

**ARGONNE NATIONAL LABORATORY-EAST
SITE ENVIRONMENTAL REPORT FOR
CALENDAR YEAR 1988**

by

N. W. Golchert and T. L. Duffy



ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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ABSTRACT

The results of the environmental monitoring program at Argonne National Laboratory (ANL) for 1988 are presented and discussed. To evaluate the effect of ANL operations on the environment, sample collections were made on the site, at the site boundary, and off the ANL site for comparison purposes. Measurements were made for a variety of radionuclides in air, surface water, ground water, soil, grass, bottom sediment, and milk. Samples were also analyzed for a variety of chemical constituents in surface water, ground water, and ANL effluent water. External penetrating radiation doses were also measured. The potential for radiation exposure to off-site population groups is estimated. The results of the program are interpreted in terms of the origin of the radioactive and chemical substances (natural, fallout, ANL, and other) and are compared with applicable environmental quality standards. A United States Department of Energy (DOE) dose calculation methodology, based on recent International Commission on Radiological Protection (ICRP) recommendations, is used in this report. The average annual concentrations and total amounts of radioactive and chemical pollutants released by ANL to the environment were all below appropriate standards.

1. INTRODUCTION

1.1. General

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

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

ANL is a DOE energy research and development laboratory with several principal objectives. It conducts a broad program of research in the basic energy and related sciences (physical, chemical, material, computer, nuclear, biomedical, and environmental) and serves as an important engineering center for the study of nuclear and non-nuclear energy sources. Energy-related research projects conducted during 1988 included: advanced reactor development; safety studies for light water and breeder reactors; development of components and materials for fission and fusion reactors; superconductivity; improvements in the utilization 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, chemistry of actinides in natural waters, characterization and monitoring of energy-related pollutants, and the effect of acid rain on vegetation, soil, and surface water quality. A significant portion of these laboratory studies require the 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; the Argonne Thermal Source Reactor (ATSR), a 10 kW research reactor fueled with enriched uranium; a superconducting heavy ion linear accelerator

(Argonne Tandem Linac Accelerating System, ATLAS); a 22 MeV pulsed electron Linac; a 60-inch cyclotron; several other charged particle accelerators (principally of the Van de Graaff and Dynamitron type); a large fast neutron source (Intense Pulsed Neutron Source, IPNS) in which high-energy protons strike a 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 experiments initiated in 1984 were continued in these facilities in 1988 and have some potential environmental impact: (1) radioactive waste remaining from the proof-of-breeding in light-water reactors project, which involves the dissolution and analysis of irradiated thorium and uranium-233 dioxide fuel elements and (2) recovery of tritium from reactor irradiated ceramic lithium compounds. The shut down 5-MW heavy water enriched uranium research reactor (CP-5) is awaiting decontamination and decommissioning (D&D).

The principal non-nuclear activities at ANL that may produce a measurable impact on the environment include the use of a coal-fired boiler (No. 5), 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 is designed to burn high-sulfur (3.5%) Illinois coal to produce steam for ANL use and is equipped with a slaked lime spray scrubber and bag collector to reduce sulfur dioxide and particulate emissions. In 1988 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. The major potential environmental impact of these materials would be caused by their accidental release due to 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, 43 km (27 mi) southwest of downtown Chicago, and 39 km (24 mi) due west of Lake Michigan. It lies north of the Des Plaines River Valley, south of Interstate Highway 55 and west of Illinois Highway 83. Figures 1.1 and 1.2 are maps of the site and of the surrounding area. The 826-hectare (2,040-acre) area surrounding the site (Waterfall Glen Forest Preserve) was formerly ANL property, but was deeded to the DuPage County Forest Preserve District in 1973 for use as a public recreational area, nature preserve, and demonstration forest.

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

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

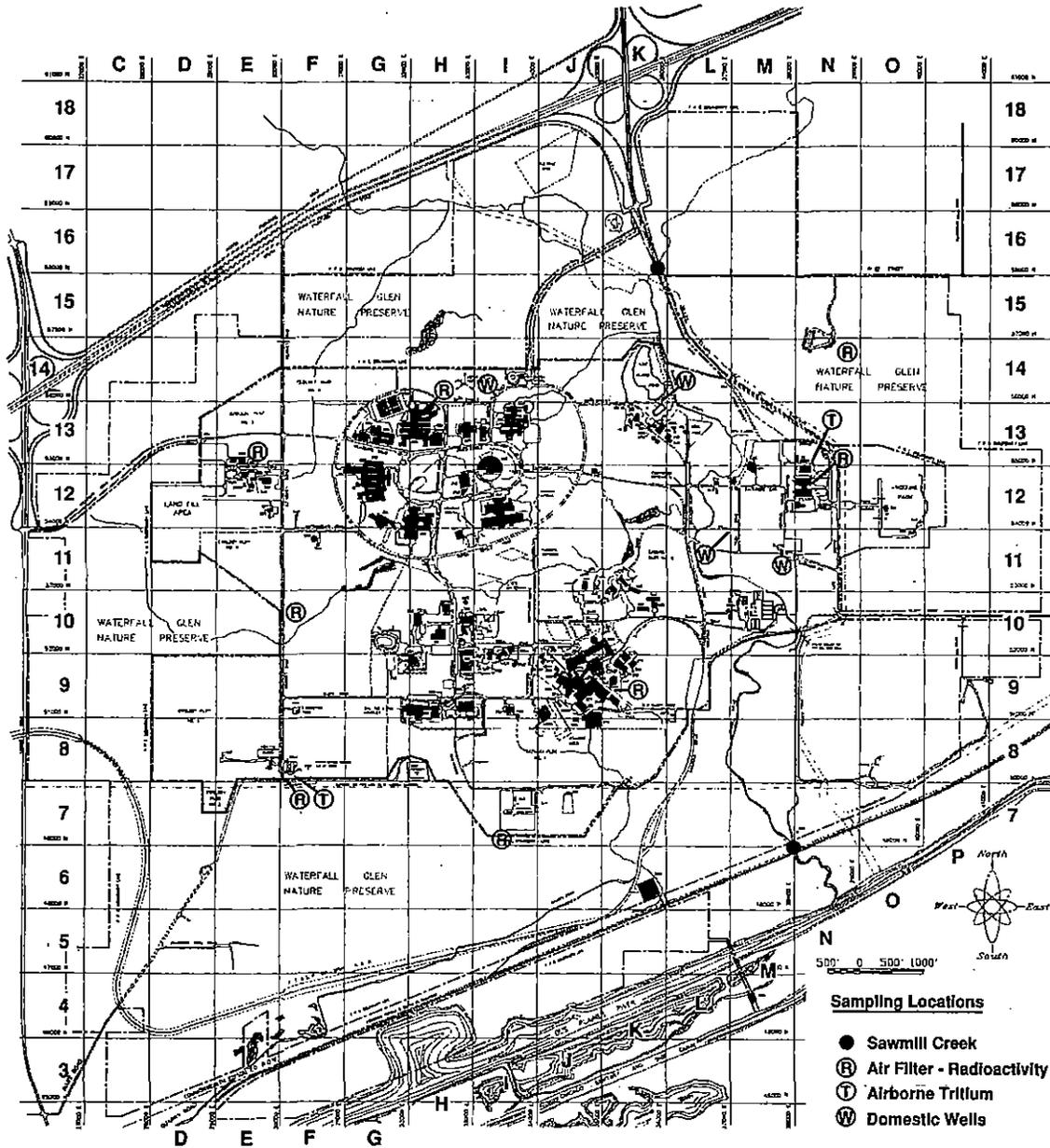


Fig. 1.1 Sampling Locations at Argonne National Laboratory

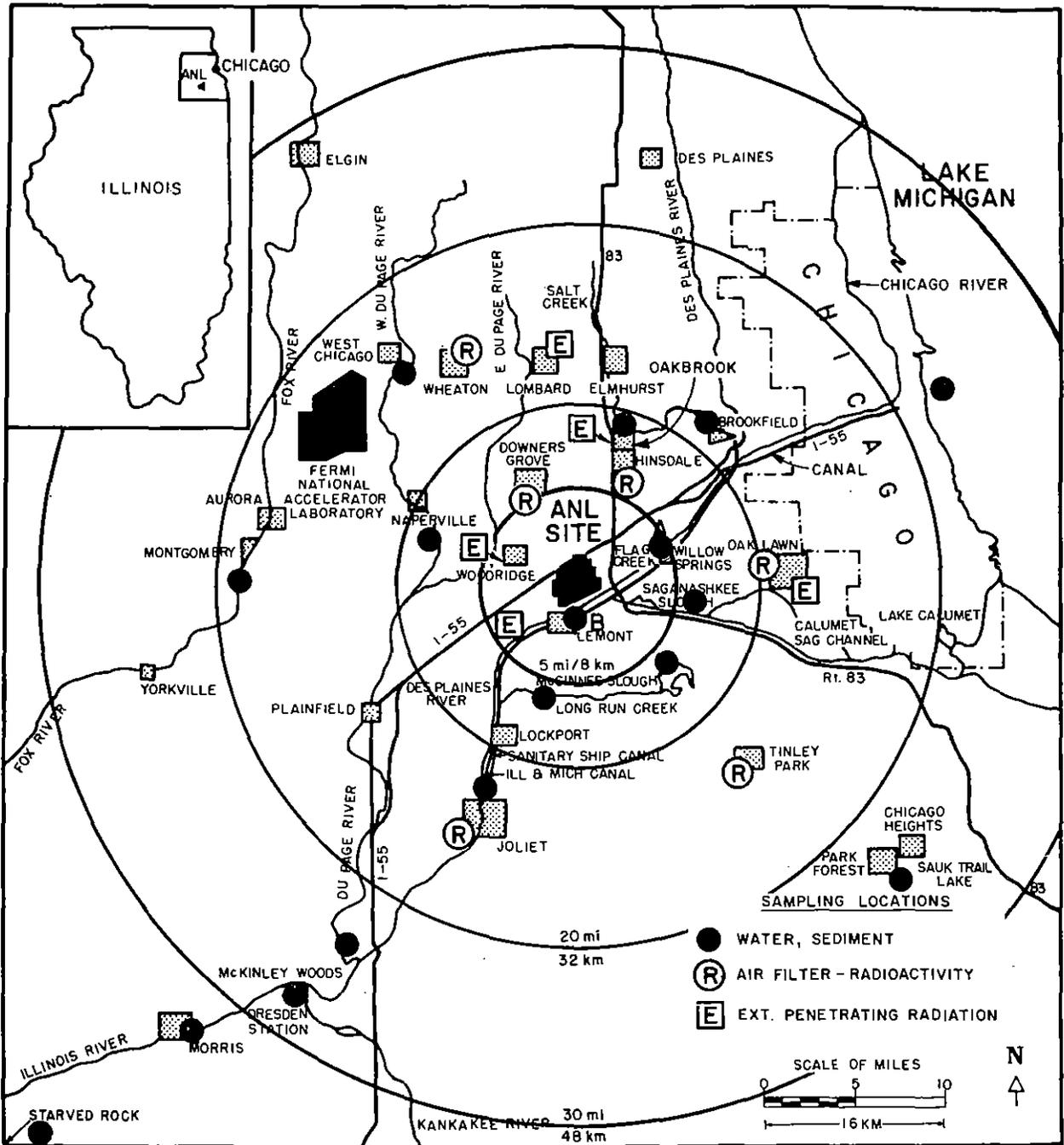


Fig. 1.2 Sampling Locations Near Argonne National Laboratory

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

1.3. Population

The area around ANL has exhibited a large population growth in the past 30 years. Large areas of farmland have been converted into housing. A directional and annular 80-km (50-mi) population distribution for the area, which is used for the population dose calculations later in this report, is shown in Table 1.1. The population distribution, centered on the CP-5 reactor (Location 9G), 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 that of the upper Mississippi Valley, as moderated by Lake Michigan. A summary of the meteorological data collected on the site from 1950 to 1964 is available³ and provides a historical sample of the climate.

The most important meteorological parameters for the purposes of this report are wind direction, wind speed, temperature, and precipitation. The wind data is used to calculate radiation doses from air emissions and in selecting air sampling locations and distances. Temperature and precipitation data are useful in interpreting some of the environmental results. The 1988 meteorological data was obtained from the on-site ANL station. The 1988 average monthly and annual wind roses are shown in Figure 1.3. The wind roses are polar coordinate plots, in which the lengths of the radii represent the percentage frequency of wind speeds in classes of 2.01-6 m/s (4.5-13.4 mph), 6.01-10 m/s (13.4-22.4 mph), and greater than 10.01 m/s (22.4 mph). The number in the center represents the percentage of

TABLE 1.1

Incremental Population Data in the Vicinity of ANL, 1981

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

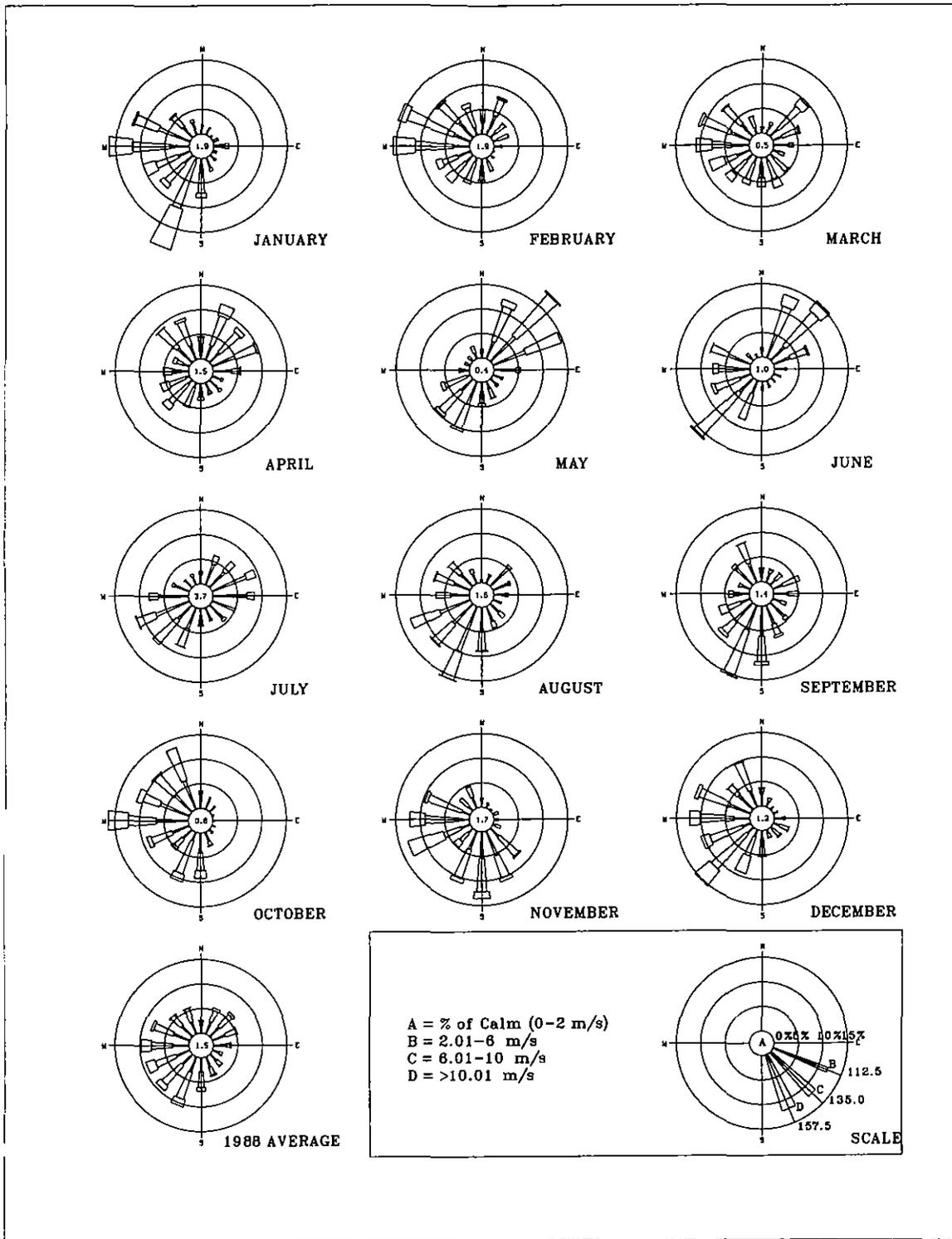


Fig. 1.3 Monthly and Annual Wind Roses at Argonne National Laboratory, 1988

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

A comparison of the monthly wind roses indicates that the winds are variable so that monitoring for airborne releases must be carried out in all directions from the site. For example, the dominant wind direction in May is northeast, while in August it is southwest. The annual average wind rose for 1988 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 1988 are shown in Table 1.2. The monthly precipitation data for 1988 were marked by large differences from the average. For example, April, May, and June were significantly below the average, while October and November were significantly above the average. However, the annual total was almost identical to the long-term average. The temperatures were above the monthly averages during the summer while the rest of the year was near normal.

1.5. Geohydrology

The geology of the ANL area consists of about 30 m (100 ft) of glacial till overlying dolomite bedrock. The bedrock is Niagaran and Alexandrian dolomite from the Silurian age. Maquoketa shale of the Ordovician age, and older dolomites and sandstones of Ordovician and Cambrian age 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 Niagaran and Alexandrian dolomite, which is about 60 m (200 ft) thick in the ANL area, and has a piezometric surface between 15 and 30 m (50 and 100 ft) below the ground surface over much of the site. The lower aquifer is Galesville sandstone, which lies between 150 and 450 m (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 upper and lower aquifers.

TABLE 1.2

ANL Weather Summary, 1988

Month	Amount	Precipitation (cm)		Monthly Average	Temperature (°C)	
		ANL Historical Average ³	Historical [*] Average		ANL Historical Average ³	Historical [*] Average
January	4.78	4.98	4.06	-6.8	-7.1	-5.9
February	3.28	2.90	3.33	-5.2	-5.6	-3.3
March	5.46	6.50	6.58	3.4	3.3	2.2
April	5.28	5.92	9.30	9.0	9.0	9.3
May	3.02	5.08	8.00	16.1	16.5	15.1
June	2.67	5.59	10.36	22.1	21.8	20.3
July	6.95	4.98	9.22	24.9	24.4	22.8
August	8.61	5.77	8.97	24.9	24.3	22.2
September	9.63	2.39	8.51	18.8	18.6	18.2
October	12.83	9.63	5.79	7.8	7.6	11.9
November	16.38	13.74	5.23	5.4	4.9	4.3
December	6.10	6.60	5.33	-2.4	-2.4	-2.4
Total	84.75	74.08	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.

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

1.6. Water and Land Use

The principal stream that drains the site is Sawmill Creek. It carried effluent water continuously from a sewage treatment plant (Marion Brook Treatment Plant) located a few kilometers north of the site until October 27, 1986, when the plant was closed. The residential and commercial development in the area has resulted in the collection and channeling of runoff water into Sawmill Creek. Treated sanitary and laboratory wastewater from ANL are combined and discharged into Sawmill Creek at location 7M in Figure 1.1. This effluent averaged 4.0 megaliters (1.06 million gallons) per day. The combined ANL effluent consisted of 52% laboratory wastewater and 48% sanitary wastewater. The water flow in Sawmill Creek upstream of the wastewater outfall averaged about 17 megaliters (4.4 million gallons) per day during 1988.

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

the Illinois River about 48 km (30 mi) southwest of ANL. The Dresden Nuclear Power Station complex is located at the confluence of the Kankakee, Des Plaines, and Illinois Rivers. This station uses water from the Kankakee River for cooling and discharges the water into the Illinois River. The first place where water is used for drinking is at Alton, on the Mississippi River about 710 km (370 mi) downstream from ANL. There, water is used indirectly to replenish ground water supplies by infiltration. In the vicinity of ANL, only subsurface water (from both shallow and deep aquifers) and Lake Michigan water are used for drinking purposes.

The principal recreational area near ANL is Waterfall Glen Forest Preserve, which surrounds the site as described in Section 1.2 and as shown in Figure 1.1. The area is available for hiking, skiing, and equestrian sports. Sawmill Creek flows south through the eastern portion of the preserve on its way to the Des Plaines River. Several large forest preserves of the Cook County Forest Preserve District are located east and southeast of ANL and the Des Plaines River. The preserves include the two sloughs shown in Figure 1.2, McGinnis and Saganashkee, as well as other smaller lakes. These areas are used for picnicking, boating, fishing, and hiking. A small park located in the eastern portion of the ANL site (Location 12-0 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 environmental data so as to characterize site environmental management performance, confirm compliance with environmental standards and requirements, and highlight significant programs and efforts. This is one in a series of annual reports prepared to provide DOE, environmental agencies, and the public with information on the level of radioactive and chemical pollutants in the environment and on the amounts of such substances added to the environment as a result of ANL operations. Included in this report are the results of measurements obtained in 1988 for a number of radionuclides in air, surface water, groundwater, soil, grass, bottom sediment, and milk; for a variety of chemical constituents in surface and subsurface water; and for the external penetrating radiation. The previous report in this series is ANL-88-13.⁴

The major airborne radionuclides released from ANL were hydrogen-3, carbon-11, nitrogen-13, oxygen-15, argon-41, krypton-85, and radon-220 (plus daughters). The maximum whole body effective dose equivalent from these nuclides at the site boundary was 1.5 mrem/y in the north direction, as calculated from an atmospheric dispersion model. The calculated dose to the closest full-time resident, who is located about 0.5 km (0.3 mi) north of the site boundary, was 0.66 mrem/y, which is 0.66% of the DOE 100 mrem/y limit for prolonged public exposures. The limit set by the United States Environmental Protection Agency (EPA) in the Clean Air Act is 25 mrem/y for atmospheric releases. The dose related to these releases constitute an insignificant addition to the dose received from the natural external background radiation, which is about 93 mrem/y, based on the thermoluminescent dosimetry (TLD) measurements. The total 80-km population dose from these radionuclides was 25 man-rem for 1988, compared to approximately 7.3×10^5 man-rem from the natural background radiation. The risk due to a given concentration of radionuclide or quantity of external radiation is assessed in this report by calculating the corresponding effective dose equivalent and comparing it to the DOE recommended dose limits discussed in Sections 4.1 and 4.7, and described in References 5 and 6.

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

ANL wastewater is discharged into Sawmill Creek, and this creek was sampled above and below the site to evaluate the effect of ANL operations on its radioactive content. If the creek water had been used as a potable water supply, the nuclides (for which analyses were made) added to the creek in the wastewater, and the ingestion doses from their net average creek concentrations were hydrogen-3, 0.011 mrem/y; strontium-90, 0.036 mrem/y; cesium-137, 0.036 mrem/y; neptunium-237, 0.0008 mrem/y; plutonium-239,240, 0.004 mrem/y; and americium-241, 0.026 mrem/y. The concentrations and corresponding doses are all very low compared to the 100 mrem/y dose limit.

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

Plutonium concentrations in soil showed the same general range at the site perimeter and off the site as in the past years. The average plutonium-239,240 content of the top 5 cm (2 in) of soil was 0.83 nCi/m² at the site perimeter and 0.55 nCi/m² off the site. The corresponding plutonium-238 averages were 0.07 nCi/m² and 0.04 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 from the same locations. The results were within the range reported by other laboratories for fallout from test detonations, and the plutonium found in soil and grass is attributed to this source. The plutonium content of samples from beds of off-site streams and ponds ranged from 1 fCi/g to 48 fCi/g of plutonium-239,240, a range found in previous years to be normal for fallout plutonium in such materials. However, concentrations twice the ambient level were found in the sediment

just below the ANL wastewater outfall as a result of their presence in ANL wastewater.

Milk from a dairy farm located 10 km (6 mi) south of ANL was collected monthly and analyzed for hydrogen-3 and strontium-90. Hydrogen-3 concentrations averaged < 100 pCi/L. The strontium-90 concentration of 2.6 pCi/L was similar to the 1986 and 1987 results. These radionuclides resulted from fallout from nuclear test detonations, and are not related to ANL operations based on measured air concentrations of hydrogen-3 and strontium-90 at the site perimeter.

Measurements of penetrating radiation were made at several locations at the site boundary and off the site. The off-site results averaged 93 ± 5 mrem/y, which is in the average background range for the area. At two site boundary locations, above-background readings were recorded that were attributable to ANL operations. At the south fence (grid 7I in Figure 1.1), the dose rate averaged about 51 mrem/y above background as a result of radiation from an on-site temporary storage facility for radioactive waste. About 300 m (0.2 mi) south of the fence, the measured dose rate decreased to 94 ± 3 mrem/y, which is within the background range. Along the north side of the site, the net dose at the fence at location 14I was 27 mrem/y due to radiation from cobalt-60 sources in Building 202. Since there are no residences at these locations, there are no individuals receiving these measured doses. The calculated outdoor dose rate from these sources to the residents closest to the south boundary, about 1.6 km (1 mi) from the fence line, was about 0.01 mrem/y, which is 0.01% of the dose limit. Similarly, the dose rate to the residents closest to the north boundary, about 0.75 km (0.5 mi) from the fence, was about 0.14 mrem/y, which is 0.14% of the dose limit.

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

Results obtained at the NPDES sampling locations were generally within permit limits with the exception of chloride and total dissolved solids at location 001 and iron and pH at internal location 001C (see Figure 5.1). The locations in the figure are without the leading zeroes. The chloride and total dissolved solids are generated by sewerage of the spent regenerant solution (sodium chloride) resulting from 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 is an internal sampling point which contains water from the coal pile storage area prior to treatment which effectively neutralizes the pH and removes the iron from the wastewater before it is discharged.

