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THE IDAHO NATIONAL ENGINEERING LABORATORY SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1990

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PREFACE[a]

Every person living in the United States (or the world) is exposed to sources of ionizing radiation—radiant energy that produces ions as it passes through cells. There are three general types of radiation sources: those of natural origin unaffected by human activities, those of natural origin but enhanced by human activities, and those produced by human activities (manmade).

The first group includes terrestrial radiation from natural radiation sources in the ground, cosmic radiation from outer space, and radiation from radionuclides naturally present in the body. Exposures to natural sources may vary depending upon the geographical location and even the altitude at which a person resides. When such exposures are substantially higher than the average, they are considered to be elevated.

The second group includes a variety of natural sources that have been increased by human action. For example, radon exposures in a given home may be elevated because of natural radionuclides in the soil and rock on which the house is built; however, the radon exposures of occupants may be enhanced by characteristics of the home, such as extensive insulation and weatherizing. Another example is the increased exposure to cosmic radiation that airplane passengers receive when traveling at high altitudes.

The third group includes a variety of exposures from manmade materials and devices such as x-rays in medicine, radiopharmaceuticals in the diagnosis and treatment of disease, and consumer products containing minute quantities of radioactive materials. Exposures may also result from radioactive fallout from nuclear weapons testing, accidents at nuclear power plants, and other such episodic events caused by man's activities in the nuclear industry. Except for major nuclear accidents, such as the one that occurred at Chernobyl, exposures to workers and members of the public from activities at nuclear industries are very small compared to exposures from natural sources.

To verify that exposures resulting from operations at the Department of Energy (DOE) nuclear facilities have remained very small, each site at which nuclear activities are underway operates an environmental surveillance program to monitor the air, water, and any other pathway where radionuclides from operations might conceivably reach workers or members of the public. The monitoring results are reported annually to the DOE–Headquarters (DOE–HQ) Environmental Compliance Division. This report presents data collected in 1989 for the routine environmental surveillance program conducted by the Radiological and Environmental Sciences Laboratory (RESL) of DOE and the U.S. Geological Survey (USGS) at the Idaho National Engineering Laboratory (INEL) Site. The report is prepared in accordance with the requirements in DOE Order 5400.1 and is not intended to cover the numerous special environmental research programs being conducted at the INEL by RESL and others.

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a. Introductory information is paraphrased from the National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 93, September 1, 1987, p. 1.

EXECUTIVE SUMMARY OF THE ENVIRONMENTAL SURVEILLANCE PROGRAM

The results of the various monitoring programs for 1990 indicate that most radioactivity from the Idaho National Engineering Laboratory (INEL) operations could not be distinguished from worldwide fallout and natural radioactivity in the region surrounding the INEL Site. Although some radioactive materials were discharged during Site operations, concentrations and doses to the surrounding population were of no health consequence and were far less than State of Idaho and Federal health protection guidelines. The first section of the report summarizes Calendar Year 1990 and January 1 through April 1, 1991, INEL activities related to compliance with environmental regulations and laws. The balance of the report describes the surveillance program, the collection of foodstuffs at the INEL boundary and distant offsite locations, and the collection of air and water samples at onsite locations and offsite boundary and distant locations. The report also compares and evaluates the sample results and discusses implications, if any. Nonradioactive and radioactive effluent monitoring at the Site, and the U.S. Geological Survey (USGS) ground-water monitoring program are also summarized.

Gross beta measurements, which are used as a screening technique for air sampler filters, were investigated by making statistical comparisons between onsite or boundary location concentrations and the distant community group concentrations. In none of those comparisons in which a statistical difference existed (4% of the total number of comparisons made) was there any evidence that gross beta concentrations increased due to INEL operations. Gross beta concentrations also show trends for natural and man-made radionuclides.

Air samples were also analyzed for specific radionuclides. Some radionuclides were detected at offsite locations, but their presence was attributable to natural sources, worldwide fallout, or statistical variations in the analyses rather than to Site operations. The annual concentrations of all specific nuclides detected at all locations were well below the derived concentration guides for radiation protection. The presence of Am-241 and Pu-239/240 at onsite locations was probably due to windblown resuspension of slightly contaminated soil at the facilities where the nuclides were detected.

Concentrations of tritium in air samples were seen in half the total number of samples, but were highest at the distant, offsite location in Idaho Falls. Examination of the geographical distribution and Site operations information provided no evidence that these concentrations were related to Site activities.

However, during December 1990, low concentrations of tritium were found in precipitation samples onsite. The presence of tritium in these samples may be due to Site activities because no tritium was detected in rain samples from Idaho Falls or a snow sample from Monida Pass. (See "Tritium" in the Environmental Radiological Program Information section.)

Approximately 29% of all drinking water samples collected during 1990 contained detectable concentrations of gross alpha activity and about 15% contained detectable gross beta activity. All concentrations were near the minimum detectable concentration. Both gross alpha and gross beta concentrations were probably due to natural radioactivity or to statistical variation in the analyses. Annual averages for all onsite and offsite drinking water samples were below the Environmental Protection Agency (EPA) maximum contaminant level for community drinking water systems. No offsite water samples contained detectable tritium concentrations. Five onsite production (drinking water) wells contained measurable concentrations of tritium. An effective dose equivalent of 0.77 mrem/yr was estimated for INEL workers at CFA, the location with the highest tritium concentration in drinking water. Concentrations of volatile organic compounds measured in production wells at TAN in 1987, which were slightly above the EPA maximum contaminant levels (MCLs), have been in compliance with the MCLs through 1990 after appropriate remedial action was taken.

None of the milk samples contained detectable concentrations of I-131, Sr-90, or tritium. Some wheat and lettuce samples contained small amounts of Sr-90. The presence of Sr-90 in food samples is probably due to its deposition on soil as a result of worldwide fallout. A low concentration of Cs-137 was found in muscle tissue of one sheep that had grazed onsite and was consistent with the concentrations from control sheep sampled in earlier years.

Concentrations of radionuclides in offsite soil samples in 1990 were within the ranges recorded at each location in past years. The reported concentrations in boundary and distant location samples were consistent with levels expected from worldwide fallout.

Ionizing radiation measured simultaneously at the Site boundary and distant locations showed only natural background levels.

For details on monitoring results, see the appropriate sections that summarize results of radioactive, nonradioactive, and ground–water monitoring and surveillance programs.

A measurable amount of radioactivity, primarily in the form of noble gases and tritium, is released into the atmosphere annually from various plant facilities and is subsequently carried offsite. Upon reaching the Site boundary, this radioactivity is in such a low concentration that its effect on direct radiation levels cannot be measured; but its potential contribution to offsite dose equivalents is nevertheless calculated.

The hypothetical maximum individual effective dose equivalent was found to occur near Atomic City and was calculated to be 0.006 mrem (6×10^{-5} mSv) using the MESODIF air dispersion model. The calculation considered continuous submersion in and inhalation of radioactivity in air, ingestion of radioactivity in leafy vegetables, and exposure to radioactive particulates deposited on the ground surface at that location. This calculated effective dose equivalent is about 0.0017% of the natural background radiation effective dose equivalent of approximately 350 mrem per year in this area. The 1990 effective dose equivalent calculated using the required CAP–88 code was 0.001 mrem and was compared with EPA radiation protection standards. (See the section entitled "Maximum Individual Dose—Airborne Emissions Pathway Only.") The maximum calculated dose to an individual by either of the methods is clearly in compliance with the applicable radiation protection standards.

The maximum potential population dose from submersion, ingestion, inhalation, and deposition to the approximately 121,000 people residing within an 80–km (50–mi) radius from the center of the TRA–ICPP area of the INEL Site was estimated to be 0.04 person–rem (4×10^{-4} person–Sv) using the MESODIF air dispersion model. This population dose is about 0.00009% of the estimated 42,400 person–rem (424 person–Sv) population dose from natural background radioactivity. These calculations and their implications are discussed in the section "Assessment of Potential Radiation Dose to the Public."

Calculations indicate that the maximum potential 50–year dose commitment to an individual from ingestion of wild game animals is about 2% of the DOE radiation protection standard for individuals at points of maximum probable exposure.

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ACRONYMS

Acronym	Definition
ACB	Analytical Chemistry Branch of RESL
ANL–W	Argonne National Laboratory—West
ARA	Auxiliary Reactor Area
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CFSGF	Coal–Fired Steam Generating Facility
CWA	Clean Water Act
DOE	U.S. Department of Energy
DOE–HQ	Department of Energy, Headquarters in Washington, D.C.
DOE–ID	Department of Energy, Idaho Operations Office
EA	Environmental Assessment
EBR–I	Experimental Breeder Reactor–I
EBR–II	Experimental Breeder Reactor–II
EDE	Effective dose equivalent
EFS	Experimental Field Station
EG&G	EG&G Idaho, Inc.
EIS	Environmental Impact Statement
EMSL–LV	Environmental Monitoring Systems Laboratory in Las Vegas
EPA	U.S. Environmental Protection Agency
EPA–10	EPA Region 10
IAG	Interagency Agreement
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory
ISU	Idaho State University
IWMIS	Industrial Waste Management Information System
LDR	Land Disposal Restrictions
MCL	Maximum Contaminant Level
MDC	Minimum Detectable Concentration
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Protection Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NON	Notice of Noncompliance
NPDES	National Pollutant Discharge Elimination System
NRF	Naval Reactors Facility
NWPA	National Waste Policy Act
PBF	Power Burst Facility
PCB	Poly–chlorinated Biphenyl
PREPP	Process Experimental Pilot Plant
PSC	Public Service Company of Colorado
RCRA	Resource Conservation and Recovery Act
RESL	Radiological and Environmental Sciences Laboratory
RIFR	Rifle Firing Range
RMW	Radioactive mixed waste
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
SDWA	Safe Drinking Water Act
TAN	Test Area North

Acronym	Definition
TCE	Trichloroethylene
TLD	Thermoluminescent dosimeter
TRA	Test Reactor Area
TSCA	Toxic Substances Control Act
USGS	U.S. Geological Survey
WEC	Westinghouse Electric Corporation
WERF	Waste Experimental Reduction Facility
WINCO	Westinghouse Idaho Nuclear Company
WIPP	Waste Isolation Pilot Plant, Carlsbad, New Mexico
WRRTF	Water Reactor Research Test Facility

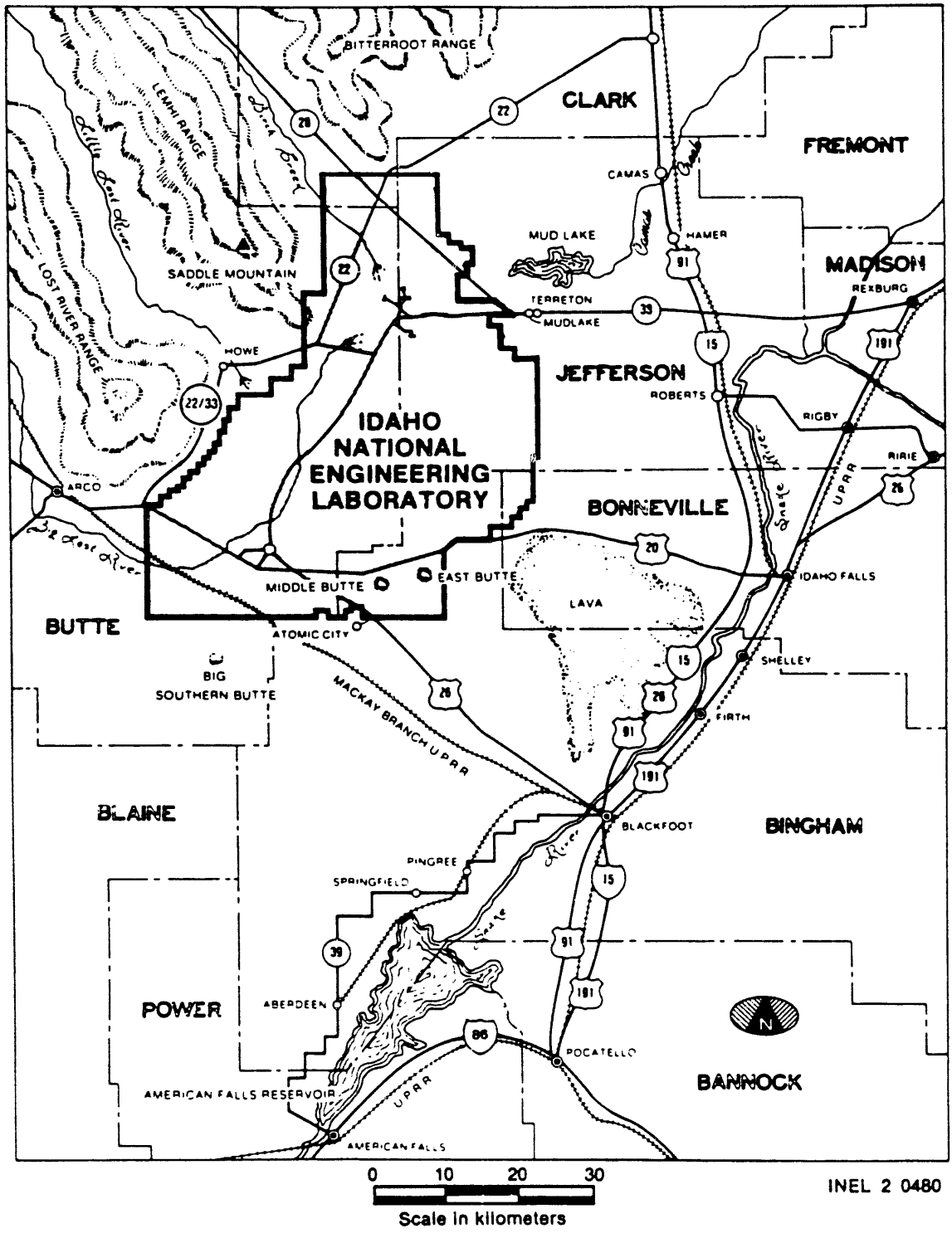

Figure 1. INEL Site vicinity map.

THE IDAHO NATIONAL ENGINEERING LABORATORY SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1990

INTRODUCTION

The Idaho National Engineering Laboratory (INEL) of the Department of Energy (DOE) was established by the Federal Government in 1949 to conduct research and further the development of nuclear reactors and related equipment. Major DOE programs at the Site include test irradiation services, uranium recovery from highly enriched spent fuels, calcination of liquid radioactive waste solutions, light–water–cooled reactor safety testing and research, operation of research reactors, environmental restoration at the Site, and storage and surveillance of solid transuranic wastes. Major facilities at the INEL are operated by Argonne National Laboratory—West (ANL–W), EG&G Idaho, Inc. (EG&G), Rockwell–INEL, Westinghouse Electric Corporation (WEC), and Westinghouse Idaho Nuclear Company (WINCO).

The 2300–km^2 (890–mi^2) INEL Site is located on the upper Snake River Plain in southeastern Idaho. The nearest INEL Site boundaries are 35 km (22 mi) west of Idaho Falls, 37 km (23 mi) northwest of Blackfoot, 71 km (44 mi) northwest of Pocatello, and 11 km (7 mi) east of Arco, Idaho (see Figure 1). With a population of about 1100, Arco is the largest boundary community in the area surrounding the Site. Approximately 121,000 people reside within a radius of 80 km (50 mi) of the Site's operational center, but there are no residents within 16 km (10 mi) of that center.

Vegetation and wildlife on the Site are typical of those found in a cool, desert–shrub biome. Figure 2 shows a part of the Site and its vegetation. In 1975, the INEL was the second area to be designated as one of the nation's seven National Environmental Research Parks, where scientists from universities, government, and private agencies study environmental changes caused by man's activities and obtain data subsequently applied to making land–use decisions.

The surface of the plain is a combination of basalt (lava) outcrops and alluvial sedimentary deposits. There are no surface streams or rivers flowing from onsite to offsite locations, but the Snake River Plain aquifer lies beneath the INEL Site. The Big and Little Lost Rivers and Birch Creek, which originate in mountains to the northwest, flow onto the Site and sink into its porous soils. Water from the aquifer and from surface streams and rivers of the Snake River Plain is used for drinking water and crop irrigation.

A more detailed description of the Site location, environment, and current major activities is given in Appendix A.

Figure 2. Typical vegetation on the INEL Site.

ENVIRONMENTAL COMPLIANCE INFORMATION SUMMARY

Compliance Status

The INEL is committed to operating in compliance with all environmental laws, regulations, Executive Orders, DOE Orders, and compliance agreements with Environmental Protection Agency (EPA) and State agencies. The following is a summary of the INEL's current compliance status with major environmental statutes for the period January 1990 through April 1991.

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

In November of 1989, the INEL was placed on EPA's National Priorities List (NPL), which is the list of hazardous waste sites identified by EPA for possible long-term remedial action under CERCLA. During 1990, DOE-ID entered into negotiations concerning an Interagency Agreement (IAG) with the State of Idaho and EPA Region 10 (EPA-10). The purpose of the IAG is to establish the criteria for the restoration of the INEL, as required by section 120 of CERCLA regulations. Negotiations are nearly completed and the IAG is expected to be signed in late 1991.

Clean Air Act (CAA)

The INEL has several facilities with air quality permits from the State of Idaho. These facilities are operated in compliance with permit conditions. Permit applications are currently pending with the State of Idaho for proposed new or modified emission sources. Table I lists current permits, under the CAA, in effect and pending at the INEL (through April 1, 1991).

In addition, an inventory of all potential radioactive and criteria pollutant emission sources were completed and sent to the State of Idaho in April 1991. The inventory contains information necessary for the State to issue the INEL a Permit to Operate.

National Emission Standards for Hazardous Air Pollutants (NESHAPs)

Radioactive emissions at the INEL are regulated under both EPA and State of Idaho requirements. EPA statutory requirements are contained in 40 CFR 61, Subpart H "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities."[1] The EPA revised these standards on December 15, 1989. The revisions included a lower dose standard to members of the public (lowered from 25 mrem per year to 10 mrem per year), prescriptive monitoring and emission testing procedures for certain emission sources, and additional annual reporting requirements.

The 1990 effective dose equivalent (EDE) to the public resulting from INEL radiological air emissions was well below the EPA dose standard of 10 mrem per year. The calculated dose for 1990, using the EPA-approved CAP-88 model, was 0.0017 mrem/yr (1.7×10^{-5} mSv/yr). This dose, used to demonstrate INEL compliance with NESHAPs, was calculated differently from the 0.001 mrem (1×10^{-5} mSv) reported in the Executive Summary. See the section entitled "Maximum Individual Dose-Airborne Emissions Pathway Only" for the discussion of differences in approach.

In 1990, the DOE began evaluating all potential radiological emission sources at the INEL. One purpose of the evaluation was to identify those sources required to meet the emission monitoring and testing procedures of 40 CFR 61, Subpart H (see Reference 1). Concurrent with this evaluation, on June 18, 1990, DOE requested a waiver from the emission monitoring and test procedures to allow for completion of the evaluation.

On October 23, 1990, EPA-10 granted the INEL a two-year waiver from the emission monitoring and test procedures. The waiver is retroactive to December 1989, and is valid through December 1991. The waiver was based on information provided to EPA by INEL and on information gathered during a May 1990, EPA-10 onsite visit. The waiver was granted subject to the following conditions:

- Radioactive emissions from INEL meet the 10 mrem per year standard
- Current emission monitoring practices shall continue
- Submission to EPA-10 by November 30, 1990, an inventory of radiological release points and a determination of those points requiring continuous monitoring per 40 CFR 61, Subpart H requirements

TABLE I
AIR PERMITS IN EFFECT[a] (1990)

Facility	Issued By	Compliance Status
Coal–Fired Steam Generation Facility (CFSGF) at ICPP	EPA	In Compliance
Fuel Processing Restoration Facility (FPR) at ICPP	State of Idaho	Under Construction
Hot Fuel Examination Facility/South (HFEF/S) at ANL–W	State of Idaho	In Compliance
Small Incinerator for burning classified documents at TAN	State of Idaho	In Compliance
Boilers at TAN	State of Idaho	In Compliance
Waste Experimental Reduction Facility (WERF) at PBF	State of Idaho	In Compliance
Boiler at CFA 609	State of Idaho	In Compliance
Boiler Modification at ICPP	State of Idaho	In Compliance
Drum Venting Facility at RWMC	State of Idaho	In Compliance
Hazardous Chemical/Waste Handling Facility at ICPP	State of Idaho	In Compliance
A1W Temporary Boiler at NRF	State of Idaho	In Compliance
Sodium/Potassium Processing System at WRRTF near TAN	State of Idaho	In Compliance
Fluoric Acid Handling System at ICPP	State of Idaho	In Compliance
Paint Booth at ANL–W	State of Idaho	In Compliance
SMC Research and Development at TAN	State of Idaho	In Compliance
TSA Retrieval Building at RWMC	State of Idaho	In Compliance
Evaporation Pond at TRA	State of Idaho	Not Constructed

a. All are Permits to Construct (PTC) or Prevention of Significant Deterioration (PSD) permits.

- Submission to EPA–10 by July 31, 1991, a detailed assessment of the release points requiring continuous monitoring

- Submission to EPA–10 by October 31, 1991, a plan for any upgrades to monitoring equipment required to meet the 40 CFR 61, Subpart H monitoring requirements.

The INEL is currently meeting all conditions of the waiver.

On November 30, 1990, an inventory and monitoring evaluation of all INEL radioactive airborne emission points was submitted to EPA–10. The evaluation identified two sources at the Idaho Chemical Processing Plant (ICPP) and two sources at the Waste Experimental Reduction Facility (WERF) that require continuous monitoring per the EPA requirements. These emission points are currently monitored on a continuous basis. An evaluation of the monitoring systems is currently underway. A schedule for performing any upgrades to the existing monitoring systems will be submitted to EPA–10 by October 1991.

Clean Water Act (CWA)

The INEL does not discharge liquid effluents to surface waters. Sewage treatment plants are operated in compliance with applicable State regulations. DOE–ID is currently assessing the need for storm water discharge permits under the new National Pollutant Discharge Elimination System (NPDES) regulations.

Resource Conservation and Recovery Act (RCRA)

DOE–ID has a Consent Order and Compliance Agreement (COCA) with EPA–10 governing corrective action and compliance activities at the INEL. In preparing for the transition to the CERCLA Interagency Agreement, letters were sent to EPA–10 and the State of Idaho in February 1991 to reclassify certain Solid Waste Management Units to Land Disposal Units. Closure plans for 18 units were submitted to EPA and 31 Summary Assessments were approved.

In February 1990, DOE–ID received a Notice of Noncompliance (NON) from EPA–10 for 28 alleged violations of RCRA regulations arising from an inspection in June 1989. DOE–ID is negotiating a consent order with the State of Idaho that addresses these allegations. The majority of the alleged violations have been resolved and long–term technical solutions for the Radioactive Waste Management Complex (RWMC) and ICPP have been agreed upon. However, the issue of sodium storage at Argonne National Laboratory–West (ANL–W) has been elevated to DOE and EPA headquarters for resolution.

During September 1990, the State of Idaho and the EPA conducted a week–long RCRA inspection. The inspection was conducted by the State with the EPA providing oversight. The State of Idaho notified DOE that there will be an enforcement action stemming from the inspection; however, as of April no letter had been received and the issues and units involved were still unknown.

In November 1990, the State of Idaho determined DOE had established equivalency with secondary containment requirements for lines embedded in concrete at the ICPP.

In a letter dated March 13, 1991, the State of Idaho notified DOE–ID of an upcoming inspection of the ICPP. The inspection took place during the week of March 18, 1991. To date, the state has not discussed the results of the inspection with the DOE–ID.

In a letter dated March 15, 1991, the state requested information on the ICPP concerning air permits, monitoring records, procedures, new construction activities, waste streams, and solid waste management. DOE–ID compiled the information and sent it to the State.

National Environmental Policy Act (NEPA)

Activities to ensure compliance with NEPA are ongoing at the INEL. Seven Environmental Assessments (EAs) were submitted to DOE–HQ for approval. The ICPP Process Equipment Waste/Process Waste Liquid Collection System and the Fort St. Vrain Fuel Shipments to ICPP EAs were both approved with a Finding of No Significant Impact. During 1990, 49 Categorical Exclusions were approved by DOE–HQ.

Work on the New Production Reactor (NPR) Environmental Impact Statement (EIS) is ongoing. When complete, the EIS will assess the potential impacts concerning a proposed action to provide new tritium production capacity. The EIS will evaluate impacts related to air quality; noise levels; surface water, groundwater, and wetlands; land use; recreation; visual environment; biotic resources; historical, archaeological, and cultural resources; socioeconomics; transportation; waste management; and human

health and safety. The EIS will also describe in detail the potential radioactive releases from the new production reactors and support facilities and will assess the potential doses to workers and the general public.

Safe Drinking Water Act (SDWA)

SDWA Underground Injection Control regulations require that deep injection wells be permitted or that permits be submitted to the state, and that shallow wells be inventoried. DOE–ID filed nine injection well permit applications with the State of Idaho which are currently being reviewed. The injection wells are used to dispose of storm water runoff. DOE also inventoried shallow injection wells at the INEL and submitted the information to the State as required. A sanitary survey was conducted by the State of Idaho in December 1990 and followup actions are being coordinated with the State.

Toxic Substances Control Act (TSCA)

Efforts to comply with TSCA included the implementation of a plan to remove or retrofill poly–chlorinated biphenyl (PCB) and PCB–contaminated transformers and capacitors. Following a September 1988 inspection, EPA issued a Complaint and Notice for Opportunity for Negotiation concerning alleged TSCA violations. The Complaint alleged that the INEL violated the record keeping and use provisions of the PCB regulations. After attending a settlement conference with the EPA, DOE–ID implemented a plan to remove or retrofill PCB and PCB–contaminated transformers and capacitors. During 1990, 69 PCB capacitors and 16 PCB–contaminated transformers were removed from service or retrofilled and reclassified as non–PCB. There are currently no PCB capacitors and only two PCB–contaminated transformers in service at the INEL.

Current Issues and Actions

CERCLA Interagency Agreement (IAG) Negotiations

DOE–ID has negotiated the terms, conditions, schedules, and authorities of the IAG with the State of Idaho and EPA–10. To date, the IAG has not been signed due to unresolved funding issues between DOE–ID and EPA. The funding issues have been elevated to DOE–HQ and EPA–HQ, and resolution is expected by the end of July 1991. In the interim, DOE–ID sent a letter, dated March 1991, to EPA–10 and the State of Idaho recommending implementation of the IAG Action Plan prior to IAG signature. In April, EPA–10 responded by agreeing that the IAG Action Plan should be implemented prior to the signing of the IAG.

CWA Permits

The issue of whether the State of Idaho has the authority to issue permits for waste water treatment facilities on the INEL is still unresolved. Information concerning these facilities is given to the State of Idaho as a matter of comity.

RCRA Compliance

In February 1990, DOE–ID received a Notice of Noncompliance (NON) from EPA–10 addressing 28 alleged noncompliance issues. DOE–ID developed a response to the allegations and in April 1990, a settlement conference was held between DOE–ID, the State of Idaho, and EPA–10. An agreement to settle the NON via a State consent order was reached. To date the agreement has not been signed. DOE–ID is expecting a draft consent order from the State of Idaho in July 1991. The issue of sodium storage at ANL–W will be incorporated into the consent order, as necessary, at a later date once resolved by DOE–HQ and EPA–HQ.

Land Disposal Restrictions (LDRs)

The INEL generates LDR waste that is classified as hazardous and other LDR waste that is classified as radioactive mixed waste (RMW), which is a mixture of hazardous and radioactive wastes. Some RMW does not currently have an active treatment method, while other RMW is being stored prior to disposal at Waste Isolation Pilot Plant (WIPP). Transuranic waste stored at RWMC will be disposed of at WIPP, and all other LDR waste will be disposed after a treatment method is developed. DOE–ID has formally proposed to enter into a compliance agreement with EPA–10 and the State of Idaho concerning the storage and continued generation of LDR waste until a treatment method is developed and WIPP is open for disposal. However, EPA–10 and the State of Idaho have informed DOE–ID that they currently do not have adequate resources to initiate negotiations.

Independent Monitoring

The Idaho State University (ISU) Environmental Monitoring Program operates an independent monitoring program at the INEL which samples air, water, milk, and soil and analyzes these samples for radioactivity. ISU reports their results to the State of Idaho each quarter. Results of the 1990 ISU monitoring efforts were in agreement with INEL results.

