

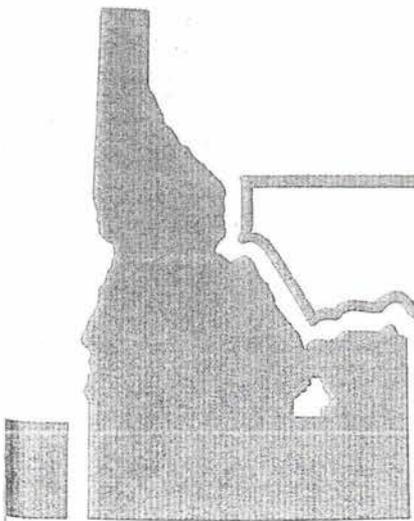
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1976
ENVIRONMENTAL MONITORING PROGRAM REPORT

May 1977



IDAHO OPERATIONS OFFICE



IDAHO NATIONAL ENGINEERING LABORATORY

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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1976 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

ENVIRONMENTAL MONITORING PROGRAM REPORT

for

IDAHO NATIONAL ENGINEERING LABORATORY SITE

May 1977

Prepared by the Environmental Sciences Branch
Health Services Laboratory
Idaho Operations Office
Energy Research and Development Administration
550 Second Street
Idaho Falls, Idaho 83401

PREFACE

This report principally presents the offsite data collected in 1976 in the routine environmental monitoring program conducted by the Energy Research and Development Administration's Health Services Laboratory at the Idaho National Engineering Laboratory (INEL) Site. The purpose of the routine program is to monitor the radioactive and nonradioactive pollutants, resulting from INEL Site operations, which may reach the surrounding offsite environment and population and to assure that concentrations remain well below the appropriate health and safety guidelines. This report is prepared in accordance with requirements of Energy Research and Development Administration Manual Chapter 0513 and is not intended to cover the numerous special environmental research programs being conducted at the INEL by the Health Services Laboratory and others. Generally, these latter programs are aimed at quantifying the effects of Site operations on the onsite environment.

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1976 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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I. INTRODUCTION

The Energy Research and Development Administration's Idaho National Engineering Laboratory (formerly the National Reactor Testing Station) was established by the Federal government in 1949 to conduct research and development on nuclear reactors and ancillary plants and equipment. The nearly 900 square mile Site is located west of Idaho Falls, Idaho on a high desert plain (See Figure 1). In 1974 the Site was also designated as one of the nation's four National Environmental Research Parks. A more detailed description of the Site location, environment, and current major activities is given in Appendix A.

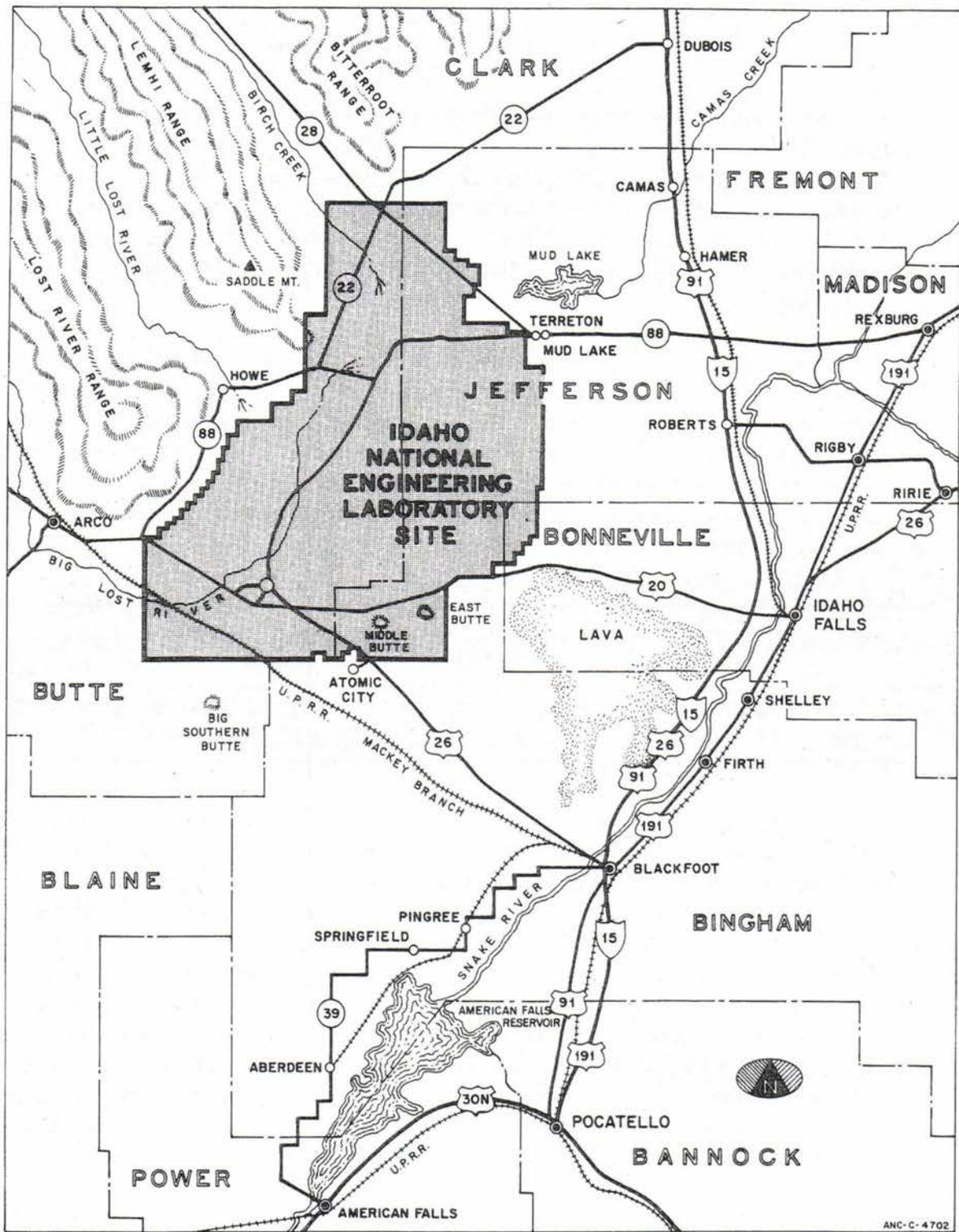


Fig. 1 Idaho National Engineering Laboratory Site vicinity map.

II. SUMMARY

The results of the various monitoring programs for 1976 indicated that radioactivity from 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. Site-contributed radioactivity continued to be far less than amounts allowed by the State of Idaho and the Federal government for safe discharge to the environment.

There was no statistical difference in particulate beta and specific radionuclide concentrations in the air as measured at Site boundary stations and those measured at distant sampling stations (Section III.2). None of the offsite well water or surface water samples contained any gross alpha, gross beta, or tritium activity above the detection limits of the analyses, which are well below the applicable health protection guides (Section III.3). Analyses for radioactivity in surface soil samples collected at Site boundary and at distant sampling locations showed only worldwide fallout levels (Section III.4). Iodine-131 at concentrations near the detection limit was measured in several of the October milk samples (Section III.5). The source of this I-131 was an atmospheric nuclear weapons test in the People's Republic of China. Some of the milk, wheat, and potato samples contained small amounts of strontium-90 from worldwide fallout (Section III.5). Penetrating radiation measured simultaneously at Site boundary and distant locations also showed only natural background levels (Section III.6). Two above-detection-limit results (one in air and the other in milk), were questionable as discussed in Sections III.2 and III.5.

A hypothetical maximum whole body dose from continuous submersion in and inhalation of airborne radioactivity that could have been received by an individual if he had lived continuously for the entire year on the immediate southern boundary of the Site was calculated to be 0.19 mrem. This hypothetical dose is about one-tenth of one percent of the dose from natural background radiation, which is about 170 mrem per year in this area. The maximum potential dose to a member of a population group from Site effluents was calculated to be 0.038 mrem at Terreton, Idaho. The maximum potential population dose from continuous submersion in and inhalation of airborne radioactivity to the approximately 92,000 people residing within an 80-kilometer radius from the center of INEL was estimated to be 1.2 man-rem. This dose is less than one-hundredth of one percent of the population dose from natural background radioactivity, which is calculated to be about 16,000 man-rem (Section IV).

Calculations indicate that the maximum potential dose to an individual from indirect exposure pathways would be less than 40 mrem. The potential population dose from indirect exposure pathways would be, at most, an addition of less than one-hundredth of one percent of the natural background man-rem dose (Section IV).

III. MONITORING DATA COLLECTION, ANALYSES, AND EVALUATION

1. GENERAL

During operation of the reactors and fuel reprocessing plant at the Site, radioactivity is routinely released to the environment. The environmental pathways from the Site to nearby populations are by atmospheric transport, possibly via water from the Snake River Plain aquifer, and indirectly through soils, foodstuffs, or animals.

The environmental monitoring program for the Site and vicinity for 1976 included the sampling and analysis of the mentioned potential pathways. Air, water, and soil were routinely monitored for radioactivity at a number of onsite, perimeter, and distant locations. Levels of radioactivity in milk, wheat, and potato samples were routinely measured at Site boundary and distant locations. Penetrating radiation exposure rates (cumulated from November 1975 to November 1976) were routinely measured at Site boundary and distant locations.

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. Several different statistical methods were used in analyzing the data depending on applicability. See Appendix B for a discussion of the statistics used in this report.

2. AIR SAMPLING

2.1 Radiological

Levels of airborne particulate radioactivity are monitored offsite by a network of 10 continuous air samplers at locations shown in Figure 2. Each air sampler maintains an average air flow of about 28 liters per minute (1 cfm) through a set of filters consisting of a membrane particulate prefilter (Gelman Model AN-800) followed by an activated charcoal-impregnated cellulose fiber filter (Gelman Model AC-1). The filters are over 99% efficient for airborne particulate radioactivity and elemental iodine vapor. Three locations also have samplers for tritium in water vapor in which air is passed at 0.3 liters per minute through a column of silica gel. Noble gases (argon, krypton, and xenon) are monitored at their onsite release points only. Air samplers are located in the small communities close to the Site boundary, and at the distant communities of Idaho Falls, Blackfoot, and Pocatello, Idaho. These distant or background locations are in directions usually crosswind of the Site and 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.

