1982 ENVIRONMENTAL MONITORING PROGRAM REPORT FOR IDAHO NATIONAL ENGINEERING LABORATORY SITE

May 1983

PREFACE

This report presents the offsite data collected in 1982 for the routine environmental monitoring program conducted by the Department of Energy's Radiological and Environmental Sciences Laboratory (RESL/ID) at the Idaho National Engineering Laboratory (INEL) Site. The purpose of this routine program is to monitor radioactive and nonradioactive materials resulting from INEL Site operations which may reach the surrounding offsite environment and population. This report is prepared in accordance with the Department of Energy requirements in DOE Order 5484.1 and is not intended to cover the numerous special environmental research programs being conducted at the INEL by the RESL/ID and others. Generally, these latter programs are aimed at quantifying the effects of Site operations on the onsite environment.

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

SUMMARY

The results of the various monitoring programs for 1982 indicated that radioactivity from the Idaho National Engineering Laboratory (INEL) site operations could not be distinguished from worldwide fallout and natural radioactivity in the region surrounding the 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. This report describes the air, water, and foodstuff samples routinely collected at the INEL boundary locations and at locations distant from the INEL Site. The report also compares and evaluates the sample results and discusses implications.

There was no statistical difference in particulate beta concentrations in air as measured at Site boundary stations and those measured at distant sampling stations. Air samples are also analyzed for specific radionuclides. Some radionuclides were detected, but their presence was attributable to natural sources, worldwide fallout, or statistical fluctuations and not to Site operations.

A few samples of offsite well water and surface water contained detectable gross alpha or gross beta activity, probably due to natural radioactivity. All offsite water samples were considerably below the EPA maximum contaminant level for community drinking water systems. No offsite water samples contained detectable tritium concentrations.

Iodine-131 was detected in two milk samples but was not attributable to Site operations. Some of the milk and lettuce samples contained small amounts of Sr-90, and a few wheat samples had detectable concentrations of Cs-127. The presence of both nuclides is probably due to worldwide fallout.

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

For details on monitoring results see the section "Monitoring Data Collection, Analyses, and Evaluation."

Measurable amounts of radioactivity, primarily in the form of noble gases, are released from various plant facilities and subsequently travel offsite. When they reach the Site boundary, these gases are in such low concentrations that their effect on radiation levels cannot be measured; but their contributions to offsite doses are nevertheless calculated.

A hypothetical maximum whole-body dose on the southern Site boundary was calculated to be 0.04 millirem (mrem). The calculation assumed continuous submersion in and inhalation of radioactivity at the location. This hypothetical dose is about 0.03% of the natural background radiation dose of about 150 mrem/yr in this area. The potential maximum individual dose to a real person was calculated to be 0.02 mrem at Atomic City, Idaho. This also represents the maximum potential dose to a member of a population group. The maximum potential population dose from continuous submersion in and inhalation of airborne radioactivity to the approximately 114,400 people residing within an 80 km (50 mi) radius from the center of INEL was estimated to be 0.17 man-rem. This dose is about 0.001% of the population dose from natural background radioactivity, which is estimated to be 17,200 man-rem. These doses and their implications are discussed in the section "Radiological Impact of INEL Site Operations."

Calculations indicate that the maximum potential dose to an individual from indirect exposure pathways due to ingestion of wild game animals is about 2% of the radiation protection standard for individuals at points of maximum probable exposure. See the section "Environmental Standards and Regulations." The potential man-rem dose to all offsite populations from these exposure pathways would realistically be less than the dose from submersion and inhalation pathways.

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Figure 1.   INEL Site vicinity map.

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INTRODUCTION

The Department of Energy's (DOE) Idaho National Engineering Laboratory (INEL) was established by the Federal Government in 1949 to conduct research and further the development of nuclear reactors and ancillary equipment. The 2300-km^2 (890-mi^2) Site is located west of Idaho Falls, Idaho on a high desert plain (see Figures 1 and 2). In 1975 the Site was also designated as one of the nation's five National Environmental Research Parks (NERP). A more detailed description of the Site location, environment, and current major activities is given in Appendix A.

Figure 2.   North facing view of part of the INEL Site.

MONITORING DATA COLLECTION, ANALYSES, AND EVALUATION

General

During normal operation of the reactors and the fuel reprocessing plant at the Site, some radioactivity is released to the environment. The environmental pathways by which radioactive materials may be transported from the Site to nearby populations are directly through atmospheric transport or indirectly through soils, foodstuffs, or animals. No evidence is available that radionuclides in water in the Snake River Plain aquifer have reached the INEL southern boundary. However, computer model projections indicate that trace concentrations of radioactivity will migrate offsite in the future. The environmental monitoring program for the Site and vicinity for 1982 included the collection and analysis of samples from potential exposure pathways. Table I gives a summary of the offsite program. Measurements at Site boundary locations are compared to measurements at distant locations to assess the impact of INEL Site operations on the offsite environment. The amounts of radioactive and some nonradioactive pollutants in the environment are compared to applicable standards and guides and to background and natural radioactivity. Most radioactive concentrations in this report are compared to the concentration guides for uncontrolled areas listed in "Requirements for Radiation Protection," *DOE Order 5480.1A*, Chapter XI. See the section "Environmental Standards and Regulations."

Air and water were routinely monitored for radioactivity at a number of onsite, as well as boundary, and distant locations. The amounts of radioactivity in milk, wheat, and lettuce samples were measured at Site boundary and distant locations. Environmental radiation exposure rates (cumulative from November 1981 to November 1982) were measured at Site boundary and distant locations. See Appendix B for a description of the quality control and assurance program maintained by the Radiological and Environmental Sciences Laboratory.

A discussion of each routine program follows. For each program a presentation and interpretation of the data are given, as are the location of each sampling station and the number of samples collected. See Appendix C for a discussion of the statistics used to analyze the data in this report.

Air Sampling

Radiological. Airborne particulate radioactivity is monitored offsite by a network of 10 continuous air samplers at locations shown in Figure 3. Air samplers are located in the small communities close to the Site boundary and at the more distant locations of the Craters of the Moon National Monument, Idaho Falls, and Blackfoot, Idaho. These distant or background locations are in directions usually crosswind of the Site and are sufficiently remote to ensure that radioactivity detected is due to natural background or sources other than Site operations. The whole network provides comprehensive surveillance of atmospheric radioactivity and theoretically makes it possible to differentiate Site releases from worldwide fallout and long-lived natural radioactivity.

Each air sampler (see Figure 4) 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 AN-1200) followed by an activated charcoal-impregnated cellulose fiber filter (Gelman Model AC-1). The filters are 99% efficient for airborne particulate radioactivity and elemental iodine vapor. One offsite and two onsite locations also have samplers for tritium in water vapor in which air is passed at 0.3 L/min (0.65 ft^3/hr) through a column of silica gel. Noble gases (argon, krypton, and xenon) are monitored at their onsite release points only.

The filters are collected weekly and analyzed after waiting a minimum of five days to allow the naturally occurring short-lived radon and thoron daughters to decay. Gross beta analysis is performed on each filter in a low background beta counter. If the beta activity on a membrane filter exceeds about 1×10^{-12} μCi/mL, the filter is analyzed by gamma spectrometry. All activity detected on the charcoal-impregnated filters is initially assumed to be I-131. If the beta activity on the charcoal filter exceeds about

TABLE I
OFFSITE MONITORING PROGRAM SUMMARY

Medium Sampled	Type of Analysis	Frequency of Analysis	Sample Size	Count Time (minutes)	~Minimum Detectable Concentration (MDC)
Air	Gross beta	Weekly	1 to 4 x 10^8 mL	20	8 x 10^{-15} μCi/mL
	HTO[a]	3 to 7 weeks	1 to 10 x 10^6 mL	100	1 x 10^{-11} μCi/mL
	Specific gamma	Quarterly	3 to 5 x 10^9 mL	60	1 to 10 x 10^{-15} μCi/mL
	Pu	Quarterly	3 to 5 x 10^9 mL	1000	6 x 10^{-18} μCi/mL
	Am	Quarterly	3 to 5 x 10^9 mL	1000	8 x 10^{-18} μCi/mL
	Sr-90	Quarterly	3 to 5 x 10^9 mL	20	1 x 10^{-15} μCi/mL
Water	Gross alpha	Semiannually	100 mL	60	3 x 10^{-9} μCi/mL
	Gross beta	Semiannually	250 mL	20	5 x 10^{-9} μCi/mL
	HTO	Semiannually	10 mL	20	4 x 10^{-7} μCi/mL
Milk	I-131	Monthly[b]	3800 mL	1000	1 x 10^{-9} μCi/mL
	Sr-90	Annually	1000 mL	20	2 x 10^{-9} μCi/mL
	H-3	Annually	10 mL	100	4 x 10^{-7} μCi/mL
	I-129	Annually[c]	3800 mL	10	6 x 10^{-11} μCi/mL
Wheat	Specific gamma	Annually	2500 g	1000	4 x 10^{-9} μCi/g
	Sr-90	Annually	500 g	20	4 x 10^{-9} μCi/g
Lettuce	Specific gamma	Annually	30 g (dry wt)	1000	1 x 10^{-8} μCi/g
	Sr-90	Annually	30 g (dry wt)	20	8 x 10^{-8} μCi/g
Soil	Specific gamma	Biennially	400 g[d]	1000	4 x 10^{-8} μCi/g
	Pu	Biennially	10 g[d]	1000	2 x 10^{-9} μCi/g
	Am	Biennially	10 g[d]	1000	3 x 10^{-9} μCi/g
	Sr-90	Biennially	10 g[d]	100	9 x 10^{-8} μCi/g
Direct radiation exposure	Thermoluminescent dosimeter	Semiannually	5 TLDs per dosimeter	NA[e]	5 mR

a. Tritiated water.

b. One dairy is sampled weekly.

c. Three locations only.

d. Aliquot from a composited 2000-g sample.

e. NA—not applicable.

7 x 10^{-14} μCi/mL, the filter is analyzed by gamma spectrometry to determine the I-131 component. At the end of each quarter, the membrane filters are composited according to location. The composited samples from each location are analyzed for specific radionuclides by gamma spectrometry. One composite from a distant location is analyzed each quarter for specific alpha-emitting radionuclides by chemical separation followed by alpha spectrometry. Five other composites are analyzed on a rotating schedule for specific alpha-emitting radionuclides and for Sr-90. Analyses for Sr-90 utilize chemical separation techniques followed by beta counting.

The particulate beta activity measured at the boundary locations was not distinguishable from worldwide fallout and naturally-occurring radioactivity as measured at the distant locations (see Table II). The average monthly concentrations of particulate beta activity are shown in Figure 5 for 1977 through 1982. None of the charcoal filters had an activity above the action level of approximately 7 x 10^{-14} μCi/mL.

Because the quantity and identity of radionuclides released from Site facilities is known, specific radionuclide analysis is a more sensitive

RENO RANCH

MONTEVIEW

MUD LAKE

HOWE

I N E L

ARCO

CRATERS OF THE MOON
NATIONAL MONUMENT

ATOMIC CITY

FAA TOWER

IDAHO FALLS

♦ = LOW-VOLUME AIR SAMPLERS

♦ BLACKFOOT

10   0   10   20
SCALE IN KILOMETERS
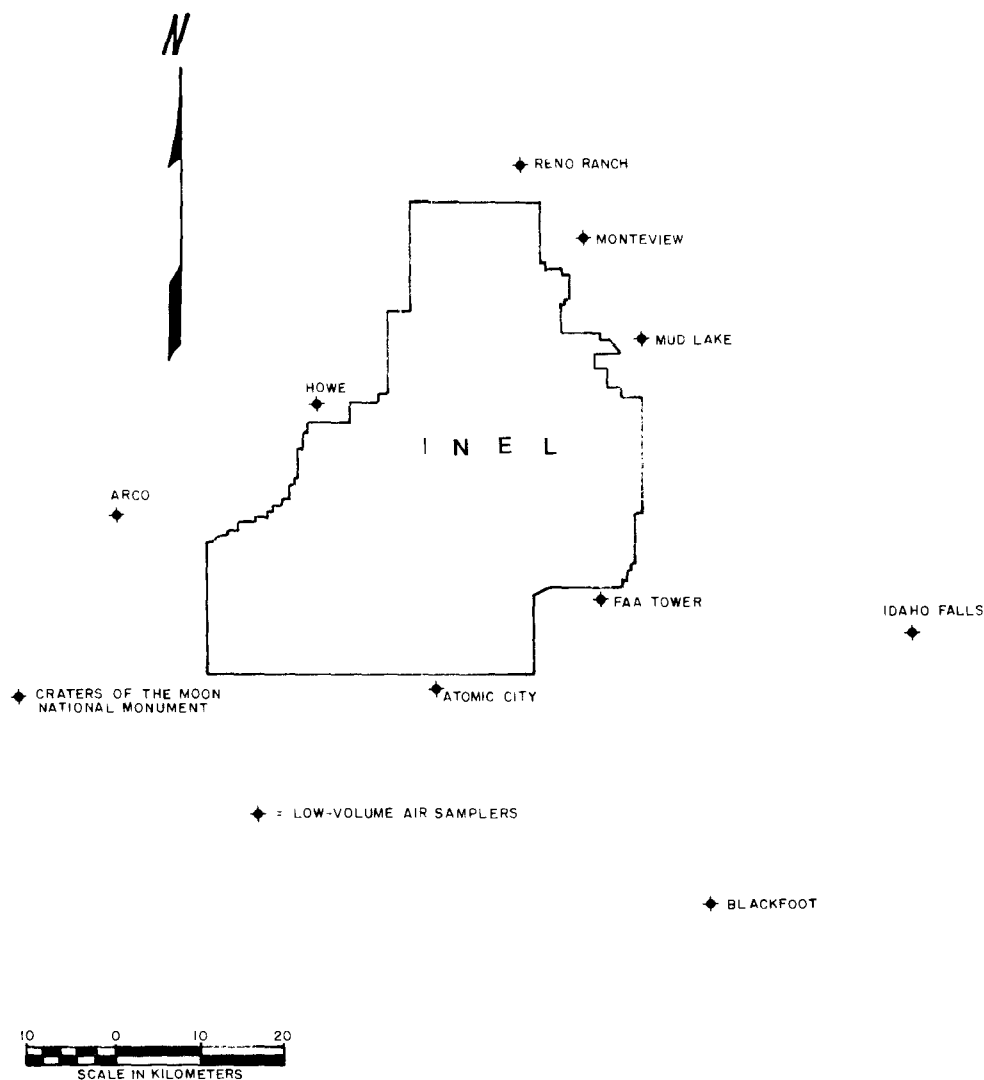
Figure 3.   INEL Site air sampling network.