In May 1990, DOE–ID and the State of Idaho signed an Environmental Oversight and Monitoring Agreement for independent environmental monitoring by the State.

Clean Air Act

As a result of new requirements formulated by EPA under 40 CFR 61 (see Reference 1) on December 15, 1989, the INEL began evaluating potential radiological airborne emission sources. The evaluation was to determine if the monitoring and emission test procedure requirements of 40 CFR 61, Subpart H were being met. In conjunction with the evaluation, DOE–ID requested a waiver from the emission monitoring and test procedure requirements of 40 CFR 61, Subpart H. On October 23, 1990, the INEL was granted a two–year waiver, retroactive to December 15, 1989. Conditions of the waiver are included in the "Compliance Status" section of this report. In 1990, the INEL began identifying and upgrading those monitoring systems that are required to meet the 40 CFR 61, Subpart H requirements. Their efforts are expected to be completed during 1991.

NEPA (Fort St. Vrain Litigation)

In 1965, the DOE signed a contract with the Public Service Company of Colorado (PSC). The contract requires that the DOE reprocess or pay for the reprocessing of fuel from the Fort St. Vrain gas–cooled reactor, located near Platteville, Colorado. The Contract states that the PSC is responsible for delivering the spent fuel to the INEL, at which time the DOE takes title. This contract was modified in 1980 to state that DOE would accept and store the spent fuel in a facility built in the early 1970s for that purpose.

The draft Fort St. Vrain Fuel Shipments to ICPP Environmental Assessment was prepared and sent to the State of Idaho on September 4, 1990. Comments, dated October 18, 1990, were received from the State and responded to. The Finding of No Significant Impact on the environment was approved on February 5, 1991, with State notification on February 6, 1991.

There are currently three lawsuits pending, one in the United States Court of Appeals for the 9th Circuit, and two in the United States District Court for the District of Idaho. In the 9th Circuit Court litigation, the State of Idaho seeks an order pursuant to the National Waste Policy Act (NWPA) declaring, among other things, that the spent fuel Environmental Assessment and the Finding of No Significant Impact issued by the DOE is in violation of NEPA and applicable regulations. The State of Idaho is also seeking an order enjoining DOE from accepting or storing the Fort St. Vrain spent nuclear fuel at the INEL until DOE has complied with all applicable environmental laws and regulations. In the District Court cases, DOE and the Public Service Company of Colorado are seeking injunctions enjoining Idaho and Governor Andrus from interfering with the transportation and storage of Fort St. Vrain spent nuclear fuel.

Self–Assessment

During 1990, DOE–HQ directed all DOE line management organizations to implement comprehensive self–assessment programs to identify and characterize environmental safety and health concerns. DOE–ID's self–assessment program includes functional and management appraisals of contractors by DOE line management, as well as internal appraisals conducted by contractors and DOE operating–level staff. Also, management performance within the DOE line organizations is being assessed.

ENVIRONMENTAL PROGRAM INFORMATION

General Summary of the Environmental Surveillance Program

During normal operation of the reactors, fuel reprocessing plant, and other facilities at the INEL some materials are released to the environment. The environmental pathways by which radioactive and nonradioactive materials may be transported from the Site to nearby populations include passage directly through atmospheric transport or indirectly through soils, foodstuffs, or animals. Through 1990, substances originating from Site operations have not been detected in the water of the Snake River Plain aquifer beyond the INEL southern boundary; thus, the aquifer is not presently a pathway to members of the public living near the Site.

The environmental surveillance program for the INEL and vicinity for 1990 included the collection and analysis of samples from potential exposure pathways (see Figure 3). Three basic groups of samples were collected. Those collected within the INEL boundaries will be referred to as onsite or Site samples. Samples collected offsite, but near the Site boundaries, will be referred to as boundary samples or part of a group of offsite samples. Samples collected from locations considerably beyond the Site boundaries will be referred to as distant samples or part of the offsite group. With the exception of Craters of the Moon National Monument, the distant locations are sufficiently remote from the Site to ensure that detectable radioactivity is primarily due to natural background or sources other than INEL operations. The Craters of the Moon location is too distant to be considered a boundary location, but is close enough that radionuclides from Site operations are occasionally detected there at low concentrations.

Table II summarizes the RESL environmental surveillance program that is required by DOE Order 5400.1.[2] The radiological portion of the program is considerably more extensive than the nonradiological portion, which is appropriate for operations at the INEL. As shown in Table II, air and ground water were routinely monitored for radioactivity at a number of onsite, boundary, and distant locations. Table III summarizes the USGS portion of the routine ground-water monitoring program for radiological and nonradiological substances. Concentrations of radionuclides were measured in samples of milk, wheat, and lettuce from boundary and distant locations in 1990. Environmental radiation exposure rates (cumulative from November 1989 through October 1990) were measured at onsite, boundary, and distant locations. Offsite soil samples were also collected during 1990.

Measurements at boundary and onsite locations are compared with measurements at distant locations to assess the impact of INEL operations on the environment. Concentrations of radioactive pollutants in the environment are compared to applicable standards and guides (see the section "Environmental Standards and Regulations") and to background and natural radioactivity. Most radioactive concentrations in this report are compared to the derived concentration guides given in DOE Order 5400.5.[3] Calculated doses are compared to DOE and EPA standards, and nonradioactive pollutants are compared to applicable EPA standards and guides.

In the text, more detailed descriptions of each routine program, radioactive and nonradioactive, are given in a specific section followed by a summary of the results for 1990. Data summary tables are presented in Appendix B.

The section on "Quality Assurance" provides information on RESL's quality control and quality assurance activities while conducting its environmental surveillance program. Appendix C gives a brief discussion of the statistical methods used to analyze the data in this report.

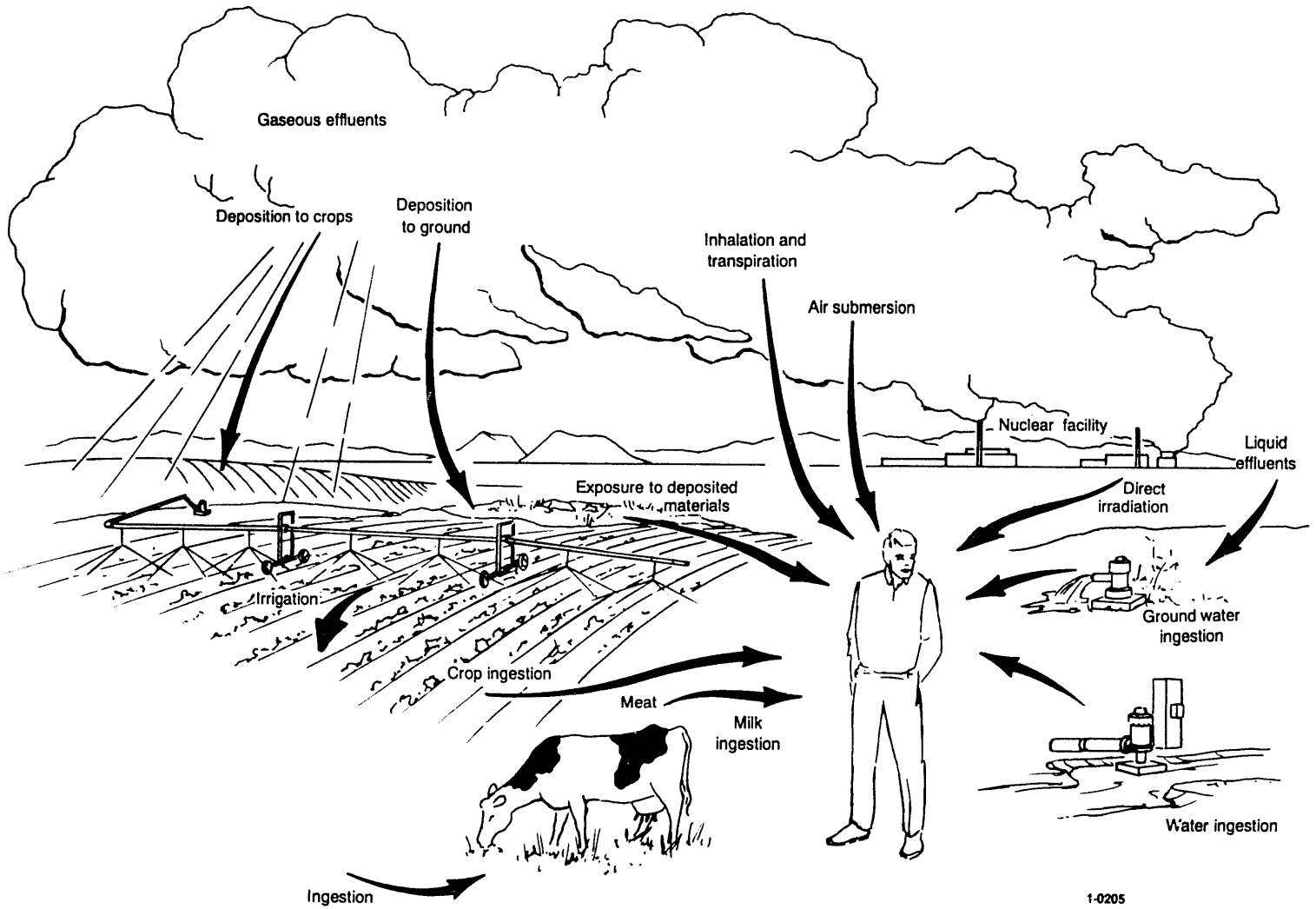

Figure 3. Potential pathways from the INEL to man.

TABLE II
RESL ENVIRONMENTAL SURVEILLANCE PROGRAM SUMMARY

Medium Sampled	Type of Analysis	Number of Location and Frequency		Minimum Detectable Concentration (MDC)
		Onsite	Offsite	
Air	**Low-Volume Samplers:**			
	Gross alpha	4 weekly	4 weekly	3×10^{-16} µCi/mL
	Gross beta	12 weekly	11 weekly	8×10^{-15} µCi/mL
	Specific gamma	12 quarterly	11 quarterly	1 to 10×10^{-15} µCi/mL
	Pu	6 quarterly	4 quarterly	6×10^{-18} µCi/mL
	Am	6 quarterly	4 quarterly	8×10^{-18} µCi/mL
	Sr-90	2 quarterly	4 quarterly	1×10^{-16} µCi/mL
	Particulate matter	12 quarterly	11 quarterly	10 µg/m^3
	High-Volume Samplers:			
	Gross gamma	2 daily	—	N/A[a]
	Specific gamma	2 monthly	—	1 to 10×10^{-14} µCi/ml
	Kr-85 Sampler	1 biweekly	—	2×10^{-12} µCi/mL
	Tritium Samplers:			
	H-3 as HTO	2 at 1 to 2/quarter	1 to 2/quarter	1×10^{-11} µCi/ml
	TSP Sampler	1 weekly[b]	—	2 µg/m^3
Water	**Drinking Water:**			
	Gross alpha	26 monthly	13 semiannually[c]	3×10^{-9} µCi/ml
	Gross beta	26 monthly	13 semiannually	4×10^{-9} µCi/ml
	H-3 as HTO	26 monthly	13 semiannually	4×10^{-7} µCi/ml
	Sr-90	2 monthly	—	5×10^{-10} µCi/ml
Animal Tissues[d]	**Beef—Muscle, Liver**			
	Specific gamma	2 biennially	2 biennially	7×10^{-9} µCi/mL
	Pu-239/240	2 biennially	2 biennially	5×10^{-11} µCi/mL
	Am-241, Pu-238	2 biennially	2 biennially	1×10^{-10} µCi/mL
	Sheep—Muscle, Liver			
	Specific gamma	4 annually	2 annually	7×10^{-9} µCi/mL
	Game Animals—Muscle			
	Specific gamma	Varies annually[e]	—	7×10^{-9} µCi/mL
Foodstuffs	**Milk:**			
	I-131	None produced	1 weekly	1×10^{-9} µCi/mL
	I-131	None produced	10 monthly	1×10^{-9} µCi/mL
	Sr-90	None produced	10 annually	2×10^{-9} µCi/mL
	H-3 as HTO	None produced	10 annually	4×10^{-7} µCi/mL
	I-129	None produced	3 annually	3×10^{-10} µCi/mL
	Wheat:			
	Specific gamma	None produced	10 annually	4×10^{-9} µCi/mL
	Sr-90	None produced	10 annually	4×10^{-9} µCi/mL
	Lettuce:			
	Specific gamma	None produced	8 annually	2×10^{-7} µCi/mL
	Sr-90	None produced	8 annually	8×10^{-8} µCi/mL
Soil	Specific gamma	Varies annually[f]	12 biennially	4×10^{-8} µCi/mL
	Pu	Varies annually	12 biennially	2×10^{-9} µCi/mL
	Am	Varies annually	12 biennially	3×10^{-9} µCi/mL
	Sr-90	Varies annually	12 biennially	9×10^{-8} µCi/mL
Direct Radiation Exposure	Thermoluminescent Dosimeters	135 semiannually	13 semiannually	5 mR
	Gamma Radiation Surveys	Varies annually[g]	—	N/A

a. Not applicable.

b. Sampler operates for 24 h every six days.

c. Two additional offsite drinking water samples and three surface water samples from springs in the Magic Valley area were split monthly with Idaho State University Environmental Monitoring Group January through June 1990 and quarterly July through December 1990.

d. "Onsite" animals grazed onsite for at least four weeks before being sampled. "Offsite" animals have never grazed onsite and serve as controls.

e. Only road-killed game animals are sampled onsite. No controls are generally collected except for specific ecological studies.

f. Onsite soil sampling is performed each year at different onsite facilities on a rotating 3-year schedule.

g. Surveys are performed each year at different onsite facilities on a rotating 3-year schedule.

TABLE III
USGS GROUND–WATER MONITORING PROGRAM SUMMARY

Radiological Monitoring:

Type of Analysis	Frequency of Analysis	Number of Samples	≈Minimum Detectable Concentration (MDC) (μCi/mL)
Gross alpha	Semiannually[a]	5	3×10^{-9}
Gross beta	Semiannually[a]	5	4×10^{-9}
Tritium[b]	Quarterly	48	4×10^{-7}
Tritium	Semiannually[a]	83	4×10^{-7}
Specific gamma	Quarterly	9	1 to 10×10^{-8}[c]
Specific gamma	Semiannually	17	1 to 10×10^{-8}
Specific gamma	Annually	26	1 to 10×10^{-8}
Sr–90	Quarterly	29	5×10^{-9}
Sr–90	Semiannually	26	5×10^{-9}
Am	Quarterly	4	5×10^{-11}
Am	Semiannually	4	5×10^{-11}
Pu	Quarterly	5	4×10^{-11}
Pu	Semiannually	4	4×10^{-11}
I–129	≈5 years	20–35	6×10^{-11}

Nonradiological Monitoring:

Type of Analysis	Frequency of Analysis	Number of Samples	≈Minimum Detectable Concentration (MDC) (mg/L)
Specific conductance	Quarterly	48	N/A[d]
Specific conductance	Semiannually[a]	83	N/A
Sodium ion	Quarterly	5	5
Sodium ion	Semiannually	2	5
Sodium ion	Annually	104	5
Chloride ion	Quarterly	48	5
Chloride ion	Semiannually[a]	83	5
Nitrates (as NO_3)	Annually	62	0.5
Chromium (total)	Quarterly	21	0.05
Chromium (total)	Semiannually	31	0.05
Purgeable organic compounds[e]	Monthly	1	0.0002
	Quarterly	4	0.0002
	Semiannually	3	0.0002
Major inorganic water quality constituents	≈5 years	65	Varies

a. In addition, one offsite well is sampled annually.

b. Tritiated water.

c. Varies depending upon radionuclides present in the sample.

d. Not applicable.

e. Each sample analyzed for 36 compounds. Other wells may be sampled for special studies.

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

Summary of Results of Environmental Monitoring Performed

Air Sampling

Low–volume Samplers—Airborne particulate radioactivity is monitored continuously by a network of 12 air samplers within the INEL and 11 air samplers outside the Site boundaries at the locations shown in Figure 4. Locations of onsite samplers were selected to give adequate coverage in the event of facility releases of radioactivity. Seven offsite air samplers are located near the Site boundary in communities, when possible, or at noncommunity locations when necessary to encompass the perimeter of the Site. Four samplers are located at the distant communities of Blackfoot, Craters of the Moon National Monument, Idaho Falls, and Rexburg to provide background measurements for comparison with data from boundary or onsite samplers that might be affected by INEL operations. The whole network provides comprehensive surveillance of particulate atmospheric radioactivity and makes it possible to differentiate INEL releases from worldwide fallout and long–lived natural radioactivity.

Each air sampler maintains an average air flow of about 40 L/min (1.5 ft^3/min) through a set of filters consisting of a membrane filter (Gelman Model V–1200) followed by an activated charcoal–impregnated cellulose fiber filter (Gelman Model AC–1).[a] The filters are 99% efficient for airborne particulate radioactivity and elemental iodine vapor.

Gross Alpha, Gross Beta—The filters from the low–volume air samplers are collected weekly and analyzed after waiting a minimum of four days to allow the naturally occurring, short–lived radon and thoron daughters to decay. "Gross" (nonspecific) analyses of the airborne particulates trapped on the membrane filters are performed weekly, and the activity detected

a. Use of commercial product names is for accuracy in technical reporting and does not constitute endorsement of the product by the United States Government.

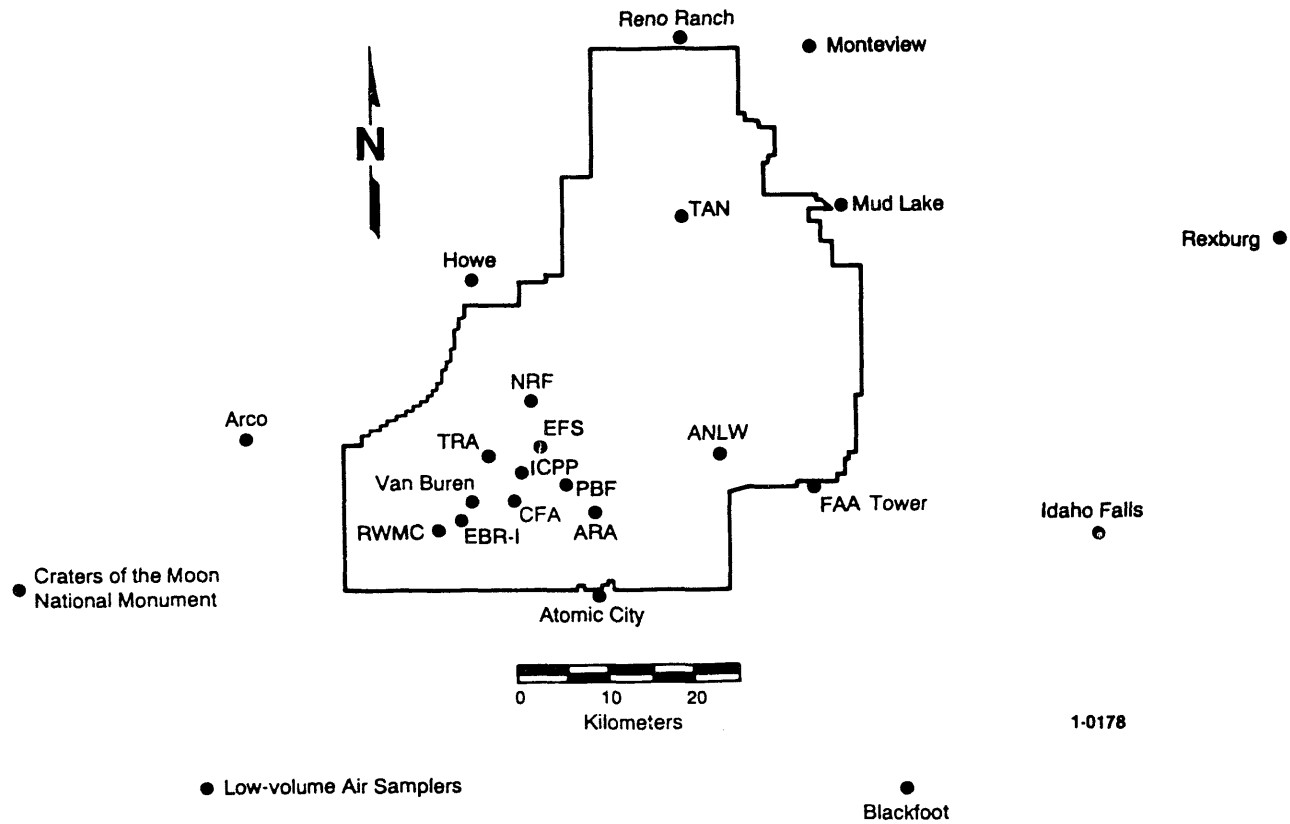

Figure 4. INEL Site and vicinity air sampling network.

is termed "gross alpha" or "gross beta" to differentiate these results from analyses for specific radionuclides. Because the distant community group is small, a low concentration at only one or two locations can cause the statistical test to indicate that onsite mean concentrations are significantly higher than that of the distant community group. This variable alone can make interpretation of results of nonspecific gross alpha or beta measurements difficult. Therefore, when interpreting air sampling data, RESL relies on the results and comparisons of specific nuclide data rather than on gross alpha and beta concentrations. Furthermore, the source of the radioactivity can be determined more easily from the specific nuclide concentrations than the nonspecific "gross" concentrations. Specific nuclide analyses are also more sensitive than gross alpha and gross beta analyses.

Analyses for gross alpha activity are performed on eight selected filters: Blackfoot, Craters of the Moon, Arco, Mud Lake, ANL-W, the Experimental Field Station (EFS), Radioactive Waste Management Complex (RWMC), and Test Area North (TAN). Gross alpha concentrations are sometimes greater at the distant location of Blackfoot than at the other locations because of sources outside the INEL Site. The annual mean concentration at Mud Lake for 1990 was statistically greater than the distant community mean concentration, but this appears to be due to an unusually low concentration at Craters of the Moon rather than to any Site operations. Gross alpha data for 1990 is presented in Table B-1, Appendix B.

Analysis for gross beta activity is performed on each membrane filter from all 23 locations in a low background beta counter. If the gross beta activity on a filter exceeds an action level of 1×10^{-12} µCi/mL, or if a Site release is suspected, the filter is analyzed by gamma spectrometry. All gross beta activity detected on the charcoal-impregnated filters is initially assumed to be I-131. If the gross beta activity on the charcoal filter exceeds an action level of 7×10^{-14} µCi/mL, the filter is analyzed by gamma spectrometry to determine the I-131 component.

The gross beta activity is determined weekly for all filters as a screening technique to give timely information in the event of INEL releases or worldwide fallout. This information may be difficult to interpret, however, because of local variations in beta concentrations of airborne particulates at any given time or location. Any of several factors may be responsible for the variations observed. Examples of these factors include dust or soot loading on individual filters, varying concentrations of natural radioactivity at different locations, and uneven distribution of worldwide fallout radioactivity as a result of diverse local meteorological conditions. For example, wood smoke loading of filters in communities sometimes occurs during cold weather. When an individual filter's pores are plugged early in the week, abnormally low gross beta concentrations often result.

The 1990 results of gross beta analyses of particulates on the membrane filters are summarized in Table B-2, Appendix B. The gross beta activity measured at each onsite and boundary location was statistically compared to gross beta activity measured at the group of distant locations for each month and for the entire year. Table B-3, Appendix B, shows 1990 results of the monthly and annual statistical comparisons of boundary and Site locations to the distant community group mean gross beta activity. Site operations information and meteorological data were considered in each case where a location or group was statistically greater than the distant location group. A statistical difference was found in about 4% of the comparisons.

During the last week of December 1990, four weekly filters with relatively high gross beta concentrations were submitted for gamma spectrometry. These filters were from samplers located at Craters of the Moon National Monument, Howe, Naval Reactor Facility (NRF), and Idaho Chemical Processing Plant (ICPP). Gamma spectrometry showed no detectable concentrations of any manmade radionuclides. No Site operations information could be found to explain the elevated gross beta concentrations on filters from those four samplers during that week in December.

One onsite location had a monthly mean gross beta concentration statistically greater than background for October 1990, and five onsite locations and one boundary location had monthly mean gross beta concentrations statistically greater than the distant group for November 1990. The onsite and boundary group means were also statistically greater than the distant group mean for November (see Table B-2, Appendix B). Mud Lake showed a higher annual gross beta mean concentration than the distant group. After analysis of INEL release data and examination of results of specific radionuclide analyses reported in the next section, no evidence could be found to indicate that the higher gross beta concentrations at any of these locations during any 1990 time period were due to manmade radionuclides or to Site operations.

The average monthly concentrations of gross beta activity for onsite, boundary, and distant location groups are shown in Figures 5 and 6 for 1982-1990.

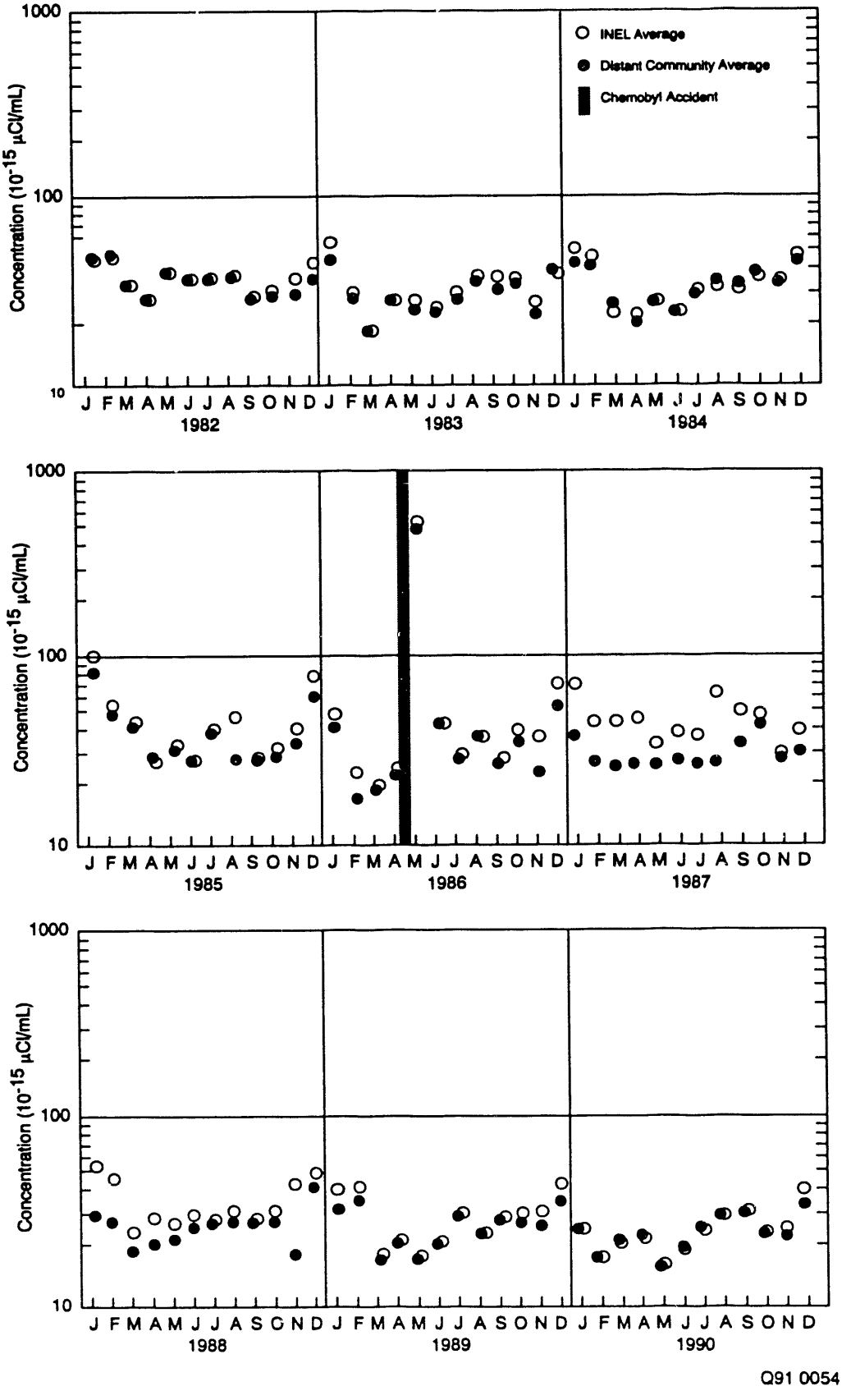

Figure 5. Site and distant gross beta concentrations in air.