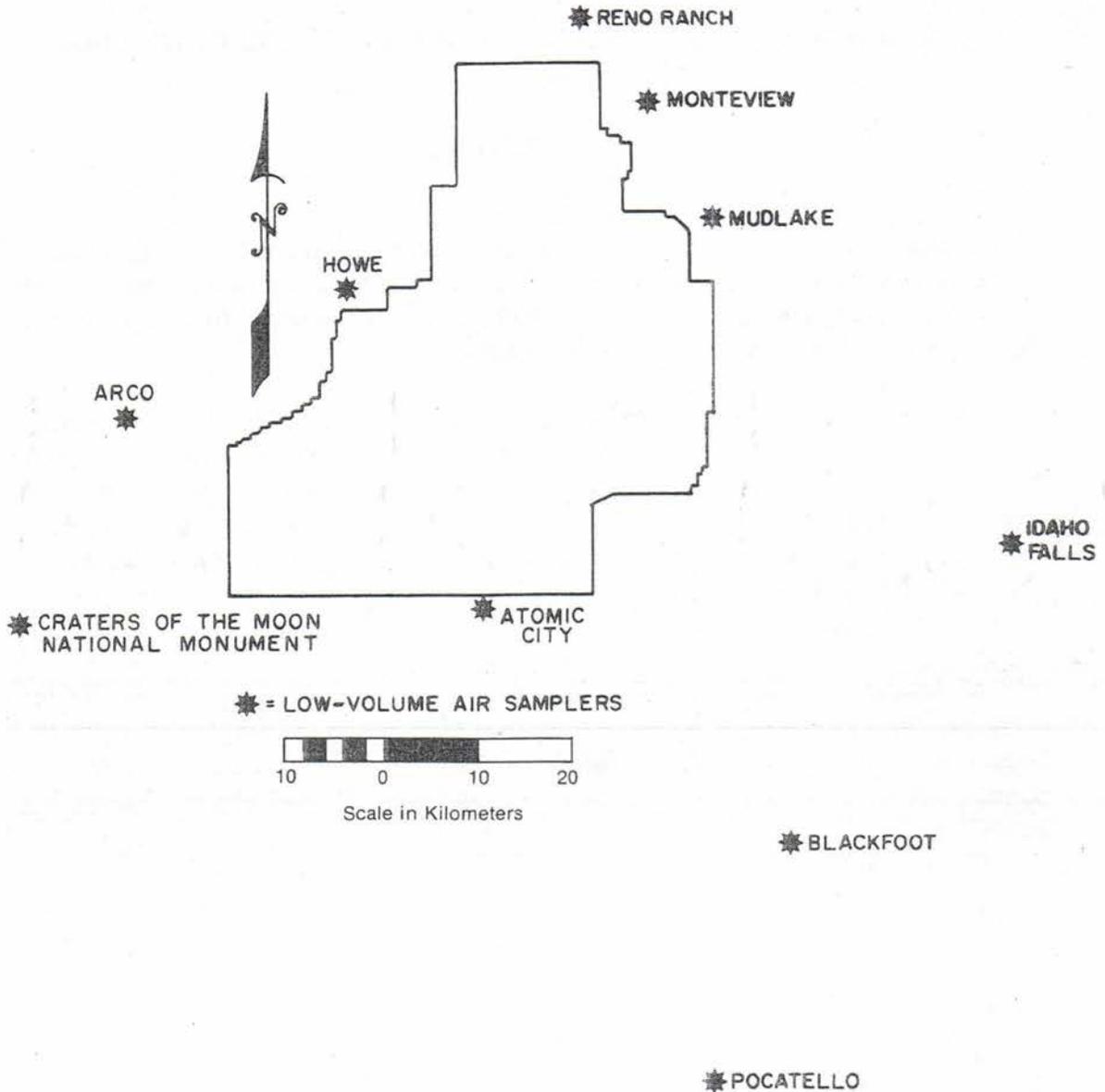


Fig. 2 Idaho National Engineering Laboratory Site air sampling network.

The filters are collected weekly and analyzed after waiting a minimum of five days to allow the short-lived radon and thoron daughters to decay. Gross beta analyses are performed on both filters in a low background beta counter. If the beta activity on a membrane filter is decidedly greater than expected, 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 20 dpm (about 7×10^{-14} $\mu\text{Ci/ml}$), the filter is analyzed by gamma spectrometry to determine unequivocally the I-131 component. At the end of each quarter, the particulate filters are composited according to location. Composites at all locations are analyzed for specific radionuclides by

gamma spectrometry. Seven locations are analyzed semiannually for specific alpha emitting radionuclides by chemical separation followed by alpha spectrometry. Six locations are analyzed semiannually for Sr-90 by chemical separation followed by beta counting.

Results of particulate beta activity measurements for 1976 are shown in Table I. The amounts of particulate beta activity measured at the air sampling stations offsite were too small to be distinguished from worldwide fallout and naturally occurring radioactivity at those locations. The average concentrations of particulate beta activity were 1.4×10^{-13} $\mu\text{Ci}/\text{ml}$ for both distant and boundary locations. The maximum concentration was observed at each of the stations during October and was a result of fallout from an atmospheric nuclear detonation in the People's Republic of China on September 26. The average monthly concentrations of particulate beta activity are shown in Figure 3 for the 5-year period from 1972 through 1976. Analysis of particulate beta activity permits the detection of only gross changes in atmospheric radioactivity.

Activity in the charcoal filters, assumed to be I-131, was not above the approximate detection limit of 7×10^{-14} $\mu\text{Ci}/\text{ml}$ at any station at any time other than in October. A few locations, both distant and boundary, indicated I-131 at near detection limit concentrations in October due to the nuclear weapons test. This result was also confirmed by data from special high volume samplers that were used to monitor fallout in October.

Specific radionuclide analysis is a more sensitive indicator than beta analysis of the impact of Site operations on the environment. The results of specific nuclide analyses of the quarterly composites are shown in Table II. The radionuclide with the highest concentration, Be-7, is a naturally occurring nuclide formed by the interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. Ce-141, Ce-144, Ru-103, and Zr-95 had above normal concentrations in the fourth-quarter of 1976 because of the nuclear weapons test; hence, their fourth-quarter concentrations are listed separately. Only once did a boundary location indicate a radionuclide concentration statistically different than the background locations. The third-quarter composite of filters from Montevieu indicated an Am-241 concentration of $3.8 \pm 0.6 \times 10^{-17}$ $\mu\text{Ci}/\text{ml}$ (0.02% of the concentration guide for an uncontrolled area, ERDAM 0524, Table II, Column 2). Special analyses of nearby onsite and offsite locations did not indicate Am-241 above its detection limit so the Montevieu measurement appears to have resulted from contamination in collection or analysis.

Atmospheric tritium in the form of HTO is monitored at two onsite locations and at Idaho Falls (background). At no time were the measurements at the onsite locations statistically different from those at the background location.

TABLE I
PARTICULATE BETA ACTIVITY IN AIR (1976)

<u>Location</u>	<u>Samples</u>	<u>Concentration (10^{-15} μCi/ml)</u>		
		<u>Minimum Observed</u>	<u>Maximum Observed</u>	<u>Annual Average</u>
<u>Distant Stations</u>				
Idaho Falls	52	21	1360	150
Blackfoot	52	24	1480	150
Pocatello	52	20	1130	130
Distant Stations Average				144+16 ^[a]
<u>Boundary Stations</u>				
Arco	52	19	1290	140
Atomic City	52	17	1740	140
Craters of the Moon	52	22	1620	170
Howe	52	15	1500	150
Monteviu	52	17	990	120
Mud Lake	52	16	1260	130
Reno Ranch	52	18	1310	140
Boundary Stations Average				141+11 ^[a]

[a] Average and two standard deviations of the mean calculated from averages of individual locations. Effects of INEL operations would be demonstrated by a boundary average statistically higher than distant average. Table shows that the averages are statistically equal.

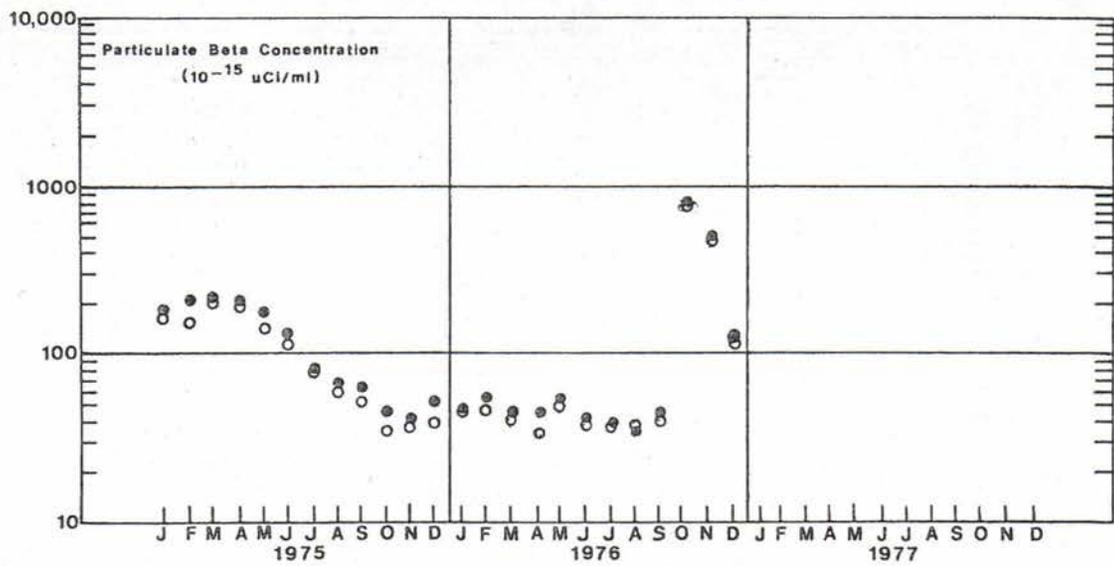
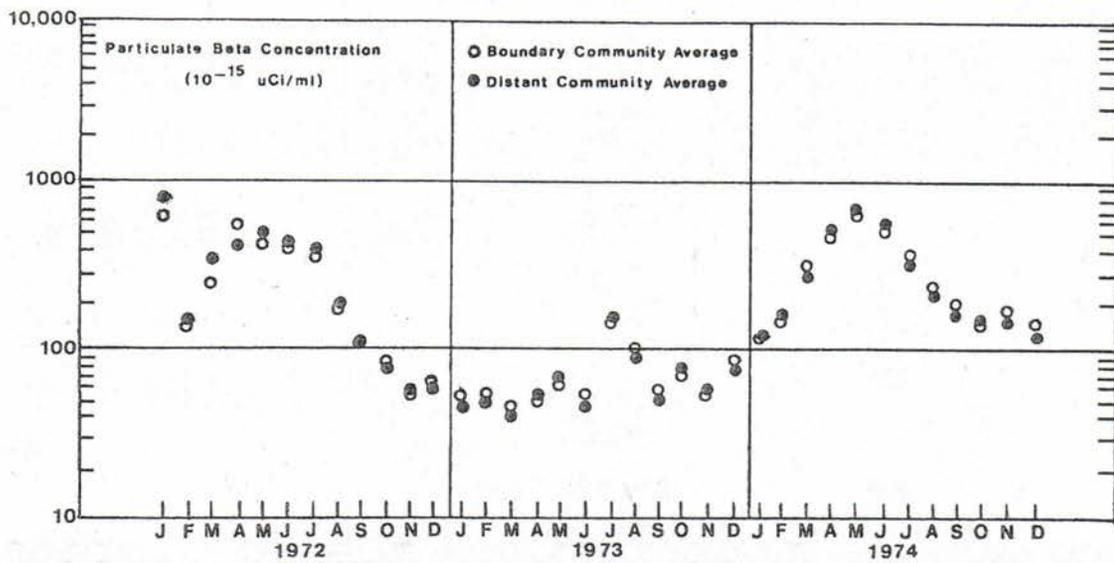


Fig. 3 Particulate beta concentrations in air.

