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FINAL REPORT

**EXPOSURE SCENARIOS FOR USE IN  
ESTIMATING RADIATION DOSES TO THE PUBLIC  
FROM HISTORICAL ATMOSPHERIC RELEASES  
OF RADIONUCLIDES AT INEL**

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A report to the  
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## 1.0 INTRODUCTION

The purpose of this report is to describe credible exposure scenarios for use in the estimation of doses to reference individuals due to atmospheric releases of radionuclides from selected operations and time periods at the Idaho National Engineering Laboratory<sup>1</sup> (INEL). This report was prepared in response to Task 3 of the INEL dose reconstruction study commissioned by the Centers for Disease Control and Prevention (CDC). The study focuses on emissions from normal RaLa operations at Idaho Chemical Processing Plant (ICPP – The “Chem” Plant) from 1957 through 1959, emissions during the RaLa criticality accident at ICPP on October 16, 1959, and emissions from the Aircraft Nuclear Propulsion Program (ANP) Initial Engine Tests (IET) performed during the late 1950s and early 1960s.<sup>2</sup> For the purpose of analyzing the effects of these emissions, CDC requested the development of at least five scenarios for exposure of the members of the public, out of which at least one scenario should refer to onsite exposures and the rest should address offsite exposures. Although the largest exposures were experienced during the years the releases occurred, additional exposures occurred for many years after these releases because of the presence of the long-lived radionuclides (e.g., <sup>137</sup>Cs, <sup>90</sup>Sr) in the environment.

The exposure scenarios are designed to provide reasonably realistic representations of the exposures to the members of the public. Thus, the scenarios have been tailored to site-specific environmental conditions and the living habits of the individuals who might have been exposed. For this reason, this report includes site-specific information collected from detailed documents about the INEL site and surrounding regions (USDA 1999a, b; IDFG 2002; Bowman et al. 1984; Stacy 2000; INEL 1998, 2000, 2002a, b, c), from individuals living in the area (Shay 2002), and from members of the Idaho Health Effects Subcommittee (IHES) (Garcia 2003).

The exposure scenarios described in this report pertain only to radionuclides that have been identified as potentially important in the screening process (Kocher 2005a and 2005b).

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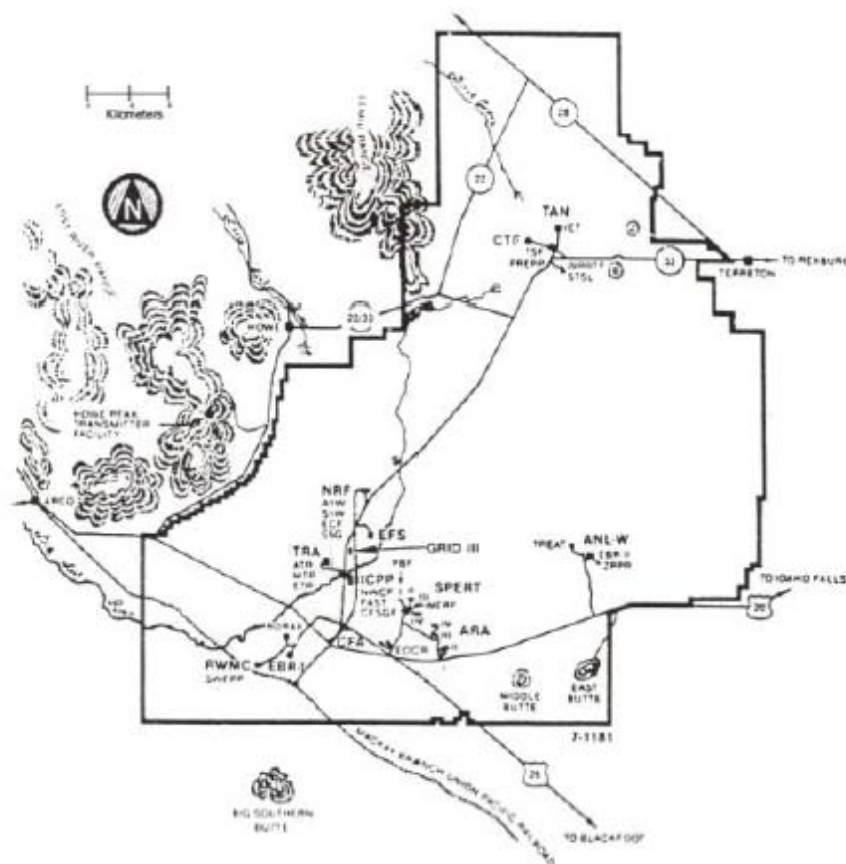
<sup>1</sup>In this report, the site is referred to by its historical name (INEL), rather than its current name: Idaho National and Engineering Laboratory (INEEL).

<sup>2</sup>Twenty-six engine tests were organized as part of the ANP. Tests #3, #4 and #10 released the majority of the radioactivity. The dates of these tests are: #3 in Feb 1956, # 4 in May-June 1956, and # 10 in Dec 1957 – March 1958.

