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**DRAFT ENVIRONMENTAL ASSESSMENT
OF
ARGONNE NATIONAL LABORATORY
EAST**

October 1975

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MASTER

DRAFT ENVIRONMENTAL ASSESSMENT OF
ARGONNE NATIONAL LABORATORY--EAST

by

ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION

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October 1975

B Steeb
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1. SUMMARY

This environmental assessment of the operation of the Argonne National Laboratory is related to continuation of research and development work being conducted at the Laboratory site at Argonne, Illinois. The site is in DuPage County, 25 miles southwest of downtown Chicago. The principal Laboratory facilities and buildings are on a 1700-acre site surrounded by a security fence to restrict public access.

Argonne National Laboratory (ANL) was founded in 1946; it has operated at the present Illinois site since 1949. The facilities of the Laboratory are owned by the United States Government. Under the terms of a contract between the U. S. Energy Research and Development Administration, the University of Chicago, and Argonne Universities Association, the University employs the staff and operates the Laboratory in accordance with policies formulated, approved, and reviewed by the Association.

The Argonne National Laboratory is one of the Energy Research and Development Administration's multiprogram national laboratories and is equipped and staffed to perform research and development in many areas of engineering and in the physical and life sciences. ANL's unique

facilities at the Illinois site include reactors, accelerators, particle-detection devices, special engineering facilities, laboratories for remote handling of radioactive materials, computers, and other specially designed laboratories and work areas. ANL also has an assortment of support facilities; they include shops, stores, and utilities such as water supply, sewage treatment, steam production, electrical switchgear, and waste management.

The Laboratory is considered to be a national resource and the major benefits derived from its operation are contributions made in many diverse scientific and developmental fields. The development of the boiling-water and pressurized-water reactors for commercial and military uses, of the only operating breeder reactor in the U. S., of other experimental reactors and test facilities, of the Zero Gradient Synchrotron (ZGS), and of a high-energy-density storage battery are some examples of Argonne activities that have provided a national (in some cases, worldwide) benefit.

The Laboratory has in the past devoted much of its efforts to solving problems of national scope and will continue to do so in the future; it is currently mounting a major effort to make meaningful contributions to the country's general energy problem and has long been active in analyzing the environmental effects of energy generation. Many of the basic research studies carried on by Argonne scientists are of nationwide, indeed worldwide, importance because they add to the store of knowledge of mankind.

The construction and operation of the Argonne National Laboratory have resulted in substantial contributions, both monetary and societal, to the economies of the neighboring communities.

The estimated population (for 1980) within a 50-mile radius of the site is about 8.6 million. In general, population growth in the immediate vicinity has been, and is expected to continue to be, slow.

The terrain of the site is flat to slightly hilly, with an elevation of 700 to 750 feet MSL for several miles north and east but dropping slowly toward the southwest. The normal level of the Des Plaines River south of the site is 583 feet MSL. The floodplain extends about 1/8 mile onto the forest preserve that surrounds the site. The land rises sharply from the edge of the floodplain, and outcroppings of Niagara dolomite may be seen to the top of the bluffs overlooking the Des Plaines Valley. The bedrock (which is almost 100 ft below the surface) is dolomite, under which there is shale, limestone, and sandstone. The soil above the bedrock is dense, tough, silty clay. It is believed that none of the earthquakes that have occurred or are likely to occur in the vicinity will have a damaging effect on structures of adequate design at the site.

The effects of the maximum tornado envisioned for the site have been analyzed using a highly conservative model. A more refined analysis would require a more detailed inventory of special nuclear material (SNM) and a more complex modeling than present meteorological data will permit. In all probability, more sophisticated treatment will lead to

lower dose estimates than those given in the text because of the conservative assumptions involved in the present model.

Potable water is obtained from two principal aquifers--the Niagara dolomite and the deeply buried Ordovician and Cambrian sandstones. The Laboratory has five shallow supply wells that obtain water from the Niagara dolomite and one deep well, cased and sealed through the Niagara dolomite, that obtains water from the deep sandstones. Total water usage is about 1.8 million gallons per day, of which about 0.07 million gallons per day is lost by evaporation under conditions of peak summer heat load. The remainder is discharged to the Des Plaines River via Sawmill Creek.

Concentrations of chemicals discharged to Sawmill Creek have on occasion exceeded present standards for certain metallic elements.

The climate of the area is typically continental, with cold winters, hot summers, and frequent short-period fluctuations in temperature, humidity, wind speed and direction, and cloudiness. About 67% of the average annual precipitation falls during the period April through September. During periods of northeasterly winds in spring and summer, temperatures at the site are moderated by the effects of Lake Michigan.

The ANL site provides a large area of natural habitat that serves as a sanctuary for many forms of wildlife. Of the 1700 acres occupied by the Laboratory, about 1275 acres are devoted to Laboratory structures, roads, and landscaped grounds. Several hundred acres of the landscaped

grounds have been maintained in their original condition as native oak-opening and hardwood forest. The remaining acreage shows considerable natural diversity, and includes a variety of lowland and upland forests, old fields, pine plantations, streams, lakes, marshes, and a variety of temporary ponds reflecting the surrounding forests and fields. The surrounding 2040-acre DuPage County forest preserve reflects a similar diversity, but with a much heavier predominance of pine plantations. A unique aspect of the site ecology is a herd of several hundred fallow deer (*Dama dama*) that roam freely over the site. There are no records of registered historical sites, archaeological sites, or fossil deposits on the area occupied by ANL.

The Laboratory has been monitoring various environmental parameters both offsite and onsite since 1949. Meteorological data have been collected to support development of models for atmospheric dispersion of radioactive and other pollutants. Gaseous and liquid effluents, both radioactive and non-radioactive, have been measured by portable monitors and by continuous monitors at fixed sites. Monitoring of constituents of the terrestrial ecosystem provides a basis for identifying changes should they occur in this regime. The Laboratory has established a position of leadership in monitoring methodologies and their application.

Very small quantities of non-radioactive gases and particulates are discharged to the atmosphere, primarily from fossil-fueled boilers. The concentrations are far below State and Federal standards.

Offsite impacts of nonradiological accidents are primarily those associated with the release of chlorine and with sodium fires. Both result in releases that cause no health damage offsite.

Radioactive materials released to the environment result in a cumulative dose to persons residing within 50 miles of the site of about 47 man-rem per year, compared to an annual total of about 950,000 man-rem delivered to the same population from natural background radiation.

The public risk associated with exposure to radioactive materials released as a result of the maximum hypothetical accident or natural disaster would be a maximum individual lifetime dose commitment of 3.8 rem, and a maximum lifetime population dose commitment of about 70,000 man-rem to those living within 50 miles of the site. These dose commitments are within the values established by 10 CFR 100.

The continued operation of the Argonne National Laboratory is not in conflict with any known land-use plans in the vicinity of the Laboratory and, furthermore, is in harmony with the Northeastern Illinois Planning Commission's policy of increasing the extent of open lands in the area.

Before construction of the Laboratory, the primary use of the land had been agricultural; because the land was not highly productive, it was not under intensive agricultural use. In construction, many of the original ecological features were retained or restored.

For the duration of Laboratory activities, the 1700-acre site will be unavailable for productive usage other than that of a large research institution. However, the many results of laboratory operation that have been listed indicate a net benefit.

Construction of existing buildings, roads, and other supporting facilities has been completed, so effects of construction on the environment have already been realized. Additional facilities have been proposed for construction on the site, but very little new construction is in progress; thus, no appreciable environmental impact is expected.

Effects of construction, withdrawal and discharge of cooling water, and other water uses on streams, groundwater, navigation, flooding, fish and wildlife resources, water quality, water supply, and esthetics have not been found to be significant and no other uses of the water resources are precluded by Laboratory activities.

The principal resources irreversibly and irretrievably committed through construction and operation of the Laboratory are materials of construction (some of which may be recycled if economics favor such action) and chemicals and other supplies consumed in Laboratory operations. Some of these materials are from renewable resources, most are in good supply and in broad use in industry, and those few that are scarce are recovered within the limits of the recovery process. Because of the importance of conserving the depletable resources consumed in providing heat and electricity to the facilities, a continuing effort to reduce

energy usage at the Laboratory is under way. This effort has resulted in about a 20% reduction from usage in FY 1969.

Most of the changes to the ANL site that have been made or are planned are slight and are reversible. The fact that a large part of the site remains in its original condition should enhance both short- and long-term productivity. Thus, ANL enhances the use and productivity of certain aspects of man's environment and does not prevent maintenance and enhancement of long-term productivity.

2. BACKGROUND

2.1 PHYSICAL LOCATION, PURPOSE, AND HISTORY OF ANL

Argonne National Laboratory (ANL), one of the major laboratories of the Energy Research and Development Administration (ERDA), is a direct outgrowth of the Manhattan Project and of the first self-sustaining nuclear reaction, which occurred at the University of Chicago in December 1942.¹ ANL is operated by the University of Chicago and the Argonne Universities Association within a 3740-acre tract in DuPage County 25 miles southwest of the center of Chicago (see Fig. 2.1). The facilities occupy about 1200 acres, 500 acres are devoted to forest and landscaped areas within the site perimeter, and 2040 acres of forest preserve surround the site in the form of a green-belt. Legal title to this 2040 acres surrounding the Laboratory site has recently been transferred to the DuPage County Forest Preserve Commission. The site is usually denoted ANL-East, but earlier literature also refers to the same site as ANL-Illinois, ANL-DuPage, or Site D.

Since expansion and later relocation from its original quarters at the University of Chicago, ANL has occupied a series of sites, the best known (other than those currently occupied) being Site-B and New-Chemistry (near the University of Chicago), and Site-A (in the Palos Park Forest

Fig. 2.1. Argonne National Laboratory Site in Relation to the Chicago Metropolitan Area.

Preserve southwest of Chicago, the permanent location of the world's first operating nuclear reactor). The Laboratory is one of ERDA's multi-program National Laboratories and is equipped to perform experiments covering most aspects of engineering and the physical and life sciences. It has been included among the "facilities that represent national assets of enormous importance."²

ANL's operating budget in FY 1975 was \$124 million. About \$9 million was for non-AEC work (budget predates existence of ERDA), primarily for other Federal agencies. The magnitudes of the individual programs are shown in Table 2.1.

By 31 December 1974, Laboratory employment had increased to 4511 after a minimum of about 4200 that followed the peak employment of about 5600 in mid-1968. The professional staff had the following educational distribution at the end of 1974.

<u>Highest Degree Attained</u>	<u>Number of Individuals</u>
Ph.D. or M.D.	657
M.S.	331
B.S.	<u>656</u>
Total	1644

Some staff members are on temporary appointments; in addition, an average of about 550 faculty and students utilize the facilities of the Laboratory annually but are not paid by ANL.

The distribution of the Laboratory's employees by occupation on 31 December 1974 was as follows:

Table 2.1. Argonne National Laboratory FY 1975
Operating Costs (Millions of dollars)

<i>Program</i>		<i>Costs</i>
Reactor Development		58.2
AEC ^a	58.2	
High Energy Physics		13.8
AEC	13.8	
Nuclear Materials & Molecular Sciences		25.3
AEC	23.0	
Other ^b	2.3	
Biomedical & Environmental Research		12.6
AEC	12.1	
Other	0.5	
Regulation Activities		2.1
AEC	1.9	
Other	0.2	
Controlled Thermonuclear		1.3
AEC	1.3	
Advanced Energy Systems		6.5
AEC	3.8	
Other	2.7	
Fossil Fuel Technology		3.7
AEC	0.3	
Other	3.4	
Other Programs		0.8
AEC	0.8	
Total AEC	115.2	
Total Work for Others	9.1	
Laboratory Total		124.3

^a Budget predates abolishment of the Atomic Energy Commission and creation of the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC).

^b Includes both ERDA and work for others.

<u>Occupation</u>	<u>Permanent Employees</u>
Engineers	979
Computer Scientists/Mathematicians	100
Life Scientists	133
Physical Scientists	477
Technicians and Draftsmen	780
Administrative and Support	<u>2042</u>
Total	4511

The Laboratory's recent projections of its activities through fiscal year 1981³ are as follows:

(1) In the Civilian Reactor Development Program, ANL has been carrying the major national responsibility for those crucial areas of the liquid-metal fast breeder reactor (LMFBR) program that include operations, irradiation testing, physics, and safety. Much of the large-scale experimental phase of this program is conducted at Argonne-West, located in Idaho. This concentration on the LMFBR will continue but with expanding attention being given to the gas-cooled fast breeder and/or other alternatives. If generic problems for water reactors need the Laboratory's special skills, the small current effort in this area could also grow.

Analytical and experimental work in reactor safety, again concentrated, but not exclusively, on the breeder program, will grow to more than one-third of the reactor development total. Current and near-term experimental programs utilize the Transient Reactor Test (TREAT) reactor and the Sodium Loop Safety Facility (SLSF), (both facilities are in Idaho). Work with

longer-term objectives includes the development of the Safety Research Experiment Facility (SAREF)--to be built in Idaho--to service both ANL and other large-scale experimental programs involving plutonium. Expanded post-irradiation examination facilities will also be required to support the foregoing safety work and also the national fuels and materials development effort; this will include a continuing program on demonstration elements for the gas-cooled fast reactor based on current liquid-metal fuel technology, as well as a comprehensive program aimed at a fuel system that will lead to higher breeding gains for either type of breeder. An expanded fuel cycle program will complement the fuels work and contribute to the achievement of a shortened doubling time. A strengthened components technology program will emphasize full-scale prototype testing, an effort for which new, improved facilities will be needed and must be constructed.

(2) Although the fact that the Zero Gradient Synchrotron (ZGS) has a basic role in the high-energy physics research community has recently been reaffirmed, the current shortage of funding for the national high-energy physics program permits only about 50% utilization of the ZGS and its major facilities; a moderate increase is projected to allow their greater utilization. In particular, it is planned to exploit the unique polarized proton beam and the recent important discoveries in neutrino physics, using the 12-foot bubble chamber. A booster accelerator is now being built to increase ZGS

intensities by a large factor in FY 1977. Longer-term facility plans for the Argonne high-energy physics program are now under careful study.

(3) In the Nuclear Sciences a set of coordinated programs will seek a comprehensive understanding of the structure, dynamics and interactions of atomic nuclei and will generate at an accelerated pace a rational framework for the chemistry of the heavy elements of nuclear significance. Materials Science research will attack a range of problems in condensed phases--on both microscopic and macroscopic levels--with a focus on energy-technology relationships. Conduct of radiation damage studies is an important example. In Molecular Sciences, selected atomic, molecular, and chemical processes will be studied to establish a firm basis of understanding of these processes and to provide a fundamental undergirding for work having environmental, energy, and biological significance.

The acquisition of entirely new research facilities is planned so that the Laboratory's strong capabilities can be exploited and advantage can be taken of new techniques and concepts. These facilities, which will have pace-setting influence on the research, include a high-voltage electron microscope complex, an intense pulsed neutron source for the study of condensed phases of matter, and a radically new accelerator for appropriate exploitation of capabilities in nuclear research.

(4) Activities in Biomedical and Environmental Research will sharpen focus on identifying and quantifying the specific biological and environmental problems arising from all forms of energy generation. Although in the past most of the studies were nuclear-related, there is now a broad approach to clarifying the pathways, the effects, and the costs of all energy-related pollutants and the environmental effects of all portions of each energy fuel cycle. The program scope will include new, wide-ranging environmental studies on the fate and the impact of non-nuclear pollutants and new, coupled biological studies of the toxic effects of these pollutants. The Great Lakes and the area in which they have a pervasive influence will be the target region for the environmental assessment. Special consideration is being given to environmental studies involving reclamation of surface-mined land. All these studies will be facilitated by the construction of an environmental evaluation laboratory, but until expected occupancy late in FY 1979, space will be at a premium.

(5) Environmental impact assessment for nuclear power plants has been conducted for several years and is expected to continue at the present rate to meet the needs of the Nuclear Regulatory Commission (NRC). At the same time, new assessments for non-nuclear plants (for other agencies) are expected to increase. Utilizing these assessments, new guides for the effective selection of optimum sites for power plants will be developed.

(6) The accelerated pace of U. S. development in the field of fusion power will require increased attention to the difficult problems associated with the development of practical power reactors. The kind of engineering experience and much of the specific technical knowledge that has gone into the development of fission power are equally applicable to fusion power. Based on its broad experience in fission reactors and in the technology supporting high-energy physics, the Laboratory plans major expansion of its role in the development of fusion power. In addition to an increase in the effort in the development of base technology for controlled thermonuclear reactors (CTR) and fusion reactors, it is proposed to add an effort leading to the design and construction of an experimental power reactor.

(7) There will be far-reaching national and worldwide developments in Advanced (non-nuclear) Energy Systems. The activities are intended to exploit and accelerate non-nuclear programs in which Argonne has demonstrated capability and that would aid in meeting new energy demands, evaluating energy alternatives, and improving the environmental acceptability of energy production. Based on ten years of direct experience, high energy-density lithium metal/sulfide batteries are being developed (a) for storage of energy on utility networks, to reduce the demand for peak-load generating capacity, and (b) as non-polluting power sources for vehicles. The development program, involving industrial participation, is directed toward

the demonstration of both objectives prior to 1980.

Argonne has a program for the development of magnetohydrodynamics (MHD). Liquid-metal MHD is under development as a primary cycle or a topping cycle that, in combination with fluidized-bed combustion of coal, LMFBRs, or CTRs, can increase the efficiency of these heat sources. Open-cycle MHD is a highly efficient alternative to present methods of central-station electric power generation utilizing the direct combustion of coal. The development program is directed toward the utilization of high-sulfur coal directly in an efficient, environmentally acceptable manner.

The Laboratory has a record of successful design and construction of large superconducting magnets. Such magnets will be needed for CTR and MHD application and in a variety of industrial processes. Increased magnet development and supporting materials work is anticipated.

The development of practical devices to utilize solar energy actively is an important national goal. Argonne's Compound Parabolic Concentrator (CPC) is a significant advance in the state-of-the-art of solar collectors. A program is anticipated for the development of this device for space conditioning, steam production, and the direct generation of electrical energy. It is expected that other innovative solar-energy

programs will be initiated during the period covered in this document.

In the Laboratory's systems analysis and technology assessment program, various strategies of resources management and public policy options will be evaluated within practical ranges of energy supply and demand. Important factors in these evaluations are relative risks, costs, benefits, and potential environmental impacts of alternative energy extraction, conversion, storage, and utilization technologies. Other assessments relate to land use, transportation, and environmental protection policies. This program helps focus the scientific and engineering programs at the Laboratory.

(8) Argonne's Fossil-Fuel Technology Program is directed toward increased involvement in more efficient and environmentally acceptable methods of utilizing coal reserves. For several years, the Laboratory has been developing the fluidized-bed combustion process, which effectively removes SO_2 and other pollutants from the flue gas. In addition, broad programs in fossil-fuel technology are getting underway. Highlights of the proposed programs are (a) the development of practical fluidized-bed combustion processes, including small pilot plant work at ANL, (b) base technology support in research and development in areas such as materials and chemistry for a variety of industrial and laboratory development efforts, (c) the development of processes, instrumentation, and equipment

for improved conversion, combustion, coal-extraction, and land reclamation projects, and (d) development of control technology to ameliorate possible adverse environmental consequences of increased coal use.

In the past few years, a vigorous effort has been made to strengthen Argonne's capabilities in coal technology. Recently, funding for a number of proposed programs has been received or substantially increased; as a result, a strong future involvement in coal technology is now predicted. The projected budget is consistent with Argonne's plan to establish a major national Coal Technology Center. The program in Fossil-Fuel Technology will, of course, be closely coordinated with the program in Advanced Energy Systems.

(9) To meet future needs, education and training programs will be augmented to broaden cooperation with schools, colleges, and universities in the motivation and training of people for selected areas of science and engineering; also, to retrain scientists, to keep engineers' knowledge current, to indoctrinate managers with up-to-date understanding, and to improve communication of energy and environment relationships to the public. In addition, it is anticipated that a course in nuclear energy project planning and implementation will be offered to key senior personnel of developing nations, with joint sponsorship of ERDA and the International Atomic Energy Agency (IAEA).

2.2 DETAILED DESCRIPTION OF LABORATORY AND DISCHARGES

2.2.1 Site

2.2.1.1 External Appearance

A map showing the location of the Laboratory in relation to the Chicago metropolitan area has been given in Figure 2.1 and a perspective view of the Laboratory is given in Figure 2.2. Facilities and their identification numbers are given in Table 2.2. Prominent features viewed from within the site are the hillock, circular auditorium, and building complex of the Zero Gradient Synchrotron (360-385); the silvery dome of the Experimental Boiling Water Reactor (331); the "temple mount" buildings of the CP-5 Research Reactor; the white monolith of the cafeteria (213); the glade that encompasses the pool and Guest Facilities (600-621); the consortium of the Inner Research Circle (200-233); the playground, picnic areas, and recreation building of Argonne Park (951); and the herds of white fallow deer that browse freely about the grounds. Because of the screen provided by the pines and oaks about the Laboratory, the chief features visible from offsite are the water storage towers, microwave tower, and, especially in winter, the white, tridentate plume of the Central Steam Facility.

Fig. 2.2. Perspective of the ANL Site.

FAC. NO.	DESCRIPTION				
2	ADMINISTRATION	80	U.S. POST OFFICE - MAIL SERVICES	314	FAST NEUTRON GENERATOR
6-5	WAREHOUSES	91	GUARD SHELTER - ENTRANCE EASTWOOD DRIVE	315	APPLIED PHYSICS
6	STORAGE BUILDING	92	GUARD SHELTER - EAST AREA	316	APPLIED PHYSICS
7	FLORA & FAUNA STORAGE			317	WASTE STORAGE BUILDING
8	FIRE HOUSE			318	REMOTE CONTROL TOWER - 317 AREA
10	EXECUTIVE OFFICES	108	CENTRAL BOILER HOUSE	319	LAND FILL AREA
11	ENVIRONMENTAL STATEMENT PROJECT	109	STORAGE BUILDING	328	TANK FARM
11-A	ENVIRONMENTAL STATEMENT PROJECT	110	FUEL OIL STORAGE TANK (420,000)	325	HYDROGEN TRANSFER STATION
12	CENTER FOR ENVIRONMENTAL STUDIES	111	FUEL OIL STORAGE TANK (420,000)	328	STORAGE BUILDING
13	MATERIAL STORAGE	114	STORAGE BUILDING	330	RESEARCH REACTOR CP-5
14	OCCUPATIONAL HEALTH & SAFETY	128	CHEMICAL STORAGE BUILDING - W.T.P.	331	SPECIAL MATERIALS - DIVISION OFFICE
15	CENTER FOR EDUCATIONAL AFFAIRS	129	WATER TREATMENT PLANT	336	PLANT OPERATIONS - DIVISION OFFICE
16-17	CENTRAL SHOPS - SPECIAL MATERIALS	160	DEEP WELL #1, PUMP HOUSE	350	EXPERIMENTAL ANIMAL QUARTERS
19	OCCUPATIONAL HEALTH & SAFETY	163	SHALLOW WELL #5, PUMP HOUSE	350	PLOWTONIUM FUEL FABRICATION
20	CENTRAL SHOPS	180	METEOROLOGY TOWER	360	OFFICE, LABORATORY & CONTROL BUILDING
21	SECURITY OFFICES	181	METEOROLOGY & ECOLOGY	361	INJECTOR BUILDING
22-23	CENTER FOR EDUCATIONAL AFFAIRS			361-A	INJECTOR BUILDING ANNEX
24	OLD BOILER HOUSE	200	CHEMISTRY	362	HIGH ENERGY PHYSICS BUILDING & AUDITORIUM
25	TRAINING CENTER	202	BIOLOGICAL & MEDICAL RESEARCH	363	SHOP & ASSEMBLY BUILDING
26	CYLINDER STORAGE	203	PHYSICS & RADIOLOGICAL ENVIRONMENTAL RESEARCH	364	CENTER BUILDING
27	SOLVENT STORAGE	206	CHEMICAL ENGINEERING	366	RING BUILDING
28	ACID STORAGE	206	REACTOR ANALYSIS & SAFETY	385	PROTON AREA I-A
30	SEWAGE PUMPING STATION	208	REACTOR ANALYSIS & SAFETY - APPLIED PHYSICS	387	500 LITER BUBBLE CHAMBER
31	SHALLOW WELL #1, PUMP HOUSE	211	CYCLOTRON	388	EXPERIMENTAL POWER BUILDING
32	SHALLOW WELL #2, PUMP HOUSE	212	MATERIAL SCIENCE	389	PROTON AREA I
33	CREDIT UNION	213	CAFETERIA	370	NEOSON BUILDING
34	INDUSTRIAL WASTE TREATMENT PLANT	214	ENGINEERING	371	30' BUBBLE CHAMBER
35	GAS METER HOUSE	220	STORAGE BUILDING	372	12' BUBBLE CHAMBER OFFICE & LABORATORY
36	TECHNICAL AREA MAIL	221	APPLIED MATHEMATICS	373	12' BUBBLE CHAMBER TEST BUILDING
37	FAR HOUSE #1	228	SOLID STATE SCIENCE	373-A	12' BUBBLE CHAMBER TEST TOWER
38	FAR HOUSE #2	291	GUARD SHELTER - NORTHWATE ROAD	373-B	12' BUBBLE CHAMBER STORAGE BUILDING
39	FAR HOUSE #3			374	12' BUBBLE CHAMBER BUILDING
40	CENTRAL SHOPS	301	HOT LABORATORY	374-A	HYDROGEN COMPRESSOR ROOM
41	FAR HOUSE #4	304	PLANT OPERATIONS - RECLAMATION	374-B	CRYOGENIC YARD
42	DOMESTIC WATER TANK - ELEVATED (150,000)	308	COMPONENTS TECHNOLOGY	374-C	NITROGEN COMPRESSOR ROOM
44	PEDESTRIAN SHELTER EAST AREA	309	COMPONENTS TECHNOLOGY	374-D	BUBBLE CHAMBER BUILDING
44	CENTRAL SHOPP STORAGE FACILITY	310	EXPERIMENTAL BREEDER REACTOR II & ENGINEERING	374-E	CONTROL ROOM
55	SPECIAL MATERIALS STORAGE BUILDING	311	EXPERIMENTAL BUILDING	374-F	FIRE WATER PUMP BUILDING
56	STORAGE BUILDING				
57	STOCK & STORAGE BUILDING				

2.2.1.2 Plant Water Use

Cooling water of poor quality is pumped to the Argonne site from the Chicago Sanitary and Ship Canal and is treated and clarified before use. Withdrawal is about 10^6 gallons per day (gpd). The clarified water is distributed to the various cooling towers and heat exchangers at the Laboratory, then drains through ponds and storm sewers to Sawmill Creek. Cooling tower waters are treated to reduce corrosion scaling and fouling with low chromate and nonchromate treatments. The low treatment levels used permit compliance with strict pollution standards. For perspective, a modest-sized power plant, either fossil (e.g., the Commonwealth Edison Will County Plant a few miles downstream of the Laboratory) or nuclear (e.g., Dresden-2, about 30 miles downstream) withdraws about 10^9 gpd of cooling water from the same source.