TABLE II
SPECIFIC RADIONUCLIDE ACTIVITY IN AIR (1976)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)						
	Be-7			Ce-141			
	Minimum ^[c]	Maximum	Annual ^[d] Average	Minimum	Maximum	Three Quarters Average	Fourth Quarter
Detection Limit ^[a] Concentration Guide ^[b]	5 40,000,000			4 5,000,000			
<u>Distant Stations</u>							
Idaho Falls	170+10	310+20	219+8	BDL ^[e]	BDL	NSS ^[f]	54+4
Blackfoot	200+30	320+30	240+20	BDL	BDL	NSS	48+5
Pocatello	140+20	370+30	220+10	BDL	BDL	NSS	41+5
Distant Average			222+6			0.4+0.5	49+3
<u>Boundary Stations</u>							
Arco	170+30	290+30	250+20	BDL	BDL	NSS	46+5
Atomic City	150+30	240+30	220+20	BDL	BDL	NSS	41+5
Craters of the Moon	190+20	290+30	240+10	BDL	BDL	NSS	48+5
Howe	190+20	260+30	230+10	BDL	BDL	NSS	48+5
Montevieu	140+30	270+30	210+20	BDL	BDL	NSS	46+5
Mud Lake	150+20	270+30	210+10	BDL	5+4	NSS	41+5
Reno Ranch	160+30	320+30	250+20	BDL	BDL	NSS	44+5
Boundary Average			299+5			0.1+0.7	45+2

See footnote references on pages 15 and 16.

TABLE II (continued)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)						
	Ce-144				Cs-134		
	Minimum	Maximum	Three Quarters Average	Fourth Quarter	Minimum	Maximum	Annual Average
Detection Limit			7				1
Concentration Guide			200,000				400,000
<u>Distant Stations</u>							
Idaho Falls	BDL	3+1	1.6+0.7	15+2	BDL	BDL	NSS
Blackfoot	BDL	BDL	NSS	9+4	BDL	BDL	NSS
Pocatello	BDL	BDL	NSS	8+4	BDL	BDL	NSS
Distant Average			1.6+0.6	13+2			0.0+0.1
<u>Boundary Stations</u>							
Arco	BDL	6+4	4+3	10+4	BDL	BDL	NSS
Atomic City	BDL	BDL	NSS	10+4	BDL	BDL	NSS
Craters of the Moon	BDL	BDL	NSS	8+7	BDL	1.5+1.0	NSS
Howe	BDL	BDL	NSS	9+4	BDL	BDL	NSS
Montevieu	BDL	BDL	NSS	9+4	BDL	BDL	NSS
Mud Lake	BDL	BDL	NSS	12+7	BDL	BDL	NSS
Reno Ranch	BDL	BDL	NSS	11+4	BDL	BDL	NSS
Boundary Average			1.1+0.9	10+2			0.0+0.1

TABLE II (continued)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)					
	Cs-137			Co-60		
	Minimum	Maximum	Annual Average	Minimum	Maximum	Annual Average
Detection Limit		2			2	
Concentration Guide		5,000,000			300,000	
<u>Distant Stations</u>						
Idaho Falls	0.7+0.2	2.2+0.4	1.0+0.1	BDL	BDL	NSS
Blackfoot	BDL	2.3+1.2	1.1+0.6	BDL	BDL	NSS
Pocatello	BDL	BDL	0.7+0.6	BDL	BDL	NSS
Distant Average			1.0+0.1			0.1+0.1
<u>Boundary Stations</u>						
Arco	BDL	1.5+1.4	0.7+0.5	BDL	BDL	NSS
Atomic City	BDL	1.2+0.8	0.9+0.5	BDL	BDL	NSS
Craters of the Moon	BDL	BDL	NSS	BDL	BDL	NSS
Howe	BDL	2.0+1.2	0.8+0.5	BDL	BDL	NSS
Montevue	BDL	1.1+0.8	0.5+0.4	BDL	BDL	NSS
Mud Lake	BDL	1.7+1.2	0.9+0.5	BDL	BDL	NSS
Reno Ranch	BDL	1.9+1.2	1.1+0.5	BDL	BDL	NSS
Boundary Average			0.7+0.2			0.2+0.2

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TABLE II (continued)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)						
	Mn-54			Ru-103			
	Minimum	Maximum	Annual Average	Minimum	Maximum	Three Quarters Average	Fourth Quarter
Detection Limit Concentration Guide		1 1,000,000				3 3,000,000	
<u>Distant Stations</u>							
Idaho Falls	BDL	BDL	NSS	BDL	BDL	NSS	45+3
Blackfoot	BDL	BDL	NSS	BDL	BDL	NSS	42+8
Pocatello	BDL	BDL	NSS	BDL	BDL	NSS	38+4
Distant Average			0.1+0.1			0.3+0.4	42+2
<u>Boundary Stations</u>							
Arco	BDL	BDL	NSS	BDL	BDL	NSS	50+8
Atomic City	BDL	BDL	NSS	BDL	BDL	NSS	36+4
Craters of the Moon	BDL	BDL	NSS	BDL	BDL	NSS	38+4
Howe	BDL	BDL	NSS	BDL	BDL	NSS	40+8
Montevieu	BDL	1.2+1.1	NSS	BDL	BDL	NSS	42+4
Mud Lake	BDL	0.8+0.7	NSS	BDL	BDL	NSS	44+8
Reno Ranch	BDL	0.6+0.4	0.5+0.3	BDL	BDL	NSS	42+4
Boundary Average			0.2+0.2			0.3+0.4	40+2

TABLE II (continued)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)					
	Ru-106			Sb-125		
	Minimum	Maximum	Annual Average	Minimum	Maximum	Annual Average
Detection Limit						
Concentration Guide		13 200,000			4 900,000	
<u>Distant Stations</u>						
Idaho Falls	BDL	BDL	NSS	BDL	BDL	NSS
Blackfoot	BDL	BDL	NSS	BDL	BDL	NSS
Pocatello	BDL	BDL	NSS	BDL	BDL	NSS
Distant Average			1+1			-0.1+0.3 [g]
<u>Boundary Stations</u>						
Arco	BDL	BDL	NSS	BDL	1.8+1.6	NSS
Atomic City	BDL	BDL	NSS	BDL	BDL	NSS
Craters of the Moon	BDL	BDL	NSS	BDL	BDL	NSS
Howe	BDL	BDL	NSS	BDL	6+4	NSS
Montevieu	BDL	6+4	NSS	BDL	BDL	NSS
Mud Lake	BDL	BDL	NSS	BDL	BDL	NSS
Reno Ranch	BDL	BDL	NSS	BDL	BDL	NSS
Boundary Average			2+1			0.4+0.4

TABLE II (continued)

Location	Concentration (10^{-15} $\mu\text{Ci/ml}$)						
	Sr-90			Zr-95			
	Minimum	Maximum	Annual Average	Minimum	Maximum	Three Quarters Average	Fourth Quarter
Detection Limit		0.6				3	
Concentration Guide		200,000				1,000,000	
<u>Distant Stations</u>							
Idaho Falls	BDL	BDL	0.5+0.3	BDL	0.8+0.6	0.6+0.4	43+3
Blackfoot	BDL	BDL	0.5+0.3	BDL	BDL	NSS	37+6
Pocatello	NA ^[h]			BDL	BDL	NSS	38+6
Distant Average			0.5+0.2			0.6+0.4	41+3
<u>Boundary Stations</u>							
Arco	BDL	BDL	0.3+0.2	BDL	BDL	NSS	45+10
Atomic City	NA			BDL	BDL	NSS	32+6
Craters of the Moon	0.5+0.4	0.8+0.6	0.6+0.3	BDL	BDL	2+1	43+6
Howe	NA			BDL	BDL	NSS	38+6
Monteview	0.5+0.4	0.6+0.4	0.6+0.3	BDL	BDL	NSS	37+6
Mud Lake	BDL	BDL	NSS	BDL	BDL	NSS	32+6
Reno Ranch	NA			BDL	BDL	NSS	29+6
Boundary Average			0.4+0.1			0.3+0.5	36+2

TABLE II (continued)

Location	Concentration (10^{-18} $\mu\text{Ci/ml}$)								
	Pu-238			Pu-239 + 240			Am-241		
	Minimum	Maximum	Annual Average	Minimum	Maximum	Annual Average	Minimum	Maximum	Annual Average
Detection Limit	6			6			6		
Concentration Guide	70,000			60,000			200,000		
<u>Distant Stations</u>									
Idaho Falls	BDL	10+8	NSS	10+8	19+6	16+5	BDL	BDL	NSS
Blackfoot	BDL	BDL	NSS	BDL	12+6	9+4	BDL	BDL	NSS
Distant Average			2+3			12+3			2+3
<u>Boundary Stations</u>									
Arco	BDL	6+4	NSS	11+6	12+6	12+4	BDL	BDL	4+3
Atomic City	BDL	BDL	NSS	BDL	10+4	6+2	BDL	BDL	NSS
Craters of the Moon	Only 1 sample		NSS	Only 1 sample		5+4	Only 1 sample		NSS
Montevieu	BDL	BDL	NSS	6+4	7+4	7+3	BDL	38+6	21+4
Mud Lake	BDL	10+4	5+3	7+4	9+4	8+3	BDL	BDL	NSS
Boundary Average			2+1			7+1			3+1

[a] Detection limits are approximate. Detection limits varied because of different airflow volumes, counting times, radionuclide composition, and time prior to analysis.

[b] Concentration guides are based on ERDAM 0524 standards. These standards apply only to concentrations above natural radioactivity.

TABLE II (continued)

- [c] The analytical results are given $\pm 2\sigma$ and were decay corrected assuming a constant concentration for the sampling period.
 - [d] Weighted average ± 2 weighted standard deviations of the mean. For radionuclides present in fallout from the nuclear test by the People's Republic of China, the first three quarters of the year are averaged and the fourth quarter is listed separately. Possible Site effects could best be determined by comparing averages not totally dominated by fallout.
 - [e] Below detection limit.
 - [f] Not statistically significant. The mean was less than or equal to two standard deviations of the mean, i.e., not significant at 95% confidence.
 - [g] A negative weighted average may be interpreted as being zero.
 - [h] No analysis.
-

2.2 Nonradiological

Nonradioactive atmospheric particulates are routinely monitored at the same stations using the same filters as the radioactive particulates. The analysis involves determining the net particulate weight on the quarterly composite of weekly filters at each station. Results of atmospheric particulate measurements for 1976 are shown in Table III. This method gives an approximate detection limit of $35 \mu\text{g}/\text{m}^3$ compared to the most restrictive standard of $60 \mu\text{g}/\text{m}^3$. The boundary average was $46 \mu\text{g}/\text{m}^3$ compared to the distant average of $83 \mu\text{g}/\text{m}^3$. The higher distant community average probably reflects the greater amount of farming and industrial activity along the Snake River, whereas most of the airborne particulates in the Site vicinity are probably wind blown dust from the desert floor.

