monitoring Well Locations in the 317 and 319 Areas	120
6.2	Monitoring Well Locations for Landfill in the 800 Area	137

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ABSTRACT

This report discusses the results of the environmental monitoring program at Argonne National Laboratory (ANL) for 1989. To evaluate the effects of ANL operations on the environment, samples of environmental media collected on the site, at the site boundary, and off the ANL site were analyzed and compared. A variety of radionuclides were measured in air, surface water, groundwater, soil, grass, bottom sediment, and milk samples. In addition, chemical constituents in surface water, groundwater, and ANL effluent water were analyzed. External penetrating radiation doses were measured and the potential for radiation exposure to off-site population groups was estimated. The results of the monitoring program are interpreted in terms of the origin of the radioactive and chemical substances (natural, fallout, ANL, and other) and are compared with applicable environmental quality standards. A U. S. Department of Energy (DOE) dose calculation methodology, based on International Commission on Radiological Protection (ICRP) recommendations, is used in this report. This report also discusses progress being made on corrective actions and restoration projects from past activities.

1. INTRODUCTION

1.1. General

This annual report on the Argonne National Laboratory (ANL) monitoring program provides the U. S. Department of Energy (DOE), environmental agencies, and the public with information on the levels of radioactive and chemical pollutants in the vicinity of ANL and on the amounts, if any, added to the environment by ANL operations. The report follows the guidelines

given in DOE Order 5400.1.¹ Argonne conducts a continuing program of environmental monitoring on and near the site to determine the identity, magnitude, and origin of radioactive and chemical substances in the environment. The detection of any such materials released to the environment by ANL is of special interest. One important function of the program is to verify the adequacy of ANL's pollution controls.

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, computer, nuclear, biomedical, and environmental) and serves as an important engineering center for the study of nuclear and nonnuclear energy sources. Energy-related research projects conducted during 1989 included: advanced reactor development; safety studies for light water and breeder reactors; component and material development for fission and fusion reactors; superconductivity advances and applications; improvements in the use of coal for power production (particularly high-sulfur coal); synchrotron radiation accelerator design; development of electrochemical energy sources, including fuel cells and batteries for vehicles and for energy storage; and evaluation of heat exchangers for the recovery of waste heat from engines.

Other areas of research are the use of superconducting magnets for improved nuclear particle accelerators, fundamental coal chemistry studies, 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; characterization and monitoring of energy-related pollutants; and the effects of acid rain on vegetation, soil, and surface water quality. A significant number of these laboratory studies require the controlled use of radioactive and chemically toxic substances.

The principal nuclear facilities at ANL are: a 185 kW light-water cooled and moderated biological research reactor (JANUS), fueled with enriched uranium; a superconducting heavy ion linear accelerator (Argonne Tandem Linac Accelerating System, ATLAS); a 22 MeV pulsed electron Linac; a

60-in cyclotron; several other charged particle accelerators (principally of the Van de Graaff and Dynamitron types); a large fast neutron source (Intense Pulsed Neutron Source, IPNS) in which high-energy protons strike a uranium target to produce neutrons; cobalt-60 irradiation sources; chemical and metallurgical plutonium laboratories; and several hot cells and laboratories designed for work with multi-curie quantities of the actinide elements and with irradiated reactor fuel materials. The DOE New Brunswick Laboratory, a safeguards plutonium and uranium measurements and analytical chemistry laboratory, is located on the ANL site.

Two activities initiated in 1984 and continued in 1989 have some potential environmental impact: (1) management of radioactive contamination remaining from the proof-of-breeding in light-water reactors project, which involved the dissolution and analysis of irradiated thorium and uranium-233 dioxide fuel elements and (2) recovery of tritium from reactor irradiated ceramic lithium compounds. The shut down 5-MW heavy water enriched uranium research reactor (CP-5) is awaiting decontamination and decommissioning.

The principal nonnuclear activities at ANL in 1989 that may have measurable impacts on the environment include the use of a coal-fired boiler (No. 5), studies of the closed-loop heat exchanger for waste heat recovery, work in the Fossil Energy Users Laboratory (FEUL), and use of large quantities of chlorine for water treatment. The boiler, designed to burn high-sulfur (3.5%) Illinois coal to produce steam for ANL use, is equipped with a slaked lime spray scrubber and bag collector to reduce sulfur dioxide and particulate emissions. The closed-loop heat exchanger studies involved the use of moderately large quantities of toxic or flammable organic compounds, such as toluene, Freon, biphenyl oxides, methyl pyridine, and trifluoroethanol. No experiments were conducted at the FEUL facility and chlorine usage for waste water treatment was without incident. The major potential for environmental impact from these materials would be associated with any accidental releases caused by equipment malfunction. However, no such releases have occurred.

1.2. Description of Site

Argonne National Laboratory (Illinois site) occupies the central 688 hectares (1,700 acres) of a 1,514-hectare (3,740-acre) tract in DuPage County. The site is 43 km (27 mi) southwest of downtown Chicago and 39 km (24 mi) west of Lake Michigan. It is north of the Des Plaines River valley, south of Interstate Highway 55 (I-55) and west of Illinois Highway 83. Figures 1.1 and 1.2 are maps of the site, the surrounding area, and sampling locations of the monitoring program. The 826-hectare (2,040-acre) Waterfall Glen Forest Preserve surrounding the site is former ANL property that was deeded to the DuPage County Forest Preserve District in 1973 for use as a public recreational area, nature preserve, and demonstration forest. Figure 1.1 contains numbers on the abscissa and letters on the ordinate. In this report, facilities are identified by the alpha-numeric designations in Figure 1.1 to facilitate their location.

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

The largest topographical feature of the area is the Des Plaines River channel, which is 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 created by the ANL site and surrounding forest preserve about 1.6 km (1 mi) south of the site. The elevation of the channel surface is 180 m (578 ft) above sea level. The bluffs that form the southern border of the site rise from the river channel at 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

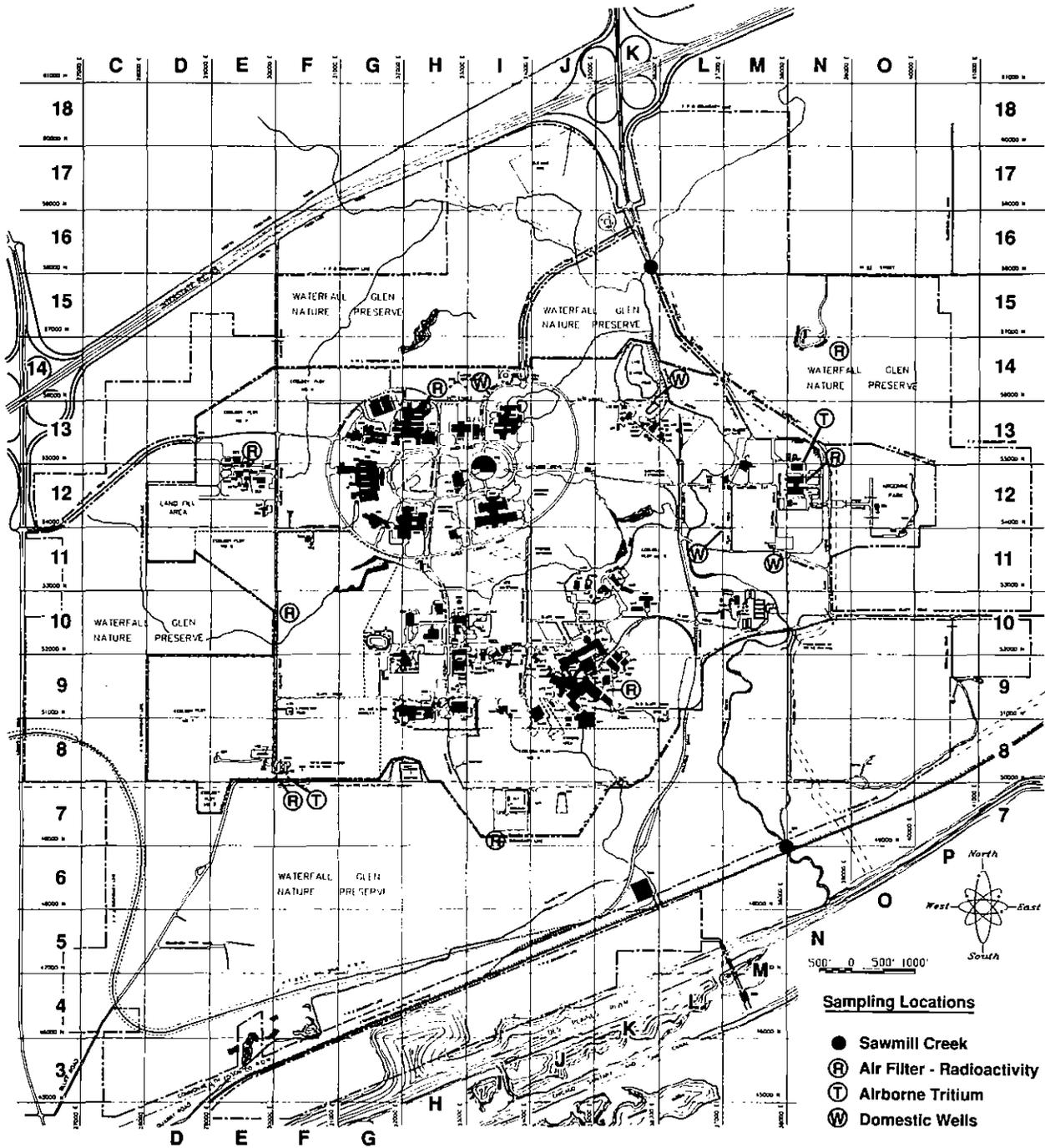


Fig. 1.1 Sampling Locations at Argonne National Laboratory

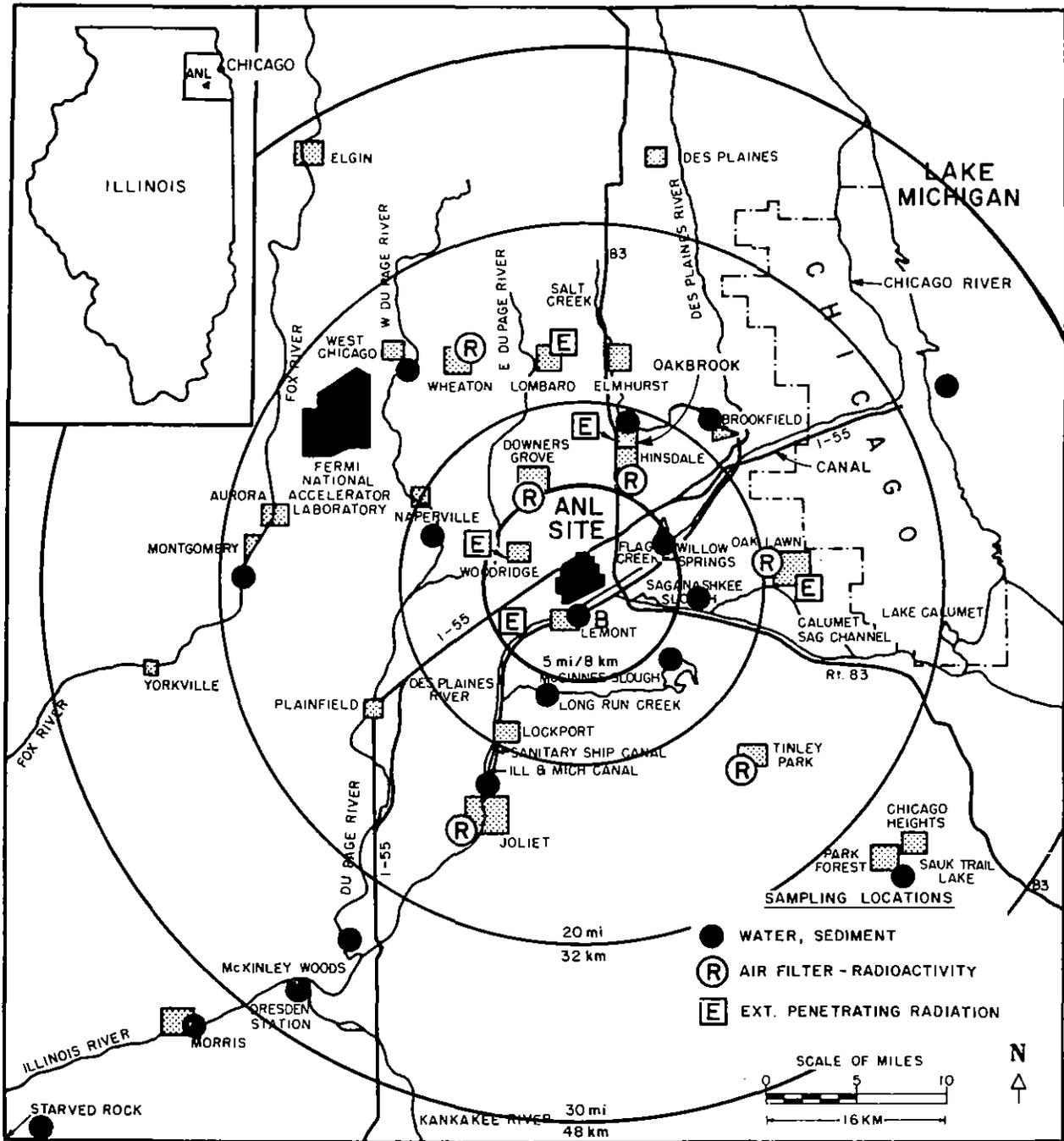


Fig. 1.2 Sampling Locations Near Argonne National Laboratory

915 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 horizontal distance of 150 m (500 ft). The Chicago District Pipe Line Co. and the Atchison, Topeka, and Santa Fe (AT&SF) Railroad have rights-of-way in the southern portion of the forest preserve. Additional information about the site is given in the 1982 Argonne Environmental Assessment.²

1.3. Population

The area around ANL has experienced a large population growth in the past 30 years. Large areas of farmland have been converted into housing. Table 1.1 presents directional and annular 80-km (50-mi) population distribution for the area, which is used for the population dose calculations later in this report. The population distribution, centered on the CP-5 reactor (Location 9G in Figure 1.1), was prepared by Urban Decision Systems, Inc., and was based on the 1980 census. The populations for distances within 8 km (5 mi) of the site were modified by using quarter-section population data supplied by the Northeastern Illinois Planning Commission, as adjusted on the basis of local observations.

1.4. Climatology

The climate of the area is representative of the upper Mississippi Valley, as moderated by Lake Michigan. Summaries of the meteorological data collected on the site from 1949 to 1964 are available³ and provide a historical sample of the climatic conditions. 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 select air sampling locations and distances from sources and to calculate radiation doses from air emissions. Temperature and precipitation data are useful in interpreting some of the monitoring results. The 1989 data were obtained from the on-site ANL meteorological station. The 1989 average monthly and

TABLE 1.1

Population Distribution in the Vicinity of ANL, 1981

Direction	Population (individuals) at 0-5 Miles*					Population (thousands) at 5-50 Miles*				
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
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

*To convert from miles to kilometers, multiply by 1.6.

**Cumulative total = total of this sector plus totals of all previous sectors.

annual wind roses are shown in Figure 1.3. The wind roses are polar coordinate plots in which the lengths of the radii represent the percentage frequency of wind speeds in classes of 2.01-6 m/s (4.5-13.4 mph), 6.01-10 m/s (13.4-22.4 mph), and greater than 10.01 m/s (22.4 mph). The number in the center of each wind rose represents the percentage 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.

The monthly wind roses indicate that the winds are variable, so that monitoring for airborne releases must be carried out in all directions from the site. For example, the dominant wind direction in March is northeast, while in August it is southwest. The annual average wind rose for 1989 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 1989 are shown in Table 1.2. The monthly precipitation data for 1989 showed some differences from the average. For example, April and December were below the average, while September was above the average. However, the annual total was almost identical to the long-term average. Except for January and February, the temperatures were near normal compared to the long-term averages.

1.5. Geohydrology

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

Two principal aquifers are used as water supplies in the vicinity of ANL. The upper aquifer is the Niagaran and Alexandrian dolomite, which is about 60 m (200 ft) thick in the ANL area and has a piezometric surface between 15 and 30 m (50 and 100 ft) below the ground surface for much of the

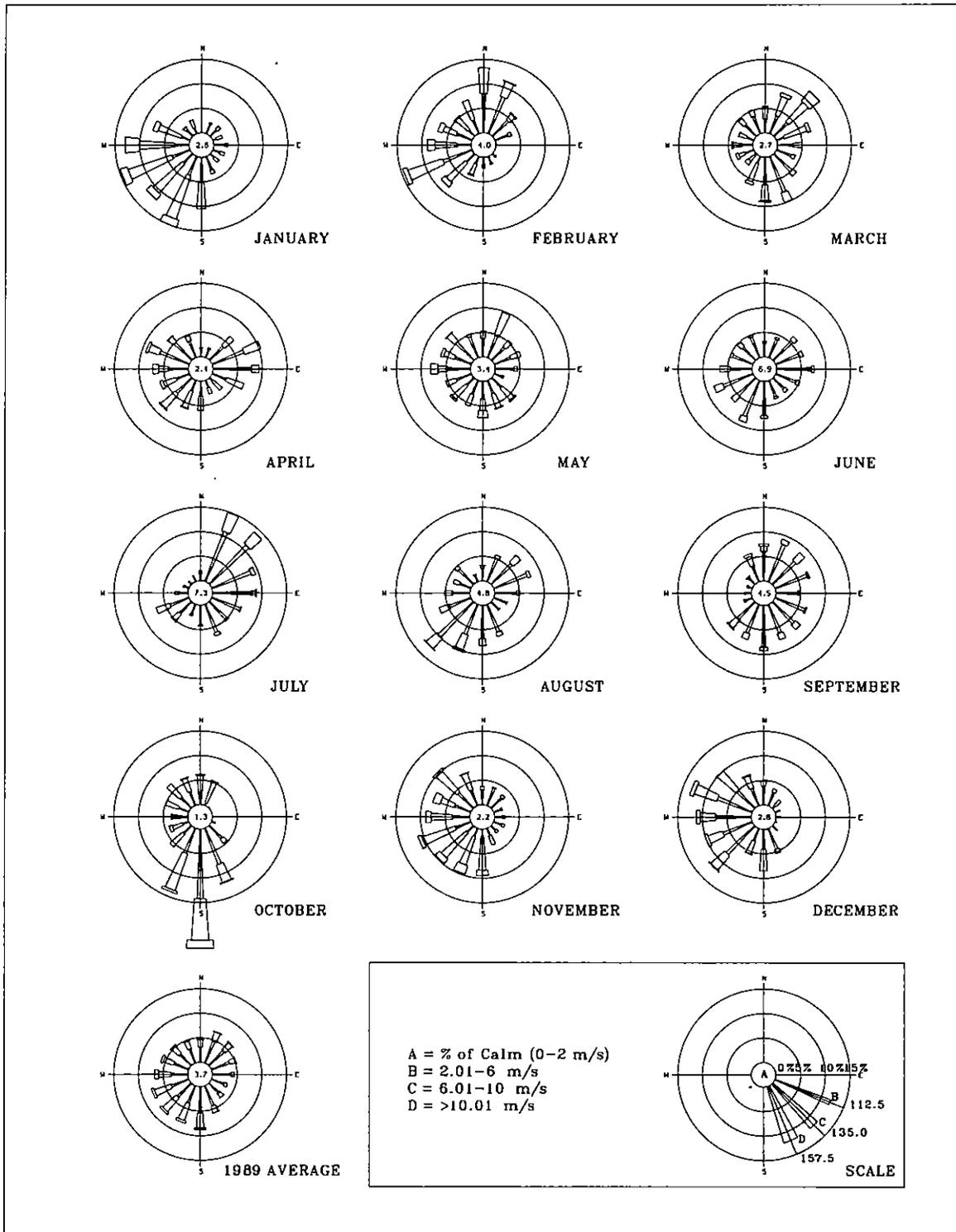


Fig. 1.3 Monthly and Annual Wind Roses at Argonne National Laboratory, 1989

TABLE 1.2

ANL Weather Summary, 1989

Month	Precipitation (cm)			Temperature (°C)		
	ANL 1989	ANL Historical** Average	Historical*	ANL 1989 Monthly Average	ANL Historical** Average	Historical*
January	2.63	3.61	4.06	-0.1	-5.9	-5.9
February	2.95	3.38	3.33	-7.0	-3.7	-3.3
March	6.19	5.56	6.58	2.3	0.6	2.2
April	3.40	9.14	9.30	8.5	8.3	9.3
May	8.85	7.82	8.00	14.6	14.5	15.1
June	7.26	9.47	10.36	20.1	19.7	20.3
July	12.32	10.97	9.22	23.0	21.7	22.8
August	9.05	8.71	8.97	21.4	20.9	22.2
September	11.09	7.14	8.51	16.8	16.8	18.2
October	7.55	6.58	5.79	12.8	11.4	11.9
November	6.27	4.37	5.23	3.4	2.9	4.3
December	1.09	3.20	5.33	-8.9	-4.2	-2.4
Total	78.65	79.95	84.68			

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

** ANL data obtained from Reference 3.

site. The lower aquifer is Galesville sandstone, which lies between 150 and 450 m (500 and 1,500 ft) below the surface. Maquoketa shale separates the upper dolomite aquifer from the underlying sandstone aquifer. This shale retards hydraulic connection between the two aquifers.

The four domestic water supply wells now in use on the ANL site (see Figure 1.1) are drilled about 90 m (300 ft) deep terminating in the Niagaran dolomite. A well drilled in the Galesville sandstone 490 m (1,600 ft) deep has been closed. The water level in the Niagaran dolomite has remained reasonably stable under ANL pumping, dropping about 3.7 m (12 ft) between 1960 and 1980. The aquifer appears to be adequate for future ANL use, but this ground water source is used throughout the area. Several monitoring wells and small capacity water wells used for laboratory experiments, fire protection, and sanitary facilities also occur on the site.

1.6. Water and Land Use

The principal stream that drains the ANL site is Sawmill Creek. It carried effluent water continuously from a sewage treatment plant (Marion Brook Treatment Plant) located a few kilometers north of the site until October 27, 1986, when the plant was closed. Residential and commercial development in the area has resulted in the collection and channeling of runoff water into Sawmill Creek. Treated sanitary and laboratory wastewater from ANL are combined and discharged into Sawmill Creek at location 7M in Figure 1.1. This effluent averaged 4.0 million liters (1.06 million gallons) per day. The combined ANL effluent consisted of 46% laboratory wastewater and 54% sanitary wastewater. The water flow in Sawmill Creek upstream of the wastewater outfall averaged about 13 million liters (3.4 million gallons) per day during 1989.

Sawmill Creek and the Des Plaines River above Joliet, about 21 km (13 mi) southwest of ANL, receive very little recreational or industrial use. A few people fish in these waters downstream of ANL and some duck hunting takes place on the Des Plaines River. Water from the Chicago Sanitary and Ship Canal is used by ANL for cooling towers and by others for industrial purposes, such as hydroelectric generators and condensers, and

for irrigation at the state prison near Joliet. The ANL usage is about 0.4 million liter (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 combine into one waterway, which continues until it joins the Kankakee River to form the Illinois River about 48 km (30 mi) southwest of ANL. The Dresden Nuclear Power Station complex is located at the confluence of the Kankakee, Des Plaines, and Illinois rivers. This station uses water from the Kankakee River for cooling and discharges the water into the Illinois River. The first downstream location where water is used for drinking is at Alton, on the Mississippi River about 710 km (370 mi) downstream from ANL. At that location, water is used indirectly to replenish groundwater supplies by infiltration. In the vicinity of ANL, only subsurface water (from both shallow and deep aquifers) and Lake Michigan water are used for drinking purposes.

The principal recreational area near ANL is Waterfall Glen Forest Preserve, which surrounds the site (see Section 1.2 and Figure 1.1). The area is used for hiking, skiing, and equestrian sports. Sawmill Creek flows south through the eastern portion of the preserve on its way to the Des Plaines River. Several large forest preserves of the Cook County Forest Preserve District are located east and southeast of ANL and the Des Plaines River. The preserves include the McGinnis and Saganashkee sloughs (shown in Figure 1.2), as well as other, smaller lakes. These areas are used for picnicking, boating, fishing, and hiking. A small park located in the eastern portion of the ANL site (Location 12-0 in Figure 1.1) is for the use of ANL and DOE employees only.

2. SUMMARY

The purpose of this report is to present summary data characterizing ANL environmental management performance, confirming compliance with environmental standards and requirements, and highlighting significant programs and efforts. This is the latest 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 around ANL and on the amounts of such substances released as a result of ANL operations. This document reports measurements made in 1989 of a number of radionuclides in air, surface water, groundwater, soil, grass, bottom sediment, and milk; of a variety of chemical constituents in surface and subsurface water; and of the external penetrating radiation. The previous report in this series is ANL-89/8.⁴

The major airborne radionuclides released from ANL during 1989 were hydrogen-3, carbon-11, nitrogen-13, oxygen-15, argon-41, krypton-85, and radon-220 (plus daughters). Calculations made with an atmospheric dispersion model indicated that the maximum whole body effective dose equivalent from these nuclides at the site boundary was 1.2 mrem/y at the northern boundary of the site. The calculated dose to the maximally exposed full-time resident, who is located about 0.5 km (0.3 mi) north of the site boundary, was 0.36 mrem/y, which is 0.36% of the DOE 100 mrem/y limit set by DOE for public exposures. The limit set by the U. S. Environmental Protection Agency (USEPA) in the Clean Air Act is 25 mrem/y for atmospheric releases. The dose resulting from these releases constitute an insignificant addition to the dose received from the natural external background radiation, which is about 87 mrem/y, based on the thermoluminescent dosimetry (TLD) measurements. In 1989, the total 80-km population dose from these radionuclides was 17 man-rem, compared to approximately 6.8×10^5 man-rem received from natural background radiation. The risk 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 discussed in Sections 4.1 and 4.7 and described in References 5 and 6.

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

Argonne wastewater is discharged into Sawmill Creek, and this creek was sampled upstream and downstream from the site to evaluate the effect of ANL operations on the level of radioactivity in the water. If the creek water was used as a potable water supply (which it is not), the nuclides (for which analyses were made) added to the creek in the ANL wastewater, and the ingestion doses from their net average creek concentrations would have been hydrogen-3, 0.0007 mrem/y; strontium-90, 0.018 mrem/y; cesium-137, 0.033 mrem/y; neptunium-237, 0.043 mrem/y; plutonium-239,240, 0.034 mrem/y; and americium-241, 0.037 mrem/y. These doses are all very low compared with the 100 mrem/y dose limit.

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

Plutonium concentrations in soil showed the same general range at the site perimeter and off the site as in past years. The average plutonium-239,240 content of the top 5 cm (2 in) of soil was 0.62 nCi/m² at the site perimeter and 0.58 nCi/m² off the site. The corresponding plutonium-238 averages were 0.029 nCi/m² and 0.031 nCi/m², respectively. The plutonium content in grass was similar to that found in previous years and was about a factor of 10⁴ lower than soil concentrations 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 in the ANL vicinity is attributed to this source. The plutonium content of sediment samples from the beds of off-site streams and ponds ranged from 1 fCi/g to

9 fCi/g of plutonium-239,240, a range found in previous years to be normal for fallout plutonium in such materials. However, concentrations above the ambient level were found in the sediment just below the ANL wastewater outfall in Sawmill Creek as a result of their presence in ANL wastewater.

Milk from a dairy farm 10 km (6 mi) south of ANL was collected monthly and analyzed for hydrogen-3 and strontium-90. Hydrogen-3 concentrations were all less than the detection limit of 100 pCi/L. The strontium-90 concentration of 2.3 pCi/L was similar to the results obtained in 1987 and 1988. Measured air concentrations of hydrogen-3 and strontium-90 at the site perimeter indicated that these radionuclides resulted from fallout from past nuclear test detonations and were not related to ANL operations.

Penetrating radiation was measured at several locations at the ANL site boundary and off the site. The off-site results averaged 87 ± 3 mrem/y, which is in the average background range for the area. Above-background readings attributable to ANL operations were recorded at two site boundary locations. At the south fence (grid 7I in Figure 1.1), the dose averaged about 135 mrem/y above background as a result of radiation from a temporary storage facility for radioactive waste on the site. About 300 m (0.2 mi) south of the fence, the measured dose rate decreased to 87 ± 3 mrem/y, which is within the background range. Along the northern side of the site, the above background dose at the fence at location 14I was 23 mrem/y due to radiation from cobalt-60 sources in Building 202. Since no residences are at these locations, no individuals were receiving these measured doses. The calculated outdoor dose rate from these sources to the residents closest to the southern boundary, about 1.6 km (1 mi) from the fence line, was about 0.03 mrem/y, which is 0.03% of the dose limit. Similarly, the dose rate to the residents closest to the northern boundary, about 0.75 km (0.5 mi) from the fence, was about 0.13 mrem/y, which is 0.13% of the dose limit.