indicator than beta analysis of the impact of Site operations on the environment. Detectable concentrations of radionuclides such as Ce-144, Ce-141, Ru-103, Cs-137, Mn-54, Sr-90, and Pu-239/240, which are associated with worldwide fallout, were present at one or more locations during 1982. Comparisons of concentrations of these radionuclides to releases from Site facilities led to the conclusion that their presence was not due to Site operations. A summary of the results of specific nuclide analyses of the filter composites for distant and boundary air sampling locations is shown in Table III. Beryllium-7, a radionuclide produced by the interaction of cosmic radiation and nitrogen in the atmosphere, is excluded.

Because of the low concentrations of radioactivity in environmental samples, some of the

results are very near the minimum detectable concentration. There is always some risk in attempting to draw firm conclusions from these results. There are many factors which can influence the result to some degree and for which we try to account in the methods used for determining the uncertainty of the measurement. Small factors are not particularly important when the size of the measurement is many times larger than the uncertainty (e.g., 40 ± 2), but may become quite important when working near the minimum detectable concentration where the uncertainty in the measurement is nearly equal to the measurement itself and the lower limit of the range of the measurement approaches zero. For example, 0.8 ± 0.7, means that one could predict with 95% confidence that the actual value lies between 0.1 and 1.5. Such a number by itself would not be

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Figure 4.   Low-volume air sampler used at the INEL Site.

greatly significant; because if there is a small factor which has not been included in the uncertainty, then the true value of the measurement may be zero. Or, the material being measured is not, in fact, present. Therefore, when analytical results show a measurement very near the minimum detectable concentration, statistical tools and all additional information available must be used to reach a conclusion.

Four radionuclides which are not generally included in fallout were detected at one offsite location each. Antimony-125 at a concentration of $2.9 \pm 2.0 \times 10^{-15}$ μCi/mL was reported at Howe during the third quarter, Cs-134 at a concentration of $1.1 \pm 0.8 \times 10^{-15}$ μCi/mL was reported at Craters of the Moon National Monument during the first quarter, Co-60 at a concentration of $0.7 \pm 0.6 \times 10^{-15}$ μCi/mL was reported at the FAA Tower station during the first quarter, and Sb-124 at a concentration of $2.3 \pm 2.0 \times 10^{-15}$ μCi/mL was reported at Blackfoot during the first quarter. None of the radionuclides exceeded 0.0004% of the uncontrolled area concentration

TABLE II
PARTICULATE BETA ACTIVITY IN AIR (1982)

Group	Locations	Number of Samples	Concentration (10^{-15} μCi/mL) Range	Concentration (10^{-15} μCi/mL) Annual[a] Average
Distant	Blackfoot	51	16-127	37 ± 5
	Craters of the Moon	51	14-114	36 ± 4
	Idaho Falls	51	14-75	32 ± 4
	Grand Mean	—	—	35 ± 2
Boundary	Arco	51	17-71	32 ± 3
	Atomic City	51	18-97	35 ± 4
	FAA Tower	51	17-97	35 ± 4
	Howe	51	16-91	35 ± 4
	Monteview	51	14-95	32 ± 4
	Mud Lake	51	20-127	42 ± 6
	Reno Ranch	51	18-85	32 ± 3
	Grand Mean	—	—	35 ± 2

a. Average with the 95% confidence interval. See Appendix C.

guide during the quarter in which they were detected. Statistical tests showed that the concentrations, although positive, were not different from the quarterly distant group average nor were average boundary concentrations different from the distant average for the quarter or the year. In addition, meteorological conditions, Site releases, and onsite monitoring results were reviewed but no correlation with Site operations could be found. This led to the conclusion that the reported concentrations of these four radionuclides represented random statistical variations within the group of samples.

Of all radionuclides detected in air, Sr-90 was the only nuclide for which the annual boundary group mean concentration was statistically greater than the distant group mean concentration. Strontium-90 was detected only once at one offsite location, Monteview, at a concentration of $0.33 \pm 0.26 \times 10^{-15}$ μCi/mL which is near the minimum detectable concentration. As discussed

earlier no firm conclusion can be drawn from such concentrations when the uncertainty is nearly equal to the measurement itself. When Site releases of Sr-90 and meteorological information are taken into consideration, it appears unlikely that the Sr-90 is due to Site operations.

Atmospheric tritium in the form of tritiated water (HTO) is monitored at Idaho Falls (a background location) and at two locations onsite. No concentration of HTO at any location exceeded the approximate minimum detectable concentration of 1×10^{-11} μCi/mL.

Nonradiological. Atmospheric particulate matter is routinely monitored at the low-volume air sampling stations using the filters previously described. The analysis involves determining the net particulate weight on the quarterly composite of weekly filters at each station. The boundary average was 30 μg/m^3 which was statistically the same as the distant average of 34 μg/m^3. Results of
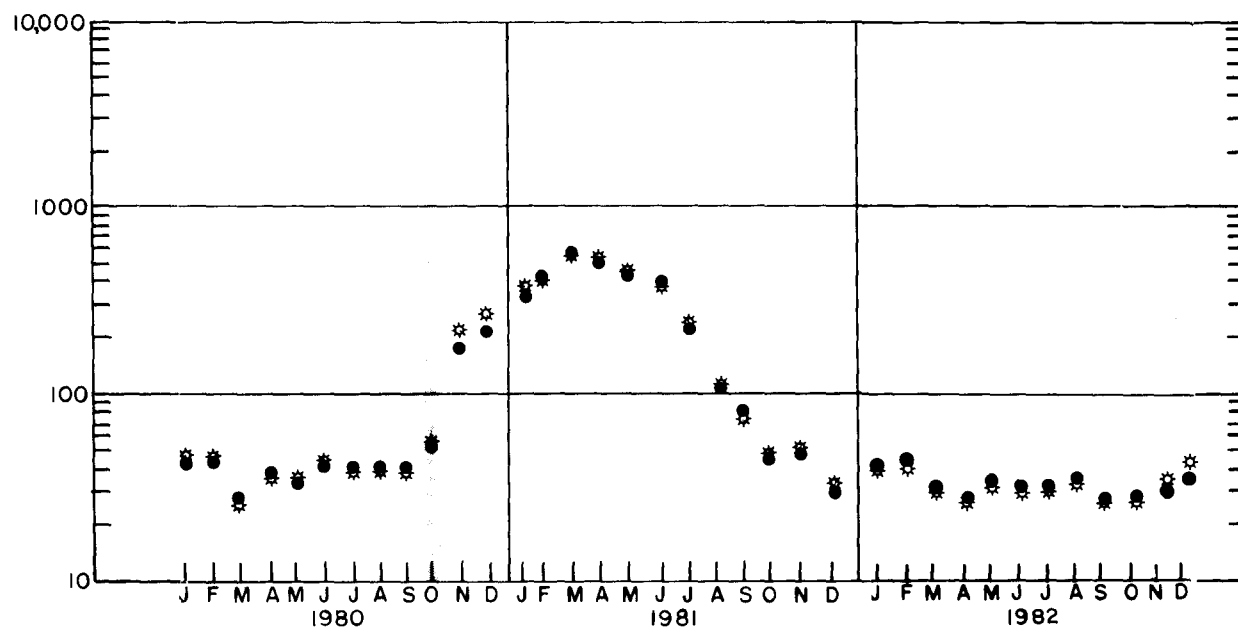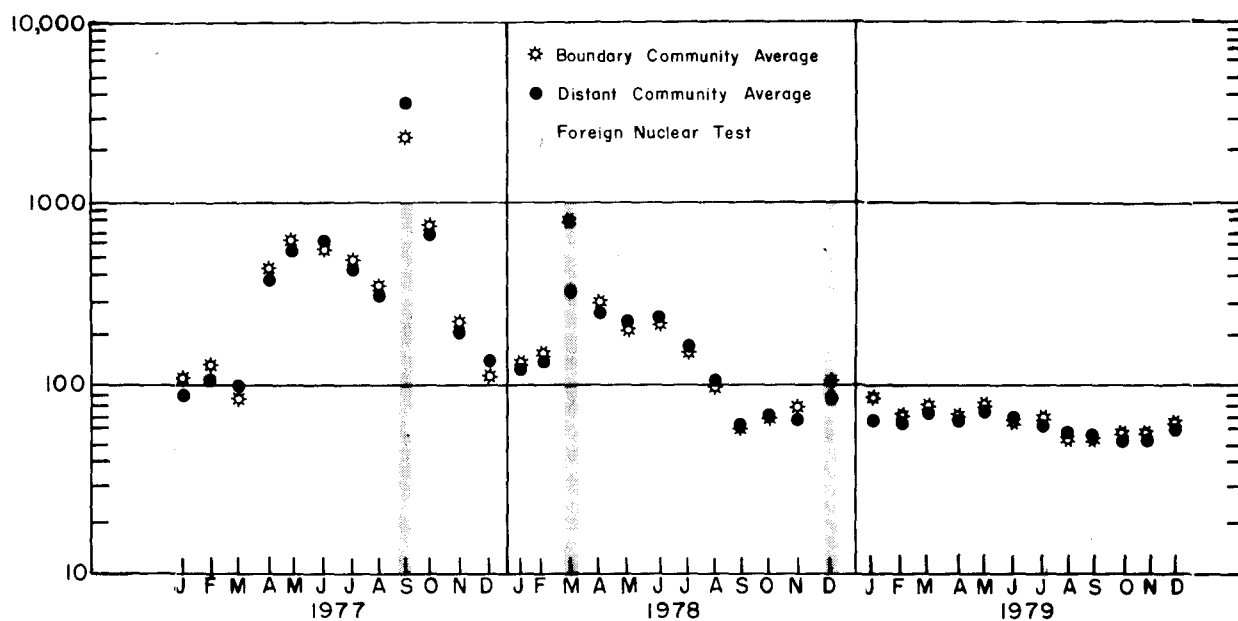
PARTICULATE BETA CONCENTRATIONS (10^{-15} uCi/ml)

Figure 5. Particulate beta concentrations in air.

TABLE III
SPECIFIC RADIONUCLIDE ACTIVITY IN AIR (1982)

Radionuclide	Composite Group[a]	Concentration (10^{-15} μCi/mL)			Concentration Guide[d]	~MDC[e]
		Minimum[b]	Maximum[b]	Mean[c]		
Ce-141	Distant	<MDC[f]	<MDC	NSS[g]	50,000	2
	Boundary	<MDC	5 ± 4	NSS		
Ce-144	Distant	<MDC	<MDC	NSS	200,000	7
	Boundary	<MDC	8 ± 5	NSS		
Co-60	Distant	<MDC	<MDC	NSS	300,000	2
	Boundary	<MDC	0.7 ± 0.6	NSS		
Cs-134	Distant	<MDC	1.1 ± 0.8	NSS	400,000	2
	Boundary	<MDC	<MDC	NSS		
Cs-137	Distant	<MDC	1.3 ± 0.8	NSS	500,000	1
	Boundary	<MDC	1.1 ± 0.8	0.41 ± 0.17		
Mn-54	Distant	<MDC	<MDC	NSS	1,000,000	1
	Boundary	<MDC	0.9 ± 0.7	NSS		
Ru-103	Distant	<MDC	<MDC	NSS	30,000	1
	Boundary	<MDC	3.0 ± 1.0	NSS		
Sb-125	Distant	<MDC	<MDC	NSS	900,000	6
	Boundary	<MDC	3 ± 2	NSS		
Sr-90	Distant	<MDC	<MDC	NSS	30,000	0.6
	Boundary	<MDC	0.3 ± 0.3	0.2 ± 0.1		

		Concentration (10^{-18} μCi/mL)				
Pu-239/240	Distant	<MDC	7 ± 4	NSS	60,000	6
	Boundary	<MDC	7 ± 4	NSS		

a. Distant stations are Blackfoot, Craters of the Moon, and Idaho Falls. Boundary stations are Arco, Atomic City, FAA Tower, Howe, Monteview, Mud Lake, and Reno Ranch.