## 2.0 DESCRIPTION OF THE IDAHO NATIONAL ENGINEERING LABORATORY SITE AND SURROUNDING REGION

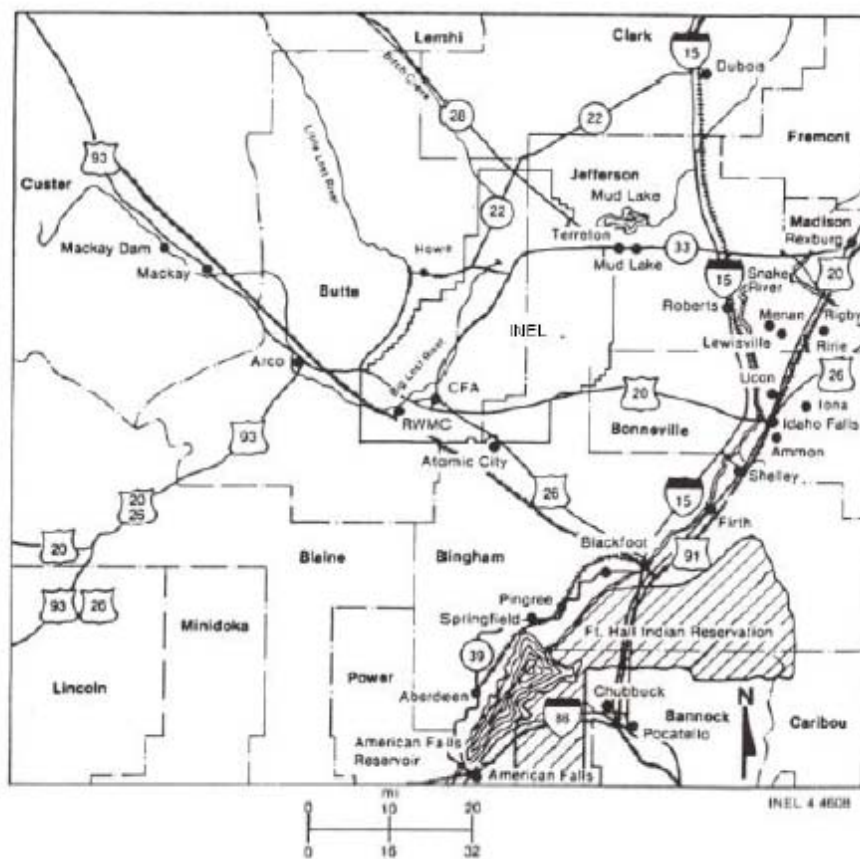
### 2.1 General Description<sup>3</sup>

The Idaho National Engineering and Environmental Laboratory is located in the northwest portion of the Upper Snake River Plain in southeast Idaho. The site covers an area of approximately 2305 km<sup>2</sup> (890 mi<sup>2</sup>); it is about 63 km (39 mi) long from North to South and about 58 km (36 mi) wide from West to East in the broadest southern portion (Figure 1). The extreme limits of the site are between 43° 26' and 44° 01' N latitude, and between 112° 28' and 113° 9' W longitude. The region southeast of the INEL site is the Upper Snake River Plain (Figure 2), while three mountain ranges (Lost River, Lemhi, and Bitterroot) are located northwest of INEL. The average elevation on the INEL site is 1525 m (5000 ft), ranging from 1585 m (5200 ft) in the northeast part to 1450 m (4750 ft) in the southwest part. Within this relatively flat area, impressive volcanic buttes stand above the desert floor. The INEL site includes portions of five Idaho counties (Bingham, Bonneville, Butte, Clark and Jefferson). The counties potentially impacted by releases from the INEL, and which have the most numerous and active human communities, are Bingham, Bonneville, Butte, Clark, Jefferson, Madison and Bannock.



**Figure 1 The Idaho National Engineering Laboratory site and the main facilities**  
A list of acronyms is provided as an appendix. The map is reproduced from [DOE 1991](#).

<sup>3</sup>Sources: [Bowman et al. 1984](#); [DOE 1991](#); [INEL 1998, 2000, 2002a, 2000b, and 2000c](#).



**Figure 2** The region surrounding the Idaho National Engineering Laboratory site  
The map is reproduced from [Bowman et al. 1984](#).

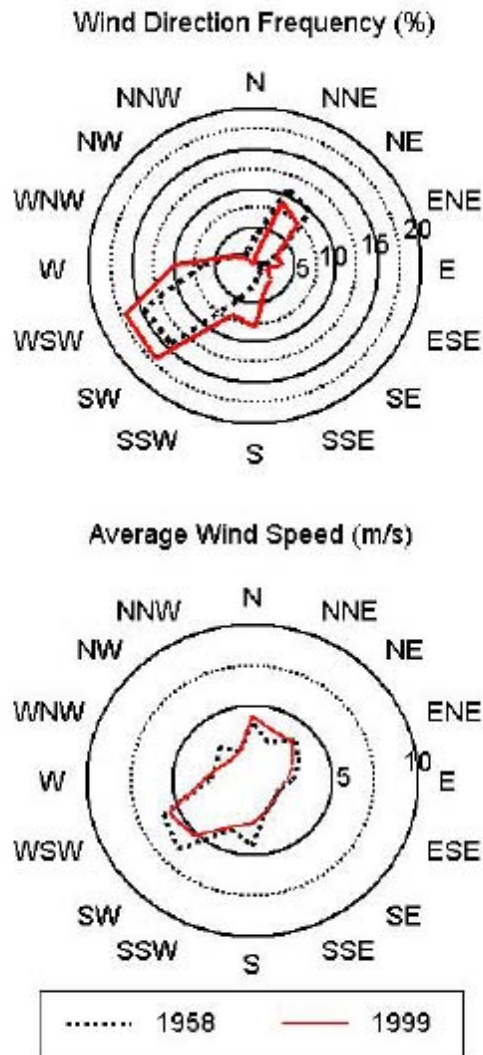
## 2.2 Climate of the Idaho National Engineering Laboratory Area<sup>4</sup>

The INEL area is a semiarid, sagebrush desert located in a flat valley surrounded by mountains. Air masses normally precipitate most of their moisture as they pass over the mountains before entering the Upper Snake River Plain.

The bordering mountains are oriented northeast-southwest, and they tend to channel the winds in this direction. In the valley, the prevailing winds come from the southwest, and the second most frequent winds are from the northeast ([Figure 3](#)). The annual average wind speeds are  $3.4 \text{ m s}^{-1}$  (7.5 mph) at 6.1 m (20 ft) and  $5.6 \text{ m s}^{-1}$  (13 mph) at 76 m (250 ft) above ground level. The variation in monthly average wind speed is 2.3 to  $4.2 \text{ m s}^{-1}$  (5 to 9 mph) at 20 ft and 4.3 to  $6.5 \text{ m s}^{-1}$  (9.7 to 15 mph) at 250 ft.