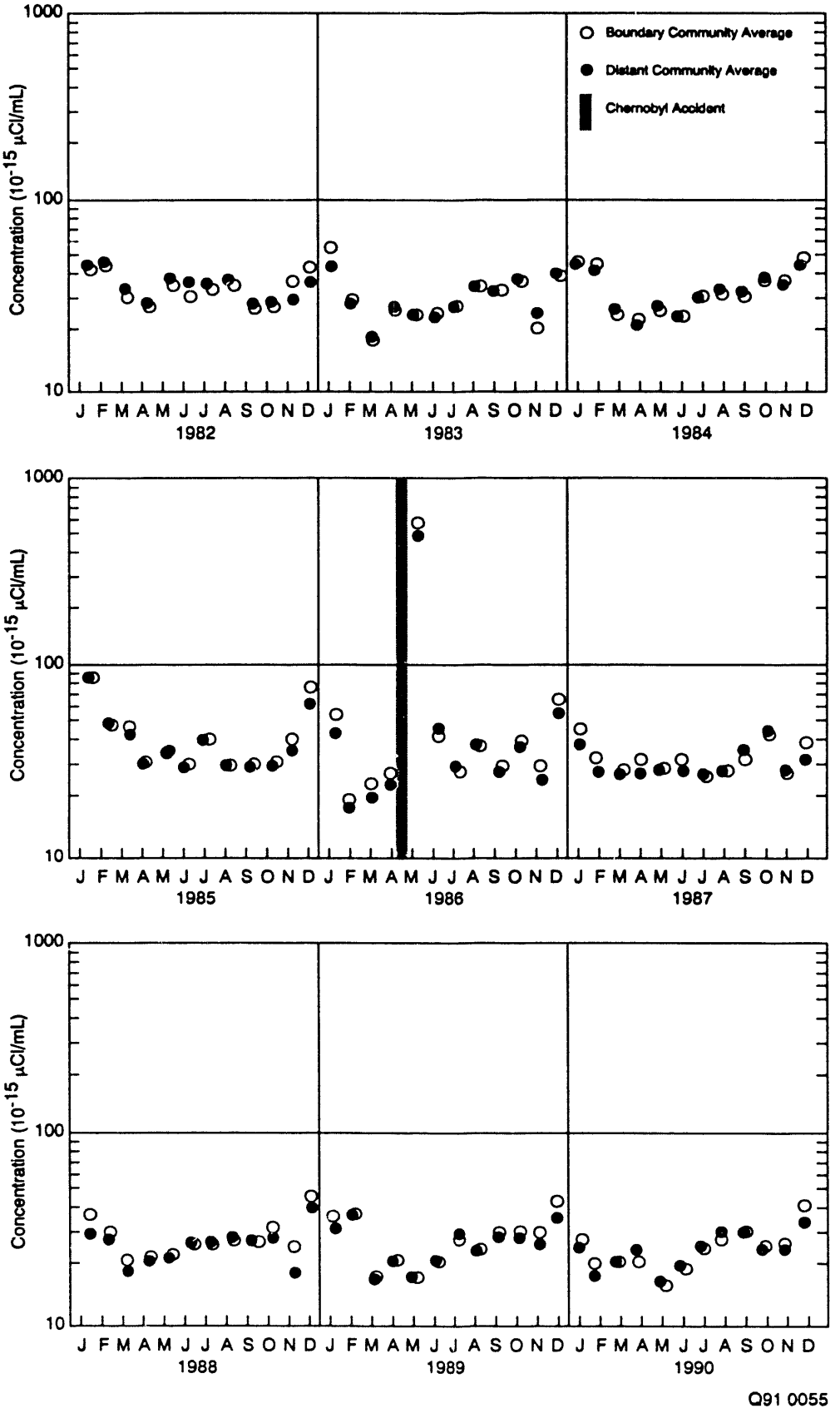

Figure 6. Boundary and distant gross beta concentrations in air.

The figured bar represents the time of the Chernobyl accident after which gross beta activity peaked dramatically. In recent years, there appears to be a small pattern of variation, with slightly higher concentrations occurring near the end and the beginning of most years. Reasons for this variation are most likely related to meteorological conditions.

Specific Radionuclides—Specific radionuclide analyses are more sensitive indicators than gross beta analyses of concentrations of manmade radionuclides in air. Therefore, the membrane filters of the low-volume samplers are composited according to location at the end of each quarter, and all composites are analyzed for specific radionuclides by gamma spectrometry. Selected composites are then submitted for analyses for alpha-emitting radionuclides or Sr-90. The analyses for alpha-emitting nuclides utilize chemical separation techniques followed by alpha spectrometry; for Sr-90, the chemical separation is followed by beta counting. Because both of the followup analyses consume the entire sample, only one of the two types can be performed on a given composite. The composites from one distant location and four onsite locations are analyzed each quarter for specific alpha-emitting radionuclides. The composites from another distant location and four other onsite locations are analyzed each quarter for Sr-90. In addition, six offsite and four onsite location composites are analyzed on alternating schedules, giving a total of ten rotating analyses. (Five composites are submitted for alpha-emitting nuclides and five for Sr-90 one quarter; during the next quarter, the groups are reversed and submitted for the other type of analysis.)

The quantity and identity of radionuclides released from INEL facilities are reported quarterly in the Radioactive Waste Management Information System (RWMIS) report. Whenever any question exists as to the impact of Site operations on the environment, results of the specific radionuclide analyses are compared to release data from the RWMIS reports in an attempt to determine the source of the detected material.

Results of the quarterly specific radionuclide analyses of membrane filter composites are summarized in Table B-4, Appendix B. Beryllium-7, a naturally occurring radionuclide produced by the interaction of cosmic radiation and nitrogen in the atmosphere, is excluded. Although Be-7 is also a manmade radionuclide produced at some National Laboratories, it is not a significant product of the processes at the INEL. Radionuclides included in Table B-4 are those that could potentially be released from INEL operations.

Two gamma-emitting radionuclides, Cs-137 and Ru-106, were measured at concentrations near their minimum detectable concentrations. When the reported concentrations are this low, it is difficult to draw firm conclusions about the source of the radioactivity (see Appendix C).

Strontium-90, a nuclide deposited on soil worldwide as a result of fallout from nuclear weapons tests, is often detected at concentrations near the minimum detectable concentration on both onsite and offsite samplers. Although not detected during 1990 on filter composites from any location, the annual average for the distant group was calculated as statistically significant at $1.1 \pm 1.0 \times 10^{-16}$ µCi/mL. RESL does not interpret this as meaning that Sr-90 was indeed present. However, if the assumption is made that it was, this annual concentration is 0.001% of the annual derived concentration guide for radiation protection of the public.

Plutonium-239/240 and Am-241 are frequently detected on RWMC filters as a result of resuspension of contaminated soil by the wind during quarters when there is no snow cover. During 1990 Am-241 was detected at RWMC during the third quarter at a concentration of $2.5 \pm 1.0 \times 10^{-17}$ µCi/mL and Pu-239/240 during the fourth quarter at a concentration of $4.4 \pm 1.0 \times 10^{-17}$ µCi/mL. However, the concentration of Pu-239/240 measured was greater than typically detected at RWMC. Extensive ground disturbance has occurred in the vicinity of the sampler while a new office building has been under construction. The presence of Pu-239/240 may have been due to soil resuspension by the ground disturbance activities, the wind, or a combination of both. The annual concentrations of both nuclides were less than 0.06% of the appropriate annual derived concentration guide. Americium-241 was also detected at Experimental Breeder Reactor-1 (EBR-I) at a concentration of $1.1 \pm 0.6 \times 10^{-17}$ µCi/mL and at ICPP at a concentration of $5 \pm 4 \times 10^{-18}$ µCi/mL during the fourth quarter.

Comparisons of onsite group mean concentrations to boundary group means and distant community means revealed no statistical differences for any manmade radionuclides. After examination of the geographical pattern and magnitude of detectable concentrations, the presence of Am-241 and Pu-239/240 at RWMC appears to be related to RWMC operations or to resuspension of slightly contaminated soil at the RWMC area. Although EBR-I is located near the RWMC, and the presence of Am-241 could conceivably be explained by operations at the RWMC area, it is unlikely. No specific source for the nuclide at EBR-I has been determined. The reported concentration at

ICPP was near the minimum detectable concentration and cannot be easily interpreted (see Appendix C).

Tritium—Samplers for tritium in water vapor are located in Idaho Falls and at the EFS and Van Buren locations on the INEL. In these samplers, air is passed through a column of silica gel at a rate of 0.3 L/min (0.65 ft^3/h). Tritium concentrations are determined by liquid scintillation counting of water extracted from the silica gel columns.

Tritium concentrations at the three locations are summarized in Table B–5, Appendix B. During 1990, three of the four samples collected at Idaho Falls and three of the eight Site samples (two at EFS and one at Van Buren) contained detectable concentrations of tritium. No significant difference was found between onsite and offsite locations. Because Idaho Falls lies outside the prevailing wind patterns for the Site and is distant from the INEL, it is unlikely that the tritium detected there originated from Site operations. Furthermore, the tritium concentrations in Idaho Falls samples were higher than those from the onsite samplers. No tritium was detected in any onsite or offsite 1981–1987 samples, but it was detected during 1988 at all locations and during 1989 at Idaho Falls and once at Van Buren. Examination of Site facility releases and meteorological information showed no evidence that the presence of tritium at any of these locations was due to INEL operations. Future tritium monitoring results will continue to be closely examined for trends in an attempt to discover a definite explanation for these detectable tritium concentrations. Table B–5, Appendix B, shows that the annual mean tritium concentration at each location is a very small percentage (0.0007% or less) of the annual derived concentration guides for radiation protection of the public.

Tritium in air in the form of water vapor may also be detected in rain and snow samples. Precipitation samples are routinely collected at CFA and Idaho Falls and analyzed for pH and for tritium. The December 1990 sample from CFA contained detectable tritium at a concentration of 1.3 ± 0.4 pCi/L. Snow samples collected for research purposes approximately 1 km northeast and 1 km southwest of ICPP in late December also had detectable concentrations of tritium at 2.8 ± 0.6 pCi/L and 1.9 ± 0.4 pCi/L, respectively. One snow sample collected on Monida Pass did not have detectable tritium. Releases of tritium reported in the Radioactive Waste Management Information System (RWMIS) appeared to be too small to result in concentrations of these levels unless meteorological conditions were unusual. Investigations are continuing and conclusions will be summarized in the 1991 annual report.

Krypton–85—Krypton–85 is monitored at one Site location, CFA. Ambient air is collected continuously in a large Tedlar bag. Twice a month, the sample (about 0.75 m^3 of air) is compressed into a cylinder. Two cylinders are shipped each month to the EPA Environmental Monitoring Systems Laboratory in Las Vegas (EMSL–LV) for analysis. The EMSL–LV analyzes for Kr–85 by condensing the samples at liquid nitrogen temperature and using gas chromatography to separate the krypton gas. The separated gas is dissolved in a scintillation cocktail and counted in a liquid scintillation counter.[4]

Compressed air samples from CFA were analyzed for Kr–85 from December 26, 1989 to December 27, 1990; and results are reported in Table B–6, Appendix B. The results are typical of levels found in the western United States by EMSL–LV, and are consistent with the lower–than–normal releases of Kr–85 by the INEL during 1989 and 1990. The annual average concentration of 3×10^{-11} µCi/mL is 0.001% of the derived concentration guide for radiation protection of the public. (See the section entitled "Environmental Standards and Regulations.")

Aerial Monitoring for Radioactivity—An aerial radiological survey of the entire INEL Site was conducted during June and July of 1990 by EG&G Energy Measurements, Inc., Las Vegas, Nevada, for DOE. The survey consisted of aerial measurements of both natural and manmade radiation from the ground surface on and around the INEL Site using helicopter flights. The distribution of isotopic concentrations in the survey area will be estimated from these measurements. A report is expected to be completed in mid–1991. Similar, but less extensive, surveys were conducted in 1966, 1974, and 1982.

RESL Water Sampling

General—No streams or rivers flow from within the INEL to locations outside the boundaries. Therefore, water sampling at the Site is limited to ground–water monitoring. Offsite community drinking water is also sampled, plus surface water samples from the Snake River, which flows at a considerable distance outside the Site boundaries, and a few surface springs in the Twin Falls, Idaho area. The Snake River Plain aquifer, which lies beneath the INEL Site, serves as a primary source for drinking water and crop irrigation in the Snake River Basin.

Onsite and offsite water samples are collected routinely to monitor the movement of waste substances,

both radioactive and nonradioactive, through the aquifer. RESL collects drinking water from boundary and distant communities and Snake River water samples and submits them for radionuclide analyses, (see Table II). Approximate locations of RESL offsite water sample collection sites are shown in Figure 7, along with locations of four of the observation wells beyond the southern and western Site boundaries that the USGS samples routinely. During the last half of 1989 and the first half of 1990, three surface water locations in the Magic Valley area (Twin Falls and points west) were added to the RESL program and two from communities (Shoshone and Minidoka) were sampled monthly. Each sample was split between RESL and the ISU Environmental Monitoring Program for their independent environmental surveillance program. Beginning in July 1990 the frequency of this sampling was changed from monthly to quarterly. Onsite drinking water samples are collected monthly from production (drinking water) wells in use at active Site facilities. ISU also splits some samples with the USGS.

In addition to the production well monitoring performed by RESL, the USGS extensively monitors ground water on the INEL Site. The USGS portion of the water sampling program and two maps showing locations of USGS sampling wells are described in the section "Ground-Water Monitoring Program Information."

Gross Alpha, Gross Beta—Each RESL water sample is submitted for gross (nonspecific) analyses for alpha and beta-emitting radionuclides that might be present in the water. For gross alpha analysis, a portion of the sample is evaporated on a stainless steel planchet and counted with a scintillation counter system. For gross beta activity, a portion is evaporated and counted in a low-background beta counter. The minimum detectable concentrations for gross alpha and gross beta are 3×10^{-9} and 4×10^{-9} μCi/mL, respectively, or about 10% and 4% of the DOE derived concentration guides for radiation protection of the public (see the section entitled "Environmental Standards and Regulations"). These minimum detectable concentrations are also 20% and 8%, respectively, of maximum contaminant levels for community drinking water listed by the EPA in 1990.

Approximately 29% of all drinking water samples collected in 1990 contained detectable concentrations of gross alpha activity. Sixteen of the 54 boundary and distant water samples collected and analyzed by RESL in 1990 contained detectable gross alpha activity, and 100 of the 329 Site drinking water samples had detectable gross alpha activity. All detectable concentrations were lower than 5×10^{-9} μCi/mL and represent measurements near the minimum detectable concentration (see Appendix C). Annual gross alpha average concentrations for the 1990 samples at all locations were less than 2.5×10^{-9} μCi/mL, which is within the expected concentration range for naturally occurring alpha activity in the aquifer underlying the INEL and surrounding areas.[5] According to recent USGS reports,[6,7] alpha-emitting wastes from Site operations have not migrated far from their entrance into the aquifer near ICPP. Therefore, the offsite gross alpha activity is unlikely to be due to migration of wastes from Site operations, and all onsite drinking water wells lie outside the migration plumes for alpha-emitting nuclides. Gross alpha concentrations in all samples were less than the EPA community drinking water standard for gross alpha activity of 15×10^{-9} μCi/mL.

Forty-eight of the 329 Site samples and 14 of the 76 boundary and distant samples showed gross beta concentrations of $10 \pm 4 \times 10^{-9}$ μCi/mL or lower, i.e., near the minimum detectable concentration. At these low concentrations, it is difficult to draw firm conclusions about the presence of the radioactivity (see Appendix C). Annual averages for gross beta activity at all locations were below the EPA community drinking water standard of 50×10^{-9} μCi/mL.

Natural radioactivity is found in the Snake River Plain aquifer in areas upgradient, parallel to, and distant from the INEL Site. The natural radioactivity is the probable source of the presence of low concentrations of gross alpha and gross beta activity.

Specific Radionuclides—Tritium analyses are routinely performed on the water samples collected by RESL; and Sr-90 analyses are performed each month on samples from drinking water wells in the ICPP area because two of these wells lie within the Sr-90 waste plume as determined by the USGS. Figures 8 and 9 taken from USGS reports (References 7, 8) illustrate the approximate extent of the tritium and Sr-90 waste plumes. A waste plume is defined as the spread of various contaminants in the aquifer and perched water originating from INEL facilities. The drawing of plumes, such as those shown in Figures 8 and 9, utilizes judgment of competent professionals based on points of data from the wells shown. Scientists must interpret the data in order to represent it on maps. As seen in Figures 8 and 9, the 0.5-pCi/mL concentration contour, which represents the leading edge of each plume, was inside the Site boundary in 1988 for both Sr-90 and tritium.

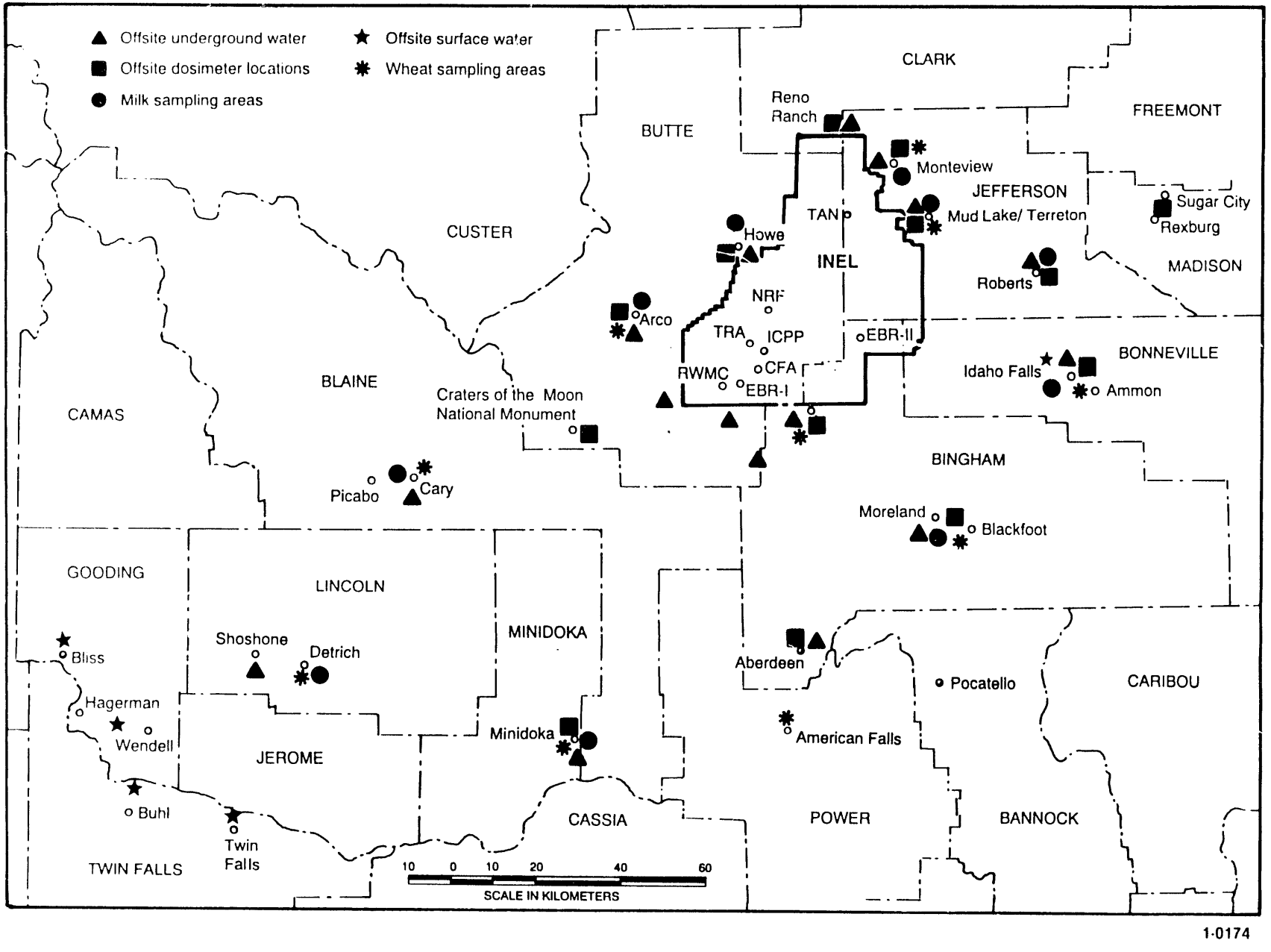

Figure 7. Boundary and distant water, milk, and wheat sampling locations and environmental dosimeter locations.

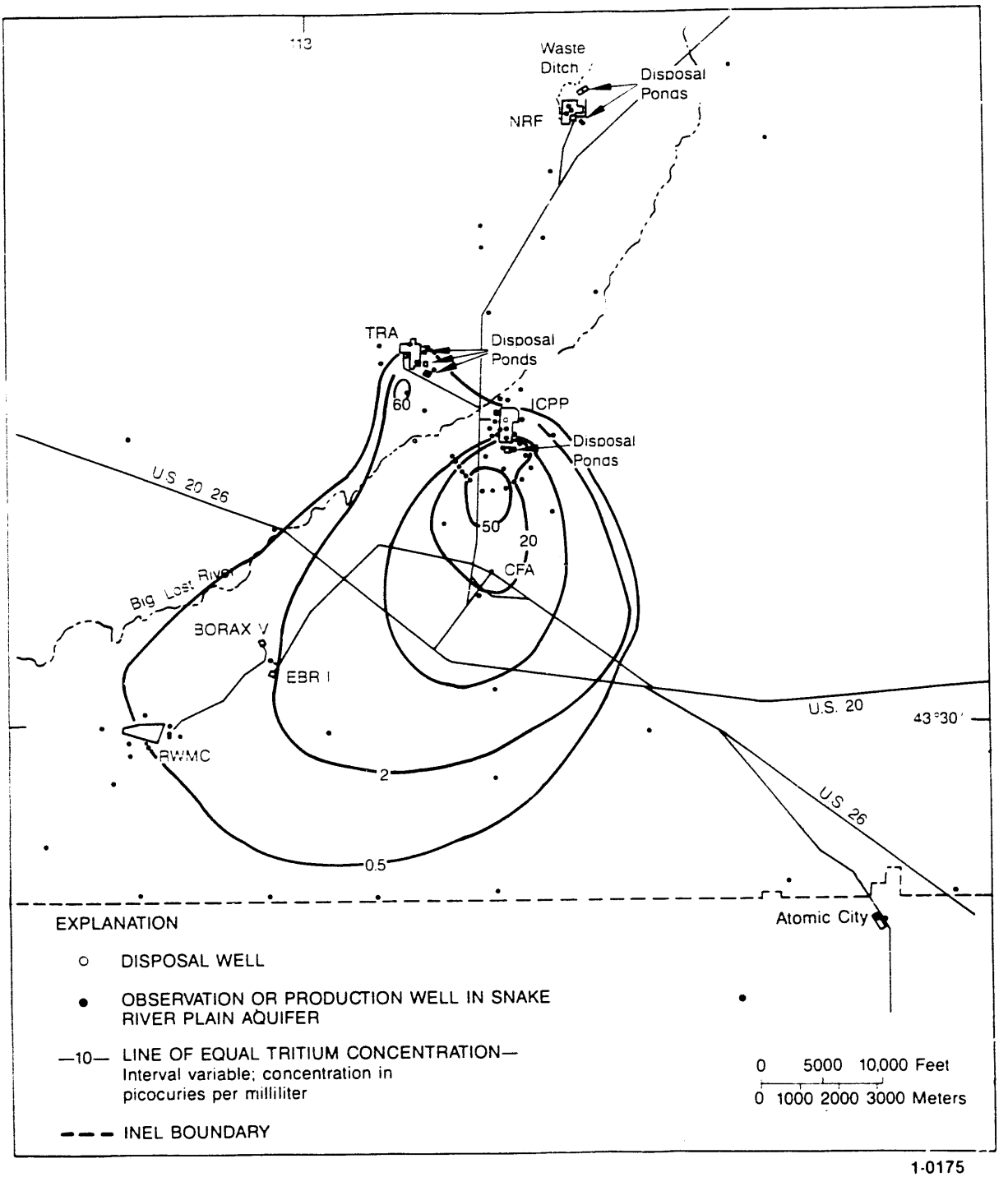

Figure 8. Distribution of tritium in the Snake River Plain aquifer in the southcentral part of the INEL, 1988 (Reference 8).

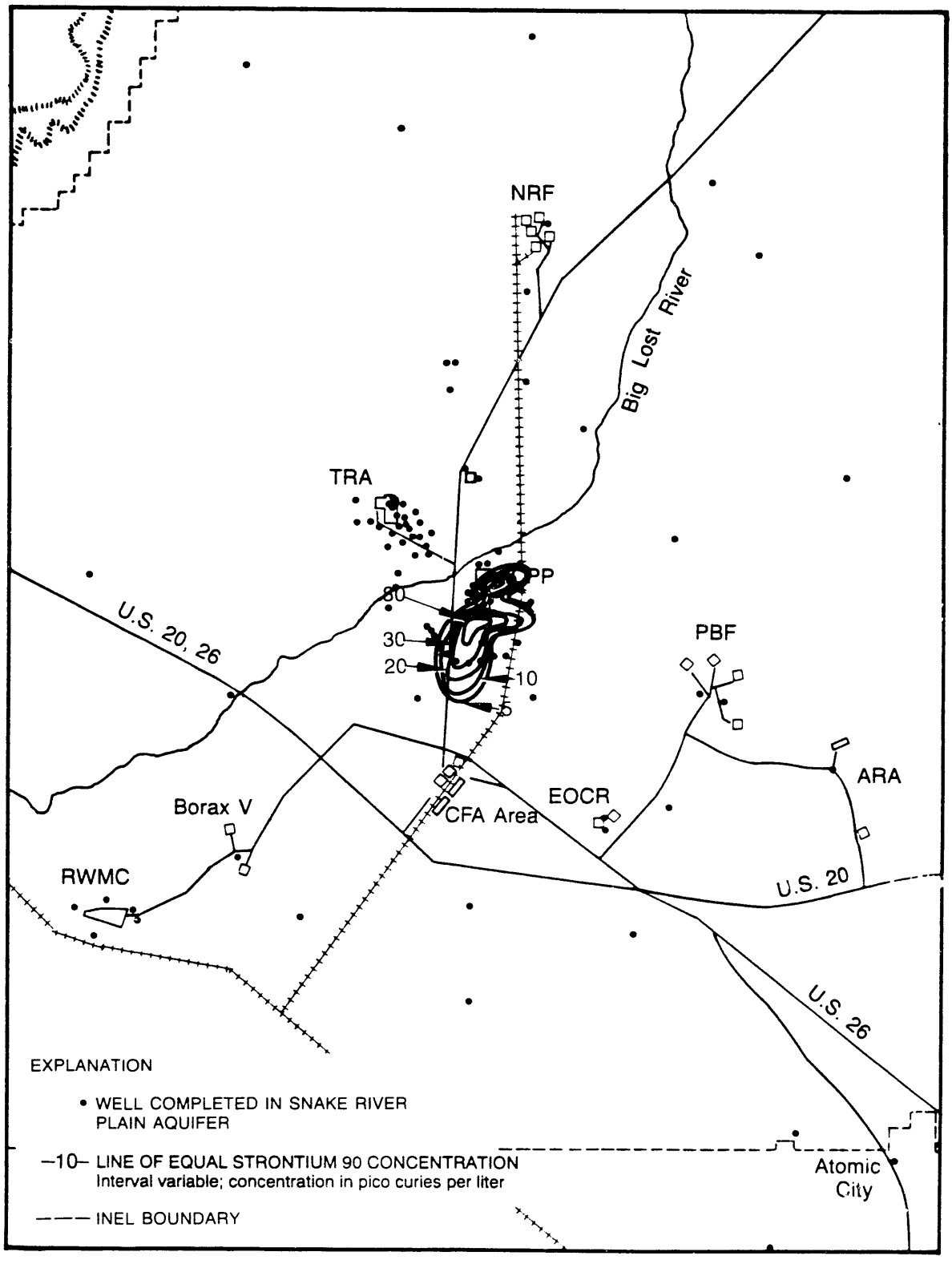

Figure 9. Distribution of Sr–90 in the Snake River Plain aquifer in the southcentral part of the INEL, 1988 (Reference 7).