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

c. Arithmetic mean with the 95% confidence interval. See Appendix C.

d. Concentration guides are based on DOE Order 5480.1A, Chapter XI guides for release to an uncontrolled area.

e. The minimum detectable concentrations (MDC) are approximate and are calculated for typical values for airflow volume, counting time, radionuclide composition of the sample and time lapsed 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 within the 95% confidence interval about the mean. See Appendix C.

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atmospheric particulate measurements for 1982 are shown in Table IV. Most of the airborne particulates in the Site vicinity are probably windblown dust from the desert floor.

The maximum sulfur dioxide and nitrogen oxides concentrations at the Site boundary were calculated using the total 1982 discharges and a computer model of the dispersive characteristics of the air for 1982. The calculation method is the same as described in the section "Radiological Impact of INEL Site Operations—General" using mass units for releases instead of radioactivity units. The total nitrogen oxides released in 1982 was about 2.7×10^5 kg and for sulfur dioxide was about 3.3×10^5 kg as reported in the Industrial Waste Management Information System Report.[1] The calculated maximum offsite concentrations of nitrogen dioxide and sulfur dioxide occurred near the southern Site boundary and were 0.25 and 0.30 $\mu g/m3$, respectively. These concentrations are well below the national primary ambient air quality standards of 100 and 80 $\mu g/m^3$.

The Idaho Chemical Processing Plant (ICPP) at the INEL received a variance from the State of Idaho from opacity requirements on September 9, 1982. A two-year extension of the variance was issued on January 13, 1983. The variance is for visible emissions (deep yellow color) due to nitrogen

TABLE IV
PARTICULATE CONCENTRATIONS IN AIR (1982)

	Concentration ($\mu g/m^3$)	Group	Locations	Concentration ($\mu g/m^3$)	
				Range	Average[b]
~Minimum Detectable Concentration	15	—	—	—	—
Concentration Guide[a]	60	—	—	—	—
		Distant	Blackfoot	15-43	29 ± 24
			Craters of the Moon	2-13	8 ± 7
			Idaho Falls	38-84	65 ± 31
			Grand Mean[b]	—	34 ± 18
		Boundary	Arco	19-70	43 ± 33
			Atomic City	5-36	18 ± 22
			FAA Tower	5-21	12 ± 11
			Howe	4-46	28 ± 34
			Monteview	12-113	51 ± 73
			Mud Lake	22-56	38 ± 24
			Reno Ranch	10-47	22 ± 23
			Grand Mean[b]	—	30 ± 9

a. Concentration guide is based on the Environmental Protection Agency's national secondary ambient air quality standards.

b. Average with 95% confidence interval. See Appendix C.

oxides in the plume from the main stack at ICPP. The nitrogen oxides from the stack do not constitute any health problem to INEL workers or to residents of offsite communities. Atmospheric dispersion modeling for an average year predicts nitrogen dioxide concentrations at the southern Site boundary of about 1 $\mu g/m^3$ or 1% of the national ambient air quality standard. Short-term ambient measurements on the INEL Site during 1982 confirm low nitrogen dioxide concentrations from all sources.

Water Sampling

The Snake River Plain aquifer which lies beneath the INEL Site serves as the primary source for drinking water and for irrigation of crops by residents of the Snake River Plain. Onsite and offsite water samples are collected routinely to monitor for movement of waste substances, both radioactive and nonradioactive, through the aquifer.

Offsite water samples are collected semiannually from drinking water production wells and from the Snake River. Water is also collected at three U.S. Geological Survey (USGS) wells near the southern Site boundary. See Figure 6. All radioactivity detected in offsite water samples is reported and evaluated in this section. Gross alpha, gross beta, and tritium analyses are routinely performed on the water samples. For gross alpha analysis, a portion of the sample is evaporated on a stainless steel planchet and counted with a scintillation counter system. Another portion is evaporated and counted for gross beta activity in a low-background beta counter. Tritium concentrations are determined with a liquid scintillation counter. The minimum detectable concentrations for gross alpha, gross beta, and tritium are 3×10^{-9}, 5×10^{-9}, and 4×10^{-7} $\mu Ci/mL$, or about 10, 20, and 0.01%, respectively, of DOE concentration guides for an uncontrolled offsite area. These detection limits are also 20, 10, and 2%, respectively, of regulations listed by the U.S. Environmental Protection Agency in 1982 for community drinking water.

Only three of the 38 offsite water samples contained gross alpha activity in 1982, one each from Reno Ranch, USGS Well #11, and USGS Well #14. Activity in the three samples ranged from 4 ± 2 to 5 ± 4 x 10^{-9} $\mu Ci/mL$. Gross beta activity above the minimum detectable concentration was found in only five of the 38 water samples, one each from Mud Lake, Roberts, Idaho Falls, Cerro Grande, and USGS Well #11. Activity in these five samples ranged from 5 ± 4 to 8 ± 6 x 10^{-9} $\mu Ci/mL$. Annual averages for gross alpha and gross beta activity at all locations were below the EPA community drinking water standards.

Natural radioactivity is found elsewhere in the Snake River Plain groundwater in areas upgradient, parallel to, and far distant from the INEL Site. Since Reno Ranch, Mud Lake, Roberts, and Idaho Falls are either upgradient or parallel to groundwater flow beneath the INEL,[2] the radioactivity detected is not due to Site operations. USGS Wells #11 and #14 and Cerro Grande are located south of the INEL boundary, beyond the leading edge of any Site waste plumes.[3] Therefore, it is most likely that the radioactivity detected in those wells is due to either statistical variations or to natural radionuclides from soil and rock. One sample from each of these three offsite wells was submitted for gamma spectrometry, and no manmade gamma-emitting nuclides were detected.

Most of the onsite water sampling is conducted by the USGS. The southernmost well in which tritium has been detected is about 4 km (2.5 mi) inside the Site boundary. However, analyses of USGS water samples taken from wells in the southern portion of the Site, indicate that the leading edge of the tritium waste plume is about 2 km (1.2 mi) upgradient from the boundary.[3] Iodine-129, which has a less extensive plume than tritium, is detectable about 6 km (3.7 mi) inside the nearest Site boundary. Strontium-90 analyses were above the minimum detectable concentration only for those samples collected within 3 km (1.9 mi) of the release point at the ICPP disposal well, or approximately 10 km (6.2 mi) inside the nearest Site boundary. The estimated minimum detectable concentrations for Sr-90 and I-129 are about 5×10^{-9} and 1×10^{-10} $\mu Ci/mL$, respectively, or about 2 and 0.2% of the concentration guides for an uncontrolled area. Cesium and actinides are even less mobile in the aquifer than strontium.

Nonradiological wastes in the aquifer are determined by measuring the specific conductance and the chloride, sodium, nitrate, and total chromium content of the water. (See references 2 and 3.) All of these waste products were at background levels at least 3 km (1.9 mi) inside the nearest Site boundary, indicating that INEL groundwater waste plumes had not migrated offsite by the end of 1982.
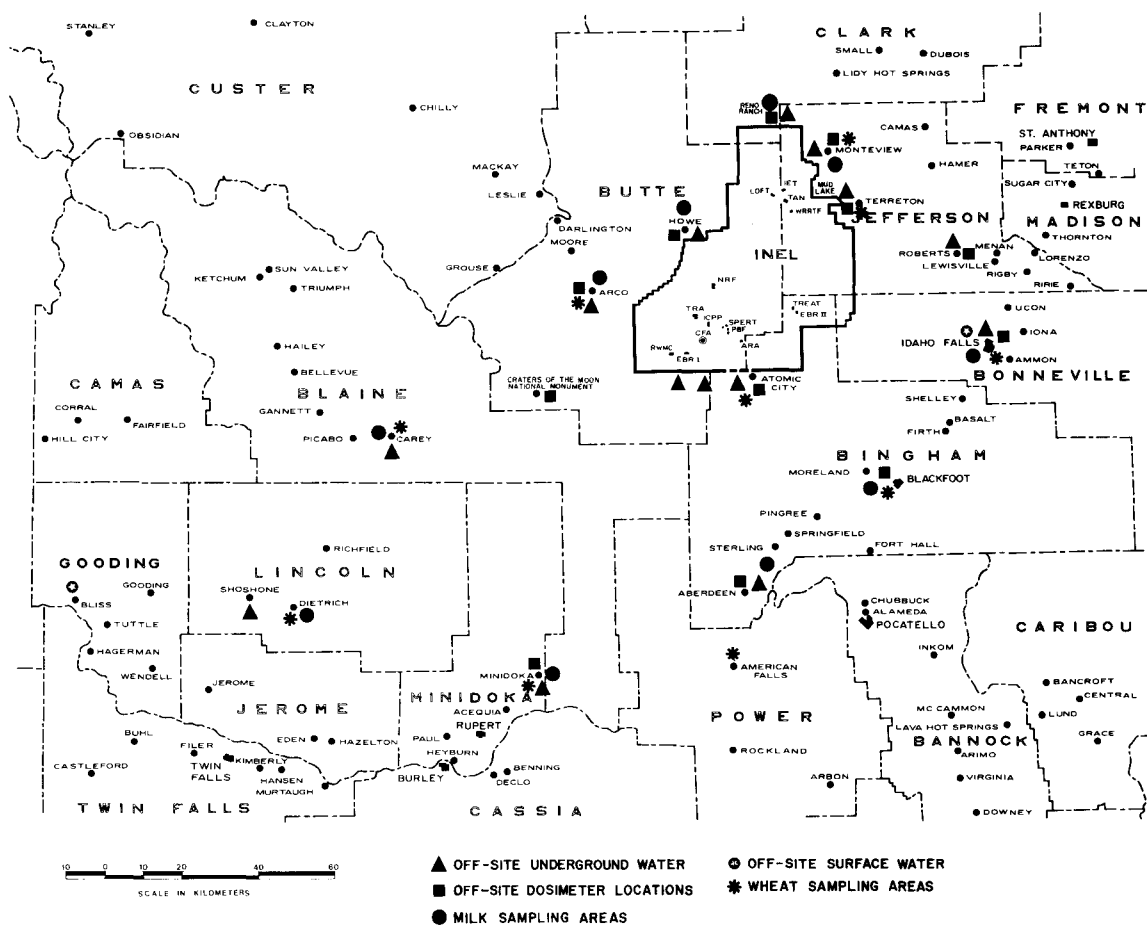
Figure 6. Offsite water, milk, and wheat sampling locations and environmental dosimeter locations.

A 1982 publication of the results of a 1980 USGS reconnaissance survey of organic solutes in ground-water at the INEL indicates no appreciable areas of organic groundwater contamination were found.[4] None of the samples contained organic contamination in the form of dissolved organic carbon above the screening level of 20 mg/L. Analyses for volatile and semivolatile organic solutes did not indicate the presence of hazardous organic contaminants in significant amounts (greater than 10 μg/L). Only one well contained a detectable insecticide or herbicide concentration. Dichlorodiphenyltrichloroethane (DDT) was found in this well at a concentration of 0.01 μg/L which is not considered a significant contamination level according to the USGS report.

Foodstuff Sampling

Milk, wheat, and leafy garden lettuce are sampled routinely since they are part of the typical American diet. These three foodstuffs could be pathways to the public for radionuclides from nuclear weapons fallout or from Site operations. Boundary areas are compared to distant areas to assess possible impacts from Site operations. Milk and wheat sampling locations are shown in Figure 6. Lettuce was collected at Atomic City, Idaho Falls, Arco, Howe, Mud Lake, Blackfoot, and Pocatello.

A total of 155 milk samples were collected from dairies around the Site. Samples are collected monthly, except in Idaho Falls where a sample is collected weekly. An exception was Reno Ranch from which only seven samples were collected because the family cow was dry part of the year. All milk samples are passed through anion exchange resins which are analyzed for I-131 by gamma spectrometry. Milk from each location is analyzed for Sr-90 and tritium once during each year. In addition, three September milk samples, one each from Idaho Falls, Mud Lake and Carey, were analyzed for I-129.

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In 1982 two milk samples from distant community (background) areas contained I-131 in concentrations near the minimum detectable concentration. From the dairy at Carey a concentration of $1.1 \pm 0.8 \times 10^{-9}$ μCi/mL was detected in one sample of the 12 collected during the year. From an area south of Idaho Falls toward Blackfoot, Idaho, a concentration of $0.9 \pm 0.8 \times 10^{-9}$ μCi/mL was detected in one sample of the 12 collected. Both concentrations are well below the health protection guides. As previously discussed, there is a risk associated with drawing conclusions from measurements near the minimum detectable concentration level. If it is assumed the I-131 was actually present in the samples, consideration of meteorological and Site operations information leads to the conclusion that the detected activity was not due to Site operations. Since there are no other known sources for this short-lived isotope at the times of the measurements, it is likely the values are the result of random statistical fluctuations and not due to the actual presence of I-131.