About 0.8×10^6 gpd of domestic-quality water is withdrawn from five onsite wells, treated, softened, and stored as needed in elevated water storage tanks. This water is distributed to a domestic system and a laboratory service system. Sanitary sewage wastes are treated at the sewage treatment plant, with the service-system water collected and monitored at the laboratory waste plant. Effluents of the sewage plants are combined and discharged to the Des Plaines River via Sawmill Creek. For perspective, total groundwater pumpage in Du Page County is 70×10^6 gpd.

2.2.1.3 Heat Dissipation and Energy Use

The Laboratory uses about 30 megawatts (MW) of electrical power and fuel equivalent to 46 MW of heat capacity. The latter is accounted for chiefly by the Central Steam Facility (36 MW), with smaller contributions from consumption of uranium-235 in the CP-5 and JANUS reactors (5 MW) and of domestic gas and miscellaneous fuels (5 MW). At the onset of the current energy crisis, the Laboratory instituted an energy-sparing program; the average energy use in FY 1975 dropped by about 20% from the average used in FY 1969, despite an increasing level of employment and Laboratory activity. Steam is utilized for the bulk of fixed-station motive power (e.g., refrigeration and air conditioning) because of its energy and fuel efficiency for such uses.

Because of long holdup times in the Laboratory water returns to the environment, all 76 MW are dissipated to the air or ground at the Laboratory. The bulk of this exits to the air from the numerous cooling cells associated with the facilities. The remainder is lost by re-radiation and conduction. Evaporative cooling releases a maximum of about 70,000 gallons of water vapor to the atmosphere per day. This will not increase the absolute humidity at any point offsite by more than 0.25 mg/m^3 .

Increases in fogging, icing, or salt concentration are confined to areas within a few dozen meters of each cell, are not detectable offsite, and produce no observable impact on local transportation or biota. The maximum temperature increase in effluent water, 0.1°F , is well within State limits⁴ and well below the levels that might produce a biological impact.

For perspective, the maximum of 76 MW released to the environment is comparable to the average solar radiation incident on about 30 acres at the site,⁵ i.e., about 2% of the area within the site perimeter fence. The evaporation, at its maximum, is about the same as that of 97 acres of pond or stream surface in the area.

2.2.1.4 Radioactive Waste

Small amounts of radioactive wastes from Laboratory operations enter the liquid waste streams, the exhausted ventilation air, and the solid wastes processed for removal from the site. These waste streams are processed and monitored within the plant to minimize the quantity of radionuclides released to the air, to the Des Plaines River, or to the ultimate burial sites.

The waste-handling and treatment systems are discussed in a large number of internal reports, the most recent of which was issued in June 1975.⁶ In these documents the Laboratory has prepared an analysis of its treatment systems, and has provided estimates of the annual releases of radioactive effluents.

The following analysis of the waste treatment systems of the Laboratory is based on models of the Laboratory waste systems. These models have been developed from a review of available data from this Laboratory and other operating plants, adjusted to apply over a 30-year operating life. The parameters used in the evaluation are based on empirical data therefrom,

with allowances made for operational occurrences, incidents, and aging effects over the life of the Laboratory. As a result, the subsequent calculated releases vary somewhat from those given in the Laboratory's reports. These differences do not lead to adverse conclusions in the evaluation.

A diagrammatic description of the Laboratory Radioactive Waste System is shown in Figure 2.3. Subsystems are described in more detail below.

Liquid Wastes

The liquid radioactive waste treatment system consists of process equipment and instrumentation necessary to collect, process, monitor, and recycle, or dispose of, potentially radioactive liquid wastes. Prior to release, samples of liquid wastes are analyzed to determine the types and amounts of radioactivity present. Based on the results of these analyses, wastes are released under controlled conditions or retained for further processing. Waste effluent that meets the analytical criteria of the Laboratory Permissible Discharge Levels is released to Sawmill Creek. A complete, technical description of the Laboratory waste treatment methods has appeared in the open literature.⁷

It has long been a firm policy of the Laboratory that any release of radioactive wastes shall be conducted only in such manner as to ensure that present and future radiation exposures to individuals and population groups will not exceed applicable standards, e.g., those of 10 CFR 20 and/or the ERDA manual, "Standards for Radiation Protection,"

Fig. 2.3. Flow Chart of ANL Radioactive Waste.

ERDAM 0524. In consequence, the Laboratory adopted the following annual limits for discharge of radioactivity from the liquid outfall into Sawmill Creek:

<u>Activity</u>	<u>Annual Limit</u>
Alpha emitters	0.15 curie
Strontium-90 (Sr-90)	0.45 curie
Beta/gamma emitters other than Sr-90, but including tritium (H-3)	10 curies

Laboratory experience is shown in Table 2.3 and in Section 2.4. With the exception of the least-hazardous nuclide, H-3, Laboratory releases have been about two orders of magnitude below the above limits. Concentrations for all nuclides in Sawmill Creek have been two to three orders of magnitude below the limits for uncontrolled areas given by 10 CFR 20 and/or ERDAM 0524 (see also Sec. 2.4).

Based on evaluation of the waste treatment systems, and for purposes of conservative dose assessment, the releases of radioactive materials in the effluent were taken to be 0.15 Ci/yr alpha activity, chiefly uranium (U), and 10 Ci/yr beta activity, chiefly tritium (H-3), in an annual effluent volume of 2.8×10^8 gallons. These values are the site limits for such releases, and are markedly greater than actual releases, as shown in Table 2.3. These assumed releases represent annual average concentrations in Sawmill Creek, which are less than 1% of the 10 CFR 20 (ERDAM 0524) concentrations permitted to unrestricted areas, based on the most restrictive radionuclides [Californium (Cf)-254 soluble, for alpha; and plutonium (Pu)-241, soluble, for beta].

Table 2.3. Liquid Discharges to the Outfall by Fiscal Years

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total volume discharged to outfall, gallons	2.51×10^8	2.80×10^8	2.95×10^8	2.66×10^8	2.93×10^8	3.24×10^8	3.15×10^8	2.82×10^8	2.90×10^8	2.77×10^8
Alpha radioactivity discharged, Curies	13.0×10^{-3}	7.90×10^{-3}	8.73×10^{-3}	4.05×10^{-3}	1.78×10^{-3}	1.08×10^{-3}	1.31×10^{-3}	1.71×10^{-3}	1.46×10^{-3}	1.17×10^{-3}
Average alpha concentration, $\mu\text{Ci/ml}$	13.7×10^{-9}	7.45×10^{-9}	7.82×10^{-9}	4.02×10^{-9}	1.60×10^{-9}	0.88×10^{-9}	1.10×10^{-9}	1.60×10^{-9}	1.33×10^{-9}	1.11×10^{-9}
Beta radioactivity discharged, Curies	16.1×10^{-2}	14.6×10^{-2}	16.0×10^{-2}	11.86×10^{-2}	3.70×10^{-2}	3.21×10^{-2}	4.90×10^{-2}	4.93×10^{-2}	4.70×10^{-2}	5.09×10^{-2}
Average beta concentration, $\mu\text{Ci/ml}$	17.0×10^{-8}	13.8×10^{-8}	14.3×10^{-8}	11.8×10^{-8}	3.34×10^{-8}	2.62×10^{-8}	4.11×10^{-8}	4.62×10^{-8}	4.28×10^{-8}	4.85×10^{-8}
Strontium-90 radioactivity discharged, Curies	a	a	9.92×10^{-3}	8.50×10^{-3}	7.39×10^{-3}	4.79×10^{-3}	5.72×10^{-3}	5.93×10^{-3}	5.05×10^{-3}	3.28×10^{-3}
Average strontium-90 concentration, $\mu\text{Ci/ml}$	----	----	8.89×10^{-9}	8.44×10^{-9}	6.66×10^{-9}	3.90×10^{-9}	4.80×10^{-9}	5.56×10^{-9}	4.60×10^{-9}	3.12×10^{-9}
Tritium radioactivity discharged, Curies	a	a	a	a	a	a	a	a	3.81	2.65
Average tritium concentration, $\mu\text{Ci/ml}$	----	----	----	----	----	----	----	----	3.47×10^{-6}	2.52×10^{-6}

^a Routine analysis not performed.

Gaseous Wastes

The gaseous waste treatment and ventilation system consists of equipment and instrumentation necessary to reduce releases of radioactive gases and airborne particulates from equipment and building ventilation streams. The dominant source of radioactive waste is argon (Ar)-41 from the CP-5 reactor, with much smaller contributions from tritiated water vapor, fission products, activation products, accelerator-produced nuclides, and transuranium elements from other facilities, in about that order of importance.

A typical building design is shown in Figure 2.4. Airflow is controlled by a system of decreasing (relatively negative) pressures so that net flow is always in the direction of increased probability of airborne radioactivity. The ventilation system consists of three main systems in series: the outer access area, the inner laboratory area, and the hood or glove box line. Air leaving each potentially contaminated area is exhausted through a high efficiency particulate air (HEPA) filter system, generally a hood filter, sometimes followed by an intermediate, and always a final HEPA filter, before exiting through the ventilation exhaust stack. Air is partially recirculated only in a few outer access areas. The inner areas are all once-through systems.

The exhaust system is provided with radiation monitor and alarm systems to allow prompt corrective action in the event that radiation exceeds preset levels. The exhaust systems that are currently monitored in the discharge stack, and alarmed, are listed in Table 2.4. A few filters

Fig. 2.4. Environmental Contamination Control Systems.

Table 2.4. Continuously Monitored^a Radiological Exhaust Stacks

<i>Stack Location</i>	<i>Source of Potential Discharge</i>
Building 202	JANUS Reactor and Associated Facilities
Building 205	Glove Box and Senior Cave Areas
Building 212	Cave Area
Building 330	CP-5 Reactor and Associated Facilities
Building 350	Glove Box and Storage Areas

^aWith associated alarm systems.

are provided with fire protection and with parallel branches capable of carrying the full flow. This system redundancy provides for filter changes and maintenance without interruption of flow, as well as for protection against malfunction and operational downtime. Estimates of annual airborne releases are shown in Table 2.5. Based on evaluation of the ventilation and gas treatment systems, the actual release was calculated to be but a fraction of the values given in the table. However, to compensate for equipment downtime, expected operational occurrences, program expansions, and plant aging effects, the values have been normalized to an annual release based on the processing and examination of 1.5 tonnes (metric tons) per year of a high-burnup, fast reactor fuel; the continuous operation of the CP-5 and JANUS reactors at power levels of 5 megawatts, thermal (MWt) and 0.25 MWt, respectively; and the increase of activity levels at other facilities by a factor of three. Even at these levels, doses were estimated to be less than 1% of those permitted by 10 CFR 20 (ERDAM 0524).

Solid Wastes

Solid waste containing radioactive materials is generated during plant operation. A portion of this arises from solidification of liquid wastes, sanitary sludge bed, and organic solvent streams.⁷ The remaining portions are solids such as paper, plastic, grinding wastes, filter elements, hardware, protective clothing, and clothing too highly contaminated for normal laundry.

In accordance with prevailing ERDA and Department of Transportation

Table 2.5. Estimated Average Airborne
Radioactive Effluents

<i>Nuclide^a</i>	<i>Release, mCi/sec</i>
Ar-41	4.3×10^{-1}
H-3	1.5×10^{-2}
Kr-85	4.3×10^{-1}
Sr-89	7.6×10^{-9}
Sr-90	8.8×10^{-9}
Y-90	8.8×10^{-9}
Y-91	1.6×10^{-8}
Zr-95	2.8×10^{-8}
Nb-95	5.3×10^{-8}
Ru-103	8.4×10^{-9}
Ru-106	5.0×10^{-8}
I-129	1.5×10^{-9}
I-131	1.2×10^{-8}
Cs-134	1.9×10^{-8}
Cs-137	1.2×10^{-8}
Ce-141	5.5×10^{-9}
Ce-144	8.4×10^{-8}
Pm-147	1.5×10^{-8}
U-234	7.0×10^{-14}
U-235	7.0×10^{-16}
U-238	2.0×10^{-14}
Pu-238	1.3×10^{-10}
Pu-239	1.2×10^{-11}
Pu-240	2.1×10^{-11}
Pu-241	5.5×10^{-9}
Pu-242	1.1×10^{-13}
Am-241	3.2×10^{-11}
Am-242	6.3×10^{-13}
Cm-242	3.7×10^{-9}
Cm-243	2.5×10^{-12}
Cm-244	3.9×10^{-10}
All other α emitters ^a	1.5×10^{-10}
All other β, γ emitters ^a	2.6×10^{-8}

^aShort-lived decay products are also present
in equilibrium quantities.

(DOT) regulations, all solid or solidified waste is packed into ERDA- and DOT-approved containers for offsite disposition. No solid waste is released to the environment by or at the Laboratory.

Transportation

Liquid and gaseous wastes are not transported from the Laboratory. Shipments of solid wastes are currently at a level of about 40 truckloads per year, each load containing the equivalent of 200 drums of DOT specification 17H. Shipments may be expected to increase to a maximum of about 60 truckloads per year. All shipments are by truck in ERDA- and DOT-approved shipping containers. Dose levels do not exceed 200 mrem/hr at the surface of any container, 10 mrem/hr at a distance of 6 feet from a shipment truck, nor 1.2 mrem/hr at a distance of 50 feet. Each shipment of radioactive material is surveyed before shipment. If contamination is detected, the vehicle and shipment are completely surveyed and decontaminated before release from the Laboratory.

2.2.1.5 Non-Radioactive Wastes

Solid non-radioactive wastes are packaged and buried in a controlled landfill area onsite. They are handled as carefully as are radioactive wastes⁷ so as to maintain control.

Liquid wastes are treated in much the same manner as radioactive liquid wastes so as to maintain control of potentially noxious chemical species.

Wastes of high chemical content are concentrated, solidified, and treated much as if they were radioactive liquid wastes.⁷ After holdup in the local facility tanks, dilute chemical wastes in the Laboratory service water are treated at the Laboratory waste treatment plant.⁷ The actual levels of discharge and their potential for environmental impact are covered in Section 2.4.

Gaseous wastes that arise within sensitive facilities are also subjected to the same reduction of concentration levels whether or not they are radioactive. However, gaseous wastes that arise in non-sensitive facilities (e.g., the Central Steam Facility) are subjected to methods of level reduction adapted to their own needs. Thus, the steam facility utilizes cyclone separators rather than HEPA filters.

The total non-radiological gaseous emissions from the Laboratory are listed in Table 2.6. All emissions meet applicable State and Federal standards and/or guidelines (e.g., Code of Federal Regulations, Title 10). For perspective, the Will County Electric Generating Station and the petroleum refineries at Lemont, Joliet, and Lockport, all upwind of the plant, emit 10^4 to 10^5 times as much of each of the noted pollutants as does the Laboratory.

2.2.1.6 Noise Levels

Noise levels have been surveyed at various points on the site fence line. The average level was about 44 dBA, a level categorized as "highly

Table 2.6. Total Gaseous Emissions
from the Laboratory

<i>Effluent</i>	<i>Emission, tonnes/yr</i>
Particulates	34
SO ₂	7.3
CO	86
Hydrocarbons	45
NO _x	127
NH ₃	0.6
Cl ⁻	0.1
F ⁻	0.01
Aldehydes	6.4
Organic acids	0.9

acceptable" by HUD,⁸ - intermediate between a library and a quiet home.

Individual readings are tabulated below (refer also to Fig. 2.2 and Table 2.2 for locations):

<u>Measurement Point</u>	<u>Sound Level, dBA</u>
1200 ft N of Steam Plant (Bldg 108)	49
Near Guard Post 291 on Northgate Road	44
1000 ft N of Bldg. 208	46
Near Guard Post 891 on Westgate Road	46
Near Gate at Bldg. 181	43
1000 ft S of Bldg 350 (St. Patrick's Cemetery)	43
Near Guard Post 591 on Bluff Road	44
1000 ft SE of Bldg 2	43
500 ft NE of Bldg 6	41

2.2.1.7 Sanitary Effluents and Biocides

Sanitary effluents are discussed in Section 2.4.2.2. The use of biocidal chemicals on a site-wide basis at ANL is very limited. They are employed to control pests such as weeds, insects, and rodents at or around occupied areas and to curb algae growth in cooling tower basins. Biocidal wastes are not normally generated at the Laboratory.

All site pest-control activities are under the direction of a Plant Operations Supervisor knowledgeable in the use of these chemicals. Only 130 acres of the site receive any type of pesticide treatment. The criteria used to determine need of application are (1) improvement of appearance, (2) elimination of fire hazards, (3) protection of shade trees, and (4) reduction of health hazards. Most vegetation is kept under control by mowing except in transformer areas, material yards,

and along fence lines where it is impractical or impossible to do so. In those cases, Televar is applied to sterilize the areas, but not more often than every three years. Application of chemicals is performed by trained employees or licensed contractors under the direction of the Plant Operations Supervisor. He conducts evaluations of the effectiveness of the chemicals by checking conditions before and after use.

The Laboratory complies with all applicable rules and regulations of the Environmental Protection Agency and has established that pest control practices will include the following:

- All pesticides to be used must be registered under the Federal Insecticide, Fungicide, and Rodenticide Act and employed only in the manner specified.
- No chemicals requiring special approval by the Federal Workers Group on Pest Management are to be used.
- All pesticide usage is to be under the direct supervision of an ANL employee who has knowledge and training in the safe and effective manner of application.
- Storage and application are to be accomplished so as to preclude contamination of all irrigation and domestic water supplies.

2.2.2 Facilities and Inventories

2.2.2.1 Research Installations

Reactors

The Laboratory has two major nuclear reactors, CP-5 and JANUS, and three smaller ones, ZPR-6 and -9 and ATSR.

CP-5. The older of the two major reactors, CP-5 was placed in operation in 1954. It serves as a reliable and copious source of neutrons and gamma-rays for a variety of experiments and irradiations. Heavy-water-moderated and cooled, this reactor is fueled with enriched uranium. A converter permits experiments to be conducted with fission-energy neutrons.

The core of the reactor may consist of as many as 17 fuel elements. Each element is a tubular assembly containing a 24-inch length of fuel alloyed and clad with aluminum. The nominal critical mass is 1.2 kilograms of uranium-235; a typical loading is 2 to 2.1 kilograms of uranium-235. The core is surrounded by an aluminum tank, 6-1/2 feet in diameter, a graphite reflector, and a high-density concrete biological shield that is 4-1/2 feet thick. The portion of Building 330 that houses the reactor is constructed of one-foot-thick poured concrete. The interior is maintained at a slightly negative pressure, in relation to the outside atmosphere, to prevent the uncontrolled escape of any gases released from the reactor.

With a schedule of use that requires continuous operation at or near its full thermal power rating of 5000 kW, CP-5 has an average fuel cycle of about six weeks. At the end of a cycle, three of the fuel elements are removed from the reactor and replaced. An element is moved by means of a shielded cask to a cooling canal where it is stored until it has decayed sufficiently to permit its movement to a hot cell. In the hot cell, the element is cut into sections that are shipped to a reprocessing plant.

A storage facility within the reactor shell permits the storage of as many as 24 new fuel elements. A typical inventory is about nine.

Wastes and other radioactive materials that result from operation of the reactor and the disassembly of fuel elements, as well as irradiated specimens, etc., are stored or processed in accordance with long-established procedures.

JANUS. The second of Argonne's research reactors is JANUS, which is used by the Laboratory's Division of Biological and Medical Research in studies of the effects of neutrons on living systems. The reactor design permits the simultaneous exposure of large numbers of biological specimens either to acute or chronic doses of fission energy neutrons. It is at the east end of J Wing in Building 202.

Somewhat similar to CP-5, JANUS can accommodate 19 fuel elements, each with an active length of enriched uranium of about 24 inches. These elements are contained in an aluminum tank, which in turn is surrounded

by a graphite reflector and a high-density biological shield. The nominal critical mass is 2.5 kilograms of uranium-235 and the present loading is 2.6 kilograms. Two neutron converters contain 9.5 and 31.6 kilograms of uranium-235, respectively.

The thermal power rating of the reactor is 250 kW and at present is being operated at 10% power on a six-hour day, five-day week basis. The corresponding fuel cycle is estimated to be six years.

Storage of fuel outside the reactor core is not permitted in Building 202, and other radioactive materials may be stored only with the approval of the JANUS manager.

ZPR-6 and 9. Two flexible, low-power, experimental reactors, ZPR-6 and ZPR-9, are located in Building 316, somewhat to the west and south of almost all the other Laboratory facilities. Essentially identical, these two units, which are being used to obtain reactor physics data in support of the LMFBR program, are known as critical assemblies, or zero-power reactors. Their power usually is limited to levels well below 1000 watts.

Each reactor consists of one stationary and one movable table. Lattices mounted on the tables permit the trial assembly of an unlimited number of core configurations as large as a 2.4-meter cube, one-half on each table. Materials used in these models include depleted uranium, stainless steel, aluminum, zirconium graphite, and oxides of heavy metals, as well as enriched uranium and plutonium.

Both reactors are surrounded by reinforced concrete cells, which in turn are surrounded by a steel containment shell.

ATSR. The Argonne Thermal Source Reactor (ATSR) serves as a sample irradiation facility and as a precise means of determining the reactivity of samples inserted in a central thimble. It also provides large quantities of thermal and fast neutrons for measuring reactor physics parameters and testing neutron detectors.

Light water is used as a moderator and reflector; the critical mass is about three kilograms of uranium-235. A 5×5 array of vertical compartments in the core section of the reactor permits loadings to be modified to suit experimental needs. Fuel elements are of the BORAX type; ten curved, aluminum-clad, uranium-aluminum alloy plates are welded into a parallel plate assembly containing 157 grams of uranium-235.

An aluminum tank measuring $66 \times 51 \times 91$ cm surrounds the fuel lattice. Beyond this, there is 15-cm layer of lead that shields the reactor on three sides and the bottom.

Accelerator Facilities

Zero Gradient Synchrotron. The largest accelerator on the site is the Zero Gradient Synchrotron (ZGS). It is capable of producing particles with energies up to 12.5 Gev for studies of the fundamental properties of the atomic nucleus.

The ultimate energy of the particles is the product of three stages of acceleration. The first of these may be either of two Cockcroft-Walton accelerators, which impart an energy of 750 kev. Next, the particles are directed into a linear accelerator (linac) that increases their energy to 50 Mev. At this energy level, the particles are directed into the 200-foot-diameter ring, or synchrotron. In the ring, a radio frequency cavity synchronized with the speed of the particles and the strength of the ring's magnetic field raises the energy of the particles to 12.5 Gev. Depending upon the experiment, particles may be protons, polarized protons, H^- , or others.

The beam may be directed to targets within the ring itself, or to any of several experimental areas. Two booster, or synchrotron, accelerators are planned to raise the energy of particles from the 50-Mev linac to 500 Mev prior to their injection into the ring. The first of these is now being prepared for testing; the second is scheduled for completion in FY 1976.

A great deal of experimental equipment of various sizes and shapes surrounds the ZGS. Most numerous are magnets, electrostatic separators, computers for control or data analysis, shielding, and detectors. The latter include simple counters, spark chambers, analyzers, and a 12-foot hydrogen bubble chamber in Building 374.

A variety of radioactive materials is produced or used in connection with ZGS operations. These are targets of several types with typical half-lives of about 53 days (for beryllium) and about one year (for

copper), obsolete or broken equipment for one of the beam lines or accelerators, and encapsulated sources, typically less than 10 millicuries (mCi) in strength. All are handled in accordance with standard Laboratory procedures for wastes, storage, or use of radioactive materials.

Tandem Van de Graaff. This accelerator and its associated experimental facilities are located in a separate wing at the rear of Building 203. The principal components are a negative-ion source, the accelerator (a model FN Tandem Van de Graaff manufactured by the High Voltage Engineering Corporation and rated at 7.5 Mev), two 90° analyzer magnets and two ion beam switching magnets, together with beam pipes, vacuum pumps and the necessary electronics.

The Tandem is used for varied research reflecting the diverse interests of about 30 scientists. Except for adjustments, modification, or periodical maintenance, the machine is operated continuously. The beam may be deflected 90° to the left or to the right into either of two target areas, each of which houses a number of large experimental facilities.

Negative ions are produced at the north end of the accelerator vault by either of two source systems.

The Tandem is in a well-shielded, concrete-walled building. The walls are four feet thick between the experimental areas and the vault and 5-1/2 feet thick between the experimental areas and the rest of the building. The floor of the vault over the accelerator and to its south, and the roofs over the experimental areas, are three feet thick. Earth

piled against the walls to the height of the ceiling provides additional shielding. Interlocks prevent entry to areas that are hazardous when the machine is in operation. Generally, radiation is present only while the beam is on. Components that become activated have short half-lives and decay rapidly when the operation is terminated.

Fast Neutron Generator. The Fast Neutron Generator (FNG), located in Building 314, is a tandem Dynamitron accelerator that produces positive beams of ^1H , ^2D , or $^4\text{He}^{++}$ ions at energies as high as 8 Mev with currents up to 1.0 milliamperes. Target materials exposed to the beams become research sources producing as many as 10^{12} neutrons per second.

Normally scheduled for operation 24 hours per day, five days per week, the FNG is surrounded by a massive concrete shield that reduces exterior radiation to a level well below that accepted for continuous human exposure. Shielding walls and exclusion fences also isolate the experimental area and permit access only in accordance with established procedures. Although one instrument (the 100-meter flight tube) extends beyond the security area, no radiation or other hazard is associated with the arrangement. Except for a small amount of induced activity in the target area, there is no residual radiation after shutdown.

About 2500 cubic feet of sulfur hexafluoride (SF_6) at a pressure of 90 psi is contained in the FNG. Operation of the machine also requires considerable amounts of liquid nitrogen. The former is chemically inert, and in the event of a leak, the latter would evaporate--both passing into the atmosphere without hazard.

Although a wide variety of radioactive materials is produced in the normal course of FNG operations, all the activities are low (about one mCi or less) and generally of short half-life (minutes to days). The most common material is beryllium-7 (53 days) produced by the reaction ${}^7\text{Li}(p,n){}^7\text{Be}$. This may be either a liquid or a solid. In the future, as much as one curie of tritium may be used within the building. If so, suitable instruments will be incorporated in a protective scheme designed to prevent its release.

In addition to the above accelerators, the Laboratory has a variety of other accelerators at different locations, including the Dynamitron in Building 203 and a 4-Mev positive-ion accelerator and a 60-inch cyclotron in Building 211.

High-Level Facilities

Hot Cells. Hot-cell facilities are located in several Laboratory buildings. All have the general characteristics of thick shielding walls and windows; devices for the remote movement, handling, and control of radioactive materials; and negative interior pressures. Features such as alpha barriers or inert atmospheres have been incorporated to meet special needs.