Two effluent samples from the Waste Water Treatment Plant (Outfall 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 values in Sawmill Creek for dissolved oxygen and most chemical constituents were within the State of Illinois Water Quality Standards (see Table 5.5). The average levels of copper and iron were 203% and 93% of the state stream standards, and individual values exceeded the standards 69% and 20% of the time, respectively (see Table 5.6). The levels of iron in the upstream as well as the downstream samples increase during periods of rain due to soil carried into the stream by storm runoff. The levels in the ANL effluent are not sufficient to materially effect background levels and thus, the relatively high values were probably due to natural causes. The effluent levels of copper are only 4% of the state standard of 1 mg/L but these levels are sufficient to have a significant effect on the stream standard of 20 $\mu\text{g/L}$ due to the low flow in Sawmill Creek. Drought conditions in the summer exacerbated this situation. 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 monitoring wells at the sanitary landfill on a quarterly basis. The samples were characterized by elevated levels of iron and manganese and by decreasing water levels. These conditions are thought to be drought related. Arsenic was detected in Wells 9 and 6 and silver was also detected in Well 9 (see Tables 6.25 and 6.28). No significant level of volatile organic compounds (VOC) was 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. Results have shown that organic contamination exists in the area. The major organic contaminants are perchloroethene, trichloroethene, 1,1,1-trichloroethane, carbon tetrachloride, and chloroform. Elevated levels of lead, hydrogen-3, strontium-90, and cesium-137 are present in several of the wells. A characterization program has begun to assess the extent of the problem.

The average concentrations and total amounts of radioactive and chemical pollutants released by ANL are believed to have no significant environmental impact. Any individual discharges from ANL that exceeded acceptable standards were temporary, and when they did occur, investigations were undertaken to identify the source and reduce the discharge.

3. COMPLIANCE SUMMARY AND ENVIRONMENTAL PROGRAM INFORMATION

It is the policy of ANL to conduct its operations so as to comply with all applicable environmental laws and regulations. The following is a review of those environmental requirements that are relevant to the functions at ANL. The applicable regulations are identified in DOE Order 5400.1.¹

3.1. Clean Air Act (CAA)

The Clean Air Act (CAA) is a broad federal statute, which among other things, specifies ambient air quality standards, sets emission limits for specific air pollutants from certain sources, and determines limits and operating criteria for a number of hazardous air pollutants. In a specific state the program is implemented through the preparation of a State Implementation Plan (SIP), which determines how that state will assure compliance with the air quality standards. Though ANL is not a large source of air pollutants, it does have several operations that are subject to provisions of the CAA.

3.1.1. National Emission Standards for Hazardous Air Pollutants (NESHAP)

The National Emission Standards for Hazardous Air Pollutants (NESHAP) are a body of federal regulations, which set forth emission limits, as well as a number of other requirements, such as monitoring, recordkeeping, 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 set forth 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-site contain large amounts of asbestos on pipes, tanks, building components, and other equipment, as do most buildings constructed in the same time period. When asbestos-containing material is encountered in a renovation or demolition project, it is completely removed and disposed of

in accordance to the regulations. This removal is done in strict accordance with the NESHAP regulations as well as with the much stricter Occupational Safety and Health Administration's (OSHA) worker protection regulations. Air monitoring is conducted in the vicinity of such work to ensure that adequate precautions have been taken. 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.

The asbestos standards require that the Illinois Environmental Protection Agency (IEPA) be notified before large asbestos removal projects [over 80 m (260 ft) of pipe insulation or 15 m² (160 ft²) of other material] are begun. In 1988, ANL, through DOE, made three notifications of such projects. In addition, numerous small removal projects were carried out. In all, over 133 m³ (4,700 ft³) of asbestos or asbestos-contaminated material such as air filters and protective clothing were disposed of during 1988.

The NESHAP regulations for radionuclide emissions from DOE facilities (40 CFR 61, Subpart H) sets forth the emissions standard for release of radionuclides to the air, as well as for monitoring reporting and record-keeping requirements. Section 4.7.1. contains a more detailed discussion of this standard.

3.1.2. Conventional Air Pollutants

The ANL site contains several sources of conventional air pollutants such as the steam plant, the gasoline and methanol fuel dispensing facilities, and a facility for combustion and power generation research (FEUL facility). Each of these sources has been granted an operating permit by the IEPA as discussed in Section 3.9.1. During 1988, operating permit applications were prepared for the alkali metal reaction booths in Buildings 206 and 308. It is anticipated that permits will be granted in early 1989. These two sources, as well as the FEUL facility, operate infrequently and are minor sources of emissions. The steam plant and fuel dispensing

facilities operate continuously and represent the only significant sources of conventional air pollutants.

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 SO₂ per million BTU averaged over a one-hour period). During 1988, there were 163 SO₂ limit excursions and 184 opacity limit excursions reported. The length of each excursion incident varied from a few minutes to several hours. The vast majority of excursions were of short duration and were due to operations (such as clearing ash deposits off of the boiler steam tubes) or process control problems (such as plugging of piping and poor control of scrubber flow rates).

The fuel dispensing facilities are used to service vehicles associated with ANL only and 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 (CWA)

The Clean Water Act (CWA), established in 1977 as a major amendment to the Federal Water Pollution Control Act of 1972 and substantially modified by the Water Quality Act of 1987, provides a legal framework intended to support 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, which have developed a program substantially the same as and at least as stringent as the federal NPDES program.

The 1987 amendments to the Clean Water Act, known as the Water Quality Act, has significantly changed the thrust of future enforcement activities.

In the future, much greater emphasis will be placed on monitoring and control of toxic constituents in wastewater, the permitting of outfalls composed entirely of stormwater, and imposing of regulations governing sewage sludge disposal. ANL is currently evaluating the impact of these changes in the NPDES requirements on laboratory operations. Funding has been requested for several wastewater treatment system upgrades necessary to comply with the changing requirements.

3.2.1. Liquid Effluent Discharge Permit

The primary tool for enforcing the requirements of the NPDES program is through the NPDES permitting process. A permit listing each wastewater discharge point (outfall) must be included in an NPDES permit which sets specific limits on pollutants known to be present and defines a number of conditions with which that outfall must comply, including self-monitoring, sampling, analysis, reporting, and recordkeeping requirements. ANL wastewater generation activities are covered by NPDES permit IL 00334592 (DOE is the legal permit holder for all ANL environmental permits). This permit expires on March 1, 1989. An extension was granted by the IEPA on September 20, 1988, after considerable discussions. A renewal application was submitted to the IEPA by DOE on October 5, 1988.

The current permit authorizes the discharge of wastewater from 13 separate outfalls and internal monitoring points and specifies limits and monitoring requirements. The wastewater is generated by a number of activities and is composed of treated sanitary wastewater, laboratory wastewater (laboratory sinks and floor drains from most buildings), and stormwater (containing cooling water and cooling tower blowdown). Table 3.1 describes each of these outfalls and the locations are shown on Figure 5.1. Table 3.2 contains a list of pollutants regulated at each outfall and effluent limits for each pollutant. Due to recent changes in the operation of ANL, several of these outfalls no longer actively discharge wastewater. They either do not discharge at all (pipe permanently sealed) or they discharge only under highly unusual conditions such as very heavy precipitation (emergency overflows). The recently submitted permit renewal application

TABLE 3.1

Description of NPDES Outfalls

Outfall Number	Description	Status	Average Flow (Million Gallons/Day)
001	Combined discharge of 001A, 001B, and 001C - 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
001C	Coal pile runoff, boiler blow-down and water treatment plant filter backwash-pumped to sanitary sewer	Active - internal sampling point	0.04-0.06
002	Same as 001C, previous direct outfall to stream	Inactive	0
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

TABLE 3.2

NPDES Effluent Quality Summary, 1988

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R <u>Measured Permit</u>
			30 Day Average	Daily Max.		
001A	50	Flow	None		0	-
		BOD	30	60	0	-
		TSS	30	60	0	-
001B	50	Flow	None		0	-
		Chemical Oxygen Demand	-	-	0	-
		TSS	15	30	0	-
		Mercury	0.003	0.006	0	-
001C	18	Iron	2	4	12	1.5-220
		Lead	0.2	0.4	0	-
		Zinc	1	2	2	1.4-2.5
		Manganese	1	2	2	1.2-2.5
		Chromium (Total)	1	2	0	-
		Copper	0.5	1	0	-
		Oil and Grease	15	30	0	-
		TSS	15	30	8	1.1-7.8
		pH		6-9	4	2.5, 2.7, 9.2, and 11.21
001	50	pH	6-9		0	-
		Fecal Coliform	-	<u>400 organisms</u> 100 mL	2	1.7-4.3
		BOD	30	60	0	-
		TSS	30	60	0	-
002	6	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	0	-
		Temperature	< 2.8°C Rise		0	-

TABLE 3.2 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R <u>Measured Permit</u>
			30 Day Average	Daily Max.		
003	12	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	4	1.2-2.7
		Temperature	< 2.8°C Rise		0	-
004	12	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	4	1.1-2.0
		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	0	-
		Zinc	1.0	2.0	0	-
007	12	Flow	None		0	-
		pH	6-9		0	-
		Temperature	< 2.8°C Rise		0	-
008	12	Flow	None		0	-
		pH	6-9		0	-
009	1	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	1	2.0

*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).

attempts to modify the permit requirements to reflect the change in status of these outfalls.

3.2.2. Effluent Limitations

Along with numeric effluent limits, the permit also contains a number of conditions which all outfalls must satisfy, including adherence to maximum temperature limitations in the receiving stream and compliance with regulations for discharge of radioactive wastewater administered by the U. S. Nuclear Regulatory Commission (NRC) (10 CFR 0.735-1). One additional permit condition is the requirement to comply with water quality standards for total dissolved solids, sulfates, and chlorides. Biweekly sampling of Sawmill Creek is also mandated by this permit condition. Since Sawmill Creek typically has a very low flow, often going completely dry during the summer, the stream does not provide much dilution of the wastewater, so the ANL outfalls themselves often must meet the water quality criteria to insure compliance with this condition.

In addition to specific permit conditions, ANL discharges are required to comply with general effluent limits developed by the IEPA (35 Ill. Adm. Code, Chapter 1, Subtitle C, Part 304), and these discharges must be of sufficient quality to insure that Sawmill Creek complies with the IEPA's General Use Water Quality Standards (35 Ill. Adm. 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 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 on 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.

Table 3.2 contains a summary of the analytical data generated by NPDES monitoring activities. This data shows that, with several notable exceptions, the discharge limitations were consistently met (over 95% of the results were in compliance with the limits). Outfalls 001A, 001B, 002, 005, 006, 007, and 008 showed no violations throughout 1988. Outfalls 003 and 004 had several violations of total suspended solids (TSS) limitations, believed to be caused by heavy storm runoff carrying clay and silt, which were washed from excavations and dirt piles at construction sites, into the storm drain system that flows out of these particular outfalls.

Outfall 001 recorded two instances of excess fecal coliform count. In one case, the chlorinator was inoperative for about one hour and in the other case, the elevated fecal coliform count was believed due to an upstream source. Steps have been taken to eliminate the former in the future.

Outfall 009, which is the emergency overflow from the water treatment plant lime pond, experienced one instance of outflow in 1988 due to unusually heavy rain. A sample of this wastewater exhibited a high TSS due to resuspension of particulate present in the pond. To prevent TSS violations in the future, ANL is initiating a seven-year project to remove the spent lime by applying it to farmland. Until this work is complete, occasional overflows of this pond may continue.

The other instances of noncompliance noted in Table 3.2 are associated with Outfall 001C, which is an internal sampling point containing untreated storm water runoff from the boiler house coal pile area. This wastewater tends to have a highly variable pH and typically contains significant concentrations of iron, zinc, and manganese as well as fine coal particles and insoluble iron solids. This material is not discharged directly into the stream but rather is pumped to the sanitary sewer system, where it is treated in the wastewater treatment plant. This treatment effectively neutralizes the pH and removes much of the iron, zinc, manganese, and suspended solids. Therefore, it is felt that this wastewater stream, after treatment, has no significant impact on stream quality. The noncompliance noted is primarily the result of the selection of the location for sampling this stream, since the current location does not take the full treatment

process into account. The permit application submitted in October 1988 attempts to correct this problem by moving the sampling point for constituents in this wastewater to Outfall 001A, the sanitary wastewater treatment plant outfall. The IEPA has acknowledged the problem and has indicated that it will consider making this change. In addition to this permit change, ANL is currently initiating final design and will soon start construction of a new wastewater treatment facility specifically designed to treat this wastewater stream, as well as several other streams generated in the same area, for direct discharge to Sawmill Creek.

3.2.4. NPDES Inspections and Audits

In early 1988, the USEPA and IEPA conducted separate compliance Evaluation Inspections of the NPDES program and related facilities. No major deficiencies were noted. Minor problems with certain of the laboratory QA/QC documents were noted. These problems were quickly rectified.

As will be discussed in Section 3.9.2, DOE conducted its annual environmental appraisal in July 1988. This appraisal identified no wastewater-related deficiencies; however, it did note that a water-filled excavation known as the A²R² site (construction site of a proposed research reactor that was never built) was being filled with rubble and construction debris, in violation of CWA, Section 404. This section requires that a "Dredge and Fill" permit be obtained from the Army Corps of Engineers before "waters of the State" are filled in. No such permit was obtained before initiating filling of this excavation. The filling activities were immediately halted and a "Dredge and Fill" permit was requested and received November 30, 1988. In addition, the appropriate NEPA documents were prepared and reviewed. Filling operations will resume in 1989 and be completed by the summer.

3.2.5. Spill Prevention Control and Countermeasures Plan (SPCC)

ANL has a SPCC plan in place to satisfy the requirements of the Clean Water Act (40 CFR 112), TSCA (40 CFR 761), and RCRA (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 or recordkeeping requirements imposed by the various regulations. Effective use of this plan is assured by regular training, including both classroom instruction and field exercises. This plan was revised and updated in February 1988.

The ANL site has few hazardous chemicals present in amounts large enough to, if spilled, cause concern beyond the immediate spill area. Gasoline, fuel oil, chlorine, sulfuric acid, and PCB-containing oils are the only hazardous chemicals subject to spills which are present in large amounts. 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 and will quickly be cleaned up. In 1988 there were no significant spills requiring implementation of the SPCC plan.

3.3. Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA) was enacted in 1976 and implementing regulations were promulgated in May of 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. This act also placed increased emphasis on waste minimization activities and provided for a mechanism to force cleanup of leaking solid waste management units. In September 1988, the EPA published final regulations governing management of underground storage tanks containing hazardous materials or petroleum products. The IEPA has received authorization to administer the base RCRA program in Illinois and expects to receive authorization to administer the HSWA amendments sometime in 1989.

3.3.1. Hazardous Waste Treatment and Disposal

Due to the nature of the research activities conducted at ANL, a large number of waste chemicals are generated (but in relatively small quantities), many classified as hazardous waste under RCRA. Most such chemicals are collected by Waste Management Operations (WMO) from individual generators and shipped off-site for disposal at an approved hazardous waste disposal facility. During 1988, 9,654 gallons of hazardous waste were shipped off-site for disposal. Small quantities of certain hazardous chemicals are treated on-site in one of several permitted treatment units. These units render the waste nonhazardous. To assist in management of hazardous waste prior to 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 is a listing of all on-site RCRA permitted units.

3.3.2. Permit Status

ANL was granted interim status under RCRA by submitting a Part A permit application during 1980. In August 1985 and December 1985, the Part B permit application for final permit status was filed with the IEPA. The revised permit application was submitted in December 1988 in response to IEPA comments. As of December 1988, no action had been taken on this application. The IEPA has indicated that due to limited manpower and the large number of Part B permit applications they must process, it may be several more years before the final permit will be issued. In the meantime, ANL will continue to utilize the interim status standards found in 40 CFR 265.

3.3.3. Facility Modifications

During August 1988, Building 325A, which was listed in the Parts A and B permit applications as a potential hazardous waste storage facility, was demolished and discarded. This building was never used for such storage and was demolished due to excessive deterioration of the structure. Formal

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.
Shock Sensitive Area	319 Area	Proposed replacement for 317 Area shock treatment facility.
Container Storage (Never Used)	Building 325A	Demolished building, formerly listed as a potential storage site.
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.

*Part B permit application is being modified to include these facilities.

closure procedures were carried out in accordance with 40 CFR 265, Subpart G.

3.3.4. Mixed Waste Handling

On September 23, 1988, the EPA published a clarification note concerning the permitting and operating requirements for interim status facilities handling mixed waste (radioactive and hazardous). This agreement states that such wastes are to be regulated 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. ANL generates several mixed wastes, primarily acids or solvents contaminated with radionuclides, which are stored in Buildings 329 and 306 pending identification of a final disposal site. The permit application will be modified in early 1989 to include 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 four treatment units at ANL; the alkali metal reaction booths in Buildings 206 and 308, the shock treatment units (shoot-and-burn pile) in the 317 Area, and the proposed unit in the 319 Area. During 1989, the Part B permit application will also be modified to include the required information for these units. The 317 Area shock treatment unit is scheduled to undergo formal closure sometime in 1989. The 319 Area shock treatment unit has not yet been built, but was included in the permit in case such a facility is needed in the future.

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 site currently contains 46 existing underground storage tanks and nine previously removed tanks. 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 as well. The compliance plan sets out a two-phase program for removal of unused underground tanks, relocation of underground tanks to above-ground locations (where this is possible), and upgrading of those underground tanks that must remain underground for safety considerations in order to satisfy the requirements of the new regulations. Work on this plan will begin in mid-1989 with completion of the entire program by September 1992.

3.3.7. Corrective Action for Solid Waste Management Units

As mentioned previously, the HSWA amendments added language to RCRA (40 CFR 264.101) which requires that any Part B permit issued must include provisions for corrective actions for all releases of hazardous materials from any solid waste management unit 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. Currently, ANL is engaged in several detailed characterization studies of these units to determine if hazardous material has been released. This data will be made available to the IEPA so that a decision regarding corrective action requirements can be made.

3.4. National Environmental Policy Act (NEPA)

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 government-sponsored projects would have on the environment, including historic or cultural resources. To assure compliance with this policy, NEPA requires that projects with potentially significant impacts be carefully reviewed through the generation of a number of public documents, such as an Environmental Assessment or Environmental Impact Statement. 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 given opportunity to comment on the project.

To insure that all projects under consideration at ANL are reviewed to determine if they will have any significant environmental impact, ANL recently instituted an Environmental Planning and Review Program. This program subjects each proposed project to a careful consideration of all potential impacts on air (dust, gaseous effluents), water (liquid effluents, wetland destruction), and soil (solid waste generation, construction activity), as well as on critical wildlife habitats, historic and cultural resources, radiation emission, noise, aesthetics, and public relations. 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 spelled out in DOE Order 5440.1B.

During 1988 the only project identified as a having potentially significant environmental impact was the proposed construction of the Advanced Photon Source (APS) facility. 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 were documented through the publication of an Environmental Assessment, which was submitted to DOE requesting a Finding Of No Significant Impact (FONSI). The FONSI represents an official declaration that this facility should have no significant adverse impacts on the environment and clears the way for final design and construction of the facility, once funding for the project is approved.

3.5. Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act (SDWA) of 1974 established a program to insure 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. It 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 which supply raw water to the water treatment plant. The treatment plant removes iron and softens the water before pumping it to the site-wide distribution system. This system is classified by the SDWA as a non-transient, non-community water supply, and as such is subject to most 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, and secondary water quality standards.

3.5.2. Monitoring Requirements

The primary drinking water standards set forth certain monitoring and analytical requirements. ANL samples each of the four wells and the treated water four times per year. The water has consistently been found to be 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 (FIFRA)

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) establishes a program for registration of pesticides, regulates transportation and disposal of pesticides, and determines standards for their use. Within ANL, all applications of pesticides are done 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 insure that it is used and any residue is disposed of properly. ANL, through DOE, will notify the EPA before such an application is begun.

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

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 EPA collects data pertinent to sites subject to CERCLA action through generation of a Preliminary Assessment (PA) report followed up by a Site Investigation (SI). Based on this data, the sites are ranked according to their potential to cause human health 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

CERCLA has historically approached federal facilities in a manner somewhat different from non-federal facilities, with federal agencies being permitted to establish their own independent CERCLA program subject to EPA oversight. DOE's CERCLA program is contained in DOE Order 5480.14. Under the provisions of this Order, preliminary assessment (PA) reports were submitted to DOE for 12 inactive sites at ANL in July 1986. Due to changes in the CERCLA program, brought about by the Superfund Amendments and Reauthorization Act (SARA) of 1986, the EPA is required to publish a comprehensive inventory of Federal Facility Sites known as the Federal Agency Hazardous Waste Compliance Docket. In support of this effort, the EPA required submittal of PA reports for all sites at ANL. These reports were submitted in April of 1988. A list of the sites included in these reports appears in Table 3.4. None of these sites have been identified as potential NPL sites due to their relatively small potential impact on the surrounding environment. Clean up of sites that may warrant some type of remedial action 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 when issued, rather than under CERCLA program.

TABLE 3.4

List of Inactive Disposal Sites Described
in Preliminary Assessment Reports

Site Description	DOE Reports		EPA Reports
	Phase I	Phase II	
French Drain in 800 Area Sanitary Landfill	X	X	X
French Drain and Landfill in 319 Area	X	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	X
Mixed Waste Storage Vaults, 317 Area	X		X
Shock Treatment Facility, 317 Area	X		X
Wastewater Holding Basin, Sewage Treatment Plant	X		X
Liquid Waste Treatment Facility, Building 34	X		X
Reactive Waste Disposal, Underwriters Pond	X		X
Decommissioned Reactor CP-5, Building 330	X		X
Gasoline Spill, Gasoline Station	X		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 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 Material Safety Data Sheets (MSDS), an inventory of hazardous substances stored on-site, and completed data sheets (Tier I form) for each hazardous substance stored in quantities above a certain threshold planning quantity (typically 10,000 lbs; lower for certain compounds) to applicable emergency response agencies. In November of 1987, an inventory and MSDS forms for nine chemicals were submitted to the local emergency planning committee, and in March 1988, Tier I reports providing additional information on these chemicals were submitted. In December, this list was updated to include sodium carbonate. Table 3.5 contains a list of hazardous compounds reported under SARA Title III.

Section 304 of SARA Title III contains provisions requiring notification of Local Emergency Planning Committees (LEPC) and State emergency planning agencies of accidental or unplanned releases of certain hazardous substances to the environment. To assure compliance with such notification provisions, the Spill Prevention Control and Countermeasure (SPCC) plan for ANL was modified to include SARA Title III requirements.

3.8. Toxic Substances Control Act (TSCA)

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 compound in general use at ANL are polychlorinated biphenyl (PCB) capacitors and transformer oil containing PCBs. Regulations governing PCB use and disposal are found in 40 CFR 761. These regulations provide detailed requirements for use and disposal of PCB-containing mixtures (over 500 ppm PCB) and PCB-contaminated

TABLE 3.5

Compounds Reported Under SARA Title III

Compound	Hazard Class			
	Fire	Sudden Release of Pressure	Reactive	Acute Health Hazard
Diesel Fuel	X			
Gasoline	X			
Methanol/ Gasoline	X			
Sodium	X		X	
Chlorine		X		X
Chlorofluoro- carbon 11		X		
Lime				X
Sodium Carbonate				X
Sulfuric Acid				X

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

3.8.1. PCBs in Use at ANL

The vast majority of all PCBs at ANL are contained in a large number of transformers, capacitors, and switches throughout the site. In 1987, ANL began a program of removing and disposing of all PCB-containing electrical equipment, starting with the high-risk indoor transformers. To date, 16 indoor units have been removed and transported off-site for proper disposal. During 1989 and 1990, the large outdoor units 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 done in compliance with applicable TSCA regulations.

There are currently approximately 144 small, outdoor, pole mounted transformers that may or may not contain PCBs. During 1988 a project to sample each of these transformers and analyze the oil for PCB content was initiated. Those transformers found to contain over 50 parts per million (ppm) PCBs will be scheduled for reclassification or removal and disposal as soon as funds are available.

3.9. Environmental Permits, Assessments, and Audits

3.9.1. Permits

Table 3.6 contains a list of all environmental permits currently in effect 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 Section 5. As mentioned in Section 3.1, several air pollution permit applications have been submitted to the IEPA. Approval is anticipated in early 1989.

TABLE 3.6

IEPA Environmental Permits in Effect at ANL

Permit Type	Facility	Permit/ Application No.	Expires
Operating	Fossil Energy Users Laboratory (FEUL), Building 145	C8012024 ID 043802AA	6/23/90
Operating	Steam Plant, Building 108	79090047 ID 043802AA	8/1/90
Operating	Gas Dispensing Facility, Building 827	HG490	5/30/90
Joint Construction and Operating	Methanol Storage	86020043	2/7/91
NPDES	Laboratory Wastewater Effluents	IL0034592	3/1/89
Operating	Landfill, 800 Area	1981-29-OP Site Code - 0438020002	Special Conditions
RCRA Hazardous Waste Storage, Generation, and Treatment	Facilities 306, 317, 325A, 325C, and 329	IL3890008946	Interim Status

3.9.2. Assessments and Audits

In November 1988, DOE issued a draft preliminary report on the Environmental Survey conducted in June 1987. This survey was a broad DOE-wide audit of each major DOE facility which was designed to provide baseline information regarding existing or potential environmental problems and liabilities. It did not focus primarily on regulatory compliance issues but on identifying conditions that could result in environmental damage. The findings of this survey were classified as Category I -- immediate threat to human life, Category II -- multiple or continual exceedances of health-based standards, Category III -- conditions that could potentially pose a hazard to human health, and Category IV -- improper administrative or management practices. Table 3.7 contains a numeration of findings in each of these categories for the major environmental elements audited.

The findings described in Table 3.7 represent a wide array of potential environmental problems caused primarily by inadequate operational control over 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 constitute an imminent threat to human health or the environment. By late 1988, all findings were addressed and an action plan was developed and submitted to DOE early in 1989. Many of the noted deficiencies were resolved quickly, while others will require long-term environmental monitoring and possible remediation.

During July 1988, 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 environmental impact reviews (NEPA compliance), internal auditing, solid waste disposal, spill response, and air pollution permit compliance. ANL has implemented the recommendations made by this assessment, resulting in significant improvements in many areas.