Average monthly maximum temperatures range from  $30^{\circ}\text{C}$  ( $86^{\circ}\text{F}$ ) in July to  $-2^{\circ}\text{C}$  ( $28^{\circ}\text{F}$ ) in January. Average monthly minimum temperatures range from  $9^{\circ}\text{C}$  ( $48^{\circ}\text{F}$ ) in July to  $-16^{\circ}\text{C}$  ( $3^{\circ}\text{F}$ ) in January.

<sup>4</sup>Sources: [Bowman et al. 1984](#); data received from Idaho National Oceanic and Atmospheric Administration (NOAA).



**Figure 3 Wind speed and wind frequency recorded at Central Facilities Area meteorological station in 1958 and 1999**

Data provided by Idaho NOAA.

The long-term annual average precipitation is 23 cm (9 in) of water, with yearly totals varying from 11 to 37 cm (4.5 to 14 in). Individual months have had as little as no precipitation to as much as 11 cm (4.4 in). The precipitation in any 24-hour period is expected to be less than 5 cm (2 in), while any hourly precipitation is expected to be less than 2.5 cm (1 in). The air over the INEL is typically very dry, with relative humidities during summer afternoons ranging from 5% to 15%. The long-term annual average snowfall is 66.0 cm (26 in), with observed values ranging from 28 to 104 cm (11 to 41 in). The ground is usually free of snow from mid-April to mid-November. The average maximum snow depth in January and February is 18 cm (7 in).

For the purpose of atmospheric dispersion modeling in the INEL area during the years of interest (late 1950s), historical meteorological data provided by the National Oceanic and Atmospheric Administration (NOAA) will be used.

Hourly data reported for wind speed, wind direction, and temperature were collected from two weather stations located within the INEL borders. A more complete data set was collected from the weather station at the Central Facilities Area (CFA; Figure 1), which is near the ICPP (labeled the South station). The second (North) station is located in Test Area North (TAN), near the IET site. The data were collected at 6 m (20 ft) and 76 m (250 ft) at the South station and at 6 m (20 ft) and 46 m (150 ft) at the North station.

Detailed meteorological data from the South station for the early morning of October 16, 1959 when the RaLa criticality accident occurred are reported by [Ginkel et al. \(1960; Table IV\)](#). The data include 10-minute average wind speed and direction for 6 m (20 ft) and 76 m (250 ft) for four hours during the accident (2 a.m. to 6 a.m.).

A detailed description of how these data are used to estimate concentrations of radionuclides in air will be given in a separate report on atmospheric dispersion.

### 2.3 Agricultural Information<sup>5</sup>

The soils in the INEL region have resulted from alluvial or aeolian deposition over basalt lava flows. Rock outcrops are common and some are relatively shallow. Most of the soils are relatively deep, well-drained loams, but sandy soils can also be found. The uncultivated vegetation in the INEL area is dominated by sagebrush, rabbitbrush, and various species of bunchgrass (e.g., bluebunch wheat grass, Indian rice grass, needle-and-thread grass).

Within the current INEL boundaries, but before the INEL was established, the Navy operated a Naval Proving Ground (NPG). The NPG was established by the withdrawal of 702 km<sup>2</sup> (271 square mi) from the public domain. This facility was divided into two parts: a residence area and a 34-ha (85-acre) proving area where naval guns were tested and fired from 1943-1949. Research and testing of conventional (i.e., non-nuclear) explosives also took place on NPG ground. The NPG residence area was officially named Scoville. In addition to the military personnel, a small civilian community (including families and children) existed at Scoville. One of the civilian families kept a small herd of dairy cows a mile or so northwest of the village. Stacy (2000) describes this dairy operation as follows: "The father and the sons went each day to collect the milk, brought it home to the basement of their house, separated and pasteurized it, and delivered it to the other residents in a milk truck." When INEL was established in 1949, the Navy ceased its NPG operations, and the families moved out of the NPG area. The ICPP started operations in 1953, while the first ANP nuclear power engine test took place in January 1956. The former NPG residences were transformed into the INEL's CFA.

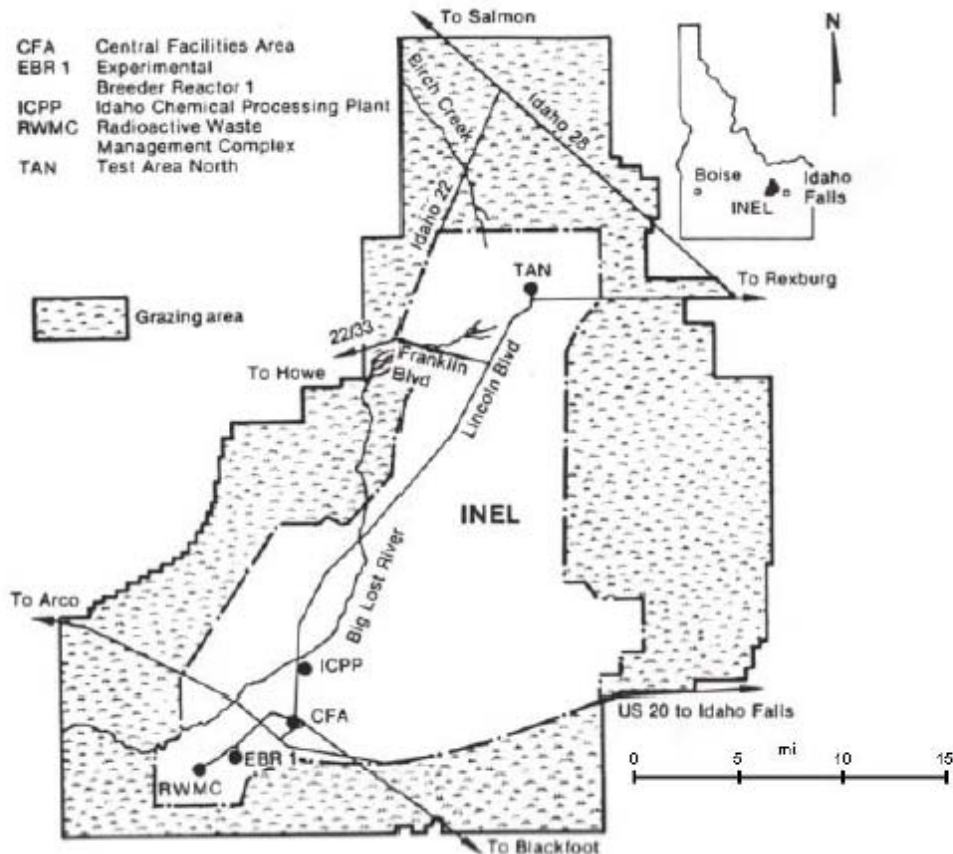
The INEL site has been committed to energy research and development and was designated as a National Environmental Research Park. A series of Public Land Orders dating back to 1946 has established the present uses of the INEL site land.