The largest hot-cell facility is at the rear of Wing M in Building 200. Essentially, this is a two-floor complex of twelve cells joined by an elevator and corridors. It is designed to permit the handling of substantial quantities of alpha-gamma emitters and materials that are sources of fission neutrons.

Thick walls, with windows at strategic locations, surround the entire facility as well as the individual cells. Complicated experiments and operations are carried out by means of master-slave manipulators and other remotely-controlled devices such as carts, robots, and cranes.

At present, several of the cells are empty and others are infrequently used. Cells A-1, A-2, A-3, and A-4 are being used to varying degrees for a project that occasionally requires the dissolution of small (one gram or less) samples of irradiated uranium or plutonium. Inasmuch as these operations are conducted in a closed system, the fission product gases are contained; however, several hundred milliliters of solution are generated. Except for aliquots removed for study, this liquid ultimately is handled in accordance with the procedures for fission-product wastes. No other current operations are likely to generate fission product gases.

Cell M-4 is being used by the Chemical Engineering Division, K-1 by the Materials Science Division, K-2 by the Reactor Analysis and Safety Division, and M-2 by the Chemistry Division Gamma Facility for irradiations that may involve as much as 93,000 curies (Ci) of cobalt-60.

A similar hot cell, although not as large, is located in Building 212. In addition, the Laboratory has other, smaller, hot cells in several locations.

Irradiation Facilities. A number of irradiation facilities are located within the Laboratory. All have built-in safety devices and each source

is encased to prevent contamination. The largest unit is in Cell M-2 of the Chemistry Hot Laboratory, located at the rear of Wing M in Building 200. At present, about 93,000 curies of cobalt-60 are available in this facility. Other cobalt-60 irradiation units are located in Room A059 on the service floor (8000 Ci) and in Room A175 (500 Ci). Other facilities for irradiation are in Building 202.

2.2.2.2 Research and Development Facilities

To carry out the research program discussed in Section 2.1, the Laboratory has a variety of research and development facilities. These are listed in Table 2.7. A brief summary of the activities is given below. A wide range of operations supports the research and development activities of the Laboratory. These include technical services, health and safety, and educational and informational facilities. Support facilities such as waste processing and handling, water processing and handling, etc., are also carried out by the Laboratory. A listing of the support operations is given in Table 2.8.

Applied Mathematics Division (Bldg. 221)

Activities in this building are associated with the fields of mathematics and computer science as they relate to the broad interests of the Laboratory and ERDA.

The major items of equipment are an IBM 370/195 and an IBM 360/75. In addition, there are the customary components associated with large

Table 2.7. Research and Development Facilities

<i>Division</i>	<i>Location</i>
Applied Mathematics Division	Building 221
Applied Physics Division	Buildings 208, 314, 316
Biological and Medical Research Division (including animal facilities)	Buildings 202, 340
Chemistry Division	Building 200
Components Technology Division	Building 308
Engineering Division	Buildings 24, 214, 310
Physics Division	Building 203
Radiological and Environmental Research Division	Buildings 181, 203
High Energy Physics Division	360 Area
Solid State Science Division	Building 223
Chemical Engineering Division	Building 205
Materials Science Division	Building 212
Energy and Environmental Systems Division	Building 12
Environmental Statement Project	Buildings 11, 11A
EBR-II Project Division	Buildings 212, 310, 362
Reactor Analysis and Safety Division	Buildings 17, 206, 208, 311

Table 2.8. Technical Support Facilities

Technical Services

Central Shops

Electronics

Occupational Health and Safety

Special Materials and Services

Educational and Informational Facilities

Affirmative Action Program

Center for Educational Affairs

Office of Public Affairs

Library Services

Recreational and Lodging Facilities**Plant Operations**

Building Maintenance

Central Management

Property Management

Support Facilities

Waste Processing and Handling

Storage Areas

Water Processing and Handling (including domestic, laboratory,
fire, and cooling)

Power Generation and Transmission Facilities

Heat Dissipation Systems (primarily cooling towers)

computers, a number of smaller computers, a film processing laboratory, and several electronics laboratories. Two microwave communications systems utilize a reflector mounted on a 180-foot tower about 250 feet from the nearest site boundary.

Applied Physics Division (Bldgs. 208, 314, & 316)

Applied Physics experimental activities in these buildings are focused on ZPR-6 and ZPR-9, and on the Fast Neutron Generator, primarily in support of the fast breeder program.

The effort is equally divided between theoretical and experimental studies. A major portion of the program is concerned with the physics requirements of the fast breeder program, principally the liquid metal system, but with some attention to the gas-cooled version. Other areas of interest, predominantly theoretical, include thermal and fast reactor safety, test facility design, and controlled thermonuclear reactors and fusion.

Facilities used to a lesser extent in the experimental programs include a radiochemistry laboratory for low-level work with alpha, beta, and gamma radiochemicals as well as high-level alpha operations with plutonium, uranium-233, and transplutonium isotopes; and counting rooms and computers.

Biological and Medical Research Division (Bldgs. 202 & 340)

Research in Building 202 is concerned with neutron and gamma-ray toxicity

studies, radiation toxicity in dogs, carcinogenesis, aging, biochemistry, biophysics, and molecular and radiation genetics. A program concerned with experimental radiation pathology is carried out in Building 340.

The multistory building (202) contains many research laboratories and unique facilities. Among the latter are the animal quarters with 600 purebred dogs, 60,000 rodents and numerous other specimens, and irradiation facilities of various kinds, foremost of which are the JANUS reactor and three gamma rooms. A radioisotope laboratory and a storage facility in a separate wing are equipped to handle isotopes with as much as 20 curies of gamma activity.

Chemistry Division (Bldg. 200)

A diverse research program primarily concerned with nuclear, radiation, heavy- or transuranium-element, high-temperature, and isotope-effects chemistry is conducted in this building. The research is primarily basic in nature, although some applied projects resulting from basic studies are included.

The main portion of the building consists of six wings connected by cross corridors at the front and rear. The typical research area arrangement is for laboratories to be on the north side of the corridor in each wing and the offices on the south side of the corridor. A service floor beneath the office and corridors, but not under the laboratories, provides space for a few additional laboratories, a machine shop, maintenance personnel, and storage. Three laboratories with mass spectrometers are in the sub-basement.

Administrative offices, a library, and the central telephone switchboard are at the front of the building; service facilities are at the rear. The building contains an auditorium on the second floor.

In Wing M, research is primarily concerned with the very heavy elements--usually those of the transplutonium group, but occasionally with protactinium, uranium, neptunium, and plutonium. A small (40-mCi) radium-226 source is used as a radon generator for a study seeking to develop solid absorbents for radon.

In general, the quantities of radioactive materials used in experiments are relatively small--micrograms or milligrams per experiment. However, chemical properties investigations may occasionally utilize gram amounts for the less radioactive and more available elements such as uranium and neptunium. Typically, a nuclear experiment is associated with a target that is bombarded in an accelerator and then returned to Wing M for chemical separation and treatment.

An isotope separator is on the service floor of Wing M. This is a large mass spectrometer with the capability of separating tens of micrograms per day of almost any element. Isolation of the loading and collecting portions of the machine with glove boxes permits the use of radioactive samples. While such samples cause no problems during operation, decontamination of the instrument has resulted in a temporary increase in the building's solid contaminated waste.

Components Technology Division (Bldg. 308)

An ever-changing variety of reactor-related engineering tests and experiments is carried out in Building 308. Liquid metals engineering tests have been conducted by the Laboratory for the past 28 years. At present, several facilities are being operated in Building 308. These are the Core Components Test Loop with 920 gallons of sodium at a maximum temperature of 1200°F and a maximum pressure of 100 psig; the Heat Transfer Simulation Loop with 25 gallons of sodium at a maximum temperature of 1200°F and a maximum pressure of 500 psig; and the Steam Generator Test Facility with 30 gallons of sodium at a maximum temperature of 1200°F and a maximum pressure of 40 psig, and 30 gallons of water at a maximum temperature of 650°F and a maximum pressure of 2400 psig. A Mercury-Freon Loop with 700 pounds of mercury operated at a maximum temperature of 450°F, and with the Freon at a maximum pressure of 400 psig, is being maintained in stand-by condition.

Building 308 has several features that make it particularly suitable for experiments with liquid sodium. It has a sodium oxide scrubber, sealed floor drains, elevated waste water drains, and sodium oxide smoke detectors.

Engineering Division (Bldgs. 24, 214, & 310)

Facilities for magnetohydrodynamics (MHD) experiments are located in Building 24. The goal of the program is to develop an MHD generator that will substantially improve the efficiency of either nuclear- or fossil-fuel electric plants, with a concurrent reduction in both particulate and thermal pollution.

About 100 gallons of sodium-potassium alloy (NaK) are utilized as a liquid electrical conductor. Nitrogen gas is mixed with the NaK and at the conclusion of an experiment is separated by gravitational settling and exhausted to the atmosphere through a series of splash baffles.

Buildings 214 and 310 house office and storage facilities.

Physics Division (Bldg. 203)

Part of this building is used for research into the structure, modes of excitation, and reactions of the atomic nucleus. Principal facilities used in this research include several accelerators housed in the building. For some studies, targets from these machines are moved to other locations for examination in an ion microprobe (located in Bldg. 205), or in optical or scanning electron microscopes, X-ray diffraction or Auger effect machines.

Mass spectrometers (the largest of which is the 100" Double Focusing Mass Spectrometer), an ion milling machine, an X-ray diffraction machine, and a scanning electron microscope are principal research tools.

Radioactive materials involved in physics experiments usually have been irradiated in a reactor or bombarded in the 60-inch cyclotron, or in another accelerator. The radiation from these specimens and targets may be alpha, beta, gamma, or any combinations of these. Amounts are small, typically two or three roentgens with a three-day half-life. The materials are stored in hoods behind lead bricks until they decay sufficiently

to be handled in accordance with the procedures for dry active waste. Accelerator components occasionally are activated by scattered radiation and must be similarly handled.

Some plutonium and other transuranic elements are stored in one of several hoods designed for radioactivity. Amounts correspond to a few milligrams of plutonium. Ion sources used with plutonium or other such elements are cleaned in hoods with chemicals such as HNO_3 and H_2F_2 . The latter are removed from the building and processed in accordance with procedures for liquid active wastes.

Radiological and Environmental Research Division (Bldgs. 181 & 203)

Four principal programs constitute the research carried out by this division. The Center for Human Radiobiology is concerned with long-term effects of radium and other internal emitters in humans; the Radiation Physics Section studies the interactions of ionizing particles or photons on molecular substances; an Ecology Section conducts research on the behavior of toxic substances in the environment; and an Atmospheric Physics Section investigates the physical phenomena of the lower one or two kilometers of the atmosphere.

High Energy Physics Division (360 Area)

For the most part, studies conducted in this area are directed toward obtaining knowledge of the fundamental structure of the nucleus. The principal tool is the Zero Gradient Synchrotron (ZGS), an accelerator

capable of producing particles with an energy of 12.5 Gev. Several experimental areas and a great deal of special equipment and facilities surround the ZGS. Those deserving of special note are located in Buildings 368, 369, 370, 374 and 375.

The extracted proton beam areas are in Buildings 369 and 375, the meson area in Building 370 and the 12-foot hydrogen bubble chamber in Building 374.

The extracted proton beams are directed to a series of target stations, each of which produces secondary beams. As many as three simultaneous experiments are carried out with secondary particles from a single target. Septum magnets on the extracted proton beam lines may be used to direct fractions of the beam to various polarized proton experiments.

Mesons, or secondary particles, are formed when the beam in the ZGS ring impinges upon a metallic target. The mesons then adopt trajectories dependent on their energies, charge, and position of the target. Experiments with these beams are conducted in the area just outside the ring, near the target.

Detecting equipment used in the experiments varies from simple counters to spark chambers, momentum spectrum analyzers, and the 12-foot hydrogen bubble chamber. The latter is used for neutrino and other particle studies. As particles pass through the chamber, gas bubbles in the hydrogen indicate the paths as well as those of other particles that are caused to move as a result of collisions. The presence of neutrinos, which are not ionized, may be inferred by the paths of collision fragments caused by passage of the neutrinos through the chamber.

Occasionally, radioactive sources such as ruthenium-106, cesium-137, cobalt-60, and strontium-90 are used to test experimental apparatus. These typically are from 1 to 10 mCi in strength and are encapsulated and handled in accordance with procedures that prevent exposure of personnel and releases to the atmosphere. Similarly, hot targets and accelerator components are moved to shielded areas, where they are stored until activity decays to levels low enough to permit disposition.

Solid State Science Division (Bldg. 223)

Except for personnel of the Office of the Laboratory Director, who are involved solely in administrative matters, this area is devoted to theoretical and experimental studies of the properties of materials. These investigations are in the fields of physics, physical metallurgy, chemistry, and electronics.

The experimental facilities include a 12,000-curie cobalt-60 source used in a 36" x 36" x 40" cell shielded by 1-1/2 to two feet of steel plate. With the source in use, the radiation reading through the shielding is less than .01 mr/hr except for a collimated 10 mr/hr beam around the control rod that holds the source.

Several radioactive materials are used, primarily by the Mossbauer Studies Group. Most of these are solids and include beta-gamma emitters such as cobalt-57 and thulium-170, and alpha emitters such as neptunium-237 and americium-243. Intensities vary from less than one mCi to about 30 mCi per sample, with a total of about 300 mCi. In a majority of cases these materials are received fully encapsulated.

Chemical Engineering Division (Bldg. 205)

A variety of research programs is carried out in this building. Included are those concerned with energy conversion, fluidized-bed combustion of coal, the analysis of airborne combustion particulates, meteorite studies, and thermochemistry, none of which is nuclear-related. Those that are nuclear-related are waste management, LMFBR support, physicochemical research on CTR materials, and thermochemistry of CTR-related programs.

Principal facilities used in conducting the research programs are divided into three major groups: (1) engineering areas, (2) laboratories, and (3) biological shielded facilities (caves and glove boxes). The latter facilities are presently in sparse use, but the near-future plans for these facilities are substantial. The cave areas will house apparatus for dissolution work of radioactive samples from flow coastdown experiments, and glove boxes in the G-Wing areas will be used for expanded plutonium analytical work. Eventually all plutonium-related work will be concentrated in this area.

Laboratories are used to house instrument complexes, such as F-124, 138, 128, for examination of highly-irradiated nuclear fuel samples by ion and electron microprobes. The samples are prepared in the Shielded Fuel Evaluation Facility, Cell M4 in M-Wing of Building D-200, and transported to Building D-205 by means of a 2000-foot-long pneumatic tube. Other laboratories in A, B, and X-Wings are devoted to studies of energy conversion by means of electrically rechargeable lithium/sulfur batteries. These batteries are being developed as energy storage devices for electric

utilities and as a power source for electric vehicles. All experiments with the battery cells are presently conducted in hermetically sealed, inert atmosphere glove boxes, low in oxygen and moisture content for protection of air-sensitive lithium and for fire protection.

Engineering areas such as J-Wing are used to house fluidized bed coal combustion studies. Being studied are the effects of operating variables in reducing emissions such as SO_2 , NO, and particulates when fossil fuels are burned in a fluidized bed of sulfur acceptor additives, such as limestone or dolomite; the regeneration of the sulfate additive for reuse in the combustor; and the quantity and type of trace-element pollutants emitted in combustion flue gases. About three 6-hour runs are made each week with coal feed-rates varying from 18 to 40 pounds per hour. During these runs the flue gas is continuously monitored for concentrations of O_2 , SO_2 , NO, CO, and CH. Concentrations of CO_2 are determined periodically during each run. These experiments are carried out at combustor temperatures of 1445°F to 1665°F.

Another major facility in the engineering area is the Apparatus for Monitoring and Purifying Sodium (AMPS) in J-102. The apparatus is used to test meters for the measuring of hydrogen in cover gases over sodium. There are two main sodium loops in AMPS that operate at temperatures between 750°F and 800°F at two pounds per square inch (gauge) pressure. About 100 gallons of sodium are involved.

Materials Science Division (Bldg. 212)

The general objective of activities in this area is the development of materials suitable for advanced energy systems. Applied work is concerned with the properties and behavior of materials in extreme environments as well as the development of suitable materials for potential utilization in specific energy systems. Basic research is directed to the study of structures, properties, and processes that are characteristic of materials and their applications.

Among the facilities available for materials studies are the Alpha-Gamma Hot Cell in Wing F, the Low Level Cave in Wing E and the Structural Materials Cell in Wing G.

Other facilities include the plutonium glove boxes in Wings D, F, and G. Characteristically, these have aluminum frames and panels, and safety glass or plastic windows with arm-length neoprene gloves. Boxes containing radioactive materials have inert gas (nitrogen or argon) atmospheres maintained at negative pressures. Safety provisions include criticality standards for fissile material inventories and special liquid coolant systems.

A heavy-ion accelerator is used for radiation damage studies, and a sodium loop is located in Wing G.

Energy and Environmental Systems Division (Bldg. 12)

This division (EES) consists of an interdisciplinary team of scientists and engineers that specializes in mission-oriented applied research, systems analysis, planning and field studies focused on technology assessment, natural resource management, and environmental protection issues. The activities of EES include both a program of geophysical studies and the development and evaluation of plans, programs, and policies relating to energy supply and demand, urban and rural land use, air and ground transportation, natural resource management, and environmental waste management.

Environmental Statement Project (Bldgs. 11 & 11A)

This project (ESP) comprises another interdisciplinary activity wherein the skills of life scientists are combined with those of physical scientists and engineers to produce detailed statements of the potential impact of proposed or operating nuclear facilities (power plants and fuel fabrication or fuel reprocessing plants). Under the terms of the National Environmental Policy Act (NEPA) of 1969, environmental impact statements must be prepared and approved before the Nuclear Regulatory Commission (NRC) can issue a construction permit or operating license for a given facility. ESP was established in September 1971 in response to an AEC/Regulatory (now NRC) request for assistance in the preparation of such statements.

EBR-II Project Division (Bldgs. 212, 310, & 362)

Research and engineering studies related to EBR-II, Argonne's Experimental Breeder Reactor located at the Idaho National Engineering Laboratory (INEL), are carried out in each of the above buildings. Personnel in Building 362 conduct a continuing series of analyses to assure the safety of the reactor, design experiments, and engineer reactor modifications. In Building 310, mockups are used to test equipment prior to its shipment to Idaho. In Building 212, laboratory facilities are used for welding tests and for the assembly of equipment such as high-worth control rod capsules.

Reactor Analysis and Safety Division

One of the Laboratory's major areas of responsibility in the reactor program is the field of safety. ANL activities in this area of interest are both analytical and experimental and involve facilities in Buildings 17, 206, 208, and 311.

Building 17. Test trains are being constructed in this building for installation in the Sodium Loop Safety Facility in Idaho. The assembly of these trains involves the attaching of instrumented wire wraps to 19 prefabricated $^{235}\text{UO}_2$ fuel pins, assembly of a 19-pin bundle, insertion of the bundle into a container, and assembly of the container, flow meters, pressure sensors, and other components into a train.

A nuclear criticality safety analysis of this operation indicated that

safety is assured even during flooding. Criticality and security alarms guard the area and checklist instructions must be followed by those working on the project.

Building 206. Among facilities for the experimental programs is the Out-of-Pile Expulsion and Reentry Apparatus (OPERA) located in this building. This is used to investigate the early voiding stages in an LMFBF subassembly following a postulated flow transient. Two storage vessels surrounded by a $3 \times 4 \times 18$ -foot enclosure contain 65 gallons of sodium. During operation, the entire system is lowered into a service pit to provide extra protection against spills. Additional protection is provided by electrical devices, smoke detectors, and an argon purging system. Tests are conducted in an inert atmosphere and are held after hours on weekdays or on Saturdays.

The UO_2 Debris Bed Boiling Sodium Heat Transfer Apparatus is located adjacent to a sodium-oxide scrubber. A reflux condenser coil contains about two gallons of sodium-potassium alloy; one pound of sodium is placed in the debris container, and the UO_2 charge does not exceed 5.0 kilograms.

The Molten Salt Pool Heat Transfer Experiment involves the use of liquid metal, at a pressure of one atmosphere absolute, as a coolant, and zinc chloride as the experimental medium. Current up to 200 amperes may be used to produce temperatures as high as 732°C at the internal face of the salt container. An enclosure that surrounds the apparatus permits a negative pressure to be maintained during operation to prevent the escape of dangerous fumes.

The Small Sodium Test Loop is used in the out-of-pile portion of the Sodium Loop Safety Facility program. It operates at temperatures as high as 1200°F with flows to 150 gallons per minute and pressures to 200 pounds per square inch (gauge). The sodium capacity is 100 gallons.

The Large Sodium Flow Calibration Facility located in the building consists of two 20-inch-diameter x 12-foot-high stainless steel tanks located about 20 feet apart and connected by a 2-inch-diameter pipe in which the object to be calibrated is placed. About 100 gallons of sodium are in the system, which is heated to 800°F when the apparatus is in use.

The Components and Materials Evaluation Loop is used for out-of-pile experiments simulating the release of fuel during an unprotected overpower transient. UO_2 generated by the thermite-type process is injected into a high velocity sodium stream. A high-voltage X-ray system detects local motion of the fuel. Lead shielding surrounds the entire facility and photo-cells will cause the X-rays to be turned off should personnel approach a hazardous area. Experiments are conducted after working hours or on Saturdays.

The Sodium Fume Scrubbing Facility consists of a walk-in hood that is 5 feet wide x 8 feet high x 8 feet deep. This contains a pan in which sodium is burned. A 30-horsepower motor-blower capable of moving about 3000 cubic feet of air per minute draws the fumes into a stack and into a Venturi scrubber where water is injected radially at a pressure of 15 pounds per square inch and at a rate of 24 gallons per minute. After

passing through the Venturi, the droplets, which contain a high percentage of the sodium fumes, are removed by a centrifugal separator, while the air is drawn through a filter. This unit not only is used for the disposal of sodium but also as a means of containing the fumes of an accidental fire.

The Sodium Loop Components Calibration Facility is also in the building.

Building 208. The Transient Flow Test Facility (TFTF) is located in this building. It is designed to provide the means of investigating the effect of the rapid release of fission-gas on coolant flow, including the determination of the lower and upper liquid-gas interfaces; transitory radial mechanical loads due to pressure pulses on adjacent fuel pins as a result of the rapid release of fission gas; subchannel-crossflow as well as the effects of flow starvation in subchannels, with emphasis being placed on 91-pin arrays; heat-transfer and fluid mechanics characteristics associated with the blockage of a single, or more than one, subchannel; and flow coastdown accidents in single subassemblies.

The TFTF provides up to 60 seconds of full flow of either water or other nonflammable coolants through a 91-pin full-length mockup of a typical LMFBR subassembly. Full flow is about 10 m/sec in each subchannel. The system is basically a blowdown test facility with two reservoirs and a test section between them. One reservoir contains the high-pressure test fluid that is propelled through the test section. The other reservoir functions as the receiver. The flow continues as long as a pressure difference exists between the reservoirs. Since the fluids are

only slightly compressible, the propelling force is provided by compressed gas. Upon opening a flow-control valve, the fluid is forced out of the lower high-pressure reservoir through the test section into the upper low-pressure collector.

The Multistation Water Loop in this building produces pressures as high as about 9.0 bars gauge with demineralized water. Flow-rates range from zero to about 40 liters per second. It has three bays in which test sections may be inserted. Maximum water temperature is 66°C, and total volume is about 6000 liters.

In-Reactor Test Apparatus (R-series) is designed for simulated loss-of-flow tests with sodium in the TREAT reactor in Idaho. The equipment is assembled in this building. In operation, fresh oxide fuel will undergo transients resulting from the intentional reduction of sodium coolant flow while the test fuel is maintained at constant power. Up to seven Fast Flux Test Facility UO₂ fuel pins, with up to seven cubic feet of sodium coolant, make up the test assembly.

The General Purpose Hydraulic Loop operates at a pressure of 250 pounds per square inch (gauge) and a temperature of 100°F. The flow rate is 2400 gallons per minute, with a head of 200 pounds per square inch (gauge). It is a closed water loop cooled by canal water flowing at 100 gallons per minute and with a temperature rise of about 15°F. At full capacity, two 150-horsepower pumps use 240 kilowatts of electricity. The noise level at the operating panel frequently is above 85 dBA and near the pump is 110 dBA.

Building 311. The Large Scale Simulant Fuel-Coolant Interaction Apparatus is housed in this building. Explosive interactions are studied in this facility by mixing hot and cold water, sodium chloride, and Freon-22. Experiments, which usually are conducted bimonthly, result in explosions that disperse the mixture through an open front of a blast cell onto an adjoining driveway and open field. Quantities involved are 50 gallons of water, 5 pounds of sodium chloride, and 1/2 gallon of Freon-22. A three-foot-thick concrete wall surrounds the blast site, and a fence surrounds the general area. Experiments are controlled by an interlock system protecting all personnel. To determine the offsite sound levels due to these tests, measurements were made between the facility and the nearest point on the site periphery, St. Patrick's Cemetery. Weather conditions were cloudy and cool with little air movement. Background noise due to traffic and nearby building ventilation was 50 to 55 dBA. Aircraft flyovers produced peaks to 70 dBA. During an explosive test, no impulsive noise was detected by instrumentation that was set to indicate in the range of 54 to 70 dBA, nor was there noise that was audibly detectable by the instrumentation operator. Residents at the nearest site boundary will remain undisturbed by the explosive tests.

Energy Dissipation Tests conducted in this building are designed to contact molten UO_2 and liquid sodium at temperatures characteristic of those likely to be reached in an LMFBR accident. The studies use the thermite-type method of generating molten UO_2 and generally deal with fuel quantities of 1/2 kilogram and sodium quantities of 10 to 12 kilograms. The entire test section and containment vessel are in a concrete cell with three-foot-thick walls. During tests, an argon atmosphere minimizes the possibility of a sodium fire.

2.2.2.3 Radiological Inventory and Impact

The 227 structures and facilities at the Laboratory (see Table 2.2) may be divided into seven categories, depending on their inventories of radionuclides and radiation sources and on their potential for radiological impact on the environment.

Category I

This includes all those facilities that by the nature of their use neither contain significant quantities of radionuclides nor are involved in radionuclide transportation. Any one of them might, transiently, contain small check sources, e.g., those used by Health Physics personnel in the deployment of their survey instruments. In the extreme, such sources would never exceed a total of 1 microcurie (μCi) and would always be far below the amounts permitted to the public at large without license control. Facilities included in this category (by identification number) are Buildings 2, 6-13, 21, 25-36, 41-54, 56-181, 213, 214, 220, 308, 310, 311, 319, 323-325, 395, 519-981, and 11 unnumbered trailers, etc., surveyed by the staff.