TABLE 3.7

Summary of Findings of the DOE Environmental Survey

Survey Element	Number of Findings			
	Category I	Category II	Category III	Category IV
Air	None	None	3	8
Soil	None	None	None	None
Surface Water	None	None	8	2
Groundwater	None	None	2	1
Waste Management	None	2	5	3
Toxic and Chemical Materials	None	2	2	6
Radiation	None	None	None	1
Quality Assurance	None	None	None	4
Inactive Waste Sites and Releases	None	None	12	3

Note: This listing does not include findings at Site A/Plot M or the U. S. Department of Defense's old Nike missile site, which are not the responsibility of ANL.

4. ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

4.1. Description of Monitoring Program

The radioactivity of the environment was determined by measuring the concentrations of radioactive nuclides in naturally occurring materials and by measuring the external penetrating radiation dose. Sample collections and measurements were made at the site perimeter and off the site principally for comparison purposes. Some on-site results are also reported when they are useful in interpreting perimeter and off-site results. Since radioactivity is usually transported by air and water, the sample collection program has concentrated on these media. In addition, soil, plants, food-stuffs, and materials from the beds of lakes and streams were also collected and analyzed. The program followed the guidance provided in the DOE Environmental⁷ and Effluent⁸ Surveillance Guides. About 1,650 samples were collected and approximately 4,130 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 (mrem) per year and population dose in man-rem. Other units are defined in the text.

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

TABLE 4.1

Detection Limits		
Nuclide or Activity	Air (fCi/m ³)	Water (pCi/L)
Americium-241	-	0.001
Beryllium-7	5	-
Californium-249	-	0.001
Californium-252	-	0.001
Cesium-137	0.1	1
Curium-242	-	0.001
Curium-244	-	0.001
Hydrogen-3	100	100
Neptunium-237	-	0.001
Plutonium-238	0.0003	0.001
Plutonium-239	0.0003	0.001
Radium-226	-	0.1
Strontium-89	0.1	2
Strontium-90	0.01	0.25
Thorium-228	0.001	-
Thorium-230	0.001	-
Thorium-232	0.001	-
Uranium-234	0.0003	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 was less than the detection limit, the average was calculated with the assumption that such results were equal to the detection limit, and the resulting average value is expressed as less than (<) the computed average; (2) if only a small fraction of the individual results was less than the detection limit, the average was calculated with the assumption that such results were actually one-half of the detection limit, and the average is given as a definite value. The 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 and is a measure of the range in the concentrations encountered at that location. It does not represent the conventional uncertainty in the average of repeated measurements on the same or identical samples. Since many of the variations observed in environmental radioactivity are not random, but occur for specific reasons (e.g., seasonal variations), samples collected from the same location at different times are not replicates. The more random the variation in activity at a particular location, the closer the confidence limits will represent the actual distribution of values at that location. The averages and confidence limits should be interpreted with this in mind. When a plus-or-minus figure accompanies an individual result in this report, it represents the statistical counting error at the 95% confidence level.

DOE has provided draft guidance⁶ for dose equivalent calculations for members of the public, based on ICRP-26 and ICRP-30. These procedures have been used in this report, and it is expected that this approach will replace the Concentration Guides (CGs) in DOE Order 5480.1A, Chapter XI, that have been used in the past to compare environmental radionuclide concentrations with DOE standards.⁹ The new methodology requires three components to be calculated: (1) the committed dose equivalent from all sources of ingestion, (2) the committed dose equivalent from inhalation, and (3) direct dose equivalent from external radiation. These three components are summed for comparison with the new DOE dose equivalent limits for environmental exposure. The draft guidance requires that sufficient data be available on exposure to radionuclides and sources to assure that at least 90% of the total committed effective dose equivalent is accounted for. The primary radiation dose limit for members of the public is 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 Effective Dose Equivalent Factors (EFF.D.E.) and compared to the annual dose limits for uncontrolled areas. The EFF.D.E. and annual dose limits are both given in the draft guidance.⁶ The numerical values of the EFF.D.E. used in this report are given in Section 4.7. Although the EFF.D.E. apply only to concentrations above natural levels, the calculated dose is sometimes given in this report for activities that are primarily of natural origin for comparison purposes. Such values are enclosed in parentheses to indicate this. Occasionally, other standards are used, and their source is identified in the text.

4.2. Air

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

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

The alpha activity, principally due to naturally occurring nuclides, averaged the same as in the past several years and was in its normal range. The perimeter beta activity averaged 26 fCi/m^3 , which is the same as the average value for the past four years. The gamma-ray emitters listed in Table 4.3 are those that have been present in the air for the past few years and are of natural origin. The beryllium-7 exhibits an increase in concentration in the spring, indicating its stratospheric origin. The lead-

TABLE 4.2
 TOTAL ALPHA AND BETA ACTIVITIES IN AIR-FILTER SAMPLES, 1988*
 (CONCENTRATIONS IN FEMTOCURIES/CUBIC METER)

MONTH	LOCATION	NO. OF SAMPLES	ALPHA ACTIVITY			BETA ACTIVITY		
			AV.	MIN.	MAX.	AV.	MIN.	MAX.
JANUARY	PERIMETER	24	2.6	1.3	6.2	33	18	46
	OFF-SITE	17	1.9	0.1	3.3	32	12	58
FEBRUARY	PERIMETER	32	2.1	1.4	3.5	29	20	41
	OFF-SITE	16	1.8	0.8	2.9	25	11	36
MARCH	PERIMETER	40	1.7	0.8	3.1	19	12	27
	OFF-SITE	19	1.4	0.6	2.3	18	9	25
APRIL	PERIMETER	27	2.2	1.1	4.4	20	14	33
	OFF-SITE	18	2.0	1.1	3.0	18	8	25
MAY	PERIMETER	33	2.2	1.1	5.4	20	11	32
	OFF-SITE	19	1.9	0.8	3.5	19	12	26
JUNE	PERIMETER	38	2.6	1.3	4.8	26	17	34
	OFF-SITE	21	2.2	1.0	3.5	25	16	35
JULY	PERIMETER	32	2.7	0.7	5.8	26	10	42
	OFF-SITE	20	2.3	0.7	5.5	27	8	40
AUGUST	PERIMETER	39	2.8	1.6	6.0	32	18	50
	OFF-SITE	23	2.5	1.6	3.4	32	18	48
SEPTEMBER	PERIMETER	32	2.0	0.8	5.3	25	16	35
	OFF-SITE	18	1.9	0.8	3.1	24	16	36
OCTOBER	PERIMETER	31	1.8	0.3	4.2	24	4	55
	OFF-SITE	20	1.6	0.2	2.6	23	8	34
NOVEMBER	PERIMETER	40	1.5	0.6	2.7	24	14	34
	OFF-SITE	21	1.4	0.1	2.0	24	12	34
DECEMBER	PERIMETER	21	2.6	1.6	3.4	35	18	49
	OFF-SITE	19	2.6	1.4	5.4	34	23	43
ANNUAL SUMMARY	PERIMETER	389	2.3 ± 0.1	0.3	6.2	26 ± 1	4	55
	OFF-SITE	231	1.9 ± 0.1	0.1	5.5	25 ± 1	8	58

* 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 RADIO-ACTIVE DECAY.

TABLE 4.3

GAMMA RAY ACTIVITY IN AIR-FILTER SAMPLES, 1988
(CONCENTRATIONS IN FEMTOCURIES/CUBIC METER)

MONTH	LOCATION	BE7	PB210
JANUARY	PERIMETER	67	48
	OFF-SITE	63	52
FEBRUARY	PERIMETER	82	38
	OFF-SITE	79	36
MARCH	PERIMETER	90	21
	OFF-SITE	94	19
APRIL	PERIMETER	110	23
	OFF-SITE	113	23
MAY	PERIMETER	121	19
	OFF-SITE	141	25
JUNE	PERIMETER	145	30
	OFF-SITE	165	35
JULY	PERIMETER	110	31
	OFF-SITE	134	40
AUGUST	PERIMETER	93	36
	OFF-SITE	121	47
SEPTEMBER	PERIMETER	77	32
	OFF-SITE	90	39
OCTOBER	PERIMETER	63	33
	OFF-SITE	60	39
NOVEMBER	PERIMETER	54	36
	OFF-SITE	65	47
DECEMBER	PERIMETER	78	54
	OFF-SITE	77	56
ANNUAL SUMMARY	PERIMETER	91 ± 16	33 ± 6
	OFF-SITE	100 ± 21	38 ± 7
DOSE (REM)	PERIMETER	(0.00021)	(0.036)
	OFF-SITE	(0.00023)	(0.042)

210 in air is due to the radioactive decay of gaseous radon-222 and is about 10% higher than in the past years due to low precipitation and high temperatures during the year. No airborne radionuclides from the accident at the Russian nuclear power facility near Chernobyl were measurable in 1988.

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. Samples were ignited at 600°C to remove organic matter and prepared for analysis by vigorous treatment with hot hydrochloric, hydrofluoric, and nitric acids.

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

The average strontium-90 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 are about a factor of two higher, both on-site and off-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 during the past several years and are considered to be of natural origin. The amounts of thorium and uranium in a sample were proportional to the mass of inorganic material collected on the filter paper. The bulk of these elements in the air was due to resuspension of soil. In contrast, the

TABLE 4.4

Strontium, Thorium, Uranium, and Plutonium Concentrations
in Air-Filter Samples, 1988(Concentrations in Attocuries/m³)

Month	Location ¹	Strontium-90	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Uranium-238 ²	Plutonium-239 ³
January	7I	< 10	9 ± 1	11 ± 1	4 ± 1	11 ± 1	7 ± 1	0.6 ± 0.4
	12N	< 10	11 ± 1	16 ± 2	7 ± 1	17 ± 1	13 ± 2	1.0 ± 0.4
	Off-Site	15 ± 18	17 ± 2	22 ± 2	5 ± 2	11 ± 1	8 ± 1	1.3 ± 0.6
February	7I	< 10	14 ± 1	19 ± 2	5 ± 1	15 ± 3	10 ± 4	2.0 ± 0.6
	12N	< 10	11 ± 1	18 ± 2	8 ± 1	16 ± 1	14 ± 1	1.7 ± 0.6
	Off-Site	12 ± 10	17 ± 2	15 ± 2	2 ± 2	9 ± 3	4 ± 4	1.3 ± 0.5
March	7I	< 10	23 ± 3	28 ± 2	7 ± 2	10 ± 3	2 ± 3	2.3 ± 0.5
	12N	< 10	9 ± 1	12 ± 1	4 ± 1	11 ± 4	5 ± 4	1.8 ± 0.7
	Off-Site	12 ± 18	21 ± 2	16 ± 2	7 ± 2	33 ± 4	22 ± 4	3.3 ± 0.9
April	7I	20 ± 30	13 ± 2	15 ± 2	5 ± 1	10 ± 1	8 ± 2	1.8 ± 0.6
	12N	< 10	14 ± 2	16 ± 1	6 ± 1	12 ± 1	9 ± 2	1.1 ± 0.5
	Off-Site	-	11 ± 1	6 ± 1	3 ± 1	6 ± 1	5 ± 1	0.9 ± 0.3
May	7I	< 10	15 ± 2	23 ± 2	13 ± 2	19 ± 2	16 ± 2	3.8 ± 0.8
	12N	< 10	20 ± 2	31 ± 3	14 ± 2	20 ± 2	16 ± 2	1.6 ± 1.2
	Off-Site	14 ± 9	18 ± 2	24 ± 2	12 ± 2	20 ± 2	15 ± 1	5.6 ± 1.0
June	7I	< 10	-	-	-	20 ± 2	15 ± 2	2.5 ± 0.5
	12N	< 10	11 ± 1	12 ± 2	7 ± 1	10 ± 1	11 ± 1	6.0 ± 1.0
	Off-Site	25 ± 17	8 ± 1	13 ± 1	6 ± 1	19 ± 2	16 ± 1	2.0 ± 0.5
July	7I	25 ± 16	10 ± 1	19 ± 2	9 ± 2	16 ± 1	14 ± 2	4.3 ± 0.7
	12N	20 ± 19	3 ± 1	6 ± 1	2 ± 1	19 ± 2	15 ± 2	1.9 ± 0.6
	Off-Site	30 ± 12	14 ± 2	19 ± 2	11 ± 3	21 ± 2	18 ± 2	3.9 ± 1.5
August	7I	< 10	8 ± 1	13 ± 1	6 ± 1	9 ± 1	8 ± 2	1.3 ± 0.4
	12N	< 10	10 ± 1	16 ± 2	7 ± 2	13 ± 2	12 ± 2	1.3 ± 0.4
	Off-Site	13 ± 17	6 ± 1	8 ± 2	5 ± 2	9 ± 4	4 ± 3	-
September	7I	< 10	7 ± 1	8 ± 1	5 ± 1	11 ± 2	7 ± 2	1.1 ± 0.6
	12N	< 10	6 ± 1	18 ± 2	3 ± 1	10 ± 2	7 ± 2	0.8 ± 0.4
	Off-Site	< 10	3 ± 1	7 ± 1	3 ± 1	9 ± 2	7 ± 2	1.0 ± 0.4
October	7I	< 10	5 ± 1	9 ± 1	5 ± 1	-	-	1.0 ± 0.4
	12N	< 10	3 ± 1	4 ± 1	3 ± 1	-	-	1.3 ± 0.7
	Off-Site	< 10	5 ± 1	8 ± 1	2 ± 1	5 ± 1	3 ± 1	0.6 ± 0.3
November	7I	16 ± 5	10 ± 1	18 ± 1	9 ± 2	19 ± 4	12 ± 4	0.8 ± 0.3
	12N	10 ± 20	9 ± 1	14 ± 2	8 ± 2	17 ± 2	14 ± 2	1.1 ± 0.6
	Off-Site	< 10	6 ± 1	6 ± 1	3 ± 1	6 ± 1	4 ± 1	0.9 ± 0.3
December	7I	< 10	14 ± 1	21 ± 3	8 ± 2	13 ± 2	12 ± 2	1.7 ± 0.4
	12N	< 10	8 ± 1	18 ± 1	8 ± 2	17 ± 1	15 ± 1	4.2 ± 0.9
	Off-Site	17 ± 13	-	-	-	10 ± 2	10 ± 2	3.1 ± 0.8
Annual Summary	7I	< 13	12 ± 4	17 ± 5	7 ± 2	14 ± 3	10 ± 3	1.9 ± 0.6
	12N	< 11	10 ± 3	15 ± 4	6 ± 2	15 ± 4	12 ± 4	2.0 ± 0.6
	Off-Site	15 ± 8	11 ± 4	13 ± 4	5 ± 2	13 ± 3	10 ± 3	2.2 ± 0.7
Dose (mrem) (x 10 ⁻³)	7I	< 14	(0.30)	(0.89)	(0.007)	(0.15)	(0.10)	0.052
	12N	< 12	(0.25)	(0.80)	(0.006)	(0.16)	(0.12)	0.054
	Off-Site	17	(0.28)	(0.70)	(0.005)	(0.14)	(0.10)	0.059

¹Perimeter locations are given in terms of the grid coordinates in Figure 1.1.²The concentrations in units of micrograms/cubic meter can be obtained by multiplying the value in attocuries/cubic meter by 2.96 x 10⁻⁶ for uranium-238 and by 9 x 10⁻⁶ for thorium-232. The mass of the other thorium isotopes in comparison to thorium-232 and the other uranium isotopes in comparison to uranium-238 is negligible.³Plutonium-240 is included (see text).

amount of plutonium in the air samples contributed by soil ranged from about 3% to 28% and averaged 14% of the total plutonium in the samples. This assumes that the resuspended soil has the same plutonium concentration as the first centimeter on the ground. The remainder of the plutonium-239 is due to worldwide fallout.

The major airborne effluents released during 1988 are listed by location in Table 4.5. The radon-220 from Building 200 is due to stored waste from the "proof-of-breeding" program and nuclear medicine studies. Even though the reactor ceased operations in 1977, hydrogen-3 continues to be emitted from Building 330 (CP-5). The hydrogen-3 from Building 212 is from the tritium recovery studies. In addition to the nuclides listed in Table 4.5, several other fission products were also released in millicurie or smaller amounts. The quantities listed in Table 4.5 were measured by on-line stack monitors in the exhaust systems of the buildings.

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

TABLE 4.5

Summary of Airborne Radioactive Emissions, 1988

Building	Nuclide	Half-Life	Amount Released (curies/y)
200	Radon-220	56 s	3730
202 (JANUS)	Argon-41	1.8 h	1.3
211	Carbon-11	20 m	0.5
	Nitrogen-13	10 m	1.3
	Oxygen-15	122 s	8.0
212	Hydrogen-3 (HT)	12.3 y	9.1
	Hydrogen-3 (HTO)	12.3 y	5.8
	Krypton-85	10.7 y	7.1
	Radon-220	56 s	1.2
330 (CP-5)	Hydrogen-3 (HTO)	12.3 y	35
375 (IPNS)	Carbon-11	20 m	86
	Argon-41	1.8 h	1.5

4.3. Surface Water

Total (nonvolatile) alpha and beta activities were determined by counting the residue remaining after evaporation of the water, and applying counting efficiency corrections determined for uranium-233 (for alpha activity) and thallium-204 (for beta activity) to obtain disintegration rates. Hydrogen-3 was measured on a separate sample, and this activity does not appear in the total nonvolatile beta activity. Uranium was measured using a laser fluorometer, and the results were calculated in terms of activity, with the assumption that the isotopic composition was that of natural uranium. Analyses for other radionuclides were performed by specific radiochemical separations followed by appropriate counting. One-liter aliquots were used for all analyses except hydrogen-3 and the transuranium nuclides. Hydrogen-3 analyses were performed by liquid scintillation counting of 10 mL in a gel medium. Analyses for transuranium nuclides were performed on 10-liter samples using chemical separation methods followed by

TABLE 4.6

Tritiated Water Vapor in Air₃ 1988
(Concentrations in pCi/m³)

Month	Location*	No. of Samples	Avg.	Min.	Max.
January	8F	8	0.27	< 0.1	0.97
	12N	8	0.51	< 0.1	2.51
	Off-Site	2	0.28	0.20	0.36
February	8F	8	0.28	< 0.1	0.85
	12N	8	0.13	< 0.1	0.32
	Off-Site	2	-	-	< 0.1
March	8F	9	0.87	< 0.1	3.45
	12N	9	0.29	< 0.1	0.58
	Off-Site	2	-	-	< 0.1
April	8F	9	0.92	0.15	3.22
	12N	9	0.26	< 0.1	0.88
	Off-Site	2	0.38	< 0.1	0.71
May	8F	7	1.25	0.21	3.10
	12N	8	0.88	< 0.1	1.42
	Off-Site	2	0.63	0.36	0.90
June	8F	9	3.15	0.57	11.51
	12N	9	1.04	< 0.1	2.64
	Off-Site	2	0.92	0.26	1.58
July	8F	9	1.61	0.18	4.52
	12N	9	1.19	0.27	3.98
	Off-Site	1	-	-	1.01
August	8F	9	1.40	0.25	4.27
	12N	9	1.37	0.43	4.28
	Off-Site	2	1.74	1.62	1.86
September	8F	8	0.48	< 0.1	0.85
	12N	8	0.29	< 0.1	0.53
	Off-Site	2	0.40	< 0.1	0.76
October	8F	9	0.21	< 0.1	0.59
	12N	8	0.29	< 0.1	0.69
	Off-Site	2	0.17	0.15	0.19
November	8F	9	0.50	0.18	1.00
	12N	9	0.47	< 0.1	1.02
	Off-Site	2	-	-	< 0.1
December	8F	6	0.38	0.25	0.52
	12N	6	0.45	< 0.1	0.73
	Off-Site	2	0.54	0.30	0.77
Annual Summary	8F	100	0.94	< 0.1	11.51
	12N	100	0.60	< 0.1	4.28
	Off-Site	23	0.44	< 0.1	1.86
Dose (mrem)	8F	-	0.00050	< 0.00005	0.0061
	12N	-	0.00032	< 0.00005	0.0023
	Off-Site	-	0.00023	< 0.00005	0.00098

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

alpha spectrometry.^{10,11} Plutonium-236 was used to determine the yields of plutonium and neptunium, which were separated together. A group separation of a fraction containing the transplutonium elements was monitored for recovery with americium-243 tracer.

ANL 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 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 a continuous sampler, which operated about 89% of the year. When the continuous sampling device was not functioning, a grab sample was collected each working day. Equal portions of the daily samples collected each week were combined and analyzed to obtain an average weekly concentration. Above the site, samples were collected once a month and were analyzed for the same radionuclides as the below-outfall samples.

Annual summaries of the results obtained for Sawmill Creek are given in Table 4.7. Comparison of the results and 95% confidence levels of the averages for the two sampling locations shows the nuclides found in the creek water that can be attributed to ANL operations were hydrogen-3, strontium-90, cesium-137, neptunium-237, plutonium-239, americium-241, and occasionally plutonium-238, curium-242 and/or californium-252, and curium-244 and/or californium-249. The percentage of individual samples containing activity attributable to ANL was 75% for hydrogen-3, 90% for strontium-90, 44% for cesium-137, 88% for neptunium-237, 100% for plutonium-239, and 98% 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 is similar above and below the site and in the range of concentrations found in the past. However, the total beta activity

TABLE 4.7
 RADIONUCLIDES IN SAHMILL CREEK WATER, 1988

TYPE OF ACTIVITY	LOCATION *	NO. OF SAMPLES	CONCENTRATION (PICOCURIES/LITER)			AVG.	DOSE (MREM)	
			AVG.	MIN.	MAX.		MIN.	MAX.
ALPHA (NONVOLATILE)	16K	11	1.6 ± 0.3	0.6	2.5	-	-	-
	7M	239	2.3 ± 0.3	1.2	7.9	-	-	-
BETA (NONVOLATILE)	16K	11	8 ± 1	6	10	-	-	-
	7M	249	19 ± 3	7	92	-	-	-
HYDROGEN-3	16K	11	< 114	< 100	188	< 0.0052	< 0.005	0.0087
	7M	249	361 ± 269	< 100	6363	0.0166	< 0.005	0.2927
STRONTIUM-90	16K	11	0.25 ± 0.08	< 0.25	0.40	0.024	< 0.02	0.04
	7M	249	0.63 ± 0.26	< 0.25	6.47	0.060	< 0.02	0.61
CESIUM-137	16K	11	-	-	< 1.0	-	-	< 0.03
	7M	244	< 2.0	< 1.0	22.9	< 0.07	< 0.03	0.76
URANIUM (NATURAL) **	16K	11	2.1 ± 0.6	1.0	3.5	(0.35)	(0.168)	(0.59)
	7M	249	1.1 ± 0.2	< 0.2	5.2	(0.19)	(< 0.034)	(0.87)
NEPTUNIUM-237	16K	11	< 0.001	< 0.001	0.002	< 0.0004	< 0.00028	0.00066
	7M	249	0.0039 ± 0.0011	< 0.001	0.022	0.0011	< 0.00028	0.0062
PLUTONIUM-238	16K	9	< 0.0012	< 0.001	0.002	0.00033	< 0.00028	0.00057
	7M	249	0.0036 ± 0.0015	< 0.001	0.029	0.00101	< 0.00028	0.0079
PLUTONIUM-239	16K	11	< 0.00134	< 0.001	0.005	< 0.00042	< 0.00031	0.00149
	7M	249	0.0129 ± 0.0086	0.001	0.215	0.0040	0.00033	0.0674
AMERICIUM-241	16K	9	0.0012 ± 0.0005	< 0.001	0.002	0.0019	< 0.0016	0.003
	7M	249	0.0172 ± 0.0052	< 0.001	0.092	0.0276	< 0.0016	0.149
CURIUM-242 AND/OR CALIFORNIUM-252	16K	9	< 0.0010	< 0.001	0.0013	< 0.0004	< 0.0003	0.0005
	7M	249	< 0.0012	< 0.001	0.0031	< 0.0004	< 0.0003	0.0011
CURIUM-244 AND/OR CALIFORNIUM-249	16K	9	< 0.0012	< 0.001	0.0016	< 0.0019	< 0.0017	0.0027
	7M	249	0.0031 ± 0.0011	< 0.001	0.0263	0.0053	< 0.0017	0.044

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

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

at 16K was down by a factor of three compared to 1986. It was noted last year that after the Marion Brook wastewater treatment plant closed on October 27, 1986, the beta activity decreased by a factor of three in the creek above the site, and this reduction is assumed to be due to the absence of natural radioactivities in human excretions (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.

One composite sample from 7M collected the week of September 26, 1988, contained the year's highest concentrations of: alpha (7.9 pCi/L), beta (92 pCi/L), strontium-90 (6.47 pCi/L), cesium-137 (22.9 pCi/L), plutonium-238 (0.029 pCi/L), and plutonium-239 (0.215 pCi/L). Releases of these nuclides for the rest of the year were in the normal range but this single discharge had a measurable impact on the annual averages. The annual average concentrations of hydrogen-3 and plutonium-239 were slightly higher than 1987 and strontium-90 and cesium-137 were lower. All annual averages were well below the applicable standards.

The 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 1.9 Ci of hydrogen-3, 0.003 Ci of strontium-90, 0.008 Ci of cesium-137, 0.02 mCi of neptunium-237, 0.09 mCi of plutonium-239, 0.12 mCi of americium-241, and < 0.01 mCi of curium and californium nuclides.