The maximum SO_2 and NO_2 concentrations at the Site boundary were calculated using the total 1976 discharges and a model of the dispersive characteristics of the air for 1976. (See Figure 6 and a discussion in Section IV.1 for explanation of the mesoscale dispersion map.) The maximum offsite concentrations occurred along the southern Site boundary. The calculated SO_2 concentration was $0.4 \mu\text{g}/\text{m}^3$ and the NO_2 concentration was $0.4 \mu\text{g}/\text{m}^3$. These concentrations are below the national secondary ambient air quality standards for SO_2 and NO_2 of 60 and $100 \mu\text{g}/\text{m}^3$, respectively.

TABLE III
PARTICULATE CONCENTRATIONS IN AIR (1976)

Location	Concentration ($\mu\text{g}/\text{m}^3$)		
	Minimum	Maximum ^[b]	Average ^[c]
Approximate Detection Limit			35
Concentration Guide ^[a]			60
<u>Distant Stations</u>			
Idaho Falls	BDL ^[d]	130+40	78
Blackfoot	BDL	130+40	62
Pocatello	BDL	140+30	111
Distant Average ^[e]			83+10
<u>Boundary Stations</u>			
Arco	BDL	200+30	88
Atomic City	BDL	50+30	BDL
Craters of the Moon	BDL	100+30	BDL
Howe	BDL	90+30	54
Monteview	50+30	160+30	95
Mud Lake	BDL	120+30	BDL
Reno Ranch	BDL	60+30	BDL
Boundary Average ^[e]			46+5

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

[b] Analytical results $\pm 2\sigma$.

[c] Weighted average.

[d] Below detection limit.

[e] Weighted average ± 2 weighted standard deviations of the mean.

3. WATER SAMPLING

Water samples are collected from offsite drinking water production wells and from the Snake River. Offsite water sampling locations are shown in Figure 4. All offsite samples are collected semiannually. Gross alpha, gross beta, and tritium analyses are routinely performed on the water samples. For gross alpha analysis, an aliquot of the sample is evaporated on a stainless planchet and counted with a scintillation counter system. Another aliquot is evaporated and counted for gross beta activity in a low-background beta counter. Tritium concentrations are determined with a liquid scintillation counter.

None of the offsite water samples collected during 1976 contained concentrations of radioactivity above the detection limits of the analyses. The detection limits for gross alpha, gross beta, and tritium are 3×10^{-9} , 5×10^{-9} , and 4×10^{-7} $\mu\text{Ci}/\text{ml}$ or about 10%, 20% and 0.01%, respectively, of the concentration guides for an uncontrolled area.

Most of the onsite water sampling is conducted by the U.S. Geological Survey. Analyses of water samples collected onsite indicate that Sr-90 concentrations were above the detection limit only for those samples collected within two miles of the release point at the Idaho Chemical Processing Plant disposal well, or approximately six miles inside the nearest Site boundary. The detection limit for Sr-90 is about 1×10^{-9} $\mu\text{Ci}/\text{ml}$ or 2% of the concentration guide. Cesium and actinides have been shown to be even less mobile in the aquifer than Sr-90.

Nonradiological wastes in the aquifer are determined by measuring the specific conductance and the chloride, sodium, and total chromium content of the water. None of these waste products have affected offsite water. All of these waste products were at background levels or below detection limits three miles inside the nearest Site boundary.

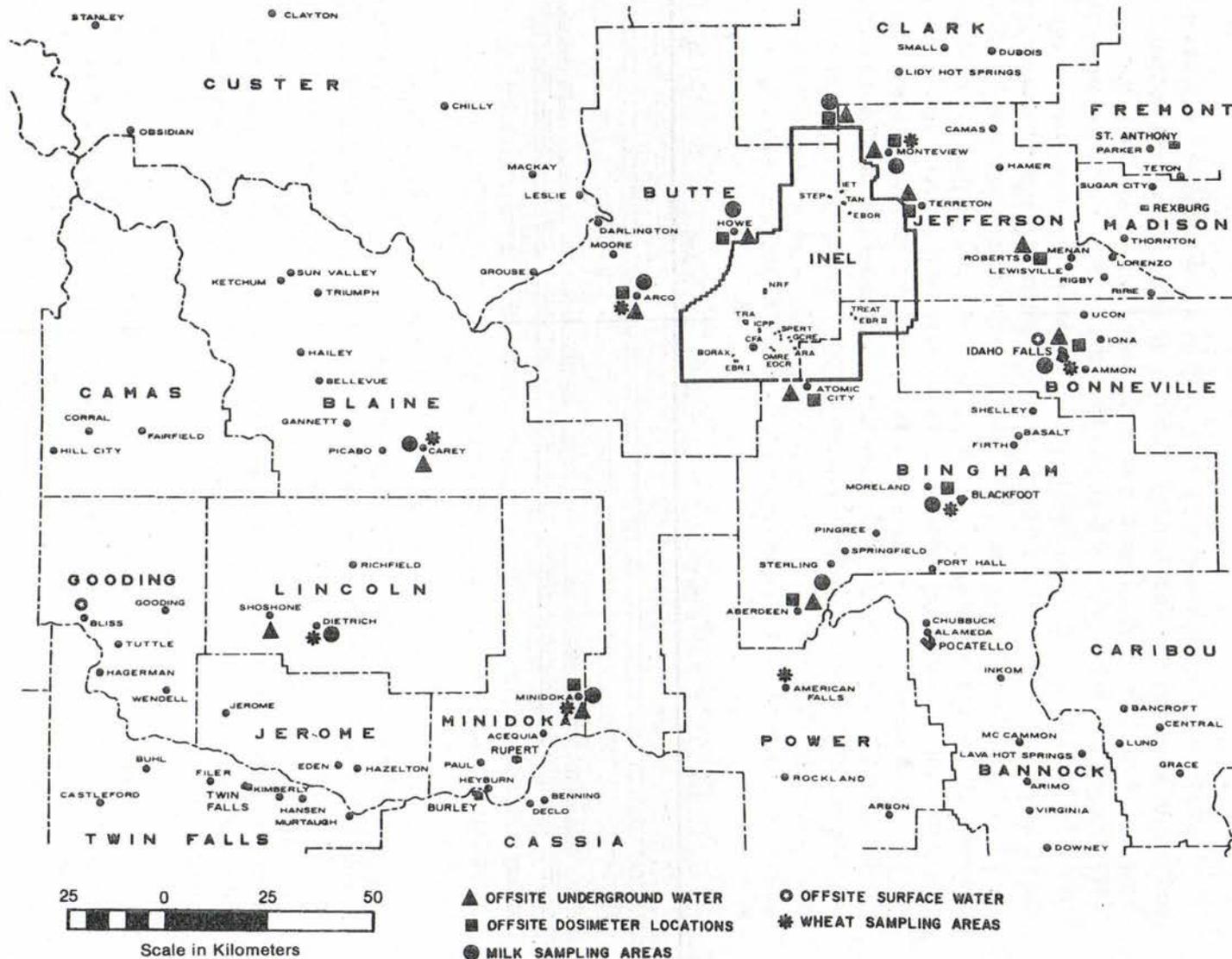


Fig. 4 Offsite water, milk, and wheat sampling locations and penetrating radiation dosimetry locations.

4. SOIL SAMPLING

In order to establish background levels of natural and fallout radioactivity in surface soil and to assess any potential buildup of activity from Site operations, soil samples have been collected from distant and boundary undisturbed locations each year since 1971 except 1972. Soil samples collected in 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 1974, 1975, and 1976 a 100 m² area was sampled for each composite. A number of 5 to 10 cm, 10 to 20 cm, and 20 to 30 cm depth samples were also collected to determine the depth distribution of radioactivity. All soil samples were analyzed for gamma-emitting radionuclides. Most were also analyzed for Sr-90 and alpha-emitting nuclides. The soils were dried at least three hours at 120°C, or if much organic debris was present, at 400°C. Only soil less than 500 microns in diameter (35 mesh) was analyzed. The data are reported in units of activity per gram of soil (pCi/g dry weight) and also in units of areal activity (pCi/m²), which is the total activity in each soil sample (including greater than 500 microns) divided by the surface area (0.039 m²) of the sample.

Concentrations of natural radioactivity in the surface soil are shown in Table IV. The Th-232 and U-238 activities were determined from those of the progeny radionuclides, Ac-228 and Pb-214. Oakley^[1] indicated that the average concentrations of uranium, thorium, and potassium-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^[a], respectively, so they are higher in natural radioactivity than earth crustal averages. 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 NCRP Report No. 45^[2]. Page 63 of the same report shows the decrease in gamma radiation with depth of snow cover. Assuming that the Site and vicinity had 4 cm of snow for one-quarter of the year, the expected soil gamma dose becomes 73 mrem.

Concentrations of Cs-137, Sr-90, Pu-238, Pu-239 + 240 and Am-241 in surface soil as found in 1971-1975 (1976 samples are not fully analyzed yet) are shown in Table V. Ce-144 was also detected in some of the early samples at both distant and Site boundary locations, but it has not been detected since 1973. A comparison of the mean concentrations of each radionuclide at distant and boundary locations indicates that both means are from the same population. Although all the soil samples for 1971-1975 were grouped together in order to

[a] These values are slightly different than those reported in the 1975 "Environmental Monitoring Program Report" due to more detailed analysis.

TABLE IV

NATURAL RADIONUCLIDES IN INEL AREA SURFACE SOILS (1970 to 1975)^[a]

Radionuclide	Geometric Average ^[b]		Number of Samples	~ Detection Limit	
	(pCi/g)	(pCi/m ² x10 ³)		(pCi/g)	(pCi/m ² x10 ³)
U-238 ^[c]	1.52 \times 1.03	95.1 \times 1.05	116	0.04	3
Total Series ^[d]	21	1300			
Th-232 ^[e]	1.34 \times 1.04	84 \times 1.05	114	0.04	3
Total Series ^[d]	13	840			
K-40	19.5 \times 1.03	1220 \times 1.04	125	0.05	4

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

[b] Geometric average \times 2 standard geometric deviations of the mean. If data is 1.52 \times 1.03, then upper 95% confidence level is 1.52x1.03, and lower 95% confidence level is 1.52 \div 1.03. See Appendix B.