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

sampling locations were generally within permit limits with the exception of chloride and total dissolved solids at location 001 and iron and pH at internal location 001C (see Figure 5.1 for sampling locations). The chloride and total dissolved solids at location 001 are from discharge of the spent regenerant solution generated by the recharging of the ion-exchange treatment system for the domestic water supply. A treatment plant has been designed to reduce the discharge of this solution. Location 001C was an internal sampling point that contains precipitation runoff from the coal pile storage area at the boiler plant. Treatment of this water at the Waste Water Treatment Plant effectively neutralizes the pH and removes the iron from the wastewater before it is discharged. In July, the IEPA revised the permit and eliminated the requirement to sample at 001C, but sampling was required for the 001C constituents at location 001A. Since this change, no violations for iron, pH, or any other constituent have occurred.

Two effluent samples from the Waste Water Treatment Plant (001) exceeded the $0.5 \mu\text{g/L}$ state effluent standard for mercury but were well below the one time limit of $2.5 \mu\text{g/L}$ (see Table 5.4). All of the other constituents were below the state standards. These two samples were well below the NPDES permit limits for this outfall.

The average concentrations for most of those chemical constituents in Sawmill Creek were within the State of Illinois Water Quality Standards (see Table 5.5). The average levels of copper and iron were 140% and 52% of the state stream standards, and individual values exceeded the standards 80% and 16% of the time, respectively (see Table 5.5). The effluent levels of copper are only 10% of the state standard of 1 mg/L , but these levels are sufficient to have a significant effect on the stream standard of $20 \mu\text{g/L}$ because of the low flow in Sawmill Creek. The levels of iron in the upstream and the downstream samples increase during periods of rain because of the iron in soil carried into the stream by storm runoff. The iron levels in the ANL effluent are not sufficient to materially affect background levels and thus, the relatively high values were probably due to natural causes. Mercury concentrations exceeded the state standard 12% of the time, and the average concentration was 61% of the standard. The concentration of mercury in the Des Plaines River was less than the detection limit of

0.1 $\mu\text{g/L}$ and was not affected by the amounts present in the ANL effluent water.

Samples were obtained from the groundwater monitoring wells at the sanitary landfill on a quarterly basis. The samples indicated elevated levels of iron and manganese and decreasing water levels. No significant levels of volatile organic compounds (VOC) were detected. Hydrogen-3 levels of less than 1 nCi/L were found in some wells.

Studies at the 317/319 Radioactive Waste Management Area were expanded by the addition of new monitoring wells. The results showed that organic contamination exists in the area. The major organic contaminants detected were perchloroethene, trichloroethene, 1,1,1-trichloroethane, carbon tetrachloride, and chloroform. Elevated levels of lead, hydrogen-3, strontium-90, and cesium-137 were present in several of the wells. A characterization program has begun to assess the extent of the problem.

3. COMPLIANCE SUMMARY AND ENVIRONMENTAL PROGRAM INFORMATION

It is the policy of ANL to conduct its operations in compliance with all applicable environmental laws and regulations. This chapter contains a review of the major environmental regulations and requirements that are relevant to the functions at ANL. The applicable regulations are identified in DOE Order 5400.1,¹ which establishes DOE's policy concerning environmental compliance.

3.1. Clean Air Act

The Clean Air Act (CAA) is a broad federal statute that specifies ambient air quality standards, sets emission limits for conventional air pollutants from certain sources, and determines emission limits and operating criteria for a number of hazardous air pollutants. The program is implemented in specific states through the preparation of a State Implementation Plan (SIP), which determines how that state will ensure compliance with the air quality standards. The permitting process for point source emissions is a major part of all states' SIP processes. Although the ANL facility does not generate large amounts of air pollutants, it does have several operations that are subject to provisions of the CAA and the State of Illinois SIP.

3.1.1. National Emission Standards for Hazardous Air Pollutants

The National Emission Standards for Hazardous Air Pollutants (NESHAP) are a body of federal regulations that set forth emission limits, as well as a number of other requirements such as monitoring, record keeping, and operational requirements, for processes and activities generating emissions containing certain hazardous air pollutants. The standards for asbestos and radionuclides are currently the only two effecting ANL operations.

The standards for asbestos specify detailed requirements for removal and disposal of friable (easily crushed) asbestos-containing materials, such as pipe and ductwork insulation and fire protective coatings. The older buildings on the ANL site contain large amounts of asbestos on pipes, tanks, building components, and other equipment, as do most buildings around the

country constructed before the potential dangers of asbestos were well known. When asbestos-containing material is encountered during a renovation or demolition project, it is carefully wetted or otherwise encapsulated and completely removed. The work area is sealed off using disposable glove bags or temporary plastic sheeting barriers, and high-efficiency air filtration equipment is used. Asbestos is removed in strict accordance with the NESHAP regulations as well as with the much stricter Occupational Safety and Health Administration's (OSHA) worker protection standards. Air is monitored in the vicinity of such work to verify that adequate precautions have been taken and that neither the workers nor members of the general public are exposed to excess amounts of asbestos. All asbestos-containing waste material is sealed in special leak-proof plastic bags and disposed of in a specially designated section of the ANL landfill, in accordance with the NESHAP regulations. Also, as required by the NESHAP regulations, this waste material is buried before the end of the work shift; normally immediately after it is placed in the landfill.

The asbestos NESHAP standards require that the IEPA be notified before large asbestos removal projects [involving more than 80 m (260 ft) of pipe insulation or 15 m² (160 ft²) of other material] are begun. During 1989, ANL, through DOE, made five notifications of such projects involving 1445 linear meters (4745 linear feet) of pipe insulation and 73 m² (790 ft²) of surface insulation. In all, approximately 78 m³ (2751 ft³) of asbestos or asbestos-contaminated materials, such as air filters and protective clothing, were disposed of during 1989 in the sanitary landfill.

The NESHAP regulations for radionuclide emissions from DOE facilities (40 CFR 61, Subpart H) establishes the emission standards for release of radionuclides to the air and requirements for monitoring, reporting, and record keeping. A number of emission points at ANL are subject to these requirements. These points include ventilation systems for hot cell facilities for storage and handling of highly radioactive materials (Buildings 200 and 212), ventilation systems for currently operating and inactive reactors (Building 202, JANUS reactor, and Building 330, inactive reactor CP-5), and ventilation systems for particle accelerators (Building 211, cyclotron, Building 372, IPNS facility, and the proposed APS facility). In addition, many small ventilation systems and fume hoods are occasionally used for

processing of small quantities of radioactive materials. All such air emission sources are currently being reevaluated to ensure that the requirements of the radionuclide NESHAP are being properly addressed. Routine, continuous monitoring of the larger emission sources has indicated that the amount of radioactive material released to the atmosphere is extremely small, resulting in a very small incremental radiation dosage to the neighboring population. Section 4.7.1. contains a more detailed discussion of these emission points and compliance with the standard.

3.1.2. Conventional Air Pollutants

The ANL site contains several sources of conventional air pollutants including a steam plant, gasoline and methanol fuel dispensing facilities, and a facility for combustion and power generation research (FEUL facility), two alkali metal treatment booths, a vapor degreaser used in the machine shop and several small ventilation systems. These emission sources have either been granted operating permits by the IEPA or a permit has been applied for, as discussed in Section 3.9.1. During 1989, operating permits were granted for the alkali metal reaction booths in Buildings 206 and 308. Operating permit applications were prepared during 1989 for the vapor degreaser and a dust collection system at the boiler house.

The steam plant and fuel dispensing facilities operate continuously and represent the only significant sources of conventional air pollutants on the site. The other sources, including the FEUL facility, operate infrequently and even while running are only minor sources of emissions.

The operating permit for the steam plant requires continuous opacity and sulfur dioxide monitoring of the smoke stack from Boiler 5, the only one of the five boilers equipped to run on high-sulfur coal. The permit requires submission of a quarterly report listing any excursions beyond emission limits for this boiler [30% opacity averaged over six minutes and 1.8 lb sulfur dioxide (SO_2) per million Btu averaged over a one-hour period]. During 1989, 99 SO_2 limit excursions and 300 opacity limit excursions were reported. The length of each excursion incident varied from a few minutes to several hours. Most of the excursions were of short duration and were due to routine operations (such as clearing ash deposits off of the boiler

steam tubes), equipment failure, or routine process control problems (such as plugging of piping and inadequate scrubber flow rates). The SO₂ scrubber on Boiler 5 was designed and built as an experimental test unit in 1980. It has operated in recent years as a production unit. Many of the components have reached the end of their useful life, resulting in frequent breakdowns and malfunctions.

The fuel dispensing facilities are used to service vehicles associated with ANL only and, except for methanol vapors, have VOC emissions typical of any commercial gasoline service station. The underground fuel storage tanks are equipped with vapor recovery systems to minimize emissions.

3.2. Clean Water Act

The Clean Water Act (CWA) was established in 1977 as a major amendment to the Federal Water Pollution Control Act of 1972 and was substantially modified by the Water Quality Act of 1987. The CWA provides the legal framework for the restoration and maintenance of water quality in all waters throughout the country, with the ultimate goal of "fishable and swimmable" water quality. The act established the National Pollutant Discharge Elimination System (NPDES), which is the regulatory mechanism designed to achieve this goal. The authority to implement the NPDES program has been delegated to those states, including Illinois, that have developed a program substantially the same and at least as stringent as the federal NPDES program.

The 1987 amendments to the CWA have significantly changed the thrust of enforcement activities. Much greater emphasis is currently being placed on monitoring and control of toxic constituents in wastewater, the permitting of outfalls composed entirely of stormwater, and the imposition of regulations governing sewage sludge disposal. The changes in NPDES regulations have affected ANL by imposing much stricter discharge limits and greatly expanded the number of chemical constituents monitored in the effluent. Several projects involving construction of new or upgraded wastewater treatment systems are being planned in order to comply with the changing requirements. These and similar projects have been incorporated into the Environmental Restoration and Waste Management Five Year Plan for ANL, discussed in Section 3.10.

3.2.1. Liquid Effluent Discharge Permit

The primary tool for enforcing the requirements of the NPDES program is through the NPDES permitting process administered by the IEPA. Each wastewater discharge point (outfall) must be characterized and described in a permit application. The IEPA then issues a permit that contains numeric limits on certain pollutants likely to be present and defines a number of specific and general requirements, including sampling and analysis schedules and reporting and record keeping requirements. Wastewater generation activities at ANL are covered by NPDES permit IL 00334592 (DOE is the legal permit holder for all ANL environmental permits). This permit was renewed in July 1989. The renewed permit contains several significant changes from previous versions of the permit, as discussed below.

Process wastewater at ANL is generated by a number of activities and consists of sanitary wastewater (from bathrooms, cafeteria sinks and sinks in certain buildings and laboratories), laboratory wastewater (from laboratory sinks and floor drains in most buildings), and cooling water and cooling tower blowdown. The current permit authorizes the release of wastewater from nine separate outfalls, most of which discharge directly or indirectly into Sawmill Creek. In addition, the permit requires monitoring of the wastewater at two internal sampling points that eventually combine to form the main wastewater outfall. Table 3.1 describes these outfalls, and the locations are shown in Figure 5.1. Two of these outfalls, 009 and 010, are intended for emergency discharge of wastewater only; normally there is no discharge from these points.

Two outfalls listed on the previous permit were deleted from the July 7, 1989, revision of the permit. Outfall 001C was an internal sampling point on a wastewater stream, generated near the boiler house, that flows to the sanitary wastewater treatment plant. To minimize analytical and reporting requirements, the effluent limits and associated monitoring requirements for this outfall were combined with the effluent standards and monitoring requirements for outfall 001A, the sanitary wastewater treatment plant discharge, and outfall 001C was eliminated. Outfall 002 consisted of an inactive discharge point from a wastewater retention basin. Modification of the basin rerouted this discharge to the laboratory sewer system, eliminating

TABLE 3.1

Description of NPDES Outfalls at ANL

Outfall* Number	Description	Status	Average Flow (Million Gallons/Day)
001	Combined discharge of 001A and 001B - main site outfall (7M)	Active	0.8-1.2
001A	Sanitary wastewater treatment plant effluent	Active - internal sampling point	0.4-0.6
001B	Laboratory wastewater treatment plant effluent	Active - internal sampling point	0.4-0.6
003	Stormwater runoff, cooling water and cooling tower blow-down	Active	0.1-0.3
004	Cooling water, stormwater	Active	0-0.05
005	Cooling water and cooling tower blowdown, stormwater	Active	0-0.2
006	Water treatment plant wastewater, cooling tower drainage, cooling water, stormwater	Active	0-0.12
007	Cooling water, stormwater	Active	0-0.01
008	Stormwater	Active	0-0.01
009	Lime sludge pond overflow	Emergency overflow	0
010	Coal pile runoff overflow	Emergency overflow	0

*Locations are shown in Figure 5.1.

the flow to outfall 002. Consequently outfall 002 was removed from the permit.

Other changes to the permit in 1989 include: the reduction of the effluent five-day biological oxygen demand (BOD₅) and total suspended solids (TSS) limits for outfalls 001A and 001B from 30 mg/L for both BOD₅ and TSS to 10 mg/L BOD₅ and 12 mg/L TSS, the addition of numeric limits for total dissolved solids, sulfates and chlorides to outfall 001, the addition of semiannual monitoring of outfall 001B for 126 priority pollutants and annual aquatic toxicity testing of outfall 001. Table 3.2 lists effluent limits for each outfall and summarizes analytical data generated in 1989. Since the permit was modified during 1989, monitoring data were collected for both the current and old effluent limits.

As required by the new permit, outfall 001B was sampled and analyzed for 126 priority pollutants. The only organics identified were several chlorinated and brominated methanes present at less than 100 µg/L total, believed to be the result of chlorination of the potable water supply. Copper and zinc also were identified at very low concentrations, probably resulting from the use of copper and galvanized steel water piping.

To better define the amount and types of hazardous chemicals present in the wastewater generated by the laboratories, a program was initiated in 1989 to analyze and characterize the influent to the laboratory wastewater treatment plant. Five influent samples collected per day for five days in January were analyzed for volatile organic carbon compounds. Fifteen volatile organics were detected, five of which were present in significant concentrations: methylene chloride at concentrations up to 2500 µg/L, acetone up to 15,500 µg/L, chloroform up to 500 µg/L, carbon tetrachloride up to 600 µg/L, and toluene up to 54 µg/L. Since January, the influent has been analyzed monthly for VOCs. The results have been similar to those of January, with methylene chloride, acetone, 1,2-dichloroethene, chloroform, carbon tetrachloride, trichloroethene and tetrachloroethane present at concentrations ranging from barely detectable to 6900 µg/L (acetone). The concentrations of these constituents typically ranged between 20 and 500 µg/L. The degree of these compounds removed as the wastewater travels

through the laboratory treatment plant has not been well documented. However, judging by the analytical results from the effluent sampling, it appears that low levels of these compounds are leaving the site in the effluent. To ensure the maximal removal of organic and heavy metal pollutants from the laboratory wastewater, ANL has proposed a project (scheduled for FY 1991 and FY 1992) to upgrade the treatment system by adding solids-removal equipment, air stripping and activated carbon adsorption. This project is listed in the ANL Environmental Restoration and Waste Management Five Year Plan as ADS No. 1006.

During the last few years, ANL has experienced numerous violations of stream quality limits for chlorides and total dissolved solids. These violations could have been caused by the disposal of a water treatment system spent regenerant solution (concentrated brine solution). To prevent future violations, a treatment plant for this brine solution is planned. The newly issued permit contains a compliance schedule calling for completion of this plant by June 30, 1990.

3.2.2. General Effluent and Stream Quality Standards

In addition to specific permit conditions, ANL discharges are required to comply with general effluent limits contained in 35 Illinois Administration Code, Chapter 1, Subtitle C, Part 304. Also, wastewater discharges must be of sufficient quality to insure that Sawmill Creek complies with the IEPA's General Use Water Quality Standards found in 35 Illinois Administrative Code, Chapter 1, Subtitle C, Part 302, Subpart B. Section 5 of this report, which presents the results of the routine environmental monitoring program, also describes the general effluent limits and water quality standards applicable to the outfalls and discusses compliance with these standards.

3.2.3. Effluent Monitoring Results

Results of the routine monitoring required by the NPDES permit are submitted monthly to the IEPA and quarterly to the USEPA in a Discharge Monitoring Report (DMR). As required by the permit, any noncompliance with

permit limits or conditions is reported to the IEPA within 24 hours, and a written explanation of such noncompliance is submitted with each DMR.

The summary of the analytical data generated by NPDES monitoring activities shown in Table 3.2 indicates that, with several notable exceptions, the discharge limitations were consistently met (over 93% of the results were less than the compliance limits). Chapter 5 of this report contains a detailed discussion of the noncompliance instances noted in Table 3.2. To reduce the number of noncompliance episodes, ANL is building additional wastewater treatment facilities or upgrading existing facilities. These corrective action projects are described in the Environmental Restoration and Waste Management Five Year Plan for ANL.

3.2.4. NPDES Inspections and Audits

In January 1989, the USEPA conducted a multi-media Evaluation Inspection which included NPDES outfalls and related facilities as well as associated sampling and analysis and record keeping requirements. No deficiencies were found.

In February 1989, the IEPA conducted a compliance sampling inspection of NPDES outfalls and related facilities. No violations or deficiencies were noted in the state inspection.

As will be discussed in Section 3.9.2, DOE conducted its annual environmental appraisal of ANL in July 1989. This appraisal identified no wastewater-related deficiencies. The only significant item identified in the 1988 appraisal, unpermitted filling of the A²R² excavation, was rectified in 1989. A Dredge and Fill Permit was obtained from the Corps of Engineers and the excavation was filled by placing the original soil, stockpiled on the site since the excavation was originally dug, back into the excavation.

3.2.5. Spill Prevention Control and Countermeasures Plan

Argonne maintains an up-to-date Spill Prevention Control and Countermeasures Plan (SPCC) plan as required by the Clean Water Act (40 CFR 112), the Toxic Substances Control Act (40 CFR 761), and the Resource Conservation

TABLE 3.2

NPDES Effluent Quality Summary, 1989

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	* _R ($\frac{\text{Measured}}{\text{Permit}}$)
			30 Day Average	Daily Max.		
001A	26	Flow	None		0	
		BOD	10	20	0	
		Iron	2	4	0	
		Lead	0.2	0.4	0	
		Zinc	1	2	0	
		Manganese	1	2	0	
		Chromium (total)	1	2	0	
		Copper	0.5	1	0	
		Oil and grease	15	30	0	
		TSS	12	24	0	
		pH (units)	6-9		0	
001B	52	Flow	None		-	
		Chemical oxygen demand	-	-	-	
		TSS	12	24		
		Mercury	0.003	0.006		
001C	9	Iron	2	4	9	1.9-4.6
		Lead	0.2	0.4	0	
		Zinc	1	2	0	
		Manganese	1	2	0	
		Chromium (total)	1	2	0	
		Copper	0.5	1	0	
		Oil and grease	15	30	0	
		TSS	15	30	7	1.3-3.0
		pH	6-9		2	9.1-11.2

TABLE 3.2 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	* $R\left(\frac{\text{Measured}}{\text{Permit}}\right)$
			30 Day Average	Daily Max.		
001	52	pH	6-9		0	-
	52	Fecal Coliform	-	$\frac{400 \text{ organisms}}{100 \text{ mL}}$	3	1.6-40
	12	TSS	12	24	0	-
	12	Chloride		550	12	1.02-1.40
	12	Sulfate		575	0	-
	12	TDS		1045	12	1.46-1.83
003	12	Flow	None		0	
		pH	6-9		0	
		TSS	15	30	1	1.2
		Temperature	< 2.8°C Rise		0	
004	12	Flow	None		0	
		pH	6-9		0	
		TSS	15	30	3	1.2-1.5
		Temperature	< 2.8°C Rise		0	
005	12	Flow	None		0	
		pH	6-9		0	
		Temperature	< 2.8°C Rise		0	
		Oil and Grease	15	30	0	
006	12	Flow	None		0	
		pH	6-9		0	
		TSS	15	30	1	1.4
		Zinc	1.0	2.0	0	

TABLE 3.2 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R ($\frac{\text{Measured}}{\text{Permit}}$)
			30 Day Average	Daily Max.		
007	11	Flow	None		0	
		pH	6-9		0	
		Temperature	< 2.8°C Rise		0	
008	0	Flow	None			
		pH	6-9			
009	0	Flow	None			
		pH	6-9			
		TSS	15	30		
010	0	Flow	None			
		pH	6-9			
		TSS	15	30		
		Iron	2	4		
		Lead	0.2	0.4		
		Zinc	1.0	2.0		
		Manganese	1.0	2.0		
		Chromium (total)	1.0	2.0		
		Copper	0.5	1.0		
		Oil and grease	15	30		

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

and Recovery Act (40 CFR 265, Subpart D). This plan describes the actions to be taken in case of a spill or other accidental release of hazardous materials into the environment. Persons with specific duties and responsibilities in such situations are identified, as are reporting and record-keeping requirements mandated by the various regulations. Effective use of this plan is ensured by regular training, including both classroom instruction and field exercises. As required, this plan was revised and updated in 1989.

The ANL site has few hazardous chemicals present in amounts large enough to cause concern beyond the immediate spill area should a spill or release occur. Gasoline, fuel oil, chlorine, sulfuric acid, and PCB-containing oils are the only hazardous chemicals present in large amounts that are subject to spills. While there are hundreds of other hazardous chemicals in use throughout the site in small quantities, a spill of one of these would be expected to have a negligible impact on the environment or the health of anyone outside of the immediate spill area.

3.2.6. Unusual Occurrences

On September 21, 1989, a release of several hundred gallons of highly acidic washwater occurred within the ANL sanitary landfill. This washwater was generated when an industrial cleaning contractor removed sludge from the inside of a bulk sulfuric acid storage tank at the boiler house. The washwater was supposed to have been neutralized by mixing with spent lime dust from the flue gas scrubber. Instead, the liquid was transported to the landfill and released onto a pile of the lime dust. The resulting reaction generated a foamy acid-sludge material that flowed into several depressions and ditches inside the landfill. The ANL Fire Department responded immediately to ensure that there were no personal injuries or property damage. The site was judged to be stable and no off-site release was anticipated. The next day, additional diking was built to ensure containment and a hazardous materials cleanup contractor was brought in to clean up the spilled material. The material was neutralized and the neutralized residue was trucked off the site for disposal in a special waste landfill. No acid was released from the site.

The disposal of acidic wastewater in the landfill represented several significant violations of the landfill operating permit. On October 2, 1989, the DuPage County Department of Environmental Concerns, which manages the enforcement of landfill permit conditions in the county for the State of Illinois, cited ANL for six violations of permit requirements. Argonne received an "Administrative Citation" from the IEPA for violation of the permit conditions and paid a \$500 settlement sum. Consequently, the State's Attorney General dismissed the case against ANL. As a result of this incident, ANL conducted an exhaustive investigation and instituted a number of significant changes in the oversight of contractor operations on ANL property and management of waste-disposal activities.

On June 8, 1989, an incident occurred in Building 200 involving the inappropriate disposal of a small amount of potentially hazardous liquid waste into the laboratory wastewater collection system. Several ANL employees, unaware of applicable regulations governing disposal of hazardous waste, dumped approximately 200 small bottles of discarded laboratory chemicals into a sink connected to a wastewater retention tank. From the description on the labels on a number of the bottles, the contents should have been classified as hazardous waste and disposed of by proper methods (lab packing and shipment off the site). The incident was discovered before the retention tank was emptied. The contents of the retention tank were removed and placed in portable tanks until they could be analyzed and disposed of by a licensed hazardous waste disposal contractor. None of these chemicals was released into the sewer system or Sawmill Creek.

3.3. Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) was enacted in 1976 and implementing regulations were promulgated in May 1980. This extremely complex body of regulations is intended to insure that hazardous wastes are disposed of in an environmentally safe manner and that facilities that treat, store, or dispose of hazardous waste do so in a way that protects human health and the environment. The Hazardous and Solid Waste Amendments of 1984 (HSWA) created a set of restrictions on land disposal of hazardous wastes unless certain treatment standards can be satisfied. These amendments also require that releases from any solid waste management unit

located on the same site as a RCRA permitted hazardous waste handling unit be cleaned up, regardless of when the waste was placed in the unit or if the unit was originally intended as a waste disposal unit. As discussed below, these provisions, termed RCRA corrective action provisions, will have far reaching impact on ANL. The HSWA amendments also placed increased emphasis on waste minimization and pollution prevention activities. In September 1988, the USEPA published final regulations governing management of underground storage tanks containing hazardous materials or petroleum products. The IEPA has been authorized to administer most aspects of the RCRA program in Illinois. Authorization for the state to administer the mixed waste and corrective action provisions of RCRA is expected in early 1990.

3.3.1. Hazardous Waste Treatment and Disposal

Because of the nature of the research activities conducted at ANL, small quantities of a number of waste chemicals are generated. Many of these materials are classified as hazardous waste under RCRA. Most such chemicals are collected by Waste Management Operations (WMO) from individual generators and shipped off the site for disposal at an approved hazardous waste disposal facility. During 1989, 29,500 liters (7805 gallons) of hazardous waste were shipped off the site for disposal. In addition, small quantities of certain hazardous chemicals are treated on the site in one of several permitted treatment units. These units render the waste nonhazardous and allow disposal in the normal refuse or in wastewater. During 1989, 3085 liters (815 gallons) of waste were treated on site, primarily by elementary neutralization.

To assist in management of hazardous waste before off-site shipment or on-site treatment, ANL operates several temporary storage facilities. These facilities, designed and operated in compliance with RCRA requirements, allow for accumulation of small quantities of waste and storage of waste pending identification of a disposal site. Table 3.3 lists all on-site RCRA permitted units. The current Part A permit contains a shock sensitive treatment area in the 319 Area. This unit was proposed at the time of permit application, but has never been built. Currently, there are no plans to build this facility.

TABLE 3.3

Hazardous Waste Treatment and Storage Facilities

Description	Location	Purpose
Waste Treatment and Storage	Building 306	Primary facility for hazardous and mixed waste treatment, accumulation, packaging, and short-term storage.
Water Reaction Tank	317 Area	Reaction (passivation) of water reactive compounds.
Shock Sensitive Area	317 Area	Treatment (detonation) of extremely reactive, explosive, or shock-sensitive wastes.
Container Storage	Building 325C	Storage of sealed containers of waste pending off-site disposal.
Mixed Waste Storage	Building 329	Storage of containers of mixed waste and lead contaminated mixed solid waste.
Alkali Metal Reaction Booth	Building 206	Destruction of alkali metals.
Alkali Metal Reaction Booth	Building 308	Destruction of potentially radioactive alkali metals.

3.3.2. Permit Status

Argonne was granted interim status under RCRA by submitting a Part A permit application during 1980. In August 1985, the Part B permit application for final permit status was filed with the USEPA. A revised permit application was submitted in December 1988 in response to USEPA comments. Since the State of Illinois now has been granted authority to administer the RCRA program, the Part B permitting process has been transferred to the IEPA. During 1989, the IEPA notified ANL that a revised Part B permit application must be submitted by January 1, 1991. Argonne is updating the application to include information required to comply with the RCRA corrective action provisions. The IEPA has indicated that because of limited manpower and the large number of Part B permit applications to be processed, it may be several years before the final permit will be issued. In the meantime, ANL will continue to abide by interim status standards found in 40 CFR 265.

3.3.3. Facility Modifications

Plans are being finalized to expand and refurbish Building 306. In addition, a new radioactive and hazardous waste processing and storage building is also being planned. Both facilities are scheduled for construction in 1990. The Part A and Part B permit applications will be revised before construction of these facilities is begun.

3.3.4. Mixed Waste Handling

On September 23, 1988, the USEPA published a clarification note concerning the permitting and operating requirements for interim status facilities handling mixed waste (radioactive and hazardous). This note states that such wastes are to be governed by both RCRA and the Atomic Energy Act (AEA) regulations and facilities storing or disposing of mixed waste must comply with RCRA permitting and facility standards. Argonne generates several mixed wastes, primarily acids or solvents contaminated with radionuclides. These mixed wastes are stored or treated to remove the hazardous characteristic (by acid neutralization and evaporation) in Buildings 329 and 306 pending identification of a final disposal site. The IEPA is expected

to receive authorization for the mixed waste provisions of RCRA in early 1990. The Part B application will address mixed-waste management procedures.