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

Annual summaries of the results obtained for these two locations are given in Table 4.8. The average nonvolatile alpha, beta, and uranium concentrations in the river were very similar to past averages and remained in the normal range. Results were quite similar above and below the creek

TABLE 4.8
RADIOMUCLIDES IN DESPLAINES RIVER WATER, 1988

TYPE OF ACTIVITY	* LOCATION	NO. OF SAMPLES	CONCENTRATION (PICOCURIES/LITER)			DOSE (MREM)		
			AVG.	MIN.	MAX.	AVG.	MIN.	MAX.
ALPHA (NONVOLATILE)	A	12	1.3 ± 0.1	0.9	1.8	-	-	-
	B	24	1.4 ± 0.2	0.7	3.1	-	-	-
BETA (NONVOLATILE)	A	12	14 ± 1	8	21	-	-	-
	B	24	14 ± 2	8	25	-	-	-
HYDROGEN-3	A	12	< 113	< 100	159	< 0.0052	< 0.005	0.0073
	B	24	< 118	< 100	262	< 0.0054	< 0.005	0.0121
STRONTIUM-90	A	11	0.25 ± 0.06	< 0.25	0.38	0.02	< 0.02	0.04
	B	23	0.21 ± 0.04	< 0.25	0.37	0.02	< 0.02	0.04
** URANIUM (NATURAL)	A	12	1.3 ± 0.1	0.5	3.4	(0.22)	(0.092)	(0.57)
	B	24	1.2 ± 0.2	0.4	2.3	(0.20)	(0.064)	(0.39)
NEPTUNIUM-237	A	10	< 0.0010	< 0.001	0.002	< 0.0003	< 0.00028	0.00049
	B	11	< 0.0011	< 0.001	0.001	< 0.0003	< 0.00028	0.00039
PLUTONIUM-238	A	11	< 0.0011	< 0.001	0.002	0.00031	< 0.00028	0.00042
	B	10	< 0.0010	< 0.001	0.001	0.00029	< 0.00028	0.00039
PLUTONIUM-239	A	12	< 0.0011	< 0.001	0.001	< 0.0003	< 0.0003	0.0004
	B	11	< 0.0010	< 0.001	0.001	< 0.0003	< 0.0003	0.0004
AMERICIUM-241	A	9	0.0011 ± 0.0004	< 0.001	0.002	0.0017	< 0.0016	0.003
	B	10	< 0.0011	< 0.001	0.002	< 0.0017	< 0.0016	0.0031
CURIUM-242 AND/OR CALIFORNIUM-252	A	11	< 0.0010	< 0.001	0.0012	< 0.0004	< 0.0003	0.0004
	B	10	< 0.0010	< 0.001	0.0010	< 0.0004	< 0.0003	0.0004
CURIUM-244 AND/OR CALIFORNIUM-249	A	11	< 0.0012	< 0.001	0.0020	< 0.0019	< 0.0017	0.0033
	B	10	< 0.0010	< 0.001	0.0014	< 0.0017	< 0.0017	0.0023

* LOCATION A, NEAR WILLOW SPRINGS, IS UPSTREAM AND LOCATION B, NEAR LEMONT, IS DOWNSTREAM FROM THE MOUTH OF SAWMILL CREEK. SEE FIGURE 1.2

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

for all radionuclides, since the activity in Sawmill Creek was reduced by dilution, so that it was not detectable in the Des Plaines River. The average nonvolatile alpha and beta activities, 1.2 pCi/L and 12.9 pCi/L, respectively, of 19 off-site surface water samples collected this year were similar to the levels found in previous years. The hydrogen-3 concentration in these surface water samples averaged 177 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,¹² an unusual occurrence was reported which consisted of the loss of about 7.5 megaliters (2 million gallons) of ponded water containing about 26 mCi of tritiated water from the Argonne Advanced Research Reactor (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. Approval has been obtained to fill the excavation with the original material.

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 soil activity near ANL is normal. For this purpose, the American Society for Testing and Materials (ASTM) site-selection criteria, and sample collection and sample preparation techniques were used.¹³ 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

TABLE 4.9

Radionuclides in Illinois River Water, 1988
(Concentrations in pCi/L)

Date Collected	Location	Alpha*	Beta*	Hydrogen-3	Uranium** (natural)	Plutonium-239
May 11	McKinley Woods State Park	1.4 ± 0.3	14.8 ± 0.5	130 ± 88	0.9 ± 0.1	< 0.001
May 11	Below Dresden Power Station	1.1 ± 0.3	6.6 ± 0.4	277 ± 92	1.2 ± 0.1	< 0.001
May 11	Morris	0.9 ± 0.3	9.8 ± 0.4	215 ± 90	0.9 ± 0.1	-
May 11	Starved Rock State Park	1.2 ± 0.3	10.4 ± 0.4	171 ± 89	1.0 ± 0.1	-
October 13	McKinley Woods State Park	0.7 ± 0.2	6.8 ± 0.4	128 ± 94	0.1 ± 0.1	< 0.001
October 13	Below Dresden Power Station	0.3 ± 0.2	6.7 ± 0.5	397 ± 100	0.7 ± 0.1	-
October 13	Morris	0.4 ± 0.2	6.8 ± 0.5	467 ± 101	0.2 ± 0.1	-
October 13	Starved Rock	0.4 ± 0.2	9.0 ± 0.5	321 ± 98	0.5 ± 0.1	-

*Nonvolatile activity.

**Uranium concentrations in units of $\mu\text{g/L}$ can be obtained by multiplying the concentration by 1.48.

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 in area by 5 cm deep. Through 1976, samples had been collected down to 30 cm to measure total deposition, and as a result of five years of sample collection at this depth, the total deposition in the ANL environment has been established. Reducing the sampling depth to 5 cm will make the analysis more sensitive to changes in current deposition. The grass samples were obtained by collecting the grass from a 1 m² area in the immediate vicinity of a soil sample. A grab sample technique was used to obtain bottom sediment. After drying, grinding, and mixing, 100 g portions of each soil, bottom sediment, and grass 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 and off-site samples are similar. The plutonium and americium concentrations are given in Table 4.11. The range and average concentrations of plutonium and americium in soil are similar at both perimeter and off-site sampling points. For fallout americium-241 in soil, about 10% is due to direct deposition, while about 90% is from the decay of the previously deposited plutonium-241.¹⁴ The measured deposition of americium-241 and the americium-241/plutonium-239 ratio is consistent with reported values.¹⁴

The results of radionuclide concentrations measured in grass are given in Table 4.12. The annual averages and concentration ranges were similar at the perimeter and off-site locations, as well as similar to those of previous years, indicating no contribution from ANL operations. In terms of

TABLE 4.10

Gamma-Ray Emitting Radionuclides in Soil, 1988
(Concentrations in pCi/g)

Date Collected	Location	Potassium-40	Cesium-137	Radium-226	Thorium-228	Thorium-232
	<u>Perimeter*</u>					
May 18	12C	15.44 ± 0.56	0.73 ± 0.03	1.19 ± 0.06	0.81 ± 0.03	0.83 ± 0.08
May 18	12-0	17.99 ± 0.61	0.76 ± 0.03	1.05 ± 0.06	0.90 ± 0.04	0.88 ± 0.09
May 18	14L	17.58 ± 0.38	0.47 ± 0.02	1.23 ± 0.04	0.88 ± 0.02	0.84 ± 0.06
May 18	8N	17.17 ± 0.57	0.66 ± 0.03	1.11 ± 0.06	0.77 ± 0.03	0.76 ± 0.08
May 18	5D	16.13 ± 0.56	0.57 ± 0.03	0.98 ± 0.06	0.77 ± 0.03	0.74 ± 0.08
October 14	10E	20.91 ± 0.80	0.71 ± 0.04	1.31 ± 0.07	1.04 ± 0.04	0.93 ± 0.10
October 14	14I	17.87 ± 0.77	0.85 ± 0.04	1.07 ± 0.07	0.96 ± 0.04	0.82 ± 0.09
October 14	6J	18.63 ± 0.78	0.66 ± 0.03	1.11 ± 0.07	0.77 ± 0.04	0.76 ± 0.09
October 14	9N	19.68 ± 0.76	0.78 ± 0.04	1.39 ± 0.07	0.94 ± 0.04	0.86 ± 0.09
October 14	10N	18.28 ± 0.77	0.56 ± 0.03	0.98 ± 0.07	0.75 ± 0.04	0.75 ± 0.09
	Average	17.97 ± 1.00	0.68 ± 0.07	1.14 ± 0.09	0.86 ± 0.06	0.82 ± 0.04
	<u>Off-Site</u>					
May 11	Dresden Lock and Dam, IL	20.13 ± 0.63	0.92 ± 0.04	1.20 ± 0.06	1.11 ± 0.04	1.10 ± 0.10
May 11	McKinley Woods State Park, IL	21.44 ± 0.66	0.66 ± 0.03	1.35 ± 0.07	0.93 ± 0.04	0.90 ± 0.09
May 11	Morris, IL	20.13 ± 0.76	0.36 ± 0.03	1.68 ± 0.09	1.01 ± 0.04	1.00 ± 0.11
May 12	McCormick Woods, Brookfield, IL	16.68 ± 0.58	0.67 ± 0.03	1.23 ± 0.06	0.79 ± 0.03	0.83 ± 0.08
May 12	Bemis Woods, Western Springs, IL	15.37 ± 0.58	0.51 ± 0.03	1.44 ± 0.07	0.73 ± 0.03	0.66 ± 0.08
October 11	Saganashkee Slough, IL	20.04 ± 0.79	0.61 ± 0.03	1.54 ± 0.08	0.97 ± 0.04	0.86 ± 0.09
October 11	McGinnis Slough, IL	23.71 ± 0.80	0.90 ± 0.04	1.57 ± 0.08	0.98 ± 0.04	0.85 ± 0.10
October 13	Channahon, IL	19.98 ± 0.79	0.86 ± 0.04	1.19 ± 0.07	1.03 ± 0.04	0.99 ± 0.09
October 13	Starved Rock State Park, IL	18.17 ± 0.75	0.16 ± 0.03	2.12 ± 0.08	1.00 ± 0.04	0.92 ± 0.09
	Average	19.52 ± 1.66	0.63 ± 0.17	1.48 ± 0.20	0.95 ± 0.08	0.90 ± 0.08

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

TABLE 4.11

Transuranics in Soil, 1988

Date Collected	Location	Plutonium-238 (fCi/g)	Plutonium-238 (nCi/m ²)	Plutonium-239 (fCi/g)	Plutonium-239 (nCi/m ²)	²³⁸ Pu/ ²³⁹ Pu	Americium-241 (fCi/g)	Americium-241 (nCi/m ²)	²⁴¹ Am/ ²³⁹ Pu
<u>Perimeter*</u>									
May 18	12C	1.5 ± 0.3	0.050 ± 0.010	17.0 ± 1.2	0.567 ± 0.041	0.088	3.5 ± 0.8	0.116 ± 0.026	0.21
May 18	12D	1.7 ± 0.4	0.062 ± 0.013	16.2 ± 1.3	0.603 ± 0.048	0.105	5.2 ± 1.9	0.191 ± 0.069	0.32
May 18	14L	1.4 ± 0.3	0.063 ± 0.012	11.3 ± 0.9	0.522 ± 0.040	0.124	3.1 ± 0.6	0.143 ± 0.030	0.27
May 18	5D	1.1 ± 0.2	0.039 ± 0.008	15.2 ± 1.0	0.554 ± 0.035	0.072	3.6 ± 0.7	0.130 ± 0.025	0.24
May 18	8N	0.6 ± 0.3	0.027 ± 0.012	12.4 ± 1.3	0.541 ± 0.057	0.048	3.3 ± 0.6	0.144 ± 0.028	0.27
October 14	10E	2.8 ± 0.6	0.133 ± 0.028	26.2 ± 2.3	1.224 ± 0.107	0.107	3.7 ± 0.7	0.173 ± 0.031	0.14
October 14	10N	1.0 ± 0.4	0.036 ± 0.016	17.8 ± 2.2	0.650 ± 0.080	0.055	2.7 ± 0.4	0.097 ± 0.015	0.15
October 14	14I	2.6 ± 0.5	0.104 ± 0.019	35.7 ± 2.5	1.400 ± 0.097	0.073	4.7 ± 0.7	0.186 ± 0.028	0.13
October 14	6J	2.2 ± 0.5	0.112 ± 0.025	32.5 ± 2.6	1.637 ± 0.130	0.068	4.1 ± 0.6	0.205 ± 0.032	0.12
October 14	9N	1.2 ± 0.3	0.048 ± 0.011	14.5 ± 1.1	0.597 ± 0.044	0.083	4.3 ± 0.7	0.176 ± 0.029	0.29
	Average	1.6 ± 0.5	0.067 ± 0.023	19.9 ± 5.4	0.830 ± 0.266	0.082	3.8 ± 0.5	0.156 ± 0.022	0.21
<u>Off-Site</u>									
May 11	Dresden Lock & Dam, IL	0.8 ± 0.2	0.035 ± 0.009	19.2 ± 1.3	0.869 ± 0.057	0.042	6.0 ± 1.4	0.271 ± 0.065	0.31
May 11	McKinley Woods State Park, IL	0.8 ± 0.3	0.038 ± 0.012	14.6 ± 1.3	0.671 ± 0.058	0.055	3.3 ± 0.6	0.150 ± 0.028	0.22
May 11	Morris, IL	0.5 ± 0.2	0.027 ± 0.012	5.8 ± 0.7	0.331 ± 0.042	0.086	0.9 ± 0.3	0.054 ± 0.015	0.16
May 12	McCormick Woods, Brookfield, IL	0.7 ± 0.2	0.033 ± 0.009	14.9 ± 1.0	0.676 ± 0.047	0.048	6.0 ± 3.1	0.275 ± 0.139	0.40
May 12	Bemis Woods, Western Springs, IL	0.8 ± 0.3	0.038 ± 0.013	12.1 ± 1.1	0.576 ± 0.054	0.065	6.2 ± 4.0	0.296 ± 0.192	0.51
October 11	McGinnis Slough,	0.6 ± 0.2	0.026 ± 0.008	16.2 ± 1.1	0.661 ± 0.047	0.037	3.6 ± 0.5	0.147 ± 0.019	0.22
October 11	Saganashkee Slough, IL	0.7 ± 0.2	0.026 ± 0.007	11.4 ± 0.9	0.413 ± 0.032	0.063	2.6 ± 0.4	0.093 ± 0.015	0.23
October 13	Channahon, IL	2.0 ± 0.4	0.082 ± 0.016	16.0 ± 1.3	0.666 ± 0.055	0.125	4.8 ± 0.7	0.200 ± 0.031	0.30
October 13	Starved Rock State Park, IL	0.4 ± 0.10	0.018 ± 0.006	2.7 ± 0.4	0.112 ± 0.015	0.156	1.0 ± 0.3	0.041 ± 0.013	0.36
	Average	0.8 ± 0.3	0.036 ± 0.012	12.5 ± 3.5	0.553 ± 0.152	0.075	3.8 ± 1.4	0.170 ± 0.065	0.30

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

TABLE 4.12

Radionuclides in Grass, 1988

Date Collected	Location	Potassium-40 (pCi/g)	Cesium-137 (fCi/g)	Plutonium-239 (fCi/g)	Deposited Plutonium-239 (nCi/m)
<u>Perimeter*</u>					
May 18	12C	18.44 ± 0.55	9 ± 12	< 0.1	< 0.01
May 18	8N	16.26 ± 0.53	10 ± 12	0.2 ± 0.1	0.03 ± 0.01
May 18	12D	22.29 ± 0.75	18 ± 16	0.4 ± 0.1	0.08 ± 0.02
May 18	14L	27.34 ± 0.64	19 ± 14	0.2 ± 0.1	0.03 ± 0.02
May 18	5D	34.91 ± 0.83	17 ± 15	< 0.1	< 0.01
October 14	10E	12.34 ± 0.48	11 ± 13	0.1 ± 0.1	0.04 ± 0.02
October 14	14I	6.45 ± 0.43	14 ± 13	< 0.1	< 0.01
October 14	10N	10.23 ± 0.43	< 10	0.2 ± 0.2	0.06 ± 0.10
October 14	6J	9.39 ± 0.43	< 10	0.1 ± 0.1	0.01 ± 0.01
October 14	9N	14.30 ± 0.58	< 10	0.1 ± 0.1	0.04 ± 0.02
	Average	17.16 ± 5.58	11 ± 3	0.2 ± 0.1	0.04 ± 0.02
<u>Off-Site</u>					
May 11	Dresden Lock and Dam, IL	24.39 ± 0.78	17 ± 16	0.2 ± 0.1	0.03 ± 0.02
May 11	McKinley Woods State Park, IL	15.91 ± 0.45	< 10	0.4 ± 0.5	0.02 ± 0.02
May 11	Morris, IL	24.11 ± 0.49	11 ± 12	0.2 ± 0.1	0.04 ± 0.02
May 12	Brookfield, IL	21.41 ± 0.55	27 ± 13	0.3 ± 0.1	0.03 ± 0.01
May 12	Western Springs, IL	23.70 ± 0.96	62 ± 34	1.7 ± 0.2	0.08 ± 0.01
October 11	McGinnis Slough, IL	25.09 ± 0.64	< 10	< 0.1	< 0.01
October 11	Saganashkee Slough, IL	24.81 ± 0.62	< 10	2.3 ± 0.3	0.30 ± 0.03
October 13	Channahon, IL	5.05 ± 0.35	11 ± 12	0.1 ± 0.1	0.02 ± 0.02
October 13	Starved Rock State Park, IL	13.32 ± 0.49	< 10	< 0.1	< 0.01
	Average	19.75 ± 4.63	16 ± 12	0.6 ± 0.5	0.06 ± 0.06

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

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

Results of analyses of bottom sediment samples for gamma-ray emitters and transuranics are given in Table 4.13. The annual off-site averages are in the same range found in off-site samples collected in previous years, except for the contribution to the plutonium and americium results from the sample collected at Morris, Illinois, which is five times higher than the 1987 average and ten times higher than the average in previous years. Plutonium results vary widely between locations and are strongly dependent on the retentiveness of the bottom material.

A set of samples was collected on July 27, 1988, 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 are listed in Table 4.13 and show that the concentrations in the sample above the 7M outfall are similar to those of the off-site samples. The plutonium and americium concentrations are slightly elevated below the outfall, indicating that their origin is in ANL wastewater. Similar sets of samples were collected on August 12, 1987, June 24, 1986, June 17, 1985, July 27, 1984, August 11, 1983, September 15, 1982, and September 24, 1980. Comparison of plutonium concentrations indicates that the 1982 results were an order of magnitude higher at the outfall, but similar farther downstream, while the 1980, 1983, 1984, 1985, 1986, and 1987 results were more like the 1988 set at the same locations. The plutonium and americium results from the 1988 sample collected 100 m below the outfall are inexplicably low. 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 was collected monthly from a local dairy farm south of Lemont and analyzed for several radionuclides. The water was separated from the milk by low-temperature vacuum evaporation and the hydrogen-3 concentration 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. The average strontium-90 concentration was similar to the 1987 concentration. These nuclides are fission products from nuclear tests and are not related to ANL operations.

TABLE 4.14

Radionuclides in Milk, 1988
(Concentrations in pCi/L)

Date Collected	Hydrogen-3	Strontium-90
January 13	< 100	2.3 ± 0.2
February 3	< 100	2.2 ± 0.4
March 2	< 100	2.5 ± 0.1
April 6	< 100	2.7 ± 0.4
May 4	< 100	1.9 ± 0.3
June 2	< 100	2.8 ± 0.3
July 6	< 100	2.7 ± 0.2
August 3	< 100	2.5 ± 0.4
September 7	< 100	3.6 ± 0.4
October 5	< 100	4.0 ± 0.1
November 2	< 100	2.4 ± 0.4
December 8	< 100	1.8 ± 0.2
Average	< 100	2.7 ± 0.3

The concentrations given in Table 4.14 may be compared to the EPA 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

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

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 4.15

Environmental Penetrating Radiation at Off-Site Locations, 1988

Location	Dose Rate (mrem/year)				Average
	Period of Measurement				
	1/18-4/19	4/19-7/14	7/14-10/19	10/19-1/12	
Lemont	92	101	95	89	94 ± 5
Lombard	93	102	99	95	97 ± 4
Oak Brook	91	103	-	94	96 ± 6
Oak Lawn	85	88	81	82	84 ± 3
Woodridge	95	97	93	92	94 ± 2
Average	91 ± 4	98 ± 6	92 ± 8	90 ± 5	93 ± 5

TABLE 4.13

Radionuclides in Bottom Sediment, 1988

Date Collected	Location	Potassium-40	Concentrations in pCi/g				Concentrations in fCi/g		
			Cesium-137	Radium-226	Thorium-228	Thorium-232	Plutonium-238	Plutonium-239	Americium-241
	<u>Perimeter*</u>								
July 27	Sawmill Creek - 25 m Above Outfall	12.41 ± 0.28	0.18 ± 0.01	1.04 ± 0.03	0.59 ± 0.02	0.67 ± 0.04	0.4 ± 0.2	6.6 ± 0.8	1.5 ± 0.3
July 27	Sawmill Creek - At Outfall	9.45 ± 1.01	0.61 ± 0.07	1.23 ± 0.14	0.69 ± 0.07	0.76 ± 0.17	2.3 ± 0.4	20.7 ± 1.3	12.2 ± 0.4
July 27	Sawmill Creek - 50 m Below Outfall	7.86 ± 0.41	1.15 ± 0.04	0.79 ± 0.05	0.38 ± 0.03	0.45 ± 0.07	3.4 ± 0.4	29.9 ± 1.8	10.0 ± 0.8
July 27	Sawmill Creek - 100 m Below Outfall	11.31 ± 0.49	1.02 ± 0.04	1.05 ± 0.06	0.61 ± 0.03	0.79 ± 0.09	0.3 ± 0.1	0.6 ± 0.2	0.5 ± 0.2
July 27	Sawmill Creek - At Des Plaines River	11.93 ± 0.51	3.50 ± 0.07	1.11 ± 0.06	0.62 ± 0.03	0.62 ± 0.08	3.6 ± 0.5	29.6 ± 1.7	14.6 ± 0.8
	<u>Off-Site</u>								
May 11	Illinois River, Dresden, IL	9.03 ± 0.43	0.17 ± 0.02	0.51 ± 0.05	0.32 ± 0.02	0.33 ± 0.06	0.3 ± 0.3	3.9 ± 1.0	0.6 ± 0.2
May 11	Illinois River, McKinley Woods State Park, IL	8.55 ± 0.45	0.04 ± 0.01	0.79 ± 0.06	0.40 ± 0.03	0.47 ± 0.07	0.3 ± 0.3	2.6 ± 0.9	0.8 ± 0.2
May 11	Illinois River, Morris, IL	7.51 ± 0.25	0.02 ± 0.01	0.18 ± 0.02	0.18 ± 0.01	0.24 ± 0.03	4.3 ± 0.4	47.9 ± 2.2	17.6 ± 1.8
May 12	Des Plaines River, Brookfield, IL	16.55 ± 0.57	0.50 ± 0.03	1.22 ± 0.07	0.67 ± 0.03	0.72 ± 0.08	0.6 ± 0.3	10.2 ± 1.1	1.8 ± 0.8
May 12	Salt Creek, Western Springs, IL	17.72 ± 0.59	0.10 ± 0.02	1.98 ± 0.07	0.87 ± 0.03	1.00 ± 0.09	0.3 ± 0.1	2.4 ± 0.4	0.5 ± 0.6
October 11	McGinnis Slough, Orland Park, IL	16.94 ± 0.73	0.97 ± 0.04	1.07 ± 0.06	0.68 ± 0.03	0.65 ± 0.09	1.0 ± 0.2	21.8 ± 1.2	9.7 ± 1.6
October 11	DuPage River, Channahon, IL	12.91 ± 0.72	0.34 ± 0.03	1.00 ± 0.07	1.18 ± 0.04	0.99 ± 0.09	0.3 ± 0.2	6.9 ± 0.8	1.4 ± 0.4
October 11	Saganashkee Slough, IL	17.99 ± 0.83	0.07 ± 0.02	0.71 ± 0.07	0.49 ± 0.04	0.42 ± 0.09	0.2 ± 0.2	2.0 ± 0.4	0.8 ± 0.2
October 13	Illinois River, Starved Rock State Park, IL	3.97 ± 0.58	0.02 ± 0.02	0.68 ± 0.06	0.23 ± 0.03	0.30 ± 0.07	0.1 ± 0.1	0.7 ± 0.2	1.4 ± 0.2
	Average	12.35 ± 3.49	0.25 ± 0.21	0.90 ± 0.34	0.56 ± 0.22	0.57 ± 0.19	0.8 ± 0.9	10.9 ± 10.2	3.8 ± 3.9

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

TABLE 4.16

Environmental Penetrating Radiation at ANL, 1988

Location*	Dose Rate (mrem/year)				Average
	Period of Measurement				
	1/18-4/19	4/19-7/14	7/14-10/19	10/19-1/12	
14L - Boundary	80	88	84	80	83 ± 4
14I - Boundary	116	127	123	116	120 ± 5
14G - Boundary	94	98	97	91	95 ± 4
9/10EF - Boundary	87	94	95	90	92 ± 4
8H - Boundary	87	96	94	91	92 ± 4
8H - Boundary, Center, St. Patrick's Cemetery	91	102	96	94	96 ± 5
7I - Boundary	103	108	142	225	144 ± 56
6I - 200 m N of Quarry Road	-	95	97	91	94 ± 3
9H - 50 m SE of CP-5	1420	1440	1360	1260	1370 ± 81
8H - 65 m S of Building 316	81	91	90	85	87 ± 5
8H - 200 m NW of Waste Storage Area (Heliport)	88	91	96	93	92 ± 3
7I - Center, Waste Storage Area Facility 317	212	226	1150	6460	2010 ± 3000
10/11K - Lodging Facilities	79	81	79	77	79 ± 2
9I - 65 m NE of Building 350, 230 m NE of Building 316	84	91	83	80	84 ± 5

*See Figure 1.1.