Five of the six milk samples from distant areas contained Sr-90 at detectable concentrations with a group mean of 2.1×10^{-9} μCi/mL. This mean concentration is consistent with the trend of Sr-90 levels in Idaho Falls milk samples reported by the Environmental Protection Agency for previous years. Three of the four samples from Site boundary areas also had detectable concentrations of Sr-90 with a group mean of 2.1×10^{-9} μCi/mL which is not statistically different from the background mean. The origin of the nuclide in the eight background area samples was probably worldwide fallout. None of the three samples analyzed for I-129 had detectable concentrations of the nuclide.

Wheat and leafy garden lettuce sampling results are shown in Table V. The lettuce was washed with water to remove the obvious dirt, then dried and weighed. Lettuce samples were analyzed for Sr-90 and gamma-emitting radionuclides. Comparison of average concentrations of Sr-90 for boundary and distant communities (background) showed no statistical difference between the two groups. No manmade gamma-emitting radionuclides were detected.

The wheat was weighed prior to analysis but not washed. All wheat samples were analyzed for Sr-90, and average concentrations were statistically the same for boundary and distant samples. Six samples

of wheat, three from distant communities and three from boundary communities, were analyzed by gamma spectrometry. Cesium-137 was detected in only two boundary area samples at concentrations of $5 \pm 4 \times 10^{-9}$ and $6 \pm 4 \times 10^{-9}$ μCi/g. The boundary group mean concentration of Cs-137 was statistically greater than the distant group mean. When reported Site releases of Cs-137, 1982 air monitoring data, and concentrations in wheat in previous years are considered, it is unlikely that these concentrations are due to Site operations.

Muscle and liver samples were taken from four sheep which had grazed onsite in the northeastern grazing areas and from two sheep from the Rupert area which had not grazed near the Site in 1982. There was no statistical difference between the averages for onsite and offsite sheep for either tissue.

Four beef cattle which had grazed onsite were sampled during 1982, two from the grazing area near the RWMC and two from range near Mud Lake. Muscle and liver samples were taken from each animal and were submitted for Sr-90 analyses, gamma spectrometry, and alpha spectrometry. One muscle sample had a Sr-90 concentration of $2.4 \pm 1.6 \times 10^{-9}$ μCi/g, but none was detected in the rest of the muscle samples nor in any of the liver samples. Cs-137 was detected in one muscle sample at $2.0 \pm 0.8 \times 10^{-8}$ μCi/g and in three liver samples, the highest of which was $1.9 \pm 0.8 \times 10^{-8}$ μCi/g. The average concentrations for muscle and for liver tissues are comparable to those found in the muscle and liver tissues of both onsite and offsite sheep and somewhat lower than those of antelope tissues sampled in 1982. Plutonium 239/240 was detected in the liver samples of all four animals at an average concentration of 6×10^{-11} μCi/g. The bone dose to an individual who had eaten an entire beef liver with this concentration has been calculated to be about 0.0002 mrem. This dose is inconsequential when compared to the natural background doses described in the next section. All three of the nuclides detected in the beef tissues are part of worldwide fallout as well as Site releases.

Since concentrations of Sr-90 in foodstuff samples from distant stations were statistically the same as those found in samples from boundary stations, it is assumed that the origin of this radionuclide is worldwide fallout. Only in wheat sam-

TABLE V
RADIONUCLIDE CONCENTRATIONS IN WHEAT AND LETTUCE (1982)

| | | Concentration[a] (10^{-9} μCi/g dry wt) | | |
| | | Wheat | | Garden Lettuce |
Group	Sample Location	Sr-90	Cs-137	Sr-90
~Minimum Detectable Concentration	—	4	4	80
Distant	American Falls	12 ± 4	2 ± 4[b]	NA[c]
	Blackfoot	11 ± 4	NA	220 ± 40
	Carey	9 ± 4	3 ± 4[b]	NA
	Dietrich	17 ± 4	NA	NA
	Idaho Falls	11 ± 4	NA	110 ± 40
	Minidoka	11 ± 4	1 ± 4[b]	NA
	Pocatello	NA	NA	120 ± 40
	Average[d]	12 ± 3	2 ± 3	150 ± 150
Boundary	Arco	10 ± 4	NA	180 ± 40
	Atomic City	8 ± 4	5 ± 4	330 ± 60
	Howe	NA	NA	140 ± 40
	Monteview	7 ± 4	4 ± 4[b]	NA
	Mud Lake	NA	NA	250 ± 60
	Terreton	20 ± 4	6 ± 4	NA
	Average[d]	11 ± 9	5 ± 2	230 ± 130

a. Analytical result ±2σ. See Appendix C.

b. Below minimum detectable concentration.

c. No analysis.

d. Average with 95% confidence interval. See Appendix C.

ples were the Cs-137 concentrations statistically greater for boundary areas than for distant areas, and as discussed earlier, it is unlikely that Site operations contributed to the Cs-137 concentrations seen.

Environmental Radiation Measurements

Thermoluminescent dosimeters (TLDs) are used to measure ionizing radiation exposures (beta greater than about 200 keV and gamma greater than 10 keV) at six boundary community locations and six distant community locations. The boundary and distant groups are compared, individual station data are presented, and trends over time, if any, are analyzed. At each location, a dosimeter containing five individual Harshaw

TLD-700 chips (3.18 x 3.18 x 0.89 mm) is placed 1 m above ground level. The dosimeter at each location is changed semiannually. The measured cumulative exposure for the time period from November 1981 to November 1982 is shown in Table VI. For purposes of comparison, annual exposures for 1979 through 1981 are also included for each location. Variations of ionizing radiation between locations are evident but have been consistent at each location for the past four years. 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.

The average annual TLD exposures for boundary and distant community locations were 115 and 116 mR, respectively (110 and 111 mrem). The

TABLE VI
ENVIRONMENTAL RADIATION EXPOSURES (1979-1982)

		Annual Exposures[a] (mR)			
	Location	1979	1980	1981	1982
Distant	Aberdeen	116 ± 9	121 ± 6	120 ± 4	116 ± 7
Group	Blackfoot	120 ± 8	118 ± 8	119 ± 4	117 ± 6
	Craters of the Moon	122 ± 7	116 ± 6	123 ± 4	125 ± 4
	Idaho Falls	96 ± 5	102 ± 6	104 ± 4	104 ± 7
	Minidoka	110 ± 7	—[b]	106 ± 4	105 ± 8
	Roberts	126 ± 9	135 ± 9	134 ± 5	130 ± 7
	Average[c]	115 ± 11	118 ± 15	118 ± 12	116 ± 11
Boundary	Arco	114 ± 8	120 ± 6	113 ± 4	109 ± 4
Group	Atomic City	126 ± 7	121 ± 8	128 ± 4	119 ± 4
	Howe	105 ± 7	109 ± 6	113 ± 4	116 ± 3
	Monteview	112 ± 7	112 ± 6	113 ± 4	112 ± 6
	Mud Lake	125 ± 11	126 ± 8	126 ± 6	124 ± 4
	Reno Ranch	108 ± 7	119 ± 7	115 ± 4	110 ± 2
	Average[c]	115 ± 9	118 ± 7	118 ± 7	115 ± 6

a. Annual exposure ±2σ. See Appendix C.

b. Results were available for only six months of the year at this location.

c. Average with 95% confidence interval. See Appendix C.

boundary and distant mean exposures are statistically the same, so there were no significant contributions to ionizing radiation doses at boundary locations from INEL operations.

Table VII summarizes the calculated dose rate an individual receives on the Snake River Plain from various background radiation sources. This dose rate varies from year to year depending on the amount of snow cover. For 1982, the background dose rate was about 150 mrem.

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 have been collected from undisturbed distant and boundary locations most years between 1970 and 1978, except 1972 and 1977. (The biennial soil sampling program was established in 1978, and Figure 7 shows routine sampling locations.) Soil samples collected in 1970, 1971, and 1973 represented a composite of five cores of soil from a 1-m² area. Each core was

a cylinder 10 cm in diameter and 5 cm in depth. In all other years, a 100 m² area was sampled for each composite. A number of samples from the 5-to 10-cm depth were also collected. All soil samples were analyzed for gamma-emitting radionuclides. Most were also analyzed for Sr-90 and alpha-emitting radionuclides. The soils were dried at least three hours at 120°C. Only soil particles less than 500 microns in diameter (35 mesh) were analyzed. The data are reported in units of activity per gram of soil (pCi/g dry wt) and also in units of areal activity (nCi/m²), which is the total activity in each soil sample divided by the surface area (0.039 m²) of the sample.

Concentrations of natural radioactivity in the surface soil were reported in 1977.[7] The Th-232 and U-238 activities were determined from those of the progeny radionuclides, Ac-228 and Pb-214. Oakley[8] 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 which are higher in natural radioactivity than earth crustal averages.

TABLE VII
BACKGROUND RADIATION DOSE RATE (1982) (mrem/year)

Source of Background Dose		Estimated[a]	Measured (TLD)[b]
External	Terrestrial	71	—
	Cosmic (ionizing)	43	—
	Subtotal	114	111
	Cosmic (neutron)	6	—
Internal	K-40 and others	27	—
	Total	147	—

a. Doses are estimated from charts and tables in NCRP Report No. 45.[5] Doses are not strictly additive since some are expressed as exposure in air and others are tissue doses.

b. For conversion from mR in air to mrem in tissue, f factor was 0.96, estimated from Johns and Cunningham.[6]
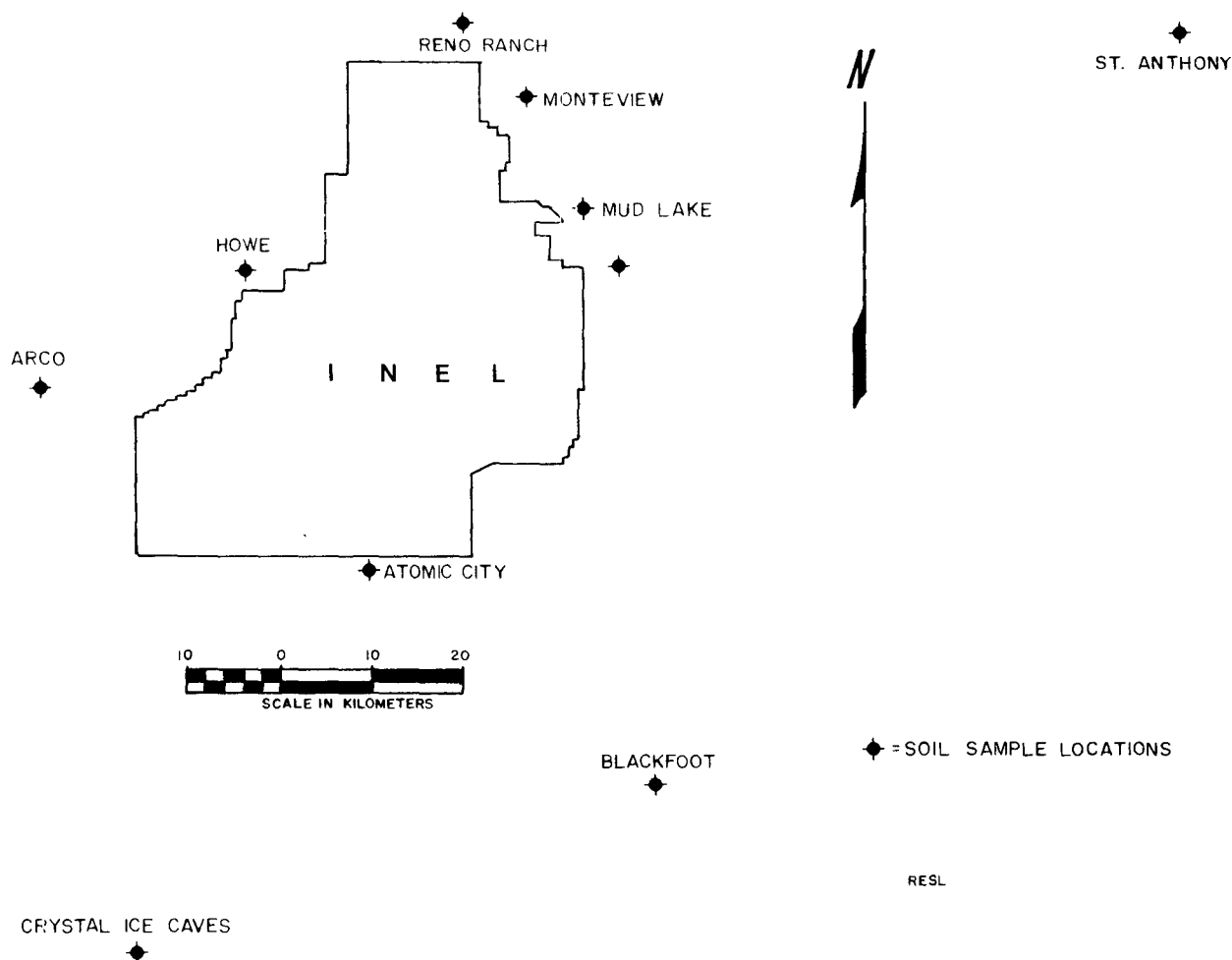
Figure 7.   Soil sampling locations for the INEL Site vicinity.