[c] Based on the Pb-214 activity.

[d] Secular equilibrium assumed. Does not account for radon diffusion.

[e] Based on the Ac-228 activity.

TABLE V

RADIONUCLIDES IN INEL AREA SURFACE SOILS (1970 to 1975)

Radionuclide	Location	Geometric Average		Number of Samples	~ Detection Limit	
		(pCi/g)	(pCi/m ² × 10 ³)		(pCi/g)	(pCi/m ² × 10 ³)
Cs-137	Boundary	0.83 \bar{x} 1.2	50 \bar{x} 1.2	41	0.04	3
	Distant	1.14 \bar{x} 1.3	66 \bar{x} 1.3	18	0.04	3
Sr-90	Boundary	0.50 \bar{x} 1.2	29 \bar{x} 1.2	36	0.09	10
	Distant	0.55 \bar{x} 1.7	40 \bar{x} 1.2	18	0.09	10
Pu-238	Boundary	0.0025 \bar{x} 1.4	0.14 \bar{x} 1.2	35	0.002	0.2
	Distant	0.0030 \bar{x} 1.4	0.18 \bar{x} 1.3	18	0.002	0.2
Pu-239	Boundary	0.018 \bar{x} 1.2	0.98 \bar{x} 1.2	35	0.004	0.3
	Distant	0.022 \bar{x} 1.4	1.17 \bar{x} 1.4	18	0.004	0.3
Am-241	Boundary	0.0043 \bar{x} 1.3	0.26 \bar{x} 1.3	22	0.004	0.3
	Distant	0.0050 \bar{x} 1.6	0.31 \bar{x} 1.4	14	0.004	0.3

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

[b] Geometric average \bar{x} 2 standard geometric deviations of the mean.

have enough data to obtain a valid lognormal analysis, there was no noticeable increase in concentrations from 1971 to 1975. This is to say that any activity in the boundary soils which may have resulted from Site operations cannot be distinguished from worldwide fallout activity.

Soil sample data even from undisturbed locations are highly variable. For instance, for 95% of all offsite soil concentrations of Cs-137, the highest concentration was 9 times the lowest. (Two standard geometric deviations of individuals was 3.1.) The other radionuclides have similar concentration ranges.

Soil samples taken in 1974, 1975, and 1976 were taken to 30 cm depths in subdivisions of 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, and 20 to 30 cm. If one visualizes a one square meter column of soil to a depth of 100 cm, 95% of all the Cs-137 activity and 85% of all the Sr-90 activity in the column is in the top 5 cm. (The relaxation depths are 2.0 cm for Cs-137 and 2.5 cm for Sr-90.) Since the natural radioactivity is nearly equally distributed throughout the crustal soil, the 100 cm column of soil has a total of 26,000 nCi of U-238 and daughters, 17,000 nCi of Th-232 and daughters, and 24,000 nCi of K-40 compared to man-made radioactivity of only 60 nCi of Cs-137 and 41 nCi of Sr-90. Hence, the man-made radioactivity is only a small fraction of the total radioactivity in the top and most environmentally important part of the soil.

5. FOODSTUFF SAMPLING

Milk, wheat, and potatoes are sampled routinely since they, or their by-products, are part of the typical American daily diet and are potentially important pathways to the public due to foliar or ground-deposited radionuclides from nuclear weapons fallout or, possibly, from Site operations. Milk and wheat sampling locations are shown in Figure 4. Potatoes were collected at Ashton, Blackfoot, Dietrich, Moore, and Montevieu, Idaho.

A total of 156 milk samples were collected from dairies around the Site. All locations are collected monthly except for the weekly collection of the Idaho Falls sample. All milk samples are analyzed for I-131 by gamma spectrometry. Milk from each location is analyzed for Sr-90 and tritium once during each year.

Several, but not all, of the October samples had concentrations of I-131 above the detection limit, as shown in Table VI. These results were due to fallout from the nuclear weapons test. The maximum I-131 concentration was 8.7×10^{-9} $\mu\text{Ci/ml}$ in the Mud Lake sample. It did not constitute a health hazard. Two special milk samples were taken from a grazing cow but neither sample indicated I-131 concentrations different from the routine samples. In general, concentrations of I-131 in milk were lower in the Idaho Falls area than in many other areas in the United States.

TABLE VI

CONCENTRATIONS OF I-131 IN MILK (1976)

<u>Sample Location and Frequency</u>	<u>Number of Analyses</u>	<u>Number Above Detection Limit</u>	<u>Concentration (10^{-9} μCi/ml) [a]</u>	
			<u>Maximum</u>	<u>Average [c]</u>
Approximate Detection Limit				1
Concentration Guide [b]				100
Idaho Falls (Weekly)	52	3	1.6 \pm 1.2	0.07 \pm 0.09
Minidoka (Monthly)	12	0	BDL [d]	0.01 \pm 0.15
Dietrich (Monthly)	12	1	2.0 \pm 0.6	0.4 \pm 0.3
Carey (Monthly)	12	1	1.2 \pm 1.0	0.0 \pm 0.2
Mud Lake (Monthly)	12	1	8.7 \pm 1.4	0.3 \pm 0.2
Reno Ranch (Monthly)	10	0	BDL	-0.1 \pm 0.3
Howe (Monthly)	12	1	1.7 \pm 1.2	0.3 \pm 0.2

TABLE VI (continued)

<u>Sample Location and Frequency</u>	<u>Number of Analyses</u>	<u>Number Above Detection Limit</u>	<u>Concentration (10^{-9} μCi/ml) [a]</u>	
			<u>Maximum</u>	<u>Average [c]</u>
Arco (Monthly)	12	0	BDL	0.2+0.2
Firth Route (Monthly)	11	1	1.3+0.8	0.0+0.3
Riverside Route (Monthly)	11	0	BDL	0.2+0.2

- [a] Analytical results $+2\sigma$ decay corrected to time of collection. All the minimum concentrations were below the detection limit.
- [b] Concentration guide for milk established by the Federal Radiation Council (Report No. 2). The guide value given corresponds to the upper limit of Range II.
- [c] Weighted average $+2$ weighted standard deviations of the mean. A negative weighted average may be interpreted as being zero.
- [d] Below detection limit.

Excluding the October samples, only one other sample showed I-131 above the detection limit. This was the November sample composited from dairies along the east side of the Snake River from Pocatello to Roberts. Since the November sample from dairies along the west side of the Snake River (closer to the Site) was below the detection limit, since this area is not in the predominant wind direction from the Site, and since there were no unusual releases of I-131 at that time, it is not probable that the positive sample resulted from Site operations. Consequently, it is believed that the positive result was due to contamination of the sample during collection or analyses. Whatever its origin, the concentration was very low, 1.3×10^{-9} $\mu\text{Ci/ml}$ or 1% of the concentration guide^[a].

Seven of the 10 dairies had Sr-90 in milk in concentrations just above the detection limit of 2×10^{-9} $\mu\text{Ci/ml}$. The maximum concentration was 4×10^{-9} $\mu\text{Ci/ml}$ at Howe and Mud Lake. These concentrations are consistent with worldwide fallout levels in that they are statistically the same as concentrations in Portland, Seattle, Spokane, and Laramie as determined by the Environmental Protection Agency in July 1976.^[3] None of the samples analyzed for tritium were above the detection limit of 4×10^{-7} $\mu\text{Ci/ml}$.

Wheat and potato sampling results are summarized in Table VII. All samples were analyzed for Sr-90, and wheat samples from Carey and Montevue were analyzed for gamma emitting radionuclides by gamma spectrometry. The only gamma emitting radionuclide discovered was naturally occurring K-40. The Sr-90 average in wheat was the same as last year (1975). This was the first year potatoes were analyzed, and it appears from Table VII that potatoes are not as good an indicator of Sr-90 in the environment as wheat. The activity was attributed to worldwide fallout, since the Sr-90 activity in wheat and potatoes close to and downwind from Site operations was the same as or less than that measured in more distant samples.

[a] The guides for milk were established by the Federal Radiation Council. The upper limit of range II was used. It should be noted that the guide was based on an individual drinking one liter of milk containing I-131 at the guide concentration each day of the year.

TABLE VII
 CONCENTRATIONS OF RADIONUCLIDES IN FOODSTUFFS (1976)

	<u>Sr-90 Concentration (pCi/g dry wt)</u>	
	<u>Wheat [a]</u>	<u>Potatoes [a]</u>
Approximate detection limit	0.004	0.002
<u>Sample Location</u>		
American Falls	0.012+0.004	NA [b]
Arco	0.007+0.004	NA
Ashton	NA	0.019+0.002
Blackfoot	0.012+0.004	0.002+0.001
Carey	0.017+0.004	NA
Dietrich	0.002+0.004	0.005+0.002
Idaho Falls	0.015+0.006	NA
Minidoka	0.019+0.004	NA
Moore	NA	0.006+0.002
Montevieu	0.002+0.004	0.003+0.002
Average [c]	0.013+0.005	0.007+0.006

[a] Analytical results $\pm 2\sigma$.

[b] No analysis.

[c] Average ± 2 standard deviations of the mean.

6. PENETRATING RADIATION MEASUREMENTS

Thermoluminescent dosimeters (TLDs) are used to measure penetrating radiation (gamma plus beta > 200 keV) exposure rates at seven boundary community locations and five distant community locations. At each location a dosimeter containing 5 individual Harshaw LiF: 700 chips (3.18mm by 3.18mm by 0.89mm) is placed one meter above ground level. The dosimeter at each location is changed semiannually. The measured cumulative exposure for the time period from November 1975 to November 1976 is shown in Table VIII. The data indicate penetrating radiation exposures from natural radioactivity in the air and soil, cosmic radiation, fallout from nuclear weapons testing, and any radioactive effluent from Site operations, other industrial processes, and fossil fuel burning.

The average annual exposures for boundary and distant community locations were 117 and 113 mR, respectively, the two numbers being statistically the same.

TABLE VIII

PENETRATING RADIATION EXPOSURE
(November 1975 to November 1976)

<u>Location</u>	<u>Exposure (mR)^[a]</u>
<u>Distant Stations</u>	
Aberdeen	116
Blackfoot	119
Idaho Falls	100
Minidoka	106
Roberts	<u>125</u>
Average ^[b]	113+9
<u>Boundary Stations</u>	
Arco	117
Atomic City	129
Craters of the Moon	109
Howe	110
Monteview	114
Mud Lake	126
Reno Ranch	<u>115</u>
Average ^[b]	117+6

[a] For analytical results, 2 sigma is 10% or less.

[b] Average ± 2 standard deviations of the mean.

Table IX 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 1976 it was about 173 mrem per year.