Concentrations of tritium are determined by using a liquid scintillation counter. Strontium–90 is separated from the sample chemically and after an ingrowth period, its Y–90 daughter is separated chemically and counted in a low–background beta counter to determine the amount of Sr–90 initially present in the sample. The minimum detectable concentrations for tritium and Sr–90 are 4×10^{-7} and 5×10^{-10} µCi/mL, or about 0.02% and 0.05%, respectively, of the DOE derived concentration guides for radiation protection of the public. These minimum detectable concentrations are also 2% and 6%, respectively, of maximum contaminant levels for community drinking water listed by the EPA in 1990.

None of the boundary or distant community water samples contained detectable concentrations of tritium. Some samples from onsite wells that lie within the tritium plume consistently contain detectable concentrations of tritium. Data from these wells are presented in Table B–7, Appendix B. Samples from two of the ICPP production wells sometimes have detectable concentrations of Sr–90. These data are also presented in Table B–7. The highest annual average concentration of tritium in Site drinking water (at CFA) is 0.8% of the derived concentration guide for radiation protection. For Sr–90, the highest annual average concentration (at ICPP) was 0.07% of the derived concentration guide.

The USGS detected tritium in water samples from some of the observation wells just inside the southern Site boundary for the first time in 1983, but it has not been detected in samples collected from those wells since January 1986. In the nearest offsite well, which is about 0.8 km (0.5 mi) south of the Site boundary, tritium has never been detected above the minimum detectable concentration of 4×10^{-7} µCi/mL.

Strontium–90 analyses were above the minimum detectable concentration (5×10^{-9} µCi/mL) only for those samples collected within 3.2 km (2.0 mi) of the former disposal well at ICPP, or approximately 9.8 km (6.1 mi) inside the nearest Site boundary. As seen in Figure 8, those wells lie within the Sr–90 plume. Isotopes of cesium and plutonium are even less mobile in the aquifer than strontium, and the locations at which detectable concentrations of these isotopes can be detected are still near the point of entrance into the aquifer.

The effective dose equivalent from drinking water to a worker at CFA was calculated. CFA was selected because the tritium concentrations found in these wells are the highest of any drinking water wells. The current effective dose equivalent calculation was based on the 1990 average tritium concentration of 16.8×10^{-6} µCi/mL (16.8 pCi/L) in the samples from the CFA distribution system (Table B–7, Appendix B). CFA Well #2 was used for more than 96% of the drinking water at CFA during 1990. Although CFA #1 contained a detectable concentration of I–129 in the 1986 study, CFA #2 did not; therefore, no I–129 component appeared in the 1990 dose estimate. The assumption was made that each worker's total water intake came from the CFA #2 well. This assumption actually overestimates the dose because workers typically consume only about half their total intake during working hours, and they typically work only 240 days rather than 365 days per year. The estimated effective dose equivalent to a worker from consuming drinking water at CFA during 1990 was 0.77 mrem/year. This is clearly below the EPA standard of 4 mrem for community drinking water systems.

Foodstuff Sampling

General Information—Milk, wheat, and leafy garden lettuce are sampled annually. Muscle and liver samples from sheep are also collected annually. Muscle and liver samples from beef cattle are usually sampled biennially, but were not sampled in 1988 through 1990 because the grazing areas near the RWMC were not used due to drought conditions. Because they are part of the typical American diet, all these foodstuffs could be pathways to the public for radionuclides from fallout or from INEL operations. Boundary areas are compared to distant areas to assess possible impacts from INEL operations. Milk and wheat sampling locations are shown in Figure 7. Lettuce was collected at Arco, Atomic City, Blackfoot, Carey, Howe, Idaho Falls, Mud Lake, and Pocatello.

Milk—Milk samples (158 total) were collected from dairies and single–family milk cows in the INEL vicinity. Samples are normally collected monthly except in Idaho Falls, where a sample is collected weekly. All milk samples are passed through an anion exchange resin, which is then analyzed for I–131 by gamma spectrometry. Milk from each location is analyzed for Sr–90 and tritium annually. In addition to the tritium and Sr–90 analyses, three September samples, one each from Carey, Idaho Falls, and Mud Lake are submitted for I–129 analysis each year. For I–129 analysis, when the gamma spectrometric analysis of the three samples for I–131 is complete, the iodide is chemically stripped from the anion exchange resin, activated in a reactor to convert I–129 to I–130, and analyzed for I–130 by gamma spectrometry. During 1990 the "rabbit" loop of the reactor at the INEL used

for activation of the samples was removed from service and the I–129 analyses could not be done.

In 1990, no milk samples contained detectable concentrations of I–131, and none of the ten milk samples submitted for tritium and Sr–90 analyses showed detectable concentrations of those nuclides.

Lettuce—Lettuce samples were washed with water to remove any soil (as in normal food preparation) then dried and weighed. All lettuce samples were analyzed for Sr–90 and gamma–emitting radionuclides. No gamma–emitting radionuclides were found, and Sr–90 concentrations reported in most samples were at approximately the same levels as in past years. Comparison of average concentrations of Sr–90 for boundary and distant communities showed no statistical difference between the two groups. The Sr–90 results are shown in Table B–8, Appendix B.

Wheat—Wheat samples were weighed prior to analysis but not washed. No manmade gamma–emitting radionuclides were detected in any sample. All wheat samples were also analyzed for Sr–90; and results are shown in Table B–8, Appendix B. Average concentrations of Sr–90 in wheat were statistically the same for boundary and distant samples, and no major differences in concentrations were seen when compared to results of recent years.

Because concentrations of Sr–90 in lettuce and wheat samples were at typical levels and were statistically the same at distant and boundary locations, the origin of this radionuclide is assumed to be deposition of worldwide fallout on the soils of southeastern Idaho during past years.

Sheep—Muscle and liver samples were taken from sheep that had grazed onsite (see Figure 10). During 1990, two sheep were sampled from the southern area and two were taken from the eastern area of the INEL. In addition, two sheep from the Blackfoot area, which had never grazed on the INEL, were sampled as controls.

Cs–137 was detected near the minimum detectable concentration in the muscle tissue of one onsite animal at a concentration of $3 \pm 2 \times 10^{-8}$ μCi/g wet weight. This nuclide was not detected in the tissues of any other sheep sampled, nor were any other nuclides found in any sheep tissue samples for 1990. This concentration is similar to those seen in onsite, boundary, and control sheep from previous years.

Figure 10. Sheep grazing on the INEL.

Soil Sampling

To establish background levels of natural and fallout radioactivity in surface soil and to assess any potential buildup of radioactivity from Site operations, soil samples were collected annually from distant and boundary locations from 1970–78 (except 1972 and 1977). The biennial soil sampling program was established in 1978, and Figure 11 shows routine offsite sampling locations. A rotating seven-year schedule is used to sample onsite soils around major INEL facilities.

Soil samples collected in 1970, 1971, and 1973 represented a composite of five cores of soil from a 1-m^2 area. Each core was a cylinder 10 cm in diameter and 5 cm in depth. In all other years, the five cores were collected from a 100-m^2 area. A number of samples from the 5- to 10-cm depth were also collected.

Concentrations of natural radioactivity in the surface soil were reported in 1977.[9] The Th-232 and U-238 activities were determined from those of the progeny radionuclides, Ac-228 and Pb-214. Oakley[10] indicated that the average concentrations of uranium, thorium, and K-40 in the earth's upper crust, when translated from ppm to pCi/g, are 0.9, 1.1, and 17 pCi/g, respectively. The local soils averaged about 1.5, 1.3 and 19 pCi/g, respectively, values that are slightly higher in natural radioactivity than earth crustal averages. Although much of the surface rock on the Snake River Plain is basalt, the local soil is largely derived from silicic volcanics, which have higher uranium and thorium concentrations than basalt.

Estimates of the average external dose equivalent received from U-238 plus daughters, Th-232 plus daughters, and K-40 in average Site area soil were calculated to be 21, 28, and 27 mrem/yr, respectively, for a total of 76 mrem/yr. Because heavy snow cover can reduce the effective dose equivalent Idaho residents receive from the soil of the area, a correction for the snow cover reduction of the terrestrial dose is made in the following section entitled, "Environmental Radiation Measurements."

Currently all soil samples are analyzed for gamma-emitting radionuclides. All offsite surface samples (0–5 cm) are also analyzed for Sr-90 and alpha-emitting radionuclides. The soils are dried at least three hours at 120°C. Only soil particles less than 500 μm in diameter (35 mesh) are analyzed. The data are reported in units of activity per gram of soil (pCi/g dry weight) and also in units of areal activity (nCi/m^2), which is the total activity in each soil sample divided by the surface area (0.039 m^2) of the sample.

Surface soil concentrations of Cs-137, Sr-90, Pu-238, Pu-239/240, and Am-241, as measured from 1970–75, are compared to biennial samples since 1978 in Table B-9, Appendix B. The 1976 data are not included because the sampling locations used that year are not considered to be representative of the area. Three samples from 1984—Mud Lake No. 1, Mud Lake No. 2, and Crystal Ice Caves—were excluded from 1984 data because the concentrations were uncharacteristically low compared to previous years. This may have been caused by disturbance (farming, erosion, vehicular traffic, etc.) of the sampling locations. These sampling locations, plus the location at Monteview, were re-evaluated and moved to more representative undisturbed locations in 1986.

The boundary group average concentrations for 1990 were not statistically greater than the distant group concentrations for any radionuclide. It is concluded, therefore, that all of the radionuclides detected are present as a result of worldwide fallout.

Environmental Radiation Measurements

Thermoluminescent dosimeters (TLDs) are used to measure ionizing radiation exposures (beta greater than 200 keV and gamma greater than 10 keV). The TLDs measure ionizing radiation exposures from natural radioactivity in the air and soil, cosmic radiation from outer space, fallout from nuclear weapons tests, radioactivity from fossil fuel burning, and radioactive effluents from Site operations and other industrial processes.

At each location, a dosimeter card containing five individual Harshaw TLD-700 chips (3.18 × 3.18 × 0.89 mm) is placed 1 m above ground level. The dosimeter card at each location is changed semi-annually. There are seven distant community locations and six boundary locations (see Figure 7). The measured cumulative exposure for the time period from November 1989 to November 1990 for offsite locations is shown in Table B-10, Appendix B. For purposes of comparison, annual exposures from 1987–89 are also included for each location. As reported in the 1987 annual report,[11] dosimeter exposures for that year appeared unusually low as a group due to drift of the TLD reader used to analyze the TLD chips.

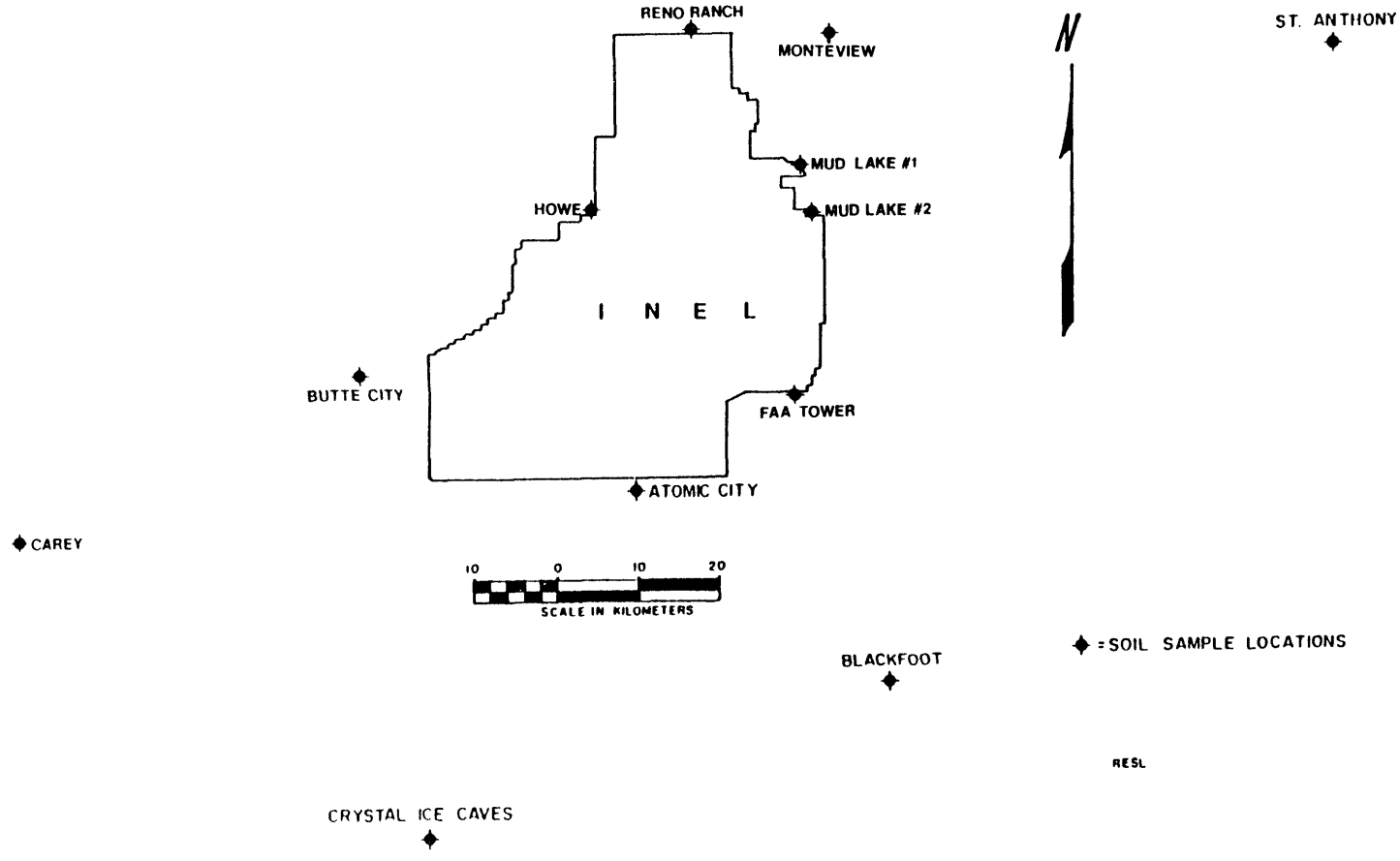

Figure 11. Soil sampling locations for the INEL vicinity.

The mean annual exposures for distant and boundary community locations in 1990 were 115 ± 9 mR and 115 ± 7 mR, respectively, as measured by TLDs. This exposure is approximately equivalent to 118 mrem when a dose equivalent conversion factor of 1.03[12] is used to convert from mR to mrem in tissue.

Table IV summarizes the calculated dose equivalent rate an individual receives on the Snake River Plain from various background radiation sources. The terrestrial portion of this value varies from year to year, depending on the amount of snow cover.[13] For 1990, the snow cover resulted in about a 7% dose reduction; the terrestrial background dose equivalent rate was calculated to be about 71 mrem.

The cosmic component varies primarily with altitude. The average annual dose equivalent of 26 mrem at sea level essentially doubles with each 2000 m (6560 ft) increase in altitude.[14] The INEL Site altitude is approximately 1500 m (4900 ft). The sum of the estimated terrestrial and cosmic components is 110 mrem, which is similar to the 118 mrem measured by TLDs at distant locations.

The component that varies the most is that of inhaled radionuclides. According to the National Council on Radiation Protection (NCRP) (Reference 13), the major radionuclides contributing to this component are short-lived decay products of radon, and the amount of radon in buildings and ground water depends upon the natural radionuclide content of the soil and rock of the area. There is also variation between buildings of a given geographic area depending upon the materials they contain, the amount of ventilation and air movement, and other factors. The U.S. average of 200 mrem has been used in Table IV for this component of the total background dose because no specific estimate for southeastern Idaho has been made, and measurements in homes in this area are few. Therefore, the effective dose equivalent from natural background radiation for residents in the INEL vicinity may actually be higher or lower than the 350 mrem shown and will vary from one location to another.

Game Species

Hunting and fishing are not usually allowed on the INEL Site. However, beginning in 1989, an exception was made by permitting hunter access to one-half mile within the northern INEL boundaries facilitating access to the adjacent farm lands. This portion of the

TABLE IV
ESTIMATED NATURAL BACKGROUND EFFECTIVE DOSE EQUIVALENT (1990)

Source of Radiation Dose Equivalent	Total Average Annual Effective Dose Equivalent (mrem) Estimated[a]	Measured (TLD)[b]
External Terrestrial[c]	71	—
Cosmic[d]	39	—
Subtotal	110	118
Internal Cosmogenic[e]	1	
Inhaled radionuclides[f]	200	
K-40 and others	39	
Subtotal	240	
Total	350	

a. Total average annual effective dose equivalents for components as estimated in NCRP Report No. 93.[14]

b. For conversion from mR in air to mrem in tissue, the dose equivalent coversion factor used was 1.03.

c. The terrestrial component for the INEL Site vicinity is based upon soil sampling for natural radionuclides in 1976, and a correction for snow cover during winter months of 1989.

d. The cosmic component is derived from the estimate in NCRP Report No. 93.[14]

e. The cosmogenic component is due primarily to C-14 in tissues and is uniform globally.[14]

f. The inhaled radionuclides component varies widely with geographic location. The 200 mrem shown represents the U.S. population average.[13]

INEL was part of an offsite hunting unit for pronghorn and elk in 1989 and for pronghorn only in 1990. The hunts were scheduled in response to farmers' claims of significant big game animal depredation and were negotiated between the Idaho Department of Fish and Game and DOE-ID. Just prior to the 1989 pronghorn hunt, RESL collected three antelope from farms adjacent to the INEL and submitted tissue samples for analysis to document radionuclide concentrations, if any. No manmade radionuclides were detected in the edible tissues of any of the animals.

By migrating to and from the Site, game animals represent a potential, but not very likely, exposure pathway. The probability that an individual in the population would consume an animal containing

detectable amounts of radioactivity is small because most animals that migrate from the INEL do not contain elevated levels of contaminants. While onsite, some game animals may use the waste infiltration ponds at TRA and ICPP for water. Although the ponds are fenced to exclude antelope, the TRA fence may not exclude all deer. Neither, of course, do the fences exclude game birds, which have used the ponds in the past for resting and feeding sites. Larger game animals may also ingest vegetation and soil that has been contaminated by Site operations. However, these particular animals are not likely to be harvested before the radionuclides have been eliminated from their bodies.

Data from game species may be obtained as part of DOE research programs rather than as part of the routine environmental surveillance program. Generally, data from only road-killed animals are summarized in this report. Results from the radioecology and ecology research programs, which use the expertise of university faculty and graduate students, are reported in the scientific literature and supplement the results of the routinely scheduled environmental monitoring included in this report. Results from some of the radioecology studies that investigated potential doses to man from game animals migrating from the Site are discussed in the section entitled "Maximum Individual Dose—Game Animal Pathway."

Muscle and liver samples from three mule deer, ten pronghorn antelope, and two elk, all killed by vehicles on Site roads in 1990, were submitted for analysis by gamma spectrometry.

Among the ten pronghorn onsite road-kills, two had detectable concentrations of Cs-137 in muscle tissue at $1.2 \pm 1.0 \times 10^{-8}$ μCi/g and $2.0 \pm 0.8 \times 10^{-8}$ μCi/g wet weight. None of the other pronghorn tissues sampled contained manmade radionuclides, and no manmade radionuclides were found in the tissues of the road-killed elk or mule deer.

While it is known that the soil around some facilities is contaminated with Cs-137, this nuclide was also a constituent of worldwide fallout during atmospheric weapons testing and has been found in the soil at locations distant from the Site. As a result, game animals sampled from offsite distant areas (control animals) occasionally contain Cs-137 in their muscle and liver tissues. The 1980 monitoring report gave the average concentrations of Cs-137 found in tissues of control animals sampled in studies of earlier years as 3.8×10^{-8} μCi/g for muscle and 4.7×10^{-8} μCi/g for liver tissues. The two onsite pronghorn sampled in 1990 with detectable Cs-137 in muscle tissues had concentrations lower than those levels.

No fish were collected from the portion of the Big Lost River within the INEL boundaries during 1990 because it was dry the entire year.

Summary of Radioactive Effluent Monitoring

Radionuclides in airborne and liquid effluents released to the environment are carefully monitored at potentially significant release points. Effluent monitoring is summarized in Appendix H of Reference 15. The Radioactive Waste Management Information System reports the results of the effluent monitoring by month, facility, and radionuclide.

A summary of the radionuclides released to the atmosphere from Site facilities in 1990 is shown in Table B-11, Appendix B. Because of radioactive decay of the short-lived radionuclides and the overestimation of Kr-85 releases for classification reasons, the activity that would reach offsite areas is less than the 24,000 Ci (9×10^{14} Bq) indicated in Table B-11. The ICPP and TRA facilities were the source of about 97% of the total radioactivity released to the atmosphere. Noble gases comprised more than 99% of the total airborne radioactive effluent.

Air emissions from nonpoint sources (RWMC, TRA ponds, and ICPP ponds) were evaluated. None of these sources emitted sufficient amounts to warrant including the effluents in the dose calculations.

The total annual airborne radioactive effluent varies from year to year, depending on which processes are active at INEL facilities. The 1990 annual total of less than 24,000 Ci was a little higher than the 1989 total. The difference is due to a small increase in the amount of noble gases, primarily Ar-41 released from TRA. For purposes of comparison, total airborne radioactive effluent releases for the past five years were as follows: 1986--14,500 Ci, 1987--less than 165,000 Ci, 1988—less than 124,000 Ci, 1989—less than 22,000 Ci, and 1990—less than 24,000 Ci.

No liquids were released directly to the offsite environment. Onsite releases are summarized in Table B-12, Appendix B. Most liquid radioactive effluents are discharged into seepage ponds. The effluent listed for CFA is discharged through a sewage treatment facility. Site-related radioactive liquids have not been detected outside the INEL boundaries, with

the possible exception of Cl–36 (see the section entitled "Ground–Water Surveillance Program Information").

Assessment of Potential Radiation Dose to the Public

General Information

Usually, the radiological impact of INEL operations on the resident public surrounding the Site has been too small to be measured by the routine monitoring program. Therefore, the radiological impact of INEL operations by the air pathway has traditionally been estimated using the known amounts of various radionuclides released during the year from Site facilities and appropriate air dispersion models, described in the next section, to determine the concentrations at selected locations in the vicinity. During 1990, this was done for the radionuclides released from Site facilities to the atmosphere, as summarized in Table B–11, Appendix B.

Because of the different applicable standards for radiation protection of the public (see the section entitled "Environmental Standards, Regulations, and Permits") and reasons discussed below, RESL uses two different air dispersion models to calculate the

- effective dose equivalent to the maximally exposed individual residing offsite using the EPA–required CAP–88 model
- effective dose equivalent to the maximally exposed individual residing offsite using the MESODIF dispersion model[16]
- collective effective dose equivalent (population dose) within an 80–km (50–mi) radius of the operations center of the Site (TRA and ICPP) using the MESODIF dispersion model.

For simplicity, the term *dose* will mean *effective dose equivalent* in the following dose assessment sections, unless another term is specifically stated. The effective dose equivalent was calculated by summing the committed dose equivalents to organs, each multiplied by a weighting factor that is proportional to the organ's radiosensitivity. The effective dose equivalent includes doses received from both external and internal sources and represents the same risk as if an individual's whole body were irradiated uniformly. DOE dose conversion factors and a 50–yr integration period are used for internally deposited radionuclides and for radionuclides deposited on ground surfaces in calculations with both air dispersion models. Because the hypothetical effective dose equivalent to the maximally exposed individual residing near the INEL is so low, no allowance was made for shielding by housing materials or residence time in the community in any of the calculations using the MESODIF dispersion model. The CAP–88 code which is used by all sites, regardless of the magnitude of the hypothetical dose, does include a factor to allow for shielding and occupancy time.

The possible exposure pathways by which radioactive materials from Site operations could be transported to offsite environs are shown diagrammatically in Figure 12. No surface streams flow from within the INEL to offsite locations. The leading edge of the tritium plume (shown earlier in Figure 8), the most mobile low–level radioactive waste in the aquifer, reached the Site boundary in 1983 at low concentrations. However, tritium from the INEL has never been detected in any of the wells south of the boundary. Thus, atmospheric transport is the principal potential exposure pathway from the Site and is described in the section "Maximum Individual Dose––Airborne Emissions Pathway Only."

Several indirect exposure pathways are being studied at the INEL to determine their effect, if any, on the highest possible dose that could have been received by a member of the public. The principal indirect exposure pathway involves eating animals of game species that have spent time on the Site. Radioactivity present in game species depends upon the length of residence at each onsite location, the time elapsed since migration from the Site, and the metabolism of the animal. Estimates of the maximum potential dose to a person consuming meat from different game animals is described in the section "Maximum Individual Dose—Game Ingestion Pathway."

Maximum Individual Dose—Airborne Emissions Pathway Only

During 1990, EPA regulations (Reference 1) were in effect that limited the amount of airborne radionuclides released from DOE facilities to that which will produce an effective dose equivalent of 10 mrem/yr to any member of the public. The EPA has specified that the CAP–88 computer code be used to demonstrate compliance unless an alternate model has been approved by the Administrator of the EPA.

Using the CAP–88 code and ICPP and TRA emissions, a 1990 hypothetical effective dose equivalent of 0.001 mrem (1×10^{-5} mSv) was calculated for

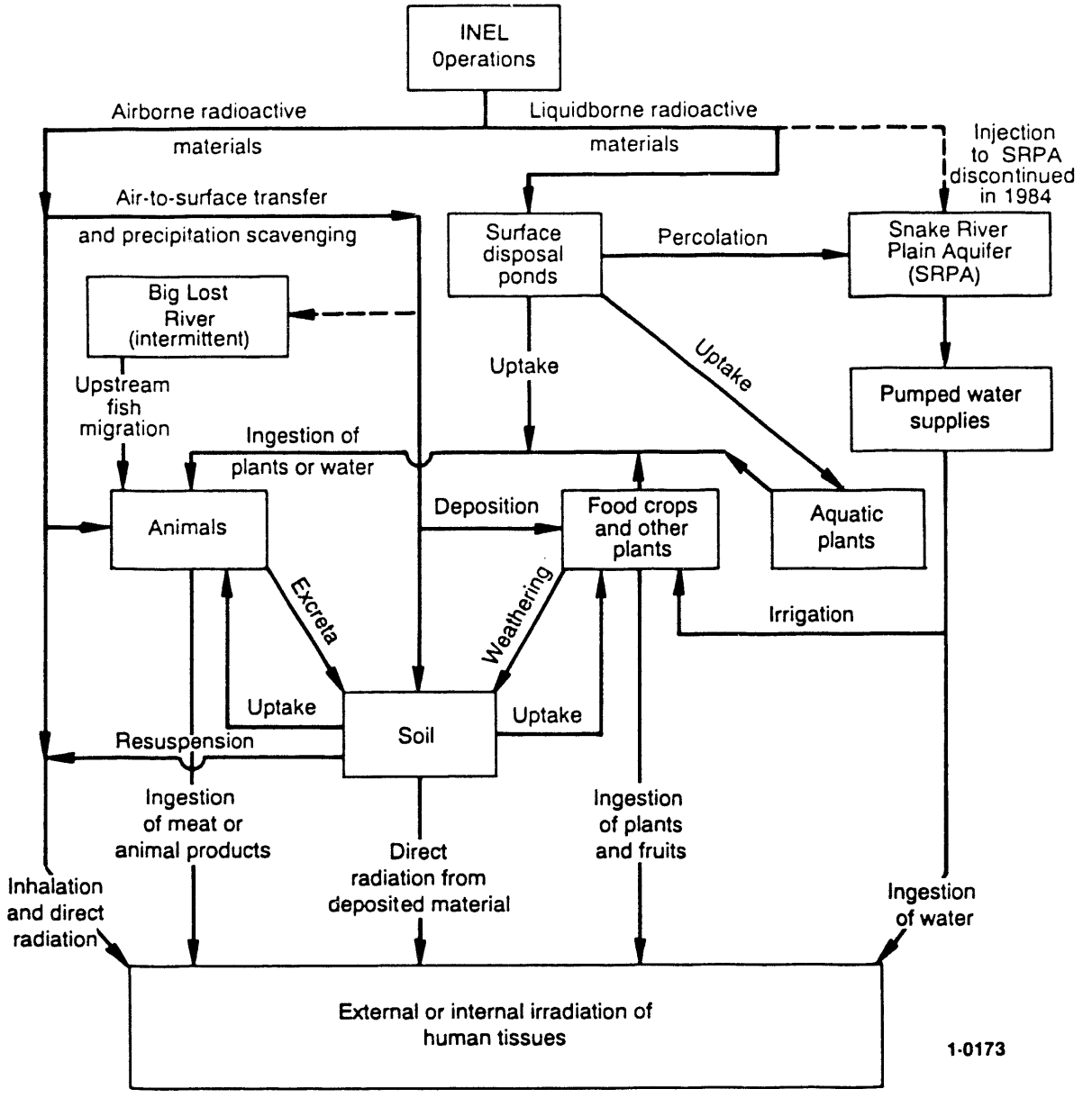

Figure 12. Detailed diagram of possible exposure pathways of the INEL Site radioactive materials to members of the public.

a member of the public at Atomic City, Idaho, 19 km (12 mi) southeast of the operations center of the INEL Site. This dose is 0.01% of the EPA radiation protection standard. ICPP and TRA emissions were summed for 1990 because they represented more than 97% of the total INEL emissions, and Atomic City is the location of the nearest offsite resident to both facilities.