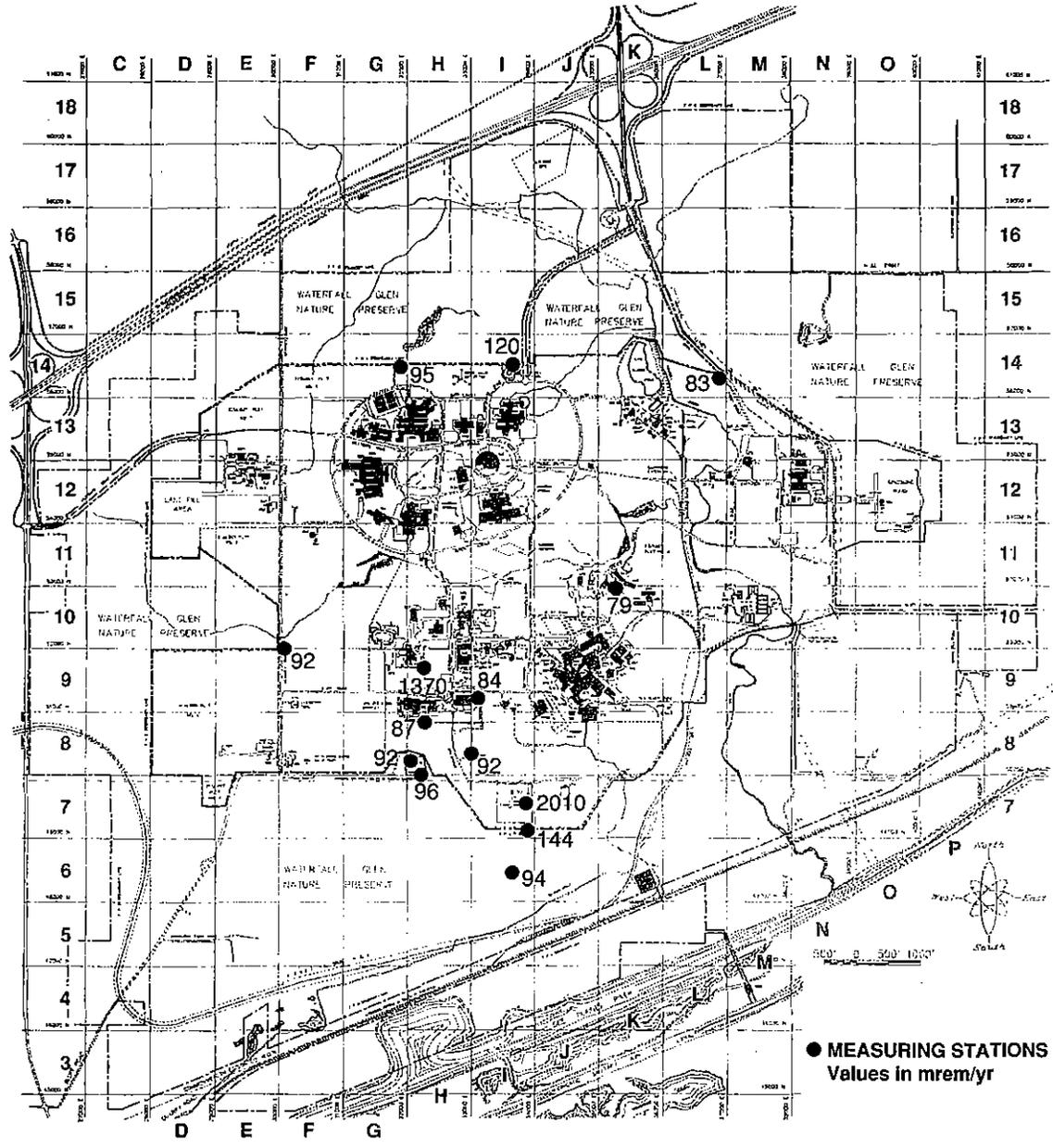


Fig. 4.1 Penetrating Radiation Measurements at the ANL Site, 1988

The off-site results averaged 93 ± 5 mrem/y and are similar to last year's off-site average of 90 ± 5 mrem/y. If the off-site locations are an accurate sample of the radiation background in the area, then annual averages at the site in the range of 93 ± 5 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 6.2 mrem/y, so that individual results in the range of 93 ± 12 mrem/y may be considered to be the average natural background with a 95% probability, unless there are known reasons to the contrary.

At two site boundary locations, 7I (south) and 14I (north), the dose rates were consistently above the average background. At 7I this was due to radiation from a Radioactive Waste Storage Facility (317) in the northern half of grid 7I. Waste is packaged and temporarily kept in this area prior to removal for permanent storage off-site. The net above-background dose at this location was about 51 mrem/y, the lowest value obtained since the TLD measurements were made at this location. In previous years, this value has ranged from 865 mrem/y in 1985 to 114 mrem/y in 1977. About 300 m (0.2 mi) south of the fence in grid 6I, the measured dose dropped to 94 ± 3 mrem/y, within the normal background range. The lower doses at the 7I boundary and in the center of the 317 facility, relative to previous years, was a result of the shipment off-site of much of the stored radioactive waste in the fall of 1987. As indicated by the increase in dose in the center of the 317 facility and the 7I boundary during the second half of 1988, radioactive waste is again accumulating in this area.

The other elevated perimeter area is at Location 14I, at the north boundary, where a dose rate of 27 mrem/y above background was measured. This is similar to the value of 22 mrem/y measured in 1987. This dose is due 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.

The dose in the south portion of grid 8H is of interest. This area includes St. Patrick's Cemetery, which was in use before ANL was constructed and is open to visitors. In 1988, as in previous years, this dose was

estimated to be 5 to 10 mrem/y above the off-site average. Possible explanations are that the 8H dose rates are natural since the differences between the off-site and 8H averages are not statistically significant at the 95% confidence level, or that the monument stones in the cemetery produce the elevated rates, because above-background dose rates were obtained from one of the large red granite stones, and granite is known to contain above-average levels of natural thorium and its decay products.

4.7. Potential Radiation Dose Estimates

The radiation doses at the site boundary and off the site, that could have been received by the public from radioactive materials and radiation leaving the site, were calculated. These calculations were made for three exposure pathways, including airborne, water, and direct radiation from external sources. DOE draft guidance⁶ requires the use of the EPA-AIRDOSE/RADRISK model and computer program¹⁵ for the calculation of the submersion dose for radionuclides released to the air.

4.7.1. Airborne Pathway

DOE facilities with airborne releases are subject to 40 CFR Part 61, Subpart H,¹⁶ which requires the use of the EPA-AIRDOSE/RADRISK code to demonstrate compliance with this regulation. The dose limits for the air pathway are 25 mrem/y to the whole body and 75 mrem/y to any organ. The EPA-AIRDOSE/RADRISK computer code uses a modified Gaussian plume equation to estimate both horizontal and vertical dispersion of radionuclides released to the air from stacks or area sources. For 1988, dose calculations were carried out 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 building. The wind speed and direction data shown in Figure 1.3 are the meteorological data used for these calculations. The calculations were carried out to 80 km (50 mi) using the population distribution of 16 segments and ten distance increments given in Table 1.1. The dose rate was calculated at the midpoint of each interval and integrated over the entire area to give the annual population cumulative dose.

Distances from the specific facilities which exhaust radiological airborne emissions to the fenceline (perimeter) and nearest resident were determined in the 16 compass segments (see Table 4.5). The EPA-AIRDOSE/RADRISK computer code was used to calculate the total dose at each of these locations. Calculations were also 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 in these tables are the committed whole body effective dose equivalents.

The dominant contributor to the doses is the radon-220 and daughters from Building 200. This accounts for 98% of the off-site dose. The highest perimeter dose rates are in the north to east sectors with maximum dose of 1.5 mrem/y at a fenceline location north of Building 203 (location 14H in Figure 1.1). The major contributor to this dose is inhalation of lead-212 (0.80 mrem/y) and the organs receiving the greatest dose are 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 dose (0.52 mrem/y), is located approximately 0.5 km (0.3 mi) north of the site boundary. The major contributor is the inhalation dose from lead-212 (0.33 mrem/y), but it is smaller than the perimeter dose because of the greater distance from the source.

The population data in Table 1.1 were used to calculate the cumulative population dose from gaseous radioactive effluents. The results are given in Table 4.27, together with the natural external radiation dose. The natural radiation dose was that measured at the off-site TLD locations, and it is assumed that this dose is representative of the entire area within an 80 km (50 mi) radius.

TABLE 4.17

Airborne Releases From Buildings 200 and 211, 1988

Source Term: Carbon-11 = 0.5 Ci
 Nitrogen-13 = 1.3 Ci
 Oxygen-15 = 8.0 Ci
 Radon-220 = 3728 Ci (plus daughters)

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	500	1.32	1000	0.41
NNE	600	1.50	1100	0.52
NE	750	0.97	2600	0.11
ENE	1700	0.21	3100	0.079
E	2400	0.12	3500	0.066
ESE	2200	0.14	3600	0.065
SE	2100	0.14	4000	0.052
SSE	2000	0.14	4000	0.053
S	1500	0.037	4000	0.0083
SSW	1000	0.29	2500	0.080
SW	800	0.62	2200	0.12
WSW	1100	0.28	1500	0.17
W	750	0.47	1500	0.15
WNW	800	0.24	1300	0.11
NW	600	0.48	1100	0.17
NNW	600	0.60	800	0.38

TABLE 4.18

Maximum Perimeter and Individual Doses From
Buildings 200 and 211 Air Emissions, 1988

(mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (600 m NNE)				
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	0.0015	0.0015
Radon-220	< 0.0001	0.58	0.0002	0.58
Lead-212	< 0.0001	0.80	0.0002	0.80
Bismuth-212	< 0.0001	0.12	0.0003	0.12
Thallium-208	< 0.0001	< 0.0001	0.0046	0.0046
Individual (1100 m NNE)				
Carbon-11	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nitrogen-13	< 0.0001	< 0.0001	0.0001	0.0001
Oxygen-15	< 0.0001	< 0.0001	0.0005	0.0005
Radon-220	< 0.0001	0.14	< 0.0001	0.14
Lead-212	< 0.0001	0.33	0.0001	0.33
Bismuth-212	< 0.0001	0.050	0.0001	0.050
Thallium-208	< 0.0001	< 0.0001	0.0016	0.0016

TABLE 4.19

Airborne Releases From Building 202 (JANUS), 1988

Source Term: Argon-41 = 1.3 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	0.0003	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	0.0001	1000	< 0.0001
NNW	250	0.0002	800	< 0.0001

TABLE 4.20

Maximum Perimeter and Individual Doses From
 Building 202 (JANUS) Air Emissions, 1988
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (250 m NNE)				
Argon-41	< 0.0001	< 0.0001	0.0003	0.0003
Individual (1500 m NE)				
Argon-41	< 0.0001	< 0.0001	< 0.0001	< 0.0001

TABLE 4.21

Airborne Releases From Building 212, 1988

Source Term: Hydrogen-3 (HT) = 9.1 Ci
 Hydrogen-3 (HTO) = 5.8 Ci
 Krypton-85 = 7.1 Ci
 Radon-220 = 1.2 Ci (plus daughters)

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	800	0.0016	2000	0.0006
NNE	1000	0.0017	2500	0.0006
NE	1300	0.0012	2000	0.0008
ENE	1500	0.0010	2500	0.0005
E	1600	0.0009	2800	0.0005
ESE	1200	0.0013	2500	0.0006
SE	1400	0.0009	3500	0.0003
SSE	1400	0.0011	4500	0.0003
S	1500	0.0001	5000	< 0.0001
SSW	1600	0.0005	5000	0.0002
SW	1400	0.0009	2400	0.0005
WSW	1300	0.0008	2300	0.0004
W	1700	0.0005	2200	0.0004
WNW	1500	0.0003	2000	0.0002
NW	1300	0.0005	2000	0.0003
NNW	1000	0.0008	2000	0.0004

TABLE 4.22

Maximum Perimeter and Individual Doses From
 Building 212 Air Emissions, 1988
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (1000 m NNE)				
Hydrogen-3	0.0001	0.0003	< 0.0001	0.0005
Krypton-85	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Lead-212	< 0.0001	0.0001	< 0.0001	0.0001
Individual (2000 m NE)				
Hydrogen-3	< 0.0001	0.0001	< 0.0001	0.0002
Krypton-85	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Lead-212	< 0.0001	< 0.0001	< 0.0001	< 0.0001

TABLE 4.23

Airborne Releases From Building 330 (CP-5), 1988

Source Term: Hydrogen-3 (HTO) = 35 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	1500	0.0006	2000	0.0004
NNE	1800	0.0007	3300	0.0003
NE	2100	0.0005	2800	0.0003
ENE	2200	0.0004	3300	0.0002
E	1500	0.0007	3100	0.0003
ESE	1300	0.0009	3500	0.0002
SE	1200	0.0009	3500	0.0002
SSE	1000	0.0013	3500	0.0002
S	500	0.0005	3000	< 0.0001
SSW	700	0.0012	3500	0.0002
SW	900	0.0013	2400	0.0003
WSW	1400	0.0006	2000	0.0004
W	700	0.0012	2000	0.0003
WNW	700	0.0007	1900	0.0002
NW	1500	0.0003	2000	0.0002
NNW	1600	0.0004	1900	0.0003

TABLE 4.24

Maximum Perimeter and Individual Doses From
 Building 330 (CP-5) Air Emissions, 1988
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (1000 m SSE)				
Hydrogen-3	0.0003	0.0001	< 0.0001	0.0013
Individual (2000 m N)				
Hydrogen-3	< 0.0001	0.0003	< 0.0001	0.0004

TABLE 4.25

Airborne Releases From Building 375 (IPNS), 1988

Source Term: Carbon-11 = 86 Ci
 Argon-41 = 1.5 Ci

Direction	Distance to Perimeter (m)	Total Dose (mrem/y)	Distance to Nearest Resident (m)	Total Dose (mrem/y)
N	1600	0.0044	3200	0.0013
NNE	1700	0.0059	3100	0.0021
NE	1700	0.0055	2700	0.0025
ENE	1500	0.0060	2500	0.0025
E	600	0.0024	2500	0.0027
ESE	600	0.0024	2500	0.0026
SE	600	0.0020	2500	0.0022
SSE	600	0.0024	3000	0.0017
S	800	0.0024	3000	0.0003
SSW	800	0.0088	3500	0.0009
SW	800	0.013	4000	0.0009
WSW	1500	0.0041	2700	0.0016
W	2200	0.0020	2700	0.0014
WNW	1500	0.0021	2600	0.0008
NW	2200	0.0014	2500	0.0011
NNW	1800	0.0024	2200	0.0018

TABLE 4.26

Maximum Perimeter and Individual Doses From
 Building 375 (IPNS) Air Emissions, 1988
 (mrem/y)

Radionuclide	Ingestion	Pathway Inhalation	Immersion	All Pathways
Perimeter (600 m SSE)				
Carbon-11	< 0.0001	0.0019	0.0214	0.0236
Argon-41	< 0.0001	< 0.0001	0.0005	0.0005
Individual (2400 m E)				
Carbon-11	< 0.0001	0.0002	0.0024	0.0026
Argon-41	< 0.0001	< 0.0001	< 0.0001	< 0.0001

TABLE 4.27

80 km Population Dose, 1988
(man-rems)

Radionuclide	Dose
Hydrogen-3	0.12
Carbon-11	0.14
Nitrogen-13	< 0.01
Oxygen-15	< 0.01
Argon-41	0.02
Krypton-85	0.21
Radon-220	0.02
Polonium-216	< 0.01
Lead-212	22.90
Bismuth-212	1.66
Thallium-208	< 0.02
Total	25.1
Natural	7.3×10^5

The potential radiation exposures by the inhalation pathways were also calculated by the methodology specified in the draft guidance.⁶ The total quantity for each radionuclide inhaled, in microcuries (μCi), is calculated by multiplying the annual average air concentrations by the general public breathing rate of $8,400 \text{ m}^3/\text{y}$.¹⁷ This annual intake is then multiplied by the EFF.D.E. for the appropriate lung retention class (D, W, or Y). Because the EFF.D.E. are in units of Rem per microcurie ($\text{Rem}/\mu\text{Ci}$), this calculation gives the 50-year committed effective dose equivalent. The applicable EFF.D.E. are collected in Table 4.28.

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

4.7.2. Water Pathway

Similarly, following the methodology outlined in the draft guidance, the ingestion annual intake, in μCi , is obtained by multiplying the concentration in microcuries per milliliter ($\mu\text{Ci}/\text{mL}$) by the annual water consumption of a member of the general public ($7.3 \times 10^5 \text{ mL}$). This annual intake is then multiplied by the EFF.D.E. for ingestion (Table 4.28) to obtain the dose. This is carried out for all radionuclides and summed to obtain the total ingestion dose.

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

TABLE 4.28

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

Nuclide	Ingestion	Inhalation
Hydrogen-3	6.3×10^{-5}	6.3×10^{-5}
Beryllium-7	-	2.7×10^{-4}
Carbon-11	-	8.0×10^{-6}
Strontium-90	0.13	1.3
Cesium-137	0.05	0.032
Lead-212	-	0.13
Radium-226	1.1	-
Thorium-228	-	0.031
Thorium-230	-	0.062
Thorium-232	-	0.0011
Uranium-234	0.26	0.013
Uranium-235	0.25	0.012
Uranium-238	0.23	0.012
Neptunium-237	0.39	-
Plutonium-238	0.38	-
Plutonium-239	0.43	0.033
Americium-241	2.2	-
Curium-242	0.065	-
Curium-244	1.1	-
Californium-249	2.3	-
Californium-252	0.48	-

dose rates were all well below the standards for the general population and 50% less than in 1987. 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, 1988

Nuclide	Total Released (millicuries)	Net Avg Conc (pCi/L)	Dose (mrem/y)
Hydrogen-3	1893	247	0.011
Strontium-90	2.9	0.38	0.036
Cesium-137	7.7	1.0	0.036
Neptunium-237	0.02	0.0029	0.0008
Plutonium-239	0.09	0.0116	0.004
Americium-241	0.12	0.0160	0.026
Sum			0.114

As indicated in Table 4.7, occasional Sawmill Creek samples (less 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 that was 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 U. S. Environmental Protection Agency (EPA) has established drinking water standards based on a dose of 4 mrem/y for man-made beta particle and photon-emitting radionuclides.¹⁸ The EPA standard is 2×10^4 pCi/L for hydrogen-3, 8 pCi/L for strontium-90, and 200 pCi/L for cesium-137. The concentrations in Table 4.29 correspond to 1.2% (hydrogen-3), 5%

(strontium-90), and 0.5% (cesium-137) of the EPA standards. No specific EPA standards exist for the transuranic nuclides.

4.7.3. External Direct Radiation Pathway

The TLD results in Section 4.6 are used to calculate the radiation dose from external sources. Above-normal fenceline doses attributable to ANL operations were found at the south boundary near the Waste Storage Facility (Location 7I) and at the north boundary near Building 202 (Location 14I).

At Location 7I, the net fenceline dose from ANL was about 51 mrem/y. Approximately 300 m (0.3 mi) south of the fenceline (grid 6I), the measured dose was 94 ± 3 mrem/y, well within the normal range of the off-site average (93 ± 5 mrem/y). There are no individuals living in this area. The closest residents are about 1.6 km (1 mi) south of the fenceline. At this distance, the calculated dose rate from the Waste Storage Facility is < 0.01 mrem/y, if the energy of the radiation was the 0.66 MeV cesium-137 gamma-ray and about 0.01 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 27 mrem/y. The nearest residents are 750 m (0.47 mi) to the north-northwest. The calculated dose at that location was about 0.14 mrem/y.

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

4.7.4. Dose Summary

The total dose received by off-site residents was a combination of the separate pathways that contribute to this total: hydrogen-3, carbon-11, nitrogen-13, oxygen-15, argon-41, krypton-85, and radon-220 (plus daughters), by the airborne pathway and cobalt-60 external radiation dose. The highest dose was about 0.66 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 25 man-rem.

In order to put the maximum individual dose of 0.66 mrem/y into perspective, comparisons can be made to annual average doses received by the public from natural or accepted sources of radiation. These are listed in Table 4.30. It is obvious that the magnitude of the doses received from ANL operations is insignificant compared to these sources. Therefore, the monitoring program results establish that the radioactive emissions from ANL are very low and do not endanger the health or safety of those living in the vicinity of the site.

TABLE 4.30

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. 93.¹⁹

5. ENVIRONMENTAL NON-RADIOLOGICAL PROGRAM INFORMATION

The chemical data collected for surface water are determined by the regulations pertaining to the type of water being studied. There are ten discharges that 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 136²⁰ and there are no exceptions to this rule. Sample collection, preservation, and holding times are also mandated and these requirements can be found in SW-846.²¹

Effluents not included in the permit are sampled and analyzed and the results are compared to general effluent standards listed in the STATE OF ILLINOIS RULES AND REGULATIONS, Title 35, Subtitle C, Chapter I.²² The specific requirements are listed in Part 304, Subpart A. The impact of all the effluents on the stream quality is studied and compared to the stream standards listed in Part 302, Subpart B, of this document. The state standards are listed in Table 5.1.

5.1. Sample Collection

The samples for NPDES compliance are collected by Environment, Safety and Health Department (ESH) personnel with the exception of samples from 001B and 001C (see Figure 5.1) which are collected by Plant Facilities and Services Division (PFS) personnel. All samples are collected using specially cleaned and labelled bottles with appropriate preservative added, custody seals, chain of custody sheets, and instructions for collection.

5.2. National Pollutant Discharge Elimination System (NPDES)

ANL discharges are regulated by NPDES Permit No. IL 0034592.²³ This permit was renewed on September 28, 1984, and several modifications took effect on June 28, 1987. The modifications consisted primarily of the addition of sampling requirements for coal pile runoff (001C). Requirements to sample wastewater from a system designed to handle excess runoff water resulting from heavy precipitation or pump failure were also added.

TABLE 5.1

Water Quality Standards
(Concentrations in mg/L)

Constituent	State Standard	
	Stream	Effluent
Ammonia Nitrogen (as N)	1.5	2.5 (Apr.-Oct.) 4.0 (Nov.-Mar.)
Arsenic	1.0	0.25
Barium	5.0	2.0
Cadmium	0.05	0.15
Chloride	500	-
Chromium	1.0	1.0
Copper	0.02	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

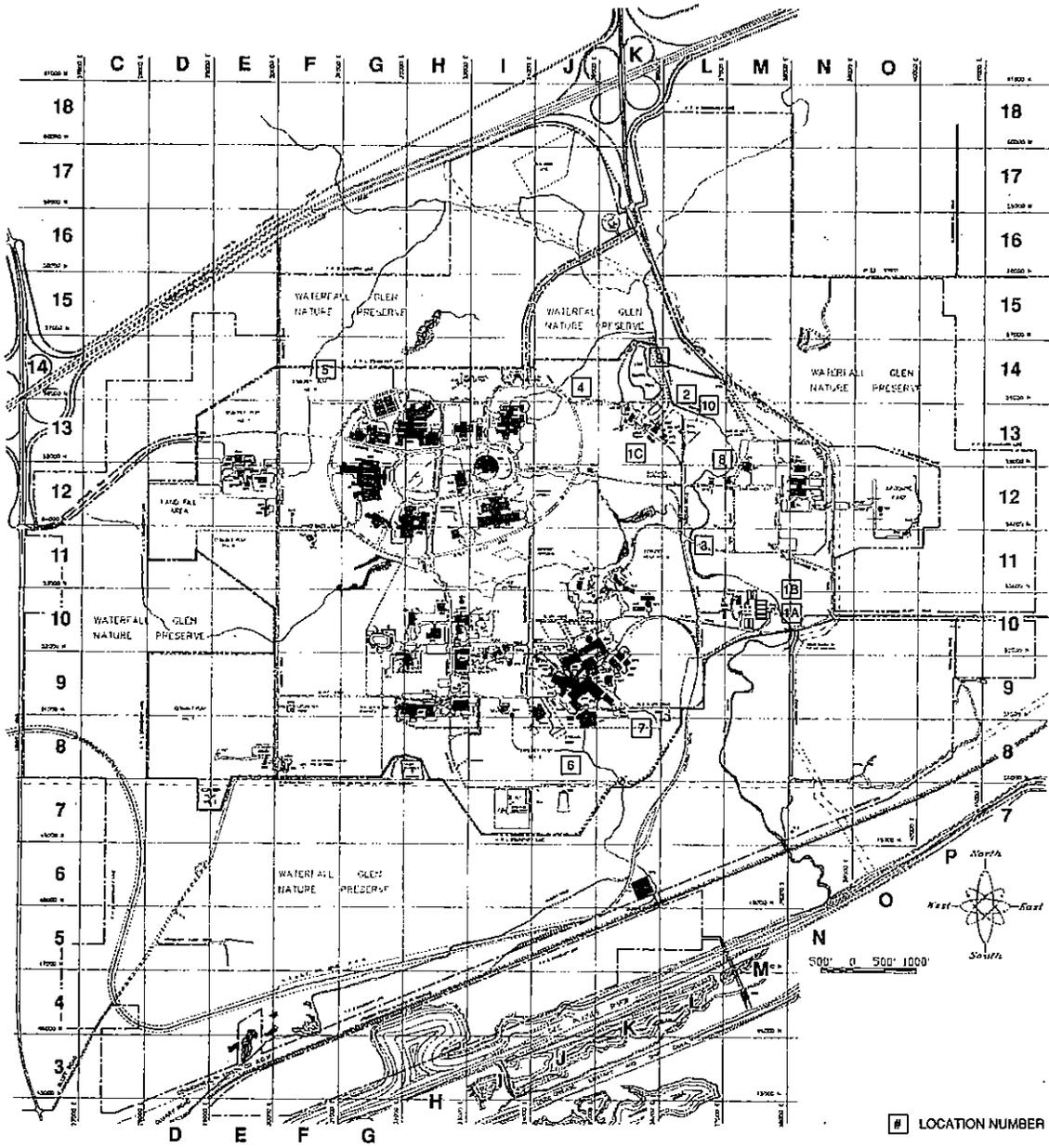


Fig. 5.1 NPDES Permit Locations

The NPDES locations are shown in Figure 5.1. For purposes of clarity, the location numbers in the figure are given without the leading zeroes. Thus, permit location 001 is given as 1. Locations 001A, 001B, and 001C are tributary to location 001, ANL's major outfall. Samples at locations 001A, 001B, and 001 are collected weekly, while most of the other samples are collected monthly.