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<sup>5</sup>Sources: [Bowman et al. 1984](#), [Stacy 2000](#); [USDA 1999a,b](#); US Department of Agriculture; National Agricultural Statistics Service on-line statistics at: <http://www.nass.usda.gov:81/ipedb/>.



Approximately 133,500 ha (330,000 acres) are open to controlled grazing by cattle and sheep (Figure 4). Grazing has taken place by permit in areas mutually agreed upon by the Department of Energy (DOE) and Department of Interior (DOI). As a general rule, grazing is prohibited within 3.2 km (2 miles) of any nuclear facility, and the livestock populations are controlled. No dairy cows are allowed.



**Figure 4 Permit grazing area for beef cattle and sheep at the Idaho National Engineering Laboratory**

The map is reproduced from [Bowman et al. 1984](#).

Because of climate, lava flows, and soil characteristics, the use of INEL land for farming is limited. The only land suitable for farming within the INEL site is close to the terminations of Big and Little Lost River, on an area about 13 km (8 mi) southeast of Howe (Figure 4).

In the seven-county area (Bingham, Bonneville, Butte, Clark, Jefferson, Madison and Bannock) surrounding the INEL, there are about 587,000 ha of cropland in use. These seven counties maintained 112,500 head of beef cattle and 20,500 dairy cows in 1980, and 88,500 head beef cattle and 17,600 head dairy cows in 2000.



During 1950s, the cow milk production in these counties was 15.8 million L (for fluid use), but consumption was estimated at 20.5 million L, indicating a milk deficit of 4.7 million L (NCI 1997).

The 1997 agricultural census indicates that Bingham, Bonneville, Bannock and Jefferson counties have at least one goat's milk farm (USDA 1999a). Bingham County has at least one Angora goat farm for producing mohair. Sheep and lambs are also produced in this area.

Alfalfa, sugar beets, oats, barley, wheat, corn (for grain and for silage) and, of course, potatoes are produced in this region. Idaho grows about one third of the total production of potatoes in the US (USDA 1999b), and Bingham County is known as the potato capital of the world (Bingham County official web-site 2003).

## 2.4 Demography<sup>6</sup>

The Upper Snake River Plain region has a low population density (Table 1). The major population areas are located in the southeast portion of the region, along the Snake River (Figure 5). The largest cities are Idaho Falls (population about 36,000 in 1980 and 50,000 in 2000) and Pocatello (population 46,000 in 1980 and 51,000 in 2000; Figure 2).

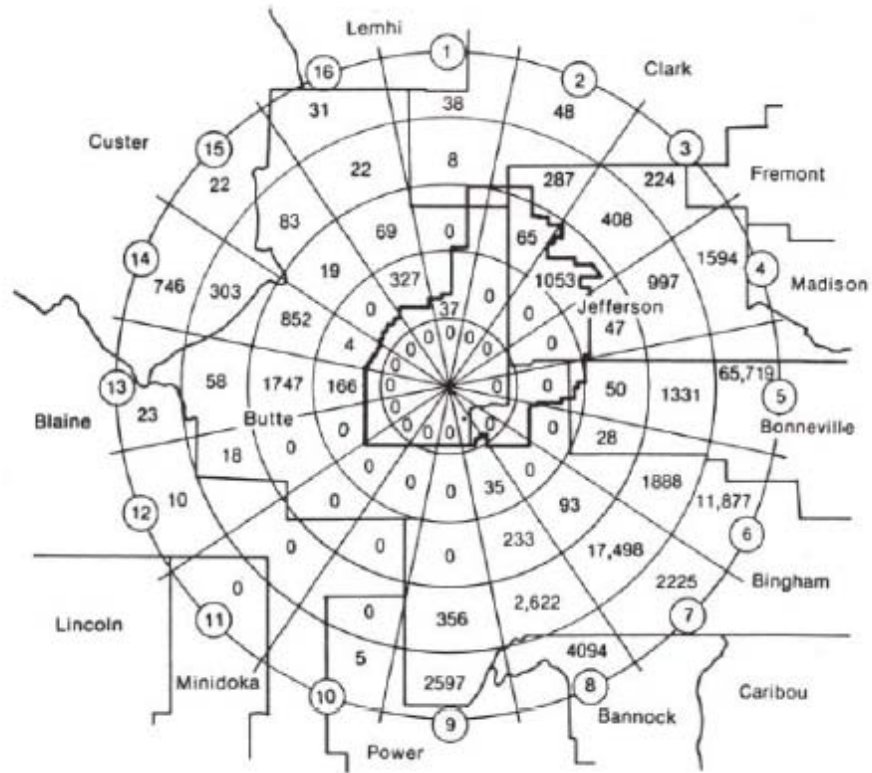
The population has many ethnic groups in addition to Caucasians (whites) who represent the majority (more than 90%). Hispanics and Native American are the most numerous ethnic groups (Table 1). The Shoshone-Bannock tribes occupy the Fort Hall Indian Reservation, a 220,000-ha (544,000-acre) area located about 72 km (45 mi) southeast of INEL, along Interstate highways I-15 and I-86. The Shoshone-Paiute tribes live on the Duck Valley Reservation in Southwestern Idaho at the border between Idaho and Nevada. The Nez Perce Reservation is located in North Central Idaho.