Category II

This encompasses the shipping and receiving buildings (Bldgs. 4 and 5). They receive and trans-ship radioactive materials, but neither utilize nor store them. All material passing through these buildings is completely contained in appropriate shipping containers, thus, movement of

radioactive materials is covered by the transportation considerations of Section 3.2.2.1. Also included in this category are Buildings 14, 24, and 209. Sources in these buildings are so sealed or encapsulated that they too are covered by the same transportation considerations. Many other facilities contain sealed sources as well, but because they also contain radionuclides in forms that might be dispersible, they are considered under the higher numbered categories below.

Category III

A number of buildings contain areas or machinery weakly contaminated by previous activities. Contaminations have been reduced to levels far below those that might constitute a hazard, even to workers, and are maintained at these levels. The majority of these facilities were contaminated only with naturally occurring radionuclides of the uranium and thorium series and represent inventories of <1 μ Ci alpha and <1 mCi beta-gamma. The radionuclides involved are fixed to the facilities in forms that would not be effectively dispersed to the environment, even by a catastrophic Act of God. In any case, the nuclide types and levels are such that they add nothing to the consequences of an event sufficiently catastrophic to carry parts of the facilities offsite. Buildings included in this category are 34, 38, 39, 208, and 37 [exclusive of the Occupational Health and Safety (OHS) station].

Category IV

Included in this category are two decommissioned facilities, portions of

which were radiologically activated and contaminated during the course of operation or of later use--the EBWR (Bldg. 331) and JUGGERNAUT (Bldg. 335) reactors. The structures involved are so massive, the levels so low, and the radionuclides so well fixed that environmental impact from radioactivity is very unlikely, even via a catastrophic event. However, were these facilities to be dismantled it would be necessary to give adequate consideration to the proper disposal of their activated structures.

A number of operating facilities also encompasses significant burdens of structural radioactivity. In approximate order of decreasing burden the buildings and facilities are: 330-CP5, 202-JANUS, 360-ZGS, 211-Cyclotron, 200-M-Wing, 316-ZPR/ATSR, 314-Fast Neutron Generator, and 203-Van de Graaf and Dynamitron facilities. Were these to be dismantled, similar consideration of structural radioactivity would be necessary.

Category V

Included in this category are facilities that may contain >1 mCi beta-gamma, but whose potential for environmental radioactive impact is small. The buildings are 17, 20, 22, 23, 40, 301, 206, and 340. Facilities in Buildings 17, 20, 40, 301, and 206 process only uranium, with an overall inventory of about 0.3 tonnes, all of it in forms of density >10 g/cm³.

Total activity is less than 0.2 Ci, so even if the entire mass were dispersed by the maximum accident of Section 3.2, the consequences would

be less than 0.0002% of those given for that accident. Buildings 22 and 23 are used by the Center for Educational Affairs for student experiments. Although certain short-lived nuclides might be received that have activities >1 mCi beta-gamma, the nature of the building, its use, and the types of nuclides used preclude all but trivial accidents or releases.

Building 340 houses mice injected with strontium-90. Although the inventory in this form might reach a fraction of a curie, the nature of the building, its procedures, and the form of the radionuclide permit nothing more than trivial accidents or releases.

Category VI

This category includes all the remaining buildings at the Laboratory and encompasses the presence and use of both sealed sources and dispersible radioactivity in types and quantities appropriate to ordinary experimentation. The buildings involved are: 19, 37 (OHS station only), 200, 202, 203, 205, 211, 212, 223, 301, 306, 314-318, 329, 330, and the ZGS complex. The total inventory for these facilities, in the context given above, runs to 10^2 Ci alpha and 10^5 Ci beta-gamma in sealed sources, and 10 Ci alpha and 10^4 Ci beta-gamma in vaults, containers, hoods, glove boxes, and the like. Despite the considerable quantities involved, several factors combine to limit the maximum releases to those covered by the first two classes of Section 3.2.1. These factors include the forms of containment, design of facilities, housekeeping, procedures governing use, guidance and monitoring by OHS, training of personnel,

and the emergency procedures of OHS and other laboratory groups. These releases have already been included in Section 2.2.1, and their consequences and environmental impacts covered in Section 3.1.

Category VII

This category encompasses those facilities with the highest likelihood of accidental radiological impact. In approximate order of decreasing impact the buildings and facilities are: 330-CP5, 316-ZPR6/9, 202-JANUS, 200-M-Wing, 16, 212, 205, 350, 55, 301, 306, and 317. For all but the maximum hypothetical accident and Act-of-God events (Section 3.2) these facilities have been covered under Category VI above. For the catastrophic event, over 90% of the total impact results from the large inventory of fission products in the operating reactors, CP-5 and JANUS (about 10^7 Ci) and from the large inventory of alpha-emitting nuclides in the ZPR critical facility. These three are covered by separate Safety Analysis Reports, and criticality in each of the facilities has similarly been covered by criticality studies and reports.

Radioactive materials currently stored in Buildings 16 and 55 will soon be transferred to more permanent facilities less subject to the possibility of damage by fire or storm. A certain amount of redeployment of radioactive materials is probably indicated in Buildings 205 and 212, particularly the removal of unused and unusable samples. Both of these improvements are the subject of current laboratory proposals and will probably be accomplished within the coming year.

Buildings 306 and 317 together contributed less than 1% to the postulated major accidents. They are included here largely for completeness. The waste areas of 306 and 317 pose a considerable degree of uncertainty as to their inventory at the time of a major unforeseen event. Also, little can be done to secure them further against the ravages of a natural catastrophe of the force of a "555" tornado (see tornado discussion in Sec. 3.2.1.3). However, they contribute so little to the consequences of such an event that analyses and modifications beyond those included in the ongoing waste program improvements are not indicated.

2.3 CHARACTERIZATION OF THE EXISTING ENVIRONMENT

2.3.1 Site Location and Layout

ANL is 25 miles southwest of downtown Chicago and 24 miles west of Lake Michigan. The site is south of Interstate Highway 55 and west of Illinois Highway 83. The terrain is gently rolling, partially wooded, former prairie and farmland. The grounds contain a number of ponds and small streams, the principal one being Sawmill Creek. The site is drained primarily by Sawmill Creek, which runs through the site in a southerly direction and enters the Des Plaines River about 1.3 miles southeast of the center of the site. The Des Plaines River joins the Kankakee River about 30 miles southwest of the Laboratory to form the Illinois River. Figures 2.5 through 2.8 depict the site and the surrounding area.

The most prominent topographical feature of the area is the two-mile-

Fig. 2.5. Sampling Locations on the Site of Argonne National Laboratory.

Legend

- major facilities
- information stations with cultural historical or ecological exhibits
- parking lots
- horseback riding trails
- hiking trails
- service road access through control point

Fig. 2.6. Aerial View of the Site.

Fig. 2.7. Area around Site Showing Radii of 1, 2, 3, 4, 5, and 10 Miles.

Fig. 2.8. Area around Site Showing Radii of 10, 20, 30, 40 and 50 Miles.

wide Illinois Waterway. This channel contains the Des Plaines River, the Chicago Sanitary and Ship Canal, and several railroads and electric transmission lines. It also includes the now-abandoned Illinois and Michigan Canal, of historic fame in opening the West. The Waterway is devoted entirely to industrial and water-control purposes. Parts of it include quarries, industrial waste ponds and lagoons, all of the appurtenances appropriate to a heavy barge and ship traffic, and a large number of medium and heavy industries. In effect, the Illinois Waterway is the industrial cloaca of the metropolitan area of Chicago. The elevation of the channel surface is 578 feet above mean sea level (MSL).

Bluffs that are south of the Laboratory site rise from the channel at slope angles of 15° to 60° to an average elevation of 650 feet. The land then slopes gradually upward, reaching the average site elevation of 725 feet MSL about 3000 feet north of the bluffs. There are several large northerly oriented ravines in the southern portion of the site. The bluffs and ravines generally are forested with deciduous trees, chiefly oaks, averaging 50 to 60 feet tall. As one moves north, the remaining portion of the site slopes more gently, averaging about 5 feet per 100 feet.

The principal Laboratory facilities and buildings are contained within a 1700-acre site. This area is surrounded by a security fence, and entrance is restricted. The central area is surrounded by a 2040-acre tract planted primarily with softwood trees (chiefly pine). A pre-existing cemetery, to which visitors are allowed, is located near the southwest portion of the site (Coordinate 8H, Fig. 2.5) outside the

security fence. This is the most closely permitted nonbusiness approach to the fence.

South of the site, the Chicago District Pipeline Company and the Atchison-Topeka and Santa Fe Railroad have right-of-ways, and a railroad spur extends into the Laboratory.

2.3.2 Regional Demography, Land and Water Use

Situated as it is within the Chicago metropolitan area, the region within 3 to 15 miles of the Laboratory has exhibited a large growth in urban, ex-urban, and occasionally rural housing. The populations of townships in the area are shown in Table 2.9. Their locations in relation to the Argonne site are shown in Figure 2.9. Townships are shown by the dotted lines, and are usually six-mile squares.

Two housing developments border the northeast portion of the new forest preserve, which was formerly part of the site. One is an apartment complex with about 4500 residents and the second is a development of single-family residences with about 2500 residents. With these two exceptions, population growth in the immediate vicinity of the Laboratory has been, and probably will continue to be, slow because of the nature of the ownership and use of the land about the site.

The heavily industrialized Illinois Waterway inhibits housing development to the east and south of the Laboratory. To the west, the Atchison-

Table 2.9. Population Density by Township

<i>Township</i>	<i>Population 1970 Census</i>	<i>Area, square miles</i>	<i>Density^a</i>
Addison	72,280	36	2,008
Berwyn	52,502	3.25	16,154
Bloom	94,757	36	2,632
Bloomington	36,654	36	1,018
Bremen	93,906	36	2,609
Calumet	23,614	3.86	6,118
Cicero	67,058	5.71	11,743
Downers Grove	92,899	48	1,935
Du Page	20,037	36	556
Frankfort	9,633	36	268
Homer	6,686	36	186
Joliet	96,001	36	2,666
Lemont	8,314	21	395
Lisle	49,061	36	1,363
Lockport	33,354	36	926
Lyons	100,898	36.7	2,749
Milton	75,750	36	2,104
Naperville	13,028	36	362
New Lenox	10,049	36	279
Orland	15,028	36	417
Palos	33,100	35	946
Plainfield	11,028	36	306
Proviso	172,760	30	5,758
Rich	44,801	36	1,244
Riverside	18,475	5.7	3,241
Stickney	41,752	18.1	2,307
Thornton	187,863	36	5,218
Troy	11,568	36	321
Wheatland	1,794	36	50
Winfield	23,001	36	638
Worth	155,834	37	4,211
York	123,724	36	3,437

^a Number of persons per square mile.

Population of Communities Near Argonne National Laboratory

(Based on 1960 and 1970 Census)

COMMUNITY	POPULATION		COMMUNITY	POPULATION	
	1960	1970		1960	1970
ADDISON	6741	25230	MATTESON	3225	4753
ALSIP	3770	10804	MAYWOOD	27330	30152
BEDFORD PARK	737	1506	MC COOK	441	441
BELLWOOD	20729	22108	MELROSE PARK	22291	23471
BERKELEY	5792	6130	MIDLOTHIAN	6605	16050
BERWYN	54224	52274	MOKENA	1332	1623
BLUE ISLAND	19618	22986	NAPERVILLE	12933	22426
BOLLINGBROOK	--	6476	NEW LENOX	1750	2817
BRIDGEVIEW	7334	17079	NORTHLAKE	12318	13644
BROOKFIELD	20429	20273	NORTH RIVERSIDE	7989	10373
BURR RIDGE	299	4853	OAK BROOK	324	4099
CAROL STREAM	836	3755	OAK BROOK TERRACE	1121	1122
CHICAGO	3550404	3322855	OAK FOREST	3724	15919
CHICAGO RIDGE	5748	9086	OAKLAWN	27471	61637
CICERO	69130	66695	OAK PARK	61093	61745
CLARENDON HILLS	5885	6715	OLYMPIA FIELDS	1503	3473
COUNTRY CLUB HILLS	3421	6827	ORLAND PARK	2592	6444
COUNTRYSIDE	2393	2886	PALOS HEIGHTS	3775	8083
CREST HILL	5887	16806	PALOS HILLS	3766	5643
CRESTWOOD	1213	5550	PALOS PARK	2169	3265
DARIEN	--	8200	PARK FOREST	29993	30388
DOWNERS GROVE	21154	31509	PLAINFIELD	2183	2900
ELMHURST	36991	46325	POSEN	4517	6742
ELMWOOD PARK	23866	26088	RICHTON PARK	933	2531
EVERGREEN PARK	24178	25476	RIVER GROVE	8464	11239
FLOSSMOOR	4624	7559	RIVERSIDE	9750	10373
FOREST PARK	14452	15391	ROBBINS	7511	9410
FOREST VIEW	1042	1042	ROCKDALE	1272	2021
FRANKFORT	1135	2294	ROMEDEVILLE	3574	12580
FRANKLIN PARK	18322	20654	ROSEWOOD TRACE	--	4500
GLENDALE	173	18976	SHOREWOOD	358	1765
GLEN ELLYN	15972	21672	STICKNEY	6239	6665
HAZELCREST	6205	10245	STONE PARK	3038	4233
HICKORY HILLS	2707	7776	SUMMIT	10374	17800
HILLSDALE	7794	8581	TIMBERLAKE	--	2500
HINSDALE	12859	13704	TINLEY PARK	6392	12253
HODGKINS	1126	2265	VILLA PARK	20391	25653
HOMETOWN	7479	6708	WARRENVILLE	1470	3134
INDIAN HEAD PARK	385	485	WESTCHESTER	18092	20190
JOLIET	66780	78623	WEST CHICAGO	6854	9942
JUSTICE	2803	9371	WESTERN SPRINGS	10838	12522
LA GRANGE	15285	18189	WESTMONT	5997	8480
LA GRANGE PARK	13793	15402	WHEATON	24312	30910
LEMONT	3397	5018	WILLOW BROOK	157	4790
LITSL	4219	6635	WILLOW SPRINGS	2348	3344
LOCKPORT	7560	9621	WINFIELD	1575	4277
LOMBARD	22561	36528	WOODRIDGE	542	10907
LYONS	9936	11124	WORTH	8196	11831
MARKHAM	11704	15303	YORK CENTER	--	1704

Fig 2.9. Communities and Townships within a 15-mile Radius of ANL.

Topeka and Santa Fe Railroad has purchased a large block of land for industrial development in connection with its own right-of-ways and with the transportation and industrial facilities on the Illinois Waterway just to the south. To the north, the presence of Interstate 55 and its frontage roads and fairly large blocks of land owned by institutions, private associations, and a monastery further inhibit urban development. Thus, in addition to the forest preserve belt about the Laboratory, there exists a number of land-use barriers to population growth within about three miles of the site. One may anticipate the maintenance of a fairly sizable low-population zone around the Laboratory well into the future.

Population distribution up to 50 miles from the Laboratory has been projected through 1980 and is given in Table 2.10. Values represent the population in annular segments, at various distances, and in 22.5° sectors. The coordinate origin is the Argonne meteorology tower (in the southwestern portion of Coordinate 8F in Fig. 2.5) at 41.70° N Latitude and 87.99° W Longitude. Data on population within four miles of the site were modified to provide a finer breakdown of information that had been reported only as census tract values. This was done on the basis of aerial, map, and on-the-spot surveys, and projected with the aid of current growth-rate data for the area.

2.3.3 Historic and Natural Landmarks

The closest of the numerous historic sites and buildings in the area

Table 2.10. Incremental Population Data in the Vicinity of ANL, 1980 Projection

Distance, miles	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
Direction										
N	0	134	2,158	3,041	363	39,021	201,477	314,253	114,948	206,998
NNE	0	16	535	4,001	5,186	42,253	358,652	582,389	120,678	0
NE	0	27	2,098	2,189	1,344	31,369	856,982	1,143,157	0	0
ENE	0	75	2,473	327	848	31,849	787,169	356,235	0	0
E	0	64	68	4	16	33,312	548,907	269,811	14,639	26,355
ESE	0	0	116	354	21	11,481	240,833	307,264	315,512	45,966
SE	0	105	83	108	17	16,250	52,176	121,403	22,695	9,752
SSE	0	214	445	284	16	1,195	12,612	7,757	14,693	19,825
S	0	493	1,351	1,699	21	3,105	14,586	1,355	28,564	41,954
SSW	0	344	2,049	3,372	34	17,392	114,799	9,262	16,144	7,864
SW	19	291	113	284	128	13,039	30,057	5,324	15,429	7,917
WSW	55	144	66	816	555	9,752	5,420	2,112	6,210	10,661
W	14	219	816	5,976	8,739	1,676	50,959	18,907	18,544	8,013
WNW	54	523	5,975	141	11	22,908	97,097	8,942	4,471	53,980
NW	56	186	183	119	11,737	14,416	44,931	79,918	15,909	12,911
NNW	54	129	842	1,387	3,916	40,525	118,885	156,465	96,862	72,471
Total	252	2,964	19,371	24,102	32,952	329,543	3,535,542	3,384,554	805,298	524,667
Cumulative Total	252	3,216	22,587	46,689	79,641	409,184	3,944,726	7,329,280	8,134,578	8,659,245

^aCentered about the point of 41° 42' 03" N. Lat. and 87° 59' 24" W. Long.

listed in the National Register of Historic Places¹ is the Lemont Central Grade School in Lemont, which is about 1-1/2 miles southwest of the Laboratory. The school is one of 63 structures or locations in Cook County listed in the Register as being historic places or as being eligible for such a designation. Most of the sites are in Chicago. Two places in Will County and one in DuPage County also are in the Register. In Will County, the tow path and locks of the Illinois and Michigan Canal, dating from 1848 and located in Channahon State Park (about 20 miles southwest of the Laboratory) are identified as historic sites. The Illinois and Michigan Canal office building in Lockport, about 10 miles southwest of the Laboratory, is also listed. The building is the headquarters of the Will County Historical Society. The only structure in DuPage County listed in the Register is the Stacy Tavern in Glen Ellyn, about 12 miles northwest of Argonne.

No natural landmarks in Cook, DuPage, or Will Counties are listed in the National Registry of Natural Landmarks.⁹

No records of any significant archeological site or fossil deposit on the Laboratory property are in the central files of the Illinois Archeological Survey. Furthermore, the area is not noted for its archeological or fossil treasures, with possibly the exception of fossils often found by amateur fossil hunters in the abandoned quarries along the Illinois Waterway near Lockport.

The Laboratory site is an ecological and nature preserve and is surrounded by a similar preserve controlled by DuPage County. A similar,

but larger, Forest Preserve District begins at the Cook County line about three miles east of the Laboratory and extends to the town of Palos Hills. The nearest major ecological and animal preserves are the Goose Lake Prairie Nature Preserve, about 25 miles southwest, and the Kankakee River Nature Preserve, about 40 miles southeast.

The Laboratory is itself of some historic interest. It is the extension and descendant of the first nuclear reactor, originally located at the University of Chicago's Stagg Field, the site of which is listed in the National Register of Historic Places.¹

2.3.4 Geology and Seismicity

2.3.4.1 General Topography

The terrain is flat to slightly hilly, with an elevation of 700 to 750 feet MSL for several miles north and east but dropping slowly toward the southwest. The normal level of the Des Plaines River south of the site is 583 feet MSL. The floodplain extends about 1/8 mile onto the forest preserve that surrounds the site. The land rises sharply from the edge of the floodplains, and outcroppings of Niagara dolomite may be seen to the top of the bluffs overlooking the Des Plaines Valley.

2.3.4.2 Bedrock

The average elevation of the bedrock directly beneath the site is about 610 feet MSL (almost 100 feet below the soil surface). It has been determined from core samples taken at the site that the upper 10 feet of bedrock is composed of large, fine-grained, gray dolomite of a slightly-weathered-to-sound condition. Figure 2.10 depicts stone formations and their thicknesses as revealed by the drilling of Laboratory deep well No. 1 to a depth of 1595 feet. Pre-glacial erosion had worn off bedrock of more recent origin and had cut deeply into the dolomitic top surface of the presently existing bedrock in the Des Plaines River Valley. Glacial till of the Wisconsin ice sheet deposited by the Valparaiso moraine overlies this bedrock and partially fills the Des Plaines Valley.

2.3.4.3 Subsurface Soils

The soil above the bedrock is composed of dense, tough, silty clays. There are a few traces of sand. These clays were laid down as the glacial drift of the Valparaiso moraine. From the log of the soil borings taken on the site, indications are that there are no soft spots or layers of soft material. The general character of the soil is tough and hard, and averages over 50 blows per foot (standard penetration--140# hammer falling 30 inches on 2-inch O.D. split spoon) in the area from the bottom of the building foundation mats down to bedrock.

Fig. 2.10. Bedrock at the Site.

2.3.4.4 Seismicity

Realistic predictions of earthquakes, or earth shocks, as well as their frequency and severity, can only be based upon the seismic history of an area and the statistical representation provided by that history.

Significant geological features known as slip-planes or faults pertinent to an area play an important role in the seismic history and are, therefore, considered as factors in the prediction of earthquakes. The only known fault zone in the Argonne area is the Sandwich Fault (passing through Sandwich, Illinois). It strikes about S 60° E, and is located about 32 km from the site as measured along a line normal to the fault, bearing from the site about S 30° W. The dip of the fault is uncertain. It has been estimated that the last major motion along the fault occurred during the Paleozoic era, sometime before the Pennsylvanian period ended and after the Silurian period. It is thought that the fault was due to the uplift of the La Salle anticline in northern Illinois after the Mississippian period. There may be other faults paralleling and associated with the Sandwich fault.¹⁰ These fault indications, about 3 km north of the Sandwich Fault, would somewhat broaden the zone of faulting.

An area of about 64 sq km of faulting about 35 km north of the site has been mapped as the Des Plaines Disturbance.¹¹ Because of the number, severity, and local nature of these faults (tilted blocks and broken rocks to depths of 500 km) conclusions made from detailed studies of this area are that this disturbance was a result of the focusing of regional forces, or was possibly due to impact of a large meteorite.¹²

Figure 2.11 shows the locations of epicenters of earthquakes within 600 km of the site that had probable intensities (as felt at the site) of III or greater on the Modified Mercalli Intensity Scale.¹³ Table 2.11 gives pertinent data for each of these tremors. None of these earthquakes can be considered as having had a damaging effect on structures of adequate design at the site (see earthquake discussion in Sec. 3.2.1.3).

2.3.5 Hydrology

Due to the nature of the soil, percolation of water is very slow. Therefore, drainage from the site is mostly by surface runoff. Potable water for the Laboratory is obtained from two principal aquifers--the Niagara dolomite and the deeply buried Ordovician and Cambrian sandstones. The Laboratory has five shallow supply wells that obtain water from the Niagara dolomite and one deep well, cased and sealed through the Niagara dolomite, that obtains water from the deep sandstones.

Only the Niagara dolomite need be considered in connection with possible contamination from an accidental spill of radioactive liquid. The deeper aquifers are separated from the surface by hundreds of feet of rock formations (see Fig. 2.10), of which the Maquoketa shale is particularly impermeable. In the event of such a spill circumventing protective measures, the contaminated liquid would move slowly through the existing glacial till and would be diluted by the normal groundwater descending with it. As the diluted liquid approached the level of the bedrock, it would be further diluted by water moving across and down the

Fig. 2.11. ANL Proximal Earthquakes.

Table 2.11. Seismicity near the Site

Map Location Number	Date	Epicenter	Extent of Tremor in Sq Miles	Maxium Intensity at Center	Estimated Probable Intensity at Site
1	20 Aug 1804	Ft. Dearborn (Chicago), Illinois	30,000	VI	V
2	16 Dec 1811	New Madrid, Missouri	2,000,000	XII	IV
2	23 Jan 1812	New Madrid, Missouri	2,000,000	XII	IV
2	7 Feb 1812	New Madrid, Missouri	2,000,000	XII	IV
3	31 Oct 1895	Charleston, Missouri	1,000,000	VIII	IV
4	26 May 1909	South Beloit, Illinois	500,000	VII	VI-VII
5	18 Jul 1909	Central Illinois	40,000	VII	III
6	2 Jan 1912	Between Aurora and Morris, Illinois	40,000	VI ^a	VI
7	9 Apr 1917	DeSoto, Missouri	200,000	VI	IV
8	8 Mar 1937	Lima, Ohio	150,000	VII-VIII	III
9	23 Nov 1939	Waterloo, Illinois	150,000	V	II-III
9	23 Nov 1940	Waterloo, Illinois	Widespread	VI	III
10	9 Aug 1947	Battle Creek, Michigan	50,000	VI	III
11	9 Nov 1968	Southern Illinois	580,000	VII	IV-V
12	15 Sep 1972	Princeton, Illinois	250,000	VI	IV-V
b	31 Aug 1886	Charleston, South Carolina	2,000,000	IX-X	III
b	28 Feb 1925	Quebec, Canada	2,000,000	VIII	III

^a 0.07 g maximum for a period ranging between 0.3 to 0.6 second (from "Report on Seismicity of the Grundy County, Morris, Illinois, Area," Coast and Geodetic Survey, 1965).

^b Two other strong tremors felt in the area, but with epicenters greater than 600 km away, are given without map numbers.

fissured dolomite. From this point the hydraulic gradient of the Niagara dolomite, which is generally southeastward, would be followed (see Fig. 2.12).

Tests in 1952 by the U. S. Geological Survey determined that water moves down through glacial till at the Laboratory at the rate of 0.1 inch per day. At that rate, it would take about 26.5 years for contaminated water entering the saturated soil at the base of the building foundation mats to reach the bedrock layer of Niagara dolomite directly beneath the site.

At the present rate of pumping it is very unlikely that any contaminated water introduced into the glacial till could find its way into the cones of depression in the piezometric surface caused by the pumping from ANL supply wells (see Fig. 2.12), and thus into the supply wells. It is likely that any contaminated liquid would seep slowly to the south or southeast and eventually reach the Des Plaines River. Dilution, radioactive decay, and retention (e.g., through leaching and/or ion exchange by the natural soil) would certainly take place in the long interval of time between insertion at the site and ultimate arrival at the Des Plaines River.

The Des Plaines River, the Chicago Sanitary and Ship Canal, the Illinois and Michigan Canal, and the Sag Channel interconnect by the time they reach Joliet, about 22 km southwest of Argonne. The water flow in the Des Plaines River just upstream of Joliet varies between 12 and 340 m³/sec, depending upon the flood stage and season. When the river is in flood

Modified from LeRoux and Drescher, 1959
 Base compiled from maps prepared by Argonne
 National Laboratory and from U.S. Geological
 Survey topographic maps

EXPLANATION

— 620 —
 Contour of the piezometric surface
 Dashed where approximate; interval 5 feet.
 Datum is mean sea level

637
 Well
 Showing altitude of piezometric surface

1000 0 1000 3000 5000 FEET

Fig. 2.12. Piezometric Surface of Water in the Niagara Dolomite at ANL,
 2-3 June 1960.

stage, excess water is diverted to the higher-capacity Sanitary and Ship Canal at a point just south of Lemont. The flow rate of the Sanitary Canal in recent years has averaged about $96 \text{ m}^3/\text{sec}$; of this, about $45 \text{ m}^3/\text{sec}$ is water diverted from Lake Michigan and the balance is domestic and industrial discharge. Both the river and the canal flow about 32 km/day. Therefore, any surface drainage from the site would be diluted first by the river bordering the Laboratory, and then further diluted by the canal, normally within 17 hours. If such drainage occurred during a wet period, it would be diluted more extensively and more rapidly.