Special conditions exist for Sawmill Creek. The domestic water at ANL is now softened using ion-exchange resins and the backwash solution is routed through the ANL wastewater system (001B) and enters Sawmill Creek at 7M. The permit requires that grab samples be collected semimonthly upstream and downstream of the outfall. A 24-hour sample, encompassing the time period of the grab samples, is collected at location 001. The permit limits for the downstream grab sample for chloride, sulfate, and TDS are not to be exceeded. The 24-hour sample at location 001 may exceed the permit limit if the downstream grab sample does not exceed the limit.

The collection of coal pile runoff has special sampling requirements (see Section 3.2.3.). The leachate from the coal storage is initially collected in a pit and flows by gravity to a lift station. The liquid is then pumped to a small settling pond. The water drains into a second lift station, where sampling for location 001C occurs. Wastewater flowing past this sampling point, 001C, also contains effluent from the water purification plant and boiler house. These latter flows were sampled at location 002 until this channel was permanently closed in mid-1987.

The system at location 010, which leads directly to Sawmill Creek, serves as an emergency overflow and must be sampled once per month when flowing. No flow was recorded in 1988.

Sampling of the lime pond effluent at location 009 is required only when overflow occurs. Sufficient solids were removed from the lime pond bottom so that the water level in the pond is normally well below the outfall pipe. One sample was obtained in 1988.

Samples were collected in accordance with EPA requirements using the proper preservatives and holding times. Analyses were performed using test procedures listed in 40 CFR Part 136.²⁰

The results for chloride, sulfate, and TDS are shown in Table 5.2 for samples collected at location 001 and upstream and downstream of location 001 in Sawmill Creek.

TABLE 5.2

Impact of Effluent Water on Sawmill Creek, 1988
(Concentrations in mg/L)

Constituent	Upstream	Location 001	Downstream	Limit
Chloride	141 ± 22	613 ± 64	475 ± 98	500
Sulfate	96 ± 14	212 ± 13	140 ± 16	500
TDS	651 ± 14	1756 ± 69	1368 ± 183	1000

The downstream levels are used to measure compliance. Levels for chloride exceeded the limit 25% of the time, primarily in the summer. The TDS exceeded the limit 79% of the time, encompassing the whole year. Sulfate has been below the limit in every sample. Domestic water is treated by ion exchange and the regeneration solutions, containing high concentrations of sodium chloride, are disposed of in the ANL laboratory wastewater system. The chloride and TDS are elevated by this process. A system has been designed to reduce these constituents.

Results for the other regulated effluents are in Table 5.3. Sample collection at 001C is only required when flow occurs from the coal pile and this resulted in 18 samples being collected in 1988. The pH ranged from 2.5 to 11.2 with 12 of 18 within the acceptable range of 6-9. Iron levels exceeded the limit of 4 mg/L on 12 occasions and manganese and zinc exceeded

TABLE 5.3

NPDES Effluent Quality Summary, 1988

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R <u>Measured Permit</u>
			30 Day Average	Daily Max.		
001A	50	Flow	None		0	-
		BOD	30	60	0	-
		TSS	30	60	0	-
001B	50	Flow	None		0	-
		Chemical Oxygen Demand	-	-	0	-
		TSS	15	30	0	-
		Mercury	0.003	0.006	0	-
001C	18	Iron	2	4	12	1.5-220
		Lead	0.2	0.4	0	-
		Zinc	1	2	2	1.4-2.5
		Manganese	1	2	2	1.2-2.5
		Chromium (Total)	1	2	0	-
		Copper	0.5	1	0	-
		Oil and Grease	15	30	0	-
		TSS	15	30	8	1.1-7.8
		pH	6-9		4	2.5, 2.7, 9.2, and 11.21
001	50	pH	6-9		0	-
		Fecal Coliform	-	<u>400 organisms</u> 100 mL	2	1.7-4.3
		BOD	30	60	0	-
		TSS	30	60	0	-
002	6	Flow	None		0	-
		pH	6-9		0	-
		TSS	15	30	0	-
		Temperature	< 2.8°C Rise		0	-

TABLE 5.3 (Contd.)

Discharge Location	Number of Samples Collected	Permit Constituent	Concentration Limits mg/L		Number Exceeding Limit	*R	<u>Measured Permit</u>
			30 Day Average	Daily Max.			
003	12	Flow	None		0		-
		pH	6-9		0		-
		TSS	15	30	4		1.2-2.7
		Temperature	< 2.8°C Rise		0		-
004	12	Flow	None		0		-
		pH	6-9		0		-
		TSS	15	30	4		1.1-2.0
		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	0		-
		Zinc	1.0	2.0	0		-
007	12	Flow	None		0		-
		pH	6-9		0		-
		Temperature	< 2.8°C Rise		0		-
008	12	Flow	None		0		-
		pH	6-9		0		-
009	1	Flow	None		0		-
		pH	6-9		0		-
		TSS	15	30	1		2.0

*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 2 mg/L limit on two occasions. Levels of chromium, copper, and lead were never above the permit limits.

Two samples at location 001 exceeded the limit for fecal coliform. In one instance the chlorinator was inoperative for one hour. The second case is believed to have been caused by upstream contamination since the upstream fecal coliform levels were comparable and high water flow probably washed creek water into the outfall sewer at location 7M. However, the residual chlorine of the effluent was 0.8 ppm and should have been more than enough to reduce bacterial levels.

One sample was obtained at location 009, which was the result of a heavy rainfall. The permit requires semimonthly inspection of this point and sampling when flow occurs. The TSS level was (60 mg/L) twice the limit. The lime pond, which location 009 drains, is to be removed in the next several years. Violations of the TSS levels at locations 003 and 004 have been observed. These can usually be related to high storm flows.

5.3. Waste Water Treatment Plant Effluent

The water volume from the Waste Water Treatment Plant averaged 1.06 million gallons per day and comprised 48% sanitary waste water and 52% laboratory process water. Laboratory process water is normally collected in 69,000 gallon tanks, and then pumped into a large holding pond. Water from the pond is discharged rate by means of a flow control valve which regulates the release rate. This results in a constant flow over a 24-hour period. For a good portion of 1988, the pumps were inoperative, and the water was released by gravity through a gate valve over an eight-hour period.

Daily samples from the Waste Water Treatment Plant are collected in a 24-hour flow proportional sampler and are then transferred to specially cleaned bottles and are security sealed. The daily samples are composited on an equal volume basis to produce a weekly sample. These weekly samples are analyzed within the required holding period using EPA methods.²⁴

The results obtained are shown in Table 5.4. All of the average concentrations were below state standards and similar to last year's values. The average value for mercury was 24% of the monthly average state effluent standard of 0.5 $\mu\text{g/L}$, however, individual samples exceeded this limit twice. This general effluent standard is much more restrictive than the mercury limit in the NPDES permit. The mercury concentration is restricted by the permit to 6 $\mu\text{g/L}$ for any sample and to a monthly average of 3 $\mu\text{g/L}$. There were no violations of these limits. The state general effluent regulations allow a single sample to be five times the state standard if the monthly average is not exceeded. In the case of mercury, a single result could be up to 2.5 $\mu\text{g/L}$. The maximum value found was 0.62 $\mu\text{g/L}$.

5.4. Sawmill Creek

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

Samples were obtained semimonthly to evaluate the effect of sanitary waste on the creek using sampling bottles designed to minimize aeration. The samples were analyzed for ammonia nitrogen, dissolved oxygen, pH, and temperature. Results are shown in Table 5.5. Results downstream are not appreciably different from upstream results, thus, no major effect is observed. The results for chloride, sulfate, and TDS are included for comparison and were discussed earlier.

Samples were also collected to evaluate the effect of ANL discharges on levels of inorganic constituents in the creek. Time proportional samples were obtained each working day of the week and composited on either a weekly or monthly basis. The results are shown in Table 5.6. The average result for copper was above the state limit of 20 $\mu\text{g/L}$, and the standard was exceeded 69% of the time. This result is about 1.5 times the value of that

TABLE 5.4
 CHEMICAL CONSTITUENTS IN EFFLUENTS FROM ANL TREATMENT PLANT, 1988
 (CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	12	-	-	< 5	< 2.0	0
BARIUM	12	107 ± 14	63	135	5.3	0
BERYLLIUM	12	0.04 ± 0.01	0.01	0.05	-	-
CADMIUM	12	0.9 ± 0.3	0.5	1.9	0.6	0
CHROMIUM	51	17 ± 1	10	24	-	-
COPPER	51	28 ± 2	14	55	5.5	0
FLUORIDE	12	412 ± 42	290	520	2.7	0
IRON	51	262 ± 32	104	584	13	0
LEAD	12	5.6 ± 0.5	4.4	6.9	2.8	0
MANGANESE	51	57 ± 16	10	326	5.7	0
MERCURY	51	0.12 ± 0.03	0.05	0.62	24	4
NICKEL	12	38 ± 6	8	48	3.8	0
* PH	248	-	7.5	8.3	-	0
SELENIUM	12	-	-	< 5	< 0.5	0
SILVER	12	2.3 ± 0.5	1.5	3.6	2.3	0
ZINC	12	99 ± 53	39	328	10	0

*
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TABLE 5.5
SAWMILL CREEK - EFFECT OF SANITARY WASTE, 1988

CONSTITUENT	* LOCATION	NO. OF SAMPLES	CONCENTRATION (MG/L)			AVG. PERCENT OF STANDARD	PERCENT EXCEEDING STATE STANDARD
			AVG.	MIN.	MAX.		
AMMONIA NITROGEN	7M (UP)	23	0.1 ± 0.1	0.1	0.2	7	0
	7M (DOWN)	23	0.2 ± 0.1	0.1	0.6	11	0
CHLORIDE	7M (UP)	24	141 ± 22	52	238	-	-
	7M (DOWN)	24	475 ± 98	107	1160	-	-
DISSOLVED OXYGEN	7M (UP)	24	11.2 ± 1.0	6.7	14.7	-	0
	7M (DOWN)	24	10.8 ± 0.6	7.6	12.9	-	0
DISSOLVED SOLIDS	7M (UP)	24	651 ± 76	290	909	-	-
	7M (DOWN)	24	1370 ± 180	560	2450	-	-
** PH	7M (UP)	24	-	7.9	8.7	-	0
	7M (DOWN)	24	-	7.9	8.3	-	0
SULFATE	*** 7M (UP)	23	96 ± 14	41	177	-	-
	7M (DOWN)	24	140 ± 16	59	197	-	-
*** TEMPERATURE	7M (UP)	24	12.4 ± 4.0	0.3	27.2	-	-
	7M (DOWN)	24	14.0 ± 3.2	3.4	25.2	-	-

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

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*** DEGREES CENTIGRADE

TABLE 5.6
 CHEMICAL CONSTITUENTS IN SAWMILL CREEK LOCATION 7M, 1988
 (CONCENTRATIONS IN MICROGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.	PERCENT OF STANDARD (AVG.)	PERCENT EXCEEDING STATE STANDARD
ARSENIC	12	-	-	< 5	< 0.5	0
BARIUM	12	109 ± 10	80	136	2.2	0
BERYLLIUM	12	0.06 ± 0.02	0.05	0.16	-	-
CADMIUM	12	0.9 ± 0.2	0.5	1.3	1.8	0
CHROMIUM	51	17 ± 1	10	22	-	-
COPPER	51	41 ± 8	10	158	203	69
FLUORIDE	12	334 ± 50	220	466	24	0
IRON	51	928 ± 314	283	7330	93	20
LEAD	12	9 ± 2	5	16	9.4	0
MANGANESE	51	153 ± 38	25	848	15	0
MERCURY	51	0.30 ± 0.12	< 0.05	2.18	61	12
NICKEL	12	34 ± 7	8	40	3.4	0
** PH	242	-	7.5	8.4	-	0
SELENIUM	12	-	-	< 5	< 0.5	0
SILVER	51	4.1 ± 1.0	0.5	17.0	82	22
ZINC	12	87 ± 36	34	247	8.7	0

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

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found in 1987 and reflects lower water flow in Sawmill Creek as a result of drought conditions. There is no known source of copper in ANL processes and the constancy of values over the years indicates that the source may be copper plumbing used at ANL. The elevated levels of iron in the creek may result from a variety of natural sources, but a portion may be due to iron from the coal pile as well as from the ion exchange water treatment.

Six samples analyzed for mercury exceeded the average limit of 0.5 $\mu\text{g/L}$. However, in no case did the value exceed the 2.5 $\mu\text{g/L}$ single sample standard. Ten samples analyzed for silver exceeded the standard of 5 $\mu\text{g/L}$ and effluent levels (see Table 5.4) indicate that ANL might not be the sole source. Average and individual results for arsenic, barium, beryllium, cadmium, chromium, fluoride, lead, manganese, nickel, selenium, and zinc were below the state standards.

5.5. Des Plaines River

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

6. GROUNDWATER PROTECTION

6.1. Potable Water System

The ANL domestic water is supplied by four wells described in Section 1.5 and the locations are shown in Figure 1.1. ANL is a non-transient, non-community water system,¹⁸ which regularly serves at least 25 of the same persons over six months of the year. This designation determines the type of analyses and limits that apply.

Samples from each well were collected quarterly at the well head and an additional sample of the finished water was collected. These samples were analyzed for several types of radioactive and inorganic constituents. Additional samples, using the same sampling protocol, were collected by PFS and analyzed for the organic constituents shown in Table 6.1 by a contract laboratory.

Samples from each well were analyzed for hydrogen-3, strontium-90 and by gamma-ray spectrometry. The results are shown in Table 6.2. In addition to the well water samples, one tap water sample was collected, and the results are also shown in Table 6.2.

Since ANL is a "non-community water system", the EPA standards for this type of system apply. For the nuclides measured in Table 6.2, the following EPA limits are established:

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

The uranium results would be covered by the gross alpha standard. Inspection of Table 6.2 indicates that all measurements are well within the EPA drinking water standards. This program is being conducted to demonstrate ANL's compliance with the EPA drinking water regulations.

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
1,1-Dichloroethane	4-Methyl-2-Pentanone
1,2-Dichloroethene (total)	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

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

TABLE 6.1 (Contd.)

1,2-Dichlorobenzene	4-Nitroaniline
2-Methylphenol	4,6-Dinitro-2-Methylphenol
bis(2-chloroisopropyl)Ether	N-Nitrosodiphenylamine
4-Methylphenol	4-Bromophenyl-phenylether
N-Nitroso-Di-n-Propylamine	Mexachlorobenzene
Hexachloroethane	

Pesticides and Herbicides

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

PCBs

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

TABLE 6.2

Radioactivity in ANL Domestic Wells, 1988
(Concentrations in pCi/L)

Type of Activity	Location	No. of Samples	Avg.	Min.	Max.
Alpha (nonvolatile)	Well #1	4	4.4	1.5	6.9
	Well #2	4	4.6	3.7	5.3
	Well #3	4	3.4	2.4	4.1
	Well #4	4	2.9	2.5	3.1
	Tap	1	-	-	0.5
Beta (nonvolatile)	Well #1	4	9.4	6.3	10.9
	Well #2	4	9.5	8.7	10.2
	Well #3	4	8.0	6.6	8.7
	Well #4	4	8.6	7.7	9.7
	Tap	1	-	-	3.6
Hydrogen-3	Well #1	4	136	< 100	240
	Well #2	4	116	< 100	155
	Well #3	4	-	-	< 100
	Well #4	4	< 100	< 100	117
	Tap	1	-	-	141
Strontium-90	Well #1	1	-	-	< 0.25
	Well #2	1	-	-	< 0.25
	Well #3	1	-	-	< 0.25
	Well #4	1	-	-	< 0.25
	Tap	1	-	-	< 0.25
Radium-226	Well #1	1	-	-	1.42
	Well #2	1	-	-	0.67
	Well #3	1	-	-	0.67
	Well #4	1	-	-	0.54
	Tap	1	-	-	0.11
Uranium (natural)	Well #1	1	-	-	0.20
	Well #2	1	-	-	0.22
	Well #3	1	-	-	0.18
	Well #4	1	-	-	0.14
	Tap	1	-	-	0.19

Wells #1 and #2 had measurable levels of hydrogen-3 at various times during the year, although the average concentration was about 1% of the EPA standard. It is speculated that the source of the hydrogen-3 was from liquid wastes that were placed in holding ponds in the sewage treatment area (Location 10M in Figure 1.1) in the 1950s. The tritiated water may have migrated down through the soil to the dolomite and was drawn into the wells. Well #1, which is about 200 m north of the treatment area, had higher hydrogen-3 concentrations than Well #2, which is about 300 m from the treatment area. Although the normal subsurface water flow gradient is in the south direction, the cone of depression created by the pumping on these wells would overpower the normal pattern. The holding ponds have not been used for a number of years. 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 results for the inorganic constituents are listed in Tables 6.3 through 6.7. The results listed in these tables are similar to previous years and are well below any applicable standards.

In addition to the above results, inorganic analyses were provided by PFS for dissolved solids, copper, and lead. The levels of dissolved solids exceeded the state limit of 500 mg/L in all samples. Levels of copper and lead were well below the state limits. Lead was not only below the current limit of 50 $\mu\text{g/L}$ but below the proposed limit of 20 $\mu\text{g/L}$.

Analysis of quarterly well water samples for volatile organic compounds showed occasional positive results, although they were below the contract required detection limits (CRDL). An exception was a value of 130 $\mu\text{g/L}$ for acetone in water from Well #1 collected in October 1988 and 26 $\mu\text{g/L}$ from a December 1988 sample. Methylene chloride (CRDL = 5 $\mu\text{g/L}$) was found in Well #2 and ranged from 6 to 15 $\mu\text{g/L}$ and in Well #3 from 3 to 15 $\mu\text{g/L}$. Traces of 1,1,1-trichloroethane and tetrachloroethene were found in one sample each from Well #1 and Well #4; xylene was reported in one sample from Well #1; and toluene was found in one sample from Well #4. Of the compounds detected, only 1,1,1-trichloroethane is listed in Subpart G of the National

TABLE 6.3
 CHEMICAL CONSTITUENTS IN DOMESTIC WATER , 1988
 WELL 001
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	95 ± 20	77	108
CHLORIDE *	4	76 ± 24	53	90
DISSOLVED SOLIDS *	4	680 ± 120	600	800
FLUORIDE	3	236 ± 63	200	268
IRON	5	1450 ± 620	1020	2370
MANGANESE	5	39 ± 4	35	43
MERCURY	1	-	-	< 0.05
PH **	5	-	7.0	7.2
SELENIUM	4	-	-	< 5
SULFATE *	5	141 ± 31	102	165
ZINC	5	11 ± 9	5	20

*
 CONCENTRATION IN MILLIGRAM/LITER.

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TABLE 6.4
 CHEMICAL CONSTITUENTS IN DOMESTIC WATER , 1988
 WELL 002
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	92 ± 9	84	98
CHLORIDE *	4	52 ± 7	47	59
DISSOLVED SOLIDS *	4	648 ± 38	620	680
FLUORIDE	3	317 ± 151	236	400
IRON	4	1240 ± 450	980	1670
MANGANESE	4	18 ± 10	10	25
MERCURY	1	-	-	< 0.05
PH **	4	-	7.1	7.5
SELENIUM	4	-	-	< 5
SULFATE *	4	143 ± 5	139	148
ZINC	4	14 ± 10	5	20

*
 CONCENTRATION IN MILLIGRAM/LITER.

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 UNITS

TABLE 6.5
 CHEMICAL CONSTITUENTS IN DOMESTIC WATER , 1988
 WELL 003
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	68 ± 12	57	78
CHLORIDE [*]	4	47 ± 3	44	48
DISSOLVED SOLIDS [*]	4	640 ± 25	620	660
FLUORIDE	3	326 ± 116	280	398
IRON	4	1250 ± 240	1100	1420
MANGANESE	4	17 ± 11	10	24
MERCURY	1	-	-	< 0.05
PH ^{**}	4	-	7.1	7.3
SELENIUM	4	-	-	< 5
SULFATE [*]	4	164 ± 15	150	174
ZINC	4	12 ± 12	5	20

^{*} CONCENTRATION IN MILLIGRAM/LITER.

^{**} UNITS

TABLE 6.6
 CHEMICAL CONSTITUENTS IN DOMESTIC WATER , 1988
 WELL 004
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	53 ± 23	44	78
CHLORIDE *	4	43 ± 5	39	46
DISSOLVED SOLIDS *	4	660 ± 54	620	710
FLUORIDE	3	364 ± 144	290	446
IRON	4	1230 ± 48	1190	1260
MANGANESE	4	15 ± 8	10	20
MERCURY	1	-	-	< 0.05
PH **	4	-	7.1	7.5
SELENIUM	4	-	-	< 5
SULFATE *	4	146 ± 3	143	148
ZINC	4	12 ± 12	5	20

*
 CONCENTRATION IN MILLIGRAM/LITER.

**
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TABLE 6.7
 CHEMICAL CONSTITUENTS IN DOMESTIC WATER , 1988
 TAP WATER
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	9 ± 2	8	11
CHLORIDE *	4	50 ± 4	47	54
DISSOLVED SOLIDS *	7	689 ± 48	600	740
FLUORIDE	3	362 ± 92	330	420
IRON	4	111 ± 18	100	126
MANGANESE	4	13 ± 7	10	20
MERCURY	1	-	-	< 0.05
PH **	4	-	7.6	8.0
SELENIUM	4	-	-	< 5
SULFATE *	4	152 ± 2	150	154
ZINC	4	16 ± 9	9	23

*
 CONCENTRATION IN MILLIGRAM/LITER.

**
 UNITS

Primary Drinking Water Regulations.¹⁸ The maximum allowable level for this compound is 200 $\mu\text{g/L}$ and levels of 3 $\mu\text{g/L}$ and 4 $\mu\text{g/L}$ were found.

6.2. 317/319 Areas

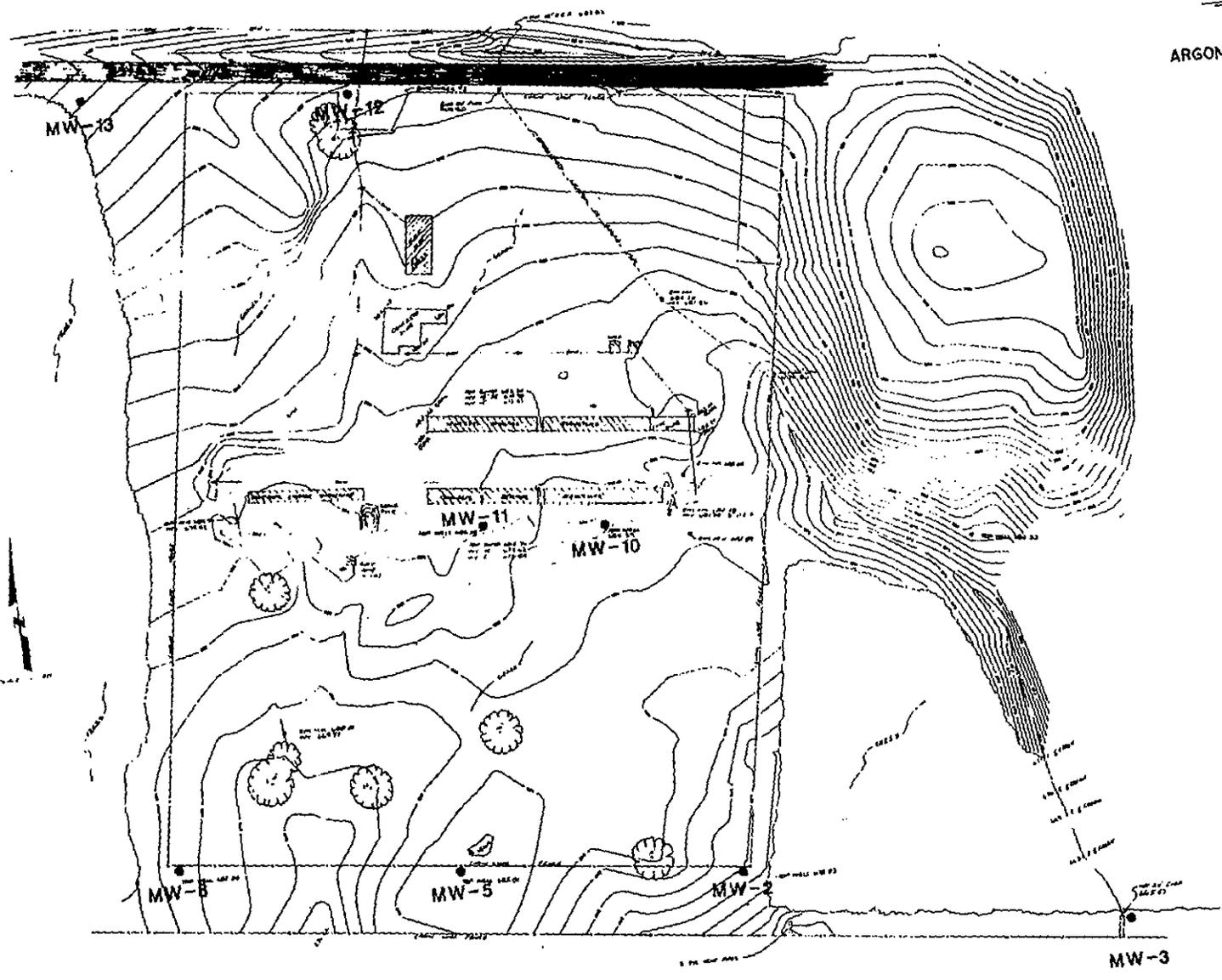
The 317 Area is a temporary storage area for radioactive waste before it is shipped off-site for permanent disposal. The 319 Area is a landfill that was used during the 1950s for the disposal of debris and equipment in which radioactive contamination could not be detected. When the complete absence of contamination could not be guaranteed, such as the inside of small pipes, the material was disposed of in this area. Recent information has indicated that two French drains, one in each area, were used for the disposal of liquid organic waste materials.