The current Native American diet is based on commercially available foods (including frozen and canned food), but an important fraction comes from hunting, fishing, and food gathering. Generally, lower income families have a higher percentage of wild foods. The diet of the Shoshone-Bannock tribe in the 1950s contained up to 75% wild foods, including both game and also berries and roots (Shay 2002). The diet of current tribal members contains approximately 30%-40% wild foods. The INEL site and the surrounding areas are part of the traditional hunting grounds for Native Americans as shown by the many archeological artifacts found in the region (Stacy 2000; Bowman et al. 1984). A study published in 1977 (Newcomer et al. 1977) found that 66% of Native Americans are lactose<sup>7</sup> intolerant, a condition observed after age five for both sexes. Lactose intolerant individuals have a tendency to consume about 75% less milk than normal individuals.

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<sup>6</sup> Sources: Bowman et al. 1984; US Census Bureau on-line database.

<sup>7</sup>Lactose is a disaccharide sugar C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> that is present in milk and yields glucose and galactose upon hydrolysis by lactase and lactic acid upon fermentation. Lactase is an enzyme that hydrolyzes beta-galactosides (such as lactose) and occurs especially in the intestines of young mammals and in yeasts.



**Figure 5 Geographical distribution of population around the Idaho National Engineering Laboratory relative to Idaho Chemical Processing Plant**

The number of people is based on the 1980 census. There are no people living within the INEL boundaries. The number of individuals for a sector that contains areas both inside and outside INEL represents people living offsite. The figure is reproduced from [Bowman et al. 1984](#).

**Table 1 Population by county and race in Idaho counties from Upper Snake River Plain region (all ages combined)**

1980 Census*								
Idaho County	White <sup>†</sup>	Black	American Indian	Asian	Hispanic	Other	TOTAL	Population density [persons/mi <sup>2</sup> ]
Bingham	30,357	6	2,153	204	2,264	1,505	36,489	17.4
Bonneville	62,421	199	275	592	1,666	827	65,980	35.9
Butte	3,143	1	31	5	102	60	3,342	1.5
Jefferson	13,889	1	125	26	688	575	15,304	14
Bannock	59,389	486	1225	557	2,254	1,510	65,421	58.8
Custer	3,289	0	23	5	55	13	3,385	0.70
Fremont	10,205	2	116	25	295	170	10,813	5.8
Madison	18,597	5	96	113	393	276	19,480	41.6

2000 Census‡								
Idaho County	White		American Indian	Asian	Hispanic	Other	TOTAL	Population density [persons/mi <sup>2</sup> ]
Bingham	32,824	52	2,564	235	5,550	510	36,185	17.3
Bonneville	74,461	360	444	664	5,703	890	76,819	41.8
Butte	2,706	8	17	7	120	41	2,779	1.2
Jefferson	16,955	21	80	43	1,907	149	17,248	15.8
Bannock	67,636	411	1,996	732	3,540	1,250	72,025	64.7
Custer	4,100	0	22	1	183	36	4,159	0.9
Fremont	10,320	15	55	43	1,255	131	10,564	5.7
Madison	25,856	56	68	153	1,078	256	26,389	56.4

\* Source: Bowman et al. (1980)

† Non-Hispanic.

‡ Source: US Census on-line database (<http://www.census.gov/>), checked on January 6, 2003.

The large majority of migrant farm workers in southeast Idaho are Hispanic. During the 1950s and 1960s, Hispanics (mainly Mexicans) traveled from Texas for temporary jobs during the farming season. Some of them became Idaho residents, but they continued in a similar lifestyle by “migrating” from farm to farm for different jobs within the same area. Migrant farm workers were adult males and females, but sometimes they traveled as families. In the 1950s and 1960s, they were housed in temporary housing at the farm or in migrant worker camps away from the farm. They were responsible for procuring their own food, but some employers provided lunch during certain jobs. In addition to farms, food-processing plants required a large number of employees during the harvest season.

The population in the Upper Snake River Plain has been growing steadily since 1950 (Table 2); INEL was responsible for part of this growth, especially between 1950 and 1980.

**Table 2 Changes in the number of people living in selected Idaho counties**

	<b>Total population* by year</b>				
	<b>1950</b>	<b>1960</b>	<b>1980</b>	<b>1990</b>	<b>2000</b>
<b>Bingham</b>	23,271	28,218	36,489	37,583	41,735
<b>Bonneville</b>	30,210	46,906	65,980	72,207	82,522
<b>Butte</b>	2,722	3,498	3,342	2,918	2,899
<b>Jefferson</b>	10,495	11,672	15,304	16,543	19,155
<b>Bannock</b>	41,745	49,342	65,421	66,026	75 323
<b>TOTAL</b>	108,443	139,636	186,536	195,277	146,311

\* Source: US Census on-line database (<http://www.census.gov/>), checked on January 6, 2003

All INEL employees reside outside the INEL boundaries, and more than 90% live in urban areas in the 16 communities located within an 80-km (50-mi) radius of the CFA. About half of the employees live in Idaho Falls. The employees who work onsite commute from their residences to INEL, with most of them using the government-owned bus system.

The closest community to the ICPP is Atomic City, located about 19 km (11.8 mi) to the southeast, while communities at Montevue and Mud Lake are about 19 km (12 mi) northeast and east of the ANP/IET test site, respectively. Given that the prevalent wind direction is southwest-northeast, only Montevue can be considered to be located “downwind,” while Mud Lake is located “crosswind” from the ANP/IET test site. Similarly, Atomic City is located “crosswind” from the ICPP. Although the probability that the wind blows towards a “crosswind” location is small, it is not zero.