3.3.5. Facility Standards for Miscellaneous Units

In December 1987, RCRA facility standards for miscellaneous units were published. These standards apply to three treatment units at ANL; the alkali metal reaction booths in Buildings 206 and 308 and the shock treatment unit (shoot-and-burn pile) in the 317 Area. The Part B permit application will be modified to include the required information for these units.

3.3.6. Underground Storage Tanks

In response to the new underground storage tank regulations, ANL has prepared a Site-Wide Underground Tank Compliance Plan. The ANL site currently contains 26 existing underground storage tanks and 32 tanks have been removed. The majority of these tanks are being used, or were used in the past, for storage of fuel oil for emergency generators or space heaters. The on-site vehicle maintenance facilities use underground gasoline and methanol tanks. Several tanks are only used for nonregulated materials, such as steam condensate, and are not affected by the new regulations. The Compliance Plan sets out a two-phase program for removal of unused underground tanks and the replacement or upgrading of tanks that must remain underground for safety considerations.

Work on this plan was begun in mid-1989 with the removal of 19 unused oil and gasoline storage tanks and four non-regulated tanks (containing water or steam condensate). As each tank was removed, a number of soil samples were collected and submitted to an independent laboratory for analysis for BETX (benzene, ethylene, toluene, and xylene) and other constituents as required by IEPA cleanup standards. Any soil found to be contaminated was excavated and disposed of off the site at a facility permitted to accept petroleum contaminated soil. A final set of soil samples was then collected and analyzed to confirm that all contamination had been removed. Of the 23 tanks removed, 15 were found to have some degree of exterior contamination

from leaks, spills, or overfills. The IEPA was notified of the discovery of the contaminated sites. All but one of these contaminated sites were successfully cleaned up and filled (clean closure). At one site, very close to an existing maintenance building, contaminated soil was found to extend under the building foundation. As much of the soil as possible was removed; however, the contaminated soil directly under the building was left in place so as not to compromise the stability of the building. Argonne has petitioned the IEPA to allow a "dirty" closure of this site, meaning that the contamination under the building will be left in place and monitoring of the site will continue to ensure that the contamination does not migrate from the current location.

The remainder of the tank removal and upgrade program is scheduled for FY 1990 through FY 1992. During this period, regulated underground tanks still in use will be removed, replaced, or upgraded to current technical requirements (secondary containment, corrosion protection, leak detection, double-walled piping, spill, and overfill protection).

3.3.7. Corrective Action for Solid Waste Management Units

As mentioned previously, the HSWA amendments added language to RCRA (40 CFR 264.101) requiring that any Part B permit issued must include provisions for corrective actions for all releases of hazardous materials from any solid waste management unit (SWMU) at the site, regardless of when the waste was placed in the unit. When issued, the permit is to describe the corrective actions necessary and provide a schedule of compliance. The ANL site has a number of waste management units, some of which may be required to undergo some type of corrective action. Argonne is currently engaged in an effort to identify all potential SWMUs on the site as well as SWMUs which are located on the portions of DuPage County Forest Preserve property that were formerly ANL property. The process of conducting detailed characterization studies to determine if hazardous materials have been released from a number of these units was begun in 1989. This information will be submitted to the IEPA with the revised Part B application.

3.4. National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 established basic Federal Government policy to restore and enhance the quality of the human environment and to avoid or minimize any adverse effects that government-sponsored projects would have on the environment, including historic or cultural resources. To ensure compliance with this policy, NEPA requires that projects with potentially significant impacts be carefully reviewed through the generation of one of several public documents, such as an Environmental Assessment (EA) or Environmental Impact Statement (EIS). This review process is designed to insure that all potential impacts are identified and minimized, all available options are considered, and all affected parties are informed and given opportunity to comment on the project.

The DOE implementation of NEPA regulations has been undergoing significant changes in the last year. The threshold at which projects are subject to NEPA review has been reduced to such an extent that almost any conceivable construction or nonroutine maintenance project is now required to undergo some level of NEPA review and documentation. The list of Categorical Exclusions, which is a list of project types that normally do not require an EA or EIS, is being expanded to help streamline the process. Review and approval of all NEPA documents is being centralized in DOE Headquarters, rather than being delegated to the various DOE field offices as was the past practice.

During 1989, ANL instituted an Environmental Planning and Review Program. This program is designed to ensure that all significant construction or nonroutine maintenance projects under consideration at ANL are reviewed to determine if they will have any significant environmental impacts. This program subjects each proposed project to a careful consideration of all potential impacts to air (dust, gaseous effluents), water (liquid effluents, wetland destruction), and soil (solid waste generation, construction activity), as well as impacts involving critical wildlife habitats, historic and cultural resources, radiation, noise, aesthetics, and public relations. Information gathered by this review process is submitted to DOE for their review and determination of the proper level of NEPA documentation. Projects that exhibit potentially adverse impacts in any area

are subject to further review, including preparation of one of the official NEPA documents mentioned previously if the extent of potential impacts warrants such detailed review. Official NEPA documents are prepared and reviewed by DOE according to the procedures specified out in DOE Order 5440.1B.

During 1989, many projects were reviewed under these NEPA review procedures. Most of them were relatively minor construction and maintenance operations with no significant impacts. These projects were determined to be either categorical exclusions requiring no additional documentation, or they had no significant impacts worthy of further review. For projects judged to have no adverse impacts, but which were not categorical exclusions, the NEPA review decision was documented by writing a Memorandum-to-File (MTF), which stated that the review had been completed and no significant impact was likely. Several projects were subjected to further review; included were construction of the leachate collection and treatment system for the sanitary landfill and the characterization study of the landfill and French drain. The level of NEPA documentation required for both projects has not yet been determined.

The DOE requested that ANL prepare an Action Description Memorandum (ADM) for these projects. The ADM is an internal document that provides the DOE with enough detailed information about the proposed project to determine the appropriate level of NEPA documentation.

During the last several years, the only project identified as a having potentially significant environmental impact is the construction of the Advanced Photon Source (APS) facility scheduled to begin in mid 1990. This facility will be an advanced particle accelerator used to generate intense beams of X-rays for a variety of research applications. Its potential environmental impacts are being documented in an EA, which was submitted to DOE in 1987. Preliminary review by the DOE has indicated that the EA provides sufficient evidence to determine that an EIS is not required. Thus, a "Finding of No Significant Impact" (FONSI) is sufficient to document environmental concerns. Final review had not been completed as of the end of 1989. The FONSI represents an official declaration that this facility

should have no adverse impacts on the environment and clears the way for final design and construction of the facility, once funding for the project is approved. The major environmental consideration described in the EA is the presence of several small wetlands that will be displaced by the facility. The construction plans call for the replacement of these wetlands with several man-made wetlands situated around the facility.

3.5. Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) of 1974 established a program to ensure that public drinking water supplies are free of potentially harmful amounts of various chemicals. This mandate is carried out through the institution of drinking water quality standards, such as Maximum Contaminant Levels (MCL) and Maximum Contaminant Level Goals (MCLG) as well as through imposition of well head protection requirements, monitoring requirements, treatment standards, and regulation of underground injection activities. The Act established Primary and Secondary National Drinking Water Regulations, which set forth requirements to protect human health (primary standards) and provide aesthetically acceptable water (secondary standards).

3.5.1. Applicability to ANL

The primary drinking water supply at ANL consists of four on-site wells that supply raw water to the water treatment plant. The treatment plant removes iron and treats the water by ion-exchange before pumping it to the site-wide distribution system. This system is classified by the State of Illinois as a non-transient, non-community water supply, and as such is subject to most, but not all, of the provisions of the SDWA. In addition, the State of Illinois also regulates public water supplies through Subtitle F of Title 35, Illinois Administrative Code, which establishes a permitting program, design, operation and maintenance requirements and secondary water quality standards.

The ANL site contains a second water treatment system, termed the "canal water" treatment system. This system pumps water from the Chicago Sanitary and Ship Canal and treats it to remove sediment and provide disinfection. This water is used only for industrial purposes, such as

cooling towers and fire fighting and is not a regulated drinking water supply.

3.5.2. Monitoring Requirements

The primary drinking water standards establish certain monitoring and analytical requirements. Argonne samples each of the four wells and the treated water annually. The water has consistently been in compliance with primary and secondary standards. Section 6 of this report presents a detailed discussion of the results of the drinking water program.

3.6. Federal Insecticide, Fungicide and Rodenticide Act

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) establishes a program to register pesticides, regulate their transportation and disposal, and determine standards for their use. Within ANL, all applications of pesticides are by licensed contractors who provide any pesticides used and remove any unused portions. Herbicides are rarely used, but when they are needed, a licensed contractor is brought in to apply them. In these situations, ANL will typically purchase the herbicide directly and ensure that it is used properly and that any residue is disposed of properly. Argonne, through DOE, will notify the USEPA before such an application is begun.

3.7. Comprehensive Environmental Response, Compensation and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) provides the regulatory framework and funding necessary to clean up closed and abandoned hazardous waste disposal sites. Under this framework, the USEPA collects data regarding sites subject to CERCLA action through generation of a Preliminary Assessment (PA) report followed up by a Site Investigation (SI). Based on the data collected, the sites are ranked according to their potential to cause human health impacts or environmental damage. The sites with the highest ranking are placed on the National Priority List (NPL) and are subject to forced cleanup actions, funded either

by Potentially Responsible Parties (PRPs) or by the allocation of Superfund money to the project.

3.7.1. Federal Facilities Under CERCLA

Historically, CERCLA approached federal facilities somewhat differently than non-federal facilities, with federal agencies being permitted to establish their own independent CERCLA program subject to USEPA oversight. The DOE's CERCLA program is detailed in DOE Order 5400.4. Under the provisions of this Order, in July 1986, ANL submitted preliminary assessment (PA) reports to DOE for the 10 inactive sites shown in Table 3.4. Because of changes in the CERCLA program brought about by the Superfund Amendments and Reauthorization Act (SARA) of 1986, the USEPA is required to publish a comprehensive inventory of Federal Facility Sites known as the Federal Agency Hazardous Waste Compliance Docket. The USEPA also was mandated to review these sites to determine if additional action is required. In support of this effort, the USEPA required submittal of PA reports for all sites at ANL (as listed in Table 3.4). These reports were submitted in April 1988. Four sites not included in the original submittal were included in the SARA submission. As of the end of 1989, the USEPA had not notified ANL of any decisions nor requested any additional information regarding these sites.

If it is determined that some level of remedial action is required at one or more of these sites, this cleanup will take place either under RCRA authority as a condition of the Part B permit, under a CERCLA action, or possibly under some combined RCRA/CERCLA program. The USEPA has not yet issued regulations regarding RCRA corrective actions, and thus the interaction between RCRA and CERCLA is unclear. Regardless of which regulatory vehicle is ultimately used to facilitate the cleanup of these sites, the DOE, through various initiatives put forth by the Secretary of Energy, has made the commitment to clean up all such sites within the next 30 years, wherever possible returning them to unrestricted use. As a response to these commitments, ANL has requested funding for the characterization and remediation of the six most significant listed sites. The remainder of the sites will be characterized in coming years. Several of the characterization projects have already begun and will continue over the next few years.

TABLE 3.4

List of Inactive Disposal Sites at ANL
Described in Preliminary Assessment Reports

	<u>CERCLA</u>	<u>SARA</u>
French Drain in 800 Area Sanitary Landfill	X	X
French Drain and Landfill in 319 Area	X	X
Landfill East-Northeast of 319 Area	X	X
Compressed Gas Cylinder Disposal Area, 318 Area	X	X
French Drain, 317 Area	X	X
Mixed Waste Storage Vaults, 317 Area		X
Shock Treatment Facility, 317 Area	X	X
Wastewater Holding Basin, Sewage Treatment Plant		X
Liquid Waste Treatment Facility, Building 34	X	X
Reactive Waste Disposal, Underwriters Pond	X	X
Decommissioned Reactor CP-5, Building 330		X
Gasoline Spill, Gasoline Station		X
Site A	X	
Plot M	X	

3.7.2. Emergency Planning and Community Right to Know Act, SARA Title III

Title III of the 1986 SARA amendments to CERCLA created a system for planning for response to emergency situations involving hazardous materials and for making information regarding use and storage of hazardous materials available to the public. Under SARA Title III, ANL is required to provide an inventory of hazardous substances stored on the site, Material Safety Data Sheets (MSDS), and completed SARA data sheets (Tier I or II forms) for each hazardous substance stored in quantities above a certain threshold planning quantity (typically 10,000 lbs; but lower for certain compounds) to applicable emergency response agencies. In November 1987, an inventory and MSDS forms for nine chemicals were submitted to the Local Emergency Planning Committee (LEPC); in March 1988, Tier I reports providing additional information on these chemicals were submitted. In January 1989, Tier II report forms were completed and submitted to the LEPC. These forms not only updated the previous listing, adding three additional chemicals, but also provided more information regarding the amount of material stored and the location of the material. Table 3.5 lists hazardous compounds reported under SARA Title III for 1989.

Section 304 of SARA Title III requires that the LEPC and state emergency planning agencies be notified of accidental or unplanned releases of certain hazardous substances to the environment. To ensure compliance with such notification provisions, the SPCC plan for ANL was modified to include SARA Title III requirements. No incidents during 1989 required notification of the LEPC.

3.8. Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) of 1976 provides for testing of manufactured substances to determine toxic or otherwise harmful characteristics and regulation of the manufacture, distribution, use, and disposal of regulated substances. The principal TSCA-regulated compounds in general use at ANL are polychlorinated biphenyls (PCB) contained in electrical capacitors and transformer oil. Regulations governing PCB use and disposal are given in 40 CFR 761. These regulations provide detailed requirements for use and disposal of PCB-containing mixtures (over 500 ppm PCB) and PCB-

TABLE 3.5

Compounds Reported Under SARA Title III

Compound	Hazard Class				
	Fire	Sudden Release of Pressure	Reactive	Acute Health Hazard	Chronic Health Hazard
Diesel Fuel	X				
Gasoline	X				
Methanol/ Gasoline	X				
Sodium	X		X		
Chlorine		X		X	
Chlorofluoro- carbon 11		X			
Sodium Carbonate				X	
Sulfuric Acid				X	
Calcium Oxide				X	
Calcium Hydroxide				X	
Oils containing PCBs					X

contaminated mixtures (over 50 ppm PCB). Most of these regulations relate to PCBs contained in dielectric fluids within electrical equipment, such as transformers and capacitors.

3.8.1. PCBs in Use at ANL

The majority of all PCBs at ANL are contained in a large number of transformers, capacitors, and switches throughout the site. In 1987, ANL began removing and disposing of all PCB and PCB contaminated electrical equipment, starting with indoor transformers. All indoor units have been removed and transported off the site for proper disposal, and 14 outdoor units have been removed or retrofilled. During 1989, all pole mounted transformers and circuit breakers suspected of containing PCBs were sampled to determine if they should be classified as PCB or PCB contaminated units. Of the 146 transformers tested, only two units are considered PCB units (concentration above 500 ppm); 38 units are PCB contaminated. During 1990, the remainder of the large outdoor units and pole mounted units containing PCBs will be removed and disposed of or reclassified (PCB-containing oils removed and replaced with non-PCB oil). All removal and disposal activities are conducted by licensed contractors specializing in such activities. Operation, removal, storage, and disposal of PCB-containing articles were conducted in compliance with applicable TSCA regulations.

3.9. Environmental Permits, Assessments, and Audits

3.9.1. Permits

Table 3.6 lists all environmental permits currently in effect or applied for at ANL. Other portions of this Section discuss special requirements of these permits and compliance with those requirements. The results of monitoring required by these permits are presented in this section, as well as in Section 5. As mentioned in Section 3.1, several air pollution permit applications have been submitted to the IEPA or are being prepared. Approval is anticipated in 1990.

TABLE 3.6

IEPA Environmental Permits in Effect at ANL

Permit Type	Facility	Permit Number	Expires
<u>Air Pollution Control Permits</u>			
Operating	Fossil Energy Users Laboratory (FEUL), Building 145	C8012024	6/23/90
Operating	Steam Plant, Building 108	79090047	8/1/90
Operating	Gas Dispensing Facility, Building 827	HG490	5/30/90
Operating	Alkali Metal Reaction Booth, Building 206	89030076	5/31/94
Operating	Methanol Fuel Dispensing Facility, Building 827	86020043	2/7/91
Operating	Alkali Metal Reaction Booth, Building 308	88120046	2/9/94
Operating	Central Shops Vapor Degreaser	90020052	3/9/95
Operating	Boiler House Spent Sorbent Dust Collector	Application Pending	N/A
Open Burning (Fire Training)	Fire Station, Building 333	8903064	4/6/90
NESHAP Approval to Construct, USEPA	APS Facility	N/A	N/A
NESHAP Construction Permit, IEPA	APS Facility	N/A	N/A

TABLE 3.6 (Contd.)

Permit Type	Facility	Permit Number	Expires
<u>Water Pollution Control Permits</u>			
NPDES	Laboratory Wastewater Effluents	IL0034592	7/15/94
Lime Sludge Utilization	Lime Sludge Holding Pond	1989-SC-4031	12/31/90
NPDES Construction	Boiler House Wastewater Treatment Plant	Application Pending	N/A
<u>Land Pollution Control Permits</u>			
Landfill Operating	Sanitary Landfill, 800 Area	1981-29-OP Site Code - 0438020002	N/A (Special Condition)
Landfill Supplemental	Sanitary Landfill, 800 Area	1982-30	N/A
Landfill Supplemental	Landfill Leachate Test Wells	Application Pending	N/A
Section 404, Dredge and Fill Permit (Corps of Engineers)	A ² R ² Excavation	Nationwide Permit - 1708906	11/30/90
<u>RCRA Permits</u>			
RCRA Hazardous Waste, TSD Facility, Part A	Facilities 306, 317, 319, 325C, 329, 206, and 308	IL3890008946	N/A (Interim Status)
RCRA Hazardous Waste, TSD Facility, Part B	Facilities 306, 317, 325C, 329, 206, and 308	Application Pending	N/A
Underground Storage Tank Removal	Nineteen Locations, Site Wide	1858 REM	N/A
<u>Miscellaneous Permits</u>			
Nuisance Animal Removal	Site Wide	N/A	2/3/90

3.9.2 Assessments and Audits

In June 1989, the DOE issued a draft of the Analysis Data Document of the ANL site prepared as a part of the DOE Environmental Survey conducted in June 1987. This data document presents the analytical results from the samples collected during that survey. (The report generated by the survey was issued in draft form during November 1988 and was discussed in last year's Annual Site Environmental Report.⁵) The analytical results reported in the data document, for the most part, confirmed the results of sampling already conducted by ANL. In several instances where the potential for environmental contamination existed due to past actions, analysis of samples collected by the DOE survey team indicated that contamination was not present. The information contained in the draft document is only preliminary, and many questions exist regarding its technical accuracy and validity.

The findings discussed in the draft DOE Environmental Survey Report for ANL represent a wide array of potential environmental problems caused primarily by inadequate operational control over past waste disposal activities, possible migration of hazardous material out of inactive waste sites, and improper operation and maintenance of emission sources and monitoring equipment. None of these findings constituted an imminent threat to human health or the environment. By late 1988, all findings were addressed to some degree. In March 1989, an action plan was developed and submitted to DOE detailing the corrective actions either completed, in progress, or planned. Many of the noted deficiencies were resolved quickly, while others will require long-term corrective actions such as characterization, monitoring and, possibly, remediation. A status report on progress toward resolving all outstanding deficiencies is submitted to the DOE on a quarterly basis.

During June 1989, DOE conducted its annual Environmental Protection Appraisal, which reviewed all phases of the ANL environmental protection program. This appraisal concluded that improvements need to be made in such areas as characterization and documentation of hazardous waste generation and disposal, particularly related to land-ban requirements; environmental impact reviews (NEPA compliance); management of PCB transformers; asbestos-containing waste disposal; and sediment and erosion control. The overall

rating given to ANL's environmental protection programs was "good" at the time of the appraisal. However, before the appraisal report was formally issued, several incidents related to improper disposal of hazardous wastes, discussed in Section 3.2.6, prompted the DOE to drop the rating to "marginal". Argonne has implemented most of the recommendations made by this appraisal.

3.10. Environmental Restoration and Waste Management Five Year Plan

During 1989, the DOE instituted a program to identify and track the progress of all environmental restoration, corrective action and waste management projects at all of the DOE installations. This program resulted in the generation of two major documents for each installation, the Environmental Restoration and Waste Management Five Year Plan and the Site Specific Plan for Environmental Restoration and Waste Management. The Five Year Plan consists of a series of forms, called activity data sheets (ADS), describing each project. The forms include such information as budget projections, schedules, priority levels, and project descriptions. Argonne's 1989 Five Year Plan contained ADS forms for 12 projects classified as corrective activities (treatment plant upgrades and rehabilitations, leachate collection, etc.), 16 projects termed remedial actions (site characterization activities, as well as site remediation), 25 waste management activities (D&D activities, waste disposal, and waste treatment), and 18 applied research and development activities. The ANL Site Specific Plan contains additional details on the above projects, as well as information related to organization and management necessary to implement these projects, NEPA review requirements and reporting and record keeping requirements. These documents are available for public review by contacting the DOE's Chicago Operations Office.

4. ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

4.1. Description of Monitoring Program

The radioactivity of the environment around ANL 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 for comparative purposes. Some on-site results are also reported when they are useful in interpreting perimeter and off-site results.

Since radioactivity is primarily transported by air and water, the sample collection program concentrated on these media. In addition, samples of soil, plants, foodstuffs, and materials from the beds of lakes and streams also were analyzed. The program followed the guidance provided in the DOE Environmental⁷ and Effluent⁸ Surveillance Guides. About 1,625 samples were collected and approximately 4,100 analyses were performed. The results of radioactivity measurements are expressed in terms of picocuries per liter (pCi/L) for water and milk; femtocuries per cubic meter (fCi/m³) and attocuries per cubic meter (aCi/m³) for air; and picocuries per gram (pCi/g), femtocuries per gram (fCi/g), and/or nanocuries per square meter (nCi/m²) for soil, bottom sediment, and vegetation. Penetrating radiation measurements are reported in units of millirem per year (mrem/y) and population dose in man-rem. Other units are defined in the text.

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

TABLE 4.1

Detection Limits

Nuclide or Activity	Air (fCi/m ³)	Water (pCi/L)
Americium-241	-	0.001
Beryllium-7	5	-
Californium-249	-	0.001
Californium-252	-	0.001
Cesium-137	0.1	1
Curium-242	-	0.001
Curium-244	-	0.001
Hydrogen-3	100	100
Lead-210	1	-
Neptunium-237	-	0.001
Plutonium-238	0.0003	0.001
Plutonium-239	0.0003	0.001
Radium-226	-	0.1
Strontium-89	0.1	2
Strontium-90	0.01	0.25
Thorium-228	0.001	-
Thorium-230	0.001	-
Thorium-232	0.001	-
Uranium-234	0.0003	0.01
Uranium-235	0.0003	0.01
Uranium-238	0.0003	0.01
Uranium - natural	0.02	0.2
Alpha	0.2	0.2
Beta	0.5	1

Averages, including individual results that were less than the detection limit, were calculated by one of the following two methods: (1) if a large fraction (usually 50% or more) of the individual results were 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; (2) if only a small fraction of the individual results were 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 expressed as a definite value. The first method 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 second method is based on the assumption that the values below the detection limit are distributed between zero and the detection limit with a frequency such that the average value is one-half of the detection limit. The averages that are obtained by using these two methods under the conditions indicated are believed to give an adequate representation of the average concentration at locations where the concentrations not only varied greatly, but were at times not detectable.

Average values are usually accompanied by a plus-or-minus (\pm) limit value. Unless otherwise stated, this value is the standard error at the 95% confidence level calculated from the standard deviation of the average. The \pm limit value 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 value accompanies an individual result in this report, it represents the statistical counting error at the 95% confidence level.

The DOE has provided guidance⁶ for effective dose equivalent calculations for members of the public, based on ICRP-26 and ICRP-30. Those procedures have been used in this report. The methodology requires three components to be calculated: (1) the committed effective dose equivalent from all sources of ingestion, (2) the committed effective dose equivalent from inhalation, and (3) direct effective dose equivalent from external radiation. These three components are summed for comparison with the new DOE effective dose equivalent limits for environmental exposure. The guidance requires that sufficient data on exposure to radionuclide sources be available 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 100 mrem/y. The effective dose equivalents for members of the public from all routine DOE operations, natural background and medical exposures excluded, shall not exceed these values and shall be as low as reasonably achievable (ALARA), or as far below these limits as is practical. 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 Committed Effective Dose Equivalent Factors (EDEF) and compared to the annual dose limits for uncontrolled areas. The EDEF are calculated from the DOE Derived Concentration Guides (DCG)⁶ for members of the public from ingested water and inhalation resulting in a radiation dose of 100 mrem/y. The numerical values of the EDEF used in this report are given in Section 4.7. Although the EDEF apply only to concentrations above natural levels, the calculated dose is sometimes given in this report for radioactivities that are primarily of natural origin for comparison purposes. Such values are enclosed in parentheses to indicate this. Occasionally, other standards are used, and their source is identified in the text.

4.2. Air

The radioactive content of particulate matter in the air was determined by collecting and analyzing air-filter samples. The sampling locations are shown in Figures 1.1 and 1.2. Separate collections were made for specific

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

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

The alpha activity, principally due to naturally occurring nuclides, averaged the same as in the past several years and was in its normal range. The perimeter beta activity averaged 27 fCi/m^3 , which is the same as the average value for the past five years. The gamma-ray emitters listed in Table 4.3 are those that have been present in the air for the past few years and are of natural origin. The beryllium-7 exhibits an increase in concentration in the spring, indicating its stratospheric origin. The lead-210 in air is due to the radioactive decay of gaseous radon-222 and is about 10% higher than in the past years. No airborne radionuclides from the accident at the Russian nuclear power facility near Chernobyl were measurable in 1989.

TABLE 4.2

Total Alpha and Beta Activities in Air-Filter Samples, 1989*
(concentrations in fCi/m³)

Month	Location	No. of Samples	Avg.	Alpha Activity		Beta Activity		
				Min.	Max.	Avg.	Min.	Max.
January	Perimeter	25	2.1	1.0	5.3	30.7	8.0	49.6
	Off-Site	18	2.1	0.8	5.0	37.7	18.5	70.6
February	Perimeter	31	2.2	1.0	4.2	32.8	21.2	42.7
	Off-Site	18	2.0	0.3	4.4	30.8	10.4	45.5
March	Perimeter	40	2.0	0.8	4.6	26.1	14.5	41.3
	Off-Site	21	2.0	0.7	3.5	24.7	10.5	40.0
April	Perimeter	30	2.5	1.0	4.3	23.8	12.9	38.8
	Off-Site	20	2.3	0.8	3.8	22.5	8.7	35.5
May	Perimeter	39	1.9	0.8	4.5	17.5	11.3	24.1
	Off-Site	23	1.7	0.7	3.3	16.2	6.5	23.2
June	Perimeter	32	2.2	0.8	5.3	21.7	11.0	33.5
	Off-Site	18	1.6	0.9	2.9	19.5	8.8	29.2
July	Perimeter	25	2.0	1.0	4.1	22.5	12.7	32.2
	Off-Site	18	2.0	0.8	3.9	22.9	13.5	36.9
August	Perimeter	31	2.7	0.9	4.9	22.1	16.4	30.7
	Off-Site	22	2.2	0.9	4.4	21.7	12.8	31.4
September	Perimeter	26	1.3	0.2	2.8	21.1	14.6	29.7
	Off-Site	14	1.5	0.4	4.4	20.3	13.1	30.6
October	Perimeter	44	3.3	0.4	18.0	30.8	17.6	51.3
	Off-Site	14	2.0	1.0	4.9	29.1	18.5	48.5
November	Perimeter	79	2.1	0.8	5.2	32.5	21.3	56.3
	Off-Site	23	2.1	1.1	3.3	28.5	15.1	52.3
December	Perimeter	21	3.3	2.1	6.0	38.9	32.0	52.5
	Off-Site	17	2.9	1.0	5.2	35.4	17.0	58.3
Annual Summary	Perimeter	423	2.3 ± 0.4	0.2	18.0	26.7 ± 4.0	8.0	56.3
	Off-Site	226	2.0 ± 0.2	0.3	5.2	25.8 ± 4.2	6.5	70.6

*

These results were obtained by measuring the samples four days after they were collected to avoid counting the natural activity due to short-lived radon and thoron decay products. This activity is normally present in the air and disappears within four days by radioactive decay.