TABLE IX
BACKGROUND RADIATION DOSE RATE (mrem/year)

<u>Source of Background Dose</u>	<u>Estimated</u>	<u>Measured (TLD)</u>
External		
Terrestrial	73	
Cosmic (ionizing)	60	
Subtotal	133	116
Cosmic (neutron)	15	
Internal		
K-40 and others	25	
Total	173	

7. GAME SPECIES

No hunting or fishing is allowed on the Site. However, game animals migrate on and off the Site and, therefore, represent a potential exposure pathway. Fish, antelope, and doves were sampled in 1976, and ducks were sampled in 1975. Data presented here were obtained as part of the ERDA research programs, not as part of the routine environmental monitoring program. For a discussion of the potential doses to humans from consumption of these game animals, see Section IV.

Five rainbow trout (*Salmo gairdneri*) and one whitefish (*Prosopium williamsoni*) were taken from the Big Lost River at several onsite and offsite locations. One trout had a Cs-137 concentration of 0.03 ± 0.01 pCi/g (wet weight), and the whitefish had Cs-137 at 0.08 ± 0.02 pCi/g. The four other trout did not have Cs-137 above the approximate detection limit of 0.01 pCi/g. No other radionuclides were detected. No background fish samples were obtained in 1976. This study will be expanded in 1977.

Muscle samples from 11 antelope (*Antilocapra americana*) taken on or near the Site and one antelope taken distant from the Site were analyzed for gamma-emitting radionuclides. Onsite antelope muscle samples had an average Cs-137 concentration of 0.04 pCi/g (wet weight) with a maximum concentration of 0.14 pCi/g. The distant antelope muscle sample had a Cs-137 concentration of 0.011 ± 0.006 pCi/g. One onsite sample also had Cr-51 at 16 ± 2 pCi/g.

Muscle samples from 10 doves (*Zenaidura macroura*) sampled on or near the Site and one dove sampled distant from the Site were analyzed for gamma-emitting radionuclides. Onsite dove muscle samples had an average Cs-137 concentration of 1.5 pCi/g (wet weight) with a maximum concentration of 5.3 pCi/g. The distant sample had less than the approximate Cs-137 detection limit of 0.8 pCi/g. No other radionuclides were detected.

Muscle samples from 19 wild waterfowl of various species were taken from an onsite pond known to contain low-level radioactive waste and from 8 waterfowl taken distant from the Site. A total of 18 gamma-emitting radionuclides were found among the 19 onsite samples, although no one sample contained all 18 nuclides. However, all of the onsite samples contained Cs-137. The average Cs-137 concentration was 410 pCi/g (wet weight) and the maximum concentration was 2470 pCi/g. All other radionuclides had much smaller average and maximum concentrations. No radionuclides were detected in distant waterfowl muscle samples^[4].

IV. RADIOLOGICAL IMPACT OF INEL SITE OPERATIONS

1. 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:

- (1) The maximum "fence post" or Site boundary dose,
- (2) The maximum potential dose to a member of a population group,
and
- (3) The potential population dose which could have been received by the public within an 80 kilometer (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 5. Atmospheric transport is the principal potential exposure pathway from the Site. There is no appreciable movement of surface water from onsite to offsite locations, and the low-level radioactive waste released to the aquifer has never been observed beyond the boundary of the Site.

Several indirect exposure pathways have been and are continuing to be 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. The data on soil and foodstuff sampling indicate that no measureable dose results from these indirect exposure pathways.

The monitoring data presented in the previous sections indicated that at offsite sampling locations, with one possible exception, no particulate radioactivity in the air from Site operations was discernible from the preexisting levels due to natural and fallout radioactivity. As mentioned in the section on air sampling, noble gas radionuclides in air 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 the various radionuclides released during 1976 from Site facilities and a meteorological model for estimating the concentrations at selected locations in the vicinity. A summary of the radionuclides released to the atmosphere from Site facilities is shown in Table X. Due to radioactive decay of the short-lived radionuclides, the activity that would reach offsite areas was less than that indicated in Table X, about 57,000 Ci. The ICPP and TRA facilities together were the source of more than 99% of the total radioactivity released to the atmosphere. Noble gases comprised about 98% of the total radioactive airborne effluent.

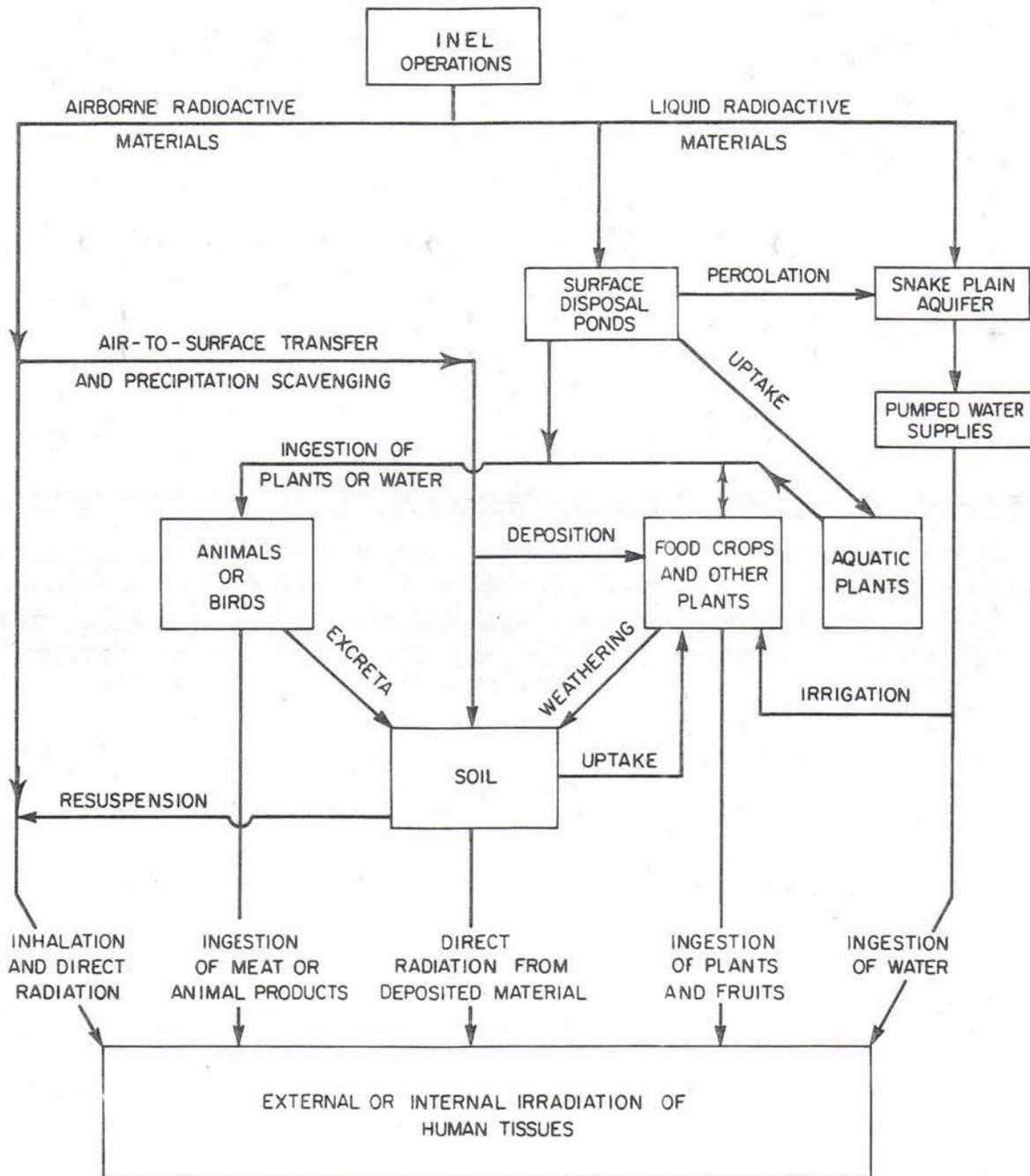


Fig. 5 Possible exposure pathways of Idaho National Engineering Laboratory Site radioactive materials to humans within 80 kilometers of ICPP and TRA.

TABLE X
 RADIONUCLIDE COMPOSITION OF AIRBORNE EFFLUENTS (1976)

Radionuclide	Half-Life	Airborne Effluent (Ci) ^[a]			
		ANL	ICPP	TRA	Total ^[b]
<u>Noble Gases</u>					
Kr-85	11 yr		31,700		31,700
Xe-138	17 min			21,100	21,100
Kr-87	1.3 hr			12,300	12,300
Xe-135	9.1 hr	96.2		10,200	10,300
Kr-88	2.8 hr	2.77		9,330	9,330
Xe-135m	16 min			5,200	5,200
Ar-41	1.8 hr	179		4,840	5,020
Kr-85m	4.4 hr			2,870	2,870
Xe-133	5.3 days	277		998	1,280
<u>Tritium</u>					
H-3	12 yr	1.28	1,000		1,000
<u>Particulates</u>					
Ba-139	1.4 hr			1,280	1,280
Cs-138	32 min			146	146
Rb-88	18 min	5×10^{-3}		117	117
Br-82	35 hr	0.12			0.12
Cs-137	30 yr		0.11		0.11
Ru-106, Rh-106 ^[c]	1.0 yr		0.10		0.10
Sb-125 ^[d]	27 yr		0.07		0.07
Sr-90, Y-90 ^[c]	28 yr		0.05		0.05
Pu-238	86 yr		1×10^{-3}		1×10^{-3}
Pu-239+240	2.4×10^4 yr		4×10^{-4}		4×10^{-4}
Th-232	1.4×10^{10} yr		1×10^{-5}		1×10^{-5}
All Others Total		<0.01	0.02	<0.01	0.02
TOTAL		~560	~33,000	~68,000	~102,000

[a] Radioactivity listed in 1976 Waste Management Information System Report^[5]. Values are not corrected for decay after release.

[b] Totals include small amounts from facilities not listed.

[c] Parent-daughter equilibrium assumed.

[d] Essentially all of the Sb-125 is released as a gas but apparently behaves as a particulate upon entering the atmosphere.

The mesoscale meteorological map (Figure 6) shows calculated year-summed concentrations normalized to a unit release rate during 1976 for the INEL Site and vicinity. This map has been prepared by the National Oceanographic and Atmospheric Administration group at the INEL from data gathered continuously at 27 meteorological stations around the Site. To facilitate the display, year-summed concentration isopleth values have been multiplied by 10^{-9} . That is, the concentration isopleth along the line labeled "30" was actually $30 \times 10^{-9} \text{ hr}^2/\text{m}^3$. To obtain the average air concentration (Ci/m^3) for a radionuclide released from TRA or ICPP along any isopleth in Figure 6, the value of the year-summed air concentration (e.g., $30 \times 10^{-9} \text{ hr}^2/\text{m}^3$) was multiplied by the number of curies of radionuclide released during 1976 and was divided by the number of hours in a year squared (7.67×10^{-7}). Logarithmic interpolation between isopleths was used to obtain concentrations at other points.