### 3.0 EXPOSURE SCENARIOS AND PATHWAYS

This study focuses on atmospheric emissions from the ICPP and ANP/IET during selected years. Releases of radionuclides into surface or ground water for the same facilities and operations are not considered, for two main reasons: (1) ICPP and ANP/IET produced little or no liquid waste that could have contaminated the public surface or ground water sources outside the INEL site boundary, and (2) no important levels of radioactivity have been found in ground water sources.

Most of INEL lies in a closed topographical depression, and surface water flows toward the Big Lost River Sinks located in the northwest portion of the INEL. Surface water infiltrates the Big Lost River channel bottom and sinks, recharging the Upper Snake River Plain Aquifer, which flows beneath INEL in a southwesterly direction. Thus, people living offsite have no access to surface water sources that originate from INEL. Most of the radioactivity in the Upper Snake River Plain ground water below the site originated from injections into special wells and seepage from liquid-waste disposal ponds that contain low levels of radioactivity. Use of injection wells started as early as 1952 and was discontinued in 1983 (Bowman et al. 1984). However, extensive monitoring of the aquifer has revealed no important levels of radioactivity in the ground water outside of the INEL boundary. Of all the radionuclides,  $^3\text{H}$  (which is the most mobile radionuclide) and  $^{36}\text{Cl}$  have traveled the farthest through the aquifer.

The potential exposure pathways for atmospheric releases include inhalation, external exposure, and ingestion of food items contaminated either via direct deposition or from uptake through the roots of soil-deposited activity. Incidental ingestion of soil can have a significant contribution to the overall exposure and will be considered when necessary (e.g., for individuals working in dusty environments). Ingestion of soil by animals will be included for all scenarios. The air/pasture/cow/milk/infant pathway is important for radioactive isotopes of iodine transferred through the food chain. For long-lived radionuclides such as  $^{137}\text{Cs}$ , both external exposure from ground deposition and consumption of contaminated food are potentially important contributors to radiation doses.

A previous dose reconstruction performed by the DOE (1991) indicates that the largest offsite exposures from the ICPP operational releases occurred in Atomic City during 1957 and 1959. Most the dose was due to exposure to  $^{131}\text{I}$ , followed by exposures to  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$ , with doses to the thyroid of infants varying from 144 to 882 mrem. For releases during ANP/IET tests #3, #4, and #10, the critical organ was also the thyroid gland (due to the quantities of  $^{131}\text{I}$  released). The highest doses from tests #3 and #4 were estimated to have occurred in Mud Lake and Terreton communities (east of ANP/IET). For test #10A, the highest doses were estimated at a location close to the point where Hwy 20 crosses INEL's eastern border. For test #10B, the highest doses were estimated for a person living in Howe (west-southwest of ANP/IET). In addition to the thyroid, DOE (1991) states that skin doses were also significant (due to external exposure to beta radiation). For instance, for 1959, DOE (1991) estimated the maximum organ dose to an adult member of the public at 44.7 mrem delivered to the skin (from routine releases from INEL).

A potential contributor to the radiation dose for some individuals could be ingestion of meat from game animals that resided on INEL. Without regard to the source of radionuclide releases, the most important game animal pathway has been ingestion of meat from waterfowl that have resided for a long time at a water pond containing low amounts of radioactive materials. For

instance, [Halford et al. \(1981\)](#) measured the concentrations of a number of radionuclides in ducks collected from January 1974 through December 1977 from the Test Reactor Area (TRA) ponds. Cesium-137,  $^{134}\text{Cs}$ , and  $^{131}\text{I}$  contributed 98% of the calculated potential whole-body radiation dose equivalent from consumption of waterfowl, which was conservatively estimated at 12 mrem. The thyroid dose was estimated at 7 mrem. Other studies on ducks reported measured concentrations, and in some cases estimated doses, for  $^{129}\text{I}$  ([Halford and Markham 1984](#)),  $^{90}\text{Sr}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$ ,  $^{241}\text{Am}$ ,  $^{242}\text{Cm}$  and  $^{244}\text{Cm}$  ([Marham et al. 1988](#)). Similar studies were performed for sage grouse ([Connelly and Markham 1983](#)), for mourning doves ([Markham and Halford 1982](#)) and for pronghorn antelopes ([Markham and Halford 1980a,b](#); [Markham et al. 1982](#)). Most of these studies are a result of the environmental monitoring program at INEL. Measurements in game animals obtained in the recent years (1994-2001) indicated the following doses from ingestion of the edible part of the fowl or animal with the highest concentration ([INEL 1998, 2000, 2002a, b, c](#)):

- For ducks, the doses varied from 0.005 to 0.1 mrem with a single extreme dose of 1.4 mrem for a duck collected at the TRA pond in 1997 (based on a portion of 227 g or 8 oz of edible meat)
- For doves, the doses varied from 0.0004 to 0.02 mrem (based on a portion of 227 g or 8 oz of edible meat)
- For pronghorn antelopes, the doses vary from 0.02 to 0.05 mrem (based on consumption of the entire muscle mass and liver of a pronghorn)

For comparison, the doses to the maximally exposed member of the public from atmospheric releases from the INEL during 1997-2001 range from 0.008 to 0.057 mrem (based on environmental measurements and computer model calculations). Similarly, the highest observed radionuclide concentrations in pronghorn antelopes during 1976-1986 produce a dose of about 2.7 mrem from ingestion of the entire edible part of an animal. Waterfowl residing on radioactive waste ponds could not have been exposed to releases from ANP/IET since there were no liquid radioactive wastes from ANP/IET tests. The high-level liquid radioactive waste from ICPP operations was temporarily stored and chemically treated in stainless steel storage tanks located onsite, then solidified by calcination and moved to solid waste disposal areas. Low-level radioactive waste from ICPP was first concentrated to extract any high-level fractions, and then mixed with non-radioactive liquid waste and discharged to a percolation pond for temporary storage. It is unlikely that the radioactivity in waterfowl can be associated solely with the ICPP operations, because birds are extremely mobile and can move in and out of various contaminated areas.<sup>8</sup> On the other hand, radioactivity in pronghorn antelopes was associated with atmospheric releases from the ICPP, although not necessarily to RaLa operations ([Markham and Halford 1980b](#)).