TABLE 4.3

Gamma-Ray Activity in Air-Filter Samples, 1989
(concentrations in fCi/m³)

Month	Location	Beryllium-7	Lead-210
January	Perimeter	67	49
	Off-Site	73	69
February	Perimeter	75	48
	Off-Site	69	49
March	Perimeter	96	36
	Off-Site	108	45
April	Perimeter	101	30
	Off-Site	107	34
May	Perimeter	81	22
	Off-Site	99	26
June	Perimeter	88	25
	Off-Site	89	30
July	Perimeter	103	31
	Off-Site	107	37
August	Perimeter	70	29
	Off-Site	67	32
September	Perimeter	75	27
	Off-Site	85	33
October	Perimeter	112	46
	Off-Site	91	47
November	Perimeter	82	52
	Off-Site	63	46
December	Perimeter	71	60
	Off-Site	62	61
Annual Summary	Perimeter	85 ± 9	38 ± 8
	Off-Site	85 ± 11	42 ± 8
Dose(mrem)	Perimeter	(0.00021)	(4.21)
	Off-Site	(0.00021)	(4.72)

Samples for radiochemical analyses were collected at perimeter locations 12N and 7I (Figure 1.1) and off the site in Downers Grove (Figure 1.2). Collections were made on polystyrene filters. The total air volume filtered for the monthly samples was about 20,000 m³ (700,000 ft³). Samples were ignited at 600°C (1080°F) to remove organic matter and were prepared for analysis by vigorous treatment with hot hydrochloric, hydrofluoric, and nitric acids.

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

The average strontium-90 concentrations were similar to the averages of the past few years, excluding the strontium-90 contribution from the Chernobyl accident in 1986. Strontium-89 was not observed above the detection limit of 100 aCi/m³. The plutonium-239 concentrations were about a factor of two higher, both on and off the site, than in the past several years. The higher results appear to occur primarily during the summer.

The thorium and uranium concentrations are in the same range found in the past 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 3% to 45% and averaged 14% of the total plutonium in the samples. This assumes that the

TABLE 4.4
Strontium, Thorium, Uranium, and Plutonium Concentrations
in Air-Filter Samples, 1989³
(Concentrations in Attocuries/m³)

Month	Location*	Strontium-90	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Uranium-238	Plutonium-239
January	71	57 ± 19	17 ± 3	48 ± 4	20 ± 2	10 ± 2	10 ± 2	1.1 ± 0.4
	12N	46 ± 29	4 ± 2	20 ± 2	6 ± 1	10 ± 1	8 ± 1	1.2 ± 0.4
	Off-Site	45 ± 85	5 ± 3	15 ± 3	3 ± 1	9 ± 1	5 ± 1	1.6 ± 0.7
February	71	-	12 ± 2	48 ± 4	12 ± 2	16 ± 2	16 ± 2	1.4 ± 0.4
	12N	23 ± 34	12 ± 3	26 ± 3	13 ± 2	19 ± 3	15 ± 3	3.2 ± 0.7
	Off-Site	74 ± 23	13 ± 3	17 ± 2	11 ± 2	34 ± 4	30 ± 4	2.8 ± 0.7
March	71	-	-	48 ± 3	4 ± 1	12 ± 2	11 ± 2	1.1 ± 0.3
	12N	14 ± 9	4 ± 3	8 ± 2	4 ± 1	16 ± 2	11 ± 2	2.9 ± 0.6
	Off-Site	85 ± 13	8 ± 3	40 ± 4	12 ± 2	19 ± 2	15 ± 2	4.5 ± 0.7
April	71	< 10	8 ± 2	11 ± 2	5 ± 1	11 ± 2	8 ± 1	1.6 ± 0.6
	12N	< 10	10 ± 2	15 ± 2	9 ± 1	12 ± 2	11 ± 1	1.3 ± 0.4
	Off-Site	47 ± 49	16 ± 2	32 ± 2	14 ± 1	16 ± 2	17 ± 2	1.4 ± 0.4
May	71	< 10	40 ± 6	119 ± 11	34 ± 5	9 ± 1	9 ± 1	0.9 ± 0.5
	12N	13 ± 9	14 ± 4	47 ± 4	12 ± 2	12 ± 2	10 ± 2	1.7 ± 0.7
	Off-Site	< 10	-	-	-	-	-	-
June	71	< 10	31 ± 6	80 ± 9	25 ± 4	10 ± 1	8 ± 1	0.8 ± 0.3
	12N	20 ± 26	2 ± 2	10 ± 1	4 ± 1	13 ± 2	8 ± 1	1.4 ± 0.4
	Off-Site	-	-	-	-	-	-	-
July	71	< 10	2 ± 2	8 ± 2	4 ± 1	10 ± 2	6 ± 1	1.2 ± 0.4
	12N	18 ± 10	2 ± 2	16 ± 2	4 ± 1	13 ± 1	9 ± 1	1.1 ± 0.4
	Off-Site	20 ± 17	3 ± 2	9 ± 1	5 ± 1	16 ± 2	7 ± 2	1.7 ± 0.5
August	71	22 ± 12	1 ± 1	5 ± 1	2 ± 0	7 ± 1	4 ± 1	1.2 ± 0.5
	12N	20 ± 14	6 ± 3	9 ± 2	3 ± 1	8 ± 2	6 ± 1	2.2 ± 0.6
	Off-Site	15 ± 15	6 ± 3	18 ± 2	4 ± 1	7 ± 1	6 ± 1	2.2 ± 0.6
September	71	11 ± 53	29 ± 10	92 ± 18	18 ± 6	6 ± 1	5 ± 1	1.2 ± 0.5
	12N	17 ± 15	5 ± 4	14 ± 3	4 ± 1	8 ± 2	6 ± 1	2.2 ± 2.8
	Off-Site	16 ± 37	7 ± 6	12 ± 4	4 ± 2	8 ± 1	6 ± 1	1.6 ± 0.6
October	71	13 ± 25	5 ± 4	7 ± 3	4 ± 2	9 ± 3	9 ± 3	3.2 ± 1.2
	12N	12 ± 30	9 ± 6	16 ± 3	4 ± 1	10 ± 2	9 ± 2	1.8 ± 0.6
	Off-Site	17 ± 19	7 ± 12	21 ± 7	3 ± 3	14 ± 3	10 ± 3	2.4 ± 0.8
November	71	< 10	11 ± 2	18 ± 2	5 ± 1	17 ± 2	10 ± 2	4.2 ± 0.7
	12N	< 10	8 ± 4	10 ± 2	5 ± 2	10 ± 2	8 ± 2	1.1 ± 0.4
	Off-Site	< 10	3 ± 6	4 ± 2	3 ± 2	7 ± 2	6 ± 2	1.8 ± 0.5
December	71	< 10	18 ± 3	44 ± 4	10 ± 2	28 ± 2	23 ± 2	-
	12N	< 10	12 ± 2	16 ± 2	6 ± 1	14 ± 2	10 ± 1	6.5 ± 0.9
	Off-Site	< 10	3 ± 1	7 ± 1	3 ± 1	14 ± 2	6 ± 1	-
Annual Summary	71	< 16	16 ± 29	44 ± 82	12 ± 22	12 ± 13	10 ± 11	1.6 ± 2.4
	12N	17 ± 25	7 ± 9	17 ± 24	6 ± 7	12 ± 7	9 ± 5	2.2 ± 3.3
	Off-Site	30 ± 63	7 ± 10	17 ± 25	6 ± 10	14 ± 18	11 ± 18	2.2 ± 2.2
Dose (mrem)	71	< (0.00518)	(0.0401)	(0.0884)	(0.619)	(0.00560)	(0.00550)	(0.0045)
	12N	(0.00518)	(0.0182)	(0.0348)	(0.560)	(0.00560)	(0.00546)	(0.0060)
	Off-Site	(0.00533)	(0.0182)	(0.0352)	(0.560)	(0.00571)	(0.00553)	(0.0060)

* Perimeter locations are given in terms of the grid coordinates in Figure 1.1

resuspended soil has the same plutonium concentration as the first centimeter of soil on the ground. The remainder of the plutonium-239 is due to worldwide fallout.

The major airborne effluents released at ANL during 1989 are listed by location in Table 4.5. The radon-220 released from Building 200 is due to radioactive contamination from the "proof-of-breeding" program and from nuclear medicine studies. Even though the CP-5 reactor ceased operations in 1977, hydrogen-3 continues to be emitted from Building 330. The hydrogen-3 emitted from Building 212 is from the tritium recovery studies. In addition to the nuclides listed in Table 4.5, several other fission products also were released in millicurie or smaller amounts. The quantities listed in Table 4.5 were measured by on-line stack monitors in the exhaust systems of the buildings.

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

4.3. Surface Water

All surface water samples collected in the monitoring program were acidified to 0.1N with HNO_3 and filtered immediately after collection. Total (nonvolatile) alpha and beta activities were determined by counting the

TABLE 4.5

Summary of Airborne Radioactive Emissions from ANL Facilities, 1989

Building	Nuclide	Half-Life	Amount Released (curies/y)
200	Radon-220	56 s	1858
202 (JANUS)	Argon-41	1.8 h	1.1
211	Carbon-11	20 m	0.7
	Nitrogen-13	10 m	2.1
	Oxygen-15	122 s	10.9
212	Hydrogen-3 (HT)	12.3 y	3.6
	Hydrogen-3 (HTO)	12.3 y	4.3
	Krypton-85	10.7 y	4.0
330 (CP-5)	Hydrogen-3 (HTO)	12.3 y	30
375 (IPNS)	Carbon-11	20 m	97
	Argon-41	1.8 h	3.4

TABLE 4.6

Tritiated Water Vapor in Air, 1989
(concentrations in pCi/m³)

Month	Location*	No. of Samples	Avg.	Min.	Max.
January	8F	8	0.27	< 0.10	0.70
	12N	8	0.18	< 0.10	0.48
	Off-Site	2	0.10	< 0.10	0.11
February	8F	8	0.29	< 0.10	0.76
	12N	8	0.12	< 0.10	0.19
	Off-Site	2	< 0.10	< 0.10	< 0.10
March	8F	9	0.51	0.14	1.15
	12N	9	0.18	< 0.10	0.78
	Off-Site	2	0.14	< 0.10	0.18
April	8F	9	0.94	0.17	4.20
	12N	9	0.73	< 0.10	2.54
	Off-Site	2	0.90	< 0.10	1.70
May	8F	8	0.53	< 0.10	1.49
	12N	8	0.67	< 0.10	1.15
	Off-Site	2	0.56	< 0.10	1.01
June	8F	9	1.03	< 0.10	2.47
	12N	9	1.03	< 0.10	2.27
	Off-Site	2	1.02	0.95	1.09
July	8F	9	1.65	0.12	3.56
	12N	9	1.08	0.41	1.72
	Off-Site	2	1.00	0.76	1.24
August	8F	9	0.76	< 0.10	2.34
	12N	9	0.45	< 0.10	2.37
	Off-Site	2	< 0.10	< 0.10	< 0.10
September	8F	8	0.93	< 0.10	2.77
	12N	8	0.87	< 0.10	2.17
	Off-Site	2	0.46	< 0.10	0.81
October	8F	9	0.46	< 0.10	1.06
	12N	9	0.38	< 0.10	1.12
	Off-Site	2	0.57	0.10	1.03
November	8F	9	0.46	< 0.10	1.02
	12N	9	0.47	< 0.10	1.32
	Off-Site	2	0.75	0.57	0.94
December	8F	6	0.17	< 0.10	0.38
	12N	6	0.23	< 0.10	0.43
	Off-Site	2	0.18	< 0.10	0.26
Annual Summary	8F	101	0.69	< 0.10	4.20
	12N	101	0.54	< 0.10	2.54
	Off-Site	24	0.48	< 0.10	1.70
Dose (mrem)	8F	-	0.00069	< 0.00010	0.00420
	12N	-	0.00054	< 0.00010	0.00254
	Off-Site	-	0.00048	< 0.00010	0.00170

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

residue remaining after evaporation of the water and then applying counting efficiency corrections determined for uranium-233 (for alpha activity) and thallium-204 (for beta activity) to obtain disintegration rates. Hydrogen-3 was measured from a separate aliquot, and this activity does not appear in the results for total nonvolatile beta activity. Uranium was measured with a laser fluorometer, and the results were calculated in terms of activity, with the assumption that the isotopic composition was that of natural uranium. Analyses for other radionuclides were performed by specific radiochemical separations followed by appropriate counting. One-liter aliquots were used for all analyses except for hydrogen-3 and the transuranium nuclides. Hydrogen-3 analyses were performed by liquid scintillation counting of 10 mL of a distilled sample in a gel medium. Analyses for transuranium nuclides were performed on 10-liter samples with chemical separation methods followed by alpha spectrometry.^{9,10} Plutonium-236 was used to determine the yields of plutonium and neptunium, which were separated from the sample together. A group separation of a fraction containing the transplutonium elements was monitored for recovery with americium-243 tracer.

Argonne wastewater is discharged into Sawmill Creek, which runs through the ANL grounds, drains surface water from much of the site, and flows into the Des Plaines River about 500 m (0.3 mi) downstream from the ANL wastewater outfall. Sawmill Creek was sampled upstream from the ANL site and downstream from the wastewater outfall to determine if radioactivity was added to the stream by ANL wastewater or surface drainage. The sampling locations are shown in Figure 1.1. Below the wastewater outfall, daily samples were collected by grab sampling. 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 measured in the below-outfall samples.

Annual summaries of the results obtained for Sawmill Creek are given in Table 4.7. Comparison of the results and 95% confidence levels of the averages for the two sampling locations shows that the nuclides found in the creek water that can be attributed to ANL operations were hydrogen-3,

TABLE 4.7

Radionuclides in Sawmill Creek Water, 1989

Activity	Location*	No. of Samples	Concentrations in pCi/L			Dose (mrem)		
			Avg.	Min.	Max.	Avg.	Min.	Max.
Alpha (Nonvolatile)	16K	12	1.7 ± 1.5	0.9	2.7	-	-	-
	7M	51	1.7 ± 0.9	0.8	2.8	-	-	-
Beta (Nonvolatile)	16K	12	7 ± 5	4	13	-	-	-
	7M	51	15 ± 9	7	28	-	-	-
Hydrogen-3	16K	12	104 ± 30	< 100	147	0.0052	< 0.0050	0.0074
	7M	51	118 ± 88	< 100	376	0.0059	< 0.0050	0.0188
Strontium-90	16K	12	0.30 ± 0.12	< 0.25	0.39	0.030	< 0.025	0.039
	7M	51	0.48 ± 0.63	< 0.25	1.70	0.048	< 0.025	0.170
Cesium-137	16K	12	< 1.0	< 1.0	< 1.0	< 0.03	< 0.03	< 0.03
	7M	51	2.0 ± 5.5	< 1.0	15.9	0.07	< 0.03	0.53
Uranium (Natural)	16K	12	1.7 ± 2.2	0.4	3.5	0.284	0.060	0.586
	7M	51	1.0 ± 0.9	0.3	2.1	0.160	0.045	0.354
Neptunium-237	16K	12	0.0012 ± 0.0010	< 0.0010	0.0025	0.0039	< 0.0033	0.0084
	7M	51	0.0134 ± 0.1113	< 0.0010	0.3106	0.0445	< 0.0033	1.0343
Plutonium-238	16K	12	0.0021 ± 0.0041	< 0.0010	0.0061	0.0052	< 0.0025	0.0151
	7M	51	0.0037 ± 0.0166	< 0.0010	0.0577	0.0092	< 0.0025	0.1442
Plutonium-239	16K	12	0.0012 ± 0.0009	< 0.0010	0.0024	0.0039	< 0.0033	0.0080
	7M	51	0.0111 ± 0.0480	< 0.0010	0.1308	0.0369	< 0.0033	0.4356
Americium-241	16K	12	0.0021 ± 0.0044	< 0.0010	0.0081	0.0069	< 0.0033	0.0270
	7M	51	0.0131 ± 0.0827	0.0015	0.2971	0.0436	0.0050	0.9893
Curium-242 and/or Californium-252	16K	12	0.0014 ± 0.0016	< 0.0010	0.0034	0.0014	< 0.0010	0.0034
	7M	51	0.0012 ± 0.0012	< 0.0010	0.0041	0.0012	< 0.0010	0.0041
Curium-244 and/or Californium-249	16K	12	0.0012 ± 0.0006	< 0.0010	0.0019	0.0038	< 0.0033	0.0064
	7M	51	0.0013 ± 0.0014	< 0.0010	0.0040	0.0042	< 0.0033	0.0133

* Location 16K is upstream from the Argonne site and location 7M is downstream from the Argonne wastewater outfall.

strontium-90, cesium-137, neptunium-237, plutonium-239, americium-241, and occasionally plutonium-238, curium-242 and/or californium-252, and curium-244 and/or californium-249. The percentage of individual samples containing activity attributable to ANL was 29% for hydrogen-3, 73% for strontium-90, 29% for cesium-137, 77% for neptunium-237, 96% for plutonium-239, and 100% for americium-241. The concentrations of all these nuclides were low and would result in very small potential doses. The total concentration, regardless of source, must be used in assessing the hazard of a radionuclide not naturally present. The principal radionuclide added to the creek by ANL wastewater, in terms of concentration, was hydrogen-3.

The total alpha activity was similar above and below the site and was in the range of concentrations found in the past. However, the total beta activity at location 16K was down by a factor of three compared with 1986. It was noted previously that after the Marion Brook wastewater treatment plant closed on October 27, 1986, the beta activity decreased by this factor of three in the creek above the site. This reduction is assumed to be due to the absence of natural radioactivities in human excretions (principally potassium-40) processed and discharged by the treatment plant. This reduction of about 12 pCi/L is also apparent in the total beta activity below the site.

At location 7M, below the ANL outfall, the annual average concentrations of most measured radionuclides were lower in 1989 than in 1988. For example, the hydrogen-3 concentration was lower by a factor of three, strontium-90 by 25%, plutonium-239 by 20%, and americium-241 by 25%. All the annual averages were well below the applicable standards.

The annual total radioactive effluent discharged to the creek in ANL wastewater can be estimated from the average net concentrations and the volume of water carried by the creek. These totals are 0.087 Ci of hydrogen-3, 0.001 Ci of strontium-90, 0.006 Ci of cesium-137, 0.08 mCi of neptunium-237, 0.06 mCi of plutonium-239, 0.07 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, data on the radioactivity in the two rivers are important in assessing the contribution of ANL wastewater to environmental radioactivity. The Des Plaines River was sampled twice a month below, and once a month above, the mouth of Sawmill Creek to determine if the radioactivity in the creek had any effect on the radioactivity in the river.

Table 4.8 presents annual summaries of the results obtained for these two locations. 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, because the activity in Sawmill Creek was reduced by dilution to the point that it was not detectable in the Des Plaines River. The average nonvolatile alpha and beta activities, 1.5 pCi/L and 9.8 pCi/L, respectively, of 20 off-site surface water samples collected in 1989 were similar to the levels found in previous years. The hydrogen-3 concentration in these surface water samples averaged 162 pCi/L.

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

In the 1982 monitoring report,¹¹ an unusual occurrence was reported, involving the loss of about 7.5 million liters (2 million gallons) of ponded water containing about 26 mCi of tritiated water from the Argonne Advanced Research Reactor (A²R²) excavation (location 10G). The concentration of the tritiated water that remains in the A²R² excavation continued to decrease from 2,900 pCi/L in 1982, to 1,200 pCi/L in 1983, to 910 pCi/L in 1984, to 730 pCi/L in 1985, to 590 pCi/L in 1986, to 490 pCi/L in 1987, and to 420 pCi/L in 1988. During 1989, the appropriate permits and authorization were obtained, and the excavation was filled with the original material in the spring of the year.

TABLE 4.8

Radionuclides in Des Plaines River Water, 1989

Activity	Location*	No. of Samples	Concentrations in pCi/L			Dose (mrem)		
			Avg.	Min.	Max.	Avg.	Min.	Max.
Alpha (Nonvolatile)	A	13	1.5 ± 1.9	0.4	4.1	-	-	-
	B	24	1.7 ± 0.9	1.0	2.7	-	-	-
Beta (Nonvolatile)	A	13	13 ± 11	3	21	-	-	-
	B	24	15 ± 7	8	21	-	-	-
Hydrogen-3	A	13	104 ± 20	< 100	126	0.0052	< 0.0050	0.0063
	B	24	111 ± 73	< 100	259	0.0056	< 0.0050	0.0129
Strontium-90	A	12	0.26 ± 0.03	< 0.25	0.29	0.026	< 0.025	0.029
	B	24	0.26 ± 0.17	< 0.25	0.43	0.026	< 0.025	0.043
Uranium (Natural)	A	12	1.1 ± 1.1	0.6	2.1	0.191	0.099	0.357
	B	24	1.0 ± 1.3	0.4	3.6	0.175	0.073	0.606
Neptunium-237	A	12	0.0010 ± 0.0003	< 0.0010	0.0014	0.0035	< 0.0033	0.0046
	B	12	0.0011 ± 0.0005	< 0.0010	0.0018	0.0036	< 0.0033	0.0060
Plutonium-238	A	12	0.0024 ± 0.0068	< 0.0010	0.0118	0.0061	< 0.0025	0.0295
	B	12	0.0014 ± 0.0020	< 0.0010	0.0038	0.0036	< 0.0025	0.0095
Plutonium-239	A	12	0.0018 ± 0.0048	< 0.0010	0.0086	0.0060	< 0.0033	0.0286
	B	12	0.0010 ± 0.0001	< 0.0010	0.0011	0.0034	< 0.0033	0.0037
Americium-241	A	12	0.0012 ± 0.0006	< 0.0010	0.0019	0.0041	< 0.0033	0.0062
	B	12	0.0019 ± 0.0026	< 0.0010	0.0039	0.0064	< 0.0033	0.0131
Curium-242 and/or Californium-252	A	12	0.0010 ± 0.0001	< 0.0010	0.0011	0.0010	< 0.0010	0.0011
	B	12	0.0013 ± 0.0011	< 0.0010	0.0024	0.0013	< 0.0010	0.0024
Curium-244 and/or Californium-249	A	12	0.0010 ± 0.0001	< 0.0010	0.0012	0.0034	< 0.0033	0.0041
	B	12	0.0012 ± 0.0013	< 0.0010	0.0019	0.0039	< 0.0033	0.0064

* Location A, near willow springs, is upstream and location B, near Lemont, is downstream from the mouth of Sawmill Creek.
See Figure 1.2

TABLE 4.9

Radionuclides in Illinois River Water, 1989
(Concentrations in pCi/L)

Date Collected	Location	Alpha*	Beta*	Hydrogen-3	Uranium (natural)	Plutonium-239
June 27	Dresden Lock & Dam, IL	1.7 ± 0.5	8.4 ± 0.5	389 ± 102	1.2 ± 0.1	< 0.001
June 27	McKinley Woods State Park, IL	0.5 ± 0.3	11.7 ± 0.5	51 ± 92	0.6 ± 0.1	0.006 ± 0.001
June 27	Morris, IL	1.2 ± 0.4	6.6 ± 0.4	367 ± 101	1.2 ± 0.1	-
June 27	Starved Rock State Park, IL	1.3 ± 0.5	8.5 ± 0.6	221 ± 98	1.1 ± 0.1	-
October 26	Dresden Lock & Dam, IL	1.4 ± 0.3	5.8 ± 0.4	436 ± 98	0.6 ± 0.0	< 0.001
October 26	McKinley Woods State Park, IL	0.4 ± 0.2	5.9 ± 0.3	260 ± 94	0.3 ± 0.0	< 0.001
October 26	Morris, IL	1.0 ± 0.3	5.9 ± 0.3	211 ± 93	0.4 ± 0.0	-
October 26	Starved Rock State Park, IL	1.2 ± 0.3	6.1 ± 0.4	192 ± 92	0.7 ± 0.1	-

* Nonvolatile activity.

4.4. 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 radioactivity of soil near ANL is normal. For this purpose, site-selection criteria and sample collection and sample preparation techniques recommended by the American Society for Testing and Materials (ASTM) were used.¹² Sites were selected in several directions and at various distances from ANL. Each site was selected on the basis that the soil appeared, or was known to have been, undisturbed for a number of years. Attempts were made to select open, level, grassy areas that were mowed at reasonable intervals. Public parks were selected when available.

Each soil sample consisted of ten cores, totaling 864 cm² (134 in²) in area by 5 cm (2 in) deep. Through 1976, samples had been collected down to 30 cm (12 in) to measure total deposition. The results of five years of sample collection at this depth has established the total deposition in the ANL environment. Reducing the sampling depth to 5 cm (2 in) will make the analysis more sensitive to changes in current deposition. The grass samples were obtained by collecting the grass from a 1 m² (10 ft²) area in the immediate vicinity of a soil sample. A grab sample technique was used to obtain bottom sediments from water bodies. After drying, grinding, and mixing, 100 g portions of each soil, bottom sediment, and grass samples were analyzed by the same methods described in Section 4.2 for air-filter residues. The plutonium and americium were separated from the same 100 g aliquot of soil. Results are given in terms of the oven-dried (110°C) weight.

The results for the gamma-ray emitting nuclides in soil are presented in Table 4.10. Intermediate half-life fission products reported in 1986 have decayed to below their detection limits and no evidence of Chernobyl fallout is apparent. The cesium-137 levels are similar to those found over the past several years and represent an accumulation from nuclear tests over a period of many years. The annual average concentrations for the perimeter

TABLE 4.10
Gamma-Ray Emitting Radionuclides in Soil, 1989
(Concentrations in pCi/g)

Date Collected	Location	Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232
	<u>Perimeter</u> [*]					
June 21	10P	18.34 ± 0.78	0.79 ± 0.04	1.34 ± 0.07	1.04 ± 0.04	0.89 ± 0.10
June 21	14E	20.33 ± 0.48	0.73 ± 0.02	1.42 ± 0.04	1.02 ± 0.03	0.85 ± 0.06
June 21	14N	17.70 ± 0.52	0.81 ± 0.02	1.30 ± 0.05	1.06 ± 0.03	0.85 ± 0.07
June 21	4EF	22.08 ± 0.79	0.10 ± 0.02	1.47 ± 0.07	1.06 ± 0.04	0.89 ± 0.10
June 21	7EF	20.27 ± 0.80	0.61 ± 0.03	1.56 ± 0.07	1.00 ± 0.04	0.88 ± 0.10
October 27	13D	19.74 ± 0.76	0.55 ± 0.03	1.50 ± 0.07	1.17 ± 0.04	0.99 ± 0.10
October 27	13N	18.93 ± 0.78	0.68 ± 0.03	1.33 ± 0.07	0.98 ± 0.04	0.95 ± 0.10
October 27	15H	19.16 ± 0.78	0.33 ± 0.03	1.18 ± 0.07	1.12 ± 0.04	1.01 ± 0.10
October 27	7M	12.56 ± 0.69	1.29 ± 0.04	1.04 ± 0.06	0.61 ± 0.04	0.52 ± 0.08
October 27	8G	18.46 ± 0.76	0.66 ± 0.03	1.13 ± 0.06	0.94 ± 0.04	0.78 ± 0.09
	Average	18.76 ± 5.68	0.65 ± 0.71	1.33 ± 0.38	1.00 ± 0.35	0.86 ± 0.31
	<u>Off-site</u>					
June 27	Dresden Lock & Dam, IL	26.34 ± 0.58	1.25 ± 0.03	1.11 ± 0.05	1.27 ± 0.03	1.08 ± 0.07
June 27	McKinley Woods State Park, IL	22.43 ± 0.96	0.62 ± 0.04	1.61 ± 0.09	1.18 ± 0.05	0.96 ± 0.12
June 27	Morris, IL	12.03 ± 0.68	1.15 ± 0.04	0.99 ± 0.06	0.82 ± 0.04	0.66 ± 0.09
July 13	Romeoville, IL	13.79 ± 0.72	0.24 ± 0.03	1.40 ± 0.07	1.05 ± 0.04	0.88 ± 0.10
July 13	Pioneer Park, Naperville, IL	15.36 ± 0.88	0.67 ± 0.04	0.93 ± 0.07	1.09 ± 0.05	0.98 ± 0.12
July 13	Lemont, IL	20.09 ± 0.94	0.21 ± 0.03	1.35 ± 0.09	1.15 ± 0.05	0.88 ± 0.12
October 26	Channahon, IL	19.98 ± 0.86	0.74 ± 0.04	1.46 ± 0.07	0.92 ± 0.04	0.93 ± 0.11
October 26	Starved Rock State Park, IL	18.05 ± 0.75	0.29 ± 0.03	2.19 ± 0.08	1.08 ± 0.04	0.91 ± 0.10
October 31	McCormick Woods, Brookfield, IL	18.69 ± 0.75	0.42 ± 0.03	1.76 ± 0.07	0.98 ± 0.04	0.89 ± 0.09
October 31	Bemis Woods, Western Springs, IL	17.87 ± 0.77	0.32 ± 0.03	2.13 ± 0.08	1.23 ± 0.05	1.06 ± 0.10
	Average	18.46 ± 9.42	0.59 ± 0.84	1.49 ± 0.99	1.08 ± 0.32	0.92 ± 0.26

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

and off-site samples were similar. The plutonium and americium concentrations are given in Table 4.11. The range and average concentrations of plutonium and americium in soil were similar at both perimeter and off-site sampling points. For fallout americium-241 in soil, about 10% is due to direct deposition, while about 90% is from the decay of the previously deposited plutonium-241.¹³ The measured deposition of americium-241 and the americium-241/plutonium-239 ratio is consistent with reported values.¹³

The radionuclide concentrations measured in grass are listed in Table 4.12. The annual averages and concentration ranges were similar at the perimeter and off-site locations and were similar to those of 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 4.13. The annual off-site averages were in the same range found in off-site samples collected in previous years. Plutonium results varied widely between locations and were strongly dependent on the retentiveness of the bottom material. A set of sediment samples was collected on July 18, 1989, from the Sawmill Creek bed, above, at the outfall, and at several locations below the point at which ANL discharges its treated waste water (location 7M in Figure 1.1). The results, as listed in Table 4.13, show that the concentrations in the sample above the 7M outfall are similar to those of the off-site samples. The plutonium, americium, and cesium-137 concentrations are slightly elevated below the outfall, indicating that their origin is in ANL wastewater. In addition to the radionuclides listed in Table 4.13, cobalt-60, up to 1 pCi/g, was identified in the sediment below the outfall. The changes in concentrations of these nuclides with time and location indicate the dynamic nature of the sediment material in this area.