Canal water is used prior to, and in Joliet, for some industrial uses such as hydroelectric generators and condensers, as well as for irrigation at the state prison. After leaving Joliet, the Des Plaines River flows southwest about 23 km before joining the Kankakee River to form the Illinois River. The first use made of this water for drinking purposes is at Alton, Illinois, which is about 442 km from Argonne and 16 km downstream from the point where the Illinois River merges with the Mississippi River. At Peoria, about 230 km downstream, river water is occasionally used to recharge shallow wells, some of which are used for municipal water.

2.3.6 Meteorology

The following is a summary of meteorological data collected at Argonne:

- At 19 feet above ground, the daily average wind speed varies from 5 mph in August to 10 mph in March and gusts exceed 50 mph about once a year. At 150 feet above ground, this latter speed is exceeded about 15 times a year.
- Daily temperatures average from the low 20's in the winter to the high 70's in the summer. There are about 6850 degree-days per year. Rarely are there maximum temperatures above 100°F, and the minimum temperature recorded is -20°F.
- Precipitation averages about 33 inches per year. Average mid-day humidity values range from about 50% in October to 75% in January; however, night readings are about 80% to 90% all year.
- Solar radiation, in Langleys on a horizontal surface, varies from about 150 per day in December to 600 per day in June.
- Atmospheric pressure varies between a high of 30.00 inches Hg and a low of 28.30 inches Hg, with a mean of about 29.20 inches Hg.
- Soil temperatures well below grade vary only from 50°F in July to 52°F in February. Temperatures at depths of four inches vary from the 80's in the summer to just below freezing in mid-winter.

Annual climatological summaries based on measurements taken at the DuPage site of the Argonne National Laboratory have been prepared and published as reports designated, ANL-4538, ANL-4792, ANL-4928, ANL-5256, and ANL-5592, with a 15-year climatological summary as ANL-7084.⁵

2.3.6.1 Regional Climatology

The climate of the area is typically continental, with cold winters, hot summers, and frequent short-period fluctuations in temperature, humidity, wind speed and direction, and cloudiness. About 67% of the average annual precipitation falls during the period April through September. During periods of northeasterly winds in spring and summer, temperatures at the site are moderated by the effects of Lake Michigan.

2.3.6.2 Local Meteorology

A program to monitor and record meteorological conditions, with special emphasis on those weather parameters that control atmospheric dispersion and transport, has been underway since mid-1949. Details of the program and 15-year (1950-1964) data summary are contained in ANL-7084.⁵

The average annual temperature of the site during this 15-year period was 47.6°F, with monthly averages ranging from 21.4°F in January to 71.1°F in July. Temperature extremes during this period were -20°F and 101°F. The 15-year average precipitation was 31.49 inches; December

was, on the average, the driest month, with 1.26 inches, and July the wettest, with 4.32 inches. As much as 13 inches of rain has fallen on the site in one month.⁵ The average annual snowfall is about 30 inches.¹⁴

The average annual wind speed at 19 feet above ground level at Argonne is 8.3 mph; at the 150-foot level, the average is 13.1 mph. As is shown in Figure 2.13, most winds at Argonne have a component from the west. The maximum wind speed recorded at Argonne was 86 mph at the 150-foot level during a severe thunderstorm in June 1964.⁵

2.3.6.3 Severe Weather

Although Illinois ranks eighth nationally in number of tornadoes, it ranks first in deaths and second in tornado property damage.¹⁵ According to Wilson and Changnon,¹⁵ the Argonne site lies in the area of "high frequency" of tornado risk for Illinois. Although tornadoes can occur during any season, 24% of all tornadoes in northern Illinois occur during the month of April and 66% during the spring (March-June). Thom¹⁶ reports that there were 20 tornadoes in 10 years in the one-degree latitude-longitude square containing the site. Using this frequency and Thom's average tornado area (2.82 square miles), the computed tornado recurrence interval is 635 years. A more recent study¹⁷ indicates a much higher tornado frequency for the same geographical area; i.e., 4.5 per year with a calculated recurrence interval of 280 years. An extensive study of tornado probabilities has recently been completed for the Laboratory, and may be consulted for more details.¹⁸

Fig. 2.13. Wind Roses Based on All Hourly Observations,
January 1950–December 1964. 19-foot Level.

The tornado frequency data discussed above are for all reported storms, irrespective of wind speed in the tornado funnel. Since 1971, the National Weather Service (NWS) severe storm data have included an estimate of storm intensity using the F (or Fujita) scale.^{19,20} As shown in Table 2.12, 64% of all tornadoes in the United States during 1971 and 1972 had peak winds less than 113 mph.¹⁹

Assuming that this distribution is representative of all Illinois tornadoes and using Pautz's tornado frequency data,¹⁷ the recurrence interval for an F5 tornado in northeastern Illinois is 233,000 years; for an F4 or stronger storm, 12,700 years; F3 or greater, 3,000 years; F2 or greater, 1,780 years; F1 or greater, 972 years.

Argonne has two tornado warning systems. The Laboratory has retained the services of a local private weather forecasting firm (Murray and Trettel, Northfield, Illinois) to forecast tornadoes and severe storms for the site. The secondary warning system is the National Warning System (NAWAS) of the NWS. The NAWAS warnings cover a much larger area than do those from the private firm. The state-of-the-art is such that forecasting of all tornadoes is not possible. A recent study indicates that, nationwide, about 30% of all tornadoes occur without an NWS tornado forecast.²¹ Thus, there exists a small, but finite, probability that a damaging tornado could strike one of the Argonne facilities with little or no advance warning.

Table 2.12. Tornado Windspeed Distribution in the U. S., 1971-1972

<i>Windspeed Classification</i>	<i>No. of Tornadoes</i>	<i>Percent of Total</i>
F5 (windspeed > 260 mph)	2	0.12
F4 (207 to 260 mph)	34	2.1
F3 (158 to 206 mph)	115	7.2
F2 (113 to 157)	430	26.6
F1 (73 to 112 mph)	710	44.0
F0 (40 to 72 mph)	321	19.9

From E. H. Markee, Jr., and J. G. Beckerley, "Technical Basis for Interim Regional Tornado Criteria," USAEC, WASH-1300 (UC-11), May 1970.

2.3.7 Ecology

Of the 1700 acres occupied by the Laboratory, about 1275 acres are devoted to Laboratory structures, roadways, and landscaped grounds. Several hundred acres of the landscaped grounds have been maintained in their original condition as native oak-opening and hardwood forest. The remaining acreage shows considerable natural diversity, and includes a variety of lowland and upland forests, old fields, pine plantations, streams, lakes, marshes, and a variety of temporary ponds reflecting the surrounding forests and fields. The surrounding 2040-acre DuPage County forest preserve reflects a similar diversity, but with a much heavier predominance of pine plantations. Ecologically, these two portions represent a single ecosystem, and will be treated as such in what follows.

Starting in 1953, and continuing over three seasons, the Laboratory planted 1.5 million pines (jack, red, and white) on much of the abandoned farmland and old fields on the site. Remaining portions were maintained in native oak-opening and hardwood forest. A considerable portion is in various stages of secondary succession following the abandonment of agricultural activity in the 1940's. The remaining old fields are dominated by Eurasian annual and perennial grasses and forbs, with occasional mixtures of agricultural grasses and native prairie grasses and forbs. These old fields are apparently returning to a deciduous forest climax. There are a few examples of undisturbed native climax vegetation, chiefly near isolated ponds and marshes in locations that were unsuitable for agricultural use.

Summaries of the results of an ecological survey of the site²² are presented in Tables 2.13 and 2.14. Tabulated flora species have included 37 trees, 40 composites, 20 grasses, and 7 legumes. Such lower plants as algae, fungi, and mosses also are well represented on the property. Vegetational mapping of the property indicates that more than half the site is in various states of old-field succession and that the rest is divided into pine plantations and deciduous broadleaf forest types (mostly oak). An extensive cattail marsh borders the Des Plaines River to the south and accompanies the lake area and its drainage in the northwest quarter of the property.

The fauna also are diverse. The checklist includes 674 identified species, with at least 199 others present in collection but only partially named (protozoans, nematodes, rotifers, and other "lower" animals were seldom collected). The total includes 732 species of insects (327 species of beetles), 86 species of birds, and 26 species of mammals.

Prairie plants are fairly well represented in the Argonne checklist, especially if one uses a classification of prairies that includes wetland species. By use of such a scheme, 28 species qualify as prairie plants. These are sometimes found in upland firebreaks or old fields, but most are in prairie islands of varying extent on the Des Plaines river floodplain.

Ties of animals to prairies generally are not so specifically documented, but some interesting collections from Argonne included the "prairie pselaphid," *Reichenbachia subsimilis* Casey, and the Silphium-restricted chrysomelid, *Microstrophala leatula* LeConte.

Table 2.13. Summary of Numbers of Species Observed at
Argonne National Laboratory during 1967-68 Survey

<i>Component</i>	<i>Named Species</i>	<i>Other Species</i>
Plants	166	10
Protozoa	1	1
Aschelminthes	0	1
Annelida	0	2
Mollusca	5	1
Arthropoda/Arachnida	1	14
/Crustacea	1	1
/Diplopoda	1	1
/Chilopoda	4	0
/Insecta/Collembola	11	3
/Aptera	0	1
/Thysanura	0	1
/Ephemerida	0	1
/Odonata	10	1
/Blattaria	2	0
/Phasmida	1	0
/Orthoptera	10	3
/Dermaptera	1	0
/Corrodentia	0	1
/Thysanoptera	7	3
/Homoptera	23	15
/Heteroptera-Hemiptera	48	4
/Coleoptera	327	59
/Neuroptera	1	0
/Trichoptera	0	1
/Lepidoptera	33	3
/Diptera	28	31
/Hymenoptera	30	50
Chordata/Osteichthyes	9	0
/Amphibia	4	0
/Reptilia	5	0
/Aves	86	0
/Mammalia	25	1
Totals	840	209

Table 2.14. Summary of the Major Arboreal Soil-Plant Associations
at Argonne National Laboratory

<i>Soil Types</i>	<i>Internal Drainage Class</i>	<i>Natural Vegetation</i>
<u>Jack Pine Plantations</u>		
Morley silt loam	Well-drained	Forest
Blount silt loam	Imperfectly drained	Forest
Ashkum silty clay loam	Poorly drained	Prairie
Beecher silt loam	Imperfectly drained	Prairie-Forest Trans.
Peotone silty clay loam	Very poorly drained	Prairie
Sawmill silty clay loam	Poorly drained	Prairie
Elliot silt loam	Imperfectly drained	Prairie
<u>Red Pine Plantations</u>		
Morley silt loam	Well-drained	Forest
Blount silt loam	Imperfectly drained	Forest
Beecher silt loam	Imperfectly drained	Prairie-Forest Trans.
Sawmill silty clay loam	Poorly drained	Prairie
<u>White Pine Plantations</u>		
Morley silt loam	Well-drained	Forest
Blount silt loam	Imperfectly drained	Forest
Beecher silt loam	Imperfectly drained	Prairie-Forest Trans.
Ashkum silty clay loam	Poorly drained	Prairie
Peotone silty clay loam	Very poorly drained	Prairie
Sawmill silty clay loam	Poorly drained	Prairie
Lorenzo silt loam	Well-drained	Prairie
<u>White Oak-Dominated Associations</u>		
Morley silt loam	Well-drained	Forest
Blount silt loam	Imperfectly drained	Forest
<u>Bur Oak-Dominated Associations</u>		
Morley silt loam	Well-drained	Forest
Blount silt loam	Imperfectly drained	Forest
Beecher silt loam	Imperfectly drained	Prairie-Forest Trans.
Sawmill silty clay loam	Poorly drained	Prairie
Peotone silty clay loam	Very poorly drained	Prairie
<u>Red Oak-Dominated Associations</u>		
Morley silt loam	Well-drained	Forest
Lorenzo silt loam	Well-drained	Prairie
Chatsworth silt loam	Well-drained	Forest
Romeo silt loam	Poorly drained	Prairie
<u>Elm and Ash-Dominated Associations</u>		
Morley silt loam	Well-drained	Forest
Lorenzo silt loam	Well-drained	Prairie
Lawson silt loam	Imperfectly drained	Prairie

Table 2.14 indicates the soil-type amplitude of the present arboreal vegetation and the observed or assumed natural vegetation on these soil types at Argonne. This tabulation is based on an unpublished soil survey by J. B. Fehrenbacher and associates, and a vegetation survey by A. S. Messenger. This comparison reveals that the white oak-dominated associations do not exist on poorly drained soils, but bur oak-dominated associations definitely do. The presence of red oak-dominated and elm and ash-dominated associations along drainageways leading to the Des Plaines River floodplain on apparent prairie soils may reflect the presence of Brown Forest soils influenced by basiphyllous hardwoods on very basic materials. These soils closely resemble grassland Brunizems. Jack and white pine plantations are located both on soils formerly forested and soils formerly under prairie. At present, one cannot tell if these soil differences are related to the variable success of the pines.

The quantitative survey of old-field plots showed 85% grass cover and 166 forbs per square meter. These forbs were primarily composites (66%), crucifers (20%), and legumes (3%). The net weight of a square meter (8 cm deep) was 64.8 kg, with herbs accounting for 1.8%, floor litter for 3%, and subterranean litter and soil for 95.2% of the totals. The free-water content varied from 17.5% for subterranean litter to 38.7% for floor litter. The fauna of an average square meter consisted of 27,711 animals, with 88.5% of these in the subterranean and a regular decrease in abundance through floor litter and herbs to the shrubs (0.03%). The most numerous faunal components were mites (Acari), 59%; springtails (Collembola), 27%; and ants (Formicidae: Hymenoptera), 4.1% of the faunal totals.

The survey also tabulated two-dozen prairie remnants in the Chicago area, some of which are good native prairie (e.g., Peacock Prairie), and others of which are abandoned cemeteries (e.g., Vermont Cemetery). The better of these prairie remnants will serve as seed sources, and in future years will be a standard of comparison for the Argonne prairie.

A unique aspect of the site ecology is a herd of several hundred fallow deer (*Dama dama*) that roam freely over the site. These are the descendants of fewer than a dozen that were on the part of the site that was known as the Freund Estate at the time the Laboratory took possession in 1947. These deer wander freely across the perimeter, and a number of them inhabit the forest preserve land adjacent to the site. They have been observed to mingle with the common white-tailed deer in the area, but apparently cannot breed with them. Their grazing and browsing habits are evident in many grass, forest edge, and wooded areas of the site and its environs, and they are often seen by Laboratory personnel close to the buildings and within the wooded and grassy areas that are landscaped within the site proper.

A survey has established the existence and locations of a rich diversity of plant and animal habitats and provides a basis for further field study on the Argonne site. The site has many examples of different plant associations growing on similar soil types and of similar plant associations growing on dissimilar soil types. Some of these are introduced, such as the plantations of jack pines, while others are remnants of forests or fields that have gone unmanaged for periods of 20 years or more. Locations of old fields in various stages of succession were

established. The entire site shows evidence of past disturbance, principally from agricultural use, although there are isolated examples of probable climax vegetation types located in remote marshes and wetlands that were not suitable for agricultural exploitation. Many of the deciduous forests appear to have been used as grazed woodlots prior to the establishment of the Laboratory. These have been protected from further agricultural use since about 1948. Their ages are not known, but it seems certain that they existed long before they became Laboratory property.

2.3.8 Background Radiological Characteristics

The radiological characteristics in the vicinity of the site are unremarkable. Cosmic, terrestrial, internal, and total backgrounds (45, 65, 25, and 135 mrem/yr, respectively) are very close to the averages for the United States as a whole (45, 60, 30, and 135 mrem/yr, respectively).²³ Medical background is about 70 mrem/yr for the inhabitants of the region.^{24,25} Fifty-six Federal and State radiological monitoring stations have been active in the area over the last two decades,²⁶ so a considerable backlog of data is available. These stations, as well as those associated with nearby nuclear facilities, are listed in Table 2.15. Operational data at and near the site have been published by the Laboratory.²⁷⁻²⁹ Stations have monitored not only the radioactivity of the Illinois Waterway but also surface, ground, and tapwater concentrations, milk, dietary, and atmospheric concentrations, and a number of trophic and transfer chains in biota typical of the region. Values obtained are

Table 2.15. Radiological Monitoring Stations within 200 Miles of the Laboratory

Station	Distance from Plant, miles	Direction from Plant	Sampling Type ^a
Argo, Ill.	10	ENE	TW
Beardstown, Ill.	173	SE	TW
Bedford Park, Ill.	11	ENE	TW
Braidwood, Ill.	32	SSW	Braidwood (NPS)
Bridgman, Mich.	75	ENE	Cook (NPS)
Burlington, Iowa	180	WSW	SW, TW
Byron, Ill.	73	WNW	Byron (NPS)
Carlton, Wis.	184	N	Kewaunee (NPS)
Cedar Rapids, Iowa	197	W	Duane Arnold (NPS)
Central, Ind.	159	SE	PM, LO
Chicago, Ill.	22	NE	PM, DA
Clinton, Ill.	118	SSW	Clinton (NPS)
Cordova, Ill.	122	W	Quad Cities (NPS)
Danville, Ill.	109	S	TW
Decatur, Ill.	137	SSW	TW
Des Plains, Ill.	25	NNE	TW
Downers Grove, Ill.	9	NNW	TW
Dubuque, Iowa	149	WNW	SW
Dunes Acres, Ill.	44	E	Bailly (NPS)
Elkhart, Ind.	103	E	TW
Franklin Park, Ill.	18	NNE	TW
Gary, Ind.	34	E	SW
Grand Rapids, Mich.	147	NE	PM, TW, LO
Green Bay, Wis.	195	N	TW
Holland, Mich.	121	NE	TW
Indianapolis, Ind.	164	SE	PM, SA, TW, TT, DA
Iowa City, Iowa	184	W	PM, SA, TT, LO
Joliet, Ill.	13	SSW	TW
Kalamazoo, Mich.	129	ENE	TW
Lafayette, Ind.	104	SSE	TW
Lansing, Mich.	189	ENE	PM, SA, TW, LO
LaSalle, Ill.	50	SW	LaSalle (NPS)
Lemont, Ill.	2	SW	TW
Logansport, Ind.	106	SE	TW
Ludington, Mich.	174	NNE	TW
Madison, Wis.	120	NW	SA, TW, TT
Manitowac, Wis.	166	N	TW
Menasha, Wis.	176	N	TW

Table 2.15. (continued)

<i>Station</i>	<i>Distance from Plant, miles</i>	<i>Direction from Plant</i>	<i>Sampling Type^a</i>
Michigan City, Ind.	55	E	TW
Middlebury, Ind.	117	E	TW
Milwaukee, Wis.	93	N	PM, TW, DA
Moline, Ill.	131	W	ST
Morris, Ill.	33	SW	ST
Morris, Ill.	26	SW	Dresden (NPS)
Muncie, Ind.	170	SE	TW
Muskegon, Mich.	137	NE	TW
New Lisbon, Ind.	188	NW	TW
Northeast, Ind.	153	ESE	PM, LO
Northwest, Ind.	80	SE	PM, LO
Orlando Park, Ill.	7	SE	TW
Oshkosh, Wis.	163	N	TW
Peoria, Ill.	109	SW	SW, TW
Peru, Ill.	66	WSW	TW
Portage, Ind.	42	ESE	TW
Rock Island, Ill.	135	W	TW
Rockford, Ill.	70	NW	TW
Rosemont, Ill.	22	NNE	TW
Saint Joseph, Mich.	82	ENE	TW
Savanna, Ill.	114	WNW	TW
Schiller Park, Ill.	18	NNE	TW
Shaven, Mich.	100	ENE	PM, ST, LO
Springfield, Ill.	158	SW	SA, TW, TT
South Haven, Mich.	96	ENE	Palisades (NPS)
Two Creeks, Wis.	181	N	ST
Two Creeks, Wis.	180	N	Point Beach (NPS)
Two Rivers, Wis.	171	N	TW
Vandalia, Ill.	198	SSW	TW
West Chicago, Ill.	16	NW	Nat'l Accelerator Lab
West Lafayette, Ind.	102	SSE	TW
Zion, Ill.	54	N	Zion (NPS)

^a DA = Diet Analysis

LO = Special Milk Station

NPS = Nuclear Power Station

PM = Pasturized & Raw Milk

SA = Surface Air

ST = Surface Water Tritium

SW = Surface Water

TT = Tap Water Tritium

TW = Tap Water

discussed in detail in Section 2.4. The large reservoir of available information easily provides an adequate baseline against which to measure present and future plant impact.

2.4 EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

(Results and Assessments to 31 December 1974)

2.4.1 Preoperational Programs

Prior to the start of construction on the present site (Site D), effluent monitoring programs had been in operation at Site B near the University of Chicago and Site A at the Palos Park Forest Preserve near the present site of the Laboratory. Although the records of these efforts have been retained, they are chiefly of historical interest. During the construction period at Site D, some of these efforts, principally the meteorology monitoring program, were extended to the new site. This program began in late 1949 in the southwest corner of the present site, and it has remained there to this date. It began with wind speed and direction measurements at 19 and 150 feet, temperature measurements and direct and diffuse solar radiation measurements, as well as continuous pressure measurements. Shortly after this, but still in the early stages of construction, additional temperature measurements were added at various altitudes. All of these data were recorded and have since been processed automatically at the Argonne Computer Center. A 15-year summary dating from this preconstruction and construction period has been published.⁵

A number of radiological surveys were also made during this early period, which predates the use of radioactivity at the present site.³⁰ These early surveys provide some information on the background radiation level at the site prior to the beginning of operations involving radioactivity, and are supplemented by various other studies that were done in the Chicago area during this period. During this early period, and based on experience at the previous Sites A and B, the Laboratory developed monitoring programs with the objectives of ensuring that planned discharges would not be exceeded, that data would be developed that could be used in the design of new operational procedures, and that data would be developed that could aid in the interpretation of the results of other studies, such as ecological monitoring programs. These developments have continued at the Laboratory since their inception in the late 1940's, and have led to progressively more refined, more sensitive, and more complete effluent and environmental monitoring programs.

2.4.2 Operational Programs

2.4.2.1 The Atmosphere

Meteorological monitoring reports that are more recent than the one published in 1967⁵ have now been published (e.g., Ref. 31). The collection, recording, analysis, and integration of these data into models and scientific hypotheses have been under the direction of the Meteorology Group and the Atmospheric Physics Section of the Laboratory. By 1960, data were being processed automatically at the Laboratory's Computer

Center, and included measurements and recordings of wind speed and direction, temperature, dew point, relative humidity, atmospheric stability, precipitation, direct and diffuse solar radiation, net radiation, pressure, and soil temperature. Meteorological data are collected at 3.5, 5.5, 15.2, 19, 34, 72.2, 144, and 150 feet above ground, and soil data at 1, 10, 20, 50, 100, 328, and 950 centimeters below ground. The equipment used is the archetype of the equipment now being required for nuclear power plant monitoring programs under Regulatory Guide 1.23.

These groups have also continued to collect, collate, and integrate into their own studies NWS information available from various stations of the National Oceanic and Atmospheric Administration (NOAA) that are within a few hundred miles of the Laboratory, and of the data being developed by such operating nuclear power stations in the area as Dresden, Zion, Quad Cities, etc. The Argonne Atmospheric Physics Section has maintained from its beginning an extensive experimental program for measurements of dispersions of plumes and releases by various tracer methods. The results of some of this continuing monitoring effort have been covered in Section 2.3.6. In recent years, this information has been integrated into the Air Pollution Information and Control System (APICS) program at the Laboratory.³² Under this program, sulfur dioxide, particulate, and other pollutant levels in the Chicago metropolitan area are measured continuously, and the results are used to calibrate atmospheric models of inversions and pollution episodes.

Monitoring of gaseous effluents and of the atmosphere in and about the site is performed under the aegis of the Division of Occupational Health

and Safety (OHS). A number of the permanent sampling locations on the site have already been shown in Figure 2.5. Offsite locations are shown in Figure 2.14. In addition to these continuous sampling sites, portable air monitors are positioned at a number of other locations on a weekly or quarterly basis. Positioning of these monitors is governed by the known wind patterns appropriate to the different seasons of the year, and/or changing release patterns from the various facilities at the laboratory. Continuous air samples also are taken in conjunction with monitoring programs for measuring the fallout from various atmospheric tests of nuclear weapons, in recent years chiefly those of the People's Republic of China and the Republic of France, but also including the small residuum from earlier weapons tests and the small contributions from various underground detonations. These programs are under the direction of the Divisions of Radiological and Environmental Research (RER) and OHS, and results appear in a continuing series of reports (e.g., Ref. 29). Effluent stacks are monitored either continuously or on a weekly to quarterly basis, depending on the nature of the area exhausted and its potential for radioactive release.

The data thus gathered over the past quarter century appear in a continuing series of reports and in the open literature (e.g., Refs. 25-29, 33). Examples of data from a recent annual summary²⁹ are given in Tables 2.16 and 2.17. The values shown are representative of the Laboratory's experience in this area. In general, the only nuclides detected are those from worldwide fallout, with the Laboratory levels less than or equal to levels offsite. The slight decrement at the Laboratory probably is due to the fact that the site is surrounded by an extensive

Fig. 2.14. Sampling Locations near Argonne National Laboratory.