Although much of the surface rock on the 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 yearly gamma ray dose received from U-238 plus daughters, Th-232 plus daughters, and K-40 in average Site area soil have been calculated to be 21, 28, and 27 mrem, respectively; for a total of 76 mrem. These calculations are based on conversion factors obtained from Reference 5. This reference also shows the decrease in gamma radiation from soil with depth of snow cover. The correction for snow cover for 1982 has already been applied to the terrestrial background dose in Table VII of the preceding section.

Concentrations of Cs-137, Sr-90, Pu-238, Pu-239/240, and Am-241 in surface soil as found

in 1970 through 1975, compared to 1978, 1980, and 1982 are shown in Table VIII. The 1976 data are not included because the sampling locations used that year are not considered representative of the area. The average concentrations of radionuclides in 1982 were greater than in 1980 but about the same as 1978 concentrations. No explanation for the decrease followed by an increase has been found. Distant and boundary location average concentrations are not statistically different for any nuclide. It is concluded, therefore, that all of the radionuclides detected are present as a result of worldwide fallout.

Game Species

Hunting and fishing are not allowed on the Site. Game animals do migrate on and off the Site (see Figure 8), representing a potential, but very small

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TABLE VIII
RADIONUCLIDES IN OFFSITE SURFACE SOILS (1982)[a]

Radionuclide	Year	Geometric Average[b] (pCi/g)	Geometric Average[b] (nCi/m^2)	Number of Samples	~MDC[c] (pCi/g)	~MDC[c] (nCi/m^2)
Cs-137	1970-75[d]	0.94x/ ÷ 1.2	54x/ ÷ 1.1	60	0.01	3
	1978	0.94x/ ÷ 1.3	58x/ ÷ 1.3	10	0.01	3
	1980	0.64x/ ÷ 1.4	41x/ ÷ 1.4	10	0.01	3
	1982	0.90x/ ÷ 1.4	44x/ ÷ 1.4	10	0.01	3
Sr-90	1970-75	0.54x/ ÷ 1.1	34x/ ÷ 1.1	55	0.09	10
	1978	0.52x/ ÷ 1.3	32x/ ÷ 1.4	10	0.09	10
	1980	0.35x/ ÷ 1.4	22x/ ÷ 1.5	10	0.09	10
	1982	0.37x/ ÷ 1.4	18x/ ÷ 1.6	10	0.09	10
Pu-238	1970-75	0.0028x/ ÷ 1.2	0.15x/ ÷ 1.2	55	0.002	0.1
	1978	0.0010x/ ÷ 2.0	0.06x/ ÷ 1.9	10	0.002	0.1
	1980	0.0007x/ ÷ 1.3	0.05x/ ÷ 1.3	10	0.002	0.1
	1982	0.0011x/ ÷ 1.5	0.05x/ ÷ 1.6	10	0.002	0.1
Pu-239/240	1970-75	0.020x/ ÷ 1.2	1.06x/ ÷ 1.1	54	0.002	0.1
	1978	0.018x/ ÷ 1.4	1.09x/ ÷ 1.4	10	0.002	0.1
	1980	0.010x/ ÷ 1.7	0.63x/ ÷ 1.7	10	0.002	0.1
	1982	0.022x/ ÷ 1.4	1.06x/ ÷ 1.4	10	0.002	0.1
Am-241	1970-75	0.0041x/ ÷ 1.2	0.24x/ ÷ 1.2	37	0.003	0.2
	1978	0.0062x/ ÷ 1.4	0.38x/ ÷ 1.3	10	0.003	0.2
	1980	0.003x/ ÷ 1.3	0.20x/ ÷ 1.4	10	0.003	0.2
	1982	0.004x/ ÷ 1.5	0.21x/ ÷ 1.6	10	0.003	0.2

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

b. Geometric average x/ ÷ 2 standard geometric deviations of the mean. The 95% confidence interval may be determined by multiplying and dividing the mean by the standard geometric deviations shown.

c. Approximate minimum detectable concentration.

d. Excluding 1972. No samples taken.

exposure pathway. Game animals which were killed on Site roads were sampled during 1982. Data were obtained as part of DOE research programs rather than as a part of the routine environmental monitoring program. Many of these programs use the expertise of university faculty and graduate students to assist in the radioecology and ecology research at the INEL Site. These research programs, reported in the technical literature, supplement the scheduled environmental monitoring reported here.

Muscle and liver tissues from three antelope were analyzed for gamma-emitting radionuclides. Cesium-137 was detected in two muscle samples and two liver samples of these animals. Average
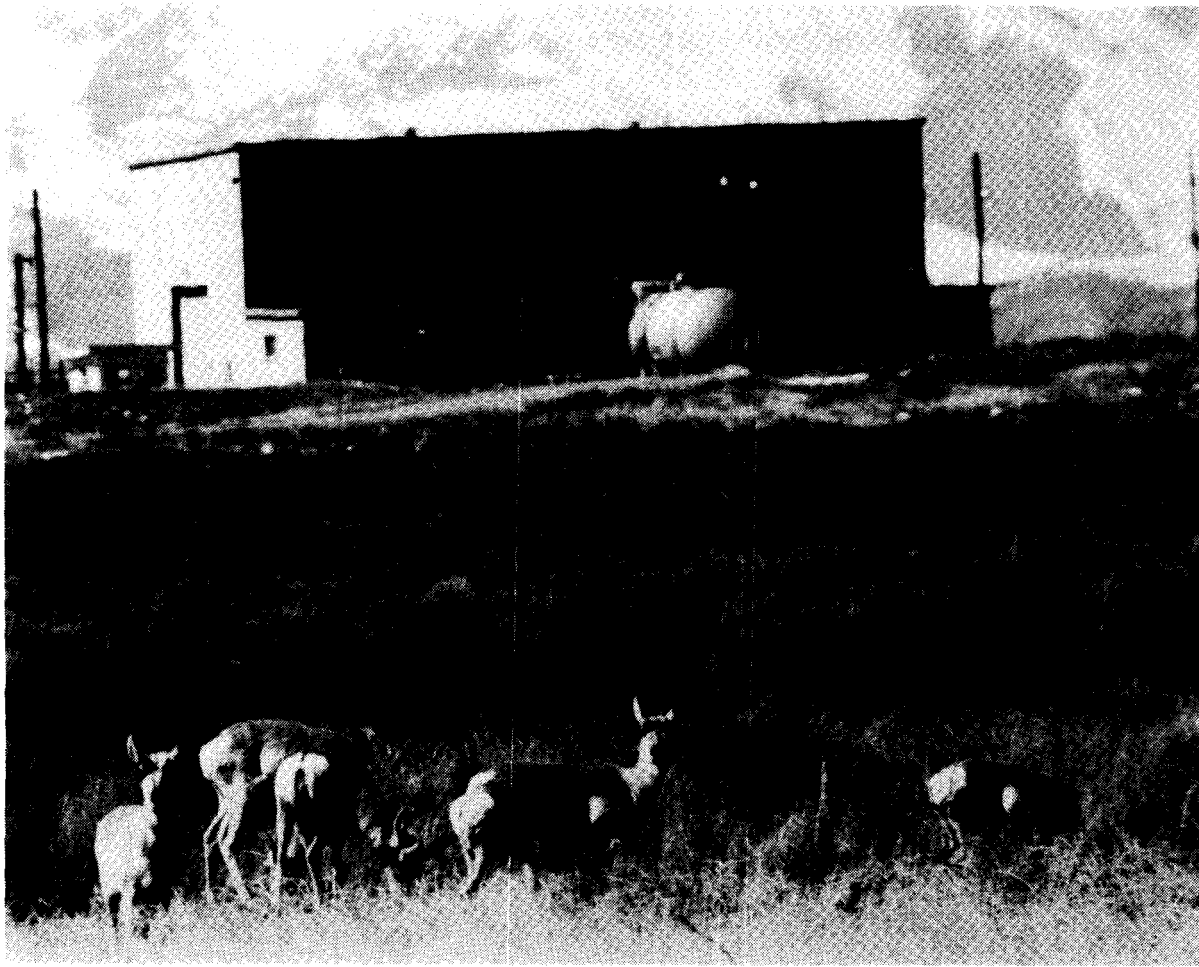
Figure 8.   Antelope grazing near the Power Burst Facility on the INEL Site.

concentrations for the group were 4.3 x 10^{-8} μCi/g for muscle and 3.1 x 10^{-8} μCi/g for liver tissues. As a comparison, one animal sampled near Mackay in 1981 but reported in 1982 had concentrations of 5.0 x 10^{-8} and 2.4 x 10^{-8} μCi/g for muscle and liver samples, respectively. Studies from earlier years included antelope collected far from the Site and the Cs-137 average concentrations for these background animals were 3.8 x 10^{-8} and 4.7 x 10^{-8} μCi/g for muscle and liver tissues, respectively. The 1982 means were not statistically different from these offsite averages. No other manmade gamma-emitting radionuclides were found in the muscle and liver tissue samples.

Muscle tissues from six sage grouse which were killed on Site roads during 1982 were submitted for gamma spectrometry. No manmade gamma-emitting nuclides were found.

Three fish were taken from the Big Lost River onsite during 1982 because the river flowed through the Site to the Big Lost River Sinks area most of the year. Three fish were taken from the Big Lost River offsite above the Mackay dam for use as controls. Fish from each area were cleaned, cut up, and tissues composited and submitted for gamma spectrometry. No manmade gamma-emitting nuclides were detected in either onsite or offsite samples.

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RADIOLOGICAL IMPACT OF INEL SITE OPERATIONS

General

The radiological impact of Site operations on the resident public surrounding the Site was too small to be measured by the routine monitoring program. Therefore, the impact was estimated by calculating:

- The maximum "fence post" or Site boundary dose

- The maximum potential dose to the nearest individual residing offsite

- The maximum potential dose to a member of a population group

- The potential population dose which could have been received by the public within an 80-km (50-mi) radius of the operations center of the Site [Test Reactor Area (TRA) and Idaho Chemical Processing Plant (ICPP)].

The possible exposure pathways by which radioactive materials from Site operations could be transported to offsite environs are shown diagrammatically in Figure 9. Atmospheric transport is the principal potential exposure pathway from the Site. There are no surface streams flowing from onsite to offsite locations, and the leading edge of the most mobile low-level radioactive waste plume in the aquifer is about 2 km (1.2 mi) inside the southern boundary of the Site.

Several indirect exposure pathways are being studied at the Site 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 the hunting or fishing for game species that have spent some time on the Site. Some radioactivity can be present in game species depending upon the length of residence onsite, the time elapsed after migration from the Site, and the metabolism of the animal. Conservative estimates of the potential dose to a person consuming meat from different game animals is described in the section "Maximum Individual Dose."

The monitoring data presented in the previous sections indicated that at offsite sampling loca-tions no particulate radioactivity in the air from Site operations was discernible from the preexist-ing levels due to natural and fallout radioactivity. As mentioned in the section on air sampling, noble gases are not sampled by the air monitoring system. Because of these limitations, an estimate of the radiological impact of Site operations on the surrounding region has been made by using the known amounts of various radionuclides released during 1982 from Site facilities and a meteorological model for estimating the concen-trations at selected locations in the vicinity. A summary of the radionuclides released to the atmosphere from Site facilities is shown in Table IX. Due to radioactive decay of the short-lived radionuclides, the activity that would reach offsite areas is less than the 24,000 Ci indicated in Table IX. The ICPP and TRA facilities together were the source of about 98% of the total radioac-tivity released to the atmosphere. Noble gases comprised about 98% of the total radioactive airborne effluent.

The mesoscale meteorological map (Figure 10) shows the calculated 1982 concentrations nor-malized to a unit release rate for the INEL Site and vicinity. This map has been prepared by the National Oceanic and Atmospheric Administra-tion (NOAA) at the INEL from data gathered continuously at 26 meteorological stations on and around the Site.[9] To facilitate the display, the dispersion coefficient values have been multiplied by 10^{-9} hr^2/m^3. To obtain the average air con-centration (Ci/m^3) for a radionuclide released from TRA or ICPP along any dispersion coeffi-cient isopleth in Figure 10, the value of the 1982 average dispersion coefficient (e.g., 30×10^{-9} hr^2/m^3) was multiplied by the number of curies of the radionuclide released during 1982 and was divided by the number of hours in a year squared (7.67×10^7). Logarithmic interpolation between isopleths was used to obtain concen-trations at other points.