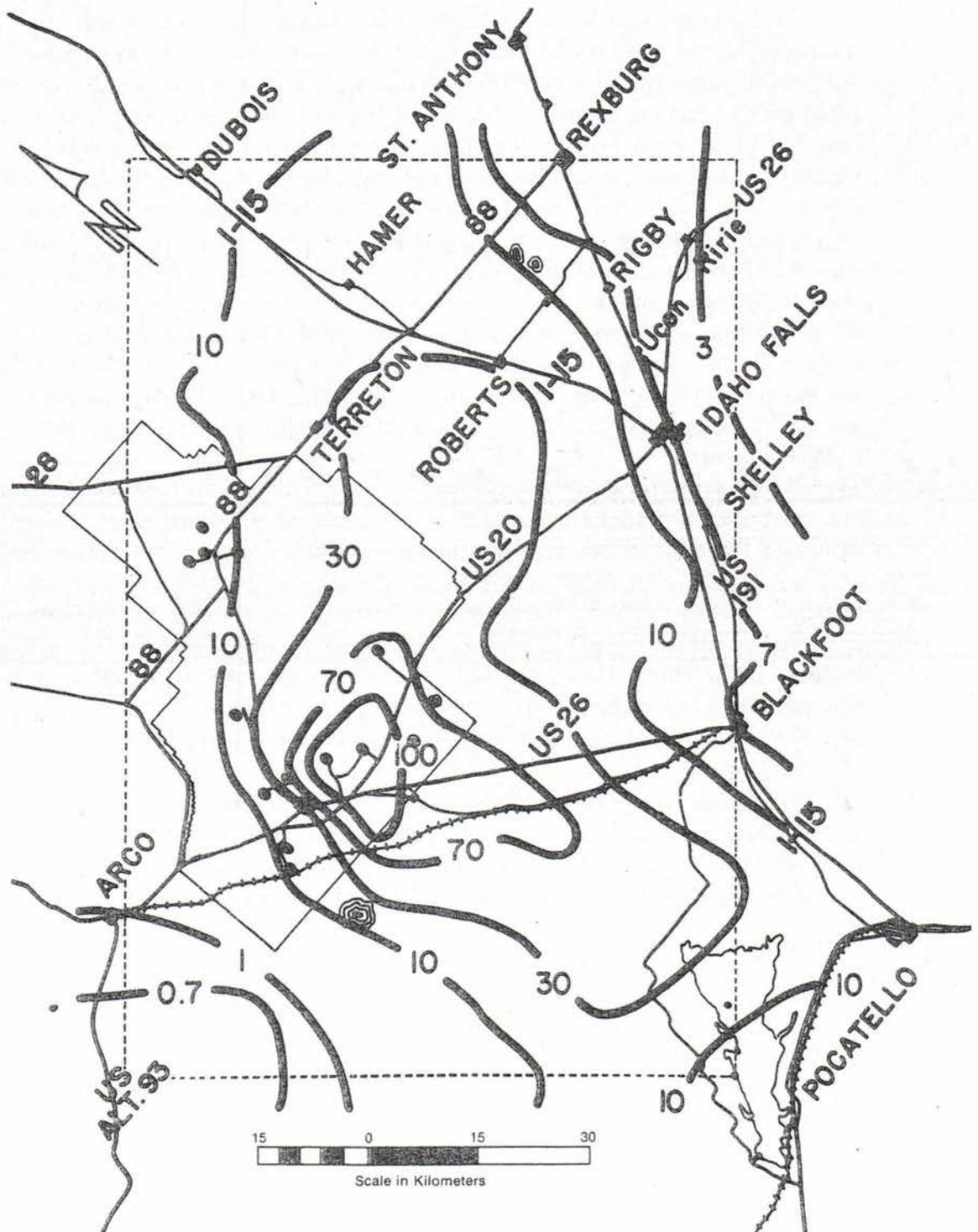


Fig. 6 Mesoscale dispersion isopleths of year-summed air concentrations at ground level during 1976, normalized to unit release rate. Units are $10^{-9} \text{ hr}^2/\text{m}^3$.

2. MAXIMUM INDIVIDUAL WHOLE BODY DOSE

The maximum hypothetical dose from inhalation or submersion was calculated assuming that an individual resided continuously for a year at the point of maximum radionuclide concentration near the Site boundary (fence-post dose). The calculation was based on the data presented in Table X and Figure 6. The maximum offsite concentration occurred along the southern Site boundary just above the isopleth labelled "100" in Figure 6. The maximum concentration was found by interpolation to be $115 \times 10^{-9} \text{ hr}^2/\text{m}^3$. The maximum whole body dose from each radionuclide (Table XI) was computed using the appropriate dose conversion factor. The estimated maximum hypothetical whole body dose from Site airborne effluent is 0.19 mrem for 1976. About 96% of that computed dose was due to noble gases and particulates having half-lives of less than 10 hours. A calculation of the possible body burden from inhalation of the bone seeking radionuclides (Sr-90, Pu-238, Pu-239) at the southern boundary indicated a level at least 10,000 times below the maximum permissible body burden for the general public. Also the possible thyroid dose due to I-131 and I-133 at the southern boundary was calculated to be negligible ($\sim 8 \times 10^{-5}$ mrem).

Potential dose to an individual from ingestion of meat from wild animals was calculated. If an individual had eaten all the flesh of a duck within 24 hours after the duck had left a radioactive liquid waste pond, the average potential dose would have been 6 mrem. A maximum dose of 40 mrem could have been received depending on how long the duck had stayed on the pond. A conservative estimate of the dose which could have been received by a single individual eating an entire antelope with the highest levels of radionuclides was less than 4 mrem. (This is based on 1974 data; 1976 data indicate a lower dose.) Even less of a dose could have been received by eating doves or fish.

The whole body dose resulting from Site operations may be compared with the approximately 148 mrem received from cosmic and terrestrial radiation each year, to the approximately 25 mrem received each year from natural radionuclides in the body, or to the approximately 2.5 mrem received during a 5-hour transcontinental jet flight^[6].

TABLE XI

MAXIMUM INDIVIDUAL WHOLE BODY DOSE (1976)

<u>Radionuclide</u> ^[a]	<u>Maximum Offsite</u> ^[b] <u>Concentration ($\mu\text{Ci/ml}$)</u>	<u>Maximum Whole</u> <u>Body Dose (mrem)</u>
<u>Noble Gases</u> ^[c]		
Kr-88	5.3×10^{-12}	0.098
Kr-87	2.3×10^{-12}	0.026
Xe-135	1.1×10^{-11}	0.021
Ar-41	1.7×10^{-12}	0.016
Kr-85m	2.3×10^{-12}	0.0027
Kr-85	4.8×10^{-11}	0.0009
Xe-133	1.9×10^{-12}	0.0004
<u>Tritium</u> ^[d]		
H-3	1.5×10^{-12}	0.0037
<u>Particulates</u>		
Ba-139 ^[d]	2.8×10^{-13}	0.016
Pu-238 ^[d]	1.4×10^{-18}	0.0014
Pu-239+240 ^[d]	6.6×10^{-19}	0.0007
Sr-90, Y-90 ^[e]	7.2×10^{-17}	0.0005
Total		~0.19

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

[b] Estimate of radioactive decay obtained by using the 1976 average windspeed from 320 to 330° of 4,600 m/hr and a distance of 18,000 m from TRA-ICPP to point of maximum offsite concentration.

[c] Whole body dose estimated using parameters given by Soldat et al, "Dosimetry for the Noble Gases"^[7].

[d] Whole body dose estimated using parameters given in ICRP Publication 2.

[e] Whole body dose estimated using parameters given in ICRP Publication 6.

3. INDIVIDUAL DOSE TO A MEMBER OF A POPULATION GROUP

As indicated in Figure 6, Terreton was the population group with the greatest potential dose from Site operations. Using $25 \times 10^{-9} \text{ hr}^2/\text{m}^3$ as the air concentration isopleth for Terreton and allowing for radioactive decay during the transit of the radionuclides to Terreton, the individual dose from inhalation and submersion was calculated to be 0.038 mrem.

4. 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-kilometer radius of the TRA-ICPP complex was made by summing the individual doses received by the people of each city within the 80-kilometer radius. The dose to an individual at a particular city is a fraction of the maximum individual dose calculated in Section 2. The fraction is obtained by taking the ratio of the air concentration isopleth at each city from Figure 6 to the air concentration value of $115 \times 10^{-9} \text{ hr}^2/\text{m}^3$ used to calculate the maximum individual dose. The dose to the population of the city is the product of the dose to each resident times the city population. The calculation is conservative since radioactive decay of the isotopes was neglected during transport over distances greater than the 18 km from the TRA-ICPP to the southern Site boundary. (Idaho Falls, for instance, is about 66 km from TRA-ICPP.)

The 80-kilometer population dose was the sum of population doses for the various cities. The results are summarized in Table XII. The estimated potential population dose was 1.2 man-rem to a population of about 92,000. This can be compared with an approximate population dose of 16,000 man-rem from natural background, or an increase of only about 0.008%.

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 the hunting season, and the levels of different radionuclides in the various animals. The contribution would realistically be less than the dose from submersion or inhalation.

TABLE XII

80-KILOMETER POPULATION DOSE (1976)

City	Dispersion ^[a] Coefficient	Population ^[b] 1976	Population Dose (man-rem)
Aberdeen	10×10^{-9}	3,830	0.063
Arco	1×10^{-9}	2,200	0.004
Atomic City	95×10^{-9}	25	0.004
Blackfoot	7×10^{-9}	21,600	0.250
Butte City	2×10^{-9}	70	0.000
Fort Hall	40×10^{-9}	400	0.026
Hamer	23×10^{-9}	960	0.036
Howe	4×10^{-9}	130	0.001
Idaho Falls	7×10^{-9}	52,000	0.601
Moore	1×10^{-9}	510	0.001
Roberts	25×10^{-9}	1,000	0.004
Shelley	7×10^{-9}	6,500	0.075
Terreton	25×10^{-9}	3,260	0.135 ^[c]
Totals		~92,000	~1.2

[a] Coefficient, obtained from Figure 7, is the year-summed concentration normalized to unit release rate (hr^2/m^3).

[b] Population for each city and vicinity estimated from 1970 census plus a growth factor estimated by city and county officials. Population of each city increased for rural inhabitants by multiplying by the ratio of the county population to the sum of the population of the cities in the county.

[c] If this number is divided by Terreton's population, the result will not equal the dose in Section IV.3 because this number does not include radioactive decay.