Monitoring wells (MW) have been installed in these areas and the locations are shown in Figure 6.1. MWs 1, 2, 3, and 4 were installed in September 1986; MWs 5 and 6 in August of 1987; MWs 7, 10, and 11 in July of 1988; and MWs 12 and 13 in September of 1988. MW 1 is upgradient of the 319 landfill and MWs 12 and 13 are upgradient of the 317 landfill. MWs 4, 5, and 7 were dry all year. MWs 8 and 9 were boreholes drilled south of the deep vault and filled with expanding cement grout after soil samples were obtained. The monitoring wells are sampled using the protocol in the RCRA Groundwater Monitoring Technical Enforcement Guidance Document.²⁵

Table 6.8 shows the well point and water elevations for the monitoring wells in the 317/319 Area. Water levels in MWs 1, 2, and 6 decreased throughout the year and are related to the drought conditions during the summer. The data in Table 6.8 were used to produce the water elevation profile shown in Figure 6.2, by using the TOPO part of the Surfer® software program obtained from the Golden Software Inc., Boulder, Colorado. As can be seen, there is an area of water at the 203 meter elevation. MWs 10, 11, and 12 do not change levels when two to three well volumes are removed indicating a relatively high soil permeability and a constant source of water in this area. The general groundwater flow from this site is in a southeasterly direction or toward the Des Plaines River.

MW-1

TOPOGRAPHIC MAP
BUILDING 317 AREA
ARGONNE NATIONAL LABORATORY



- LEGEND**
- WELL HEAD
 - UTA PIS POLE
 - OVERHEAD WIRE
 - PAVEMENT
 - FENCE
 - EXISTING BOUNDARY CONTROL
 - EXISTING AMP ELEVATION
 - ⊗ TREE
- MW-4

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

TABLE 6.8

Well Point and Water Level Elevations⁽¹⁾ of Monitoring
Wells⁽²⁾ at the ANL 317/319 Landfill Area - 1988

Well No.	Ground Surface Elevation	Well Depth	Well Point Elevation	Water Level Elevation, Quarterly				1988 Average
				1st	2nd	3rd	4th	
MW 1	210.27	12.31	197.96	202.39	201.83	199.65	198.26	200.53
MW 2	206.91	11.83	195.08	199.79	199.73	197.57	196.12	198.30
MW 3	204.43	12.05	192.38	193.43	194.46	Dry	Dry	193.95
MW 6	208.04	12.14	195.90	201.11	200.92	199.50	199.42	200.24
MW 10	208.60	8.77	199.83	--	--	204.78	205.78	205.28
MW 11	208.96	8.55	200.41	--	--	202.72	203.27	203.00
MW 12	211.50	11.74	199.76	--	--	203.55	202.46	203.01
MW 13	213.48	11.70	201.78	--	--	206.12	207.26	206.69

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

(2) Wells MWs 4, 5, and 7 were dry all year.

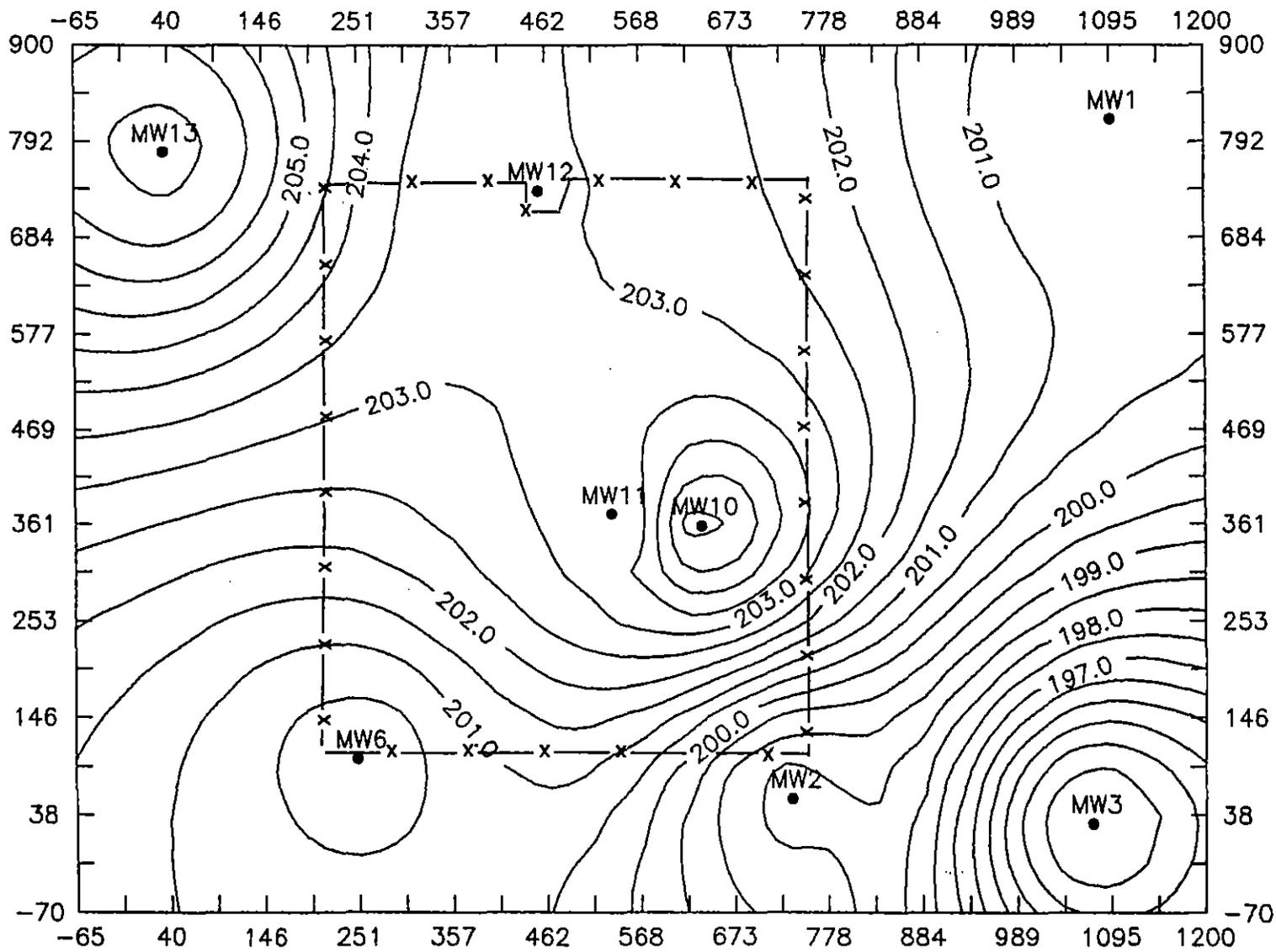


Fig. 6.2 317 Area Landfill Subsurface Water Elevation Profile, 1988

Samples were collected quarterly from these monitoring wells and analyzed for hydrogen-3, strontium-90, and for gamma-ray emitters. The results are collected in Table 6.9. The only evidence of possible migration off the site is low concentrations of hydrogen-3 and strontium-90 in MW 3. This monitoring well is directly below a small drainage swale that has contained water intermittently with measurable concentrations of hydrogen-3 and strontium-90 from the 319 Area. MWs 10 and 11 are next to facilities that have stored radioactive materials in the past. All concentrations are well below any applicable standards.

The inorganic data are in Tables 6.10 through 6.17. Some results on these and the following tables use, for example, the notation 13E3 which is 13×10^3 . The newer wells (MWs 10, 11, 12, and 13) were not completely developed when sampled in September and elevated levels of most constituents were found which may be due to high levels of suspended matter in the water. Resampling in November resulted in much less silt and considerably lower results. For example, the iron levels in MW 11 dropped from 1240 mg/L to 4.4 mg/L. Iron levels in MWs 1, 2, and 6 differed by a factor of ten or less over the course of the year. It is anticipated the results obtained in the coming year will be a better measure of the contribution of the landfill to the inorganic constituents in the monitoring wells.

Sampling was conducted quarterly for volatile organic compounds. In addition, samples were collected in September and analyzed for semivolatile organics and PCB/pesticides from all of the wells, except MW 13. The results for semivolatile organic compounds and PCB/pesticides were essentially negative. However, volatile compounds were present in these samples as well as samples obtained in the other three quarters. Results are shown in Table 6.18. Trichloroethene, 1,1,1-trichloroethane, and 1,2-dichloroethane are compounds that are probably representative of materials disposed of in this area. 1,1-dichloroethane and cis-1,2-dichloroethene are known to be decomposition products of tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane in the presence of soil microorganisms. The half-time of the reaction can vary, but is usually measured in a few months or less. The end product of the decomposition of the chloroalkenes is vinyl chloride, which was not detected in any of the samples.

TABLE 6.9

Radionuclides in the 317/319 Area Monitoring Wells, 1988
(Concentrations in pCi/L)

Type of Activity	Location*	Samples	Avg.	No. of Min.	Max.
Hydrogen-3	MW 1	4	216	< 100	327
	MW 2	4	277	213	336
	MW 3	2	1534	1388	1681
	MW 6	4	144	< 100	192
	MW 10	3	1789	735	3206
	MW 11	3	595	322	995
	MW 12	2	262	153	371
	MW 13	2	209	191	227
Strontium-90	MW 1	4	-	-	< 0.25
	MW 2	4	-	-	< 0.25
	MW 3	2	0.7	0.6	0.7
	MW 6	4	-	-	< 0.25
	MW 10	3	19.9	7.7	28.8
	MW 11	3	0.3	< 0.25	0.6
	MW 12	2	-	-	< 0.25
	MW 13	2	-	-	< 0.25
Cesium-137	MW 1	4	-	-	< 1
	MW 2	4	-	-	< 1
	MW 3	2	-	-	< 1
	MW 6	4	-	-	< 1
	MW 10	3	-	-	< 1
	MW 11	3	-	-	< 1
	MW 12	2	-	-	< 1
	MW 13	2	-	-	< 1

*See Figure 6.1.

TABLE 6.10
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 HELL M#1
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	47 ± 8	40	54
BERYLLIUM	2	0.03 ± 0.10	0.01	0.05
CADMIUM	3	0.60 ± 0.49	0.40	0.90
CHLORIDE *	3	27 ± 4	25	29
CHROMIUM	3	13 ± 20	< 1	20
COBALT	2	30 ± 43	20	40
COPPER	3	19 ± 18	10	30
DISSOLVED SOLIDS *	2	613 ± 544	486	739
FLUORIDE	3	186 ± 81	154	236
IRON	4	1430 ± 2860	100	4510
LEAD	3	14 ± 28	5	32
MANGANESE	4	135 ± 128	53	267
MERCURY	4	-	-	< 0.05
NICKEL	3	33 ± 21	20	40
PH **	3	-	7.0	7.0
SELENIUM	4	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE *	3	172 ± 30	158	190
TEMPERATURE ***	3	11.7	9.5	12.8
ZINC	4	27 ± 38	5	60

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.11
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW2
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN. MAX.	
ARSENIC	4	-	-	< 5
BARIUM	4	44 ± 44	18	90
BERYLLIUM	2	0.03 ± 0.10	0.01	0.05
CADMIUM	3	0.23 ± 0.28	< 0.20	0.40
CHLORIDE *	3	14 ± 4	12	16
CHROMIUM	3	11 ± 16	2	20
COBALT	2	30 ± 43	20	40
COPPER	3	30 ± 37	11	51
DISSOLVED SOLIDS	2	389 ± 346	308	469
FLUORIDE	3	123 ± 28	110	140
IRON	4	5440 ± 13E3	28	19500
LEAD	3	22 ± 57	2	58
MANGANESE	4	241 ± 445	13	716
MERCURY	4	-	-	< 0.05
NICKEL	3	44 ± 44	22	69
** PH	3	-	7.3	7.4
SELENIUM	4	-	-	< 5
SILVER	3	-	-	< 0.2
SULFATE *	3	86 ± 10	80	90
TEMPERATURE ***	3	11.6	10.0	12.5
ZINC	4	41 ± 59	5	86

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.12
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW3
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	2	-	-	< 5
BARIUM	2	61 ± 33	54	69
CADMIUM	1	-	-	0.7
CHLORIDE [*]	2	-	-	24
CHROMIUM	1	-	-	10
COPPER	1	-	-	14
DISSOLVED SOLIDS	2	438 ± 448	334	542
FLUORIDE	2	166 ± 95	144	188
IRON	2	1950 ± 770	1770	2130
LEAD	1	-	-	15
MANGANESE	2	359 ± 105	335	384
MERCURY	2	-	-	< 0.05
NICKEL	1	-	-	40
PH ^{**}	2	-	7.1	7.1
SELENIUM	2	-	-	< 5
SILVER	1	-	-	< 0.2
SULFATE [*]	2	76 ± 4	75	77
TEMPERATURE ^{***}	2	12.4	12.4	12.5
ZINC	2	9 ± 19	5	14

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.13
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 HELL MW6
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION	
			MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	52 ± 19	36	67
BERYLLIUM	2	0.03 ± 0.10	0.01	0.05
CADMIUM	3	0.33 ± 0.21	< 0.20	0.40
CHLORIDE *	3	53 ± 7	50	57
CHROMIUM	3	10 ± 18	< 1	20
COBALT	2	30 ± 43	20	40
COPPER	3	17 ± 7	13	20
DISSOLVED SOLIDS	2	539 ± 374	452	626
FLUORIDE	3	171 ± 69	138	212
IRON	4	653 ± 659	108	1080
LEAD	3	18 ± 44	3	46
MANGANESE	4	74 ± 73	28	120
MERCURY	4	-	-	< 0.05
NICKEL	3	33 ± 21	20	40
PH **	3	-	7.2	7.3
SELENIUM	4	-	-	< 5
SILVER	3	-	-	< 0.2
SULFATE *	3	122 ± 5	119	124
TEMPERATURE ***	3	11.6	10.0	12.5
ZINC	4	11 ± 11	5	20

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.14
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW10
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	3	194 ± 600	< 5	571
BARIUM	3	785 ± 1820	112	1920
BERYLLIUM	3	0.99 ± 2.21	0.02	2.34
CADMIUM	3	58.5 ± 182	0.5	173
CHLORIDE *	1	-	-	6
CHROMIUM	3	196 ± 407	24	446
COBALT	3	200 ± 508	40	519
COPPER	3	565 ± 1540	75	1530
FLUORIDE	2	163 ± 4	162	164
IRON	3	427E3 ± 11E5	74300	113E4
LEAD	3	334 ± 845	25	862
MANGANESE	3	8770 ± 22E3	1400	22500
MERCURY	3	-	-	< 0.05
NICKEL	3	437 ± 1150	74	1160
** PH	1	-	-	6.2
SELENIUM	3	-	-	< 5
SILVER	3	-	-	< 0.2
* SULFATE	1	-	-	80
*** TEMPERATURE	1	-	-	10.0
ZINC	3	1270 ± 3140	250	3240

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.15
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW11
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN. MAX.	
ARSENIC	2	227 ± 957	< 5	450
BARIUM	2	1220 ± 3890	310	2120
BERYLLIUM	2	1.23 ± 5.23	0.02	2.45
CADMIUM	2	70.8 ± 298	1.6	140
CHLORIDE *	1	-	-	12
CHROMIUM	2	283 ± 843	87	479
COBALT	2	272 ± 998	40	504
COPPER	2	1060 ± 4090	110	2010
FLUORIDE	1	-	-	258
IRON	2	622E3 ± 27E5	4390	124E4
LEAD	2	619 ± 1940	168	1070
MANGANESE	2	11100 ± 41E3	1490	20700
MERCURY	3	-	-	< 0.05
NICKEL	2	493 ± 1950	40	947
PH **	1	-	-	6.7
SELENIUM	2	-	-	< 5
SILVER	2			
SULFATE *	1	-	-	24
TEMPERATURE ***	1	-	-	10.0
ZINC	2	1770 ± 6990	140	3390

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.16
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW12
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	2	147 ± 572	14	280
BARIUM	2	569 ± 1040	327	811
BERYLLIUM	2	1.17 ± 5.02	0.01	2.34
CADMIUM	2	39.4 ± 153	3.8	75.0
CHLORIDE *	1	-	-	86
CHROMIUM	2	147 ± 200	101	194
COBALT	2	138 ± 308	67	210
COPPER	2	426 ± 1040	184	669
FLUORIDE	1	-	-	162
IRON	2	364E3 ± 96E4	141E3	586E3
LEAD	2	241 ± 425	142	340
MANGANESE	2	6260 ± 11E3	3690	8830
MERCURY	2	-	-	< 0.05
NICKEL	2	305 ± 656	153	458
** PH	1	-	-	7.2
SELENIUM	2	10 ± 24	< 5	16
SILVER	2	-	-	< 0.2
SULFATE *	1	-	-	156
*** TEMPERATURE	1	-	-	10.0
ZINC	2	845 ± 1700	450	1240

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.17
 CHEMICAL CONSTITUENTS AT 317/319 LANDFILL, 1988
 WELL MW13
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	1	-	-	< 5
BARIUM	1	-	-	138
BERYLLIUM	1	-	-	<0.05
CADMIUM	1	-	-	1.00
CHLORIDE *	1	-	-	107
CHROMIUM	1	-	-	2
COBALT	1	-	-	40
COPPER	1	-	-	12
FLUORIDE	1	-	-	136
IRON	1	-	-	1660
LEAD	1	-	-	7
MANGANESE	1	-	-	399
MERCURY	1	-	-	< 0.05
NICKEL	1	-	-	40
** PH	1	-	-	7.1
SELENIUM	1	-	-	< 5
SILVER	1	-	-	< 0.2
* SULFATE	1	-	-	108
*** TEMPERATURE	1	-	-	10.0
ZINC	1	-	-	200

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.18

Organic Content of Monitoring Wells in 317/319 Area, 1988
(Concentrations in µg/L)

Monitoring Well	Compound	5/19/88	6/17/88	9/15/88	11/16/88
MW 1	ND	ND	ND	ND	ND
MW 2	1,1-Dichloroethane	18	25	60	50 45
	1,2-Dichloroethene (cis)	ND	ND	ND	64 60
	1,1,1-Trichloroethane	28	26	39	46 49
	Chloroform	2.3	5.0	5.0	ND
	Carbon Tetrachloride	ND	ND	6	16
MW 3	1,1-Dichloroethane	ND	0.4	Dry	Dry
MW 6	ND	ND	ND	ND	ND
MW 10	1,2-Dichloroethene	-	-	11(Total)	48 (cis)
	Trichloroethene	-	-	8	105
MW 11	1,1-Dichloroethane	-	-	170	8
	1,2-Dichloroethene	-	-	10	93 (cis)
	1,2-Dichloroethane	-	-	21	ND
	1,1,1-Trichloroethane	-	-	160	ND
	Trichloroethene	-	-	36	ND
MW 12	Diethylphthalate	-	-	< 10	TI
MW 13	4-Methyl Fluorene	-	-	-	TI

□ - Indicates Duplicate Results
 TI - Tentatively Identified
 ND - Not Detected

The mix of organic species found in MWs 10 and 11 is what should be expected from recently-released material, but no known recent disposal or spills of these materials has occurred. One sample from MW 3 contained a trace of 1,1-dichloroethane, but the well was dry the latter half of the year. MW 2 contained 1,1-dichloroethane and 1,1,1-trichloroethane in all four samples. Cis-1,2-dichloroethene was present in the November sample. These compounds are consistent with what was measured in MWs 10 and 11. MW 2 is downgradient of the latter wells. Carbon tetrachloride and chloroform were detected in MW 2 but not MWs 10 and 11. A probable source of these contaminants has been located in a drainage system near MW 10. Studies to isolate the source of the carbon tetrachloride and chloroform and sources responsible for the other contaminants are proceeding.

6.3. Sanitary Landfill

A sanitary landfill for non-radioactive waste is located on the western edge of the ANL site. This landfill operates under Illinois EPA Permit No. 1981-29-OP and is further described in Reference 26. Operation of the ANL landfill began in July 1966. During the period from 1969 through 1978, substantial quantities of liquid organic and inorganic wastes were disposed of on-site by adding them to an open "French drain" located in the northeast sector of the landfill.² A log of disposed materials is available.

In 1979, an investigation was begun to determine the subsoil characteristics of the site and to place ground-water monitoring wells at appropriate points in and around the landfill (see Figure 6.3). Because the topography suggested a southerly water flow, Wells 1 and 5 were located outside the landfill and were meant to measure water entering and leaving the landfill. Wells 2, 3, and 4 were placed at the perimeter of the landfill. In April 1980, a more comprehensive study was initiated²⁵ to develop information required for the Illinois State operating permit. Three additional test wells were placed at the perimeter of the landfill at previously untested locations. Well 6 was placed in the east section to sample any water flowing out of the landfill in the southeasterly direction. Wells 7a and 7b were located along the south side and were nested. These were

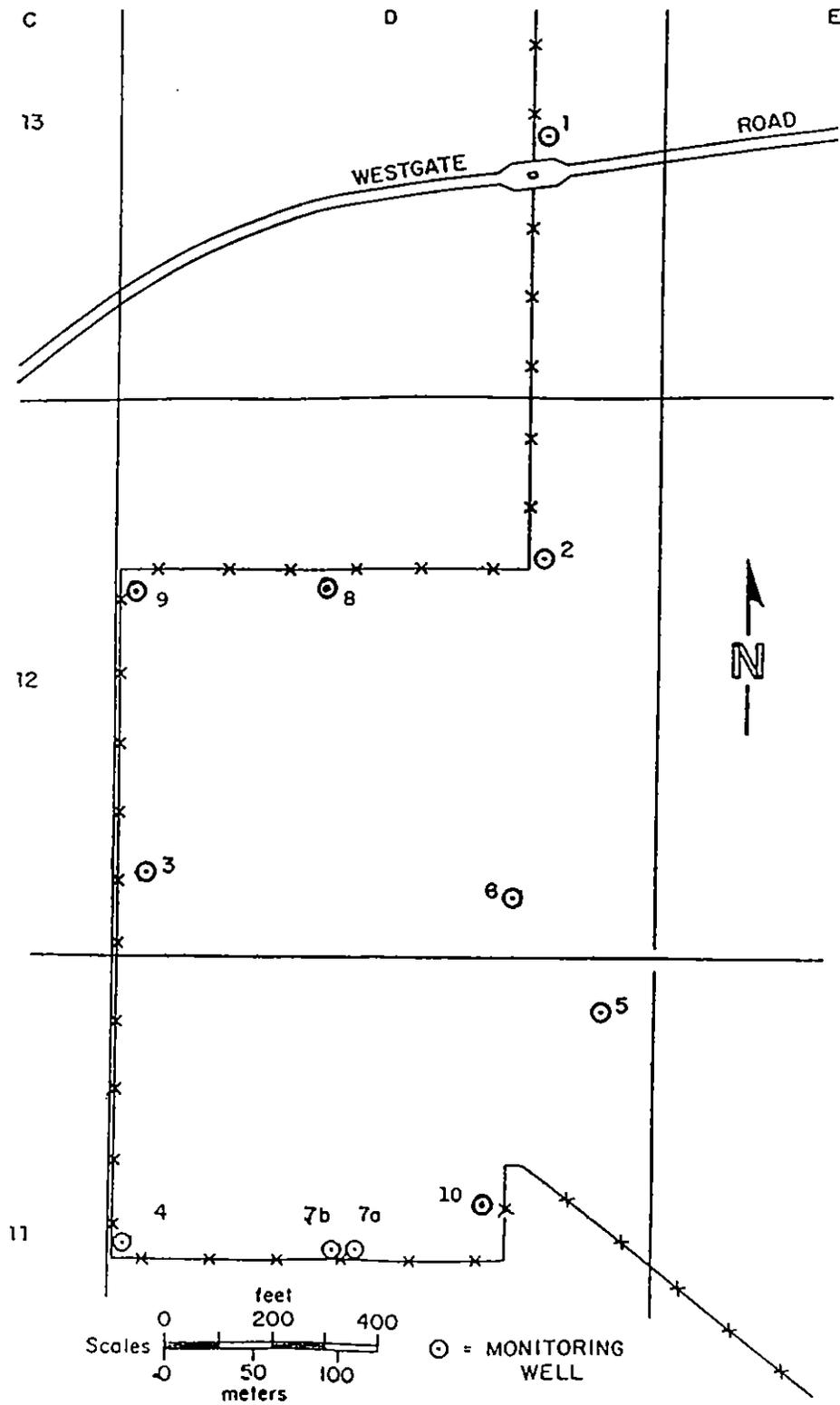


Fig. 6.3 Monitoring Well Locations for Landfill

installed to measure vertical water movement as well as to provide monitoring of water from two depths.

The permit study made some important observations. According to this study, there appears to be a perched water condition at depths varying from about 6 m (20 ft) on the north to about 7.6 m (25 ft) on the south. This apparently is caused by the relatively impermeable condition of the underlying clay, which restricts downward water flow. Soil testing revealed that the permeability of the soil beneath the landfill is very low, averaging about 1×10^{-8} cm/sec. There are several granular seams in the soil above the clay that permit lateral flow. Additionally, regional groundwater elevations indicate that the flow is generally southerly, toward the Des Plaines River.

The above stated observations tend to indicate that water in the test wells is from surface infiltration and that it moves horizontally approximately 7.6 m (25 ft) below the surface. Penetration to the dolomite aquifer used for water supplies, 15-30 m (50 to 100 ft) below the surface, is very slow. Indeed, core samples obtained at 11-12 m (35 to 40 ft) below the surface were only moist, indicating that the aquifer is below this level and that little downward movement is occurring. If movement was occurring, this stratum would be nearly saturated. In September 1986, six new wells were constructed. Wells 1, 2, and 4 were suspected of being poorly sealed and replacement wells 1-2, 2-2, and 4-2, respectively, were drilled within five feet of the originals. Additional wells, 8, 9, and 10 (see Figure 6.3) were constructed to improve the peripheral coverage. In November 1987, additional wells were constructed to 21 m (70 ft) next to Well 9 and 10 m (30 ft) and 21 m (70 ft) next to Well 6.