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<sup>8</sup>In addition to the ICPP percolation ponds, discharge ponds can be found at Test Area North (TAN), Argonne National Laboratory-West (ANL-W), and the Test Reactor Area (TRA).



### 3.1 Scenarios for Persons Exposed Offsite

The exposure scenarios described in this report have been selected to provide an overall understanding of the exposures that could have been received by members of the public due to the selected INEL operations. Thus, the exposure scenarios used for the present study will include a representative maximally exposed individual and a representative individual with commonly occurring (e.g., average) exposure. No explicit scenarios are developed for ethnic groups (e.g., Native American, Hispanic), but people of a given ethnicity will be able to find a scenario with which they can identify. Because  $^{131}\text{I}$  seems to be the most significant radionuclide (according to DOE 1991), and because ingestion of milk is the most important exposure pathway for  $^{131}\text{I}$ , the scenarios are first differentiated by the type of milk diet. Special scenarios are defined for individuals representative of groups of people performing special activities (e.g., hunters or migrant workers). Food-chain exposure pathways, and inhalation and external exposure from cloud immersion and ground deposition are considered for all exposure scenarios. The doses from a given exposure scenario will be calculated for all significant communities around INEL for which such a scenario is credible, beginning with the closest offsite locations at which the doses should be the highest. For instance, the town closest to the ICPP plant is Atomic City (19 km SE). The distance from the ICPP to other populated areas are Butte City (25 km W), Howe (23 km NW), Arco (31 km W), Mud Lake (46 km NE), Montevue (51 km NE), Reno Ranch (52 km N), and Blackfoot (52 km SE). Further away are Birch Creek (60 km N), Roberts (70 km E), Idaho Falls (76 km E) and Pocatello (80 km SE).

A summary of all offsite and onsite exposure scenarios is presented in Table 3.

#### *Offsite Scenario 1 – Rural Resident – Backyard Cow Milk Diet*

This exposure scenario is representative of an individual who grows much of his own food products or has access to locally grown food products. Thus, it is assumed that this individual drinks milk from a family-owned (“backyard”) cow, consumes locally produced vegetables and meat, and is exposed by inhalation, external exposure, and inadvertent soil ingestion. Doses will be estimated for individuals of both sexes and for all ages (at exposure), from infants to adults. For infants, ingestion of milk by breast-feeding will be considered.

For teenagers and adults, the exposure parameters will be chosen to represent an individual who spends a larger fraction of time outdoors performing more physically intensive activities, as compared with an “urban” resident. The doses will be presented for four levels of milk consumption: (1) high, (2) average, (3) low, and (4) no milk consumption.

#### *Offsite Scenario 2 – Rural Resident - Goat Milk Diet*

This exposure scenario is similar in all aspects to Scenario 1, with the exception of the type of milk consumed. Ingestion of goat milk produces the largest thyroid doses per unit release of  $^{131}\text{I}$  (NCI 1997, Apostoaei et al. 1999). Thus, this exposure scenario will ensure that doses to the maximally exposed individual are estimated, even though this exposure scenario may be relevant only for a limited number of individuals.



**Table 3 Summary of the exposure scenarios for representative members of the public from atmospheric releases from facilities at the Idaho National Engineering Laboratory**

	<b>Name</b>	<b>Ingestion pathway</b>	<b>Inhalation and external exposure</b>	<b>Age and gender</b>	<b>Location</b>
<b>1</b>	Rural resident (backyard cow milk diet)	Backyard cow milk diet and locally produced foods*	Large fraction of time spent outside; moderate physical work	Males and females; all ages at exposure	Selected offsite communities
<b>2</b>	Rural resident (goat milk diet)	Goat milk diet and locally produced foods*	Large fraction of time spent outside; moderate physical work	Males and females; all ages at exposure	Selected offsite communities
<b>3</b>	Urban resident (commercial milk diet)	Commercial milk diet and commercially available foods†	Limited time spent outside; limited physical work	Males and females; all ages at exposure	Selected offsite communities
<b>4</b>	Migrant farm worker	Cow milk from a local dairy farm and locally produced foods*	Very large fraction of time spent outside; intensive physical work	Males and females; all ages at exposure	Selected offsite communities

	<b>Name</b>	<b>Ingestion pathway</b>	<b>Inhalation and external exposure</b>	<b>Age and gender</b>	
<b>1</b>	Onsite farmer‡	Backyard cow milk diet and locally produced foods§	Large fraction of time spent outside; intense physical work	Adult male (age 20 in 1957)	Big Lost River sink area¶
<b>2</b>	Hunter**	Elk, deer, pronghorn meat	Limited time spent outside;** intensive physical activity	Adult male	Big Lost River sink area
<b>3a</b>	One-time visitor	Not applicable	Limited time spent in the plume; limited physical work	Adult (e.g., visiting scientist) Teenager (e.g., high school student)	A nuclear facility with the largest air concentration (e.g. CFA)
<b>3b</b>	Regular visitor	Not applicable	Limited time spent in the plume; moderate physical work	Adult male (age 20 in 1957)	Central Facility Area (and others)

\* Includes locally grown vegetables and locally produced meats.

† Includes commercially produced meat. Doses will be calculated for both locally grown vegetables (e.g., home gardener) and for vegetables sold commercially.

‡ Details about the amount of time spent onsite are still to be determined.

§ Includes consumption of meat from cattle and sheep grazing within the INEL boundary.

¶ The location may change based on information that will be collected during future visits to the site.