Maximum Site Boundary Whole-Body Dose

The maximum hypothetical whole-body dose to an adult from inhalation and submersion in air was calculated assuming that an individual resided continuously for a year at the point of maximum radionuclide concentration just outside the Site
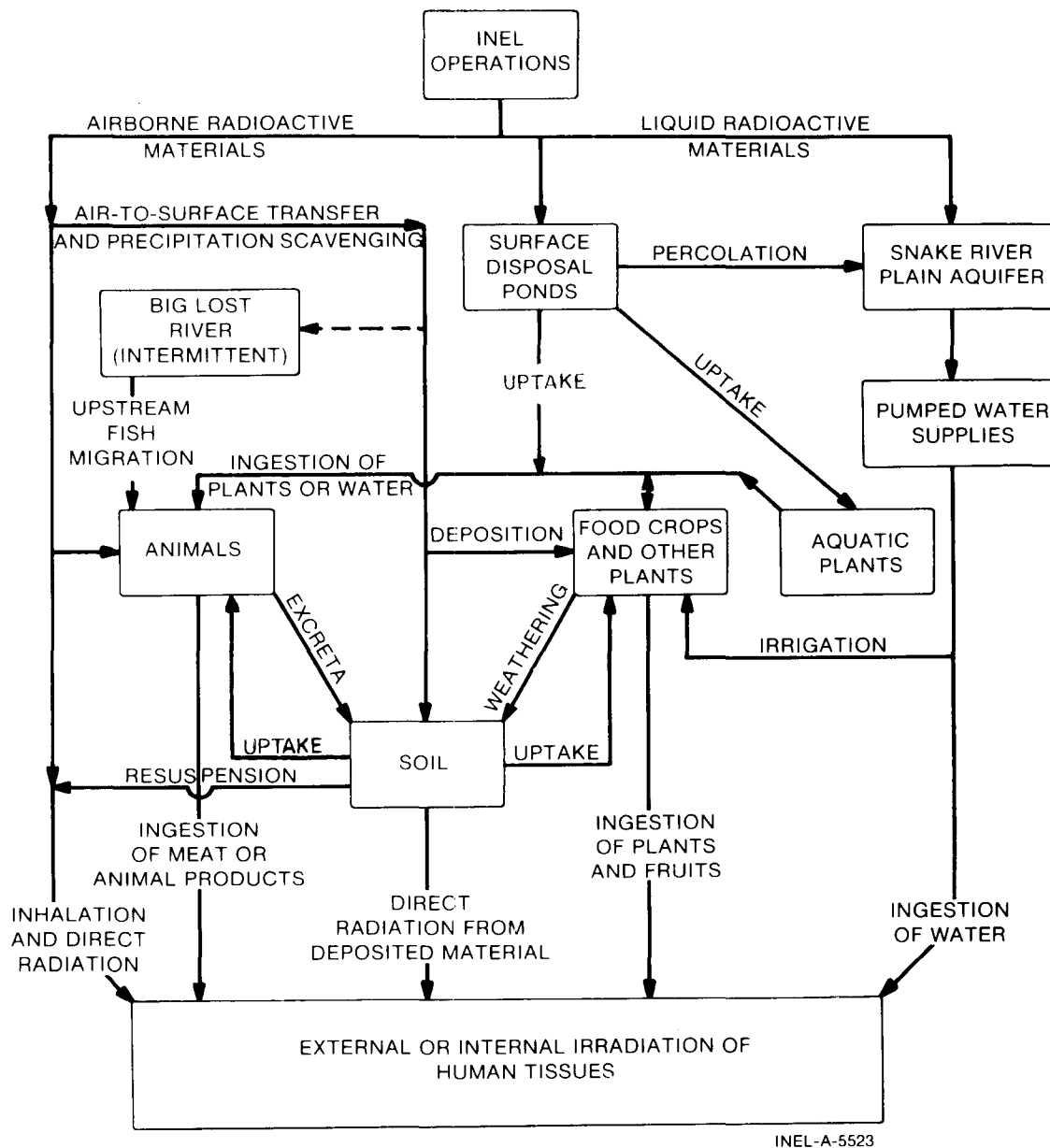
Figure 9. Possible exposure pathways of the INEL Site radioactive materials to humans within 80 km (50 mi) of ICPP and TRA.

TABLE IX
RADIONUCLIDE COMPOSITION OF AIRBORNE EFFLUENTS (1982)

	Radionuclide	Half-Life	Airborne Effluent (Ci)[a]			
			ANL	ICPP	TRA	Total[b]
Noble gases	Kr-85	10.7 yr	68	8,700	—	8,780
	Xe-138	14.2 min	1.3	—	4,600	4,600
	Ar-41	1.83 hr	140	—	2,400	2,500
	Kr-88	2.84 hr	7.4	—	1,700	1,700
	Kr-87	1.27 hr	3.9	—	1,700	1,700
	Xe-135	9.09 hr	64	—	1,600	1,700
	Kr-85m	4.48 hr	7.1	—	1,000	1,000
	Xe-133	5.25 da	140	—	900	1,000
	Xe-135m	15.3 min	1.3	—	800	800
Particulates	Ba-139	1.39 hr	—	—	290	290
	Cs-138	32.2 min	—	—	32	32
	Rb-88	17.7 min	—	—	21	21
	Br-82	1.47 da	0.12	—	—	0.12
	Cs-137	30.2 yr	—	8.7×10^{-3}	8.3×10^{-8}	8.9×10^{-3}
	Sb-125	2.73 yr	—	7.9×10^{-3}	5.4×10^{-7}	7.9×10^{-3}
	Ru-106	1.01 yr	—	5.1×10^{-3}	—	5.1×10^{-3}
	Sr-90/Y-90[c]	28.6 yr	—	2.5×10^{-3}	5.4×10^{-7}	2.6×10^{-3}
	Ce-144	284 da	—	2.0×10^{-3}	—	2.0×10^{-3}
	Pu-238	87.7 yr	—	1.5×10^{-4}	—	1.5×10^{-4}
	Pu-239/240	2.4×10^4 yr	—	2.3×10^{-5}	—	2.3×10^{-5}
H-3, C-14, and	H-3	12.3 yr	3.0	235	—	240
Iodine	C-14	5730 yr	—	0.16	—	0.16
	I-129	1.6×10^7 yr	—	0.12	—	0.12
All Others Total			3.1×10^{-6}	8.9×10^{-4}	5.3×10^{-6}	1.0×10^{-3}
Total			430	8,900	15,000	24,000

a. Radioactivity listed in 1982 Waste Management Information System Report[10]. Values are not corrected or decay after release.

b. Totals include small amounts from facilities not listed.

c. Parent-daughter equilibrium assumed.
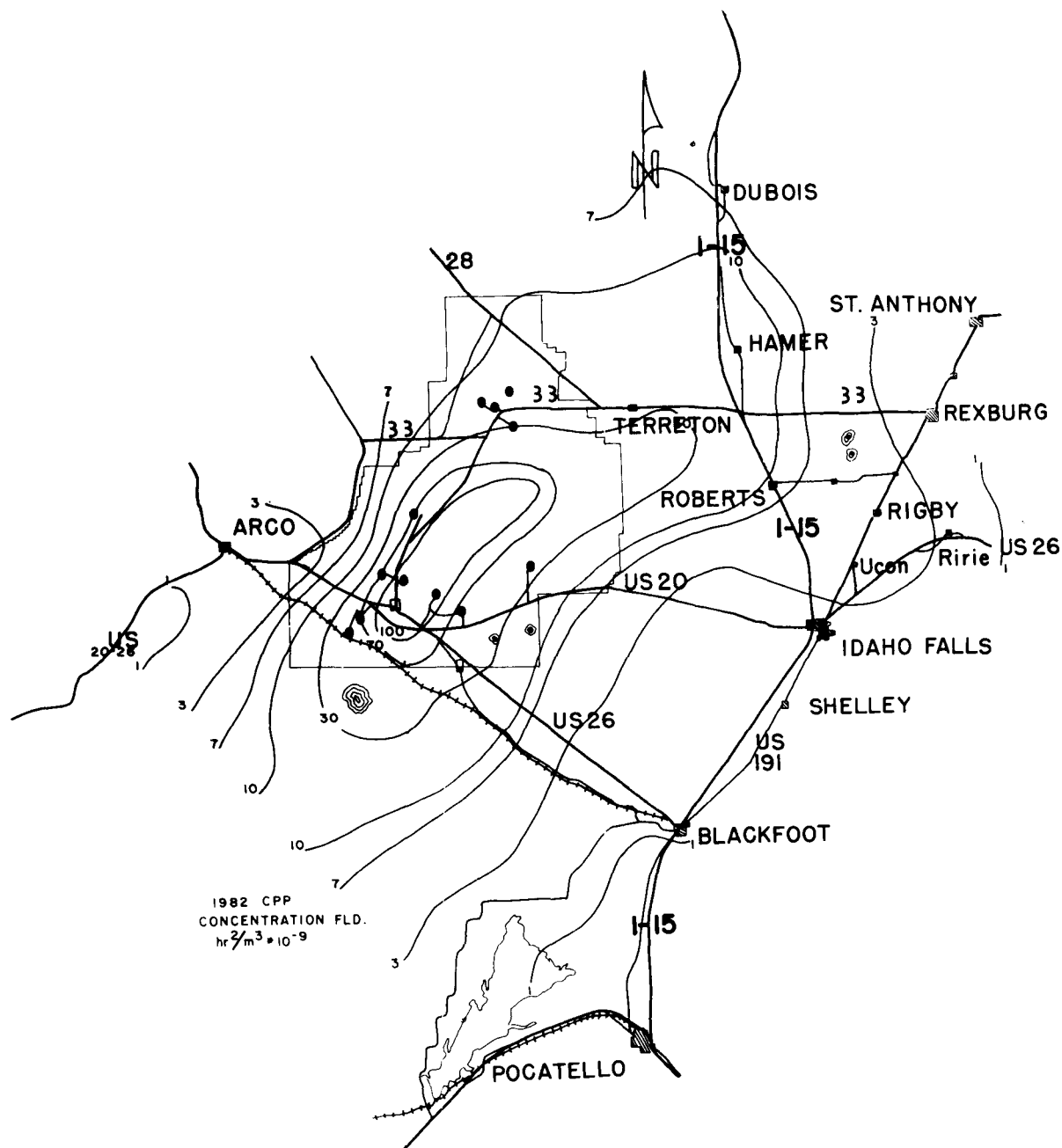
Figure 10. 1982 average of mesoscale dispersion isopleths of air concentrations at ground level, normalized to unit release rate.

boundary (fence post dose). The calculated dose represents the 50-yr dose commitment for chronic exposure occurring during 1982. The calculation was based on data presented in Table IX and Figure 10. The maximum offsite concentration occurred along the southern Site boundary at the isopleth labeled "70" in Figure 10. The dispersion coefficient used for this point is 70×10^{-9} hr^2/m^3. The whole-body

dose from each radionuclide in Table X was computed using the dose conversion factors given in References 11 and 12.

The maximum hypothetical whole-body dose estimated for an adult from Site airborne effluent is 0.04 mrem for 1982. About 60% of that computed dose was due to noble gases and particulates

TABLE X
MAXIMUM INDIVIDUAL WHOLE-BODY DOSE (1982)

Radionuclide[a]	Maximum Offsite Concentration[b] (μCi/mL)	Maximum Whole-Body Dose[c] (mrem)
Kr-88	9.7×10^{-13}	0.021
Ar-41	1.1×10^{-12}	0.010
Kr-87	5.4×10^{-13}	0.0061
Xe-135	1.3×10^{-12}	0.0023
Kr-85m	7.0×10^{-13}	0.00079
C-14	1.5×10^{-16}	0.00066
Xe-138	1.5×10^{-14}	0.00034
H-3	2.1×10^{-13}	0.00025
Xe-133	8.1×10^{-13}	0.00023
Kr-85	7.9×10^{-12}	0.00015
Total		0.042

a. Table includes only radionuclides which contribute a dose of 0.0001 mrem or more.

b. Estimate of radioactive decay obtained by using the 1982 average windspeed from 345-355 degrees of 7600 m/hr and a distance of 14,700 m from TRA-ICCP to point of maximum offsite concentration.

c. Whole-body dose estimated using parameters given in Corley et al.[11] and in Hoenes and Soldat.[12] Doses are 50-year dose commitments.

with half-lives of less than 10 hr. This dose is less than 0.01% of the radiation protection standard for exposure to an individual in an uncontrolled area (DOE Order 5480.1A, Chapter XI). Calculations were also made of doses to several critical organs (bone, thyroid, lung, and skin) for several age categories (adult, teen, child, and infant). All calculated doses were less than the whole-body dose except for the dose to the skin which was 0.09 mrem.

The whole-body dose (0.04 mrem) resulting from Site operations is very small compared to the 150 mrem received from cosmic and terrestrial radiation each year. For interest, it may also be compared to the approximately 36 mrem from medical and radiological diagnostic procedures, to the estimated 25 mrem received each year from natural radionuclides in the body, to about 3.5 mrem received during a five-hour transcon-

tinental jet flight, or to the 0.05 to 0.1 mrem received annually by the average television viewer.[16]

Maximum Individual Dose

As indicated in Figure 10, Atomic City was the location nearest to the Site boundary where people actually reside and thus represents the point of the greatest probable dose from Site operations. Using 40×10^{-9} hr^2/m^3 as the dispersion coefficient for Atomic City and allowing for radioactive decay during the transit of the radionuclides to Atomic City, the potential individual dose from inhalation and submersion was calculated to be 0.02 mrem. This dose is about 0.004% of the radiation protection standard for exposure to an individual at points of maximum probable exposure (DOE Order 5480.1A, Chapter XI). No allowance was made for shielding by housing or residence time in the community.