Table 2.16. Total Alpha and Beta Activities in Air-Filter Samples, 1974^a

Month	Location	No. of Samples	Alpha Activity (10^{-15} $\mu\text{Ci/ml}$)			Beta Activity (10^{-12} $\mu\text{Ci/ml}$)		
			Av.	Min.	Max.	Av.	Min.	Max.
January	perimeter	35	1.7	0.9	3.6	0.056	0.042	0.076
	offsite	25	2.5	1.0	11.	0.058	0.033	0.087
February	perimeter	31	1.9	0.8	3.0	0.087	0.062	0.12
	offsite	20	2.2	1.2	4.3	0.093	0.068	0.13
March	perimeter	35	2.0	0.7	4.0	0.13	0.063	0.19
	offsite	19	2.2	0.9	3.7	0.13	0.055	0.20
April	perimeter	34	2.7	1.0	5.6	0.26	0.11	0.40
	offsite	22	2.7	1.3	5.0	0.26	0.11	0.39
May	perimeter	34	2.1	0.7	4.5	0.25	0.16	0.32
	offsite	22	1.9	0.8	3.2	0.25	0.20	0.31
June	perimeter	34	2.4	0.7	6.2	0.21	0.11	0.31
	offsite	17	2.0	1.0	3.1	0.23	0.089	0.34
July	perimeter	35	3.6	1.1	7.0	0.19	0.098	0.27
	offsite	22	3.1	1.4	6.5	0.19	0.076	0.30
August	perimeter	36	2.8	1.2	5.8	0.11	0.064	0.15
	offsite	21	2.6	1.3	5.7	0.12	0.085	0.28
September	perimeter	34	3.1	1.5	8.1	0.066	0.039	0.10
	offsite	22	2.1	0.9	4.0	0.076	0.024	0.44
October	perimeter	35	2.6	1.2	5.5	0.060	0.030	0.21
	offsite	22	2.4	1.3	4.4	0.052	0.032	0.078
November	perimeter	34	1.8	0.8	3.3	0.057	0.034	0.12
	offsite	16	1.7	0.6	3.4	0.053	0.039	0.091
December	perimeter	35	2.1	1.0	6.1	0.071	0.054	0.094
	offsite	19	2.1	1.1	4.9	0.069	0.048	0.12
Annual Summary	perimeter	412	2.4 ± 0.3	0.7	8.1	0.13 ± 0.05	0.030	0.40
	offsite	247	2.3 ± 0.2	0.6	11.	0.13 ± 0.05	0.024	0.44

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

Table 2.17. Gamma-Ray Activity in Air-Filter Samples, 1974
(10^{-15} $\mu\text{Ci/ml}$)

Nuclide	Location	January	February	March	April	May	June	July	August	September	October	November	December	Annual Average
Antimony-125	perimeter	< 0.5	0.8	1.2	2.5	2.7	2.5	2.7	1.4	0.9	0.5	< 0.5	< 0.5	1.3 $\pm$ 0.6
	offsite	< 0.5	1.0	1.5	3.3	2.6	3.2	2.0	1.1	0.6	0.5	< 0.5	< 0.5	1.4 $\pm$ 0.7
Barium-140- Lanthanum-140	perimeter	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3.1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.7
	offsite	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2.8	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.7
Beryllium-7	perimeter	58	96	94	105	85	82	124	76	78	70	67	63	83 $\pm$ 11
	offsite	56	95	104	108	88	91	99	75	71	63	63	56	81 $\pm$ 11
Cerium-141	perimeter	0.6	1.0	1.0	1.3	0.8	0.5	1.3	1.6	1.1	0.6	1.0	1.0	1.0 $\pm$ 0.2
	offsite	0.6	1.0	1.1	1.4	0.8	0.5	1.2	1.4	0.9	0.6	0.9	0.9	0.9 $\pm$ 0.2
Cerium-144	perimeter	3.7	10	18	43	48	43	42	19	10	6.1	6.4	6.6	21 $\pm$ 10
	offsite	3.6	11	19	47	48	47	36	19	10	6.1	6.5	6.3	22 $\pm$ 10
Cesium-137	perimeter	< 0.5	1.0	1.7	3.9	4.4	4.1	4.5	2.2	1.4	0.8	0.8	0.7	2.1 $\pm$ 0.9
	offsite	0.6	1.0	1.6	4.3	4.5	5.1	3.9	2.3	1.3	0.8	0.8	0.6	2.2 $\pm$ 1.0
Cobalt-60	perimeter	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	offsite	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Iodine-131	perimeter	< 5	< 5	< 5	< 5	< 5	< 5	< 6	< 5	< 5	< 5	< 5	< 5	< 5
	offsite	< 5	< 5	< 5	< 5	< 5	< 5	< 6	< 5	< 5	< 5	< 5	< 5	< 5
Manganese-54	perimeter	< 0.1	< 0.1	< 0.1	0.4	0.4	0.4	0.3	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.2
	offsite	< 0.1	< 0.1	< 0.1	0.5	0.5	0.5	0.3	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2
Ruthenium-103	perimeter	1.4	2.6	3.0	4.1	2.8	1.7	2.4	1.6	1.0	0.5	1.3	1.6	2.0 $\pm$ 0.6
	offsite	1.4	2.6	3.0	4.4	2.9	1.8	2.7	1.5	0.9	0.6	1.2	1.6	2.0 $\pm$ 0.6
Ruthenium-106- Rhodium-106	perimeter	2.5	5.4	10	24	26	23	24	10	6.1	3.4	3.3	3.0	12 $\pm$ 6
	offsite	2.5	6.6	9.9	26	28	28	20	10	5.4	2.8	3.7	2.8	12 $\pm$ 6
Zirconium-95- Niobium-95	perimeter	12	29	42	78	68	48	40	20	9.0	10	15	16	32 $\pm$ 13
	offsite	13	30	44	85	70	52	34	14	8.4	12	10	17	32 $\pm$ 15

forest belt that tends to inhibit some of the lateral transport of fallout. In any case, the contribution of radioactivity from Laboratory activities is negligible with respect to the worldwide fallout, and even more so with respect to the natural background.

Another consequence of this forest belt, present because of the Laboratory, is that it tends to cause a net improvement in the air quality of the region. Forests are rare in this part of Illinois, and the forest belt about the Laboratory tends to act as a filter and removal zone for many of the noxious effluvia associated with the petroleum refineries and other industrial plants along the Illinois Waterway, with the waterway itself, and with the heavy truck traffic along Interstate 55. This circumstance is commented upon by local residents and is noticeable in the results of various monitoring activities.

2.4.2.2 The Hydrosphere

Surface waters are monitored by OHS, and monitoring of groundwater and deep aquifers is shared with the Plant Operations Division. Surface water is monitored in Sawmill Creek, the Des Plaines River, and the Illinois River at and below the Joliet basin. As it enters the ANL site, the flow of Sawmill Creek (which in 1974 averaged 7.7 million gpd above the ANL waste-water outfall) includes about 2 million gpd of effluent from a municipal sewage treatment plant (Marion Brook facility of the DuPage County Public Works). Virtually all of the effluent constituents are maintained well below applicable State limits³⁴ for the Des Plaines River.

As in the past, the current major emphasis for monitoring has been placed on Sawmill Creek, because this is the principal route for waste water leaving the Argonne site. The chemical monitoring results for 1974 are given in Table 2.18,²⁹ in which all of the results have been compared to appropriate State limits (see Table 2.19).²⁹ Not listed in Table 2.18 are results for pH and ammonia nitrogen. The pH levels measured (in 1974) ranged from 7.7 to 8.6 below the waste-water outfall and from 7.9 to 8.8 above the outfall. These values are within the State limit and indicate that the outfall water had no significant effect on the pH levels in the creek. The average ammonia nitrogen levels above and below the outfall were 1.1 mg/l and 1.0 mg/l, respectively, also within the applicable State limit.²⁹

With respect to those values in Table 2.18 that exceed State limits--namely, for chromium, copper, iron, lead, mercury, silver, and zinc--it should be noted that only a small fraction were greater than the limits and all of the results in Table 2.18 are based on grab samples that were collected from Sawmill Creek at a time when maximum releases of Laboratory waste water were expected to occur. The purpose for using these collection times was to assess the situation at time of peak Laboratory release.

The principal source of chromium found in Sawmill Creek is the cooling towers, which employ chromate compounds as corrosion inhibitors. Although blowdown water from these towers may enter Sawmill Creek at any time of the day throughout the year, a maximum is reached during the cooling season. Water containing chromium reaches Sawmill Creek either

Table 2.18. Chemical Constituents in Sawmill Creek, 1974

Constituent	Location ^a	No. of Samples	Concentration (mg/l)			Percent of Total Samples Exceeding State Levels
			Av.	Min.	Max.	
Barium	7M	52	2.59 ± 0.19	1.24	4.45	0
Beryllium ^b	7M	12	0.114 ± 0.050	0.015	0.334	-
Cadmium ^b	7M	52	1.83 ± 0.29	0.4	4.4	0
Chromium (VI)	7M (up)	51	0.009 ± 0.002	0.006	0.035	0
	7M (down)	152	0.03 ± 0.01	0.006	0.426	18
Copper ^b	7M	52	11.1 ± 1.6	5	29	8
Cyanide	7M	37	-	-	< 0.02	0
Fluoride	7M	52	0.40 ± 0.04	0.21	0.69	0
Iron	7M	52	0.53 ± 0.10	0.11	1.47	14
Lead ^b	7M	52	17.2 ± 7.0	0.5	101	2
Mercury ^b	7M (up)	51	-	-	< 0.1	0
	7M (down)	152	0.16 ± 0.03	0.05	2.15	3
Nickel	7M	52	-	-	< 0.2	0
Silver ^b	7M	52	1.80 ± 0.46	0.1	9.2	4
Zinc	7M	52	0.14 ± 0.05	0.05	1.3	2

^aLocation 7M (up) is 50 ft upstream from the waste-water outfall. All other samples were collected 200 ft downstream from the outfall.

^bAll concentration values multiplied by 10³.

Table 2.19. State Water Quality Standards^a
and Laboratory Detection Limits
(concentrations in mg/l)

Constituent	Applicable Water Type		Detection Limit
	Stream	Effluent	
Ammonia Nitrogen (as N)	1.5	2.5 (Apr-Oct) 4.0 (Nov-Mar)	0.1
Barium (total) ^b	5.0	2.0	1.0
Cadmium (total)	0.05	0.15	0.0002
Chromium (total hexavalent)	0.05	0.3	0.006
Copper (total)	0.02	1.0	0.005
Cyanide	0.025	0.025	0.020
Fluoride	1.4	2.5	0.02
Iron (total)	1.0	2.0	0.08
Lead (total)	0.1	0.1	0.0015
Mercury (total)	0.0005	0.0005	0.0001
Nickel (total)	1.0	1.0	0.2
pH	6.5-9.0	5.0-10.0	-
Silver (total)	0.005	0.1	0.0002
Zinc (total)	1.0	1.0	0.01

^a Adopted by the State of Illinois and approved by the Federal Government in 1972.

^b Total limits apply to samples not filtered before analysis. All other limits apply to filtered samples.

through the Waste Treatment Plant or directly through storm drainage channels. The average level found in 1974 for hexavalent chromium in Sawmill Creek was 0.03 mg/l or 60% of the State of Illinois limit. The values exceeding the State limit are found almost entirely during the warm weather. The average level in the Waste Treatment Plant effluent was 0.04 mg/l and no samples exceeded the State limit of 0.30 mg/l for effluents. Twenty-four-hour samples collected from Sawmill Creek have shown levels much less than the State limit. For example, in July 1972 the average and maximum values for 24-hour samples were 0.01 and 0.02 mg/l, 20% and 40%, respectively, of the State limit.²⁷ It should also be noted that the results in the Des Plaines River for hexavalent chromium have been uniform from 1967 to the present. Levels in the river above and below Sawmill Creek are the same and very low (< 0.01 mg/l), indicating no effect of Sawmill Creek on the river. Also, weekly examination of all the onsite wells utilized for domestic water has shown no hexavalent chromium. However, in order to reduce even the maximum levels measured to below State limits, an intensive effort is being made to locate and further control the sources of chromium release.

The four copper samples (8% of samples analyzed) exceeding the State limit were all collected in January 1974 and were completely atypical of results obtained during the succeeding eleven months.

Soluble iron concentrations are well within the State limit for iron; however, the State limit must now be applied to unfiltered samples. Thus, the results reported include iron that was originally insoluble but dissolves when the sample is acidified. Particulate matter, such

as soil erosion during rain storms, thus contributes to the total iron concentrations reported in Table 2.18 and these contributions cannot be ascribed to ANL operations.

The lead concentrations exceeding the State limit are attributed to difficulties encountered in a new analytical procedure, which initially yielded high and variable results. Once the procedure was modified, the values for the remainder of the year were essentially the same as found prior to 1974. For example, in 1972 the average and maximum lead concentrations in Sawmill Creek were 0.011 and 0.028 mg/l.²⁷

The average mercury level for the year 1974 was about 40% of the State limit and represented a reduction from 1973 of about a factor of three. This reduction is the result of efforts to reduce effluent levels by suitable treatment before release. In addition to reducing the average levels, the maximum level in any one sample was about four times the State limit in 1974 as compared to 25 times the limit in 1973.²⁸ Efforts are continuing to further reduce these levels.

In the case of silver, only two of 52 samples exceeded the State limit. The very low average concentration indicates that these exceptions are of rare occurrence.

There was only one zinc sample that exceeded the State limit. It was the first sample obtained in January 1974 and may have been due to contamination.

The waters of Sawmill Creek, the Des Plaines River, and the Illinois River are measured for radioactive constituents as well. The results²⁹ presented in Table 2.20 are representative of the Laboratory's history. Typically, tritium, neptunium, and plutonium ascribable to Laboratory operation are detected within Sawmill Creek at very minute levels. The concentrations of remaining radionuclides are generally lower after they pass the Argonne outfall, and arise overwhelmingly from worldwide fallout (see Sec. 2.4.2.1 and Refs. 25-29, 33). The overwhelming bulk of the tritium, neptunium, and plutonium detected in Sawmill Creek, and about the Laboratory, similarly arise from worldwide fallout (see Sec. 2.4.2.1 and Refs. 25-29, 33). Although not indicated in the table, the trans-plutonium nuclides americium-241, cerium-244, californium-249, and californium-252 are also monitored. In general their concentrations are below detectable limits, but occasionally they rise to values of the order of that of plutonium-239. The levels of all of the alpha-emitting nuclides are very close to that of the minimum detection limit, and very far below applicable standards.

2.4.2.3 The Lithosphere and Biosphere

Environmental monitoring for nonbiotic constituents of the terrestrial environment is under the aegis of OHS, and monitoring of the ecosystem is under the aegis of RER. Thus, monitoring programs associated with radionuclides, chemical composition, and trace element constituents of the soil, grass, and benthic materials in and about the Laboratory site, of radioactivity in milk offsite, and of penetrating radiation on- and

Table 2.20. Radioactivity in Sawmill Creek Water, 1974

Type of Activity	Location ^a	No. of Samples	Concentration (10^{-9} μ Ci/ml)			Percent of CGB ^b		
			Av.	Min.	Max.	Av.	Min.	Max.
Alpha (nonvolatile)	15K	12	1.9 ± 0.2	1.4	3.0	(0.063)	(0.047)	(0.10)
	7M	253	1.7 ± 0.1	0.9	3.3	(0.057)	(0.030)	(0.11)
Beta (nonvolatile)	15K	12	19 ± 4	9.8	32	(0.63)	(0.33)	(1.1)
	7M	253	16 ± 2	8.0	44	(0.53)	(0.27)	(1.5)
Hydrogen-3	15K	12	< 202	< 200	212	< 0.0067	< 0.0067	0.0071
	7M	253	2140 ± 1800	240	47,000	0.071	0.0080	1.6
Strontium-89	15K	12	-	-	< 2	-	-	< 0.07
	7M	253	-	-	< 2	-	-	< 0.07
Strontium-90	15K	12	0.62 ± 0.14	< 0.5	0.93	0.21	< 0.17	0.31
	7M	253	1.1 ± 0.4	< 0.5	11	0.37	< 0.17	3.7
Iodine-131	15K	12	< 4	< 3	11	< 1.3	< 1	3.7
	7M	253	< 4	< 3	7.9	< 1.3	< 1	2.6
Barium-140	15K	12	-	-	< 2	-	-	< 0.007
	7M	253	-	-	< 2	-	-	< 0.007
Uranium (natural) ^c	15K	12	2.0 ± 0.2	1.3	2.7	(0.0050)	(0.0032)	(0.0068)
	7M	253	1.9 ± 0.2	1.0	3.9	(0.0048)	(0.0025)	(0.0098)
Neptunium-237	15K	12	-	-	< 0.002	-	-	< 0.00007
	7M	253	0.19 ± 0.09	0.013	1.5	0.0063	0.00043	0.050
Plutonium-238	15K	12	-	-	< 0.002	-	-	< 0.00004
	7M	253	< 0.0028	< 0.002	0.016	< 0.000056	< 0.00004	0.00032
Plutonium-239	15K	11	< 0.001	< 0.0005	0.0040	< 0.00002	< 0.00001	0.00008
	7M	253	0.018 ± 0.008	< 0.0005	0.12	0.00036	< 0.00001	0.0024
Americium-241	15K	12	-	-	< 0.001	-	-	< 0.000025
	7M	253	0.006 ± 0.003	< 0.001	0.057	0.00015	< 0.000025	0.0014
Curium-242 and/or Californium-252	15K	12	-	-	< 0.001	-	-	< 0.000005
	7M	253	< 0.0013	< 0.001	< 0.010	< 0.0000065	< 0.000005	0.00005
Curium-244 and/or Californium-249	15K	12	-	-	< 0.001	-	-	< 0.000014
	7M	253	< 0.0036	< 0.001	0.035	< 0.000051	< 0.000014	0.0005

^a Location 15K is upstream from the Argonne site and location 7M is downstream from the Argonne wastewater outfall. Coordinates refer to grids in Figure 2.5.

^b Concentration Guide.

^c Uranium concentrations in units of mg/l can be obtained by multiplying the concentration given by 1.48×10^3 . The average concentration in the Creek then becomes 2.9 μ g/l.

offsite are conducted by OHS. Measurements of penetrating radiation are routinely made onsite, and representative values, expressed in mrem/year, are indicated in Figure 2.15.

Analysis of radioactive constituents of foodstuffs in the Chicago area is done by OHS and RER in cooperation with the ERDA Health and Safety Laboratory. Monitoring of some selected radionuclides in the environment and of the ecology of the site is conducted by OHS and RER with the cooperation of teams from the Argonne Universities Association (AUA). The data in Tables 2.21 through 2.25 are representative of the extensive information available.²⁹

With the possible exception of tritium and plutonium in the benthos and littoral of Sawmill Creek onsite, contamination from Laboratory sources has not been detectable in either lithosphere or biosphere. The values obtained to date have been typical of atmospheric fallout in the area.

2.4.3 Related Environmental Monitoring Efforts

The Laboratory is continuously involved in at least two additional types of monitoring efforts. On the one hand the Laboratory receives, systematizes, correlates, and analyzes data from all of the Federal, State, local, and international stations of the various alert networks.²⁶ This data base and associated effort cover all forms of radioactivity, radiation, and most of the more common chemical pollutants, and is retained and managed under the code name MONITOR2. As a subset of this overall

Fig. 2.15. Penetrating Radiation Measurements at the Site Periphery.

Table 2.21. Plutonium Content of Perimeter Soil, 1974

Date Collected	Location ^a	Plutonium-239		Plutonium-238		Activity
		10^{-9} $\mu\text{Ci/g}$	10^{-3} $\mu\text{Ci/m}^2$	10^{-9} $\mu\text{Ci/g}$	10^{-3} $\mu\text{Ci/m}^2$	$^{238}\text{Pu}/^{239}\text{Pu}$
4 June	7M	6.9 ± 0.8	2.05 ± 0.25	0.4 ± 0.2	0.10 ± 0.06	0.050
4 June	120	4.3 ± 0.5	1.65 ± 0.20	0.8 ± 0.2	0.29 ± 0.09	0.18
4 June	14I	3.0 ± 0.4	1.27 ± 0.18	0.1 ± 0.1	0.05 ± 0.04	0.040
4 June	13D	5.0 ± 0.6	2.09 ± 0.23	0.3 ± 0.1	0.12 ± 0.06	0.056
5 June	12M	4.7 ± 0.6	1.82 ± 0.24	0.2 ± 0.2	0.08 ± 0.06	0.045
6 November	10M	1.8 ± 0.2	0.88 ± 0.10	0.2 ± 0.1	0.08 ± 0.04	0.090
6 November	10M	5.7 ± 0.4	2.30 ± 0.14	-	-	-
7 November	13I	2.2 ± 0.2	1.07 ± 0.10	-	-	-
7 November	13/14I	4.6 ± 0.3	2.09 ± 0.15	< 0.1	< 0.01	-
7 November	13I	2.6 ± 0.2	1.28 ± 0.12	0.1 ± 0.1	0.07 ± 0.03	0.053
Average		4.1 ± 1.0	1.65 ± 0.31	0.3 ± 0.2	0.10 ± 0.06	0.073

^aThe locations are given in terms of the grid coordinates in Figure 2.5.

Table 2.22. Plutonium Content of Offsite Soil, 1974

Date Collected	Location	Plutonium-239		Plutonium-238		Activity $^{238}\text{Pu}/^{239}\text{Pu}$
		$10^{-9} \mu\text{Ci/g}$	$10^{-3} \mu\text{Ci/m}^2$	$10^{-9} \mu\text{Ci/g}$	$10^{-3} \mu\text{Ci/m}^2$	
14 May	Starved Rock State Park, Ill.	4.7 ± 0.6	2.06 ± 0.25	0.2 ± 0.1	0.06 ± 0.05	0.032
14 May	Morris, Ill. (Continental Grain)	5.7 ± 0.6	2.05 ± 0.20	0.2 ± 0.1	0.06 ± 0.04	0.027
14 May	Morris, Ill. Stratton Park	20.1 ± 1.0	6.94 ± 0.33	1.2 ± 0.2	0.41 ± 0.08	0.059
14 May	Pioneer Park, Naperville, Ill.	7.1 ± 0.6	2.54 ± 0.23	0.4 ± 0.2	0.12 ± 0.05	0.049
21 May	McGinnis Slough	6.7 ± 0.8	2.17 ± 0.25	0.3 ± 0.2	0.11 ± 0.06	0.050
21 May	Saganashkee Slough	7.2 ± 0.7	1.96 ± 0.20	0.4 ± 0.2	0.11 ± 0.05	0.058
8 October	McKinley Woods State Park, Ill.	5.9 ± 0.4	2.10 ± 0.12	0.4 ± 0.1	0.16 ± 0.06	0.075
23 October	Bemis Woods, Hinsdale, Ill.	10.1 ± 0.4	3.45 ± 0.15	0.6 ± 0.1	0.21 ± 0.04	0.061
23 October	McCormick Woods, Brookfield, Ill.	4.8 ± 0.5	1.78 ± 0.20	0.4 ± 0.2	0.16 ± 0.07	0.088
7 November	Lemont, Ill.	4.0 ± 0.3	1.53 ± 0.10	0.2 ± 0.1	0.07 ± 0.02	0.044
	Average	7.6 ± 3.0	2.7 ± 1.0	0.4 ± 0.2	0.15 ± 0.07	0.054

Table 2.23. Radioactivity in Milk, 1974
(10^{-9} $\mu\text{Ci/ml}$)

<i>Date Collected</i>	<i>Hydrogen-3</i>	<i>Strontium-89</i>	<i>Strontium-90</i>	<i>Cesium-137</i>
2 January	< 200	< 2	3.8	< 5
6 February	< 200	< 2	7.0	< 5
15 March	< 200	< 2	2.3	< 5
3 April	< 200	< 2	6.7	7
1 May	< 200	< 2	5.5	7
5 June	< 200	3.1	14.8	12
3 July	< 200	3.1	15.3	19
7 August	260	< 2	11.6	8
4 September	320	< 2	5.0	10
2 October	205	< 2	6.1	5
6 November	245	< 2	0.6	5
4 December	< 200	< 2	3.3	< 5
Average	< 220	< 2.2	6.8 ± 2.7	6.9 ± 2.8

Table 2.24. Environmental Penetrating Radiation at Offsite Locations, 1974

Location	Dose Rate (mrem/year)						Average
	Approximate Period of Measurement						
	Jan-Feb	Mar-Apr	May-Jul	Aug-Sep	Oct-Nov	Dec	
Downers Grove	98	100	97	106	93	91	98 ± 13
Lockport	104	111	102	102	93	99	101 ± 15
Lombard	102	103	101	97	89	101	99 ± 13
Oak Lawn	91	92	87	90	83	86	88 ± 9
Oak Brook	117	112	110	110	106	107	110 ± 9
Average	102 ± 24	104 ± 21	99 ± 21	101 ± 20	93 ± 21	97 ± 21	99 ± 17

Table 2.25. Environmental Penetrating Radiation at ANL, 1974

Location ^a	Dose Rate (mrem/year)						Average
	Approximate Period of Measurement						
	Jan-Feb	Mar-Apr	May-Jul	Aug-Sep	Oct-Nov	Dec	
14L - Boundary	94	95	88	92	90	82	90 ± 12
14I - Boundary	109	103	105	108	105	101	105 ± 7
14H - Boundary	91	118	98	102	91	97	100 ± 25
13D - Boundary	-	85	77	75	74	73	77 ± 12
10EF - Boundary	-	112	-	-	-	-	-
9EF - Boundary	110	128	102	93	90	92	103 ± 36
8F - Boundary	108	98	103	110	97	92	101 ± 17
8H - Boundary	118	119	108	108	101	105	110 ± 18
7I - Boundary	297	310	296	314	245	236	282 ± 84
9L - Boundary	99	107	87	-	-	-	98 ± 30

^aCoordinates refer to grids in Figure 2.5.

major effort, data from monitoring stations within the potential area of influence of the Laboratory are carefully analyzed to detect any Laboratory-related impacts. A list of some of the stations involved within a 200-mile radius of the Laboratory has been given in Section 2.3.8 (Table 2.15).

The Laboratory also receives, correlates, and analyzes the results of biological and ecological monitoring programs at nuclear facilities in the United States, in particular those in the Midwest. This is done in cooperation with other monitoring organizations, such as other major ERDA laboratories, the U. S. Environmental Protection Agency (EPA), the Illinois Environmental Protection Agency, the ERDA Health and Safety Laboratory, the Radiation Alert Network (RAN), and programs at the universities within the AUA, to name a few. This massive effort has the effect of cross-monitoring of one station or facility with another so that anything that might have been missed by one is very likely to have been caught by another. In addition, these cooperating facilities exchange methods and standard samples to promote uniformity of methodology and results.

In addition, Laboratory personnel are often called upon to monitor special aspects of other facilities, or general aspects of special events, about the world. Laboratory personnel, chiefly from the Division of Radiological and Environmental Research and from the Environmental Statement Project, have been asked to direct, participate in, or evaluate monitoring programs in many separate parts of the world (e.g., Thule, Greenland, and Antofagasta, Chile). Finally, the Laboratory participates in the Aerial Radiological Measurement and Surveys (ARMS) effort

for fly-over radiological surveys of areas of interest within the United States and about the world. Taken all together, these monitoring efforts and the constant development of monitoring methodologies and their applications have given the Laboratory an almost unique ability to monitor the impacts of its own operations. The monitoring program for the Laboratory is considerably in excess of EPA guides for nuclear facilities (e.g., Ref. 35).