The wells have been studied from 1979 until the present to determine consistency of water levels, recharge rates, and chemical characteristics. The water levels measured in 1988 are shown in Table 6.19. A plot of the subsurface water elevation profile, using the Surfer software, is shown in Figure 6.4. The data indicate that the flow from the landfill is in a southeasterly direction. However, the northern portion of the landfill has a component that flows both southeast and northwest. There does not appear

TABLE 6.19

Well Point and Water Level Elevations⁽¹⁾ of
Monitoring Sites at the ANL Sanitary Landfill, 1988

Well Number	Ground Surface Elevation ⁽²⁾	Well Point Elevation	Quarterly Measurements				Average	
			1st	2nd	3rd	4th	1988	1986 to 88
1-2	227.69	220.00	222.84	222.47	221.53	221.44	220.07	222.04
2-2	230.83	215.01	226.07	225.28	224.12	224.36	224.96	226.11
3	226.77	218.11	224.88	224.27	222.81	223.02	223.75	224.13
4-2	227.23	220.10	225.73	225.55	222.56	223.66	224.38	223.76
5	227.53	215.40	-	220.86	Dry	Dry	220.86	220.39
6	229.91	215.07	219.64	219.52	217.81	218.51	218.87	223.34
7a	227.81	220.22	226.53	224.91	223.75	224.88	225.02	225.76
7b	227.81	214.09	Dry	Dry	Dry	Dry	Dry	Dry
8	231.53	222.84	229.45	227.66	226.01	225.86	227.25	227.67
9	230.00	224.09	227.90	226.83	224.82	226.34	226.47	227.22
10	229.15	222.60	228.75	227.84	226.44	226.31	227.34	228.29
Precipitation ⁽³⁾			84.1	24.9	96.8	194.8		

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

⁽²⁾The ground surface elevations of Wells 3 through 7b are as previously reported, while those of Wells 1-2, 2-2, 8, 9, and 10 were determined by a survey in April 1987.

⁽³⁾Precipitation (water equivalent) in millimeters for 30-day period prior to measurements. Data obtained from NOAA as measured at O'Hare International Airport.

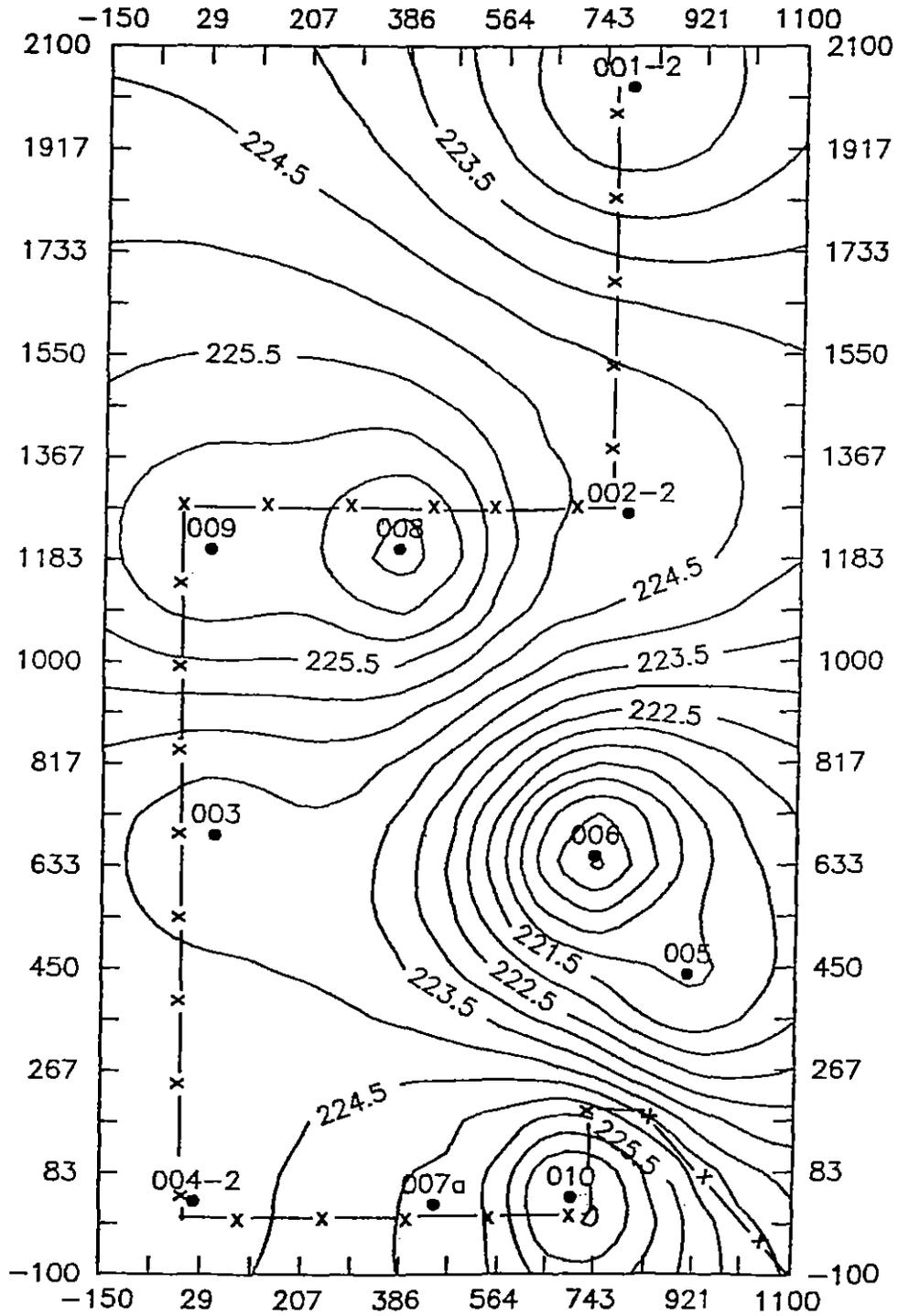


Fig. 6.4 800 Area Landfill Subsurface Water Elevation Profile, 1988

to be a uniform underlying layer of water (perched layer), rather the monitoring wells seem to be in discrete layers of groundwater which are not hydraulically connected.

The results for inorganic constituents are shown in Tables 6.20 through 6.29. Cobalt, mercury, and selenium were not detected in any of the samples. Arsenic levels were elevated in Wells 6 and 9. Well 3, which is located near Well 9, had elevated arsenic levels which were persistent until 1986. Levels of cadmium ranged from 0.1 to 4.0 $\mu\text{g/L}$. Lead levels in Well 9 were 145 $\mu\text{g/L}$ in September and 27 $\mu\text{g/L}$ in the November sample. This may be compared to the drinking water standard of 50 $\mu\text{g/L}$.

The levels of iron, chloride, sulfate, and manganese are summarized in Table 6.30. Levels of iron varied from 0.575 mg/L in Well 8 to 52.8 mg/L in Well 9. The manganese levels varied from 0.168 mg/L in Well 8 to 2.76 mg/L in Well 9. These wells are located next to each other, yet the levels of these two elements differ significantly. The levels of sulfate in Well 8 are ten times the levels in Well 9. These results are another indication that the subsurface water is discontinuous.

The chloride levels are significant because this ion serves as a tracer for water movement and as an indicator of organic decomposition. The chloride level in Well 1-2 is significantly higher than the chloride levels in the other wells, while levels in Wells 2-2, 5, and 10 are very low. The high level in Well 1-2 had previously been related to the use of salt for de-icing on the nearby road, but it could possibly be also related to a component of groundwater moving northerly from the landfill.

All of the wells containing sufficient water were sampled and analyzed for the volatile organic compounds listed in Table 6.1. The analytical technique is also capable of identifying other organic compounds. Samples from Well 6 collected in September and October showed levels of acetone and tetrahydrofuran (tentatively identified) slightly above the detection limit of 30 $\mu\text{g/L}$. Well 10 also indicated trace levels of acetone in the September sample. Additionally, 4-methyl-9H-fluorene was tentatively identified in Well 7a and tetrahydrofuran was tentatively identified in Well 6.

TABLE 6.20
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 WELL 1-2
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	3	-	-	< 5
BARIUM	3	221 ± 154	134	302
BERYLLIUM	2	-	-	0.1
CADMIUM	2	0.9 ± 1.1	0.7	1.2
CHLORIDE *	3	768 ± 150	719	862
CHROMIUM	2	8 ± 6	6	9
COBALT	2	-	-	< 40
COPPER	2	11 ± 6	10	13
DISSOLVED SOLIDS *	2	1890 ± 520	1770	2010
FLUORIDE	3	213 ± 71	172	248
IRON	3	7200 ± 8160	2230	10800
LEAD	2	11 ± 6	9	12
MANGANESE	3	536 ± 51	504	554
MERCURY	3	-	-	< 0.05
NICKEL	2	-	-	< 40
** PH	3	-	7.3	7.5
SELENIUM	3	-	-	< 5
SILVER	2	19.3 ± 82.4	0.2	38.5
* SULFATE	3	136 ± 12	132	143
*** TEMPERATURE	3	12.1	11.7	12.6
ZINC	3	30 ± 40	5	46

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.21
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 WELL 2-2
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION	
			MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	1230 ± 1330	230	2500
BERYLLIUM	3	-	-	< 0.05
CADMIUM	3	0.4 ± 0.2	0.3	0.5
CHLORIDE *	4	16 ± 12	4	24
CHROMIUM	3	1 ± 1	1	2
COBALT	3	-	-	< 40
COPPER	3	-	-	< 10
DISSOLVED * SOLIDS	3	487 ± 104	421	520
FLUORIDE	4	269 ± 104	166	344
IRON	4	1180 ± 580	640	1540
LEAD	3	4 ± 2	3	6
MANGANESE	4	459 ± 98	372	521
MERCURY	4	-	-	< 0.05
NICKEL	3	-	-	< 40
PH **	4	-	7.5	7.5
SELENIUM	4	-	-	< 5
SILVER	3	-	-	< 0.2
SULFATE *	4	81 ± 17	65	93
TEMPERATURE ***	3	12.4	11.9	13.4
ZINC	4	18 ± 13	5	27

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.22
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 HELL 3
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	5	-	-	< 5
BARIUM	5	219 ± 79	153	315
BERYLLIUM	2	-	-	< 0.05
CADMIUM	2	0.9 ± 0.2	0.9	1.0
CHLORIDE *	4	2 ± 1	1	3
CHROMIUM	2	2 ± 3	2	3
COBALT	2	-	-	< 40
COPPER	2	29 ± 84	10	49
DISSOLVED SOLIDS	4	722 ± 51	674	762
FLUORIDE	5	118 ± 45	68	172
IRON	5	2500 ± 740	1910	3480
LEAD	2	11 ± 7	10	13
MANGANESE	5	84 ± 9	74	94
MERCURY	5	-	-	< 0.05
NICKEL	2	-	-	< 40
** PH	5	-	6.8	7.0
SELENIUM	5	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE	5	34 ± 12	25	53
*** TEMPERATURE	3	12.6	11.8	13.8
ZINC	4	22 ± 30	5	50

*
CONCENTRATION IN MILLIGRAM/LITER.

**
UNITS

DEGREES CENTIGRADE

TABLE 6.23
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 HELL 4-2
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN. MAX.	
ARSENIC	4	-	-	< 5
BARIUM	4	449 ± 257	198	609
BERYLLIUM	2	0.15 ± 0.43	0.05	0.25
CADMIUM	2	0.65 ± 0.22	0.60	0.70
CHLORIDE *	3	148 ± 6	144	150
CHROMIUM	2	7 ± 24	2	13
COBALT	2	-	-	< 40
COPPER	2	25 ± 67	10	41
DISSOLVED * SOLIDS	3	836 ± 113	766	881
FLUORIDE	4	138 ± 58	76	164
IRON	4	5250 ± 11E3	610	17500
LEAD	2	13 ± 22	7	18
MANGANESE	4	401 ± 356	160	764
MERCURY	4	-	-	< 0.05
NICKEL	2	-	-	< 40
PH **	4	-	7.2	8.4
SELENIUM	4	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE *	4	100 ± 51	62	150
TEMPERATURE ***	3	11.6	11.5	11.8
ZINC	3	31 ± 61	5	69

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.24
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 WELL 5
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	1	-	-	< 5
BARIUM	1	-	-	124
CHLORIDE *	1	-	-	6
DISSOLVED SOLIDS *	1	-	-	397
FLUORIDE	1	-	-	218
IRON	1	-	-	3510
MANGANESE	1	-	-	553
MERCURY	1	-	-	< 0.05
PH **	1	-	-	7.5
SELENIUM	1	-	-	< 5
SULFATE *	1	-	-	38
TEMPERATURE ***	1	-	-	11.3
ZINC	1	-	-	14

*
 CONCENTRATION IN MILLIGRAM/LITER.

**
 UNITS

 DEGREES CENTIGRADE

TABLE 6.25
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 HELL 6
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	5	7 ± 4	< 5	13.0
BARIUM	5	123 ± 28	91	160
BERYLLIUM	2	0.29 ± 1.05	0.05	0.54
CADMIUM	2	2.5 ± 5.8	1.2	3.9
CHLORIDE [*]	4	234 ± 44	198	272
CHROMIUM	2	14 ± 58	< 3	28
COBALT	2	40 ± 2	40	41
COPPER	2	45 ± 151	10	80
DISSOLVED [*] SOLIDS	3	1190 ± 33	1170	1200
FLUORIDE	5	123 ± 69	48	181
IRON	5	16000 ± 20E3	4700	45900
LEAD	2	22 ± 69	5	38
MANGANESE	5	1770 ± 510	1450	2430
MERCURY	4	-	-	< 0.05
NICKEL	2	55 ± 67	40	71
PH ^{**}	5	-	6.6	6.8
SELENIUM	5	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE [*]	4	65 ± 41	40	103
TEMPERATURE ^{***}	3	11.9	10.2	14.0
ZINC	3	56 ± 121	5	130

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.26
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 WELL 7A
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	5	-	-	< 5
BARIUM	5	91 ± 33	60	123
BERYLLIUM	3	-	-	< 0.05
CADMIUM	3	0.5 ± 0.4	0.3	0.7
CHLORIDE *	5	29 ± 16	12	43
CHROMIUM	3	1 ± 1	< 1	2.4
COBALT	3	-	-	< 40
COPPER	3	-	-	< 10
DISSOLVED SOLIDS *	3	652 ± 291	554	835
FLUORIDE	5	113 ± 44	64	162
IRON	5	1470 ± 750	930	2450
LEAD	3	6 ± 1	5	7
MANGANESE	5	297 ± 95	188	375
MERCURY	5	-	-	< 0.05
NICKEL	3	-	-	< 40
PH **	5	-	7.0	7.1
SELENIUM	5	-	-	< 5
SILVER	3	-	-	< 0.2
SULFATE *	5	178 ± 64	105	227
TEMPERATURE ***	3	11.8	10.8	13.3
ZINC	4	27 ± 22	5	41

*
 CONCENTRATION IN MILLIGRAM/LITER.

**
 UNITS

 DEGREES CENTIGRADE

TABLE 6.27
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 HELL 8
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION	
			MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	58 ± 15	45	71
BERYLLIUM	2	-	-	< 0.05
CADMIUM	2	0.9 ± 0.2	0.9	1.0
CHLORIDE *	4	79 ± 29	58	100
CHROMIUM	2	-	-	< 3
COBALT	2	-	-	< 40
COPPER	2	-	-	< 10
DISSOLVED * SOLIDS	3	842 ± 356	713	1070
FLUORIDE	4	160 ± 94	90	221
IRON	4	575 ± 732	123	1170
LEAD	2	10 ± 17	6	14
MANGANESE	4	168 ± 62	122	229
MERCURY	4	-	-	< 0.05
NICKEL	2	-	-	< 40
PH **	4	-	7.0	7.1
SELENIUM	4	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE *	4	189 ± 15	177	202
TEMPERATURE ***	3	11.8	11.7	11.9
ZINC	3	18 ± 21	5	26

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.28
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 HELL 9
 (CONCENTRATIONS IN MICROGRAM/LITER OR MILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	25 ± 56	< 5	86.0
BARIUM	4	367 ± 374	203	768
BERYLLIUM	2	1.20 ± 4.56	0.14	2.26
CADMIUM	2	1.7 ± 5.8	0.4	3.1
CHLORIDE*	4	108 ± 47	64	146
CHROMIUM	2	57 ± 219	6	108
COBALT	2	51 ± 49	40	63
COPPER	2	103 ± 323	28	178
DISSOLVED SOLIDS*	3	927 ± 249	772	1020
FLUORIDE	4	178 ± 78	106	230
IRON	4	52800 ± 90E3	18000	151E3
LEAD	2	86 ± 254	27	145
MANGANESE	4	2760 ± 3230	920	5890
MERCURY	4	-	-	< 0.05
NICKEL	2	98 ± 252	40	157
PH**	4	-	6.7	7.0
SELENIUM	4	-	-	< 5
SILVER	2	5.5 ± 22.8	0.2	10.8
SULFATE*	4	11 ± 18	2	30
TEMPERATURE***	3	12.5	11.8	13.1
ZINC	3	190 ± 497	27	502

* CONCENTRATION IN MILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.29
 CHEMICAL CONSTITUENTS AT ANL LANDFILL, 1988
 WELL 10
 (CONCENTRATIONS IN MICROGRAM/LITER OR HILLIGRAM/LITER)

CONSTITUENT	NO. OF SAMPLES	AVG.	CONCENTRATION MIN.	MAX.
ARSENIC	4	-	-	< 5
BARIUM	4	96 ± 25	72	115
BERYLLIUM	2	-	-	< 0.05
CADMIUM	2	1.0 ± 1.7	0.6	1.4
CHLORIDE [*]	4	5 ± 2	4	7
CHROMIUM	2	-	-	< 3
COBALT	2	-	-	< 40
COPPER	2	-	-	< 10
DISSOLVED [*] SOLIDS	3	686 ± 48	662	714
FLUORIDE	4	251 ± 67	204	314
IRON	4	2820 ± 1180	2110	3840
LEAD	2	10 ± 8	8	12
MANGANESE	4	196 ± 42	174	240
MERCURY	4	-	-	< 0.05
NICKEL	2	-	-	< 40
PH ^{**}	4	-	7.1	7.4
SELENIUM	4	-	-	< 5
SILVER	2	-	-	< 0.2
SULFATE [*]	4	195 ± 11	187	205
TEMPERATURE ^{***}	3	13.2	11.9	14.8
ZINC	3	22 ± 28	5	34

* CONCENTRATION IN HILLIGRAM/LITER.

** UNITS

*** DEGREES CENTIGRADE

TABLE 6.30

Summary of Selected Sanitary
Landfill Results, 1988
(Concentrations in mg/L)

Well Number	Iron	Chloride	Sulfate	Manganese
1-2	8.090	768	136	0.536
2-2	1.180	16	81	0.459
3	2.500	2	34	0.084
4-2	5.250	148	100	0.401
5	3.510	6	38	0.553
6	1.6000	234	65	1.770
7A	1.470	29	178	0.297
8	0.575	79	189	0.168
9	52.8	108	11	2.760
10	2.820	5	195	0.196

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

TABLE 6.31

Hydrogen-3 Content of Water From Sanitary Landfill Wells, 1988
(Concentrations in pCi/L)

Location*	Date Collected				
	January 21	April 21	June 10	October 4	November 22
Well 1-2	-	-	171 ± 91	125 ± 93	< 100
Well 2-2	-	-	< 100	< 100	< 100
Well 3	-	< 100	< 100	< 100	< 100
Well 4-2	-	118 ± 90	< 100	< 100	< 100
Well 5	-	-	304 ± 93	Dry	Dry
Well 6	-	380 ± 87	488 ± 97	542 ± 102	432 ± 109
Well 7a	497 ± 89	108 ± 82	245 ± 92	1052 ± 111	1070 ± 121
Well 8	211 ± 84	233 ± 84	187 ± 91	119 ± 93	< 100
Well 9	1048 ± 98	1027 ± 98	697 ± 101	826 ± 107	603 ± 112
Well 10	-	100 ± 81	152 ± 90	< 100	101 ± 101

*See Figure 6.3.

7. QUALITY ASSURANCE

Quality Assurance plans are in place for both the radiological (H 0030-0003-QA-00) and non-radiological analysis (H 0030-0002-QA-01). Both documents were prepared in accordance with ANSI/ASMC NQA-1 and meet the requirements of ANL QA documents.^{27,28} 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 were not available for particular nuclides, NIST traceable standards from the Amersham Corporation were used. The equipment is usually checked on a daily basis with secondary counting standards to insure proper operation. Samples were periodically analyzed in duplicate or with the addition of known amounts of a radionuclide to check precision and accuracy. In addition, standard and intercomparison samples distributed by the Quality Assurance Branch of the U. S. Environmental Protection Agency (EPA-QA) are analyzed regularly. Results of our participation in the EPA-QA program during 1988 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, and the value obtained in our laboratory. Certain information may assist in judging the quality of the results, including the fact that typical uncertainties for our analyses are 2% to 50% depending on the concentration and the nuclide, and the uncertainties in the EPA-QA results are 2% to 5% (our estimate).

In addition, participation continued in the DOE Environmental Measurements Laboratory Quality Assurance Program (DOE-EML-QAP), a semi-annual distribution of four different sample matrices containing various combinations of radionuclides that are analyzed. Results for 1988 are summarized in Table 7.2. In the table, the comparison is made between the EML value, which is the result of replicate determinations by that laboratory, and the average value obtained in our laboratory. Information that will assist in judging the quality of the results includes the fact that typical

TABLE 7.1

Summary of EPA-QA Samples, 1988

Type of Sample	Analysis	Number Analyzed	Average Difference from Added
Air Filter	Total Alpha	2	53%
	Total Beta	2	5%
	Strontium-90	2	8%
	Cesium-137	2	13%
Milk	Potassium-40	2	2%
	Strontium-89	2	4%
	Strontium-90	2	9%
	Iodine-131	2	2%
	Cesium-137	2	2%
Water	Total Alpha	1	4%
	Total Beta	1	14%
	Hydrogen-3	3	6%
	Chromium-51	2	3%
	Cobalt-60	4	3%
	Zinc-65	3	3%
	Strontium-89	3	7%
	Strontium-90	3	2%
	Ruthenium-106	3	4%
	Iodine-131	4	8%
	Cesium-134	4	8%
	Cesium-137	4	10%
	Radium-226	2	10%
	Radium-228	2	7%
	Total Uranium	3	19%
Plutonium-239	1	6%	

TABLE 7.2

Summary of DOE-EML-QAP Samples, 1988

Radionuclide	Difference From EML Value			
	Air Filters	Water	Soil	Vegetation
Hydrogen-3	-	4% (2)	-	-
Beryllium-7	1% (2)	-	-	-
Potassium-40	-	-	19% (2)	9% (2)
Manganese-54	3% (2)	6% (2)	-	-
Cobalt-57	6% (2)	9% (2)	-	-
Cobalt-60	6% (2)	7% (2)	-	-
Strontium-90	6% (2)	9% (2)	19% (2)	4% (2)
Cesium-134	18% (2)	14% (2)	-	-
Cesium-137	6% (2)	7% (2)	9% (2)	10% (2)
Uranium-234	5% (2)	17% (2)	40% (2)	-
Uranium-238	14% (2)	22% (2)	44% (2)	-
Plutonium-239	3% (2)	12% (20	41% (2)	7% (1)
Americium-241	6% (1)	17% (2)	1% (1)	26% (2)

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

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

7.2. Chemical Analysis

The documentation for non-radiological operations is contained in an INDUSTRIAL HYGIENE OPERATING MANUAL (IHOM) and is composed of a sampling and analysis plan, as well as individual analytical and collection procedures. All samples for NPDES and groundwater are collected and analyzed in accordance with EPA regulations and are found in EPA-600/4-84-017,²⁴ SW-846,²¹ and 40 CFR Part 136.²⁰

Standard Reference Materials (SRM), traceable to the NIST, exist for most inorganic analyses (see Table 7.3). All standards are compared annually to the NIST values. Detection limits are determined using techniques listed in SW-846.²¹ 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 EPA, and many are used in this work. An average value, with given confidence limits, is provided. The requirement²¹ for organic analyses is dependent upon the compounds studied and includes analyses of a matrix spike, specified internal standards, recovery, and relative retention times.

The laboratory participates in the National Institute of Occupational Safety and Health (NIOSH) proficiency testing program, which requires analyses of many materials of environmental interest. Results are in agreement with the NIOSH values and are listed in Table 7.4. Our laboratory also participates in the U. S. Environmental Protection Agency Discharge Monitoring

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

Summary of NIOSH Program Samples, 1988

Constituent	Average Difference From Reference Value
Cadmium	3.6% (16)
Lead	3.7% (16)
Zinc	2.0% (16)
Benzene	6.3% (4)
Carbon Tetrachloride	4.1% (8)
Cellosolve Acetate	9.1% (4)
Chloroform	4.5% (4)
Dichloroethane	3.4% (8)
p-Dioxane	5.2% (4)
Toluene	5.7% (4)
Trichloroethylene	2.8% (4)
o-Xylene	5.7% (8)

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

Report Quality Assurance Program (EPA-DMR-QAP). Results are rated acceptable by the EPA and appear in Table 7.5.

TABLE 7.5

Summary of EPA-DMR-QAP Non-Radiological Samples, 1988

Constituent	Average Difference From Reference Value
Chromium	-13%
Copper	-1%
Iron	+3%
Lead	-3%
Manganese	-2%
Mercury	-4%
pH	0%
Zinc	+2%
Total Suspended Solids	-8%
Oil and Grease	-4%
Chemical Oxygen Demand	-5%
Biochemical Oxygen Demand	+13%

8. APPENDIX

8.1. References

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