4.5. Milk

Fresh milk collected monthly from a local dairy farm south of Lemont was analyzed for several radionuclides. The water was separated from the

TABLE 4.11
Transuranics in Soil, 1989

Date Collected	Location	Plutonium-238 (fCi/g)	Plutonium-238 (nCi/m ²)	Plutonium-239 (fCi/g)	Plutonium-239 (nCi/m ²)	Pu-238/Pu-239	Americium-241 (fCi/g)	Americium-241 (nCi/m ²)	Am-241/Pu-239
* Perimeter									
June 21	10P	0.8 ± 0.2	0.039 ± 0.012	17.6 ± 1.4	0.855 ± 0.065	0.043	4.8 ± 0.7	0.247 ± 0.034	0.272
June 21	14E	0.5 ± 0.1	0.018 ± 0.005	14.6 ± 0.9	0.552 ± 0.033	0.033	4.2 ± 0.7	0.158 ± 0.027	0.286
June 21	14N	0.5 ± 0.2	0.023 ± 0.010	14.3 ± 1.3	0.625 ± 0.057	0.036	5.5 ± 0.8	0.240 ± 0.035	0.384
June 21	4EF	0.3 ± 0.1	0.013 ± 0.004	2.0 ± 0.3	0.078 ± 0.011	0.168	0.9 ± 0.2	0.034 ± 0.009	0.428
June 21	7EF	0.6 ± 0.2	0.021 ± 0.006	12.3 ± 0.8	0.441 ± 0.030	0.047	2.4 ± 0.6	0.087 ± 0.020	0.196
October 27	13D	0.7 ± 0.2	0.032 ± 0.008	11.0 ± 0.8	0.495 ± 0.036	0.065	3.4 ± 0.8	0.151 ± 0.038	0.306
October 27	13N	1.4 ± 0.2	0.059 ± 0.011	27.2 ± 1.5	1.179 ± 0.063	0.050	3.8 ± 0.7	0.165 ± 0.031	0.140
October 27	15H	0.4 ± 0.1	0.016 ± 0.005	6.7 ± 0.5	0.267 ± 0.021	0.059	2.4 ± 0.5	0.097 ± 0.022	0.365
October 27	7M	1.1 ± 0.2	0.043 ± 0.008	26.8 ± 1.4	0.995 ± 0.052	0.043	7.1 ± 1.0	0.263 ± 0.038	0.264
October 27	8G	0.6 ± 0.2	0.030 ± 0.008	15.3 ± 1.0	0.720 ± 0.046	0.042	4.4 ± 0.7	0.205 ± 0.034	0.284
	Average	0.7 ± 0.2	0.029 ± 0.010	14.8 ± 5.6	0.621 ± 0.237	0.059	3.9 ± 1.3	0.165 ± 0.054	0.293
* Off-site									
June 27	Dresden Lock & Dam, IL	1.1 ± 0.3	0.042 ± 0.011	22.7 ± 1.7	0.860 ± 0.063	0.049	6.3 ± 0.8	0.240 ± 0.031	0.280
June 27	McKinley Woods State Park, IL	1.1 ± 0.3	0.051 ± 0.013	13.5 ± 1.1	0.646 ± 0.051	0.079	3.7 ± 0.7	0.176 ± 0.035	0.272
June 27	Morris, IL	0.9 ± 0.2	0.041 ± 0.009	22.4 ± 1.3	0.986 ± 0.058	0.041	6.3 ± 0.7	0.275 ± 0.030	0.279
July 13	Romeoville, IL	1.0 ± 0.2	0.041 ± 0.009	5.9 ± 0.5	0.251 ± 0.023	0.164	1.9 ± 0.6	0.081 ± 0.025	0.321
July 13	Pioneer Park, Naperville, IL	0.7 ± 0.2	0.034 ± 0.010	16.6 ± 1.2	0.759 ± 0.057	0.045	4.5 ± 0.7	0.205 ± 0.031	0.271
July 13	Lemont, IL	0.2 ± 0.1	0.013 ± 0.006	4.3 ± 0.5	0.233 ± 0.026	0.055	1.2 ± 0.3	0.065 ± 0.017	0.277
October 26	Channahon, IL	0.5 ± 0.2	0.026 ± 0.010	17.5 ± 1.3	0.910 ± 0.068	0.029	4.4 ± 0.5	0.229 ± 0.028	0.251
October 26	Starved Rock State Park, IL	0.2 ± 0.2	0.013 ± 0.008	7.6 ± 0.9	0.411 ± 0.047	0.031	2.2 ± 0.6	0.117 ± 0.034	0.285
October 31	McCormick Woods, Brookfield, IL	0.8 ± 0.2	0.035 ± 0.008	9.1 ± 0.7	0.422 ± 0.032	0.083	2.7 ± 0.7	0.125 ± 0.031	0.297
October 31	Bemis Woods, Western Springs, IL	0.4 ± 0.2	0.019 ± 0.011	7.2 ± 1.0	0.313 ± 0.044	0.061	3.3 ± 1.2	0.143 ± 0.054	0.458
	Average	0.7 ± 0.2	0.031 ± 0.009	12.7 ± 4.9	0.579 ± 0.205	0.064	3.6 ± 1.3	0.166 ± 0.051	0.299

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

TABLE 4.12

Radionuclides in Grass, 1989

Date Collected	Location	Potassium-40 (pCi/g)	Cesium-137 (fCi/g)	Plutonium-239 (fCi/g)	Deposited Plutonium-239 (nCi/m ²)
<u>Perimeter</u> *					
June 21	10P	17.24 ± 0.48	< 10	0.1 ± 0.1	0.02 ± 0.01
June 21	14E	20.89 ± 0.59	< 10	< 0.1	0.02 ± 0.01
June 21	14N	16.54 ± 0.66	< 10	0.1 ± 0.1	0.02 ± 0.01
June 21	4EF	15.42 ± 0.64	11 ± 14	< 0.1	0.01 ± 0.01
June 21	7EF	23.27 ± 0.62	< 10	< 0.1	0.01 ± 0.01
October 27	13D	8.27 ± 0.41	< 10	0.3 ± 0.1	0.07 ± 0.02
October 27	13N	7.57 ± 0.40	< 10	1.5 ± 0.2	0.30 ± 0.03
October 27	15H	12.06 ± 0.47	< 10	0.5 ± 0.1	0.08 ± 0.02
October 27	7M	10.79 ± 0.45	13 ± 12	0.3 ± 0.1	0.03 ± 0.01
October 27	8G	13.32 ± 0.48	18 ± 12	-	-
	Average	14.54 ± 11.64	11 ± 6	0.3 ± 1.1	0.06 ± 0.21
<u>Off-site</u>					
June 27	Dresden Lock & Dam, IL	20.61 ± 0.59	11 ± 12	0.1 ± 0.1	0.04 ± 0.02
June 27	McKinley Woods State Park, IL	19.91 ± 0.58	14 ± 12	0.2 ± 0.1	0.02 ± 0.01
June 27	Morris, IL	31.12 ± 0.77	14 ± 15	0.2 ± 0.1	0.02 ± 0.01
July 13	Romeoville, IL	19.91 ± 0.58	< 10	0.1 ± 0.1	0.03 ± 0.01
July 13	Pioneer Park, Naperville, IL	24.07 ± 0.70	< 10	0.1 ± 0.1	< 0.01
July 13	Lemont, IL	6.31 ± 0.42	19 ± 13	0.2 ± 0.1	0.03 ± 0.02
October 26	Channahon, IL	8.13 ± 0.32	< 10	0.3 ± 0.1	0.12 ± 0.04
October 26	Starved Rock State Park, IL	7.99 ± 0.41	< 10	0.8 ± 0.2	0.11 ± 0.03
October 31	McCormick Woods, Brookfield, IL	19.77 ± 0.58	19 ± 12	-	-
October 31	Bemis Woods, Western Springs, IL	22.14 ± 0.61	16 ± 13	1.0 ± 0.2	0.11 ± 0.03
	Average	18.00 ± 18.12	13 ± 8	0.3 ± 0.7	0.05 ± 0.10

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

TABLE 4.13

Radionuclides in Bottom Sediment, 1989

Date Collected	Location	Concentrations in pCi/g					Concentrations in fCi/g			
		Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232	Plutonium-238	Plutonium-239	Americium-241	
<u>Perimeter*</u>										
July 18	Sawmill Creek 25 M Above Outfall	9.35 ± 0.79	0.08 ± 0.03	0.64 ± 0.07	0.42 ± 0.04	0.43 ± 0.10	0.1 ± 0.1	3.0 ± 0.5	1.0 ± 0.3	
July 18	Sawmill Creek At Outfall	11.62 ± 0.83	2.10 ± 0.06	1.28 ± 0.08	0.66 ± 0.05	0.80 ± 0.12	11.4 ± 0.8	101.6 ± 3.9	10.9 ± 2.5	
July 18	Sawmill Creek 50 M Below Outfall	11.57 ± 0.82	1.33 ± 0.05	1.15 ± 0.08	0.64 ± 0.05	0.76 ± 0.11	4.4 ± 0.9	16.6 ± 1.9	3.4 ± 0.4	
July 18	Sawmill Creek 100 M Below Outfall	13.73 ± 0.70	1.11 ± 0.04	1.26 ± 0.06	0.74 ± 0.04	0.83 ± 0.09	3.5 ± 0.4	32.2 ± 1.7	4.8 ± 0.4	
July 18	Sawmill Creek At Des Plaines River	12.03 ± 0.68	1.29 ± 0.04	0.99 ± 0.06	0.62 ± 0.04	0.52 ± 0.09	3.4 ± 0.5	26.7 ± 1.7	9.4 ± 1.0	
<u>Off-site</u>										
June 27	Illinois River McKinley Woods State Park, IL	10.69 ± 0.42	0.05 ± 0.01	1.16 ± 0.04	0.60 ± 0.02	0.63 ± 0.05	0.1 ± 0.1	1.3 ± 0.4	0.7 ± 0.1	
June 27	Illinois River Morris, IL	11.16 ± 0.67	0.04 ± 0.02	0.46 ± 0.05	0.45 ± 0.03	0.36 ± 0.08	0.0 ± 0.1	0.5 ± 0.2	1.1 ± 0.2	
July 13	Long Run Creek Lemont, IL	17.70 ± 0.47	0.17 ± 0.02	1.38 ± 0.04	0.97 ± 0.02	0.86 ± 0.06	1.7 ± 0.4	5.0 ± 0.6	2.8 ± 0.3	
October 26	DuPage River Channahon, IL	14.78 ± 0.74	0.17 ± 0.02	1.40 ± 0.07	1.21 ± 0.05	1.15 ± 0.10	1.9 ± 0.5	6.2 ± 0.9	2.6 ± 0.7	
October 26	Illinois River Starved Rock State Park, IL	6.72 ± 0.62	0.03 ± 0.02	1.15 ± 0.06	0.40 ± 0.03	0.34 ± 0.08	0.1 ± 0.1	6.7 ± 0.6	2.5 ± 0.2	
October 31	Des Plaines River McCormick Woods, Brookfield, IL	17.00 ± 0.74	0.44 ± 0.03	1.48 ± 0.07	0.99 ± 0.04	0.85 ± 0.09	0.4 ± 0.1	8.9 ± 0.8	2.1 ± 0.3	
October 31	Salt Creek Bemis Woods, Western Springs, IL	16.36 ± 0.75	0.11 ± 0.02	1.70 ± 0.07	0.88 ± 0.04	0.86 ± 0.10	0.1 ± 0.1	2.1 ± 0.4	1.1 ± 0.4	
	Average	13.49 ± 9.94	0.14 ± 0.35	1.25 ± 0.97	0.79 ± 0.75	0.72 ± 0.72	0.6 ± 2.0	4.4 ± 7.7	1.9 ± 2.1	

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

milk by low-temperature vacuum evaporation, and the hydrogen-3 concentration was determined by liquid scintillation spectrometry. The strontium-90 was analyzed by the same method used for water and with the same detection limit. The results are given in Table 4.14. All the hydrogen-3 concentrations were less than the detection limit of 100 pCi/L. The average strontium-90 concentration was similar to the 1988 concentration. These nuclides are fission products from nuclear tests and are not related to ANL operations.

The concentrations given in Table 4.14 may be compared to the USEPA drinking water limits of 20 nCi/L for hydrogen-3 and 8 pCi/L for strontium-90. The consumption of one liter of milk per day would result in an average annual dose of 0.6 mrem/y for strontium-90 and < 0.25 mrem/y for hydrogen-3.

4.6. External Penetrating Radiation

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

The results are summarized in Tables 4.15 and 4.16, and the site boundary and on-site readings are also shown in Figure 4.1. 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 4.14

Strontium-90 in Milk, 1989

Date Collected	pCi/L
January 6	1.8 ± 0.2
February 1	2.0 ± 0.3
March 1	1.4 ± 0.1
April 5	1.8 ± 0.4
May 3	2.0 ± 0.2
June 7	3.9 ± 0.6
July 5	3.4 ± 0.1
August 2	2.9 ± 0.4
September 6	2.3 ± 0.2
October 5	2.7 ± 1.0
November 1	0.7 ± 0.1
December 6	2.4 ± 0.2
Average	2.3 ± 0.3

TABLE 4.15

Environmental Penetrating Radiation at Off-Site Locations, 1989

Location	Dose Rate (mrem/year)				Average
	Period of Measurement				
	1/12-4/12	4/12-7/19	7/19-10/17	10/17-1/10	
Lemont	85	85	89	94	88 ± 4
Lombard	90	88	90	90	90 ± 1
Oak Brook	87	86	87	90	88 ± 2
Oak Lawn	81	74	-	89	81 ± 8
Woodridge	86	83	83	92	86 ± 4
Average	86 ± 3	83 ± 5	87 ± 3	91 ± 2	87 ± 3

The off-site results averaged 87 ± 3 mrem/y and were similar to last year's off-site average of 93 ± 5 mrem/y. If the off-site locations provided an accurate sample of the radiation background in the area, then annual averages at the site in the range of 87 ± 3 mrem/y may be considered normal with a 95% probability. To compare boundary results for individual sampling periods, the standard deviation of the 19 individual off-site results is useful. This value is 6 mrem/y, so individual results in the range of 87 ± 12 mrem/y may be considered to be the average natural background with a 95% probability, unless there are known reasons to the contrary.

At two site boundary locations, 7I (south) and 14I (north), the dose rates were consistently above the average background. At 7I this was due to radiation from a ANL's Radioactive Waste Storage Facility (317 Area) in the northern half of grid 7I. Waste is packaged and temporarily kept in this area before removal for permanent storage off-site. The net above-background dose at this perimeter fence location was about 135 mrem/y. In previous years, this value has ranged from 865 mrem/y in 1985 to 51 mrem/y in 1988. About 300 m (0.2 mi) south of the fence in grid 6I, the measured dose dropped to 87 ± 3 mrem/y, within the normal background range. The higher doses at the 7I boundary and in the center of the 317 facility,

TABLE 4.16

Environmental Penetrating Radiation at ANL, 1989

Location*	Dose Rate (mrem/year)				Average
	1/12-4/12	Period of Measurement		10/19-1/10	
		4/12-7/19	7/19-10/17		
14L - Boundary	78	76	74	77	76 ± 2
14I - Boundary	114	106	108	110	110 ± 3
14G - Boundary	88	85	88	91	88 ± 2
9/10EF - Boundary	86	79	87	88	85 ± 4
8H - Boundary	87	85	84	88	86 ± 2
8H - Boundary, Center, St. Patrick's Cemetery	87	84	88	95	88 ± 6
7I - Boundary	223	223	219	222	222 ± 3
6I - 200 m N of Quarry Road	84	84	89	90	87 ± 3
9H - 50 m SE of CP-5	1280	1220	1174	1190	1216 ± 47
8H - 65 m S of Building 316	78	78	79	84	80 ± 3
8H - 200 m NW of Waste Storage Area (Heliport)	88	89	90	90	89 ± 1
7I - Center, Waste Storage Area Facility 317	6380	5700	5700	6230	6000 ± 112
10/11K - Lodging Facilities	73	72	65	78	72 ± 5
9I - 65 m NE of Building 350, 230 m NE of Building 316	80	75	79	81	78 ± 3

*See Figure 1.1.

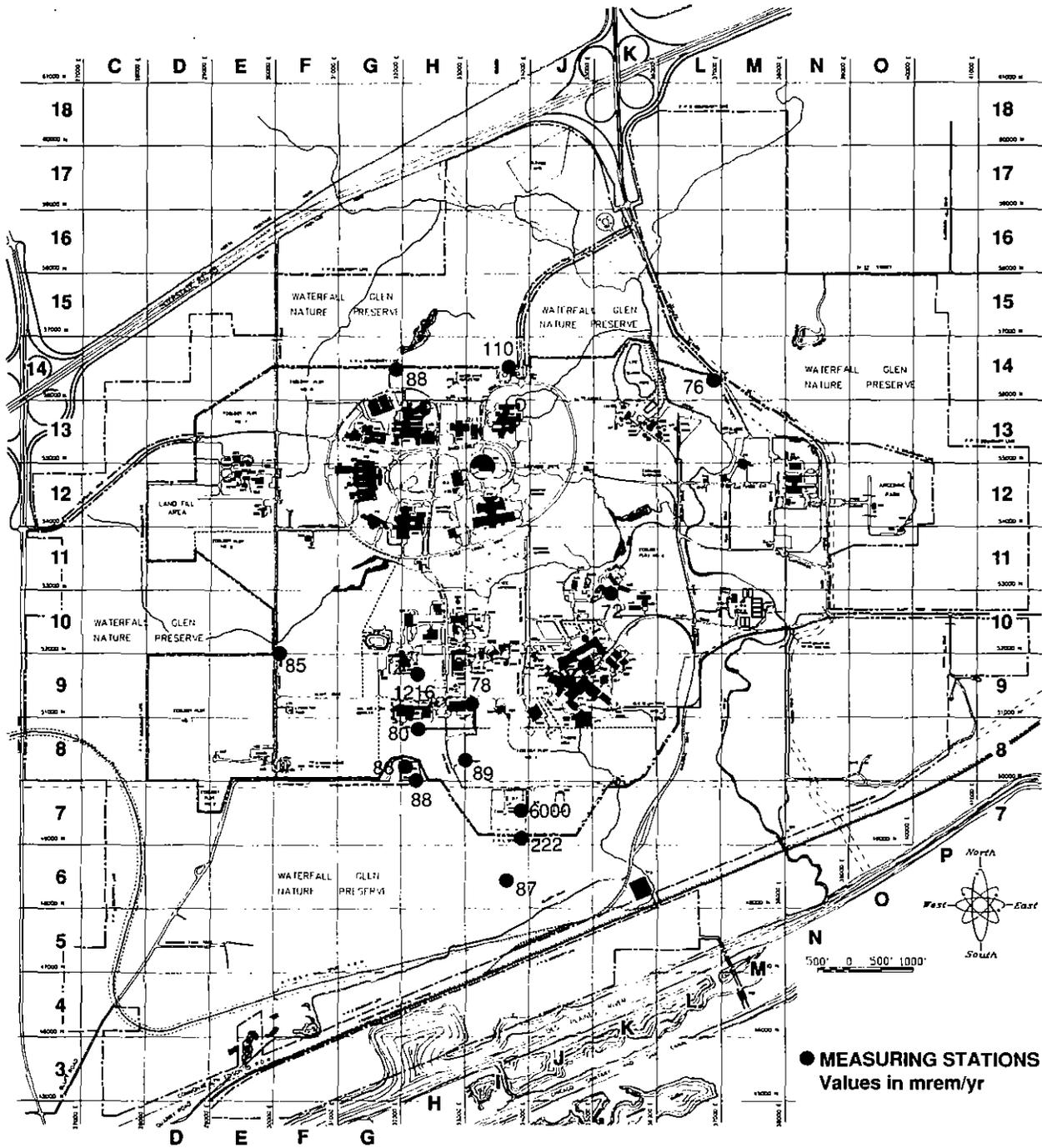


Fig. 4.1 Penetrating Radiation Measurements at the ANL Site, 1989

relative to last year, were attributed to the fact that none of the radioactive waste stored at the facility was shipped off the site during 1989.

The other elevated perimeter area was at Location 14I, at the north boundary, where a dose of 23 mrem/y above background was measured. This is similar to the value of 27 mrem/y measured in 1988. This dose is attributed to the use of cobalt-60 irradiation sources in Building 202. An elevated on-site dose was measured at Location 9H, next to the CP-5 facility, where irradiated hardware from CP-5 is stored.

4.7. Estimates of Potential Radiation Doses

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 were made for three exposure pathways, airborne, water, and direct radiation from external sources.

4.7.1. Airborne Pathway

Guidance issued by the DOE⁶ stipulates that DOE facilities with airborne releases of radioactive materials are subject to 40 CFR Part 61, Subpart H,¹⁵ which requires the use of the EPA-AIRDOSE/RADRISK code¹⁴ to calculate the dose for radionuclides released to the air and to demonstrate compliance with the regulation. The dose limits applicable for CY 1989 for the air pathway are 25 mrem/y to the whole body and 75 mrem/y to any organ. The EPA-AIRDOSE/RADRISK computer code uses a modified Gaussian plume equation to estimate both horizontal and vertical dispersion of radionuclides released to the air from stacks or area sources. For 1989, doses were calculated for hydrogen-3, carbon-11, nitrogen-13, oxygen-15, argon-41, krypton-85, and radon-220 plus daughters. The annual release rates are those listed in Table 4.5, and separate calculations were performed for each release point. The wind speed and direction data shown in Figure 1.3 were used for these calculations. Doses were calculated for an area extending out to 80 km (50 mi) from ANL. The population distribution of the 16 compass segments and ten distance increments given in Table 1.1 was used. The dose rate was

calculated at the midpoint of each interval and integrated over the entire area to give the annual population cumulative dose.

Distances from the specific facilities that exhaust radiological airborne emissions (see Table 4.5) to the fenceline (perimeter) and nearest resident were determined in the 16 compass segments. The EPA-AIRDOSE/RAD-RISK computer code was used to calculate the total dose at each of these locations. Calculations also were performed to evaluate the major airborne pathways; ingestion, inhalation, immersion, at the point of maximum perimeter exposure and to the maximally exposed resident. The total perimeter and resident doses and the maximum doses are listed, respectively, for releases from Buildings 200 and 211 (Tables 4.17 and 4.18), Building 202 (Tables 4.19 and 4.20), Building 212 (Tables 4.21 and 4.22), Building 330 (Tables 4.23 and 4.24), and Building 375 (Tables 4.25 and 4.26). The doses given in these tables are the committed whole body effective dose equivalents.

The dominant contributor to the calculated doses was the radon-220 and daughters released from Building 200. This accounted for 98% of the off-site dose in 1989. The highest perimeter dose rates were in the north to east sectors with a maximum dose of 1.2 mrem/y at a fenceline location northwest of Building 203 (location 14H in Figure 1.1). The major contributor to this dose was inhalation of lead-212 (0.75 mrem/y) and the organs receiving the greatest dose were the lung and the bone. The releases from the other facilities are very minor contributors to the total dose.

The full-time resident who would receive the largest annual dose (0.36 mrem/y) is located approximately 0.8 km (0.5 mi) north of the site boundary. The major contributor to the whole body dose is the inhalation dose from lead-212 (0.26 mrem/y). If radon-220 and daughters were excluded from the calculation, as required by NESHAP,¹⁵ the maximally exposed resident would receive a dose of 0.0061 mrem/y, primarily from carbon-11 from the IPNS facility (Building 375).

The population data in Table 1.1 were used to calculate the cumulative population dose from gaseous radioactive effluents from ANL operations. The

TABLE 4.17

Radiological Airborne Releases from Buildings 200 and 211, 1989

Source Term: Carbon-11 = 0.7 Ci
 Nitrogen-13 = 2.1 Ci
 Oxygen-15 = 10.9 Ci
 Radon-220 = 1858 Ci (plus daughters)

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	500	1.19	1000	0.34
NNE	600	0.84	1100	0.27
NE	750	0.48	2600	0.06
ENE	1700	0.11	3100	0.04
E	2400	0.06	3500	0.03
ESE	2200	0.06	3600	0.03
SE	2100	0.06	4000	0.02
SSE	2000	0.06	4000	0.02
S	1500	0.05	4000	0.01
SSW	1000	0.21	2500	0.05
SW	800	0.59	2200	0.13
WSW	1100	0.16	1500	0.09
W	750	0.38	1500	0.12
WNW	800	0.25	1300	0.11
NW	600	0.45	1100	0.16
NNW	600	0.60	800	0.36

TABLE 4.18

Maximum Perimeter and Individual Doses from
Buildings 200 and 211 Air Emissions, 1989

(mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (500 m N)				
Carbon-11	< 0.0001	< 0.0001	0.0003	0.0003
Nitrogen-13	< 0.0001	< 0.0001	0.0009	0.0009
Oxygen-15	< 0.0001	< 0.0001	0.0027	0.0027
Radon-220	< 0.0001	0.32	0.0001	0.32
Lead-212	< 0.0001	0.75	0.0002	0.75
Bismuth-212	< 0.0001	0.11	0.0003	0.11
Thallium-208	< 0.0001	< 0.0001	0.0032	0.0032
Individual (800 m NNW)				
Carbon-11	< 0.0001	< 0.0001	0.0001	0.0001
Nitrogen-13	< 0.0001	< 0.0001	0.0003	0.0003
Oxygen-15	< 0.0001	< 0.0001	0.0006	0.0006
Radon-220	< 0.0001	0.057	< 0.0001	0.057
Lead-212	< 0.0001	0.264	< 0.0001	0.264
Bismuth-212	< 0.0001	0.039	0.0001	0.039
Thallium-208	< 0.0001	< 0.0001	0.0008	0.0008

TABLE 4.19

Radiological Airborne Releases from Building 202 (JANUS), 1989

Source Term: Argon-41 = 1.1 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	200	0.0002	1700	< 0.0001
NNE	250	0.0002	1800	< 0.0001
NE	350	0.0003	1500	< 0.0001
ENE	800	0.0002	2200	< 0.0001
E	1100	0.0001	2200	< 0.0001
ESE	1600	< 0.0001	2700	< 0.0001
SE	1600	< 0.0001	4000	< 0.0001
SSE	1700	< 0.0001	4000	< 0.0001
S	2100	< 0.0001	4000	< 0.0001
SSW	2200	< 0.0001	4000	< 0.0001
SW	2600	< 0.0001	3200	< 0.0001
WSW	2000	< 0.0001	2600	< 0.0001
W	1500	< 0.0001	2100	< 0.0001
WNW	1000	< 0.0001	1300	< 0.0001
NW	300	0.0002	1000	0.0001
NNW	250	0.0002	800	0.0002

TABLE 4.20

Maximum Perimeter and Individual Doses from
 Building 202 (JANUS) Air Emissions, 1989
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (350 m NE)				
Argon-41	< 0.0001	< 0.0001	0.0002	0.0002
Individual (800 m NNW)				
Argon-41	< 0.0001	< 0.0001	0.0002	0.0002

TABLE 4.21

Radiological Airborne Releases from Building 212, 1989

Source Term: Hydrogen-3 (HT) = 3.6 Ci
 Hydrogen-3 (HTO) = 4.3 Ci
 Krypton-85 = 4.0 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	800	0.0014	2000	0.0005
NNE	1000	0.0010	2500	0.0004
NE	1300	0.0007	2000	0.0004
ENE	1500	0.0006	2500	0.0004
E	1600	0.0005	2800	0.0003
ESE	1200	0.0006	2500	0.0003
SE	1400	0.0005	3500	0.0002
SSE	1400	0.0006	4500	0.0002
S	1500	0.0003	5000	< 0.0001
SSW	1600	0.0005	5000	0.0001
SW	1400	0.0010	2400	0.0006
WSW	1300	0.0005	2300	0.0003
W	1700	0.0004	2200	0.0003
WNW	1500	0.0004	2000	0.0003
NW	1300	0.0005	2000	0.0003
NNW	1000	0.0011	2000	0.0004

TABLE 4.22

Maximum Perimeter and Individual Doses from
 Building 212 Air Emissions, 1989
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (800 m N)				
Hydrogen-3	< 0.0001	0.0003	< 0.0001	0.0003
Krypton-85	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Individual (2400 m SW)				
Hydrogen-3	< 0.0001	0.0001	< 0.0001	< 0.0001
Krypton-85	< 0.0001	< 0.0001	< 0.0001	< 0.0001

TABLE 4.23

Radiological Airborne Releases from Building 330 (CP-5), 1989

Source Term: Hydrogen-3 (HTO) = 30 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	1500	0.0009	2000	0.0006
NNE	1800	0.0006	3300	0.0003
NE	2100	0.0004	2800	0.0003
ENE	2200	0.0004	3300	0.0002
E	1500	0.0006	3100	0.0002
ESE	1300	0.0007	3500	0.0002
SE	1200	0.0007	3500	0.0001
SSE	1000	0.0010	3500	0.0001
S	500	0.0014	3000	< 0.0001
SSW	700	0.0018	3500	0.0002
SW	900	0.0023	2400	0.0006
WSW	1400	0.0005	2000	0.0003
W	700	0.0019	2000	0.0004
WNW	700	0.0014	1900	0.0003
NW	1500	0.0005	2000	0.0003
NNW	1600	0.0006	1900	0.0005

TABLE 4.24

Maximum Perimeter and Individual Doses From
Building 330 (CP-5) Air Emissions, 1989

(mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (900 m SW)				
Hydrogen-3	0.0005	0.0018	< 0.0001	0.0023
Individual (2400 m SW)				
Hydrogen-3	0.0001	0.0005	< 0.0001	0.0006

TABLE 4.25

Radiological Airborne Releases from Building 375 (IPNS), 1989

Source Term: Carbon-11 = 97 Ci
 Argon-41 = 3.4 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	1600	0.0083	3200	0.0024
NNE	1700	0.0074	3100	0.0026
NE	1700	0.0065	2700	0.0030
ENE	1500	0.0073	2500	0.0030
E	600	0.0304	2500	0.0029
ESE	600	0.0252	2500	0.0024
SE	600	0.0250	2500	0.0024
SSE	600	0.0283	3000	0.0016
S	800	0.0080	3000	0.0008
SSW	800	0.0163	3500	0.0012
SW	800	0.0291	4000	0.0017
WSW	1500	0.0051	2700	0.0019
W	2200	0.0032	2700	0.0022
WNW	1500	0.0049	2600	0.0019
NW	2200	0.0028	2500	0.0022
NNW	1800	0.0053	2200	0.0038

TABLE 4.26

Maximum Perimeter and Individual Doses from
 Building 375 (IPNS) Air Emissions, 1989
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (600 m E)				
Carbon-11	< 0.0001	0.0024	0.0264	0.0290
Argon-41	< 0.0001	< 0.0001	0.0014	0.0014
Individual (2200 m NNW)				
Carbon-11	< 0.0001	0.0003	0.0032	0.0036
Argon-41	< 0.0001	< 0.0001	0.0002	0.0002

results are given in Table 4.27, together with the natural external radiation dose. The natural radiation dose listed is that measured at the off-site TLD locations; it is assumed that this dose is representative of the entire area within an 80-km (50-mi) radius.