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3. ENVIRONMENTAL IMPACT

3.1 EFFECTS OF NORMAL OPERATION

3.1.1 Nonradiological Impacts

The heat and chemical effluent systems at the Argonne National Laboratory and their present and potential effects have been described in Section 2.2.1. No important deleterious effects, either unitary or synergistic, have been observed or are anticipated. The only water intake other than onsite wells is from an artificial canal (the Chicago Sanitary Canal) that has very low water quality at present and hence little biotic potential. The planktonic or nektonic forms that are entrained are only a small fraction (about 1%) of those in the normal flow in the canal, and they are largely removed by the purification and treatment plant. The biomass involved is negligible. Similarly, the ambient-temperature, low-velocity (<1 cfs) discharge into Sawmill Creek^{1,2} has not had, nor is it anticipated to have, a deleterious impact on the creek or its biota.³⁻⁵ After consideration of the existing poor water quality of Sawmill Creek⁶ and the limited biota, it was concluded that the incremental increase in nonradiological impacts due to the operation of ANL will not significantly affect the aquatic ecosystem. Likewise, it is doubtful that any detectable influence from

the Laboratory's effluent will occur in the Des Plaines River, which receives the water from Sawmill Creek.^{6,7}

3.1.2 Radiological Impact on Biota other than Man

3.1.2.1 Exposure Pathways

The pathways by which biota may receive radiation in the vicinity of the plant are shown in Figure 3.1. Radioactivity bioaccumulation factors used in the evaluation are shown in Table 3.1, which includes the various biotic and transfer chains up to man. Several recent reports⁸⁻¹⁰ have been concerned with radioactivity in the environment and pathways of transfer. These can be read for a more detailed explanation of the subjects treated below. Depending on the pathway being considered, terrestrial and aquatic organisms will receive either about the same radiation doses as man or somewhat greater doses. Although no guidelines have been established for acceptable limits for radiation exposure to species other than man, it is generally agreed that the limits established for humans are also conservative for these species.¹⁰⁻¹³ In treating dispersions and effects, equilibration between geosphere, hydrosphere, and atmosphere was considered (e.g., resuspension of terrestrial radioactivity, aqueous deposition of atmospheric radioactivity, etc.), as well as among the various trophic levels within the biosphere.

3.1.2.2 Radioactivity in the Environment

The quantities and species of radionuclides expected to be discharged

Fig. 3.1. Exposure Pathways to Biota Other Than Man.

Table 3.1. Freshwater Bioaccumulation Factors

Element	Fish	Invertebrates (pCi/kg organism per pCi/liter water)	Plants
C	4,550	9,100	4,550
Na	100	200	500
P	100,000	20,000	500,000
Sc	2	1,000	10,000
Cr	200	2,000	4,000
Mn	400	90,000	10,000
Fe	100	3,200	1,000
Co	50	200	200
Ni	100	100	50
Zn	2,000	10,000	20,000
Rb	2,000	1,000	1,000
Sr	30	100	500
Y	25	1,000	5,000
Zr	3	7	1,000
Nb	30,000	100	800
Mo	10	10	1,000
Tc	15	5	40
Ru	10	300	2,000
Rh	10	300	200
Ag	2	770	200
Sn	3,000	1,000	100
Sb	1	10	1,500
Te	400	150	100
I	15	5	40
Cs	2,000	100	500
Ba	4	200	500
La	25	1,000	5,000
Ce	1	1,000	4,000
Pr	25	1,000	5,000
Nd	25	1,000	5,000
Pm	25	1,000	5,000
Sm	25	1,000	5,000
Cu	25	1,000	5,000
Gd	25	1,000	5,000
W	1,200	10	1,200
Np	10	400	300
Pu	4	100	350
Am	25	1,000	5,000
Cm	25	1,000	5,000

From Report UCRL-50564, Rev. 1.

annually by the plant and the pathways of release were given in Section 2.2.1.4. For this plant, one environmental interface dominates the release of radioactivity, that of the liquid effluent of the sanitary flow with the peak concentration of airborne effluents. This occurs at the littoral of Sawmill Creek and represents the region of maximum dose to local biota. Doses to terrestrial biota due to gaseous effluents are quite similar to those calculated for man and arise from the same dispersion pathways and considerations. For this reason the dose computations for gaseous effluents are discussed in detail in Section 3.1.3.

3.1.2.3 Dose Rate Estimates

The annual radiation doses to both aquatic and terrestrial biota, including man, were estimated on the assumption of constant concentrations of radionuclides at a given point in both the water and air. Radiation dose has both internal and external components. External components originate from immersion in radioactive air and water and from exposure to radioactive sources on surfaces, in distant volumes of air and water, and in equipment. Internal exposures are a result of ingesting and inhaling radioactivity.

The results of dose analysis are shown in Table 3.2, which lists dose rates for biota in the vicinity of the plant. These include phytoplankton, zooplankton, benthic organisms, terrestrial and aquatic plants, and local and migrating birds and mammals. Other terrestrial organisms will receive doses intermediate between those of terrestrial plants and birds. Doses at the effluent outlet in Sawmill Creek are applicable only to aquatic

Table 3.2. Doses to Biota in the Vicinity
of the Plant

<i>Organism</i>	<i>Dose Rate, mrem/yr</i>	
	<i>Effluent</i>	<i>Littoral</i>
Aquatic plants	5.2×10^{-6}	2.1×10^{-8}
Aquatic invertebrates	1.0×10^{-4}	4.1×10^{-7}
Aquatic vertebrates	1.2×10^{-4}	4.5×10^{-7}
Terrestrial plants	-	0.07
Terrestrial invertebrates	-	0.13
Birds	-	2.6
Mammals	-	2.6

forms. The littoral adjacent to the effluent outlet has been chosen to represent the maximum doses to be expected on land or at the aquatic-terrestrial interface. Doses in all other terrestrial areas will be markedly lower than those given for this littoral. In each case, the doses given are those for the limiting species, i.e., the species that are critical for this particular area by reason of rarity, habitat, local importance, physiological, and behavioral parameters that would tend to maximize their dose, or placement in a trophic chain of importance to man.

Inspection of the table shows that these doses are, in fact, quite low for all of the biota in the area. At these dose levels, no deleterious effects are anticipated for any of the biota in the area,⁸⁻¹³ and no unfavorable impact is expected.

3.1.3 Radiological Impact on Man

3.1.3.1 Exposure Pathways

Routine operation of the plant will result in the release of small quantities of radionuclides to the environment. This evaluation provides dose estimates that can serve as a basis for a determination that releases to unrestricted areas will be well within the limits specified in 10 CFR 20 and/or ERDAM 0524. An estimate of the probable radionuclide releases from the plant was made based on experience and on an evaluation of the radioactive waste treatment systems. These releases have been discussed in Section 2.2.1.4. It is concluded that the waste treatment

systems proposed are quite acceptable, and that the resultant releases are as low as feasible at the present state-of-the-art.

Estimates were made of radiation doses to man at and beyond the controlling site boundary via the most significant pathways among those diagrammed in Figure 3.2. The calculations are based on conservative assumptions, such as the minimal dilution of effluent gases and radionuclides in the liquid discharge and the continuous use by man of the plant surroundings.

3.1.3.2 Liquid Effluents

Expected nuclide releases in the liquid effluent have been computed for the plant and are given in Section 2.2.1.4. It is concluded that the liquid radwaste treatment systems reduce liquid radioactive effluents to levels as low as presently feasible, judged on the basis of analysis and of operating experience at the Laboratory and other plants, and are, therefore, acceptable. Water is not used for potable, municipal, or agricultural purposes on the Des Plaines River. Thus, neither consumption of water nor irrigation of crops is a potentially significant exposure pathway to the population. Fishing, boating, and swimming do occur in the Des Plaines River, however, and represent potential exposure pathways.

Individual doses from consuming water, fish, or invertebrates taken in the vicinity of the discharge zone and from swimming, boating, and fishing are given in Table 3.3. Doses are given for the critical organ, i.e., for the organ or tissue that will receive the highest dose via the pathway involved.

Fig. 3.2. Exposure Pathways to Man.

Table 3.3. Annual Individual Doses from Liquid Effluents
in the Plant Discharge Zone

<i>Pathway</i>	<i>Critical Organ</i>	<i>Dose, mrem/yr</i>
Fish ingestion	Bone	9.1×10^{-3}
Invertebrate ingestion	Bone	2.1×10^{-3}
Swimming (100 hr/yr)	Total body	1.6×10^{-5}
Fishing and boating (500 hr/yr)	Total body	6.0×10^{-7}

3.1.3.3 Gaseous Effluents

Radioactive effluents released to the atmosphere from the plant constitute the greatest source of radiation exposure to the public. The estimates of the probable gaseous and particulate releases listed in Section 2.2.1.4 were used to evaluate potential doses. All dose calculations were performed using annual average site meteorological conditions and assuming that releases occur at a constant rate. Doses resulting from elevated and near-ground releases of radioactive gases have been calculated by considering immersion in those gases as well as radiation from the elevated plume delivered to the surface receptor, and resuspension of radioactivity deposited on the soil. The primary food pathways to man were also taken into consideration. These involve the consumption of unwashed, leafy vegetables and of meat and milk from animals that ingest radioactivity deposited onto grazing areas.

Doses due to gaseous effluents from all pathways are summarized in Table 3.4 for various points of interest in the area about the plant. Also included are the meteorological dispersion factors to those points. Present argon-41 and tritium releases from the CP-5 reactor are being reduced by a factor of about two by modifications going into effect in the last quarter of 1975. It is concluded that the air treatment systems will then reduce airborne radioactive effluents to levels as low as feasible at the present state-of-the-art, judged on the basis of analysis and of operating experience at the Laboratory and other plants, and are, therefore, acceptable.

Table 3.4. Maximum Annual Individual Dose due to Gaseous Effluents

<i>Location^a</i>	<i>Dispersion</i>	<i>Critical</i>	<i>mrem/yr</i>
Controlling site boundary (1500m NNE)	2.6×10^{-6}	Total Body	2.0
Nearest residence (1350m W)	8.0×10^{-7}	Total Body	0.43
Nearest community (2000m NE)	1.0×10^{-6}	Total Body	0.68
Nearest recreation (400m E)	4.0×10^{-7}	Total Body	0.31

^aRelative to the D-180 tower.

3.1.3.4 Direct Radiation

Direct Radiation from the Plant

Direct radiation arises chiefly from the ZGS, CP-5, and the Waste Storage Facility (see Section 2.4). The maximum probable exposure from these sources is ≤ 0.1 mrem/yr for the nearest residents and ≤ 0.5 mrem/yr for visitors to St. Patrick's Cemetery or other areas of close approach to the Laboratory's inner-perimeter fence.

Transportation of Radioactive Material

The transportation of radioactivity to the plant, of fabricated fuel to and from the plant, and of solid radioactive wastes from the plant to designated control sites constitutes a pathway of exposure for the transportation workers involved and for the general public. Most aspects of this pathway are covered in AEC Report WASH-1238 of December 1972, entitled "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants."

Using the same methodology and the estimated and predicted radioactive wastes discussed in Section 2.2.2.3, an evaluation of the environmental effects of transportation was made for the plant. This is presented in Table 3.5.

Table 3.5. Radiological Impact of Transportation of Radioactive
Wastes and Material Associated with Plant Operation

<i>Exposed Population</i>	<i>Persons Exposed</i>	<i>Dose, mrem/yr</i>	<i>Cumulative Dose, man-rem/yr</i>
Transport Workers	200	4	0.8
General Public Onlookers	1,100	0.03	0.03
Along route	600,000	0.0016	0.1

3.1.3.5 Summary of Doses

Cumulative populations and doses and annual average dose due to gaseous effluents calculated for selected annuli about the plant are listed in Table 3.6. Table 3.7 summarizes the annual doses to the population within 50 miles of the plant. Doses to biota are summarized in Table 3.2. With present reductions underway, these doses will be as low as feasible at the present state-of-the-art, and constitute a hazard to neither humans nor other members of the biosphere.

3.1.3.6 Health Effects

The health effects conversion factors used are taken from the BEIR Report¹⁴ as summarized by the EPA¹⁵ in order to be consistent with other Environmental Impact Statements. For cancer mortality a value of 200 cancer deaths per million man-rem of total body dose was used. For morbidity a value of 400 total cancer cases per one million man-rem total body was used. For genetic damage a value of 300 undesirable genetic effects per one million man-rem of total body dose was used. The total body was the only organ considered because the population doses attributable to ANL operations were completely dominated by tritium, argon, and direct radiation, all of which deliver the dose uniformly to the total body.

On the basis of these conversion factors the maximum potential health effects due to ANL operations were computed on the basis of a total population dose of 47 man-rem per year for all future years due to the doses

Table 3.6. Cumulative Populations and Doses, and Annual Average Dose due to Gaseous Effluents in Selected Annuli about the Plant

<i>Cumulative Radius, miles</i>	<i>Cumulative Population</i>	<i>Annual Cumulative Dose, man-rem</i>	<i>Average Annual Dose, mrem</i>
1	1.8×10^2	0.38	2.09
2	1.9×10^3	1.3	0.68
3	1.0×10^4	3.2	0.32
4	2.7×10^4	5.3	0.20
5	5.1×10^4	6.9	0.14
10	3.3×10^5	14.8	0.05
20	3.5×10^6	38.7	0.01
30	6.6×10^6	46.1	0.005
40	7.3×10^6	46.7	0.005
50	7.8×10^6	46.9	0.005

Table 3.7. Summary of Annual Doses to the Population
within 50 Miles of the Plant

<i>Category</i>	<i>Cumulative Dose, man-rem/yr</i>
Population Dose from Background	949,000
Restricted Area	
Occupational radiation exposure	1,600
Unrestricted Area	
Transportation of fuel and wastes	0.93
Gaseous cloud	47
Ingestion	0.03
Recreation	0.00017

received in any one year. On this basis one would compute a total of 0.018 cancer cases, of which 0.009 would be deaths. Similarly one would compute 0.014 undesirable genetic effects. Since the number of health effects from ANL operations are all very much less than one, it may be concluded that they are exceedingly small, if, indeed, they are present at all.

It can be pointed out that even this hypothetical impact on health in the surrounding community is very probably an overestimate.¹⁶ The applicable radiobiological data were extensively reviewed in 1972 by the National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiations (NAS ACBEIR)¹⁴ and by the United Nations Scientific Committee on the Effects of Atomic Radiation (UN SCEAR).¹⁷

The NAS ACBEIR concluded as follows (see p. 89 of the Report):

"At this time, then, the linear hypothesis, which allows the mean tissue dose to be used as the appropriate measure of radiation exposure, provides the only workable approach to numerical estimation of the risk in a population. Further, since there is no means at present of determining the value of the dose-effect slope in the low-dose region of interest, use of the linear extrapolation from data obtained at high doses and dose rates may be justified on pragmatic grounds as a basis for risk estimation."

On the other hand, the UN SCEAR Report,¹⁷ on the basis of the same data, concluded that risk estimates for low-level irradiation should not be made by extrapolation of risk estimates determined at high doses and/or high dose rates. It states on p. 403:

"Estimates of risk per unit dose derived from epidemiological investigations are valid only for the doses at which they have been estimated... ."

It further states on p. 392:

"Another important consideration is the reduced effect of protracted irradiation as compared to an equal dose administered in a short period of time. While considerably more data are required, the animal data available indicate that both protracted continuous irradiation and fractionated irradiation produce less carcinogenic effect than a single administration of the same total dose, suggesting that such an effect might be expected to occur in man as well."

The National Council on Radiation Protection and Measurements (NCRP) has just completed a review¹⁸ of both documents and finds itself more closely aligned with the UN SCEAR position. It states on p. 1:

"Some of these differences are important, particularly the question of the use of the linear hypothesis in risk estimations at low radiation levels and the question of the use of

such risk estimates in setting radiation protection standards. On these two issues the NCRP differs with the NAS ACBEIR Committee Report and, where applicable, is more in agreement with the UN SCEAR Report."

It states specifically on p. 3:

"The NCRP continues to hold the view that risk estimates for radiogenic cancers at low doses and low dose rates derived on the basis of linear (proportional) extrapolation from the rising portions of the dose incidence curves at high doses and high dose rates, as described and discussed in subsequent sections of this report, cannot be expected to provide realistic estimates of the actual risks from low level, low-LET radiations, and have such a high probability of overestimating the actual risk as to be of only marginal value, if any, for purposes of realistic risk-benefit evaluation."

3.1.4 Impacts on Land Use

The general features, size and location of the Laboratory site were fixed in the late 1940's. The site originally occupied 3740 acres of what chiefly had been agricultural land, with one private estate and a few residences. Since the land was not highly productive as farmland, it was not under intensive agricultural use when the Laboratory took possession.

Prior to construction, the Laboratory successfully preserved many of the indigenous plants so as to maintain the more ecologically advantageous and desirable aspects of the site. The small amount of woodland cleared was far more than replaced by pine plantations, landscaping, and other forest management programs instituted by the Laboratory during and after the peak construction period. Planting of the station site with native species and with pine helped stabilize soils and prevent erosion during and after construction.

Construction of the site required the elimination or redirection of several previously dedicated streets and roads, but these were dirt or gravel and carried little traffic. Working directly, or indirectly through the county, the Laboratory has improved the road network in the area by installing all-weather roads and appropriate traffic lights and controls. It has not only improved access to the Laboratory itself, but to various picnic and recreation areas in and about the site.

No natural landmarks or sites of historical interest have been affected, nor would they be by additions to plant facilities within the present site perimeter.

The presence of the Laboratory precludes any alternative uses of the land for the period of operation. Possible alternative uses, if the Laboratory had not located on this site, are residential development, agriculture (although shown by past experience not to be highly productive) or industry (considering the advantageous proximity to rail, highway, and barge facilities). With respect to potential use for industry,

the Laboratory provides for much more open (undeveloped) land (much needed in DuPage County) than might be expected from industrial development. These alternative uses of the site at the conclusion of Laboratory activities would not be precluded by the present use.

3.1.5 Impacts on Water Use

Construction activities caused some changes in the runoff pattern at the site. Because the area affected was small compared with that used for other activities and even smaller compared with the total area of the site at the time of construction, it is questionable whether any significant changes, either beneficial or adverse, have occurred. In any case, no significant change as a result of construction activity was discernible. Some dewatering of the site occurred during construction, but no residuum of effect was observed during inspection.

Cooling water is obtained from the Chicago Sanitary and Ship Canal for some of the facilities on the site (see Sec. 2.2.1.2). The Canal is not a natural waterway and little or no permanent effect on the environment exists as a result of the withdrawal. The quantity of water withdrawn for Laboratory use represents less than 0.05% of the average flow in the Sanitary Canal and will have no effect on its downstream uses.

An amount of water in excess of that withdrawn from the Chicago Sanitary Canal is discharged from the Laboratory via Sawmill Creek to the Des Plaines River, which joins the Canal downstream from the Laboratory.

Thus, the Canal is replenished to an extent exceeding the Laboratory's withdrawal. The major part of the water discharge to Sawmill Creek is pumped from the wells on the site and represents slightly over one percent of the total groundwater pumpage in the county. The remainder of the discharge is runoff from the ponds.

Effects of these activities on streams, groundwater, navigation, flooding, fish and wildlife resources, water quality, water supply, and esthetics have not been found to be significant and no other uses of the water resources are precluded by Laboratory activities.

3.1.6 Effects on the Community

3.1.6.1 National Effects

The Argonne National Laboratory is considered to be a national resource¹⁹ and its operations have a worldwide impact. The development of the boiling-water and pressurized-water reactors for commercial and military uses, of the only operating breeder reactor in the U. S., of other experimental reactors and test facilities, of the Zero Gradient Synchrotron (ZGS), and of a high-energy density storage battery are some examples of Argonne activities that have provided a national (in some cases, worldwide) benefit.

The Laboratory has in the past devoted much of its efforts to solving problems of national scope and will continue to do so in the future; it is currently mounting a major effort to make meaningful contributions

to the country's general energy problem and has long been active in analyzing the environmental effects of energy generation. Many of the basic research studies carried on by Argonne scientists are of nationwide, indeed worldwide, importance since they add to the store of knowledge of mankind.

It is difficult to make a quantitative assessment of the national effects of the operation of ANL because the Laboratory has not been the sole contributor to the nationwide programs discussed above. It seems reasonable, nevertheless, to credit the Laboratory with a major role in the development of the nuclear energy program and of the naval reactor program. In the area of basic research, there is no doubt that the ZGS, which has attracted scholars from all over the world, has made a substantial contribution to our knowledge of the fundamental properties of matter. In sum, it appears to the staff that the operations of the Laboratory have resulted in a positive contribution to the welfare of the country, although by its very nature such a contribution is difficult to trace through all the ramifications of complex national programs.

3.1.6.2 Local Effects

The construction and installation of the facilities of the Laboratory, as is generally conceded of all major construction efforts, resulted in an appreciable economic benefit to the local area. The direct expenditures of the contractors and their personnel, as well as the induced effect of additional economic activity generated to provide for the wants of construction personnel, contributed to the well-being of the

local residents; and, in the case of installation of major equipment, such contributions undoubtedly extended to more distant areas.

The operations of the Laboratory have furnished gainful employment for many residents of the surrounding communities; its payroll annually contributes many millions of dollars to the economies of the nearby towns. In addition, it has attracted highly skilled personnel into the Chicago area, and retained such personnel who otherwise might have emigrated. These employees, who have established homes primarily in suburbs near the Laboratory, have become active, positive members of their communities. It is evident that the Laboratory has represented a center of stable and remunerative employment for professional, technical, and supportive personnel of the nearby towns and the Chicago metropolitan area. In summary, the Laboratory has provided an economic addition to the Chicago metropolitan area of the order of \$1.5 billion or more during its existence at the present site. The other local contributions of the Laboratory and its personnel cannot easily be monetized, but it would appear that such contributions are also strongly positive.

3.2 POTENTIAL EFFECTS OF ACCIDENTS

3.2.1 Site Accidents Involving Radioactivity

A high degree of protection against the occurrence of postulated accidents at the site is provided through correct design, manufacture, and operation, as well as through a highly developed quality-assurance and quality-evaluation program used to establish and maintain the necessary

high integrity of the systems used. Deviations that may occur are handled by protective systems designed to place and hold the affected system in a safe condition. Nonetheless, the conservative postulate is made that serious accidents might occur, even though they may be extremely unlikely, and even though engineered safety features are installed to mitigate the consequences of even those postulated accidents that are judged credible. In point of fact, no accidents with offsite consequences have occurred during the 28 years of the Laboratory's existence at the present site.

The probability of occurrence of accidents and the spectrum of consequences to be considered from an environmental protection standpoint have been analyzed using best estimates of probabilities and realistic release and transport assumptions. However, where doubt existed or information adequate to the task was unavailable, extremely conservative assumptions have been used for the purpose of computing doses and environmental impacts. Thus, the actual doses received by the population and environment from the accidents that are postulated would be significantly less than those presented in this evaluation. In addition, Laboratory operation is governed by an extensive and highly developed set of safety procedures. Off-design conditions are limited by automated protective systems and administrative procedures that operate to restore a safe condition.

One branch of the Laboratory maintains surveillance over the entire plant and its individual safety systems by conducting periodic examinations of each facility and of its records. Moreover, the Laboratory

conducts regularly scheduled tests of the plant instrumentation and protective systems, as well as safety-education programs and continuous, hands-on, daily inspection that covers all areas of the Laboratory within a period of about two weeks. The latter is conducted by one of the fire inspectors. He personally inspects all areas of the Laboratory, even the smallest and least used, on a continuous basis, detecting and reporting any off-design or potentially hazardous conditions. A constantly-patrolling security force conducts 24-hour surveillance of all buildings and facilities, and the Laboratory maintains a 24-hour plant services and maintenance crew equipped with the latest state-of-the-art electronic sensors and recording instruments to detect and report hazardous or potentially hazardous conditions in the equipment. A similar, but separate, system is employed by the 24-hour fire and emergency crew. A Laboratory-wide emergency report and action system is constantly in operation along redundant channels. It permits immediate and effective response to emergency situations. Part of this system is available to any person on the site simply by dialing 13 on any telephone. This immediately alerts all potentially concerned personnel so that appropriate equipment and personnel can be dispatched immediately to the site of the emergency, and control and restitution measures can be implemented on the spot.

Notwithstanding the above safeguards, the existence of relatively large quantities of radioactive nuclides at the site, representing the entire spectrum of radionuclides known, presents a risk of environmental impact from their accidental release. Accidents have occurred in facilities of the type represented by the Laboratory, but they have never resulted in injury to a member of the general public.²⁰⁻²⁴

Guidelines have been issued for consideration of accidents in NEPA reviews of nuclear production and utilization facilities.²⁵ Nine categories of postulated accidents, ranked in order of severity from trivial to very serious, have been identified. These nine categories are characterized by reactor hardware systems appropriate to large nuclear power reactors. In general, accidents in the high potential consequence end of the ranking have a low probability of occurrence. Guidelines have not been published for the consideration of accidents at facilities of the type being considered here. The potential accidents at the site^{21-24,26-40} fall into the following categories:

1. Trivial incidents, i.e., those not resulting in a release from the primary containments within the facility.
2. Small releases outside of primary containment.
3. Design-basis accidents.
4. Very remote, hypothetical accidents (equivalent to Reactor Class 9).

Trivial accidents would include power outage, water supply failure, steam supply failure, spills within hoods, glove boxes, and similar controlled containment, ventilation system failures, and single-barrier heat exchanger failure. Accidents resulting in small releases outside of primary containment would include minor tornado strikes ($\leq F1$, refer to Table 2.12), explosions, spills of radioactivity, double-barrier heat exchanger failure, fires, leaks of tankage and piping, and the like.

Design-basis accidents would include massive explosion, widespread facility fires, criticality accidents, major tornado strikes, transportation

accidents, ≤ 0.05 g earthquake, and local floods. Destructive earthquake (greater than 0.05 g), areawide flood, and sitewide uncontrolled fire are considered to be very remote hypothetical accidents equivalent to Reactor Class 9.

As a matter of course, the release of radioactivity in liquid effluents is prevented by the holdup of liquids in retention tanks. These effluents are monitored for radioactivity prior to release into the environment. The release of abnormal quantities of radioactive airborne effluents during normal operation is prevented by high efficiency particulate air (HEPA) filters and other treatment systems, and these are monitored. Therefore, an additional abnormal driving force, such as fire, explosion, criticality, or an "Act of God" is required for the release of abnormal quantities of radioactivity from the site.

Although administrative constraints on operation and automated protection systems are designed to reduce the frequency of accidents at the site, accidents that impact on the environment are presumed to be possible. Accordingly, an independent postulation and analysis of accidents is summarized in the following paragraphs.