Potential dose to an individual from 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 which reside briefly upon a liquid waste pond used for the disposal of low-level reactor effluents (Figure 11). The average whole body dose from consumption of a contaminated duck is 9 mrem.[13] This value is based on the assumption that the duck would be killed and eaten immediately after leaving the pond. Normally, immediate killing of the duck would not occur, so a lower dose would be more realistic due to biological elimination of the radioactivity. Because only about one duck in 4000 passing through this area has a chance of becoming contaminated, the probability of receiving this dose is further decreased.[14]

A conservative estimate of the maximum dose which could have been 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 was less than 0.2 mrem.[15] This dose is lower than reported in previous years, due to a recent evaluation of data collected after the installation in 1975 of the Atmospheric Protection System at the ICPP which reduced airborne Cs-137 emissions. The maximum dose received from eating mourning doves or sage grouse would be even lower at about 0.02 mrem.
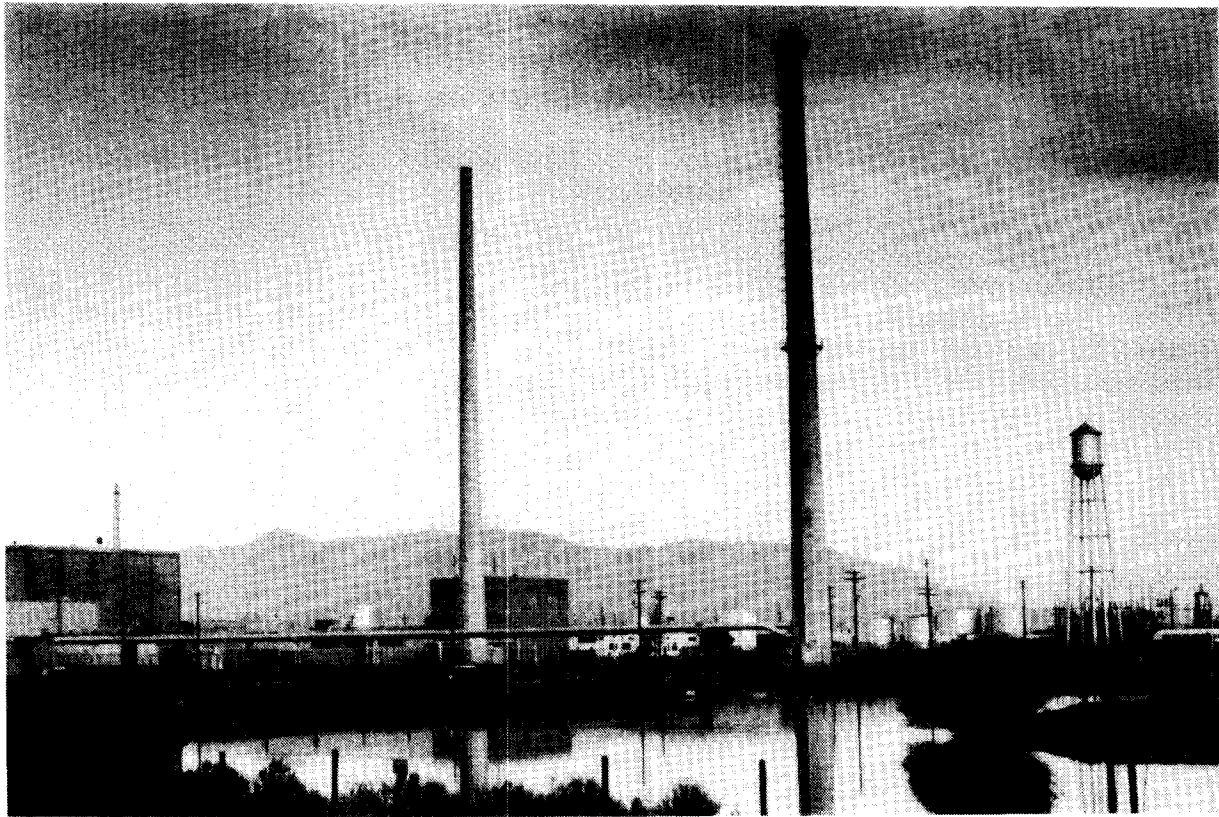
Figure 11.   TRA low-level waste disposal pond on the INEL Site.

Maximum Dose to a Member of a Population Group

Atomic City is the population group nearest to the point of maximum exposure on the Site boundary. Therefore, each resident of this community would have the same potential dose as calculated in the section above. However, this would be compared to the standard for a suitable sample of the exposed population. The 0.02 mrem dose is about 0.01% of that standard.

80-Kilometer Population Dose

An estimate of the maximum whole-body dose from submersion or inhalation which could have been received by all members of the public within an 80-km (50-mi) radius of the TRA-ICPP complex was made by summing the potential individual doses to the people of each census division within the 80-km (50-mi) radius. The dose to an individual of a particular division is a fraction of the maximum Site boundary whole-body dose (fence post dose) calculated in a previous section.

The fraction is obtained by taking the ratio of the estimated dispersion coefficient for each census division from Figure 10 to the dispersion coefficient of 70×10^{-9} hr^2/m^3 which was used to calculate the maximum individual dose. The potential dose to the population of the division is the product of the potential dose to each resident times the division population. The calculation is conservative since radioactive decay of the isotopes was not calculated during transport over distances greater than the 14 km (9 mi) from the TRA-ICPP midpoint to the southern Site boundary. Idaho Falls, for example, is about 66 km (41 mi) from TRA-ICPP.

The 80-km (50-mi) population dose was the sum of population doses for the various census divisions. The results are summarized in Table XI. The estimated potential population dose was 0.17 man-rem to a population of 114,400. When compared with an approximate population dose of 17,200 man-rem from natural background, this represents an increase of only about 0.001%. The dose of 0.17 man-rem can also be compared to the following estimated whole-body population doses for the same size population: 4,100 man-rem for

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TABLE XI
80-KILOMETER POPULATION DOSE (1982)

Census Division	Dispersion Coefficient[a]	Population[b] 1982	Population Dose[c] (man-rem)
Aberdeen	2×10^{-9}	2,850	0.0033
Arco	2×10^{-9}	2,900	0.0033
Atomic City (city)	40×10^{-9}	34	0.0008
Atomic City (division)	5×10^{-9}	2,230	0.0064
Blackfoot	1×10^{-9}	12,200	0.0070
Carey (part)	1×10^{-9}	100	0.00006
Clark, West (part)	7×10^{-9}	130	0.0005
Firth	2×10^{-9}	3,020	0.0035
Fort Hall (part)	1×10^{-9}	4,150	0.0024
Hamer	25×10^{-9}	2,340	0.033
Howe	6×10^{-9}	450	0.0015
Idaho Falls	2×10^{-9}	60,600	0.069
Idaho Falls, West	2×10^{-9}	1,660	0.0019
Lewisville-Menan	5×10^{-9}	3,180	0.0091
Mackay	2×10^{-9}	650	0.0007
Moreland	2×10^{-9}	7,770	0.0089
Roberts	8×10^{-9}	1,330	0.0061
Shelley	2×10^{-9}	5,800	0.0066
Ucon (part)	4×10^{-9}	3,000	0.0069
Totals		114,394	0.1710

a. Coefficient, obtained from Figure 10, is the 1982 average concentration normalized to unit release rate (hr^2/m^3). The value selected represents an estimated average based on the location of population centers in the census division.

b. Population for each division is based upon the 1980 Advance Census Reports for Idaho. Estimates are made when only part of a division is located within the 80-km radius. The Idaho Falls division population has been increased by 2.7% per year based upon projections by the Idaho Falls Chamber of Commerce.

c. This population dose does not include radioactive decay beyond 14.7 km.

medical and radiological diagnostic procedures and 120 man-rem for a group of three common sources of miscellaneous radiation—air transport, self-luminescent consumer products, and television viewing.[16]

The contribution of indirect exposure pathways to the population dose has not been considered because of uncertainties regarding the number of people exposed, the small probability of obtaining game animals migrating from the Site during hunting season, and the levels of different radionuclides in various animals. The dose contribution from these indirect exposure pathways would realistically be less than the dose from submersion or inhalation.

ENVIRONMENTAL STANDARDS AND REGULATIONS

The following environmental standards and regulations are applicable at the INEL Site boundary.

"Requirements for Radiation Protection," Chapter XI, *DOE Order 5480.1A*, August 1981.

U.S. Federal Radiation Council, *Background Material for the Development of Radiation Protection Standard*, Report No. 1, (1960) and Report No. 2 (1961), Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency, *National Primary and Secondary Ambient Air Quality Standards*, 40 CFR 50, 1982.

U.S. Environmental Protection Agency, *Drinking Water Regulations*, 40 CFR 141, 1982.

Department of Health and Welfare, State of Idaho, *Rules and Regulations for the Control of Air Pollution in Idaho*, 1972 as amended. (The U.S. Environmental Protection Agency approved the resubmission of the Idaho State Implementation Plan on July 28, 1982.)

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

The principal standards and guides for releases of radionuclides at the INEL are those of *DOE Order 5480.1A*, Chapter XI, dated August 13, 1981 entitled *Requirements for Radiation Protection*. Radiation protection standards and selected radioactivity concentration guides from Chapter XI are listed in Tables XIIa and XIIb. The most restrictive guide is listed when there is a difference between soluble and insoluble chemical forms. These listed guides are identical to those in the *Idaho Radiation Control Regulations*, Radiation Control Section, State of Idaho, 1982.

Ambient air quality standards are shown in Table XIII. Water quality standards are dependent on the type of drinking water system sampled. For public community drinking water systems, Table XIV is a partial list of maximum contaminant levels set by the U.S. Environmental Protection Agency. State of Idaho regulations are the same for those contaminants listed here.

TABLE XIIa
RADIATION PROTECTION STANDARDS, DOE Order 5480.1A, Chapter XI

Standards	Annual Whole-Body Dose Equivalent (mrem/year)
Individuals at points of maximum probable exposure	500
Suitable sample of the exposed population	170

TABLE XIIb
RADIOACTIVITY CONCENTRATION GUIDES FOR EFFLUENT RELEASES TO UNCONTROLLED AREAS (μCi/mL) DOE Order 5480.1A, Chapter XI

Radionuclide	In Air	In Water
Gross Alpha	2×10^{-14}	3×10^{-8}
Gross Beta[a]	1×10^{-12}	3×10^{-8}
Am-241	2×10^{-13}	4×10^{-6}
Sb-125	9×10^{-10}	1×10^{-4}
Ar-41	4×10^{-8}	—
Ba-140	1×10^{-9}	2×10^{-5}
Cs-134	4×10^{-10}	9×10^{-6}
Cs-137	5×10^{-10}	2×10^{-5}
H-3	2×10^{-7}	3×10^{-3}
I-129	2×10^{-11}	6×10^{-8}
I-131	1×10^{-10}	3×10^{-7}
Kr-85	3×10^{-7}	—
Kr-85m	1×10^{-7}	—
Kr-87	2×10^{-8}	—
Kr-88	2×10^{-8}	—
Pu-238	7×10^{-14}	5×10^{-6}
Pu-239	6×10^{-14}	5×10^{-6}
Pu-240	6×10^{-14}	5×10^{-6}
Ru-106	2×10^{-10}	1×10^{-5}
Sr-90	3×10^{-11}	3×10^{-7}
Xe-133	3×10^{-7}	—
Xe-135	1×10^{-7}	—
Xe-138	3×10^{-8}	—

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

TABLE XIII
AMBIENT AIR QUALITY STANDARDS[a] ($\mu g/m^3$)

Pollutant	Sampling Period	U.S. EPA	State of Idaho
SO_2	24-hour Average	365	365
	Annual Average	80	80
NO_2	Annual Average	100	100
Total Particulates	24-hour Average	150	150
	Annual Average	60	60

a. Primary standards are given for SO_2, the primary and secondary standard for NO_2, and secondary standards for Total Particulates.

TABLE XIV
MAXIMUM CONTAMINANT LEVELS
FOR PUBLIC COMMUNITY DRINKING
WATER SYSTEMS

Gross Alpha	15 pCi/L
Gross Beta	50 pCi/L
Manmade Radionuclides	Concentrations resulting in 4 mrem total body or organ dose equivalent
Tritium[a]	20,000 pCi/L
Strontium-90[a]	8 pCi/L
Nitrate (as N)[b]	10 mg/L
Chromium	0.05 mg/L

a. Based on a 2-L/day drinking water intake.

b. Applies to non-community water systems also.

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APPENDIX A
MAJOR PROGRAMS, LOCATION, GEOLOGY, AND CLIMATOLOGY

The Idaho National Engineering Laboratory Site (INEL) 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, primarily 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. A total of 52 reactors have been built, of which 15 are operating or operable. The INEL's broad mission is to develop economic energy sources by applying its engineering and scientific expertise to the Department of Energy's (DOE) research and development programs. Major DOE programs currently underway at the INEL Site fall into six categories:

1. Providing test irradiation services from the one operating high flux-test reactors—the Advanced Test Reactor (ATR).

2. 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).

3. Conducting light-water-cooled reactor safety testing and research at the Loss-of-Fluid Test (LOFT) and the Power Burst Facility (PBF).