TABLE 4.27

80-km Population Dose, 1989

Radionuclide	man-rems
Hydrogen-3	0.12
Carbon-11	0.20
Nitrogen-13	< 0.01
Oxygen-15	< 0.01
Argon-41	0.05
Krypton-85	0.18
Radon-220	< 0.01
Polonium-216	< 0.01
Lead-212	15.20
Bismuth-212	1.12
Thallium-208	< 0.01
Total	16.9
Natural	6.8×10^5

The potential radiation exposures by the inhalation pathways also were calculated by the methodology specified in DOE Order 5400.5.⁶ The total quantity for each radionuclide inhaled, in microcuries (μCi), is calculated by multiplying the annual average air concentrations by the general public breathing rate of $8,400 \text{ m}^3/\text{y}$.¹⁶ This annual intake is then multiplied by the EDEF for the appropriate lung retention class. Because the EDEF are in units of Rem per microcurie ($\text{Rem}/\mu\text{Ci}$), this calculation gives the 50-year committed effective dose equivalent. The applicable EDEF are listed in Table 4.28.

TABLE 4.28

50-Year Committed Effective Dose Equivalent Factors - EDEF
(Rem/ μ Ci)

Nuclide	Ingestion	Inhalation
Hydrogen-3	6.8×10^{-5}	1.2×10^{-4}
Beryllium-7	-	3.0×10^{-4}
Carbon-11	-	1.2×10^{-5}
Strontium-90	0.14	1.32
Cesium-137	0.05	0.030
Lead-210	-	13.2
Radium-226	1.37	-
Thorium-228	-	298
Thorium-230	-	238
Thorium-232	-	119
Uranium-234	0.27	5.95
Uranium-235	0.23	5.95
Uranium-238	0.23	5.95
Neptunium-237	4.57	-
Plutonium-238	3.42	-
Plutonium-239	4.57	298
Americium-241	4.57	-
Curium-242	0.14	-
Curium-244	2.28	-
Californium-249	4.57	-
Californium-252	1.37	-

The calculated doses in Tables 4.3, 4.4, and 4.6 were obtained using this procedure. Because they are all essentially at perimeter locations, these doses represent the fence-line values for those radionuclides measured. In most 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 guidance does not provide EDEF for such measurements.

4.7.2. Water Pathway

Following the methodology outlined in DOE Order 5400.5, the annual intake of radionuclides (in μCi) ingested with water is obtained by multiplying the concentration of radionuclides in microcuries per milliliter ($\mu\text{Ci/mL}$) by the average annual water consumption of a member of the general public (7.3×10^5 mL). This annual intake is then multiplied by the EDEF for ingestion (Table 4.28) to obtain the dose received in that year. This procedure is carried out for all radionuclides and the individual results are summed to obtain the total ingestion dose.

The only location where radionuclides attributable to ANL operations could be found in off-site water was Sawmill Creek below the waste-water outfall. Although this water is not used for drinking purposes, the 50-year effective dose equivalent was calculated for a hypothetical individual ingesting water at the radionuclide concentrations measured at that location. Those radionuclides added to Sawmill Creek by ANL waste water, their net concentrations in the creek and the corresponding dose rates (if water at these concentrations were used as the sole water supply by an individual) are given in Table 4.29. 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 4.29

Radionuclide Concentrations and Dose Estimates
for Sawmill Creek Water, 1989

Radionuclide	Total Released (millicuries)	Net Avg Conc (pCi/L)	Dose (mrem/y)
Hydrogen-3	86.9	14	0.0007
Strontium-90	1.1	0.18	0.018
Cesium-137	6.2	1.0	0.033
Neptunium-237	0.08	0.0128	0.043
Plutonium-239	0.06	0.0102	0.034
Americium-241	0.07	0.0112	0.037
Sum			0.166

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

The USEPA has established drinking water standards based on a dose of 4 mrem/y for man-made beta particle and photon-emitting radionuclides.¹⁷ The USEPA standard is 2×10^4 pCi/L for hydrogen-3, 8 pCi/L for strontium-90, and 200 pCi/L for cesium-137. The net concentrations in Table 4.29 correspond to 0.1% (hydrogen-3), 2.2% (strontium-90), and 0.5% (cesium-137) of the USEPA standards. No specific USEPA standards exist for the transuranic nuclides.

4.7.3. External Direct Radiation Pathway

The TLD measurements given in Section 4.6 were used to calculate the radiation dose from external sources. Above-normal fence-line doses attribu-

table to ANL operations were found at the southern boundary near the Waste Storage Facility (Location 7I) and at the northern boundary near Building 202 (Location 14I).

At Location 7I, the net fenceline dose from ANL was about 135 mrem/y. Approximately 300 m (0.3 mi) south of the fenceline (grid 6I), the measured dose was 87 ± 3 mrem/y, the same as the normal range of the off-site average (87 ± 3 mrem/y). No individuals live in this area. The closest residents are about 1.6 km (1 mi) south of the fenceline. At this distance, the calculated dose rate from the Waste Storage Facility was 0.01 mrem/y, if the energy of the radiation was the 0.66 MeV cesium-137 gamma-ray, and about 0.03 mrem/y if the energy was the 1.33 MeV cobalt-60 gamma-ray. In the area north of the site, the fenceline radiation dose from the cobalt-60 sources in Building 202 was measured at 23 mrem/y. The nearest residents are 750 m (0.47 mi) to the north-northwest. The calculated dose at that location was about 0.13 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 would be substantially less, since some of the individuals are indoors (which provides shielding) or away from their dwellings.

4.7.4. Dose Summary

The total dose received by off-site residents during 1989 was a combination of the individual doses received through the separate pathways that contributed to exposure: hydrogen-3, carbon-11, nitrogen-13, oxygen-15, argon-41, krypton-85, and radon-220 (plus daughters), through the airborne pathway and cobalt-60 external radiation dose. The highest dose was about 0.49 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 17 man-rem.

To put the maximum individual dose of 0.49 mrem/y attributable to ANL operations into perspective, comparisons can be made to annual average doses

received by the public from natural or accepted sources of radiation. These values are listed in Table 4.30. It is obvious that the magnitude of the doses received from ANL operations is insignificant compared with these sources. Therefore, the monitoring program results establish that the radioactive emissions from ANL are very low and do not endanger the health or safety of those living in the vicinity of the site.

TABLE 4.30

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

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

*NCRP Report No. 93.¹⁸

5. ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

Samples are collected for nonradiological chemical analyses from NPDES locations, ANL effluent water, and in Sawmill Creek. Different conditions, constituents, and standards apply to the water collected at each of these sampling locations. The results of the analyses are compared to applicable permit limits, and general effluent and stream quality standards.

Effluents not included in the NPDES permit are sampled and analyzed for comparison with general effluent standards listed in the STATE OF ILLINOIS RULES AND REGULATIONS, Title 35, Subtitle C, Chapter I. The specific requirements are listed in Part 304, Subpart A. The impact of all of the effluents on stream quality is studied and compared to the stream standards listed in Part 302, Subpart B. The state standards are listed in Table 5.1.

5.1. National Pollutant Discharge Elimination System

Nine surface water discharge points (outfalls) are regulated by an NPDES permit. The analyses required and the frequency of analyses are specified in the permit. The required analytical methods are listed in 40 CFR part 136 (Table 1B).¹⁹ Sample collection, preservation, and holding times are also mandated by requirements stipulated in Table 2¹⁹ of 40 CFR Part 136.

Argonne processed wastewater discharges are regulated by NPDES Permit No. IL 0034592.²¹ As discussed in Section 3.2.1., this permit was renewed on July 7, 1989, and expires on January 15, 1994. The current permit has several changes and modifications from the previous version. One major change was elimination of 001C as the sampling location for coal pile runoff. The monitoring requirements associated with this sampling point were added to outfall 001. Sampling of Sawmill Creek for chlorides, total dissolved solids, and sulfate was eliminated and monitoring for these constituents was added to location 001. Semiannual sampling was conducted at location 001B and analyzed for the 126 priority pollutants. Since the permit was revised during the middle of the year, results are be discussed in two phases.

TABLE 5.1

Illinois Water Quality Standards
(Concentrations in mg/L)

Constituent	State Standard	
	Stream	Effluent
Arsenic	1.0	0.25
Barium	5.0	2.0
Cadmium	0.05	0.15
Chloride	500	-
Chromium	1.0	1.0
Copper	0.02	0.5
Fluoride	1.4	15
Iron	1.0	2.0
Lead	0.1	0.2
Manganese	1.0	1.0
Mercury	0.0005	0.0005
Nickel	1.0	1.0
pH	6.5-9.0	6.0-9.0
Selenium	1.0	-
Silver	0.005	0.1
Sulfate	500	-
Total Dissolved Solids	1000	-
Zinc	1.0	1.0

The NPDES locations are shown in Figure 5.1. The location numbers in the figure are given without the leading zeroes. Thus, permit location 001A is given as 1A. Locations 1A and 1B are combined to form location 1, where ANL's primary effluent enters Sawmill Creek.

5.1.1. Sample Collection

The water samples for NPDES compliance are collected by ANL's Environment, Safety and Health Department (ESH) personnel, with the exception of samples from locations 001A and 001B, which are collected by Plant Facilities and Services Division (PFS) personnel. Special instructions and training are provided to the collectors. All samples are collected using specially cleaned and labelled bottles with appropriate preservative added. Custody seals and chain of custody sheets also are used. All samples are analyzed within the required holding times. Samples are collected at the other locations on a monthly basis.

5.1.2. Results of Analyses

Softening of water through ion exchange produces effluents with high levels of total dissolved solids (TDS) and chloride. As a condition of the previous permit, analyses of the levels of these constituents, as well as of sulfate were required in the effluent and at upstream and downstream locations in Sawmill Creek. The previous permit required that grab samples be collected both upstream and downstream of the effluent outfall and that a 24-hour composite of the effluent be collected during this time span. The previous permit stated that the downstream samples were not to exceed the IEPA water quality standards. Results for the period January through June 1989 are shown in Table 5.2. The stream limits for chloride and total dissolved solids were exceeded 83% and 92% of the time respectively, while all sulfate levels were within the limit.

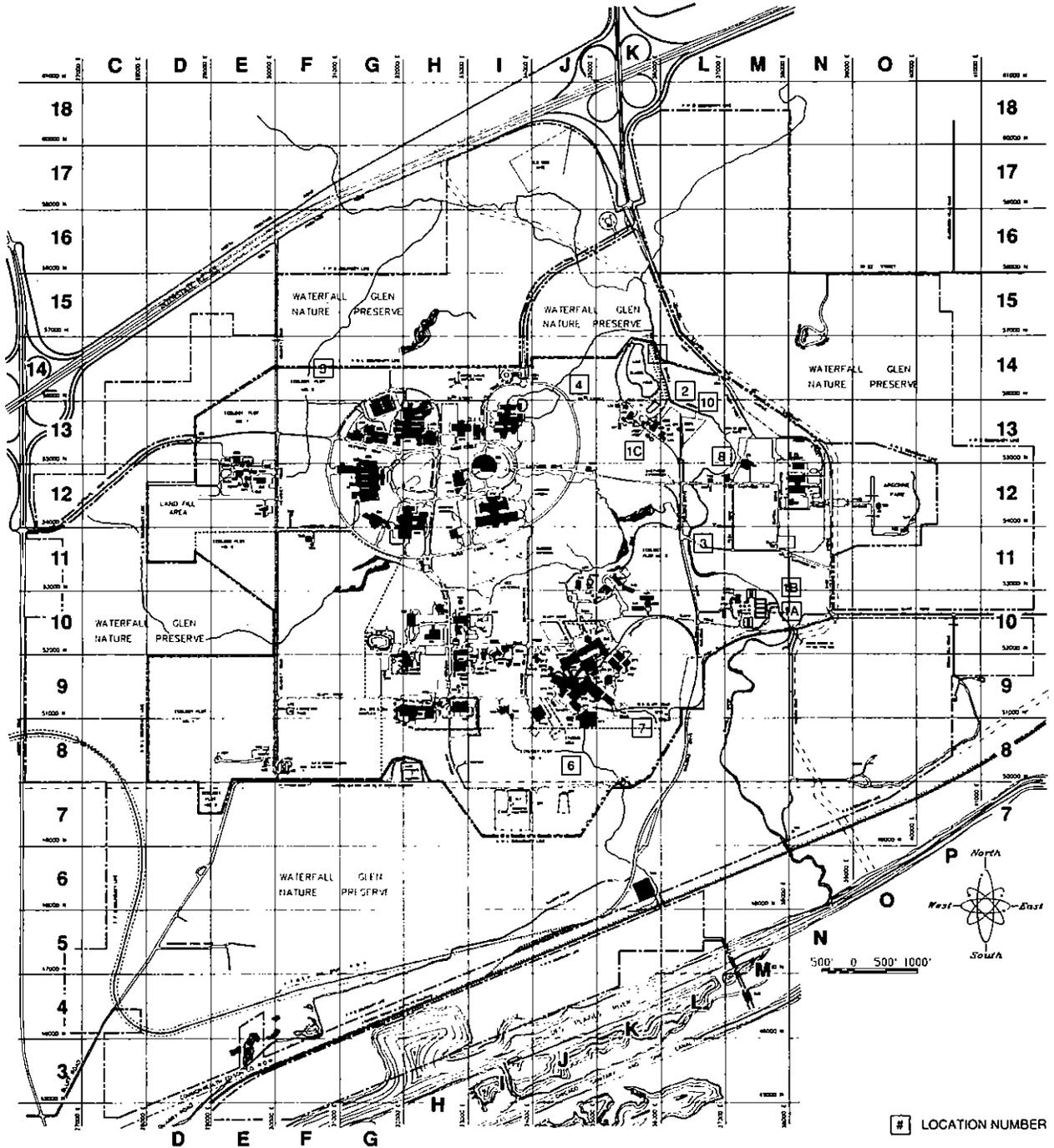


Fig. 5.1 NPDES Permit Locations

TABLE 5.2

Effects of ANL Ion Exchange Effluents on Sawmill Creek Water Quality, 1989
(Concentrations in mg/L)

Constituent	Upstream	Location 001	Downstream	Limit
Chloride	297 ± 102	706 ± 58	647 ± 163	500
Sulfate	119 ± 33	233 ± 35	156 ± 38	500
TDS	831 ± 231	1674 ± 301	1473 ± 295	1000

The revised permit provides for effluent standards for TDS, chloride, and sulfate at outfall 001 and requires bimonthly sampling of the effluent only (see Table 5.3). Stream sampling is no longer required. Results obtained from July through December for chloride and TDS have exceeded the limit in all samples, while sulfate levels were all below the limit. A wastewater treatment plant to remove these constituents from the ANL discharge has been designed and is to be built in the near future.

As required by the previous permit, the coal pile runoff stream was sampled for the first six months of the year at location 001C. Special requirements stipulated that it be sampled only when sufficient rainfall had occurred to produce flow. Nine samples were collected during the six-month period. Two samples exceeded the limit for pH, both greater than 9.0. The runoff from the coal pile normally produces a very acidic solution. These measured high pH values indicate that other wastewater streams that mix with the runoff before sampling must be highly basic. All of the samples exceeded the limits for iron and seven of nine exceeded the total suspended solids limit. In July, the sampling location was moved to 001A and weekly sampling was required for the same constituents as previously required. In addition, a minimum of three oil and grease samples were collected one day per week and analyzed separately. The arithmetic mean of the results of these analyses were reported. A facility for treatment of the coal pile runoff and other effluents in this area will be under construction shortly.

TABLE 5.3

NPDES Effluent Quality Summary, 1989

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R ($\frac{\text{Measured}}{\text{Permit}}$)
			30 Day Average	Daily Max.		
001A	26	Flow	None		0	
		BOD	10	20	0	
		Iron	2	4	0	
		Lead	0.2	0.4	0	
		Zinc	1	2	0	
		Manganese	1	2	0	
		Chromium (total)	1	2	0	
		Copper	0.5	1	0	
		Oil and grease	15	30	0	
		TSS	12	24	0	
		pH (units)	6-9		0	
001B	52	Flow	None		-	
		Chemical oxygen demand	-	-	-	
		TSS	12	24		
		Mercury	0.003	0.006		
001C	9	Iron	2	4	9	1.9-4.6
		Lead	0.2	0.4	0	
		Zinc	1	2	0	
		Manganese	1	2	0	
		Chromium (total)	1	2	0	
		Copper	0.5	1	0	
		Oil and grease	15	30	0	
		TSS	15	30	7	1.3-3.0
		pH	6-9		2	9.1-11.2

TABLE 5.3 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	* _R ($\frac{\text{Measured}}{\text{Permit}}$)
			30 Day Average	Daily Max.		
001	52	pH	6-9		0	-
	52	Fecal Coliform	-	<u>400 organisms</u> 100 mL	3	1.6-40
	12	TSS	12	24	0	-
	12	Chloride		550	12	1.02-1.40
	12	Sulfate		575	0	-
	12	TDS		1045	12	1.46-1.83
	003	12	Flow	None		0
pH			6-9		0	
TSS			15	30	1	1.2
Temperature			< 2.8°C Rise		0	
004	12	Flow	None		0	
		pH	6-9		0	
		TSS	15	30	3	1.2-1.5
		Temperature	< 2.8°C Rise		0	
005	12	Flow	None		0	
		pH	6-9		0	
		Temperature	< 2.8°C Rise		0	
		Oil and Grease	15	30	0	
006	12	Flow	None		0	
		pH	6-9		0	
		TSS	15	30	1	1.4
		Zinc	1.0	2.0	0	

TABLE 5.3 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R ($\frac{\text{Measured}}{\text{Permit}}$)
			30 Day Average	Daily Max.		
007	11	Flow	None		0	
		pH	6-9		0	
		Temperature	< 2.8°C Rise		0	
008	0	Flow	None			
		pH	6-9			
009	0	Flow	None			
		pH	6-9			
		TSS	15	30		
010	0	Flow	None			
		pH	6-9			
		TSS	15	30		
		Iron	2	4		
		Lead	0.2	0.4		
		Zinc	1.0	2.0		
		Manganese	1.0	2.0		
		Chromium (total)	1.0	2.0		
		Copper	0.5	1.0		
		Oil and grease	15	30		

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

The effluent at location 001B consists primarily of laboratory wastewater. Results of the 1989 analyses indicate that levels of mercury were substantially reduced from previous years and were frequently not detected. Levels of chemical oxygen demand were highly variable and were affected to a certain degree by high levels of chloride present from the water treatment process. The new permit requires that this effluent be examined for the materials on the priority pollutant list in June and December. Results for the December sampling showed only traces of trihalomethanes (resulting from chlorination of the drinking water) and the ubiquitous phthalates. All other constituents either were not detected (organic compounds) or were at normal levels (inorganic materials).

Occasional violations of the total suspended solids limits occurred. One violation was detected at location 003, three violations at 004, and one violation at location 006. None of the monthly average values exceeded the limit. The violations at 004 occurred during the period from May through July and the cause is unknown. The cause of the single violation at location 006 is also unknown.

Three violations of fecal coliform limits occurred at location 001. These were in January, September, and December. The cause of the September incident is unknown, but the other two occurrences were related to no or low chlorine levels. Argonne has applied for an exemption from disinfection of wastewater as allowed by the IEPA regulation and approval is expected during 1990.

5.2. Waste Water Treatment Plant Effluent

The water volume from the Waste Water Treatment Plant averaged 4 million liters per day (1.06 million gallons per day) and was comprised of 54% sanitary waste water and 46% laboratory process wastewater. Laboratory process wastewater is collected in 260,000 liter (69,000 gallon) holding tanks which are sampled and analyzed for radioactivity before release. This system is designed to discharge the water into an equalization pond that regulates discharge to Sawmill Creek. For most of 1989, the equalization pond was inoperative, and water was discharged directly from the holding

tanks using gravity flow. The release of wastewater in this manner is episodic and makes interpretation of results of grab sampling less representative of the effluent being characterized.

5.2.1. Sample Collection

Daily samples for analysis of inorganic constituents are collected from the Waste Water Treatment Plant in a cooled, 24-hour flow proportional sampler. A portion of the sample is transferred to a specially cleaned bottle containing the appropriate preservative, a security seal is affixed and chain of custody is maintained. The daily samples are composited on an equal volume basis to produce a weekly sample.

5.2.2. Results of Analyses

The analyses results are shown in Table 5.4. All of the average concentrations were below state effluent standards (Table 5.1) and similar to last year's values. The average value for mercury was 34% of the state effluent standard of 0.5 $\mu\text{g}/\text{L}$; however, two individual samples exceeded this limit. The general rules allow that individual samples may exceed the state standard by a factor of five if the monthly average is not exceeded. In the case of mercury, a single result could thus be up to 2.5 $\mu\text{g}/\text{L}$. The maximum value found in the sample was 0.6 $\mu\text{g}/\text{L}$.

5.3. Sawmill Creek

The major portion of the water in Sawmill Creek has, in the past, originated from the DuPage County Marion Brook Treatment Plant, located upstream of ANL. This facility ceased operation on October 26, 1986, and the flow upstream of ANL has become intermittent. Currently, the flow upstream of ANL consists of surface drainage from the area north and northeast of the site.

TABLE 5.4

Chemical Constituents in Effluents from ANL Wastewater Treatment Plant, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Concentration			Percent of Standard (Avg.)	Percent Exceeding State Standard
		Avg.	Min.	Max.		
Arsenic	23	-	-	< 10	< 1.0	0
Beryllium	23	0.05 ± 0.01	< 0.05	0.09	-	-
Cadmium	23	1.7 ± 0.6	< 0.4	7.2	1.1	0
Chromium	23	3.1 ± 1.0	< 1.0	9.3	3.0	0
Cobalt	51	-	-	< 40	-	-
Copper	51	51 ± 7	20	163	10	0
Fluoride	9	441 ± 72	360	660	2.9	0
Iron	51	235 ± 29	< 100	470	12	0
Lead	30	2.7 ± 0.4	< 2.0	4.9	1.4	0
Manganese	51	35 ± 4	< 10	79	3.5	0
Mercury	51	0.17 ± 0.03	< 0.10	0.6	35	4
Nickel	51	-	-	< 40	4.0	0
pH (units)	248	-	7.4	8.5	-	0
Selenium	23	-	-	< 10	< 1.0	0
Silver	23	2.1 ± 0.5	1.0	5.5	2.1	0
Thallium	17	-	-	< 10	-	-
Zinc	51	110 ± 12	53	196	11	0

5.3.1. Sample Collection

Samples were collected downstream of the ANL effluent discharges to evaluate the effect of these discharges on levels of inorganic constituents in the creek. The samples were obtained in specially cleaned bottles containing the appropriate preservative. Daily samples were collected and composited on a weekly basis.

5.3.2. Results of Analyses

The results obtained are shown in Table 5.5. The average value for copper was above the state limit and exceeded the limit 80% of the time. If the individual limit value previously discussed (100 $\mu\text{g/L}$ in the case of copper) was used, the limit would have been exceeded about 6% of the time. The constancy of the copper result over many years probably indicates that the source is copper tubing. Elevated levels of iron in the stream occur when precipitation causes siltation which also causes elevation of other constituents as well. The levels of mercury in the creek are substantially reduced from previous years.

5.4. Des Plaines River

The effect of Sawmill Creek water on the levels of mercury in the Des Plaines River was evaluated by collecting samples in the river at Willow Springs (upstream of ANL) and at Lemont (downstream of ANL). Analyses of the samples showed that concentrations of total mercury were less than the detection limit of 0.1 $\mu\text{g/L}$.

TABLE 5.5

Chemical Constituents in Sawmill Creek, Location 7M,* 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg. Concentration	Min.	Max.	Percent of Standard (Avg.)	Percent Exceeding State Standard
Arsenic	23	-	-	< 10	< 1.0	0
Beryllium	23	0.06 ± 0.01	< 0.05	0.12	-	-
Cadmium	23	2.4 ± 2.0	0.3	24.0	4.8	0
Chromium	23	11 ± 17	< 1	171	11	0
Cobalt	51	-	-	< 40	-	-
Copper	51	28 ± 3	< 10	55	140	80
Fluoride	9	361 ± 42	288	456	26	0
Iron	51	519 ± 127	136	2060	52	16
Lead	30	3.0 ± 1.0	< 1.0	14.0	3.3	0
Manganese	51	38 ± 5	< 10	95	3.8	0
Mercury	51	0.16 ± 0.03	< 0.10	0.70	32	2
Nickel	51	40 ± 1	< 40	44	4.0	0
pH (units)	246	-	7.5	8.9	-	0
Selenium	23	-	-	< 10	< 1.0	0
Silver	23	1.3 ± 0.4	< 0.1	3.7	26	0
Thallium	23	-	-	< 10	-	-
Zinc	51	60 ± 8	< 20	140	6.0	0

*Location 7M is 15 m (50 ft) downstream from the ANL wastewater outfall.