In those cases in which a postulated accident results in a significant impact on the environment, the estimated magnitude of the release, the corresponding maximum individual dose at the site boundary, the total population dose, and the estimated probable frequency of occurrence are presented in Table 3.8. The probable frequencies are estimates based on the data available for failure prediction in these areas. Data and models

Table 3.8. Summary of Doses from Maximum Hypothetical Accidents

Accident	Release	Max. Individual Dose, Lifetime, rem	Population Dose, Lifetime, man-rem	Critical Organ	Probable Frequency, yr ⁻¹
Criticality	160 µg Pu-239, Soluble	7.6×10^{-5}	1.6	Bone	1×10^{-5}
	460 µg Pu-239, Insoluble	1.2×10^{-5}	0.24	Lung	
	Direct radiation	0.023	0.1	Whole body	
	2400 Ci of Br, Kr, I, and Xe	3.8	7.0×10^4	Thyroid	
Tornado	50 gm Soluble and solution	2.1×10^{-2}	2.0×10^3	Bone	2×10^{-7}
	90 gm Insoluble, fine powders	1.7×10^{-2}	1.6×10^3	Lung	
	5 gm gases; halogens, noble gases and volatiles	0.12	1.1×10^4	Thyroid	
	All materials	0.07	6.4×10^3	Whole body	

for the behavior of radioactivity in accident situations were taken from NRC Regulatory Guides, from AEC and NRC reports, and from the recent literature.^{21-24,26-50} During the quarter century that the Laboratory has been in operation, the frequency and severity of accidents have been markedly lower than they have been in related industrial operations. The experience gained from the few accidents that have occurred has resulted in improved engineering safety features and operating procedures, and the probability that similar accidents might occur in the future is very low. Based on analysis, it is believed that even if design-basis accidents did occur, there would probably not be a significant release of contamination offsite, and radiological exposures would be too small to cause any observable effect on the environment or any deleterious effect on the health of the human population.

3.2.1.1 Trivial Incidents

A number of minor incidents are due to human, utility, or equipment failure. These are representative of the type of high-probability low-consequence accidents that occur frequently in any industrial operation. Examples include power outages; ventilation system failures; failures of water and steam supplies; electrical equipment fires; solvent and other flammable-material fires in hoods and glove boxes; trash fires; leakage and rupture of tanks and piping; minor chemical explosions; breaching or compromise of protective clothing, shields, and safety devices; drops and spills attendant on movement and transportation; temporary loss and/or misuse of radioactive materials and sources; etc. From the analyses of the Laboratory's accident and safety record and of the systems employed

at various facilities for the prevention and control of accidents, it has been concluded that the consequences of this class of accidents are essentially those of normal operation. Thus, they have already been included in the releases given in Section 2.2, and the consequences treated in Section 3.1.

3.2.1.2 Incidents Yielding Releases from Primary Containmentment

Because of their relative frequency, accidents of this type have been classified as operational occurrences. They, as well as the trivial incidents discussed above, were accordingly included in the evaluation of anticipated annual releases in Section 2.2 and of environmental impacts in Section 3.1. The incidents are trivial because they do not result in the release of radioactivity beyond the scope and the ability of the applicable radiation waste treatment systems to contain them. However, if increased in severity, any one of them has the potential for compromising the radiation waste treatment and control systems. Then the release is said to have gone beyond the primary containment on which radiation waste, treatment, and control systems are based. For example, a fire involving 25 ml of a flammable solvent inside one of the radioactivity laboratory hoods would not result in release beyond primary containment. It would not be sufficient in magnitude to breach or compromise filters, ventilation systems, the face of the hood, etc. On the other hand, a fire and explosion in the same hood involving several liters of highly flammable solvent would destroy the primary HEPA filter, probably crack the protective glass face, breach the seams of the hood, and render the ventilation system ineffective. In such a case, release

beyond primary containment would have occurred and potential release to the environment would be involved.

In general, accidents of this class will result in release of radioactivity into work spaces and, potentially, to the environs. Such releases will almost invariably result in subsequent decontamination efforts, and these very efforts may in themselves result in small additional releases.

Any one of the accidents or incidents mentioned in Section 3.2.1.1, when increased in severity, moves into this second class of accidents. In addition, by their very nature there are a number of accidents that result in release from primary containment. Among these may be included the failure of radiation waste treatment systems, the breaching or other compromise of HEPA filters, and any condition that results in compromise of the walls of the primary containment. The last event can occur in any of a number of ways: walls, gloves, seals, ducting, protective shields, hood faces, and the like can be compromised by massive fire or explosions; regions that are maintained under negative pressure for the containment of radioactivity (such as glove boxes, slot boxes, hoods, furnaces, reactor areas, etc.) can be compromised by pressurization; transfers between primary containment areas can be compromised by leaks, spillovers, and collisions; radioactive waste that has been contained for disposal via trash bag-outs, waste drums, holdup tanks, and solidification tanks can be compromised by any form of mechanical breach.

Each of these occurrences has the same end result. Some radioactivity

is released to the air of the work spaces outside of primary containment so that the primary radiation waste treatment and control systems are bypassed, blown out, or otherwise compromised. Radioactivity in the air can then proceed outward to the environment. Radioactivity is also released to surfaces and water within the facility but outside the primary containment. This is eventually washed down into the onsite sumps, drains, and decontamination tanks. Nonetheless, some of it may be expected to be tracked out by personnel or to enter solid and liquid waste streams that reach the environment directly. Review and analysis of the incidents of this type, which have occurred over the years in AEC and ERDA facilities and in commercial operations and encompass something over 10^5 reports,²⁰⁻²⁴ show that any one of them has a probable frequency of 10^{-1} to 10^{-5} per year. However, all of them taken together have a probable frequency at the Laboratory site of about three per year.

3.2.1.3 Design-Basis Accidents

The following accidents are considered to be of such low probability that it is very unlikely any will occur during the lifetime of the Laboratory. However, they are of considerably greater consequence to the environment than the incidents previously discussed. Each involves a major release of radioactivity from secondary containment, i.e., from buildings, facilities, and work spaces out into the surrounding environment. The Laboratory reactors CP-5, JANUS, and ZPR 6/9 are covered by their own Safety Analysis Reports. They are not included here because the environmental consequences of the accidents treated therein are less than those given below.

Criticality

In a quarter century and some 500 plant-years of experience in the U. S., there have been four major criticality accidents. Two of these occurred in plutonium scrap recovery operations and two in highly enriched uranium operations, the last one on 1964.^{20-24,27,28,33,36} The magnitude of the criticality accidents occurring to date has ranged from 1.3×10^{17} to 4×10^{19} fissions, and in no case has the release been of an explosive nature. The principal method of criticality control for Argonne operations is by mass controls, spacing controls, and the application of the double contingency principle. This principle requires at least two unlikely, independent, and concurrent failures before a nuclear incident is possible.

In view of the multi-level, independent review applied to procedures involving the possibility of criticality, the onsite presence of criticality officers and a criticality committee, the design of the various facilities to incorporate the latest criticality prevention methods, and the fact that at least two independent failures would be needed to permit criticality even in the aqueous plutonium systems on the site, criticality is regarded as nearly incredible. An estimated frequency of occurrence of 10^{-5} per year is considered to be conservative, given the elaborate safeguards employed at the Laboratory. A reasonable limit on the number of fissions in such an incident at the Laboratory is 10^{19} . On this basis, the consequences of a criticality accident are given in Table 3.8. A transit time of 500 seconds for airborne radioactivity to reach the site boundary, 50% retention of halogen gases within the plant

by plateout, and breaching or compromising of any HEPA filters in the system were assumed.

Earthquake

The Laboratory lies within an area classified as Zone 1 on a Seismic Risk Map of the United States. This represents a region of low seismic risk, corresponding to intensities of V and VI on the Modified Mercalli Scale. Intensity VI is the level at which damage is not likely to be widespread and is only moderate even in poorly built or badly designed structures. Intensity V to VI corresponds to an acceleration of about 0.02 g. Because all sensitive buildings at the Laboratory are stressed for accelerations of considerably greater than this value (up to 0.05 g), an abnormal release of radioactivity as a result of an earthquake producing even the design maximum ground acceleration is considered to be highly unlikely. In any case, an analysis showed the consequences of such an earthquake to be considerably less than that of the "tornado" given in Table 3.8. Accordingly, the consequences of such an earthquake have not been analyzed further.

Tornado

Most structures at the Laboratory are not built to withstand the design-basis tornado given for nuclear facilities in this area.^{41,51} Thus, a discussion of the probability and consequences of a tornado strike is appropriate. In addition to the probabilities given in Section 2.3.6.3, a recent study of tornado probabilities in this area was made for the

Laboratory.⁵² This study is used as the basis for assessment of tornado accident probability.

The Laboratory has a well-developed tornado warning system, and an administrative and operating system designed to secure the bulk of radioactivity shortly after receipt of a warning of pending severe weather conditions. In addition, methods of handling and storing hazardous materials result in only small quantities of such materials outside of containment at any given time. Thus, less than 1% of the material inventory is in an exposed condition, even under normal circumstances. As a consequence the effects of a tornado would differ little whether or not a warning were received. The "no-warning" case is treated here because it represents the upper bound for this type of accident.

Tornadoes in this area of Illinois approach almost exclusively from the west or southwest.^{40,53} Since winds from these directions would disperse debris over areas of maximum population, they are taken as the basis of the accident scenario. A tornado of rating 555 on the Fujita-Pearson-Pearson Scale (FPP = 555)^{42-48,51,54} is taken as the force and distance basis because it represents the maximum tornado currently envisioned as a design basis for nuclear facilities in this area,^{41,51} even though it is not the maximum tornado that might be conceived.⁵⁵

The force of a 555 tornado is such that it could breach the walls and ceilings of the majority of the buildings at the Laboratory, but not the containment structures of the ZPR, JANUS, or CP-5 reactors.⁵⁶ CP-5 may be damaged to the extent of allowing leakage of radioactive materials,

as will some of the vaults and containment facilities. However, none of the vaults and containment facilities will suffer wholesale losses of their radioactive inventories. The length and width of a 555 tornado are such that more than one building may be expected to suffer the full brunt of the same tornado.

The scenario used for analysis assumes the tornado passes onto the Laboratory site, through Buildings 316 and 330, then over the 200 area, and out onto Cass Avenue and I-55, lifting up near the intersection. The radioactive material lifted is assumed to consist of: insoluble powders (chiefly UO_2 and PuO_2); solutions and soluble salts (chiefly U and Pu nitrates, with some fission and activation products, and some Ra and transuranium salts); and noble gases and halogens (chiefly I-131 through 135, from the rupture of fuel elements). The fission product spectrum is taken to be that of CP-5 fuel elements at limiting burnup, and the transuranic element spectrum to be that of a U-235/238 fuel at 10 gigawatt-day/tonne burnup.²⁸ Only a fraction of the insoluble material lifted is taken to be in the respirable range, but it is the total activity of this fraction that is given in Table 3.8.

Three tornado dispersion models are used in the analysis,⁵⁶⁻⁵⁸ along with support programs for non-tornadic dispersion and dose determinations.⁵⁹⁻⁶² However, only one of these models⁵⁷ is used in making the estimates given in Table 3.8, since this model seems to be the most realistic. Even this model appears to be extremely conservative, and actual doses may be expected to be distinctly lower than those shown in Table 3.8.

The consequences of even the most serious accident are well within the guidelines suggested by 10 CFR 100, AECM 6301, or AECM App. 0550, i.e., 25 rems whole body, 150 rems bone, 300 rems thyroid, and 75 rems for all other organs. The lifetime population dose commitment from such an accident is less than that received by the same population from background radiation.

3.2.2 Other Accidents

3.2.2.1 Transportation Accidents

Radioactive materials shipped to and from the Laboratory are contained in packing that is licensed by NRC and approved by DOT. These packages are required to withstand, without loss of contents, significant loss of shielding, or the occurrence of criticality, the following test conditions:

- (1) A 30-foot drop onto an essentially unyielding surface and in the most damaging orientation, followed by:
- (2) A puncture test, consisting of a drop from a height of 40 inches onto a 6-inch diameter steel rod, striking the container in its most vulnerable spot, followed by:
- (3) A half-hour fire test at 1475°F, followed by:
- (4) Submersion in water to a depth of at least three feet for at least eight hours.

The above specifications apply to containers used for materials considered

to be of a high to moderate degree of hazard. Small quantities of radionuclides, generally in some specifically synthesized chemical form, are also received by the Laboratory from commercial suppliers and other ERDA facilities. These are packaged in such a way that the hazards involved are protected by a set of probability-consequence considerations similar to those employed above. However, the amounts and types of radionuclides are so much lower on the hazard scale that the actual criteria and specifications used are somewhat different. Similarly, small quantities of radionuclides produced by irradiation at the Laboratory are shipped out in containers and by methods of the same kinds. In every case, the probability-hazard considerations are maintained such that the assurances given by the above-described specifications apply even to the much smaller shipments containing much less hazardous quantities of radioactivity.

A recent report by the AEC⁶³ discusses the probabilities of transportation accidents of various degrees of severity, ranging from minor to extreme. These probabilities range from 1.3×10^{-6} per vehicle-mile for minor accidents to 2×10^{-14} per vehicle-mile for extreme accidents. For transport distances of up to 3000 miles and 150 shipments per year, the probable frequencies of occurrence of accidents involving radioactivity are 5×10^{-2} per year for minor accidents and 8×10^{-9} per year for extreme accidents.

Based on regulatory standards and requirements for package design and quality assurance, the extremely well-developed quality-assurance and quality-evaluation programs at the Laboratory, and the results of tests and past experience, the packages involved are likely to withstand all

but the most extraordinary and severe accidents. The probability of a package being breached is low, so low that detailed consideration is not required in this analysis. Although the consequences of release might be serious, the probability of occurrence is small and, therefore, the risk of impact on the environment is extremely small. Even so, it has been estimated that the maximum release and consequence would be less than 1% of that given for "tornado".

An estimated 100 shipments of low-level wastes may be made each year from the site. At an average one-way transport distance of 1500 miles, the probable frequency of occurrence of a minor accident is 0.02 per year, and of an extreme accident, 3×10^{-10} per year. These probable frequencies are about those given above for shipments of highly radioactive materials but involve less than 1% as much radioactivity, so the risk of radioactivity release is correspondingly smaller. Taken altogether, considering both the low probability of occurrence and the small quantities of dispersible radioactivity involved, the risk to, or impact on, the environment from transportation accidents was considered to be too low to justify further detailed analysis. However, it is estimated that at worst, release to the environment would be less than 1% of the annual release postulated for normal operation of the Laboratory.

3.2.2.2 Nonradiological Accidents

The potential environmental effects of nonradiological accidents at the site is very limited. The only chemical used at the site in sufficient quantity to seriously impact the environment is chlorine, and this is

stored in separate cylinders (≤ 1 ton) that are in facilities of their own. It is possible that chlorine lines and tanks could be ruptured, but the release rate would then be limited to less than 1000 grams of chlorine per second. Using dispersion factors appropriate for accident conditions, the maximum offsite concentration would be of the order of 0.01 g/m^3 . This is above the threshold limit value appropriate for continuous exposure, but is below short-term concentrations that produce incapacitating eye, nose, and throat irritation, and is below the short-term concentration that would act as an asphyxiant. The maximum offsite concentration is above the minimum concentration that produces a detectable odor, but because of the intervening forest and vegetation, such a chlorine release might not even be noticed by offsite residents and would cause no serious discomfort and no health damage offsite. Extensive sodium fire or rupture of cylinders containing toxic gases and liquids was also considered. However, on analysis these proved to result in even smaller impact than the chlorine release. Laboratory emergency-response plans for such accidents may be consulted for more details.

3.2.2.3 Acts of God

Several conceptual occurrences were analyzed, but were rejected for detailed presentation because of their extreme improbability, e.g., less than 10^{-8} per year. As has already been noted, the Laboratory lies within a region of low seismic risk in the United States. Thus, an earthquake of magnitude greater than 0.05 g acceleration at sensitive facilities was considered to be highly improbable. Similarly, all of the Laboratory facilities containing radioactive materials lie more

than 100 feet above the maximum 100-year flood level of the Illinois Waterway (combination of the Illinois-Michigan Canal, Chicago Sanitary and Ship Canal, and the Des Plaines River). These facilities are also well above the maximum credible flood stages of the small creeks and streams flowing through the site. An uncontrolled fire of the sort that would rupture and breach any combination of facilities containing substantial amounts of radioactive materials was also considered to be highly unlikely, and would require something in the nature of a total forest fire at the Laboratory site. In any case, detailed analyses of these occurrences showed that each had lower consequences than those of the "no-warning" tornado given in Table 3.8. Given sufficient time,⁶⁴ one might imagine that an Act of God more severe than the "no-warning" tornado might occur. That one might actually occur within the foreseeable lifetime of the Laboratory was considered to be incredible. In any case, the FPP = 555 tornado utilized in the analysis is such an extraordinary Act of God that it is labeled "incredible" by the originator of the scale.⁶⁵

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4. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

4.1 LAND

The primary impact on the land as a result of the presence and operation of the Laboratory is the diversion of the site (1700 acres of mixed woodlands and old fields) from any usage but that of a large research installation and its surroundings. About 200 acres of the site are under concrete, buildings, roadways, and parking lots. Construction of additional buildings and support facilities would cause disturbance of the established terrestrial biotic communities in the small areas directly affected; however, appropriate controls and proper construction methods would minimize other impacts of construction activities.

4.2 WATER

Currently about one million gpd of water are withdrawn from the Chicago Sanitary and Ship Canal for use in cooling systems. About 800,000 gpd of domestic-quality water are withdrawn from onsite wells. Water use from both sources is small compared with the total amounts available.

Of the 1.8 million gpd withdrawn, about 0.07 million gpd are lost by evaporation under conditions of peak summer heat load. The remainder is discharged to the Des Plaines River via Sawmill Creek. Without excep-

tion, sewage treatment and other clean-up systems now keep average concentrations of chemicals in water discharged to the Des Plaines River within State and Federal standards.¹

Radioactive nuclides are released to the waters of Sawmill Creek; concentrations have been two to three orders of magnitude below the limits for uncontrolled areas specified in 10 CFR 20 or ERDAM 0524.

4.3 ATMOSPHERE

Nonradioactive gases and particulates are discharged to the atmosphere, primarily from fossil-fueled boilers, at concentrations below State and Federal standards or guidelines (see Table 2.6). Release of radioactive gases to the atmosphere results in a total body dose of about 4 mrem/yr at the site boundary.

4.4 RADIOLOGICAL EFFECTS

The total cumulative dose from all radioactive materials released to the environment due to Laboratory operations is about 47 man-rem/yr for population within a 50-mile radius of the site. By comparison, an annual total of about 950,000 man-rem is delivered to the same population as a result of the natural radiation background. Trivial incidents due to human, utility, or equipment failure involving radioactive materials have the potential for escalating in severity to the point where releases

to the environment are possible. The dose rate given above includes an estimate of the contribution that might be realized from such occurrences.

The potential exposure of the population to radioactive materials released as a result of severe accidents or natural disasters has been computed to be well within the guidelines established in 10 CFR 100. The lifetime population dose commitment from the most severe (and lowest occurrence probability) accident is about 0.1% of that from background radiation.

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5. RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Most of the changes made to the ANL site in the past, or to be made in the foreseeable future, are slight. Long-term effects will occur in the small fraction of the site where massive concrete buildings or other facilities have been erected. To restore this land completely to its original condition would entail no insurmountable physical obstacles and would be feasible with current technology, but the decision to do so will necessarily depend on economics, principally prevailing land values.

The fact that a large portion of the site remains in its pristine condition should serve to enhance both short-term and long-term productivities. The unused portion is a valuable reservoir of open space and natural habitat. The ANL site serves to reduce population density in the region, and its unused part permits unobstructed flow of precipitation into the ground and provides a large area of natural habitat serving as sanctuary for many forms of wildlife. Another important consideration with regard to enhancement of long-term productivity is the effort by ANL to limit the use of pesticides on the site.

In short, on both short-term and long-term bases, ANL enhances the use and productivity of certain aspects of man's environment, and does not prevent the maintenance and enhancement of long-term productivity.

6. RELATIONSHIP OF CONTINUED OPERATION TO LAND USE PLANS, POLICIES, AND CONTROLS

Since initiation of construction of the site, land use patterns in proximity to the Laboratory have changed relatively little compared with changes in other portions of the Chicago area. The site was selected to be accessible to its parent institution, the University of Chicago, but still somewhat distant from the city itself. At the same time, the site is close to major railroads and railroad spurs, to a major highway, to the State's largest transmission lines and a nearby electric power generating station, and to the local Chicago Sanitary and Ship Canal for potential barge transportation of very heavy objects.

The site provides easy access to the major airports of the Chicago area, accessibility to at least one major commuting railroad, and to a considerable number of desirable suburban communities. It is located immediately between the labor markets of the City of Chicago and of the towns of Lemont, Lockport, and the City of Joliet, and on a tract of land that was itself not conspicuously attractive either for housing or for agricultural use. Furthermore, the site is well supplied with groundwater of excellent quality, with both deep and shallow aquifers, with excellent run-off characteristics and protection from flooding, and with cooling water available from an artificial waterway where such use could not impact an ecosystem.

The major change in land use in the vicinity of the Laboratory has been caused by the construction of Interstate Route 55, which passes just north of the site and replaces the older U. S. Route 66. The emplacement during the mid-1960's of this major traffic artery is primarily responsible for the development of industrial parks and residential communities along its corridor; prior to these developments, the land was largely used for agricultural purposes. The presence of the Laboratory may have contributed on a small scale in that some of its employees live in the residential communities; however, the largest segment of the Laboratory personnel had already obtained housing in older, established communities farther from the Laboratory.

The continued operation of the Argonne National Laboratory would not be in violation of any known land use plans, policies, or controls. At the time of construction, there was no comprehensive plan for land use in DuPage County, nor does the county have such a plan at present. In the interim, the Northeastern Illinois Planning Commission (NIPC) was created by an act of the Illinois General Assembly in 1957 to help promote orderly growth in the region comprising the counties of Cook, DuPage, Kane, Lake, McHenry, and Will. These six counties encompass an area of about 3700 square miles and had a population of seven million in 1970 (expected to reach nine million by 1995). The NIPC has no regulatory or enforcement power and its regional planning deals with general development policies, not specific local land use details (these are construed to be part of county and municipal planning).

Currently the main thrust of the NIPC's land planning is the preservation of existing open spaces and the acquisition and development of more open lands. (The region now has 17.8 acres of open land per 1000 population, including golf courses, compared with the recommended standard of 35 acres per 1000 residents.)¹ The Argonne site, which is largely open land, is in harmony with the NIPC planning, and the donation of 2040 acres of the site to the DuPage County Forest Preserve District was largely instrumental in increasing that district's preserves from 4253 acres in 1968 to the current 7616 acres.² The Forest Preserve District intends to maintain the preserve surrounding Argonne (known as the Waterfall Glen Forest Preserve) in a natural state, but anticipates a usage rate (for "interpretive inspection," picnicking, hiking, horseback riding, etc.) of about 400,000 visitors per year during the period five to ten years from the present. Some of the District's plans for the use of the preserve are indicated in Figure 2.6.

From an examination of the available land use plans for the sections of Cook, DuPage, and Will counties in the vicinity of the Argonne National Laboratory it is concluded that continued operation of the Laboratory is not in conflict with these plans and, furthermore, is harmonious with the NIPC's furtherance of more open lands, since continued operation insures that these 3740 acres will endure as largely open land.

References

1. "Preliminary Plan for the Preservation and Development of Open Space in Northeastern Illinois," Northeastern Illinois Planning Commission, March 1969.
2. "Suburban Factbook, 1973," Northeastern Illinois Planning Commission, April 1973.

7. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Irreversible commitments generally concern changes initiated by the proposed action that at some later time could not be altered so as to restore the present order of environmental resources. Generally, irretrievable commitments are the use or consumption of resources that are neither renewable nor recoverable for subsequent use.

7.1. COMMITMENTS CONSIDERED

The types of resources of concern in this case can be identified as:

(1) material resources (materials of construction, renewable resources material consumed in operation, and depletable resources consumed) and (2) nonmaterial resources, including a range of beneficial uses of the environment.

Resources that, generally, may be irreversibly committed are: (1) biota destroyed in the vicinity; (2) construction material that cannot be recovered and recycled with present technology; (3) materials that are rendered radioactive and cannot be decontaminated; (4) materials consumed or reduced to unrecoverable forms of waste; (5) the atmosphere and water

bodies used for disposal of heat and certain waste effluents, to the extent that other beneficial uses are curtailed; and (6) land areas removed from previous uses.

7.2 BIOTIC RESOURCES

Construction of the Laboratory buildings and associated facilities resulted in habitat alterations that caused displacement and/or loss of biota from about 1275 acres; agricultural products that would have been harvested on the site during the operating life of the Laboratory were also lost.

7.3 MATERIAL RESOURCES

Construction materials are almost entirely of the depletable category of resources. Concrete and steel constitute the bulk of these materials, but there are numerous other mineral resources incorporated in the physical plant. No commitments have been made as to whether these materials will be recycled when their present use terminates.

Some materials are of such value that economics clearly favors recycling. Laboratory operation will contaminate only a portion of the equipment to such a degree that radioactive decontamination would be needed in order to reclaim and recycle the constituents. Some parts of the reactor facilities will become radioactive by neutron activation. Radiation

shielding around each reactor and other components inside the shielding constitute the major materials in this category for which it is not feasible to separate the activation products from the base materials. Components that come in contact with reactor coolants or with radioactive wastes will sustain varying degrees of surface contamination, some of which could be removed if recycling is desired. The quantities of materials that could not be decontaminated for unlimited recycling represent very small fractions of the resources available in kind and in broad use in industry.

Construction materials are generally expected to remain in use for the full life of the facilities. There will be a long period of time before terminal disposition must be decided. At that time, quantities of materials in the categories of precious metals, strategic and critical materials, or resources having small natural reserves must be considered individually, and plans to recover and recycle as much of these valuable depletable resources as is practicable will depend on need.

7.4 CONSUMABLE MATERIALS

The principal irretrievable natural resources consumed in Laboratory operation are the fossil or nuclear fuels required to provide the heat and electricity demands of the facilities. The consumption of electricity (30 MW), natural gas, and miscellaneous fuels is a small fraction of the total supply to the Chicago area. This fact does not minimize the

importance of continuing attention to conservation of these depletable resources, as is presently practiced at the Laboratory.

Other resources consumed in operating Laboratory facilities and conducting experiments are various chemicals, biologicals, office supplies, and related materials generally in good supply and in broad use in industry or research. Except for the very small consumption of uranium-235 in the operating reactors, nuclear materials used in laboratory experiments are recovered within the practical limits of the chemical recovery processes, and therefore not consumed.

7.5 LAND RESOURCES

Land areas that were removed from previous use total about 1700 acres. Except for areas occupied by roads and structures, which are situated on about 200 acres of the site, this land could easily be converted to other uses when the structures are no longer needed by the Laboratory, and the 200 acres could also be cleared if future usage of these particular land areas were to justify the cost.

7.6 WATER AND AIR RESOURCES

The releases of chemicals, heat, and radioactive materials and the consequences of these releases are discussed in Section 3. Since only small quantities of these waste materials are discharged, other beneficial

uses of the air and water resources receiving the releases are not precluded.