4. Operating the Experimental Breeder Reactor No. 2 (EBR-II).

5. Operating the Naval Reactors Facility (NRF).

6. Storing and monitoring solid transuranic wastes.

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 airline km (39 mi) from north to south and is about 58 km (36 mi) wide at its broader southern part. 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 in the main text). With a population of about 1300, Arco is the largest boundary community in the area surrounding the Site. Land immediately beyond the boundaries of the Site is either desert or agricultural land. Most of this nearby farming is concentrated northeast of the Site. Large areas of agricultural land are farmed in the Snake River Valley regions which 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 -42°C (-43°F). Vegetation is typical of a cool desert with sagebrush conspicuous over 80% of the Site. Frequenting the Site are the pronghorn antelope and a few deer, but various kinds of birds, reptiles, and large populations of small mammals are also present. The INEL has been made a National Environmental Research Park (NERP), where scientists from DOE, other federal and state agencies, universities, and private research foundations can study changes caused by man's activities and obtain data for use in making decisions on land use. At present, about 25 different environmental studies are being conducted.

The surface of the plain is a combination of basaltic lava outcroppings 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 inter-bedded basalt flows, lucustrine, and alluvial sedimentary deposits to a depth of about 760 m (2500 ft). The most recent volcanism, 1600 years ago, 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 (8.5 in.) over the past 15 yr. Underlying the desert plain is a natural aquifer in the
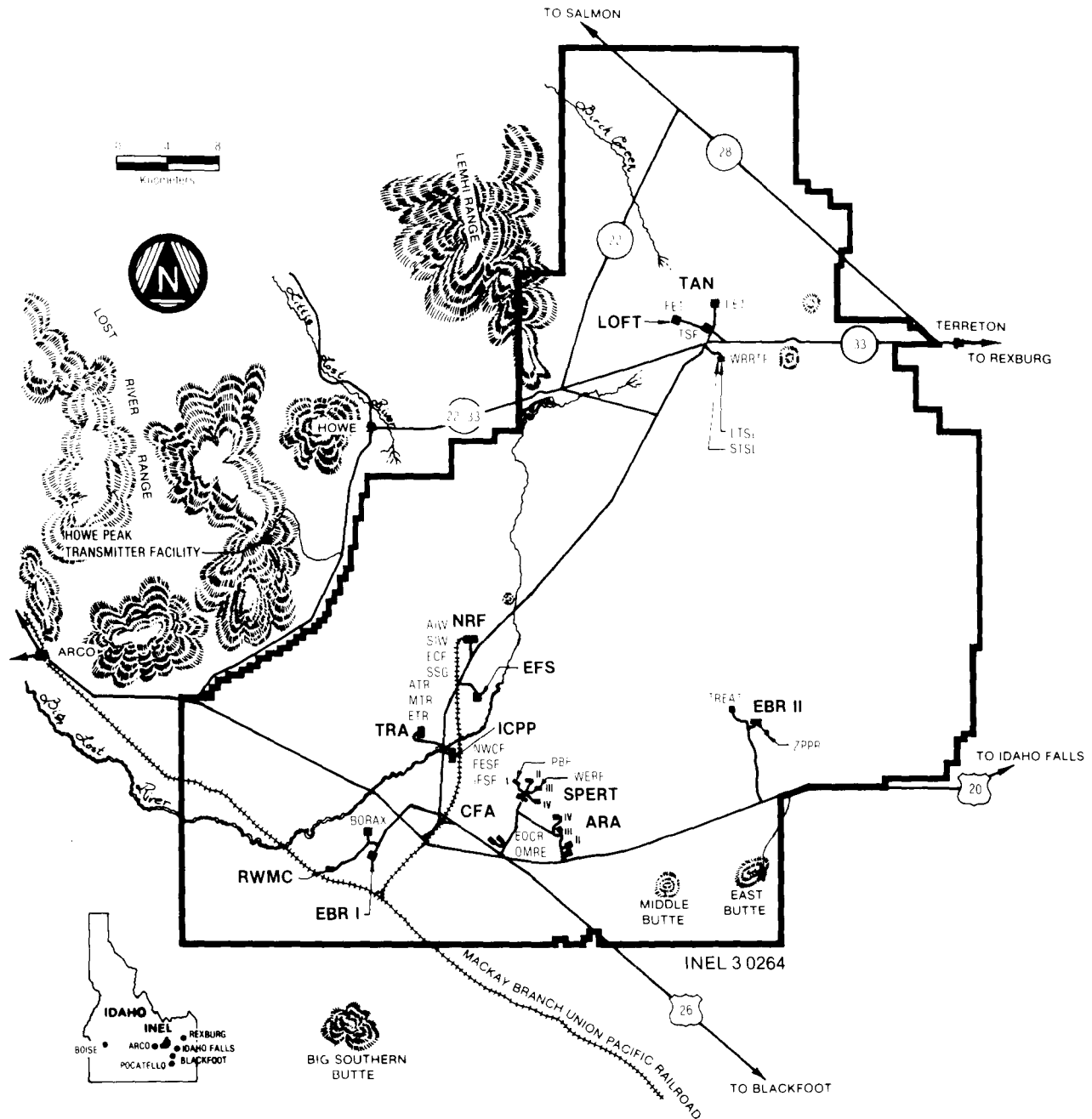
IDAHO NATIONAL ENGINEERING LABORATORY

Figure A-1. INEL Site facility locations.

TABLE A-1

TABULATION OF FACILITIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Name	Abbreviation	Operating[a] Contractor		Name	Abbreviation	Operating[a] Contractor
Reactors Operating or Operable as of December 1982				**Other Facilities in Use (Continued)**		
Advanced Reactivity Measurement Facility No. 1[b]	ARMF-I	EG&G		Computer Science Center (Idaho Falls)	CSC	EG&G
Advanced Test Reactor	ATR	EG&G		Expended Core Facility	ECF	WEC
Advanced Test Reactor Critical	ATRC	EG&G		Experimental Field Station	EFS	DOE-ID
Argonne Fast Source Reactor	AFSR	ANL		Field Engineering Test Facility	FET	EG&G
Coupled Fast Reactivity Measurement Facility[b]	CFRMF	EG&G		Fuel Element Storage Facility	FESF	ENICO
				Hot Fuel Examination Facilities	HFEF	ANL
Experimental Breeder Reactor No. 2	EBR-II	ANL		Hot Pilot Plant	HPP	ENICO
Large Ship Reactor "A"	A1W-(A)	WEC		Idaho Chemical Processing Plant	ICPP	ENICO
Large Ship Reactor "B"	A1W-(B)	WEC		Idaho Laboratory Facility (Idaho Falls)	ILF	EG&G
Loss-of-Fluid Test Facility	LOFT	EG&G		Irradiated Fuel Storage Facility	IFSF	ENICO
Natural Circulation Reactor	S5G	WEC		LOFT Test Support Laboratory	LTSL	EG&G
Power Burst Facility	PBF	EG&G		Naval Reactors Facility	NRF	WEC
Submarine Thermal Reactor	S1W (STR)	WEC		New Waste Calcining Facility	NWCF	ENICO
Transient Reactor Test Facility	TREAT	ANL		Radioactive Waste Management Complex	RWMC	EG&G
Neutron Radiography Facility	NRAD	ANL		Radiological and Environmental Sciences Laboratory	RESL/ID	DOE-ID
Zero Power Plutonium Reactor[b]	ZPPR	ANL		Reactor Training Facility	RTF	EG&G
				Semiscale Test Support Laboratory	STSL	EG&G
Reactors Dismantled, Transferred, or in Standby Status				Standards Calibration Laboratory (CF-698)	--	EG&G
				Technical Services Center (CF-688, 689)	TSC	EG&G
Boiling Water Reactor No. 1	BORAX-I	ANL		Technical Service Facility	TSF	EG&G
Boiling Water Reactor No. 2	BORAX-II	ANL		Test Area North	TAN	EG&G
Boiling Water Reactor No. 3	BORAX-III	ANL		Test Reactor Area	TRA	EG&G
Boiling Water Reactor No. 4	BORAX-IV	ANL		Waste Experimental Reduction Facility	WERF	EG&G
Boiling Water Reactor No. 5	BORAX-V	ANL		Willow Creek Building (Idaho Falls)	WCB	EG&G
Engineering Test Reactor	ETR	EG&G				
Engineering Test Reactor Critical	ETRC	EG&G				
Experimental Breeder Reactor No. 1	EBR-I	ANL		**Facilities Not Presently in Use**		
Experimental Organic Cooled Reactor (Mothballed before startup)	EOCR	PPCo		Coal-Fired Steam Generating Facility	CFSGF	ENICO
Materials Test Reactor	MTR	PPCo & INC		Initial Engineering Test Facility	IET	EG&G
Organic Moderated Reactor Experiment	OMRE	AI		Fluorinel and Fuel Storage Facility	FAST	ENICO
Special Power Excursion Reactor Test No. 1	SPERT-I	PPCo		Waste Calcining Facility	WCF	ENICO
Special Power Excursion Reactor Test No. 2	SPERT-II	PPCo & INC				
Special Power Excursion Reactor Test No. 3	SPERT-III	PPCo & INC		**Major Programs at INEL**		
Special Power Excursion Reactor Test No. 4	SPERT-IV	PPCo & INC		Chemical Processing Program		ENICO
Spherical Cavity Reactor Critical Experiment	SCRCE	ANC		Liquid Metal Fast Breeder Reactor Program		ANL
Zero Power Reactor No. 3[b]	ZPR-III	ANL		Naval Propulsion Reactors Program		WEC
				Reactor Materials Testing Program		EG&G
Other Facilities in Use				Transuranic Waste Management Program		EG&G
				Water Reactor Safety Program		EG&G
Argonne National Laboratory - West	ANL-W	ANL				
Auxiliary Reactor Area	ARA	EG&G				
Central Facilities Area	CFA	EG&G				
Chemical Engineering Laboratory	CEL	EG&G				

[a]Operating contractor acronyms: Atomics International (AI), Aerojet Nuclear Company (ANC), Argonne National Laboratory (ANL), EG&G Idaho, Inc. (EG&G), Exxon Nuclear Idaho Company, Inc. (ENICO), Idaho Nuclear Corporation (INC), Phillips Petroleum Company (PPCo), Westinghouse Electric Corporation (WEC).

[b]Zero or low power reactor.

basaltic lava rock. The lateral flow of this water is one billion gallons per day. Aquifer water is believed to be supplied by Henry's Fork of the Snake River. Additional water comes from the Big and Little Lost Rivers and Birch Creek, which start in the mountains to the north and west and sink into the porous soils of the Site area. The underground water moves laterally at an average rate between 1.5 to 6 m/day (5 to 20 ft/day) to the south and west, emerging in springs along the Snake River between Milner and Bliss, Idaho. Both aquifer and surface waters of the Snake River Plain are used for irrigation of crops.

Winds are predominately 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, and winter has more calm periods and more night-time temperature inversions.

APPENDIX B
QUALITY ASSURANCE

A quality control and assurance program is maintained by the Radiological and Environmental Sciences Laboratory (RESL/ID) to assure consistent and reliable monitoring results. An internal quality control program is maintained by:

- Adherence to written procedures for sample collection and analytical methods[B-1]

- Documentation of program changes

- Routine calibration of instrumentation

- Daily analytical equipment performance checks for background and counting rates for standards

- Routine yield determinations of radiochemical procedures

- Duplicate samples to determine precision

- Analysis of quality control standards in an appropriate matrix

- Analysis of reagent blanks to verify chemical purity

- Propagation of all random and systematic uncertainty.

The calibration of analytical instruments is carefully performed and is traceable to the National Bureau of Standards (NBS). Six times per year tracer solutions are submitted to the RESL/ID for analysis by gamma spectrometry. Comparisons are also made for beta emitters, including Sr-90 and tritium, and for alpha emitters such as Pu-238, Pu-239, and Am-241. The results are reported directly to the NBS. Results have repeatedly demonstrated traceability to the NBS.

In past years RESL/ID has also participated in the quality assurance program administered by the Environmental Measurements Laboratory of the Department of Energy, the American Society for Testing Materials round robin testing of standard methods, and in intercomparison with the Environmental Protection Agency in Las Vegas, Nevada.

To verify the quality of the environmental dosimetry program, in addition to the internal quality control program, RESL/ID has participated in five International Environmental Intercomparison Studies, organized by the Environmental Measurements Laboratory and the University of Texas School of Public Health. The RESL/ID results have been within 10% of the test exposure values. During 1981 the RESL/ID became an organizer in this program replacing the University of Texas. The environmental intercomparison project is sponsored by the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission.

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APPENDIX C
STATISTICAL METHODS

Individual analytical results are given in the report with plus or minus ($\pm$) two analytical standard deviations (2σ) where all analytical uncertainties have been properly propagated. Many of the results were less than or equal to 2σ (and, in fact, some were negative) which is considered as meaning that they were below the minimum detectable concentration.

Arithmetic averages were calculated using actual assay results, regardless of their being above or below the detection limit. The uncertainty of the average, or the 95% confidence interval was determined by multiplying the standard deviation of the mean (also called the standard error of the mean) by the t-statistic. Averages for which the 95% confidence interval does not include zero were assumed to indicate detectable amounts of activity. In situations where a group of samples contain radioactivity in amounts near the minimum detectable concentration, the 95% confidence interval about the mean may not include zero and thus be statistically significant, even though no individual sample contained detectable radioactivity.

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

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