This dose calculation uses a different approach from that used for demonstrating compliance for the 1990 NESHAPs report. Because the INEL operations are spread over a wide area, the potential offsite doses occur at a variety of receptor (nearest resident) locations. For the NESHAPs report, the offsite dose was calculated for the nearest resident to each INEL facility that reported airborne releases in 1990, and then the doses from all facilities were summed. The total dose of 0.0017 mrem (1.7×10^{-5} mSv) assumes that an individual resides at all offsite receptor locations simultaneously. This is a conservative or maximizing approach rather than a realistic approach. The calculation in this section for a resident of Atomic City based on ICPP and TRA emissions is more realistic. A more thorough discussion of the NESHAPs

calculations appears in the 1990 INEL NESHAPs Annual Report submitted to EPA on June 30, 1991.

The MESODIF air dispersion model has been used for 18 years to calculate doses to members of the public residing near the INEL. It is included here to allow comparison to previous years. Although the MESODIF model usually calculates somewhat higher doses to the public than the EPA–approved models, the more complicated puff Gaussian plume model used in MESODIF appears to be more appropriate to air dispersion at the INEL than the straight–line Gaussian Plume model used in the air dispersion portion of the CAP–88 model. The doses and offsite concentrations calculated using the MESODIF model were compared to monitoring results at offsite locations in 1986, 1987, and 1988 with good agreement. A detailed discussion of differences between the two air dispersion models was given in the 1986 annual report.[17] The MESODIF diffusion curves, developed from tests at the INEL and Hanford desert environments, appear to be more appropriate for the INEL Site. Therefore, the effective dose equivalent calculated using the MESODIF model is included in this report as well as the value calculated using the EPA–required model.

The mesoscale meteorological map (Figure 13) shows the calculated 1990 concentrations normalized to a unit release rate for the INEL Site and vicinity. This map has been prepared by the National Oceanic and Atmospheric Administration (NOAA) at the INEL using the MESODIF model and data gathered continuously at meteorological stations on and around the Site. To facilitate the display, the dispersion coefficient values are given in whole numbers and must be multiplied by 10^{-9} h^2/m^3. To obtain the average air concentration (Ci/m^3) for a radionuclide released from TRA or ICPP along any dispersion coefficient isopleth in Figure 13, the value of the 1990 average dispersion coefficient (e.g., 30×10^{-9} h^2/m^3) was multiplied by the number of curies of the radionuclide released during 1990 and divided by the number of hours in a year squared (7.67×10^7).

As indicated in Figure 13, the MESODIF model predicts that the highest concentrations of radionuclides in air for an inhabited area would occur at Atomic City, Idaho. The maximum hypothetical dose was calculated for an adult resident of that location from inhalation of air, submersion in air, ingestion of radioactivity on leafy vegetables, and exposure due to deposition of particulates on the ground surface. The calculation was based on data presented in Table B–11 and Figure 13. Using 24×10^{-9} h^2/m^3 as the dispersion coefficient for Atomic City and allowing for radioactive decay during the 19–km (12–mi) transit of the radionuclides from the TRA–ICPP complex to the Atomic City location, the potential effective dose equivalent from all radionuclides released was calculated to be 0.006 mrem (6×10^{-5} mSv) (see Table V). This dose is 0.006% of the DOE radiation protection standard for a prolonged period of exposure to a member of the public from all pathways and 0.06% of the EPA standard. The 1990 air dispersion coefficient for Atomic City was lower than the usual value in the past. According to NOAA, the difference is most likely because they have begun using the EPA–approved calculation method for stability classes rather than their previous method which assumed clear skies each day. (No data for cloud cover is available.) This leads to a smaller number for dispersion coefficients at data stations.

The ICPP was not operating for most of calendar year 1990, thus TRA releases result in the highest proportion of the doses for this year as in some previous years. In 1989, about 60% of the 0.007–mrem computed dose was due to Argon–41, which was also the major contributor to the 1990 dose. Figures 14 and 15 illustrate the proportion of specific nuclides comprising the maximum individual dose for 1989 and 1990, respectively.

One of the parameters necessary to convert air concentrations into dose equivalents is the deposition velocity—the rate at which the particulates are deposited on the surface of the ground. For the calculations based on the MESODIF model, a deposition velocity for particulates of 0.18 cm/s was used, which is consistent with other INEL dose assessments. A deposition velocity for elemental iodines of 1.8 cm/s was used. Organic iodides, which make up two–thirds of the ICPP I–129 releases, have a much lower deposition velocity to ground surfaces (0.018 cm/s).

The effective dose equivalent for 1990 for a resident of Atomic City, calculated using CAP–88, is 0.001 mrem (1×10^{-5} mSv) and the dose using MESODIF is 0.006 mrem (6×10^{-5} mSv). As discussed earlier, there are differences in the atmospheric dispersion portions of the two codes, and RESL has chosen to use the MESODIF doses for comparison to standards. The effective dose equivalent calculated by CAP–88 is primarily due to Ar–41 and Kr–85.

The calculated dose (0.006 mrem) resulting from INEL operations is very small compared to the measured 118 mrem average dose individuals in southeastern Idaho received from cosmic and terrestrial radiation during 1990. The calculated dose is even smaller compared to the total estimated effective dose equivalent from natural background radiation of

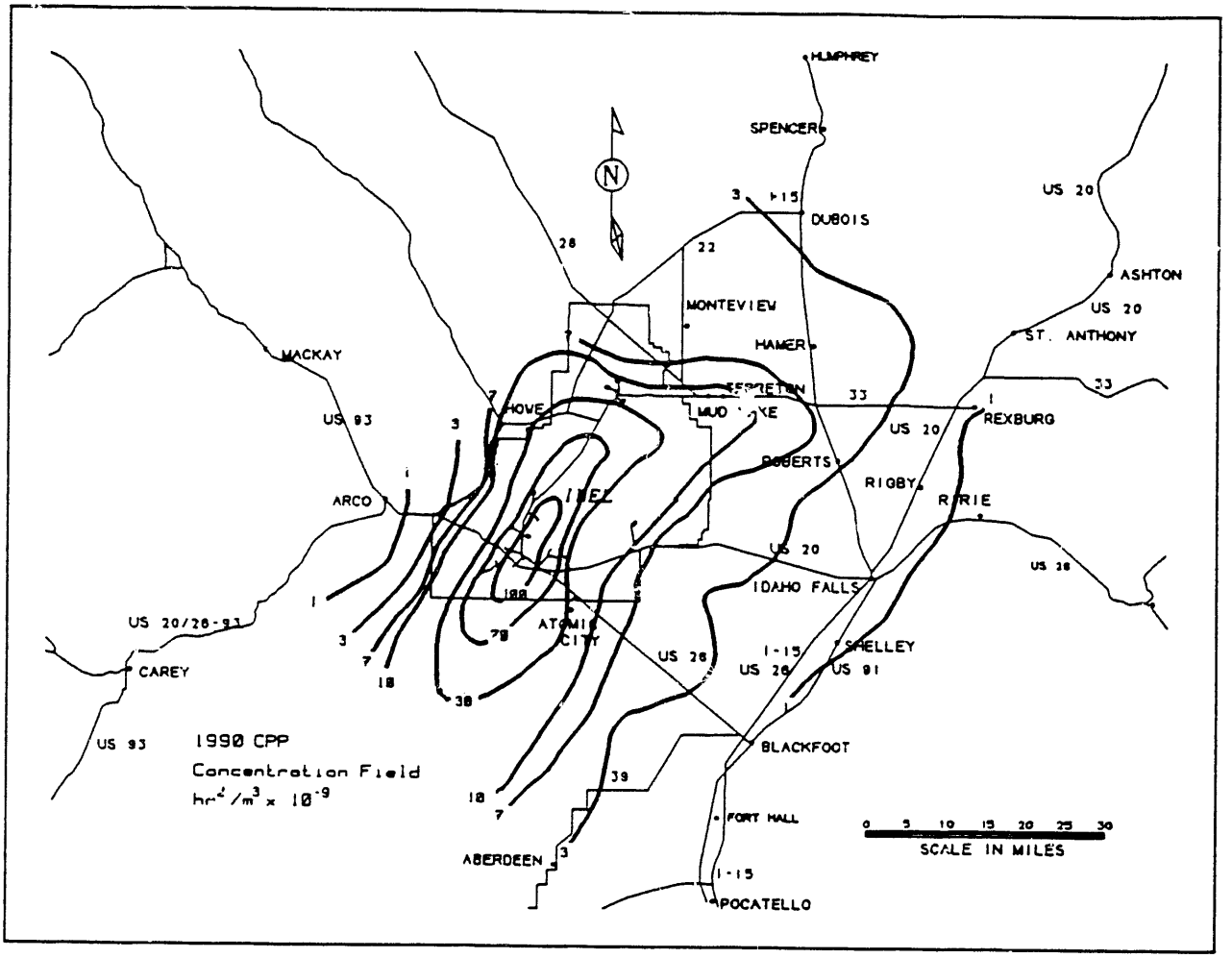

Figure 13. 1990 average of mesoscale dispersion isopleths of air concentrations at ground level, normalized to unit release rate.

350 mrem (see Table IV). For perspective, the calculated dose may also be compared to the approximately 30–mrem average dose received from medical diagnostic procedures, the 4–mrem average dose received from highway and road construction materials, and the 0.04 to 0.1 mrem received from luminous watches and clocks.[14] Another source has estimated that the average five–hour jet flight contributes a dose of about 0.7 mrem to passengers, and that the average television viewer receives about 0.05 to 0.1 mrem annually.[18]

Maximum Individual Dose—Game Ingestion Pathway

Potential dose to an individual from occasional ingestion of meat from game animals continues to be investigated. One group of studies involves the calculation of potential doses to individuals who might eat ducks that reside briefly upon liquid waste ponds used for the disposal of low–level reactor effluents. In one study, wild ducks using liquid waste ponds at TRA were collected. The average potential whole body dose equivalent from gamma–emitters due to consumption of the meat of cooked ducks (not including the juices in the pan) was calculated to be 10 mrem.[19]

In another study, wing–clipped mallards were released on the TRA pond for 56–188 days before collection. Various tissues were analyzed for concentrations of Sr–90, Pu–238, Pu–239/240, Am–241, Cm–242, and Cm–244. The potential effective dose equivalent to a human consuming the entire muscle and liver mass of one experimental duck with average nuclide concentrations was 0.046 mrem from those specific nuclides.[20] In the most recent study, migratory waterfowl were collected from several ponds onsite ranging from the sewage disposal pond at NRF, where no radioactive contamination was expected, to the

TABLE V
MAXIMUM INDIVIDUAL EFFECTIVE DOSE EQUIVALENT (1990)

Radionuclide[a]	Maximum Offsite Concentration[b] (μCi/mL)	Maximum Effective Dose Equivalent[c] (mrem)	(mSv)
Ar–41	7.1×10^{-13}	0.0047	5×10^{-5}
Kr–88 + D	2.2×10^{-14}	0.0004	4×10^{-6}
I–129	3.7×10^{-19}	0.0002	2×10^{-6}
Xe–138 + D	3.4×10^{-15}	0.0002	2×10^{-6}
Kr–87	1.7×10^{-14}	0.0001	1×10^{-6}
Xe–135	5.7×10^{-14}	0.0001	1×10^{-6}
Kr–85	6.3×10^{-12}	0.0001	1×10^{-6}
Rounded Totals		0.006	6×10^{-5}

a. Table includes only radionuclides that contribute a dose of 0.0001 mrem (1×10^{-6} mSv) or more. When indicated (+ D), the contribution of daughter decay products was included in the dose calculations.

b. Estimate of radioactive decay obtained by using the 1990 average windspeed from 315°–325° of 18.84 km/h and a distance of 19.1 km from TRA–ICPP to the Atomic City area, the location where the hypothetical maximally exposed individual would have resided. For nuclides where parent–daughter equilibria were used in dose calculations, concentration of the parent is shown.

c. Effective dose equivalent estimated using dose conversion factors for inhalation and ingestion from Reference 31 and dose conversion factors for submersion and deposition from Reference 32.

radioactive waste pond at TRA. Several tissues from these birds were analyzed for gamma–emitting radionuclides. The predicted committed effective dose equivalent to an individual eating the entire muscle and liver mass of the most contaminated duck (collected from the TRA radioactive waste pond) was 5.0 mrem (0.050 mSv). The average predicted committed effective dose equivalent, based on all waterfowl in the study, was 0.27 mrem (0.0027 mSv).

During a previous study, it was determined that Idaho hunters harvest about 25,000 ducks per year, of which about six have spent time on INEL ponds.[21] Since the volume and surface area of TRA ponds have decreased, and since other less–contaminated ponds have been constructed nearby, the number of ducks visiting the TRA ponds has most likely decreased

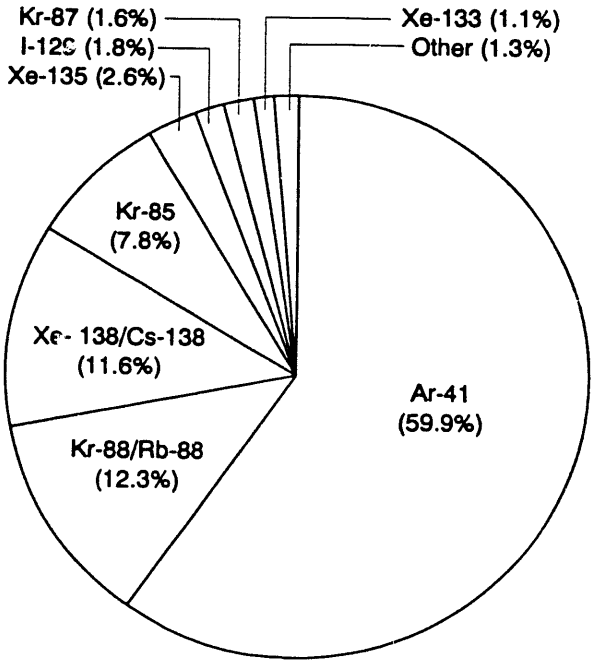

Figure 14. Nuclides contributing to maximum individual dose in 1989.

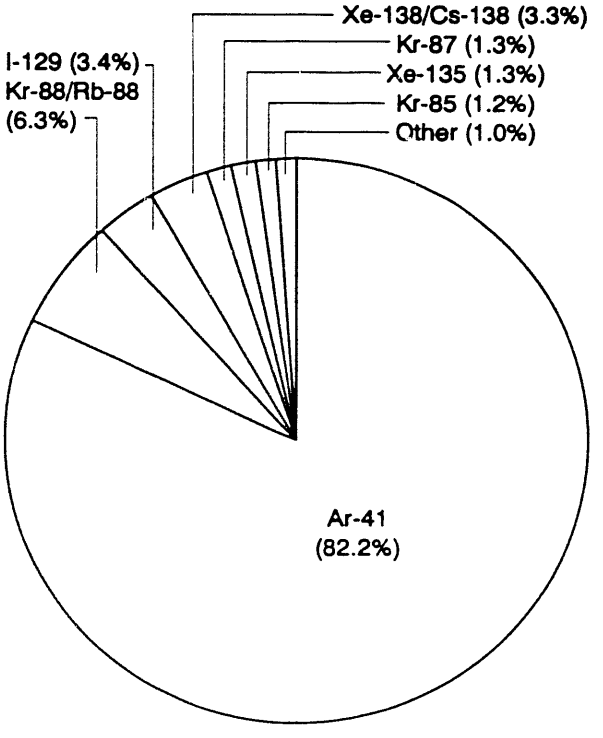

Figure 15. Nuclides contributing to maximum individual dose in 1990.

since that study was done. The doses calculated above are based on the assumption that the duck would be killed and eaten immediately after leaving the pond. It is very unlikely that a duck would be killed immediately after leaving the pond, so a lower dose would be more realistic due to biological elimination of the radioactivity. For example, the largest contributor to the dose, Cs–137, has an effective half–life in ducks of 11.2 days.[22] This means that half of the Cs–137 present when a given duck leaves the pond would be eliminated in 11.2 days. At the end of the next 11.2 days, half of the remaining radioactivity (or one–fourth of the original activity) would be eliminated, and so on until the amount of Cs–137 present in the duck's tissues can no longer be detected.

The highest estimated potential whole–body dose equivalent to a person eating the entire muscle mass of a sage grouse that summered near the TRA–ICPP area is 2 mrem.[23] The maximum whole–body dose equivalent from consumption of sage grouse from other onsite locations and offsite areas ranges from 0.01 to 0.04 mrem.

The maximum potential whole–body dose equivalent to a person eating the muscle tissue of one mourning dove from the TRA pond area is 0.3 mrem. The average whole–body dose equivalent to people consuming doves migrating from onsite to offsite areas is 0.01 mrem, which is the same as for control birds collected far from the INEL.[24]

A conservative (or high) estimate of the potential whole–body dose equivalent which could be received by a single individual eating the entire muscle and liver mass of an antelope (collected on the INEL after August 1975) with the highest levels of radionuclides is 0.2 mrem.[25]

80–Kilometer Population Dose

An estimate was made of the collective effective dose equivalent (population dose) from inhalation, submersion, ingestion, and deposition that could have been received by all members of the public within an 80–km (50–mi) radius of the TRA–ICPP complex. This population dose (person–rem) is calculated by a computer program that multiplies the population number in each square mile[26] by the MESODIF dispersion coefficient at that point (h^2/m^3) and the normalized dose received at the location of the maximally exposed individual (rem per year/h^2 per m^3). The calculation overestimates dose, however, because radioactive decay of the isotopes was not calculated during transport over distances greater than the 19 km (12 mi) from the TRA–ICPP midpoint to the Atomic City maximum location. Idaho Falls, for example, is about 66 km (41 mi) from TRA–ICPP. Neither residence time nor shielding by housing was taken into account when calculating the maximum dose (using the MESODIF model) on which the collective dose is based.

The 1990 population dose within each census division (see Table VI) was obtained by summing the results from appropriate areas contained within those divisions. The total 80–km (50–mi) population dose was the sum of population doses for the various census divisions. The estimated potential population dose was 0.04 person–rem (4×10^{-4} person–Sv) to a population of about 121,000. When compared with an approximate population dose of 42,400 person–rem (424 person–Sv) from natural background radiation, this represents an increase of only about 0.00009% (9×10^{-5}%). The dose of 0.04 person–rem can also be compared to the following estimated population doses for the same size population: 3600 person–rem for medical diagnostic procedures, about 480 person–rem from exposure to highway and road construction materials (see Reference 14) or 6 to 12 person–rem for television viewing (see Reference 18).

Table VII summarizes the calculated annual effective dose equivalents from 1990 INEL operations for both CAP–88 and MESODIF calculational methods.

The contribution of game animal consumption to the population dose has not been calculated because only a small percentage of the population hunts game, few of the animals killed have spent time on the INEL, and most of the animals that do migrate from the INEL have background concentrations of radionuclides in their tissues. The total population dose contribution from these pathways would, realistically, be less than the sum of population doses from inhalation of air, submersion in air, and deposition on soil.

TABLE VI
80–KILOMETER POPULATION DOSE (1990)

Census Division	Population[a] 1990	Population Dose[b] (person–rem)	Population Dose[b] (person–Sv)
Aberdeen	2850	0.0020	2.0×10^{-5}
Alridge (part)	160	0.000020	2.0×10^{-7}
American Falls (part)	110	0.000057	5.7×10^{-7}
Arco	2950	0.00062	6.2×10^{-6}
Atomic City (city)	35	0.00013	1.3×10^{-6}
Atomic City (division)	2300	0.00024	2.4×10^{-6}
Blackfoot	13,380	0.0035	3.5×10^{-5}
Carey	120	0.000008	8×10^{-8}
Challis	10	0	0
Firth	3720	0.00081	8.1×10^{-6}
Fort Hall (part)	3930	0.00065	6.5×10^{-6}
Hamer	2590	0.0047	4.7×10^{-5}
Howe	450	0.0020	2.0×10^{-5}
Idaho Falls	62,060	0.018	1.8×10^{-4}
Idaho Falls West	2060	0.00023	2.3×10^{-6}
Leadore	15	0.000011	1.1×10^{-7}
Lewisville–Menan (part)	2440	0.00067	6.7×10^{-6}
Mackay	1100	0.000015	1.5×10^{-7}
Moreland	8500	0.0041	4.1×10^{-5}
Rigby	640	0.00015	1.5×10^{-6}
Roberts	1430	0.0014	1.4×10^{-5}
Shelley	6550	0.0017	1.7×10^{-5}
Ucon	3690	0.00087	8.7×10^{-6}
West Clark	90	0.00018	1.8×10^{-6}
Totals	121,180	0.042	4.2×10^{-4}

a. Population for each division was based on the 1980 Advance Census Report for Idaho adjusted to estimated 1990 levels. The 1990 census report was not yet available at press time.

b. These population doses do not include radioactive decay beyond 19.1 km.

TABLE VII
SUMMARY OF ANNUAL EFFECTIVE DOSE EQUIVALENTS DUE TO 1990 INEL OPERATIONS

	Maximum Dose to an Individual[a]		Collective Dose to Population within 80 km
	MESODIF[b]	CAP–88[c]	MESODIF
Dose	0.006 mrem (6×10^{-5} mSv)	0.001 mrem (1×10^{-5} mSv)	0.04 person–rem (4×10^{-4} person–Sv)
Location	Atomic City	Atomic City	Area within 80–km circle
Applicable Radiation Protection Standard[d]	10 mrem	10 mrem	—
Percentage of Standard	0.06%	0.01%	—
Natural Background	350 mrem (3.5 mSv)	350 mrem (3.5 mSv)	42,400 person–rem (424 person–Sv)
Percentage of Background	0.0017%	0.0003%	0.00009%

a. Hypothetical dose to a maximally exposed individual residing near the INEL. Calculations do not consider occupancy time or shielding by buildings.

b. Effective dose equivalent calculated with the MESODIF air dispersion model used for 18 years to calculate doses to members of the public residing in the INEL vicinity.

c. Effective dose equivalent calculated using the CAP–88 code required to demonstrate compliance.

d. Although the DOE standard for all exposure modes is 100 mrem/yr as given in DOE Order 5400.5,[3] DOE guidance states that DOE facilities will comply with the EPA standard of 10 mrem/yr.

GROUND–WATER SURVEILLANCE PROGRAM INFORMATION

General USGS Program Information

No streams or rivers flow from within the INEL to locations outside the boundaries. Therefore, water sampling is limited to onsite and offsite ground–water monitoring plus samples from the Snake River and other surface streams and tributaries in the INEL vicinity, some of which flow onto the Site and sink into its porous soils. A brief description of the hydrogeology of the INEL and the movement of water in the Snake River Plain aquifer is given in Appendix A. Further information may be found in References 6 and 7. The Snake River Plain aquifer, which lies beneath the INEL, serves as one of the primary sources for drinking water and crop irrigation in the Snake River Basin. Therefore, the USGS extensively monitors the aquifer, and perched water bodies above it, on the INEL and at a few locations beyond the southern and western boundaries. The USGS maintains more than 90 aquifer observation wells on or near the INEL, and more than 170 wells and auger holes are available for sampling perched ground–water bodies. Figures 16 and 17 show USGS sampling locations. Water levels in wells and various radiological and nonradiological substances in the aquifer are monitored. References 6 and 7 contain maps showing the frequency of water level measurements and water sample collections, as well as information on the shape and extent of waste plumes (i.e., the spread of various contaminants in the aquifer and perched water from INEL facilities) as they were between 1982 and 1988. By examining both references, one can observe the changes which have occurred over the six–year period.

In the water sampling portion of the "Environmental Radiological Program Information" section, the RESL portion of the radiological ground–water surveillance program was described and 1990 results were summarized. The USGS routine ground–water surveillance program was summarized in Table III in the section "Environmental Program Information." However, the USGS also conducts special studies of the ground water of the Snake River Plain that are not included in the Table III summary. These special studies provide more specific geological and hydrological information on the flow and recharge of the aquifer and the movements of radioactive and nonradioactive substances in the ground water. Most of the information from these studies is published in USGS reports.

During 1990, USGS personnel collected 583 samples from ground–water and surface–water sites at the INEL, including routine samples summarized in Table III, that were analyzed by the Analytical Chemistry Branch at RESL for radionuclides. Sixty–five samples were sent to the USGS Laboratory in Arvada, Colorado for nutrient analyses (nitrates, phosphates, etc.), 48 samples for purgeable organics, 180 for trace elements, and 297 for common inorganic ions.

Summary of Radiological Surveillance Results

All radioactivity detected in drinking water samples collected by RESL is evaluated in this report and summarized in the "Environmental Radiological Program Information" section and Appendix B tables. USGS results are briefly discussed here. Results of monitoring or surveillance activities that are published in USGS reports are summarized in the year of publication but may refer to sampling programs of earlier years. If data are not to be published, a summary will be made as soon as results are available. USGS results are also available upon request from the USGS INEL Project Office at CFA.

Two samples from each of the four offsite USGS wells beyond the southern and western Site boundaries were submitted for gross alpha, gross beta, and tritium in 1990. The September sample for Well #14 had a reported gross alpha concentration of $3 \pm 2 \times 10^{-9}$ µCi/mL, and the April and October samples at Cerro Grande well had a reported gross beta concentration at $5 \pm 4 \times 10^{-9}$ µCi/mL. None of the samples showed detectable concentrations of tritium or gamma–emitting radionuclides. The reported concentrations of gross alpha and gross beta were within the range expected due to natural radionuclides in the soil and rocks of this area.

In addition to samples collected as part of the routine ground–water monitoring program at the INEL, water samples were collected from 19 downgradient ground–water sites. These samples were submitted to the USGS Laboratory in Arvada, Colorado, for analyses for radionuclides, trace elements, and nutrients. Tritium concentrations were at background levels.