6. GROUNDWATER PROTECTION

6.1. Potable Water System

The ANL domestic water is supplied by four wells. The wells are described in Section 1.5 and their locations are shown in Figure 1.1. Argonne's system is classified as a non-transient, non-community water system,¹⁷ which regularly serves at least 25 of the same persons over six months of the year. This designation determines the type of water quality analyses and limits that apply.

Samples from each well were collected quarterly at the wellhead and a sample of the finished water was collected annually. These samples were analyzed for several types of radioactive constituents. The same protocol was used by ANL's Plant Facilities and Services Division to collect additional samples that were analyzed by a contract laboratory for the organic constituents (target compounds) listed in Table 6.1.

Samples from each well were analyzed quarterly for total alpha, total beta, and hydrogen-3 and were analyzed annually for strontium-90, radium-226, and uranium. The finished water sample was analyzed for the same radiological constituents. The results are shown in Table 6.2 for well samples and finished (tap) water samples. Since ANL is a "non-community water system", the USEPA standards for this type of system apply. The following USEPA limits are established for the nuclides measured in Table 6.2:

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

The uranium results would be covered by the gross alpha standard. Results presented in Table 6.2 indicate that all measurements were well within the USEPA drinking water standards. This program is being conducted to demonstrate ANL's compliance with the USEPA drinking water regulations.

TABLE 6.1

Target Compound List

Volatile

Chloromethane	1,2-Dichloropropane
Bromomethane	cis-1,3-Dichloropropene
Vinyl Chloride	Trichloroethene
Chloroethane	Dibromochloromethane
Methylene Chloride	1,1,2-Trichloroethane
Acetone	Benzene
Carbon Disulfide	trans-1,3-Dichloropropene
1,1-Dichloroethene	Bromoform
cis-1,2-Dichloroethene	4-Methyl-2-Pentanone
1,1-Dichloroethane	2-Hexanone
Chloroform	Tetrachloroethene
1,2-Dichloroethane	1,1,2,2-Tetrachloroethane
2-Butanone	Toluene
1,1,1-Trichloroethane	Chlorobenzene
Carbon Tetrachloride	Ethylbenzene
Vinyl Acetate	Styrene
Bromodichloromethane	Xylene (total)

Semi-Volatile

Phenol	2,4,6-Trichlorophenol
bis(2-Chloroethyl)ether	2,4,5-Trichlorophenol
2-Chlorophenol	2-Chloronaphthalene
1,3-Dichlorobenzene	2-Nitroaniline
1,4-Dichlorobenzene	Dimethylphthalate
Benzyl Alcohol	Acenaphthylene
1,2-Dichlorobenzene	2,6-Dinitrotoluene
2-Methylphenol	3-Nitroaniline
bis(2-Chloroisopropyl)ether	Acenaphthene
4-Methylphenol	4-Nitrophenol
N-Nitroso-Di-n-propylamine	Dibenzofuran
Hexachloroethane	2,4-Dinitrotoluene
Nitrobenzene	Diethylphthalate
Isophorone	4-Chlorophenyl-phenylether
2-Nitrophenol	Fluorene
2,4-Dimethylphenol	4-Nitroaniline
Benzoic Acid	4,6-Dinitro-2-methylphenol
bis(2-Chloroethoxy)methane	N-Nitrosodiphenylamine
2,4-Dichlorophenol	4-Bromophenyl-phenylether
1,2,4-Trichlorobenzene	Hexachlorobenzene
Naphthalene	Pentachlorophenol
4-Chloroaniline	Phenanthrene

TABLE 6.1 (Contd.)

Hexachlorobutadiene	Anthracene
4-Chloro-3-methylphenol	Di-n-Butylphthalate
2-Methylnaphthalene	Fluoranthene
Hexachlorocyclopentadiene	Pyrene
Butylbenzylphthalate	Benzo(b)fluoranthene
3,3'-Dichlorobenzidine	Benzo(k)fluoranthene
Benzo(α)anthracene	Benzo(α)pyrene
Chrysene	Indeno(1,2,3-cd)pyrene
bis(2-Ethylhexyl)phthalate	Dibenzo(a,h)anthracene
Di-n-Octylphthalate	Benzo(g,h,i)perylene

Pesticides and Herbicides

Alpha BHC	4,4' DDT
Beta BHC	Dieldrin
Delta BHC	Endrin
Lindane	Endrin Ketone
Methoxychlor	Endosulfan I
Heptachlor	Endosulfan II
Heptachlor Epoxide	Endosulfan Sulfate
Aldrin	Alpha Chlordane
4,4' DDD	Gamma Chlordane
4,4' DDE	Toxaphene

PCBs

Aroclor 1016	Aroclor 1248
Aroclor 1221	Aroclor 1254
Aroclor 1232	Aroclor 1260
Aroclor 1242	

TABLE 6.2

Radioactivity in ANL Domestic Wells, 1989
(Concentrations in pCi/L)

Type of Activity	Location	No. of Samples	Avg.	Min.	Max.
Alpha (nonvolatile)	Well #1	3	5.8	5.2	6.5
	Well #2	4	4.4	2.4	7.5
	Well #3	4	3.0	1.8	4.4
	Well #4	4	2.9	1.7	3.6
	Tap	1	-	-	0.8
Beta (nonvolatile)	Well #1	3	10.1	9.3	10.6
	Well #2	4	6.5	4.7	7.6
	Well #3	4	6.3	5.7	7.4
	Well #4	4	6.3	5.4	7.4
	Tap	1	-	-	3.1
Hydrogen-3	Well #1	3	313	209	397
	Well #2	4	149	126	189
	Well #3	4	< 100	< 100	< 100
	Well #4	4	< 100	< 100	155
	Tap	1	-	-	138
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	-	-	0.82
	Well #2	1	-	-	0.70
	Well #3	1	-	-	0.61
	Well #4	1	-	-	0.88
	Tap	1	-	-	0.12
Uranium (natural)	Well #1	1	-	-	1.15
	Well #2	1	-	-	0.46
	Well #3	1	-	-	0.39
	Well #4	1	-	-	0.25
	Tap	1	-	-	0.30

Wells #1 and #2 had measurable levels of hydrogen-3 at various times during the year, although the average concentration was only about 1% of the USEPA standard. It is speculated that the source of the hydrogen-3 was liquid wastes placed in a holding pond in the sewage treatment area (location 10M in Figure 1.1) in the 1950s. The tritiated water may have migrated through the soil to the dolomite aquifer and was drawn into the wells. Well #1, which is about 200 m (650 ft) north of the treatment area, had higher hydrogen-3 concentrations than Well #2, which is about 300 m (1000 ft) from the treatment area. Although the normal subsurface water flow gradient is toward the south, the cone of depression created by pumping these wells would overpower the normal flow pattern. The holding pond has not been used for a number of years. One hydrogen-3 result from Well #4 was slightly above the detection limit (DL), but this is considered to be within the normal fluctuation range for the measurement of hydrogen-3 in water.

The samples also were analyzed for selected inorganic constituents. Results for antimony, beryllium, cadmium, chromium, cobalt, mercury, nickel, selenium, silver, and thallium were below detection limits. Concentrations of aluminum, arsenic, barium, calcium, copper, iron, lead, magnesium, potassium, and zinc were usually detected, but below any standards. The level of total dissolved solids was always in excess of the 500 mg/L standard. Elevated levels of total phenols were observed in wells #1 and #3 and in the domestic water in the June sample. Since, the limit for drinking water, 1 $\mu\text{g/L}$, was at the detection limit for the chemical method used, the uncertainty of the measurement is large. In a follow up sample in September, phenol was found to be less than 1 $\mu\text{g/L}$. The samples also were analyzed for constituents of the Target Compound List (Table 6.1), and all results were below the detection limit. The detection limit for the volatile organic constituents was 0.5 to 1.0 $\mu\text{g/L}$ and was 10 $\mu\text{g/L}$ for the semi-volatile organic constituents.

6.2. 317 and 319 Areas

The 317 Area is used to temporarily store radioactive waste before shipment off the site for disposal. The 319 Area is a landfill that was used during the 1950s to dispose of debris and equipment in which radioactive contamination was possible but could not be detected. When the complete absence of contamination could not be guaranteed, such as the inside of small pipes, the material was disposed of in this area. Two French drains, one in each area, were used for the disposal of liquid organic waste materials.

Monitoring wells have been installed in these areas, and the locations are shown in Figure 6.1. In previous reports these wells have been referred to as "MWs", (for example, MW1, MW2, etc.). Beginning with this report, a new numbering system is introduced. The monitoring well previously designated as MW1 is now designated as well 300010. The first three numbers identify the area in which the well is located and the well itself is defined by the last three numbers. Multiple wells exist at several locations and it is anticipated that future wells will be clustered. This numbering system will allow for unique identification of present and future wells.

Wells 300010, 300020, 300030, and 300040 were installed in September 1986; 300050 and 300060 in August 1987; 300070, 300100, and 300110 in July 1988; 300120 and 300130 in September 1988; and wells 300031, 300051, and 300052 were installed in June 1989. These wells are all completed in the glacial till. In addition, wells 300D30 and 300D40 were installed in November 1989 and reach the dolomite aquifer at about 25 m (80 ft) below the surface.

Wells 300120 and 300130 are upgradient of the 317 storage area and 300010 is upgradient of the 319 landfill area. Wells 300051, 300052, and 300031 were drilled to depths of 5-8 m (15-25 ft) to intercept a sand lens that was discovered recently. This layer is also intercepted by wells 300120, 300100, and 300110.

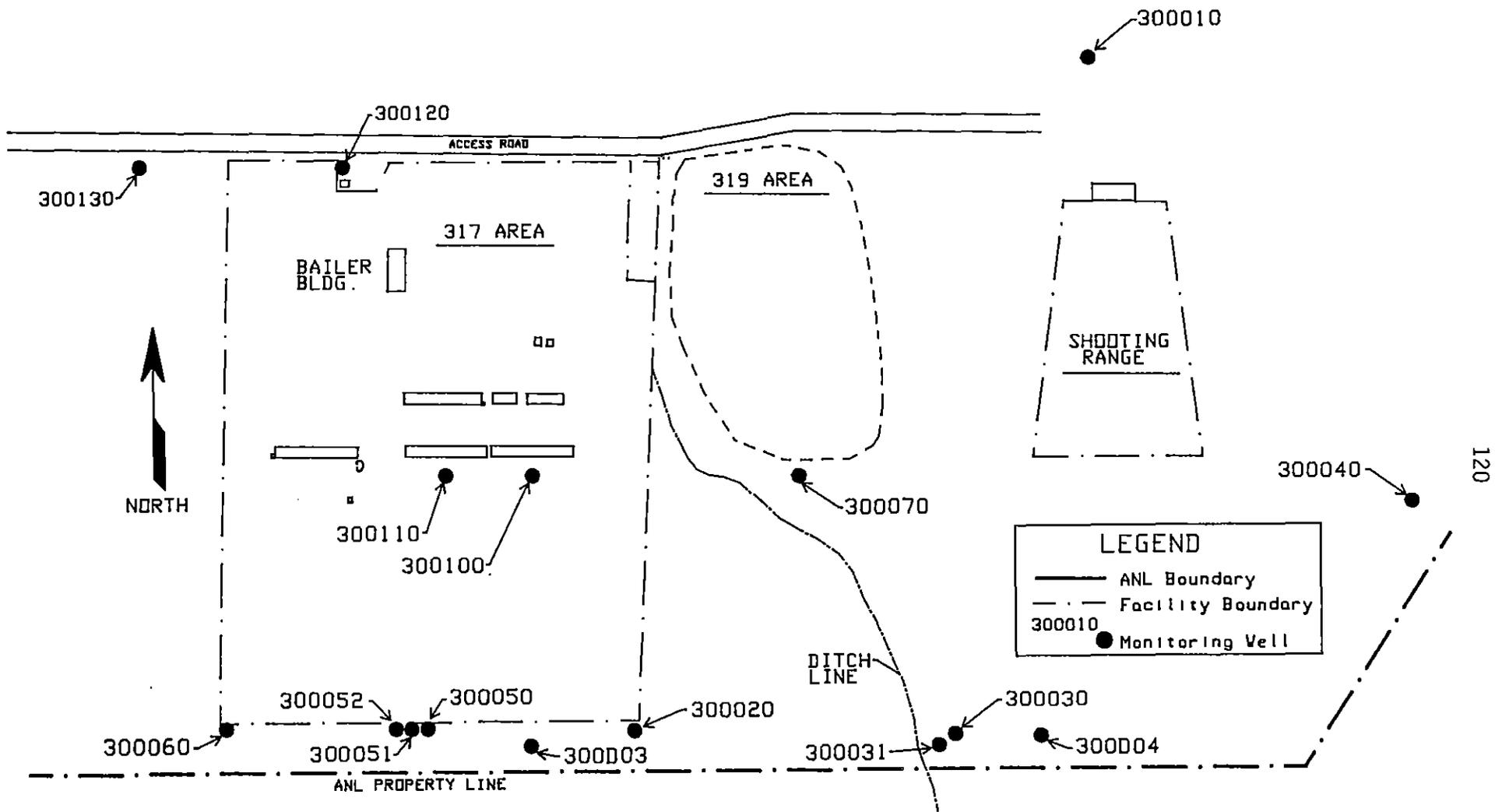


Fig. 6.1 Monitoring Well Locations in the 317 and 319 Areas

6.2.1. Sample Collection

The monitoring wells are sampled using the protocol listed in the RCRA Groundwater Monitoring Technical Enforcement Guidance Document.²² The volume of water in the casing is determined by measuring the water depth from the surface and the depth to the bottom of the well. This latter measurement also determines whether siltation has occurred that might restrict water movement. For each of the wells in the glacial till that do not recharge rapidly, the well is emptied and the volume removed is compared with the volume calculated. After 24 hours, the water level is remeasured, and the refill volume is compared with the initial volume. In most cases these volumes are nearly identical. The well is then sampled by bailing, collecting the volatile organics, other organics, trace metals, and radioactive samples in that order. The samples are placed in precleaned bottles, labelled, and preserved. For each well in the porous, saturated zone which recharge rapidly, three well volumes are removed while the pH, specific conductance, and temperature are being continuously measured. These parameters stabilize quickly in these wells. In the case of the dolomite wells, samples are collected as soon as these readings stabilize.

6.2.2. Results of Analyses

6.2.2.1. Inorganic Constituents

The analysis data for inorganic constituents are shown in Tables 6.3 through 6.13. The data from wells in the sand lens are characterized by high levels of iron, manganese, and lead. The levels of lead ranged from about 35 $\mu\text{g}/\text{L}$ in well 300031 to about 200 $\mu\text{g}/\text{L}$ in well 300110. The origin of the high levels of lead is presently being confirmed and characterized. The high levels of iron and manganese do not appear to be due to high concentrations of silt which were observed shortly after well construction since other highly silted wells do not have particularly high levels of iron and manganese.

TABLE 6.3

Chemical Constituents at 317 and 319 Areas, Well 300010, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	3	-		< 10
Barium	3	44 \pm 31	26	59
Beryllium	3	-	-	< 0.05
Cadmium	3	1.8 \pm 2.3	0.3	2.5
Chloride*	3	25 \pm 4	23	27
Chromium	3	13 \pm 19	2	20
Cobalt	3	-	-	< 40
Copper	3	15 \pm 13	10	23
Iron*	3	3.9 \pm 10.0	0.7	10.3
Lead	3	7 \pm 14	< 1	16
Manganese	3	276 \pm 634	53	673
Mercury	3	-	-	< 0.10
Nickel	3	-	-	< 40
Selenium	3	-	-	< 10
Silver	3	6.6 \pm 8.9	< 1.0	9.7
Vanadium	3	40 \pm 56	< 5	60
Zinc	3	39 \pm 30	< 20	49

*Concentration in mg/L.

TABLE 6.4

Chemical Constituents at 317 and 319 Areas, Well 300020, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	42 ± 13	33	54
Beryllium	4	0.67 ± 1.35	< 0.05	2.10
Cadmium	4	1.8 ± 1.4	0.3	2.5
Chloride*	4	14 ± 8	6	19
Chromium	4	19 ± 43	< 1	65
Cobalt	4	-	-	< 40
Copper	4	14 ± 12	< 10	27
Iron*	4	2.5 ± 3.9	0.5	6.5
Lead	4	5 ± 5	< 1	8
Manganese	4	84 ± 106	13	169
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	6.2 ± 5.6	< 1.0	10.8
Thallium	4	-	-	< 10
Vanadium	4	30 ± 41	< 5	62
Zinc	4	21 ± 3	< 20	25

*Concentration in mg/L.

TABLE 6.5

Chemical Constituents at 317 and 319 Areas, Well 300031, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	2	-	-	< 10
Barium	2	174 \pm 99	151	197
Beryllium	2	-	-	< 2.70
Cadmium	2	-	-	< 2.5
Chloride*	2	52 \pm 65	37	67
Chromium	2	22 \pm 44	12	32
Cobalt	2	-	-	< 40
Copper	2	30 \pm 86	< 10	50
Iron*	2	13.9 \pm 40.5	4.5	23.3
Lead	2	35 \pm 1	35	36
Manganese	2	681 \pm 1788	265	1100
Mercury	2	-	-	< 0.1
Nickel	2	41 \pm 2	40	41
Selenium	2	-	-	< 10
Silver	2	9.3 \pm 4.7	8.2	10.4
Thallium	2	-	-	< 10
Vanadium	2	58 \pm 4	57	59
Zinc	2	89 \pm 209	35	132

*Concentration in mg/L.

TABLE 6.6

Chemical Constituents at 317 and 319 Areas, Well 300052, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	2	-	-	< 10
Barium	2	220 \pm 26	214	226
Beryllium	2	4.30 \pm 7.32	2.60	6.00
Cadmium	2	-	-	< 2.5
Chloride*	2	11 \pm 26	5	17
Chromium	2	39 \pm 5	38	40
Cobalt	2	-	-	< 40
Copper	2	48 \pm 34	40	56
Iron*	2	27.4 \pm 11.0	24.9	29.9
Lead	2	70 \pm 30	63	77
Manganese	2	2580 \pm 1810	2160	3000
Mercury	2	-	-	< 0.10
Nickel	2	47 \pm 22	42	52
Selenium	2	-	-	< 10
Silver	2	4.3 \pm 7.3	2.6	6.0
Thallium	2	-	-	< 10
Vanadium	2	50 \pm 44	40	60
Zinc	2	144 \pm 103	120	168

*Concentration in mg/L.

TABLE 6.7

Chemical Constituents at 317 and 319 Areas, Well 300060, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	51 ± 4	46	55
Beryllium	5	0.67 ± 1.02	< 0.05	2.20
Cadmium	5	2.0 ± 1.5	1.0	3.0
Chloride*	5	49 ± 6	41	54
Chromium	5	6 ± 5	< 1	11
Cobalt	5	-	-	< 40
Copper	5	12 ± 3	< 10	16
Iron*	5	0.5 ± 0.4	0.1	0.9
Lead	5	2 ± 2	< 1	5
Manganese	5	31 ± 13	14	40
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	6.1 ± 5.6	< 1.0	11.0
Thallium	5	-	-	< 10
Vanadium	5	36 ± 32	< 5	59
Zinc	5	25 ± 13	20	46

*Concentration in mg/L.

TABLE 6.8

Chemical Constituents at 317 and 319 Areas, Well 300100, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	120 \pm 65	41	171
Beryllium	5	1.42 \pm 0.83	0.50	2.50
Cadmium	5	1.9 \pm 0.9	0.7	2.0
Chloride*	5	22 \pm 2	21	26
Chromium	5	32 \pm 20	9	56
Cobalt	5	41 \pm 2	40	43
Copper	5	66 \pm 55	14	120
Iron*	5	61.7 \pm 59.0	1.5	116.0
Lead	5	44 \pm 30	6	73
Manganese	5	1120 \pm 910	70	1970
Mercury	5	-	-	< 0.10
Nickel	5	71 \pm 35	40	102
Selenium	5	-	-	< 10
Silver	5	4.1 \pm 5.0	< 1.0	9.0
Thallium	5	-	-	< 10
Vanadium	5	41 \pm 20	24	70
Zinc	5	199 \pm 165	22	348

*Concentration in mg/L.

TABLE 6.9

Chemical Constituents at 317 and 319 Areas, Well 300110, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	232 \pm 237	87	475
Beryllium	4	3.45 \pm 4.60	0.60	8.00
Cadmium	4	19.0 \pm 5.0	2.0	68.0
Chloride*	4	13 \pm 9	5	18
Chromium	4	61 \pm 93	25	161
Cobalt	4	80 \pm 83	40	169
Copper	4	207 \pm 306	37	515
Iron*	4	127.0 \pm 230.0	3.5	360.0
Lead	4	212 \pm 207	50	407
Manganese	4	4010 \pm 4080	790	7850
Mercury	4	-	-	< 0.10
Nickel	4	107 \pm 155	< 40	273
Selenium	4	-	-	< 10
Silver	4	3.0 \pm 4.0	< 1.0	10.0
Thallium	4	-	-	< 10
Vanadium	4	52 \pm 56	< 2	98
Zinc	4	502 \pm 773	118	1300

*Concentration in mg/L.

TABLE 6.10

Chemical Constituents at 317 and 319 Areas, Well 300120, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	14 \pm 5	< 10	20
Barium	5	144 \pm 80	63	218
Beryllium	5	3.20 \pm 2.83	0.50	6.10
Cadmium	5	2.7 \pm 0.8	2.3	3.9
Chloride*	5	235 \pm 32	212	280
Chromium	5	40 \pm 31	13	85
Cobalt	5	-	-	< 40
Copper	5	84 \pm 76	22	165
Iron*	5	59.5 \pm 66.0	4.9	133.0
Lead	5	59 \pm 39	9	93
Manganese	5	1690 \pm 1140	260	2830
Mercury	5	-	-	< 0.10
Nickel	5	80 \pm 61	< 40	138
Selenium	5	-	-	< 10
Silver	5	3.8 \pm 4.1	1.0	8.0
Thallium	5	-	-	< 10
Vanadium	5	40 \pm 11	31	53
Zinc	5	180 \pm 159	52	359

*Concentration in mg/L.

TABLE 6.11

Chemical Constituents at 317 and 319 Areas, Well 300130, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	66 ± 17	62	70
Beryllium	5	0.43 ± 0.72	< 0.05	1.50
Cadmium	5	1.3 ± 1.5	0.3	3.0
Chloride*	5	73 ± 8	66	81
Chromium	5	6 ± 5	< 1	10
Cobalt	5	-	-	< 40
Copper	5	11 ± 2	<10	13
Iron*	5	1.1 ± 0.7	0.3	1.9
Lead	5	2 ± 2	< 1	6
Manganese	5	168 ± 37	138	212
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	6.3 ± 5.8	< 1.0	11.7
Thallium	5	-	-	< 10
Vanadium	5	49 ± 10	47	52
Zinc	5	26 ± 14	<20	48

*Concentration in mg/L.

TABLE 6.12

Chemical Constituents at 317 and 319 Areas, Well 300D03 (D3), 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	3	-	-	< 10
Barium	3	34 \pm 32	21	54
Beryllium	3	0.62 \pm 1.16	< 0.05	1.30
Cadmium	3	1.8 \pm 2.1	0.5	2.5
Chloride*	3	43 \pm 6	40	46
Chromium	3	7 \pm 8	2	10
Cobalt	3	-	-	< 40
Copper	3	-	-	< 10
Iron*	3	1.4 \pm 1.4	0.5	2.0
Lead	3	2 \pm 1	< 1	3
Manganese	3	26 \pm 35	10	47
Mercury	3	-	-	< 0.10
Nickel	3	-	-	< 40
Selenium	3	-	-	< 10
Silver	3	6.0 \pm 9.0	< 1.0	10.3
Thallium	3	-	-	< 10
Vanadium	3	37 \pm 53	< 5	61
Zinc	4	22 \pm 7	<20	30

*Concentration in mg/L.

TABLE 6.13

Chemical Constituents at 317 and 319 Areas, Well 300D04 (D4), 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	3	-	-	< 10
Barium	3	52 \pm 27	35	62
Beryllium	3	0.88 \pm 1.98	< 0.05	2.10
Cadmium	3	1.8 \pm 2.2	0.4	2.5
Chloride*	3	41 \pm 13	37	49
Chromium	3	6 \pm 8	2	11
Cobalt	3	-	-	< 40
Copper	3	-	-	< 10
Iron*	3	2.9 \pm 6.6	0.4	7.0
Lead	3	2 \pm 1	< 1	2
Manganese	3	26 \pm 40	10	51
Mercury	3	-	-	< 0.10
Nickel	3	-	-	< 40
Selenium	3	-	-	< 10
Silver	3	6.8 \pm 9.1	1.0	10.0
Thallium	3	-	-	< 10
Vanadium	3	41 \pm 57	5	60
Zinc	4	22 \pm 6	< 20	29

*Concentration in mg/L.

6.2.2.2. Organic Constituents

All of the wells were analyzed for semi-volatile organic compounds, polychlorinated biphenyls, and pesticides in December 1989. No significant amounts of these materials were detected in any of the wells. Small amounts of the ubiquitous phthalates found are thought not to be significant. Quarterly samples were collected and analyzed for volatile organic compounds. The results, shown in Table 6.14, are very similar to those from last year. The most significant concentrations were found in wells 300100 and 300110. The major contributing compounds were trichloroethene and its breakdown product cis-1,2-dichloroethene, and 1,1,1-trichloroethane and its breakdown product 1,1-dichloroethane. Traces of acetone, chloroform, and carbon tetrachloride also were detected on occasion. The source of these compounds, based on preliminary characterization studies, appears to be movement of shallow groundwater through the 317 Area French drain. The compounds found in well 300020 are similar, but probably reach the well in a different manner. A footing drainage system around several of the vaults is used to prevent flooding of the vaults. The groundwater was collected and flowed through an underground pipeline which discharged into a small ditch south of the 317 Area. To prevent the possibility of discharging radioactive or chemically-contaminated materials off the site, the pipeline was plugged in 1987. Currently the water, which accumulates in this system, is pumped out periodically and discharged into the wastewater treatment system. This groundwater is monitored regularly and has shown high levels of carbon tetrachloride, chloroform, and tetrachloroethene. Lesser amounts of trichloroethene and cis-1,2-dichloroethene are also usually present. The pipeline ran very near the location of well 300020. The compounds found in this well may be the result of downward migration of contaminated water coming from leaks in the pipeline, as well as lateral movement of contaminated groundwater from the French drain area. The presence of 1,1,1-trichloroethene, which has never been found in the footing drain water, indicates multiple sources of contamination of this well. The absence of volatile organic compounds in the other monitoring wells in the vicinity of well 300020 indicates that widespread movement toward the site perimeter has not yet occurred, at least at the depth to which the wells are placed. A substantial characterization study was begun in 1989, and preliminary results

TABLE 6.14

Organic Content of Monitoring Wells in the 317 and 319 Areas, 1989
(Concentrations in $\mu\text{g/L}$)

Well Number	Compound	3/8/89	5/16/89	9/4/89	11/21/89
300010	ND	ND	ND	ND	ND
300020	1,1-Dichloroethane	11	29	219	23
	Chloroform	< 5	< 5	< 5	< 5
	1,1,1-Trichloroethane	14	29	18	20
	1,2-Dichloroethane	ND	8	ND	7
	Carbon Tetrachloride	ND	< 5	ND	ND
300030	Chloroform		< 5		
	2-Butanone		< 10		
	1,1,1-Trichloroethane		< 10		
	Trichloroethene		3		
300031	ND			ND	ND
300052	ND			ND	ND
300060	ND	ND	ND	ND	ND
300100	cis-1,2-Dichloroethene	25	42	42	20
	Trichloroethene	41	18	11	15
	Tetrachloroethene	< 5	ND	ND	ND
	Chloroform	ND	< 5	< 5	ND
	Carbon Tetrachloride	ND	< 5	ND	ND
300110	1,1-Dichloroethane	ND	ND	186	29
	cis-1,2-Dichloroethene	11	42	ND	ND
	Acetone	36	< 30	ND	ND
	Trichloroethene	ND	< 5	< 5	5
	1,1,1-Trichloroethane	ND	ND	26	31
	Tetrachloroethene	ND	ND	< 5	< 5
300120	ND	ND	ND	ND	ND
300130	ND	ND	ND	ND	ND
300D03	Trichloroethene		< 5	ND	ND
	Limonene		ND	< 5	ND
300D04	Limonene		ND	< 5	ND

ND = Not Detected

< = Indication of Presence

indicate that some of the soil within the 317 Area is highly contaminated with a number of volatile organic compounds; however, it appears that most of this contamination is located in a relatively small area north of the vaults, close to the French drain site. Several compounds, particularly ketones, appear to have moved significant distances through the soil. Groundwater contaminated with a number of ketones was found near the old footing drain discharge point which is currently located on Forest Preserve property.