V. REFERENCES

1. D. T. Oakley, *Natural Radiation Exposures in the United States*, U.S. Environmental Protection Agency, ORP/STD 72-1 (1972) p 16.
2. National Council on Radiation Protection and Measurements, *Natural Background Radiation in the United States*, NCRP Report No. 45 (1975) p 61.
3. U.S. Environmental Protection Agency, Office of Radiation Programs, *Environmental Radiation Data*, Report 7 (January 77) p 24.
4. U. S. Energy Research and Development Administration, Idaho Operations, *1975 Progress Report Idaho National Engineering Laboratory Site Radioecology, Ecology Programs*, IDO-12080 (June 1976) pp 19 to 34.
5. S. S. White, *Idaho National Engineering Laboratory Radioactive Waste Management Information for 1976* IDO-100055, 76 (1976).
6. NCRP Report No. 45 op. cit., p 21.
7. J. K. Soldat, P. E. Bramson, H. M. Parker, "Dosimetry for the Noble Gases", *Noble Gases*, CONF-730915 (1973) pp 432 to 438.

VI. REFERENCES FOR ENVIRONMENTAL MONITORING STANDARDS

1. Energy Research and Development Administration, *Standards for Radiation Protection*, ERDA Manual Chapter 0524 (1975).
2. 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.
3. International Commission on Radiological Protection, *Report of Committee II on Permissible Dose for Internal Radiation*, ICRP Publication No. 2 (1959) and No. 6 (1962), Pergamon Press, New York, N. Y.
4. Environmental Protection Agency, *National Primary and Secondary Ambient Air Quality Standards*, Code of Federal Regulations 40 CFR 50.
5. International Commission on Radiological Protection, *A Report for Committees 1 and 2 on a Review of the Radiosensitivity of the Tissues in Bone*, ICRP Publication 11 (1967), Pergamon Press, New York, N. Y.

APPENDIX A

MAJOR PROGRAMS, LOCATION, GEOLOGY, AND CLIMATOLOGY

APPENDIX A

MAJOR PROGRAMS, LOCATION, GEOLOGY, AND CLIMATOLOGY

The Idaho National Engineering Laboratory Site was established in 1949 (then called 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 world. As of 1976 the number of reactors built had reached 51, of which 16 were operating or operable. The Laboratory's broad mission is to develop economic energy sources by applying its engineering and scientific expertise to ERDA's research and development programs. Major ERDA programs currently underway at the INEL Site fall into six categories:

- (1) Providing test irradiation services from the two operating high-flux test reactors – the Engineering Test Reactor (ETR) and the Advance 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 Reactor Facility (NRF)
- (6) Storage and surveillance of solid transuranic wastes.

Also, the geothermal program at Raft River Valley and Boise, Idaho is associated with locating, evaluating, and using geothermal reservoirs with medium-temperature water at about 150°C (300°F). See Figure A-1 and Table A-1 for the locations 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 feet). The Site encompasses 2314 square kilometers (894 mi²); it extends 63 airline kilometers (39 mi) from north to south and is about 58 kilometers (36 mi) wide in its broader southern part. The nearest INEL Site boundaries are 35 kilometers (22 mi) west of Idaho Falls, 37 kilometers (23 mi) northwest of Blackfoot, 71 kilometers (44 mi) northwest of Pocatello, and 11 kilometers (7 mi) east of

TABLE A-I

TABULATION OF FACILITIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Reactor Operating or Operable
As of October 1976

Name	Abbreviation	Operating Contractor
1. Advanced Reactivity Measurement Facility No. 1 ^[a]	ARMF-I	EG&G
2. Advanced Test Reactor	ATR	EG&G
3. Advanced Test Reactor Critical	ATRC	EG&G
4. Argonne Fast Source Reactor	AFSR	ANL
5. Coupled Fast Reactivity Measurement Facility ^[a]	CFRMF	EG&G
6. Engineering Test Reactor	ETR	EG&G
7. Engineering Test Reactor Critical	ETRC	EG&G
8. Experimental Breeder Reactor No. 2	EBR-II	ANL
9. Large Ship Reactor 'A'	A1W-(A)	WEC
10. Large Ship Reactor 'B'	A1W-(B)	WEC
11. Loss-of-Fluid Test Facility	LOFT	EG&G
12. Natural Circulation Reactor	S5G	WEC
13. Power Burst Facility	PBF	EG&G
14. Submarine Thermal Reactor	S1W(STR)	WEC
15. Transient Reactor Test Facility	TREAT	ANL
16. Zero Power Plutonium Reactor ^[a]	ZPPR	ANL

Reactors Dismantled, Transferred, or in Standby Status

1. Boiling Water Reactor No. 1	BORAX-I	ANL
2. Boiling Water Reactor No. 2	BORAX-II	ANL
3. Boiling Water Reactor No. 3	BORAX-III	ANL
4. Boiling Water Reactor No. 4	BORAX-IV	ANL
5. Boiling Water Reactor No. 5	BORAX-V	ANL
6. Experimental Breeder Reactor No. 1	EBR-I	ANL
7. Experimental Organic Cooled Reactor (mothballed before startup)	EOCR	PPCo.
8. Materials Test Reactor	MTR	PPCo.&INC
9. Organic Moderated Reactor Experiment	OMRE	AI
10. Special Power Excursion Reactor Test No. 1	SPERT-I	PPCo.
11. Special Power Excursion Reactor Test No. 2	SPERT-II	PPCo.&INC
12. Special Power Excursion Reactor Test No. 3	SPERT-III	PPCo.&INC
13. Special Power Excursion Reactor Test No. 4	SPERT-IV	PPCo.&INC
14. Spherical Cavity Reactor Critical Experiment	SCRCE	ANC
15. Zero Power Reactor No. 3 ^[a]	ZPR-III	ANL

[a] Zero or Low Power Reactor

Table A-I (continued)

Other Facilities In Use

<u>Name</u>	<u>Abbreviation</u>	<u>Operating Contractor</u>
1. Argonne National Laboratory - West Area	ANL-W	ANL
2. Auxiliary Reactor Area	ARA	EG&G
3. Central Facilities Area	CFA	EG&G
4. Chemical Engineering Laboratory	CEL	ACC
5. Computer Science Center (in Idaho Falls)	CSC	EG&G
6. Expanded Core Facility	ECF	WEC
7. Experimental Field Station	EFS	ERDA-ID
8. Field Engineering Test Facility (formerly Flight Engine Test Facility)	FET	EG&G
9. Fuel Element Storage Facility	FESF	ACC
10. Health Services Laboratory	HSL	ERDA-ID
11. Hot Fuel Examination Facilities	HFEF	ANL
12. Hot Pilot Plant	HPP	ACC
13. Idaho Chemical Processing Plant	ICPP	ACC
14. Irradiated Fuel Storage Facility	IFSF	ACC
15. Low Power Test Facility	LPTF	EG&G
16. Naval Reactors Facility	NRF	WEC/GE
17. Radioactive Waste Management Complex	RWMC	EG&G
18. Reactor Training Facility	RTF	EG&G
19. Shield Test Pool Facility	STPF	EG&G
20. Standards Calibration Laboratory (CF-698)	-	EG&G
21. Technical Services Center (CF-688,-689)	TSC	EG&G
22. Technical Service Facility	TSF	EG&G
23. Test Area North	TAN	EG&G
24. Test Reactor Area	TRA	EG&G
25. Waste Calcining Facility	WCF	ACC

Facilities Not Presently In Use

1. Initial Engineering Test Facility	IET	EG&G
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Facilities Under Construction

1. Irradiated Fuel Storage Facility	IFSF	ACC
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Major Programs at INEL

1. Chemical Processing Program		ACC
2. Geothermal Program		EG&G
3. Liquid Metal Fast Breeder Reactor Program		ANL
4. Naval Propulsion Reactors Program		WEC
5. Reactor Materials Testing Program		EG&G
6. Transuranic Waste Management Program		EG&G
7. Water Reactor Safety Program		EG&G

Operating Contractor Acronyms: ACC, Allied Chemical Corporation; ANC, Aerojet Nuclear Company; ANL, Argonne National Laboratory; EG&G, EG&G Idaho, Inc.; GE, General Electric; INC, Idaho Nuclear Corporation; PPO., Phillips Petroleum Company; WEC, Westinghouse Electric Corporation.

Arco, Idaho (see Figure 1). With a population of about 1300, Arco is the largest nearby 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 the 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 the cool desert with big sagebrush (*Artemisia tridentata*) conspicuous over 80% of the Site. Frequently noticeable on the Site are the pronghorn antelope (*Antilocarpa americana*), but various kinds of birds, reptiles, and large populations of small mammals are also present. To take full advantage of the Site's ecosystem, the area has been made a National Environmental Research Park, where scientists from ERDA, 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 sediments. The sediments grade from gravels and sands deposited by streams as alluvial fans, channel fillings, and deltas to silts and clays deposited in playas. Principally, basalt with interbedded strata of lacustrine and alluvial sediments underlie the plain, at least to depths of 450 meters (1500 ft). The most recent volcanism, 1600 years ago, is the scenic basalt flows at Craters of the Moon National Monument, about 30 kilometers (19 mi) to the southwest of the Site.

Annual precipitation in the Site area has averaged 22 centimeters (8.5 in.) over the past 15 years. Underlying the desert plain is a natural aquifer in the 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 a rate of 3 to 6 meters per day (10 to 20 ft/d) 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 nighttime inversions.

APPENDIX B
STATISTICAL METHODS

APPENDIX B

STATISTICAL METHODS

Individual analytical results are given in the report with plus or minus (\pm) 2 analytical standard deviations (2σ), where all analytical uncertainties have been properly propagated. Many of the results were less than or equal to their 2σ (and, in fact, were negative), which is considered as meaning that they were below the detection limit. However, the actual results obtained were used for averaging purposes regardless of their being above or below the detection limit. When analyzed in this manner, samples that truly contain undetectable amounts of radioactivity produce random results that give a mean which is less than or equal to 2 standard deviations of the mean. However, samples that give below detection limit results but, nevertheless, have small amounts of radioactivity will bias the results such that the mean will be greater than 2 standard deviations of the mean.

The usual equations for average and standard deviation for a normal distribution inherently assume that the data have equal analytical uncertainty. For results near or below the detection limit this was generally not true. When the results had varying degrees of precision, the averages and standard deviations were modified according to the formulas listed by Bevington^[B-1]. The individual results were weighted according to their precision in determining the weighted average and weighted standard deviation. This method was used for analyzing data concerning milk, foodstuffs, and radioactive and nonradioactive particulates in air.

Frequently, when environmental samples are analyzed as a group, the results follow lognormal distribution statistics. The lognormal distribution curve is characterized by a long tail at higher values of the curve; however, the distribution curve for the natural logarithm of the results is normal. The parameters giving the central tendency and dispersion of the data are called the geometric average and the geometric standard deviation. Since the curve is logarithmic, geometric standard deviations are stated as multipliers of the average. All soil sampling data were analyzed lognormally. Gross beta in air data were analyzed both normally and lognormally but were presented normally for simplicity. Exposure data were analyzed normally.

REFERENCE

- B-1 P. R. Bevington, *Data Reduction and Error Analysis for the Physical Sciences*, New York: McGraw-Hill Book Company, 1969, pp 69 to 73.

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