In June 1990, the USGS published a report giving results of their study of tritium in ground water at the INEL (see Reference 8). Between 1952 and 1988, approximately 30,900 Ci of tritium were contained in

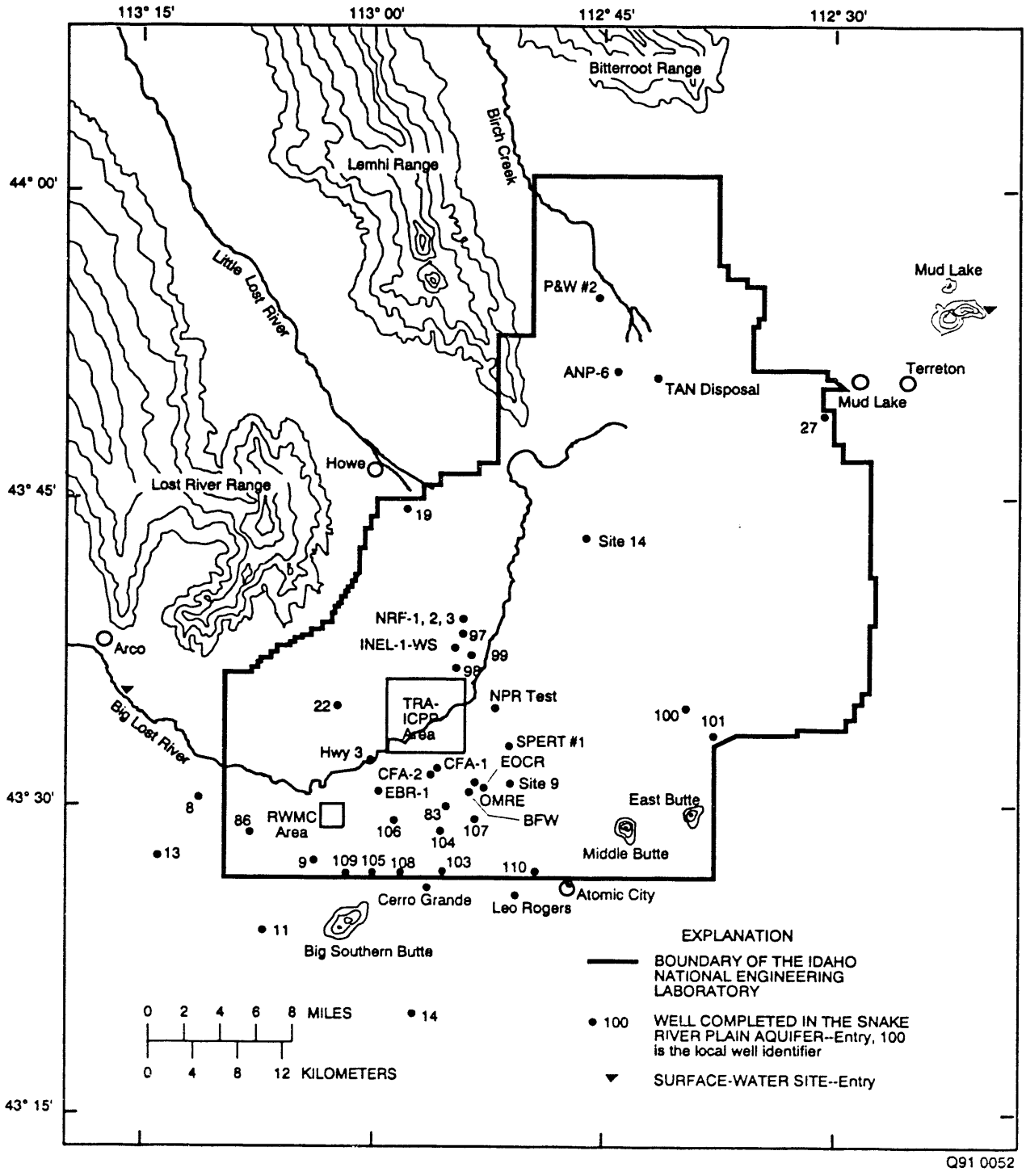

Figure 16. USGS sample location map for the INEL Site and vicinity.

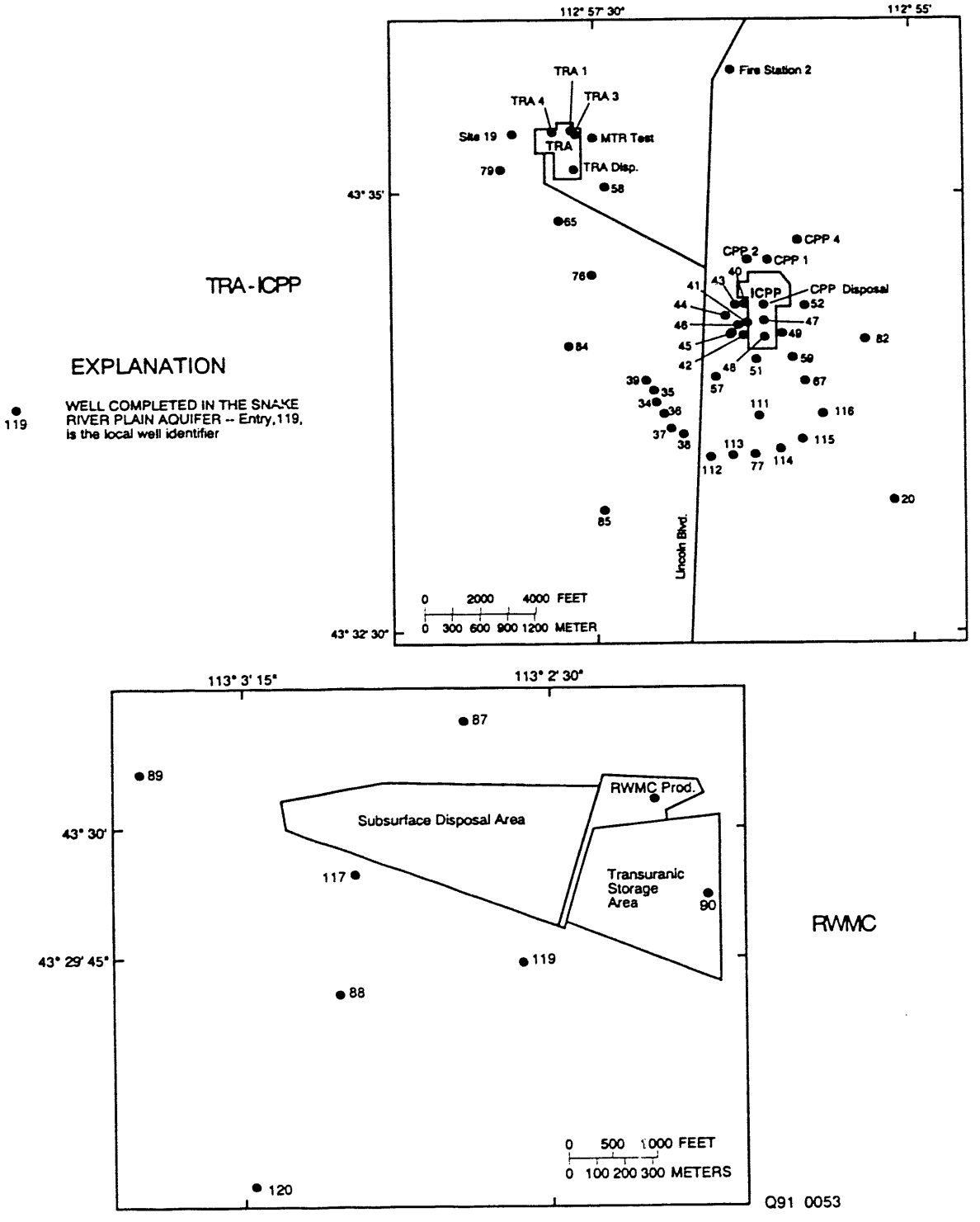

Figure 17. USGS detailed sample location map for ICPP, TRA, and RWMC.

wastewater disposed to wells and infiltration ponds at the INEL. Most of the tritium was generated and disposed at two facilities, the ICPP and the TRA.

The average concentration of tritium in water from 26 wells at the INEL decreased from 250 pCi/mL in 1961 to 18 pCi/mL in 1988, or to 7% of the 1961 average. These particular wells were selected because the USGS had sampled each during the years under study. In 1961, the maximum tritium concentration in ground water at the INEL was 844 ± 5 pCi/mL. In 1988, the maximum tritium concentration in ground water was 61.6 ± 1.1 pCi/mL. Four factors responsible for the decrease in tritium concentration in ground water were: (a) the 1961–88 decrease in the amount of tritium disposed annually to ponds and wells, (b) the change from the use of the ICPP disposal well to infiltration ponds, (c) radioactive decay, and (d) dilution from recharge.

In October 1990, DOE and USGS released information from a ground-water study in which minute concentrations of Cl-36 were detected in the INEL vicinity. The concentrations were too low to pose a health hazard to workers or members of the public. The concentrations detected were about 1 million times lower than the EPA maximum contaminant level of 700 pCi/L. Concentrations in wells upgradient (north and northwest) from the INEL ranged from 0.0008 to 0.0017 pCi/L; concentrations in onsite wells ranged from 0.0013 pCi/L to 0.14 pCi/L; and wells beyond the southern boundary ranged from 0.0007 pCi/L to 0.0014 pCi/L.

Evaluation of the results of this study indicate that three potential sources of the Cl-36 exist: (a) natural sources, (b) fallout from atmospheric weapons tests in the 1950s and 1960s, and (c) sources at the INEL. Certain past INEL waste management practices affected present Cl-36 concentrations in onsite wells. Since the concentration in a well at the southern boundary was considerably larger than offsite well concentrations, it is likely that Cl-36 has migrated offsite. However, concentrations in offsite wells south of the Site boundary were similar to concentrations from wells upgradient from the INEL.

Summary of Nonradiological Surveillance Results

Bacteriological Monitoring

Potable water at the INEL is monitored for coliform bacteria monthly by contractor personnel and analyzed by the EG&G Environmental Hygiene Laboratory. Approximately 32 samples per month are collected from the drinking water distribution systems at INEL facilities. If one colony is found in a sample by the laboratory, that particular drinking water system is resampled and retested until it is clear of bacteria. Corrective action to purify the water may vary from one facility to another.

In July 1990, four samples from the ICPP distribution system indicated bacteria were present. The drinking water system was flushed and chlorinated and subsequent samples were demonstrated clear of bacteria. At the time, ICPP did not have an active chlorination program for the water supply—chlorine was added on an "as-needed" basis determined by sampling results. However, WINCO management subsequently implemented an in-line gas chlorination program that now operates continuously.

In September 1990, one sample from the drinking water system at TAN proved to be contaminated by coliform. The system was cleaned, chlorinated, re-tested and within a few days was clear of bacteria.

Chemical Monitoring

The USGS monitors for nonradiological wastes in the aquifer by measuring specific conductance and sodium, chloride, total chromium, trace elements, and nitrate concentrations. All of these waste products were at background levels at least 4 km (2.5 mi) inside the nearest Site boundary, indicating that INEL ground-water nonradiological plumes had not migrated offsite by the end of 1990.[a] Concentrations of sodium, chloride, and nitrate ions above background levels have been found downgradient from ICPP, but not offsite. Diagrams for waste plumes of these substances are contained in Reference 7.

WINCO personnel sample the production and potable wells at the ICPP facility monthly for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, chloride, fluoride, nitrate, and sulfate ions. None of these well samples exceeded the EPA maximum contaminant levels or State of Idaho drinking water limits during 1990.[b]

[a] [illegible] USGS—INEL [illegible]

[b] [illegible] WINCO/INEL [illegible]

Purgeable Organic Compounds Monitoring

Sampling for purgeable organic compounds in ground water was conducted by the USGS at the INEL Site during January to December 1990. Water samples from five production wells and 27 ground–water quality monitoring wells that tap the Snake River Plain aquifer were collected and analyzed for 36 purgeable organic compounds. The ground–water samples were analyzed at the USGS National Water Quality Laboratory in Arvada, Colorado. A 1990 USGS report on the purgeable organic compounds sampling program describes in detail the methods used to collect the water samples and to ensure sampling and analytical quality.[27]

In the 1990 USGS sampling at the INEL, eight purgeable organic compounds were detected (above 0.2 µg/L), including carbon tetrachloride, chloroform, 1,1,1–trichloroethane, trichloroethylene, tetrachloro–ethylene, dichlorodifluoromethane, 1,1–dichlorothane, and toluene. As with any type of analytical procedure, concentrations near the minimum detectable concentration are difficult to interpret, and because of analytical and sampling uncertainties, may not actually be present in the sample (see Appendix C). Therefore, to simplify the data table, only concentrations equal to or greater than 1.0 µg/L (1.0 part per billion) for the individual wells are reproduced in Table B–13, Appendix B. In 1990 the USGS samples which contained purgeable organic compound concentrations above 1.0 µg/L were all in the RWMC area.

The only drinking water well sampled by the USGS in 1990 that contained purgeable organic compounds was the RWMC production well. The concentrations of carbon tetrachloride are shown in Table B–13, Appendix B. The annual average concentration for this compound of 1.7 µg/L is equal to 34% of the EPA maximum contaminant level. Also reported were average concentrations, not shown in the table, for trichloroethylene (0.8 µg/L), chloroform (0.3 µg/L), 1,1,1–trichloroethane (0.4 µg/L), and tetrachloroethylene (0.2 µg/L). Only the first three compounds have existing maximum contaminant levels, and when their annual concentrations are compared to those standards, the percentages are, respectively, 16%, 0.3%, and 0.2%.

At TAN, the production wells and distribution systems are sampled monthly by the EG&G Environmental Monitoring Group since the discovery in 1987 that the trichloroethylene (TCE) concentrations in drinking water in that area exceeded the maximum contaminant level. This was determined to be the result of contamination from organic wastes migrating from a former injection (disposal) well used between 1955 and 1972. Samples taken at the point of consumption were below the maximum contaminant level, but EG&G management decided to develop and implement a corrective action plan by installing an aerating device between the wellhead and the distribution system to remove the volatile TCE from the drinking water in the tank at TSF. A routine monitoring program sampling the water entering and exiting the tank indicated the aeration system was working well and a plan for remedial action to address the localized contamination in the aquifer was developed.

During 1989 and early 1990, a 60–ft column of sediment was removed from the former TAN injection well. With removal of the source of the contaminants, it is anticipated that concentrations in the water will gradually decrease. Monitoring and treatment will continue as long as is necessary to follow the contaminants already present in the water.

During August 1990, the concentration of TCE in the distribution system slightly exceeded the EPA maximum contaminant level of 5 µg/L for that one month. Investigation revealed that the aerating sparger was not working properly. The elevated level was not a compliance issue because the regulation states that the concentration must be above that level for four quarters or must be four times the regulation (20 µg/L) for the facility to be out of compliance.

Summary of RESL Air Sampling Results

Atmospheric particulate matter is routinely monitored at the low-volume air sampling stations using the filters previously described. A summary of the results for 1990 is given in Table B-14, Appendix B. The analysis involves determining the net weight of the particulate matter on the quarterly composite of weekly filters at each station. The concentrations of the samples ranged from 7 to 90 $\mu g/m^3$. The distant mean was 36 ± 12 $\mu g/m^3$, the boundary mean was 32 ± 8 $\mu g/m^3$, and the onsite mean was 20 ± 9 $\mu g/m^3$. The distant mean is greater than the onsite mean, probably because of the amount of resuspended dust from agricultural operations near the distant sampling locations. Most of the airborne particulates in the Site vicinity are windblown dust from the desert floor. The revised EPA primary and secondary standard for particulate matter is 50 $\mu g/m^3$, but it applies only to "particulates with an aerodynamic diameter less than or equal to a nominal 10 micrometers." Measurements of total suspended particulates, such as those reported here, will overestimate particulate concentrations in the 10 µm and below size range (appear greater than is actually true) in comparison with the new standard. For example, the distant mean of 36 $\mu g/m^3$ appears to be 72% of the standard, whereas the actual percentage is lower. The standard applies only to particles on the filter with diameters of 10 µm or less, but many of the particles on the RESL filters are actually larger than that size because there is no device on the samplers to screen out the larger particles. Particles larger than 10 µm are not considered by the EPA to be respirable by humans because they do not usually enter the lungs with inhaled air. The larger particles may fall out before they reach the nose, be trapped by nasal hairs, or be impacted on tissues of the nasopharynx and passed through the body via the digestive system.

One sampler dedicated to the measurement of total suspended particulates and having an approximate minimum detectable concentration of 2 $\mu g/m^3$, is located at CFA. The sampler normally operates for 24 hours every 6th day. The annual arithmetic mean particulate matter concentration of samples from the CFA sampler was 28 ± 6 $\mu g/m^3$ with a range of 6 to 108 $\mu g/m^3$. This mean is 56% of the EPA standard mentioned above. This sampler is not equipped with a device designed to screen out large particles (greater than 10 µm diameter); therefore, the CFA percentage is also overestimated.

To fulfill one of the conditions specified in the Permit to Construct the Fuel Processing Restoration facility, two nitrogen oxide monitoring stations were activated by RESL. One sampler is located near the intersection of US Highway 20/26 and Van Buren Boulevard (VANB) and the second is at the Experimental Field Station (EFS). The analyzers used are EPA equivalent methods. The VANB sampler operated satisfactorily only 70% of the time during the first quarter, but more than 97% of the time for the remaining three quarters. At VANB, the annual mean concentration of NO_x for 1990 was about 4 $\mu g/m^3$ (4% of the applicable EPA standard). At EFS, the sampler operated satisfactorily for more than 94% of the time, and the annual mean concentration was 9 $\mu g/m^3$ (9% of the standard). At these locations, the mean concentrations of these gases are calculated to be greater than at the nearest Site boundary in the directions of the prevailing winds. However, even at the onsite locations both annual means are well below the national primary ambient air quality standard of 100 $\mu g/m^3$.

Ambient sulfur dioxide was measured only at VANB, and the mean concentration was 0.5 $\mu g/m^3$ (0.5% of the EPA annual standard). The SO_2 sampler operated satisfactorily more than 91% of the time it was on line during 1990.

The average sulfur dioxide and nitrogen dioxide concentrations at the Site boundary are calculated each year using the total 1990 discharges as reported by the Industrial Waste Management Information System.[a] Concentrations are calculated from the releases from the Coal-Fired Steam Generating Facility monitoring data and the MESODIF air dispersion model (see Reference 16 and Figure 13). The calculational method is the same as described in the section "Assessment of Potential Radiation Dose to the Public General," using mass units for releases instead of radioactivity units.

Total sulfur dioxide released in 1990, shown in Table B-15, Appendix B, was about 1.2×10^5 kg. The maximum concentration of sulfur dioxide at the southern INEL boundary, where the MESODIF model predicted the highest concentration, was 0.16 $\mu g/m^3$, which is 0.2% of the national primary ambient air quality standard of 80 $\mu g/m^3$.

a. Preliminary INEL industrial waste management data, 1990.

The releases of nitrogen oxides during 1990 are also shown in Table B–15, Appendix B. When the nitrogen oxide was converted to nitrogen dioxide, the total released was about 1.9×10^5 kg. The calculated maximum Site boundary concentration of nitrogen dioxide was 0.25 $\mu g/m^3$ from all INEL sources. This concentration is 0.25% of the national primary ambient air quality standard of 100 $\mu g/m^3$.

Summary of Contractor Nonradioactive Effluent Monitoring

Nonradioactive airborne effluents originate from five primary sources at the INEL, (a) calcination of high–level radioactive liquid waste at the New Waste Calcining Facility (NWCF), (b) combustion of coal for steam generation at the Coal–Fired Steam Generating Facility (CFSGF), (c) combustion of fuel oil for heating at all INEL facilities, (d) motor vehicle exhausts, and (e) fugitive dusts from waste burial and construction activities.

Nitrogen oxide emissions are routinely monitored at the NWCF. Sulfur dioxide, nitrogen oxides, and carbon oxides are monitored at the CFSGF. Emissions of sulfur dioxide from heating oils are calculated from sulfur content and the amount of fuel used. Emissions of nitrogen oxides from fuel are calculated using emission factors developed by the EPA[28] and the amount and type of fuel burned at each facility as reported by the Industrial Waste Management Information System. Motor vehicle exhausts and fugitive dusts are not monitored at their sources. Major nonradioactive airborne effluents for 1990 are given in Table B–15, Appendix B.

Nonradioactive liquid effluents are disposed of primarily to a waste ditch at the NRF; seepage ponds at the Contained Test Facility (CTF), TAN, TRA, ICPP, and WRRTF; a lined evaporation pond at the Power Burst Facility (PBF); an industrial waste pond at ANL–W; and sewage treatment facilities at various locations (see Reference 15).

Routine direct disposal of wastes to the Snake River Plain aquifer ceased in 1984. The only other injection wells on the INEL are used for storm runoff water. Most of these wells are monitored when the storm runoff reaches the level when it flows into the injection well. Potential for contamination via this pathway is small. No waste is discharged to the Big Lost River, the only surface stream on the INEL that might conceivably accept waste water.

The extent of effluent monitoring for liquid waste streams varies depending on the nature of the effluents. The largest INEL effluent stream, from the ICPP, is monitored by monthly composite samples analyzed for arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, chloride, fluoride, nitrate, sulfate, conductivity, total dissolved solids, and pH. According to WINCO personnel, all analytical results for 1990 were less than concentrations defined as hazardous waste in 40 CFR 261.24.[a]

Other waste effluents are calculated from the amounts of chemicals used for water treatment, corrosion control, and demineralization; as cleansers, and algicides; and occasionally from waste acids. Sewage processed by treatment facilities is monitored for biochemical oxygen demand, dissolved oxygen, settleable solids, and pH. Results are reported annually by the Industrial Waste Management Information System.

a. K. R. Krivanek, Personal communication, WINCO, INEL, April 30, 1991.

QUALITY ASSURANCE

A quality control and assurance program is maintained by RESL to ensure consistent and reliable monitoring results. An internal quality control program is maintained by the following:

- Adherence to written procedures for sample collection[29] and analytical methods[30]
- Documentation of program changes
- Periodic calibration of instruments
- Equipment performance checks for background and counting rates of standards
- Routine yield determinations of radiochemical procedures
- Replicate samples to determine precision
- Analysis of *blind* duplicate and replicate samples
- Analysis of quality control standards in appropriate matrices to test accuracy
- Analysis of reagent blanks to verify that there is no radiochemical contamination
- Propagation of random and systematic uncertainties.

The calibration of counting instruments is carefully performed and is traceable to the National Institute of Standards and Technology (NIST). The Analytical Chemistry Branch (ACB) of RESL has participated each year since 1974 in a Traceability Program with the NIST. Several alpha-, beta-, and gamma-emitting nuclides, generally in liquid media, are determined and the results are reported directly to NIST. NIST issues a Report of Test in which the ACB results are compared with the previously undisclosed NIST-certified values. In addition, ACB prepares two traceability samples each year and sends them to NIST for analysis and comparison between the ACB and the NIST measured values. The criterion for traceability is that the ACB results agree to within five percent of the NIST values. The results for ACB analyses compared to NIST known values for 1990 are given in Table VIII.

TABLE VIII
NIST QUALITY ASSURANCE COMPARISON TEST RESULTS

Reference Date	Radionuclide	RESL Result[a]	NIST Result[a]	Ratio RESL/NIST[b]
9-26-89[c]	Pu-239/240	36.7 ± 1.6 Bq/g	36.6 ± 0.9 Bq/g	1.00
3-26-90	Pu-238	26.1 ± 1.7 Bq/g	25.9 ± 0.6 Bq/g	1.01
4-3-90	H-3	3770 ± 3 Bq/g	3787.0 ± 0.8 Bq/g	1.00
8-6-90	Sr-89	6482.0 ± 1.6 Bq/g	6729.0 ± 1.1 Bq/g	0.96
	Sr-90	1203.0 ± 1.8 Bq/g	1205.6 ± 1.2 Bq/g	1.00
9-1-90	Ce-144	6057 ± 2 γ/s/g	6287 ± 5 γ/s/g	0.96
10-5-90	Cs-134	5376 ± 2 γ/s/g	5509.0 ± 1.8 γ/s/g	0.98
10-30-90	Fe-55	3700 ± 4 Bq/g	3819 ± 4 Bq/g	0.97
12-1-90[d]	88.0	229 ± 4 γ/s/g	230 ± 2 γ/s/g	0.99
	122.1	106 ± 3 γ/s/g	106 ± 2 γ/s/g	1.00
	165.9	25 ± 6 γ/s/g	25 ± 1.4 γ/s/g	0.99
	391.7	40 ± 7 γ/s/g	38 ± 3 γ/s/g	1.06
	661.6	2402 ± 3 γ/s/g	2380.5 ± 1.7 γ/s/g	1.01
	898.0	79 ± 8 γ/s/g	80.4 ± 1.6 γ/s/g	0.98
	1173.2	2583.0 ± 1.4 γ/s/g	2547.1 ± 1.3 γ/s/g	1.01
	1332.5	2617.0 ± 1.8 γ/s/g	2544.6 ± 1.0 γ/s/g	1.03
	1836.0	83 ± 3 γ/s/g	84.4 ± 1.6 γ/s/g	0.99

a. Results ± overall uncertainty are given. The overall uncertainty is three times the combined uncertainty (the quadratic sum of all random and systematic uncertainties at the one standard deviation level). One Bq equals 2.7×10^{-5} μCi.

b. Comparison ratio in which the RESL value is divided by the NIST value.

c. Sample prepared by RESL and sent to NIST.

d. Specific gamma ray energy in keV.

During some years, ACB sends samples to other INEL contractor and project office laboratories who voluntarily participate in the INEL Intercomparison Test Program. Results reported by all laboratories are then compared to RESL values. This program was not operated in 1990.

The ACB has participated each year since 1976 in the Quality Assessment Program (QAP) administered by the DOE Environmental Measurements Laboratory (EML). EML prepares the quality control samples containing various alpha–, beta–, and gamma–emitting nuclides in water, soil, air filter, vegetation, and tissue media and distributes them to numerous DOE–contractor laboratories throughout the country. The program is an interlaboratory comparison in that results from the participants are compared with the experimentally determined results of EML. EML issues "QAP" Reports in which the identities of participating laboratories, their results, and comparison to EML results are presented. ACB results for 1990 compared to the EML results are reported in Table IX.

ACB may also participate in the International Atomic Energy Agency (IAEA) interlaboratory comparison on those occasions when the IAEA provides sample media of the type and level of radionuclide concentrations normally analyzed in ACB routine procedures. As time or opportunity permits, ACB participates in the American Society for Testing Materials' round–robin testing of standard methods.

The USGS submits most ground–water samples requiring radioactive analyses to ACB. Samples requiring nonradioactive or organic analyses are submitted to the USGS Laboratory in Arvada, Colorado which is certified by EPA. The INEL USGS Project Office operates a quality assurance program which includes periodically submitting reagent and equipment blank samples, and blind duplicate samples to both laboratories.

Each contractor laboratory which analyzes INEL samples operates quality assurance programs similar to that of ACB described above including participation in intercomparison programs. When possible, contractors send samples which cannot be analyzed onsite to certified commercial laboratories for analysis.

To verify the quality of the environmental dosimetry program, RESL participated in eight International Environmental Dosimeter Intercomparison Studies. The eighth intercomparison was conducted in 1986. RESL results were within 10% of the test exposure values on all intercomparisons.

A Cs–137 calibration source is used for the RESL environmental dosimetry program. The exposure rates for this source are verified quarterly using a transfer chamber calibrated by NIST. Measurement Quality Assurance (MQA) data show that they agree within ± 2.0% of the NIST values.