6.2.2.3. Radioactive Constituents

Samples collected quarterly from the monitoring wells in the 317 and 319 Areas were analyzed for hydrogen-3, strontium-90, and for gamma-ray emitters. The results are presented in Table 6.15. The only evidence of possible migration of radionuclides off the site is the low concentrations of hydrogen-3 and strontium-90 in well 300030. This monitoring well is directly below a small drainage swale from the 319 Area that has contained water intermittently with measurable concentrations of hydrogen-3 and strontium-90. Wells 300100 and 300110 are next to facilities that have stored radioactive materials in the past. All concentrations are well below any applicable standards.

6.3. Sanitary Landfill

A sanitary landfill for non-radioactive waste is located on the western edge of the ANL site in what is referred to as the 800 Area. This landfill operates under IEPA Permit No. 1981-29-op and is further described in Reference 23. Operation of the ANL landfill began in July 1966. During the period 1969 through 1978, substantial quantities of liquid organic wastes were disposed of in an open French drain located in the northeastern sector of the landfill. A log of disposed materials is available.

In 1979, an investigation was begun to determine the subsurface characteristics of the site and to place monitoring wells around the landfill (see Figure 6.2). The topography suggested that water flow was primarily southerly. Wells 800010 and 800050 were located outside the landfill and

TABLE 6.15

Radionuclides in the 317 and 319 Area Monitoring Wells, 1989
(Concentrations in pCi/L)

Type of Activity	Monitoring Well	No. of Samples	Avg.	Min.	Max.
Hydrogen-3	300010	4	277	182	417
	300020	4	302	244	384
	300031	1	-	-	1956
	300030	1	-	-	2172
	300052	2	160	133	188
	300060	4	311	168	604
	300100	4	1455	656	2110
	300110	4	443	311	560
	300120	4	250	207	316
	300130	4	197	123	316
	300D03	5	247	101	513
	300D04	5	1366	1112	1561
	Strontium-90	300010	2	-	-
300020		4	-	-	< 0.25
300031		1	-	-	0.6
300030		1	-	-	0.7
300052		2	-	-	< 0.25
300060		4	-	-	< 0.25
300100		4	46.7	15.4	75.5
300110		4	2.7	2.0	4.1
300120		4	-	-	< 0.25
300130		4	-	-	< 0.25
300D03		5	-	-	< 0.25
300D04		5	-	-	< 0.25
Cesium-137		300010	2	-	-
	300020	4	< 1	< 1	1
	300031	1	-	-	< 1
	300030	1	-	-	< 1
	300052	2	-	-	< 1
	300060	4	-	-	< 1
	300100	4	8	1	16
	300110	4	< 1	< 1	1
	300120	4	-	-	< 1
	300130	4	-	-	< 1
	300D03	5	1	< 1	1
	300D04	5	-	-	< 1

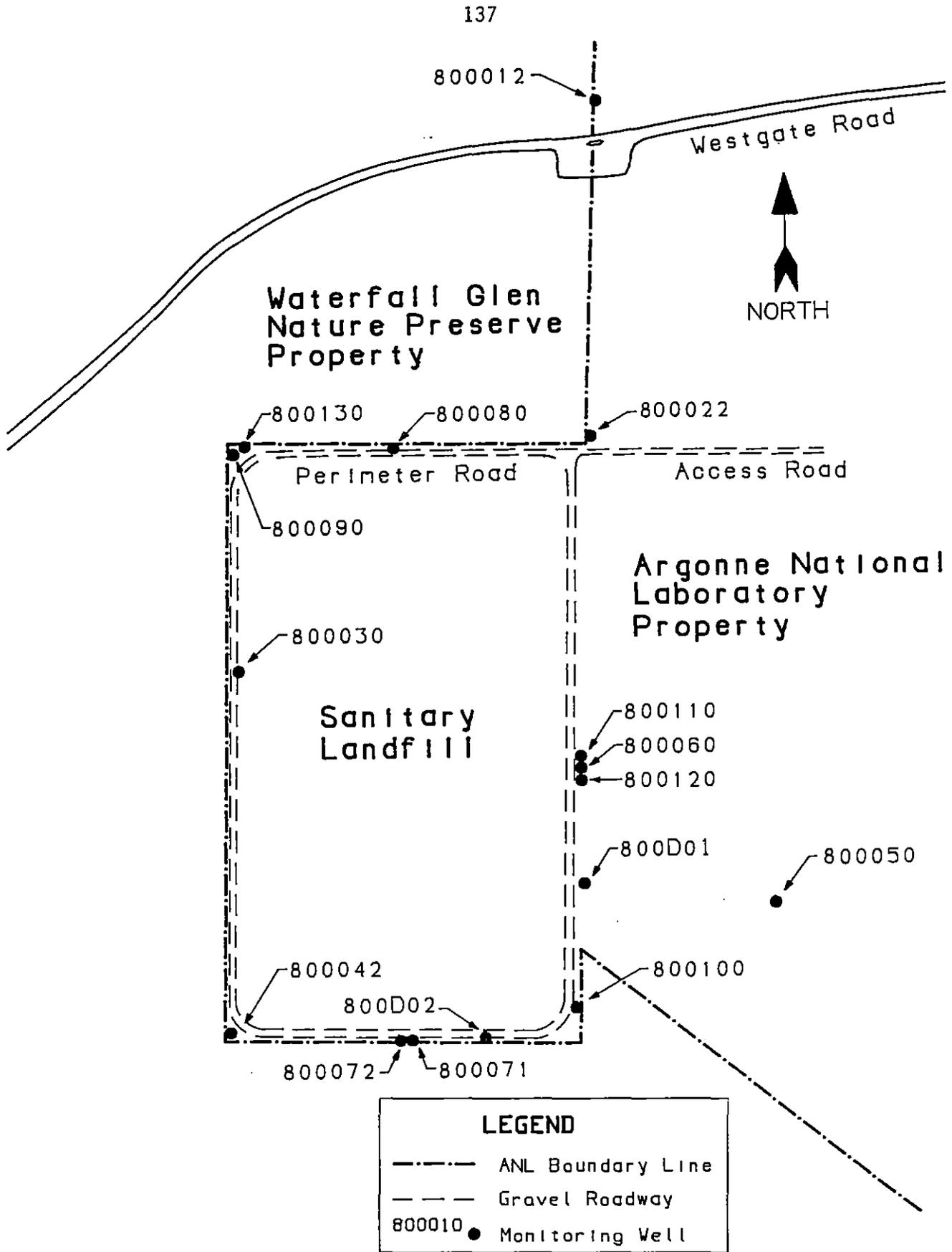


Fig. 6.2 Monitoring Well Locations for Landfill in the 800 Area

were meant to measure water entering and leaving the landfill. Wells 800020, 800030, and 800040 were placed at the perimeter of the landfill. In April 1980, a more comprehensive study was initiated to develop information required for the State of Illinois operating permit. Three additional wells were placed at the perimeter to improve coverage as well as to measure vertical movement. Well 800060 was placed in the eastern section to sample any water flowing out of the landfill in a southeasterly direction. Wells 800070 and 800071 were located along the southern boundary and were nested. In September 1986, six new wells were installed. Wells 800010, 800020, and 800040 were suspected of being poorly sealed and were removed and replaced by 800012, 800022 and 800042. The replacement wells were located within two meters (6 feet) of the original wells. In addition, wells 800080, 800090, and 800100 were constructed to improve peripheral coverage. In November 1987, additional wells were added to provide sampling at a deeper level. Both wells 800120, which is next to 800060, and 800130, which is next to 800090, were installed to a depth of 24 m (80 ft). Finally, in September 1989, two wells (800D01 and 800D02) were placed into the dolomite at a depth of 45 m (140 ft).

6.3.1. Sample Collection

The same procedure for well water sample collection previously described for the 317 and 319 Area was used for this area. Previous water-level measurements have indicated that a perched water layer exists at a depth of about 6 m (20 ft) on the north to about 7.6 m (25 ft) on the south. Wells 800012 through 800100 sample this layer. Wells 800120 and 800130, which are at a depth of 21 m (70 ft), produce very different results. Well 800130 has an abundant supply of water [casing volume of about 100 liters (27 gallons)] while well 800120 is usually dry. It is not known if there is a water layer at this depth or if well 800130 is in a local body of water. The dolomite wells are at a depth of about 45 m (140 ft), and both have an abundant supply of water.

6.3.2. Results of Analyses

6.3.2.1. Inorganic Constituents

Results for inorganic constituents are shown in Tables 6.16 through 6.26. The same uneven distribution of iron and manganese previously reported is seen. Wells 800080 and 800090 are separated by about 150 m (340 ft) and are at the same depth. The levels of iron and manganese are substantially different. Low levels of arsenic were detected in wells 800090, 800100, and 800130. The inorganic results for the dolomite wells (800D01 and 800D02) were all within the normal range. Well 800D01 exhibited an unusually high pH value of 11.0. The levels for the remaining elements are in the range normally found for uncontaminated waters.

6.3.2.2. Organic Constituents

All of the monitoring wells were sampled for volatile organic compounds on a quarterly basis. The constituent concentrations were all below detection limits, with the exception of tetrahydrofuran in well 800060. This has been reported previously and the source is unknown. The monitoring wells also were sampled and analyzed for semi-volatile organic compounds and polychlorinated biphenyls and pesticides. The only detectable compound was dibutyl phthalate, which is found in many samples. The dolomite wells were analyzed for the same series of organic compounds, and the only significant result was benzoic acid in well 800D02. The source of this compound is unknown. These wells also were analyzed for volatile organics. Five ketones were found in well 800D01 (acetone, 2-butanone, 2-hexanone, 2-heptanone, and 2-octanone). Concentrations ranged from 3 to 56 $\mu\text{g/L}$. The wells will be resampled to verify the results.

6.3.2.3. Radioactive Constituents

Samples collected from the 800 Area sanitary landfill monitoring wells for chemical analysis were also analyzed for tritiated water. The results are shown in Table 6.27. Although the disposal of radioactive material is prohibited in the sanitary landfill, very low concentrations of tritiated

TABLE 6.16

Chemical Constituents at ANL 800 Area Landfill, Well 800012, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	160 \pm 24	133	183
Beryllium	5	0.64 \pm 1.22	< 0.05	2.50
Cadmium	5	8.2 \pm 13.0	1.3	28.0
Chloride*	5	772 \pm 128	637	875
Chromium	5	4 \pm 4	< 1	7
Cobalt	5	-	-	< 40
Copper	5	14 \pm 6	<10	20
Iron*	5	1.1 \pm 1.0	0.5	2.7
Lead	5	2 \pm 1	< 1	3
Manganese	5	447 \pm 53	389	499
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	4.5 \pm 5.5	< 1.0	10.0
Thallium	5	-	-	< 10
Vanadium	5	24 \pm 31	< 5	59
Zinc	5	21 \pm 3	<20	26

*Concentration in mg/L.

TABLE 6.17

Chemical Constituents at ANL 800 Area Landfill, Well 800022, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	400 \pm 197	302	608
Beryllium	4	0.38 \pm 0.57	< 0.05	0.90
Cadmium	4	1.8 \pm 1.3	0.7	2.5
Chloride	4	27 \pm 12	20	40
Chromium	4	3 \pm 10	< 1	6
Cobalt	4	-	-	< 40
Copper	4	11 \pm 3	<10	14
Iron*	4	1.0 \pm 0.2	0.8	1.2
Lead	4	2 \pm 1	< 1	3
Manganese	4	467 \pm 28	454	496
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	4.5 \pm 5.8	< 1.0	9.0
Thallium	4	-	-	< 10
Vanadium	4	26 \pm 34	< 5	49
Zinc	4	21 \pm 2	<20	23

*Concentration in mg/L.

TABLE 6.18

Chemical Constituents at ANL 800 Area Landfill, Well 800030, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	247 \pm 56	207	289
Beryllium	4	1.15 \pm 2.49	< 0.05	3.80
Cadmium	4	3.14 \pm 4.11	0.8	7.6
Chloride*	4	8 \pm 7	3	12
Chromium	4	8 \pm 11	1	17
Cobalt	4	-	-	< 40
Copper	4	16 \pm 8	11	25
Iron*	4	9.7 \pm 13.0	1.3	18.2
Lead	4	3 \pm 2	1	4
Manganese	4	155 \pm 126	76	246
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	8.8 \pm 14.6	< 1.0	23.2
Thallium	4	-	-	< 10
Vanadium	4	34 \pm 46	< 5	63
Zinc	4	26 \pm 8	< 20	33

*Concentration in mg/L.

TABLE 6.19

Chemical Constituents at ANL 800 Area Landfill, Well 800042, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	493 \pm 41	466	534
Beryllium	4	0.79 \pm 1.51	0.06	2.40
Cadmium	4	1.9 \pm 1.0	1.1	2.5
Chloride	3	237 \pm 101	175	280
Chromium	4	5 \pm 6	< 1	9
Cobalt	4	-	-	< 40
Copper	4	13 \pm 6	< 10	19
Iron*	4	1.2 \pm 0.7	0.7	1.8
Lead	4	2 \pm 2	< 1	3
Manganese	4	259 \pm 50	207	290
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	4.6 \pm 5.8	< 1.0	8.4
Thallium	4	-	-	< 10
Vanadium	4	28 \pm 37	< 5	54
Zinc	4	20 \pm 1	< 20	21

*Concentration in mg/L.

TABLE 6.20

Chemical Constituents at ANL 800 Area Landfill, Well 800050, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	2	-	-	< 10
Barium	2	52 \pm 32	45	60
Beryllium	2	0.20 \pm 0.32	0.12	0.27
Cadmium	2	1.6 \pm 1.1	1.3	1.8
Chloride	2	9 \pm 2	8	9
Chromium	2	8 \pm 16	4	12
Cobalt	2	-	-	< 40
Copper	2	30 \pm 19	26	35
Iron*	2	9.4 \pm 7.5	7.7	11.2
Lead	2	13 \pm 12	10	16
Manganese	2	215 \pm 151	180	250
Mercury	2	-	-	< 0.10
Nickel	2	-	-	< 40
Selenium	2	-	-	< 10
Silver	2	2.4 \pm 6.0	< 1.0	3.8
Thallium	2	-	-	< 10
Vanadium	2	-	-	< 5
Zinc	2	40 \pm 26	34	46

*Concentration in mg/L.

TABLE 6.21

Chemical Constituents at ANL 800 Area Landfill, Well 800060, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	139 \pm 20	118	148
Beryllium	5	1.12 \pm 1.48	< 0.05	2.80
Cadmium	5	2.3 \pm 0.3	2.0	2.5
Chloride*	5	232 \pm 16	216	244
Chromium	5	12 \pm 5	7	15
Cobalt	5	-	-	< 40
Copper	5	16 \pm 7	< 10	23
Iron*	5	8.8 \pm 3.9	4.5	12.9
Lead	5	4 \pm 2	2	6
Manganese	5	1080 \pm 92	1000	1190
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	5.8 \pm 5.1	< 1.0	10.7
Thallium	5	-	-	< 10
Vanadium	5	40 \pm 30	< 5	51
Zinc	5	32 \pm 22	< 20	64

*Concentration in mg/L.

TABLE 6.22

Chemical Constituents at ANL 800 Area Landfill, Well 800071, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	-	-	< 10
Barium	4	110 \pm 13	96	116
Beryllium	4	0.58 \pm 1.08	< 0.05	1.70
Cadmium	4	3.2 \pm 2.2	2.3	5.6
Chloride*	4	45 \pm 10	38	53
Chromium	4	6 \pm 6	< 1	10
Cobalt	4	-	-	< 40
Copper	4	11 \pm 2	<10	13
Iron*	4	1.7 \pm 0.8	1.3	2.6
Lead	4	2 \pm 1	2	3
Manganese	4	316 \pm 152	249	480
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	4.9 \pm 6.2	< 1.0	9.0
Thallium	4	-	-	< 10
Vanadium	4	29 \pm 38	< 5	53
Zinc	4	-	-	< 20

*Concentration in mg/L.

TABLE 6.23

Chemical Constituents at ANL 800 Area Landfill, Well 800080, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	-	-	< 10
Barium	5	54 \pm 14	41	67
Beryllium	5	0.84 \pm 1.48	< 0.05	3.10
Cadmium	5	4.0 \pm 4.8	1.0	11.3
Chloride*	5	97 \pm 25	81	126
Chromium	5	6 \pm 6	< 1	13
Cobalt	5	-	-	< 40
Copper	5	13 \pm 4	<10	17
Iron*	5	1.5 \pm 3.0	0.2	6.2
Lead	5	4 \pm 3	2	8
Manganese	5	206 \pm 93	119	314
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	7.0 \pm 4.7	< 1.0	11.1
Thallium	5	-	-	< 10
Vanadium	5	30 \pm 30	< 5	50
Zinc	5	29 \pm 13	<20	48

*Concentration in mg/L.

TABLE 6.24

Chemical Constituents at ANL 800 Area Landfill, Well 800090, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	4	14 ± 12	< 10	27
Barium	4	290 ± 27	271	308
Beryllium	4	1.27 ± 2.12	< 0.05	3.20
Cadmium	4	2.2 ± 0.6	1.8	2.5
Chloride*	4	131 ± 8	125	137
Chromium	4	22 ± 22	< 1	38
Cobalt	4	-	-	< 40
Copper	4	21 ± 14	< 10	33
Iron*	4	28.9 ± 15.0	17.7	43.6
Lead	4	8 ± 8	3	17
Manganese	4	2840 ± 860	1950	3310
Mercury	4	-	-	< 0.10
Nickel	4	-	-	< 40
Selenium	4	-	-	< 10
Silver	4	7.3 ± 11.5	< 1.0	18.4
Thallium	4	-	-	< 10
Vanadium	4	30 ± 46	< 5	70
Zinc	4	36 ± 33	< 20	71

*Concentration in mg/L.

TABLE 6.25

Chemical Constituents at ANL 800 Area Landfill, Well 800100, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	5	11 ± 2	< 10	13
Barium	5	78 ± 11	68	90
Beryllium	5	0.50 ± 0.74	0.06	1.60
Cadmium	5	1.7 ± 0.9	0.9	2.5
Chloride*	5	11 ± 14	4	32
Chromium	5	8 ± 8	< 1	15
Cobalt	5	-	-	< 40
Copper	5	14 ± 9	< 10	27
Iron*	5	7.0 ± 6.8	1.7	16.1
Lead	5	6 ± 5	3	13
Manganese	5	335 ± 180	240	612
Mercury	5	-	-	< 0.10
Nickel	5	-	-	< 40
Selenium	5	-	-	< 10
Silver	5	5.4 ± 7.3	< 1.0	14.9
Thallium	5	-	-	< 10
Vanadium	5	26 ± 33	< 5	58
Zinc	5	35 ± 10	26	50

*Concentration in mg/L.

TABLE 6.26

Chemical Constituents at ANL 800 Area Landfill, Well 800130, 1989
(Concentrations in $\mu\text{g/L}$)

Constituent	No. of Samples	Avg.	Concentration Min.	Max.
Arsenic	3	10 ± 1	< 10	11
Barium	3	162 ± 19	151	171
Beryllium	3	1.54 ± 3.80	0.23	3.90
Cadmium	3	-	-	< 2.5
Chloride*	3	26 ± 12	21	34
Chromium	3	21 ± 19	14	33
Cobalt	3	-	-	< 40
Copper	3	23 ± 22	< 10	34
Iron*	3	13.8 ± 10.5	7.4	18.5
Lead	3	13 ± 13	5	18
Manganese	3	357 ± 432	121	591
Mercury	3	-	-	< 0.10
Nickel	3	-	-	< 40
Selenium	3	-	-	< 10
Silver	3	6.8 ± 9.3	< 1.0	10.0
Thallium	3	-	-	< 10
Vanadium	3	39 ± 54	< 5	56
Zinc	3	64 ± 58	28	84

*Concentration in mg/L.

TABLE 6.27

Hydrogen-3 Content of Water from 800 Area Landfill Wells, 1989
(Concentrations in pCi/L)

Location*	Date Collected			
	March 23	May 24	September 21	November 29
800012	185 ± 91	< 100	< 100	134 ± 91
800022	< 100	237 ± 85	< 100	< 100
800030	< 100	< 100	< 100	< 100
800042	< 100	< 100	< 100	103 ± 90
800050	250 ± 94	174 ± 83	-	-
800060	427 ± 97	480 ± 89	591 ± 95	657 ± 102
800071	1049 ± 108	598 ± 100	831 ± 99	1041 ± 109
800080	324 ± 96	218 ± 93	108 ± 86	155 ± 91
800090	520 ± 99	498 ± 98	361 ± 91	499 ± 98
800100	110 ± 91	234 ± 93	< 100	156 ± 95
800110	-	-	-	-
800120	-	< 100	-	-
800130	-	< 100	< 100	-

* See Figure 6.2.

water were detected, probably due to inadvertent disposal with ANL trash. However, the presence of tritiated water allows information to be obtained on the subsurface water flow pathway in the sanitary landfill area. The data indicate that the principal direction of subsurface water flow is to the south-southeast, with a small component to the northwest. This is consistent with estimated subsurface water flow based on water level measurements and general flow patterns in the area.

7. QUALITY ASSURANCE

Quality Assurance (QA) plans exist for both radiological (H 0030-0003-QA-00) and non-radiological (H 0030-0002-QA-01) analyses. Both QA documents were prepared in accordance with ANSI/ASMC NQA-I and meet the requirements of ANL QA documents.^{24,25} The plans discuss responsibilities and auditability. Both documents are supplemented by operating manuals.

7.1. Radiochemical Analysis and Radioactivity Measurements

All nuclear instrumentation is calibrated with standard sources obtained from the National Institute of Standards and Technology (NIST), if possible. If NIST standards are not available for particular nuclides, NIST traceable standards from the Amersham Corporation are used. The equipment is usually checked daily with secondary counting standards to ensure proper operation. Samples are 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 (USEPA-QA) are analyzed regularly. Results of ANL's participation in the USEPA-QA program during 1989 are given in Table 7.1. In the table, the comparison is made between the EPA-QA value, which is the quantity added to the sample by that laboratory, is compared with the value obtained in the ANL laboratory. Certain information may assist in judging the quality of the results, including the fact that typical uncertainties for the ANL analyses are 2% to 50%, depending on the concentration and the nuclide, and the uncertainties in the USEPA-QA results are 2% to 5% (ANL estimate).

In addition, participation continued in the DOE Environmental Measurements Laboratory Quality Assurance Program (DOE-EML-QAP), a semi-annual distribution of four different sample matrices containing various combinations of radionuclides that are analyzed. Results for 1989 are summarized in Table 7.2. In the table, the EML value, which is the result of replicate determinations by that laboratory, is compared with the average value obtained in the ANL laboratory. Information that will assist in judging the quality of the results includes the fact that typical uncertainties for

TABLE 7.1

Summary of EPA-QA Samples, 1989

Type of Sample	Analysis	Number Analyzed	Average Difference from Added (%)
Air Filter	Total Alpha	2	25
	Total Beta	1	2
	Strontium-90	1	15
	Cesium-137	2	12
Milk	Potassium-40	1	2
	Strontium-89	1	7
	Strontium-90	1	1
	Cesium-137	1	3
Water	Total Alpha	1	11
	Total Beta	1	28
	Hydrogen-3	3	8
	Chromium-51	1	0
	Cobalt-60	3	2
	Zinc-65	3	5
	Strontium-89	3	2
	Strontium-90	3	8
	Ruthenium-106	3	8
	Iodine-131	2	3
	Cesium-134	4	9
	Cesium-137	4	2
	Barium-133	2	5
	Radium-226	2	14
	Radium-228	2	13
	Total Uranium	3	23
Plutonium-239	2	10	

TABLE 7.2

Summary of DOE-EML-QAP Samples, 1989

Radionuclide	Percent Difference From EML Value			
	Air Filters	Soil	Vegetation	Water
Hydrogen-3	-	-	-	19 (2)
Beryllium-7	18 (2)	-	-	-
Potassium-40	-	6 (2)	14 (2)	-
Manganese-54	9 (2)	-	-	3 (2)
Cobalt-57	-	-	-	6 (2)
Cobalt-60	2 (2)	-	-	2 (2)
Strontium-90	3 (2)	6 (1)	16 (2)	4 (2)
Antimony-125	27 (1)	-	-	-
Cesium-134	16 (2)	-	-	11 (2)
Cesium-137	5 (2)	8 (2)	16 (2)	5 (2)
Cerium-144	10 (2)	-	-	10 (1)
Uranium-234	-	1 (1)	-	-
Uranium-238	19 (2)	5 (2)	-	20 (2)
Plutonium-239	9 (2)	14 (2)	6 (2)	19 (1)
Americium-241	23 (2)	33 (1)	6 (2)	29 (2)

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

ANL's analyses are 2% to 50% and that the uncertainties in the EML results are 1% to 30% (depending on the nuclide and the amount present). For most analyses for which the differences are large (> 20%), the concentrations were quite low and the differences were within the measurement uncertainties.

7.2. Chemical Analysis

The documentation for non-radiological analyses is contained in an INDUSTRIAL HYGIENE OPERATING MANUAL (IHOM), which includes a sampling and analysis plan, as well as individual analytical and collection procedures. All samples for NPDES and groundwater are collected and analyzed in accordance with USEPA regulations found in EPA-600/4-84-017,²⁶ SW-846,²⁷ and 40 CFR Part 136.¹⁹

Standard Reference Materials (SRM), traceable to the NIST, exist for most inorganic analyses (see Table 7.3). These are replaced annually. All standards are compared annually to the NIST values. Detection limits are determined with techniques listed in Report SW-846.²⁷ In general, it is the measure of the variability of a standard material measurement at 5-10 times the instrument detection limit as measured over an extended time period. Recovery of inorganic metals, as determined by "spiking" unknown solutions, must be in the range of 75% to 125%. The precision, as determined by analysis of duplicate samples, must be within 20%. These measurements must be made on at least 10% of the samples. Comparison samples for organic constituents are available from the USEPA, and many are used in this work. The requirement²⁷ for organic analyses depends upon the compounds studied and includes analyses of a matrix spike, specified internal standards, recovery, and relative retention times; at least one sample is run each month. Results for 1989 are shown in Table 7.4, along with the required recoveries.

Argonne participates in the U. S. Environmental Protection Agency Discharge Monitoring Report Quality Assurance Program (EPA-DMR-QAP). Results are rated acceptable by the USEPA and are presented in Table 7.5.

TABLE 7.3

NIST-SRM Used for Inorganic Analysis

NIST-SRM	Contents
3133	Mercury
3105	Beryllium
3104	Barium
3183	Fluoride
3182	Chloride
3181	Sulfate
2124	Cobalt Copper Iron Nickel
2125	Boron Chromium Manganese Molybdenum
2121	Cadmium Lead Silver Zinc
3101	Aluminum
3102	Antimony
3103	Arsenic
3113	Cobalt
3149	Selenium
3161	Tin
3165	Vanadium

TABLE 7.4

USEPA Quality Check Sample Results, 1989

Compound	Percent Recovery	Percent Quality Limits
Benzene	98.8 (1)	37-151
Bromobenzene	110.3	
Bromochloromethane	90.9	
Bromodichloromethane	98.9	35-155
Bromoform	83.1 (1)	45-169
m-Butylbenzene	111.2 (1)	
sec-Butylbenzene	120.0 (1)	
t-Butylbenzene	98.5	
Carbon Tetrachloride	101.0	70-140
Chlorobenzene	93.7 (2)	37-160
Chloroform	94.6	51-138
p-Cymene	97.0	
m-Dichlorobenzene	76.5	59-156
o-Dichlorobenzene	84.0 (2)	18-190
1,1-Dichloroethane	101.2	59-155
1,2-Dichloroethane	104.2	49-155
cis-1,2-Dichloroethene	153.7 (1)	
Ethyl Benzene	105.8 (1)	37-162
Isopropyl Benzene	108.4 (1)	
Methylene Chloride	118.5	D-221
Tetrachloroethene	91.0 (1)	46-157
Toluene	98.0 (1)	47-150
1,1,1-Trichloroethane	92.2 (1)	52-162
Trichloroethene	92.1	71-157
1,2,4-Trimethyl Benzene	88.0 (1)	
1,3,5-Trimethyl Benzene	100.3 (1)	
m-Xylene	85.7 (1)	
o-Xylene	96.0	
p-Xylene	95.5	

(1) Average of 2 results.

(2) Average of 3 results.

TABLE 7.5

Summary of EPA-DMR-QAP Nonradiological Samples, 1989

Constituent	Average Difference From Reference Value (%)
Chromium	-3
Copper	+3
Iron	+2
Lead	+3
Manganese	+2
Mercury	-0.4
pH	0
Zinc	-0.5
Total Suspended Solids	-10
Oil and Grease	-1
Chemical Oxygen Demand	-2

8. APPENDIX

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