TABLE IX
DOE ENVIRONMENTAL MEASUREMENTS LABORATORY QUALITY ASSURANCE PROGRAM RESULTS COMPARISON

Sample Medium	Units	Radionuclide	RESL ID#	RESL Value	RESL Uncertainty (%)[b]	EML[a] Value	EML[a] Uncertainty (%)	Ratio RESL/EML[c]
(April 1990)								
Air	Bq/filter	Be-7	1	47	8	51.4	7	0.91
		Be-7	2	47	8	51.4	7	0.91
		Mn-54	1	9.7	5	9.6	4	1.01
		Mn-54	2	9.7	5	9.6	4	1.01
		Co-57	1	6.1	4	6.5	6	0.94
		Co-57	2	6.3	4	6.5	6	0.97
		Co-60	1	8.7	5	9.4	6	0.93
		Co-60	2	7.7	5	9.4	6	0.82
		Sr-90	1	0.25	8	0.24	16	1.04
		Cs-134	1	19.4	4	18.2	8	1.07
		Cs-134	2	19.9	4	18.2	8	1.09
		Cs-137	1	19.4	4	20.4	3	0.95
		Cs-137	2	20.5	4	20.4	3	1.00
		Ce-144	1	33.0	9	31.2	4	1.06
		Ce-144	2	32.0	9	31.2	4	1.03
		Pu-239	1	0.041	7	0.039	12	1.05
		Am-241	1	0.051	5	0.054	11	0.94
		U-234	1	0.0260	7	0.0255	5	1.02
		U-238	1	0.0270	7	0.0255	5	1.06
Vegetation	Bq/kg	K-40	1	247	8	323	0	0.76
		K-40	2	290	8	323	0	0.90
		Sr-90	1	71.0	5	70.2	2	1.01
		Sr-90	2	72.0	5	70.2	2	1.03
		Cs-137	1	29.0	6	28.5	1	1.02
		Cs-137	2	30.0	6	28.5	1	1.05
		Pu-239	1	0.360	11	0.333	4	1.08
		Pu-239	2	0.350	11	0.333	4	1.05
		Am-241	1	0.360	11	0.307	4	1.17
		Am-241	2	0.300	9	0.307	4	0.98
		U-234	1	0.700	8	0.530	5	1.32
		U-234	2	0.700	8	0.530	5	1.32
		U-238	1	0.520	9	0.530	5	0.98
		U-238	2	0.550	9	0.530	5	1.04
Water	Bq/L	H-3	1	1940	2	1960	2	0.99
		H-3	2	1880	2	1960	2	0.96
		Mn-54	1	98	6	103	4	0.95
		Mn-54	2	97	6	103	4	0.94
		Co-57	1	191	3	198	5	0.96
		Co-57	2	189	3	198	5	0.95
		Co-60	1	173	4	206	4	0.84
		Co-60	2	167	4	206	4	0.81
		Sr-90	1	107	2	111	4	0.96
		Sr-90	2	104	2	111	4	0.94
		Cs-134	1	455	3	462	5	0.98
		Cs-134	2	459	3	462	5	0.99
		Cs-137	1	188	4	198	5	0.95
		Cs-137	2	187	4	198	5	0.94
		Ce-144	1	424	8	403	4	1.05
		Ce-144	2	396	9	403	4	0.98

TABLE IX
(continued)

Sample Medium	Units	Radionuclide	RESL ID#	RESL Value	RESL Uncertainty (%)[b]	EML[a] Value	EML[a] Uncertainty (%)	Ratio RESL/EML[c]
	Bq/L	Pu–239	1	1.18	3	1.04	9	1.13
		Pu–239	2	1.20	4	1.04	9	1.15
		Am–241	1	0.87	4	0.86	9	1.01
		Am–241	2	0.90	4	0.86	9	1.05
		U–234	1	0.89	3	1.00	5	0.89
		U–234	2	0.99	4	1.00	5	0.99
		U–238	1	0.91	3	1.00	5	0.91
		U–238	2	0.96	4	1.00	5	0.96
Soil[d]	—	—	—	—	—	—		—
(September 1990)[e]								
Soil	Bq/kg	U–234	1	28.5	3	28.3	4	1.01
		U–234	1	25.9	3	28.3	4	0.92
		U–234	1	28.9	3	28.3	4	1.02
		U–234	1	26.3	3	28.3	4	0.93
		U–238	1	27.4	3	27.3	3	1.00
		U–238	1	25.2	3	27.3	3	0.92
		U–238	1	27.4	3	27.3	3	1.00
		U–238	1	26.3	3	27.3	3	0.96
		Pu–239	1	1.37	8	1.15	6	1.19
		Pu–239	1	1.26	9	1.15	6	1.10
		Pu–239	1	1.18	9	1.15	6	1.03
		Pu–239	1	1.18	9	1.15	6	1.03
		Am–241	1	0.888	13	0.738	16	1.20[f]
		Am–241	1	0.851	13	0.738	16	1.15[f]
		Am–241	1	0.814	14	0.738	16	1.10[f]
		Am–241	1	0.999	11	0.738	16	1.35[f]
Water	Bq/L	U–234	1	0.248	4	0.236	3	1.05
		U–234	1	0.252	4	0.236	3	1.07
		U–238	1	0.229	5	0.244	5	0.94
		U–238	1	0.229	5	0.244	5	0.94
		Pu–239	1	0.981	4	1.09	1	0.90
		Pu–239	1	0.958	4	1.09	1	0.88
		Am–241	1	0.603	4	0.567	6	1.06
		Am–241	1	0.648	5	0.567	6	1.14

a. The EML value is the mean of replicate determinations for each nuclide. The EML Uncertainty is the standard error of the mean.

b. The RESL uncertainty is based on the 1s estimated analytical uncertainties.

c. Comparison ratio in which the RESL value is divided by the EML value.

d. Not analyzed because activity levels of some nuclides were deemed too high to handle in RESL's low-level laboratory.

e. RESL does not usually analyze autumn samples. The results shown here were obtained by RESL analyses before EML values were known, but after the EML reporting deadline

f. Results reported by most other participating laboratories reflect the values obtained by RESL.

ENVIRONMENTAL STANDARDS AND REGULATIONS

The following environmental standards and regulations are applicable, in whole or in part, on the INEL Site or at the INEL Site boundary.

U.S. Environmental Protection Agency, "National Primary and Secondary Ambient Air Quality Standards," 40 CFR 50, 1990.

U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants," 40 CFR 61, 1990.

U.S. Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," 40 CFR 141, 1990.

U.S. Environmental Protection Agency, "Hazardous Waste Management System: General," 40 CFR 260, 1990.

U.S. Environmental Protection Agency, "Identifying and Listing of Hazardous Wastes," 40 CFR 261, 1990.

U.S. Environmental Protection Agency, "Standards Applicable to Generators of Hazardous Waste," 40 CFR 262, 1990.

U.S. Environmental Protection Agency, "Standards Applicable to Transporters of Hazardous Waste," 40 CFR 263, 1990.

U.S. Environmental Protection Agency, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities," 40 CFR 264, 1990.

U.S. Environmental Protection Agency, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities," 40 CFR 265, 1990.

U.S. Environmental Protection Agency, "Interim Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities," 40 CFR 267, 1990.

Department of Health and Welfare, State of Idaho, Rules and Regulations for the Control of Air Pollution in Idaho, 1972, as amended through 1984.

Department of Health and Welfare, State of Idaho, Idaho Regulations for Public Drinking Water Systems, 1977.

The principal standards and guides for release of radionuclides at the INEL are those of DOE Order 5400.5 (see Reference 3), dated February 8, 1990, entitled "Radiation Protection of the Public and the Environment." The DOE standard is shown in Table X along with the EPA standard for protection of the public, airborne pathway only. The Derived Concentration Guides (DCG) from Reference 3 are based on the standard and have been calculated using new models and parameters.[31,32] They are shown in Table XI. The most restrictive guide is listed when there is a difference between the soluble and insoluble chemical forms. The DCGs consider only the inhalation of air, the ingestion of water, or submersion in air.

TABLE X
RADIATION STANDARDS FOR PROTECTION OF THE PUBLIC IN THE VICINITY OF DOE FACILITIES

	Effective Dose Equivalent	
	(mrem/yr)	(mSv/yr)
DOE Standard for routine DOE activities[a] (all pathways)	100	1
EPA Standard for site operations[b] (airborne pathway only)	10	0.10

a. The effective dose equivalent for any member of the public from all routine DOE operations including remedial activities and release of naturally-occurring radionuclides from DOE processes shall not exceed these values. (Routine operations refers to normal, planned operations and does not include accidental or unplanned releases.)

b. Limits of 40 CFR 61, Subpart H, established December 1989, by the EPA.

Ambient air quality standards are shown in Table XII. Water quality standards are dependent on the type of drinking water system sampled. Table XIII is a partial list of maximum contaminant levels set by the EPA for public community drinking water systems in 40 CFR 141. New regulations were promulgated by the EPA for volatile organic compounds in the Federal Register on July 1, 1987.[33] State of Idaho regulations are the same for the first five contaminants listed in Table XIII.

TABLE XI
DERIVED CONCENTRATION GUIDES FOR RADIATION PROTECTION

	Derived Concentration Guide[a] (μCi/mL)	
Radionuclide	In Air	In Water
Gross Alpha[b]	2×10^{-14}	3×10^{-8}
Gross Beta[c]	3×10^{-12}	1×10^{-7}
H-3	1×10^{-7}	2×10^{-3}
Na-24[d]	4×10^{-9}	1×10^{-4}
Ar-41	1×10^{-8}	—
Cr-51	5×10^{-8}	1×10^{-3}
Mn-54	2×10^{-9}	5×10^{-5}
Co-60	8×10^{-11}	5×10^{-6}
Br-82	9×10^{-9}	8×10^{-5}
Kr-85	3×10^{-6}	—
Kr-85m	1×10^{-7}	—
Kr-87	2×10^{-8}	—
Kr-88	9×10^{-9}	—
Rb-88[d]	3×10^{-8}	8×10^{-4}
Rb-89	3×10^{-7}	2×10^{-3}
Sr-90	9×10^{-12}	1×10^{-6}
Y-91m	4×10^{-7}	4×10^{-3}
Tc-99m	4×10^{-7}	2×10^{-3}
Ru-103	2×10^{-9}	5×10^{-5}
Ru-106	3×10^{-11}	6×10^{-6}
Sb-125	1×10^{-9}	5×10^{-5}
I-129	7×10^{-11}	5×10^{-7}

	Derived Concentration Guide[a] (μCi/mL)	
Radionuclide	In Air	In Water
Xe-131m	2×10^{-6}	—
I-131	4×10^{-10}	3×10^{-6}
I-132	4×10^{-8}	2×10^{-4}
I-133	2×10^{-9}	1×10^{-5}
Xe-133	5×10^{-7}	—
Xe-133m	6×10^{-7}	—
I-134	1×10^{-7}	7×10^{-4}
Xe-135	8×10^{-8}	—
Xe-135m	5×10^{-8}	—
Xe-138	2×10^{-8}	—
Cs-134	2×10^{-10}	2×10^{-6}
Cs-137	4×10^{-10}	3×10^{-6}
Cs-138	1×10^{-7}	9×10^{-4}
Ba-139	7×10^{-8}	3×10^{-4}
Ba-140	3×10^{-9}	2×10^{-5}
Ce-141	1×10^{-9}	5×10^{-5}
Ce-144	3×10^{-11}	7×10^{-6}
Pu-238	3×10^{-14}	4×10^{-8}
Pu-239	2×10^{-14}	3×10^{-8}
Pu-240	2×10^{-14}	3×10^{-8}
Am-241	2×10^{-14}	3×10^{-8}

a. Derived concentration guides (DCGs) are from DOE Order 5400.5[3] and are based on an effective dose equivalent of 100 mrem/yr.

b. Based on Am-241, Pu-239, and Pu-240.

c. Based on the most restrictive beta emitter (Ra-228).

d. Submersion in a cloud of gas is more restrictive than the inhalation pathway.

TABLE XII
AMBIENT AIR QUALITY STANDARDS

Pollutant	Type of Standard[a]	Sampling Period	EPA[b] ($\mu g/m^3$)
SO_2	S	3–hour average	1300
	P	24–hour average	365
	P	Annual average	80
NO_2	S&P	Annual average	100
Total Particulates[c]	S	24–hour average	150
	S&P	Annual average	50

a. National primary (P) ambient air quality standards define levels of air quality to protect the public health. Secondary (S) ambient air quality standards define levels of air quality to protect the public welfare from any known or anticipated adverse effects of a pollutant.

b. The State of Idaho has adopted these same ambient air quality standards.

c. The primary and secondary standard for the annual average applies only to "particulates with an aerodynamic diameter less than or equal to a nominal 10 micrometers."

TABLE XIII
MAXIMUM CONTAMINANT LEVELS FOR PUBLIC COMMUNITY DRINKING WATER SYSTEMS

Gross alpha	1.5×10^{-8} µCi/mL
Gross beta	5.0×10^{-8} µCi/mL
Manmade radionuclides	Concentrations resulting in 4 mrem total body or organ dose equivalent
Nitrate (as N)[a]	10 mg/L
Chromium	0.05 mg/L
Trihalomethanes	0.1 mg/L
Carbon tetrachloride[b]	0.005 mg/L
1,1,1–trichloroethane[b]	0.20 mg/L
Trichloroethylene[b]	0.005 mg/L

a. Applies to noncommunity water systems also.

b. Applies to nontransient noncommunity water systems also.

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APPENDIX A

MAJOR PROGRAMS, LOCATION, GEOLOGY, AND CLIMATOLOGY

APPENDIX A

MAJOR PROGRAMS, LOCATION, GEOLOGY, AND CLIMATOLOGY

The INEL Site was established in 1949 as the National Reactor Testing Station to provide an isolated station where various kinds of nuclear reactors and support facilities could be built and tested, and to demonstrate that nuclear energy could be safely harnessed for generating electricity and other peaceful uses. More nuclear reactors have been built at the INEL Site than at any other location in the world. Fifty-two reactors have been built at this Site, 12 of which are operating or operable. The broad mission of the INEL is to develop economic energy sources by applying its engineering and scientific expertise to DOE research and development programs. Major DOE programs currently underway at the INEL Site fall into eight categories:

- Providing test irradiation services from the high-flux Advanced Test Reactor (ATR)
- Recovering uranium from highly enriched spent fuels and calcining liquid radioactive waste solutions into a solid form for storage at the Idaho Chemical Processing Plant (ICPP)
- Conducting light-water-cooled reactor safety testing and research
- Operating the Experimental Breeder Reactor No. 2 (EBR-II)
- Operating the Naval Reactors Facility (NRF)
- Storing, processing, and monitoring radioactive wastes
- Special manufacturing of defense components
- Conducting environmental restoration at the INEL Site.

See Figure A-1 and Table A-1 for the location of INEL Site facilities and an explanation of their acronyms.

The Site is situated on the upper Snake River Plain in southeastern Idaho at an average elevation of 1500 m (4900 ft). The Site encompasses 2300 km^2 (890 mi^2); it extends 63 km (39 mi) from north to south and is about 58-km (36-mi) wide at its broader southern part. Land immediately beyond the boundaries of the Site is either desert or agricultural. Most of the nearby farming is concentrated northeast of the Site. Large areas of agricultural land are farmed in the Snake River Valley, but these regions are more distant from the Site.

The desert plain on which the INEL Site is located is part of a cool desert shrub biome. Average annual temperature at the Site is 5.6°C (42°F), with extremes of 39°C (103°F) and -44°C (-47°F).[A-1] Vegetation is typical of the Great Basin, with sagebrush conspicuous over 80% of the Site. Frequenting the Site are the pronghorn antelope, a few deer and elk, coyotes, bobcats, rabbits, large populations of small mammals, and various kinds of birds and reptiles. The INEL is one of seven National Environmental Research Parks, where scientists from DOE, other federal and state agencies, universities, and private research foundations can study changes caused by human activities and obtain data for use in making decisions on land use. At present, about 20 different environmental studies are being conducted at the INEL.

The surface of the plain is a combination of basaltic lava outcrops and alluvial sedimentary deposits. The sediments range from gravels and sands deposited by streams (as alluvial fans, channel fillings, and deltas) to silts and clays deposited in playas. The subsurface of the plain is principally composed of basalt flows interbedded with lacustrine and alluvial sedimentary deposits to a depth of about 760 m (2500 ft). The most recent volcanism, occurring about 2000 years ago,[A-2] is evident in the scenic basalt flows at Craters of the Moon National Monument, about 30 km (19 mi) to the southwest of the Site.

Annual precipitation in the Site area has averaged 22 cm (8.7 in.) over the past 15 years. Underlying the desert plain is a natural aquifer in the basaltic rock. Ground-water underflow from the Henry's Fork of the Snake River supplies a significant amount of water to the Snake River Plain aquifer below the INEL. Additional recharge to the aquifer comes from the Big and Little Lost Rivers and Birch Creek, which originate in the mountains to the northwest of the INEL, flow onto the Site during at least a few months of the year, and sink into its porous soils. The underground water moves laterally at an average rate of 1.5 to 6 m/d (5 to 20 ft/d) to the south and west, emerging in springs along the Snake River between Milner and Bliss, Idaho. Discharge volumes from springs in this region are approximately 4.3×10^9 m^3 (3.5×10^6 acre-ft) per year. Both the aquifer and surface waters of the Snake River Plain are used for crop irrigation.

Winds are predominantly along the SW-NE axis of the plain, with the most frequent and strongest winds from the SW. The NE winds are mostly nocturnal. Spring is the windiest time of the year, while winter has more calm periods and more nighttime temperature inversions.

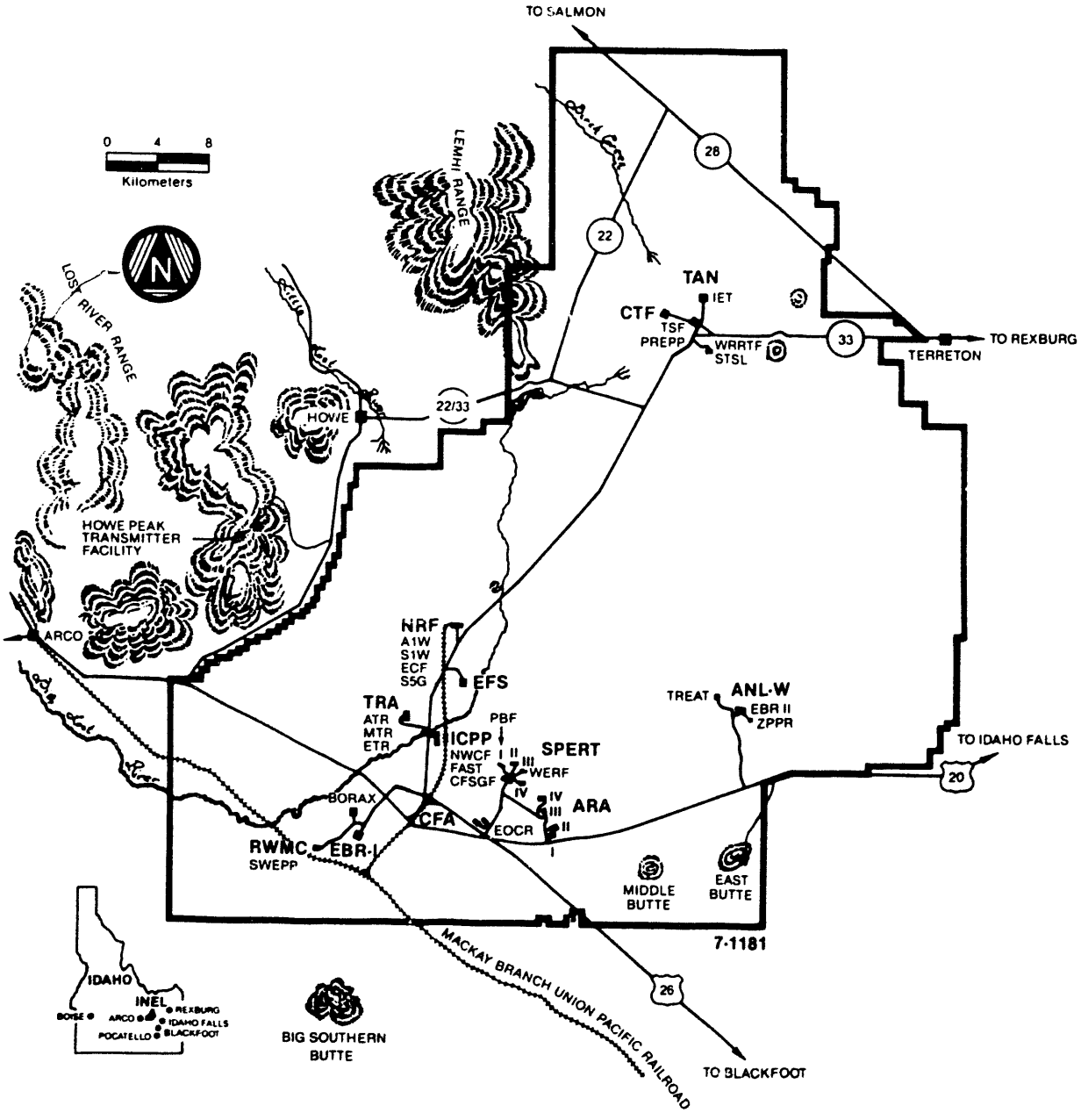

Figure A–1. INEL Site facility locations.

TABLE A–1
TABULATION OF FACILITIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY (1990)

Name	Abbreviation	Operating Contractor[a]
Reactors Operating, Operable or in Standby Status		
Advanced Reactivity Measurement Facility No. 1[b]	ARMF-1	EG&G
Advanced Test Reactor	ATR	EG&G
Advanced Test Reactor Critical	ATRC	EG&G
Argonne Fast Source Reactor	AFSR	ANL
Coupled Fast Reactivity Measurement Facility[b]	CFRMF	EG&G
Experimental Breeder Reactor No. 2	EBR-II	ANL
Large Ship Reactor "A"	A1W (A)	WEC
Large Ship Reactor "B"	A1W (B)	WEC
Natural Circulation Reactor	S5G	WEC
Power Burst Facility	PBF	EG&G
Transient Reactor Test Facility	TREAT	ANL
Neutron Radiography Facility	NRAD	ANL
Zero Power Physics Reactor[b]	ZPPR	ANL
Reactors Dismantled or Transferred		
Boiling Water Reactor No. 1	BORAX-I	ANL
Boiling Water Reactor No. 2	BORAX-II	ANL
Boiling Water Reactor No. 3	BORAX-III	ANL
Boiling Water Reactor No. 4	BORAX-IV	ANL
Boiling Water Reactor No. 5	BORAX-V	ANL
Engineering Test Reactor	ETR	EG&G
Engineering Test Reactor Critical	ETRC	EG&G
Experimental Breeder Reactor No. 1	EBR-I	ANL
Experimental Organic Cooled Reactor (Mothballed before startup)	EOCR	PPCo
Loss-of-Fluid Test Facility	LOFT	EG&G
Materials Testing Reactor	MTR	PPCo & INC
Organic Moderated Reactor Experiment	OMRE	AI
Special Power Excursion Reactor Test No. 1	SPERT-I	PPCo
Special Power Excursion Reactor Test No. 2	SPERT-II	PPCo & INC
Special Power Excursion Reactor Test No. 3	SPERT-III	PPCo & INC
Special Power Excursion Reactor Test No. 4	SPERT-IV	PPCo & INC
Spherical Cavity Reactor Critical Experiment	SCRCE	ANC
Submarine Thermal Reactor	S1W (STR)	WEC
Zero Power Reactor No. 3[b]	ZPR-III	ANL
Other Facilities in Use		
Argonne National Laboratory-West	ANL-W	ANL
Auxiliary Reactor Area	ARA	EG&G
Badging Facility	None	EG&G/M-K
Central Facilities Area	CFA	EG&G
Chemical Engineering Laboratory	CEL	EG&G
Coal-Fired Steam Generating Facility	CFSGF	WINCO
INEL Supercomputing Center	ISC	EG&G
Contained Test Facility	CTF	EG&G
Environmental Analysis Group	EAG	WINCO
Expended Core Facility	ECF	WEC
Experimental Field Station	EFS	DOE-ID
Fluornel Dissolution and Fuel Storage Facility	FAST	WINCO
Fuel Manufacturing Facility	FMF	ANL
Hot Cell Facility (TRA)		EG&G
Hot Fuel Examination Facilities	HFEF	ANL
Hot Shop Facilities (TAN)	THC	EG&G
Idaho Chemical Processing Plant	ICPP	WINCO
INEL Research Center (Idaho Falls)	IRC	EG&G
Naval Reactors Facility	NRF	WEC
New Waste Calcining Facility	NWCF	WINCO
Process Experimental Pilot Plant	PREPP	EG&G
Radiation Measurements Laboratory	RML	EG&G
Radioactive Waste Management Complex	RWMC	EG&G
Radiological & Environmental Sciences Laboratory	RESL/ID	DOE-ID
Reactor Training Facility	RTF	EG&G
Remote Analytical Laboratory (ICPP)	RAL	WINCO
Security Training Facility	STF	PTI
Semiscale Test Support Laboratory	STSL	EG&G
Standards Calibration Laboratory (CF-698)	SCL	EG&G
Stored Waste Examination Pilot Plant	SWEPP	EG&G
Technical Services Center (CF-688, -689)	TSC	EG&G
Technical Service Facility	TSF	EG&G
Technical Support Annex (Idaho Falls)	TSA	EG&G
Technical Support Building (Idaho Falls)	TSB	EG&G
Test Area North	TAN	EG&G
Test Reactor Area	TRA	EG&G
Waste Experimental Reduction Facility	WERF	EG&G
Water Reactor Research Test Facility	WRRTF	EG&G
Willow Creek Building (Idaho Falls)	WCB	EG&G
Facilities Not Presently in Use		
Initial Engine Test Facility	IET	EG&G
Field Engineering Test Facility	FET	EG&G
Waste Calcining Facility	WCF	WINCO
Major Programs at INEL		
Chemical Processing Program	—	WINCO
Environmental Restoration Program	—	All INEL
Liquid Metal Fast Breeder Reactor Program	—	ANL
Naval Propulsion Reactors Program	—	WEC
Radioactive Waste Management Program	—	EG&G
Reactor Materials Testing Program	—	EG&G
Specific Manufacturing Capability	—	R-INEL
Water Reactor Safety Program	—	EG&G

a Operating contractor acronyms: Atomics International (AI), Aerojet Nuclear Company (ANC), Argonne National Laboratory (ANL), EG&G Idaho, Inc. (EG&G), Idaho Nuclear Corporation (INC), M-K Ferguson of Idaho (M-K), Protection Technology Idaho, Inc. (PTI), Phillips Petroleum Company (PPCo), Rockwell-INEL (R-INEL), Westinghouse Electric Corporation (WEC), Westinghouse Idaho Nuclear Company (WINCO).

b Zero or low power reactor.

REFERENCES

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A–2. M. A. Kuntz, et al., "Holocene Basaltic Volcanism Along the Great Rift, Central and Eastern Snake River Plain, Idaho," *Utah Geological and Mineral Survey Special Studies 61, 1983, Guidebook, Part–3*, GSA Rocky Mountain and Cordilleran Sections Meeting: Salt Lake City, Utah, May 1983.

APPENDIX B

ENVIRONMENTAL SURVEILLANCE PROGRAM DATA SUMMARIES

APPENDIX B

ENVIRONMENTAL SURVEILLANCE PROGRAM DATA SUMMARIES

This appendix contains data summary Tables B–1 through B–15 for the RESL Environmental Surveillance Program and for some contractor monitoring data at the INEL Site for 1990.

TABLE B–1
GROSS ALPHA ACTIVITY IN AIR (1990)

Group	Location	Number of Samples	Concentration (10^{-15} µCi/mL) Range	Concentration (10^{-15} µCi/mL) Annual Average[a]
Distant	Blackfoot	51	0.9–6.3	2.01 ± 0.22
	Craters of the Moon	50	0.3–4.1	1.23 ± 0.18
	Grand Mean[a]	—	—	1.62 ± 0.16
Boundary	Arco	52	0.5–4.9	1.63 ± 0.20
	Mud Lake	49	0.7–4.2	1.84 ± 0.17
	Grand Mean[a]	—	—	1.73 ± 0.13
Site	ANL–W	51	0.5–3.9	1.51 ± 0.17
	EFS	52	0.5–4.7	1.52 ± 0.20
	RWMC	50	0.4–3.7	1.59 ± 0.18
	TAN	52	0.7–6.6	1.79 ± 0.25
	Grand Mean[a]	—	—	1.60 ± 0.10

a. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

TABLE B–2
GROSS BETA ACTIVITY IN AIR (1990)

Group	Location	Number of Samples	Concentration (10^{-15}µCi/mL) Range	Annual Average[a]
Distant	Blackfoot	52	6–86	28 ± 3
	Craters of the Moon	52	5–100	25 ± 4
	Idaho Falls	49	7–63	25 ± 3
	Rexburg	51	8–71	27 ± 3
	Grand Mean[a]	—	—	26 ± 2
Boundary	Arco	52	8–76	27 ± 3
	Atomic City	52	7–97	28 ± 4
	FAA Tower	52	4–80	27 ± 3
	Howe	50	7–102	27 ± 4
	Monteview	52	9–107	28 ± 4
	Mud Lake	51	9–80	29 ± 4
	Reno Ranch	52	9–101	26 ± 4
	Grand Mean[a]	—	—	27 ± 1
Site	ANL–W	51	5–55	23 ± 2
	ARA	51	6–91	26 ± 3
	CFA	52	6–99	25 ± 4
	EBR–I	52	6–99	29 ± 4
	EFS	52	6–98	28 ± 4
	ICPP	48	5–107	29 ± 4
	NRF	50	5–111	29 ± 4
	PBF	52	6–102	29 ± 4
	RWMC	50	6–89	27 ± 4
	TAN	52	7–89	29 ± 4
	TRA	52	7–103	29 ± 4
	VANB	51	6–113	28 ± 4
	Grand Mean[a]	—	—	27 ± 1

a. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

TABLE B–3
GROSS BETA STATISTICAL COMPARISONS[a] BY LOCATION (1990)

Location	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
ARCO	—	—	—	—	—	—	—	—	—	—	—	—	—
ATOM	—	—	—	—	—	—	—	—	—	—	—	—	—
FAAT	—	—	—	—	—	—	—	—	—	—	—	—	—
HOWE	—	—	—	—	—	—	—	—	—	—	—	—	—
MONT	—	—	—	—	—	—	—	—	—	—	+	—	—
MUDL	—	—	—	—	—	—	—	—	—	—	—	—	+
RENO	—	—	—	—	—	—	—	—	—	—	—	—	—
Boundary Group[b]	—	—	—	—	—	—	—	—	—	—	+	—	—
ANL-W	—	—	—	—	—	—	—	—	—	—	—	—	—
ARA	—	—	—	—	—	—	—	—	—	—	—	—	—
CFA	—	—	—	—	—	—	—	—	—	—	—	—	—
EBR-I	—	—	—	—	—	—	—	—	—	—	+	—	—
EFS	—	—	—	—	—	—	—	—	—	—	—	—	—
ICPP	—	—	—	—	—	—	—	—	—	—	+	—	—
NRF	—	—	—	—	—	—	—	—	—	—	+	—	—
PBF	—	—	—	—	—	—	—	—	—	+	+	—	—
RWMC	—	—	—	—	—	—	—	—	—	—	—	—	—
TAN	—	—	—	—	—	—	—	—	—	—	+	—	—
TRA	—	—	—	—	—	—	—	—	—	—	—	—	—
VANB	—	—	—	—	—	—	—	—	—	—	—	—	—
Site Group[b]	—	—	—	—	—	—	—	—	—	—	+	—	—

a. Comparison used was upaired t test (α = 0.05) between means of individual locations and the distant communities (background) group mean. Means that were statistically greater than the background mean are indicated by "+" in the array (see Appendix C).

b. Group mean was compared to the background group mean for a comparable time period.

TABLE B–4
SPECIFIC RADIONUCLIDE ACTIVITY IN AIR (1990)

Radionuclide	Composite Group[a]	Concentration (10^{-15} μC/mL) Minimum[b]	Maximum[b]	Mean[c]	Derived Concentration Guide[d]	≈ MDC[e]
Cs–137	Distant	<MDC	<MDC	NSS	400,000	1
	Boundary	<MDC	<MDC	NSS		
	Site	<MDC	0.8 ± 0.6	0.13 ± 0.10		
Ru–106	Distant	<MDC	9 ± 8	NSS	30,000	10
	Boundary	<MDC	<MDC	NSS		
	Site	<MDC	<MDC	NSS		
		Concentration (10^{-18} μC/mL)				
Am–241	Distant	<MDC	<MDC	NSS	20,000	8
	Boundary	<MDC	<MDC	NSS		
	Site	<MDC	25 ± 10	NSS		
Pu–239/240	Distant	<MDC	<MDC	NSS	20,000	6
	Boundary	<MDC	<MDC	NSS		
	Site	<MDC	44 ± 10	NSS		

a. Sampling stations are shown in Figure 4 of this report.

b. Single quarterly composite sample analytical results ± 2 s, decay corrected assuming a constant concentration and buildup during the sampling period (see Appendix C).

c. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

d. Annual derived concentration guides given in Reference 2.

e. The minimum detectable concentrations (MDCs) are approximate and are calculated for typical values for airflow volume, counting time, radionuclide composition of the sample, and time elapsed between collection and analysis. These values may vary slightly for actual samples.

f. Below minimum detectable concentration.

g. Mean is not statistically significant (NSS), or zero is included with the 95% confidence interval for the mean (see Appendix C).

TABLE B–5
TRITIUM (HTO) CONCENTRATIONS IN AIR (1990)

Sample Dates	Concentrations[a] (10^{-7} pCi/mL)		
	Idaho Falls	EFS	Van Buren
12/29/89–03/30/90	2.2 ± 0.5	<MDC[b]	<MDC
03/30/90–06/29/90	15.9 ± 0.8	11.2 ± 0.8	<MDC
06/29/90–09/28/90	<MDC	<MDC	<MDC
09/28/90–12/28/90	9.5 ± 1.0	4.0 ± 1.0	6.5 ± 1.0
Annual Mean[c]	7 ± 12[d]	4 ± 8[d]	2 ± 5[d]
% DCG[e]	0.0007	0.0004	0.0002

a. Analytical results ± 2s (see Appendix C).

b. Below minimum detectable concentration.

c. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

d. Mean is not statistically significant because zero is included in the 95% confidence interval.

e. Mean is compared to the derived concentration guide, 1×10^{-7} μCi/mL, which corresponds to 0.1 pCi/mL.

TABLE B–6
KRYPTON–85 CONCENTRATIONS IN AIR AT CFA (1990)

Sample Dates	Concentration[a] (10^{-12} µCi/mL)
Dec 26, 1989 to Jan 8	28 ± 3
Jan 8 to Jan 23	28 ± 3
Jan 23 to Feb 7	30 ± 3
Feb 7 to Feb 22	30 ± 3
Feb 22 to Mar 8	28 ± 3
Mar 8 to Mar 22	31 ± 5
Mar 22 to Apr 5	29 ± 4
Apr 5 to Apr 19	27 ± 3
Apr 19 to May 3	25 ± 4
May 3 to May 17	27 ± 3
May 17 to May 31	27 ± 3
May 31 to Jun 14	25 ± 3
Jun 14 to Jun 28	28 ± 3
Jun 28 to Jul 12	28 ± 3
Jul 12 to Jul 26	26 ± 3
Jul 26 to Aug 9	25 ± 3
Aug 9 to Aug 23	25 ± 3
Aug 23 to Sep 6	27 ± 3
Sep 6 to Sep 21	28 ± 3
Sep 21 to Oct 4	25 ± 3
Oct 4 to Oct 18	29 ± 3
Oct 18 to Nov 1	28 ± 3
Nov 1 to Nov 15	30 ± 3
Nov 15 to Nov 29	28 ± 3
Nov 29 to Dec 13	29 ± 3
Dec 13 to Dec 27	30 ± 3
Annual Mean[b]	27.7 ± 0.7

a. Results ± 2s analytical uncertainty reported by EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

b. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

TABLE B–7
RADIONUCLIDE CONCENTRATIONS IN SITE DRINKING WATER (1990)

	H–3 Concentration (10^{-6} µCi/mL)[a]				Sr–90 Concentration (10^{-9} µCi/mL)[a]			
Well Code	No. Samples[b]	Range	Annual Mean[c]	% DCG	No. Samples[b]	Range	Annual Mean[c]	% DCG
CFA[d]	13	16–18	16.8 ± 0.3	0.8	0	—	—	—
CFA #2	13	15–17	16.5 ± 0.5	0.8	0	—	—	—
ICPP #1	8	<MDC[e]–0.5	0.21 ± 0.14	0.011	8	0.3–1.1	0.7 ± 0.2	0.07
ICPP #2	4	<MDC–<MDC	NSS[f]	—	4	<MDC–<MDC	NSS	—
ICPP #4	12	<MDC–<MDC	NSS	—	11	<MDC–<MDC	NSS	—
OMRE	13	2.0–2.7	2.38 ± 0.13	0.12	0	—	—	—
Rifle Range	11	<MDC–5.3	4.6 ± 1.0	0.2	0	—	—	—
RWMC	13	1.4–1.8	1.62 ± 0.07	0.08	0	—	—	—

a. Concentrations expressed as 10^{-6} µCi/mL are equivalent to pCi/mL or 1000 pCi/L. Concentrations expressed as 10^{-9} µCi/mL are equivalent to pCi/L.

b. RESL collects samples only from wells actually in use at collection time. Tritium and Sr–90 results from samples collected by USGS from these wells appear periodically in USGS reports.

c. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

d. These samples were from the CFA distribution system during 1990.

e. <MDC refers to concentrations less than the minimum detectable concentration.

f. Mean is not statistically significant, or zero is included within the 95% confidence interval.

TABLE B–8
STRONTIUM–90 CONCENTRATIONS IN WHEAT AND LETTUCE (1990)

	Group	Sample Location	Concentrations[a] (10^{-9} µCi/g dry wt) Wheat Sr–90	Garden Lettuce Sr–90
≈Minimum detectable concentration	—	—	4	80
	Distant	American Falls	10 ± 3	NA[b]
		Blackfoot	21 ± 4	150 ± 60
		Carey	NA	180 ± 40
		Dietrich	9 ± 3	NA
		Idaho Falls	13 ± 4	—[c]
		Minidoka	12 ± 4	NA
		Pocatello	NA	210 ± 60
		Mean[d]	13 ± 6	180 ± 70
	Boundary	Arco	13 ± 4	50 ± 40
		Atomic City	NA	140 ± 40
		Howe	NA	50 ± 40
		Monteview	9 ± 3	NA
		Mud Lake	7 ± 3	90 ± 60
		Taber	10 ± 3	NA
		Terreton	12 ± 3	NA
		Mean[d]	10 ± 3	80 ± 70

a. Analytical results ± 2s (see Appendix C).

b. No analysis.

c. Sample lost in analysis.

d. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

TABLE B–9
RADIONUCLIDES IN OFFSITE SURFACE SOILS[a] (1990)

Radionuclide	Year[d]	Geometric Mean with 95% Confidence Interval[b] pCi/g		Geometric Mean with 95% Confidence Interval[b] nCi/m²		Number of Samples	≈MDC[c] pCi/g	≈MDC[c] nCi/m²
Cs-137	1970–75	0.94	(0.78–1.1)	54	(49–59)	60	0.01	1
	1978	0.94	(0.72–1.2)	58	(44–75)	10	0.01	1
	1980	0.64	(0.46–0.90)	41	(29–57)	10	0.01	1
	1982	0.90	(0.64–1.2)	44	(31–62)	10	0.01	1
	1984	0.69	(0.49–0.97)	43	(31–60)	7	0.01	1
	1986	0.81	(0.54–1.2)	48	(34–67)	13	0.01	1
	1988	0.66	(0.34–1.3)	47	(46–48)	12	0.01	1
	1990	0.73	(0.54–0.99)	43	(33–56)	12	0.01	1
Sr-90	1970–75	0.54	(0.43–0.59)	34	(31–37)	55	0.09	10
	1978	0.52	(0.40–0.68)	32	(23–45)	10	0.09	10
	1980	0.35	(0.25–0.49)	22	(15–33)	10	0.09	10
	1982	0.37	(0.26–0.52)	18	(11–29)	10	0.09	10
	1984	0.45	(0.32–0.63)	28	(20–39)	7	0.09	10
	1986	0.52	(0.43–0.62)	30	(25–37)	13	0.09	10
	1988	0.38	(0.28–0.53)	23	(17–31)	12	0.09	10
	1990	0.30	(0.22–0.40)	17	(13–23)	12	0.09	10
Pu-238	1970–75	0.0028	(0.0023–0.0034)	0.15	(0.13–0.18)	55	0.002	0.1
	1978	0.0010	(0.0005–0.0020)	0.06	(0.03–0.11)	10	0.002	0.1
	1980	0.0007	(0.0005–0.0009)	0.05	(0.04–0.07)	10	0.002	0.1
	1982	0.0011	(0.0007–0.0017)	0.05	(0.03–0.08)	10	0.002	0.1
	1984	0.0015	(0.0008–0.0027)	0.08	(0.04–0.15)	7	0.002	0.1
	1986	0.0021	(0.0010–0.0046)	0.12	(0.06–0.27)	13	0.002	0.1
	1988	0.0014	(0.0009–0.0024)	0.09	(0.05–0.14)	12	0.002	0.1
	1990	0.0006	(0.0003–0.0012)	0.04	(0.02–0.09)	12	0.002	0.1
Pu-239/240	1970–75	0.020	(0.017–0.024)	1.06	(0.96–1.17)	54	0.002	0.1
	1978	0.018	(0.013–0.025)	1.09	(0.78–1.53)	10	0.002	0.1
	1980	0.010	(0.006–0.017)	0.63	(0.37–1.07)	10	0.002	0.1
	1982	0.022	(0.016–0.031)	1.06	(0.76–1.48)	10	0.002	0.1
	1984	0.016	(0.011–0.022)	1.02	(0.73–1.43)	7	0.002	0.1
	1986	0.018	(0.012–0.027)	1.05	(0.70–1.58)	13	0.002	0.1
	1988	0.021	(0.015–0.029)	1.22	(0.91–1.65)	12	0.002	0.1
	1990	0.024	(0.017–0.035)	1.43	(1.01–2.03)	12	0.002	0.1
Am-241	1970–75	0.004	(0.003–0.005)	0.24	(0.20–0.29)	37	0.003	0.2
	1978	0.006	(0.004–0.009)	0.38	(0.29–0.49)	10	0.003	0.2
	1980	0.003	(0.002–0.004)	0.20	(0.14–0.28)	10	0.003	0.2
	1982	0.004	(0.003–0.006)	0.21	(0.13–0.34)	10	0.003	0.2
	1984	0.004	(0.002–0.007)	0.26	(0.15–0.44)	7	0.003	0.2
	1986	0.004	(0.002–0.007)	0.23	(0.13–0.41)	13	0.003	0.2
	1988	0.005	(0.004–0.008)	0.31	(0.22–0.45)	12	0.003	0.2
	1990	0.005	(0.003–0.008)	0.27	(0.16–0.45)	12	0.003	0.2

a. Soil samples collected to a depth of 5 cm.

b. Geometric mean with the 95% confidence interval for the mean (see Appendix C).

c. Approximate minimum detectable concentration.

d. Excluding 1972 in which no samples were taken.

TABLE B–10
ENVIRONMENTAL RADIATION EXPOSURES (1987–1990)

Location	Annual Exposures (mR)[a] 1987[b]	1988	1989	1990
Distant Group:				
Aberdeen	104 ± 4	108 ± 4	114 ± 6	114 ± 4
Blackfoot	100 ± 2	112 ± 5	117 ± 8	118 ± 5
Craters of the Moon	98 ± 4	118 ± 4	123 ± 7	116 ± 4
Idaho Falls	113 ± 4	113 ± 4	—[c]	126 ± 4
Minidoka	95 ± 4	92 ± 3	108 ± 6	99 ± 4
Rexburg	94 ± 3	114 ± 4	114 ± 5	110 ± 4
Roberts	—[d]	122 ± 6	127 ± 6	125 ± 5
Mean[e]	101 ± 7	111 ± 9	117 ± 7	115 ± 9
Boundary Group:				
Arco	100 ± 4	106 ± 6	117 ± 5	114 ± 4
Atomic City	95 ± 4	118 ± 7	125 ± 6	121 ± 4
Howe	98 ± 4	105 ± 6	117 ± 6	—[f]
Monteview	98 ± 4	101 ± 5	120 ± 6	110 ± 4
Mud Lake	104 ± 4	111 ± 5	125 ± 6	121 ± 6
Reno Ranch	93 ± 3	110 ± 4	105 ± 6	110 ± 4
Mean[e]	98 ± 4	109 ± 6	118 ± 8	115 ± 7

a. Annual exposure ± 2s (see Appendix C).

b. Some or all annual exposures listed for 1987 may be 11% low. See text.

c. Dosimeter missing at November 1989 collection time.

d. Dosimeter missing at May 1987 collection time.

e. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

f. Dosimeter missing at May 1990 collection time.

TABLE B–11
RADIONUCLIDE COMPOSITION OF AIRBORNE EFFLUENTS (1990)

	Radionuclide	Half-Life	Airborne Effluent (Ci)[a] ANL-W	ICPP	NRF	TRA	Total[b]
Noble Gases	Kr-85	10.7 yr	0.18	<20,000[c]	3.5×10^{-4}	—	<20,000
	Ar-41	1.83 h	57	—	—	3200	3300
	Xe-133	5.25 d	450	—	—	25	470
	Xe-138	14.2 min	15	—	—	200	210
	Xe-135	9.10 h	120	—	—	79	200
	Kr-87	1.27 h	24	—	—	68	92
	Kr-88	2.84 h	24	—	—	66	90
	Xe-135m	15.3 min	5.5	—	—	40	46
	Kr-85m	4.48 h	21	—	—	22	43
	Xe-131m	11.9 d	0.10	—	—	—	0.10
	Xe-133m	2.19 d	1.8×10^{-3}	—	—	—	1.8×10^{-3}
Particulates	Rb-89	15.4 min	—	—	—	0.73	0.73
	Cs-138	32.2 min	—	—	—	0.71	0.71
	Rb-88	17.7 min	—	—	—	0.50	0.50
	Ba-139	1.39 h	—	—	—	5.1×10^{-2}	5.1×10^{-2}
	Cr-51	27.8 d	—	—	—	5.1×10^{-3}	5.1×10^{-3}
	Na-24	15.0 h	—	—	—	3.2×10^{-3}	3.2×10^{-3}
	Tc-99m	6.01 h	—	—	—	2.6×10^{-3}	2.6×10^{-3}
	Ba-La-140	12.8 d	2.3×10^{-3}	—	—	—	2.3×10^{-3}
	Ru-106	372 d	—	1.2×10^{-3}	—	—	1.2×10^{-3}
	Cs-137	30.2 yr	—	6.2×10^{-4}	—	3.1×10^{-6}	6.2×10^{-4}
	Sb-125	2.73 yr	—	2.1×10^{-4}	—	—	2.1×10^{-4}
	Sr-90 + D[d]	28.6 yr	—	2.4×10^{-6}	—	2.6×10^{-6}	5.7×10^{-6}
	Pu (total)	—	—	2.7×10^{-8}	—	—	2.7×10^{-8}
H-3, C-14 and Iodine Isotopes	H-3	12.3 yr	2.3	1.7	4.3×10^{-2}	—	4.0
	C-14	5.7×10^{3} yr	—	0.15	0.13	—	0.28
	I-129	1.6×10^{7} yr	—	3.5×10^{-3}	—	—	3.5×10^{-3}
	I-132	83.0 min	9.1×10^{-4}	—	—	1.2×10^{-3}	2.2×10^{-3}
	I-131	8.04 d	2.2×10^{-4}	—	5.8×10^{-5}	8.3×10^{-4}	1.1×10^{-3}
	I-134	52.6 min	—	—	—	1.1×10^{-3}	1.1×10^{-3}
	I-133	20.8 h	3.7×10^{-4}	—	—	6.3×10^{-4}	9.9×10^{-4}
All Other Total			0.12	1.6×10^{-5}	8.7×10^{-5}	2.3×10^{-3}	0.12
Grand Totals (rounded)			720	<20,000	0.17	3700	<24,000

a. Radioactivity listed in 1990 Radioactive Waste Management Information System Report. Values are not corrected for decay after release. Data are preliminary.

b. Totals include small amounts from facilities not listed.

c. The actual number of curies is classifed information.

d. Parent-daughter equilibrium assumed.

TABLE B–12
RADIONUCLIDE COMPOSITION OF LIQUID EFFLUENTS RELEASED ONSITE (1990)

		Liquid Effluent (Ci)[a]				
Radionuclide	Half-Life	ANL-W	CFA	ICPP	TRA	Total[b]
H-3	12.3 yr	0.26	2.5[c]	0.47	180	180
Cr-51	27.8 d	--	—	—	3.4	3.4
Na-24	15.0 yr	—	—	—	0.12	0.12
Co-60	5.26 yr	—	—	1.1×10^{-3}	0.10	0.10
Cs-137	30.2 yr	—	—	5.0×10^{-2}	4.9×10^{-3}	5.4×10^{-2}
Sr-90	28.6 yr	—	6.4×10^{-4}	3.3×10^{-2}	—	3.3×10^{-2}
Ce-144	2.84 d	—	—	—	2.8×10^{-2}	2.8×10^{-2}
Pu-(total)	—	—	—	4.8×10^{-4}	—	4.8×10^{-4}
All Others	—	—	5.8×10^{-3}	3.2×10^{-2}	1.1	1.1
Grand Totals (rounded)		0.26	2.5	0.59	190	190

a. Radioactivity provided by Radioactive Waste Management Information System. Values are not corrected for decay after release. Data are preliminary.

b. Totals include small amounts from facilities not listed.

c. Tritium in the effluent is due to tritium in the water supply at CFA.

TABLE B–13
PURGEABLE ORGANIC COMPOUNDS IN GROUND WATER (1990)

Well Number	Date Sampled	Concentration[a] (μg/L) Carbon Tetra–chloride	Chloro–form	1,1,1–Tri–chloro–ethane	Tri–chloro–ethylene	Tetra–chloro–ethylene	1,2–trans–dichloro–ethylene	Toluene	Others
RWMC Area									
88	01–23–90	—	—	—	—	—	—	—	Dichlorodifluoromethane, 2.5
	04–10–90	—	—	—	—	—	—	—	Dichlorodifluoromethane, 2.6
	07–19–90[b]	2.1	—	—	1.0	—	—	—	—
	07–19–90[b]	2.7	—	—	1.1	—	—	—	—
	08–28–90[c]	1.9–3.5	—	—	0.7–1.3	—	—	—	—
	09–25–90	1.5	—	—	—	—	—	—	—
90	01–23–90	1.0	—	—	—	—	—	—	—
	04–10–90	1.0	—	—	—	—	—	—	—
	07–02–90	1.3	—	—	—	—	—	—	Dichlorodifluoromethane, 2.4
	10–24–90	1.0	—	—	—	—	—	—	—
RWMC	01–03–90	1.5	—	—	—	—	—	—	—
	04–05–90	1.8	—	—	—	—	—	—	—
	07–11–90	1.7	—	—	—	—	—	—	—
	08–30–90	1.3	—	—	—	—	—	—	—
	09–24–90	1.9	—	—	—	—	—	—	—
	10–30–90	1.7	—	—	—	—	—	—	—
	11–28–90	2.0	—	—	—	—	—	—	—
	12–19–90	1.7	—	—	—	—	—	—	—
MCL[d]		5	100	200	5	None	None	None	—

a. Concentrations shown are those measured that were equal to or above 1.0 μg/L. For all analyses, the reporting level was 0.2 μg/L.

b. Samples taken at different times.

c. Range of 30 samples taken over a 42–minute period.

d. Maximum contaminant level for drinking water established by the EPA on July 8, 1987, except for chloroform, which is a trihalomethane regulated under 40 CFR 141. The only well to which the MCL applies is RWMC, which is a drinking water or production well.

TABLE B–14
PARTICULATE MATTER CONCENTRATIONS IN AIR (1990)

Group	Locations	Concentration[a] ($\mu g/m^3$) Range	Mean[b]
Distant	Blackfoot	20–40	36 ± 15
	Craters of the Moon	7–14	11 ± 6
	Idaho Falls	40–90	60 ± 40
	Rexburg	20–60	40 ± 20
	Grand Mean[b]		36 ± 12
Boundary	Arco	20–90	60 ± 40
	Atomic City	13–50	30 ± 20
	FAA Tower	7–17	13 ± 7
	Howe	18–60	40 ± 30
	Monteview	14–50	30 ± 20
	Mud Lake	20–50	39 ± 19
	Reno Ranch	9–20	15 ± 13
	Grand Mean[b]		32 ± 8
Site	ANL–W	11–20	18 ± 9
	ARA	7–17	13 ± 7
	CFA	10–30	19 ± 16
	EBR–I	9–18	13 ± 7
	EFS	9–30	17 ± 15
	ICPP	13–40	24 ± 16
	NRF	15–50	30 ± 30
	PBF	10–20	16 ± 9
	RWMC	12–40	22 ± 19
	TAN	19–30	22 ± 4
	TRA	13–20	17 ± 9
	VANB	7–20	13 ± 10
	Grand Mean[b]		20 ± 9

a. The approximate minimum detectable concentration (≈MDC) is 10 $\mu g/m^3$. The EPA's national primary and secondary ambient air quality standard is 50 $\mu g/m^3$, annual average, for particulates with diameter less than or equal to 10 μm.

b. Arithmetic mean with the 95% confidence interval for the mean (see Appendix C).

TABLE B–15
NONRADIOACTIVE AIRBORNE EFFLUENTS (1990)

Facility	Emissions (Mg) NO	NO_2[a]	SO_2
ANL–W	—	3.6	6.0
CFA	—	1.6	3.9
CFSGF[b]	54.5	—	18.0
ICPP (oil)	—	0.9	6.0
ICPP (main stack)[c]	6.8	60.9	—
CTF	—	0.3	0.8
NRF	—	17.6	52.0
PBF	—	0.2	0.6
TRA	—	3.8	10.9
TSF	—	6.5	22.8
WERF	—	0.3	0.8
Totals	61.3	95.7	121.8

a. Calculated from fuel oil usage reported by IWMIS and emission factors given in Reference 28.

b. Calculated from CFSGF plant operating data supplied by T. W. Chesnovar of WINCO.

c. Reported in IWMIS on ICPP Airborne Summary page.

APPENDIX C

STATISTICAL METHODS

APPENDIX C

STATISTICAL METHODS

Individual analytical results are given in the report with plus or minus (±) two analytical standard deviations (2s), where all analytical uncertainties have been calculated and "s" is an estimate of the population standard deviation "ρ." Many of the results were less than or equal to 2s (and, in fact, some were negative), which means that they were below the minimum detectable concentration. Gamma spectrometric analyses differ from other types because the radionuclide is not considered detectable unless the net count in the peak is equal to or greater than three times its estimated analytical uncertainty (3s). A deliberate search for specific nuclides can be made and results reported, but such results might include negative values.

If the result lies in the range of two to three times its estimated analytical uncertainty (2s to 3s), and assuming that the result belongs to a Gaussian distribution, detection of the material by the analysis may be questionable because of statistical variations within the group of samples. Analyses with results in the questionable range are published in this report with the understanding that there may be some doubt as to whether the material was actually present.

There are many factors that can influence the result to some degree, and these factors are considered and included in the methods used to determine the estimated uncertainty of the measurement. Uncertainties in measurements near the minimum detectable concentration are primarily caused by counting statistics. For low concentrations near the minimum detectable concentration, the uncertainty in the measurement is nearly equal to the measurement itself, and the lower limit of the range of the measurement approaches "zero." Such a result might not be very reliable because the uncertainty is only an estimate and the actual probability distribution of the results is not usually known. In reality, the material being measured may not actually be present in the sample. Therefore, when analytical results show a measurement very near the minimum detectable concentration, statistical tools, meteorological data, and Site release information are all considered when interpreting and evaluating the results.

If the result exceeds 3s, there is confidence that the material was detected by the analysis.

Arithmetic means were calculated using actual assay results, regardless of their being above or below the minimum detectable concentration. The uncertainty of the mean, or the 95% confidence interval, was determined by multiplying the standard deviation of the mean (also called the standard error of the mean) or $s/(n)^{1/2}$ by the $t_{(0.05)}$ statistic. Means for which the 95% confidence interval does not include zero were assumed to indicate detectable amounts of activity. In situations where the analytical results of a group of samples are near the minimum detectable concentration, the 95% confidence interval for the mean may not include zero and thus appears to be statistically significant even though, on the basis of the 2s–to–3s criterion, it is doubtful that any individual sample contained detectable radioactivity.

Geometric means were calculated by summing the natural logarithms (ln) of the positive analytical results, dividing by the number of samples (n), and then transforming the quotient. If the result was either a negative number or a zero, the ln of the smallest positive, nonzero measurement in the group was used. The 95% confidence interval was determined by multiplying the standard deviation of the geometric mean by the $t_{(0.05)}$ statistic and then transforming the result. The actual interval is determined by dividing the transformed mean by the transformed 95% confidence interval term for the lower limit, then multiplying the mean by the confidence interval term for the upper limit.

Unpaired t–tests were used to determine whether the annual means for the Site or boundary stations were greater than the annual means for the distant stations. All statistical tests used a level of significance of 5% ($\alpha = 0.05$).[C-1]

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C–1. Lyman Ott, *An Introduction to Statistical Methods and Data Analysis*, Boston, Massachusetts: Duxbury Press, 1977.

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