\*\* Doses will be calculated for an occasional (one-time) hunter and for a subsistence hunter.

### ***Offsite Scenario 3 – Urban Resident – Commercial Cow Milk***

This exposure scenario is representative of an individual who purchased most of his or her food products from grocery stores, where food is brought from the extended INEL region, and from outside the INEL region. Milk is obtained from multiple large dairies where milk from many cows is mixed. As for Scenario 1, doses will be estimated for individuals of both sexes and for all ages (at exposure), from infants to adults. However, for teenagers and adults, the exposure parameters will be chosen to represent an individual who spends a larger fraction of time indoors performing less physically intensive activities (as compared with a “rural” resident). Since it is possible for an urban resident to maintain a home vegetable garden, this scenario will include dose estimates based on a diet of locally grown vegetables in addition to the doses based on a diet of regionally grown vegetables.

### ***Offsite Scenario 4 – Migrant Farm Worker***

This exposure scenario is relevant for migrant farm workers (mostly Hispanics) who participated in seasonal farming activities and applies to males and females exposed as adults, but also applies to their children who traveled with them to the work site. They were present at the site for only a fraction of the year, but they spent most of their time outdoors performing very intense physical activities. In addition to inhalation of radionuclides from a passing cloud, inhalation of resuspended material (e.g., dust) and ingestion of soil particles were potentially important exposure pathways. Their food came from local sources, but it was not obtained from their own animals or gardens. For instance, any milk they ingested was most likely obtained from a local dairy farm as opposed to a “backyard” cow.

## **3.2 Scenarios for Persons Exposed Onsite**

The current project is focused on exposures of members of the public. The National Institute of Occupational Safety and Health (NIOSH) normally analyze worker exposures. Thus, the scenarios for people exposed onsite refer to members of the public who for various reasons spent time within the boundaries of INEL. Three scenarios that we propose to develop and analyze further are presented below.

### ***Onsite Scenario 1 – Onsite Farmer***

As described in [Section 2.3](#), a sizable area within the INEL site has been open to controlled grazing ([Figure 4](#)) for beef cattle and sheep. Water has to be trucked in to the location of the animals every day or two. Animals may be moved several times depending on the season (new grass; calving; etc.) Also, farming activities (with moderate irrigation) may have taken place within the INEL site, close to the terminations of Big and Little Lost River, up to 13 km (8 mi) southeast of Howe ([Bowman et al. 1984](#)). Workers are required to come regularly to the site to take care of the animals or to inspect the crops. Such workers can be exposed onsite by inhalation or external exposure, and they probably consumed meat from beef cattle.

The representative individual is an adult assumed to be exposed in the Big and Little Lost River sink area. The doses calculated from the “onsite” exposures will be reported both separately and in combination with the doses calculated from “offsite” exposures (using offsite Scenario 1).

The offsite exposures are assumed to take place at Howe, since it is plausible that the workers lived close to the farming area.

### ***Onsite Scenario 2 – Hunter***

This scenario is plausible because contamination of pronghorn antelope tissues has been linked to atmospheric releases from the ICPP (Markham and Halford 1980b), and because pronghorn can travel up to 35 miles during a season. Elk and deer also migrate up and down the mountainous areas. Thus, it is possible to be exposed by consuming the meat from an animal hunted outside of the INEL site.

Pronghorn antelopes are abundant in the area, with about 30% of Idaho's total animal population living on the INEL site. Twenty years ago, mule deer, elk, moose, and mountain sheep were considered uncommon in the area (Bowman et al. 1984). However, the population of deer and elk has increased in recent years. Because of the large number of animals and because of the damage done by the deer and elk to crops farmed in the area, hunting was recently allowed, first around the INEL and then within ½ mile of the boundaries of the INEL, adjacent to the agricultural lands (Naderman 2003).

The representative individual for this scenario was an adult hunter who hunted during the late 1950s and who consumed the whole edible tissue on an animal that resided within 10 km of the ICPP. The doses will be calculated for an occasional hunter (i.e., only one animal), as well as for a subsistence hunter, for whom venison represents a large fraction of meat intake. The occasional hunter is a person living far from the site, who travels only for the purpose of hunting, and who has no offsite exposure to atmospheric releases from INEL. The subsistence hunter is a person living in the vicinity of INEL and who is also exposed to atmospheric releases (offsite Scenario 1, in which the general meat ingestion pathway is replaced by ingestion of venison meat). The subsistence hunter scenario can be considered representative for Native Americans who relied more heavily on hunting as a food source in the 1950s.

### ***Onsite Scenario 3 – Visitors***

Another possible scenario involves occasional visitors (e.g., a group of students taking a site tour) or outside workers who visit one of the INEL facilities regularly as part of their job (e.g., a delivery person who regularly brings refills for the vending machines to the site). Inhalation and external exposure are the normal exposure pathways for these persons (assuming no inadvertent ingestion of radionuclides).

- *Scenario 3a – one-time visitor:* It is assumed that a visitor takes one full day trip to the INEL facility where the average air concentrations of radionuclides are the highest (e.g. CFA). The radiation dose is delivered by inhalation, plume immersion, and external exposure to contaminated ground. Given the general secrecy enforced on the national nuclear complex during late the 1950s and early 1960s, such an activity was probably limited to adult visitors (e.g., scientists from other organizations, inspectors from a governmental organization). Younger people (e.g., high-school students) also visited the site, but most likely after the 1960s.

- *Scenario 3b – regular visitor:* It is assumed that an outside worker is present for a few hours each week at the CFA. The CFA had a cafeteria that operated beginning in January 1952. Later, CFA grew to include warehouses, offices, a technical library, and a dispensary (Stacy 2000). Other facilities also had operational cafeterias. This exposure scenario refers to a delivery person who comes to a central delivery location (e.g., CFA) on a weekly basis and spends a few hours unloading his products. Exposure to radiation takes place by inhalation, plume immersion, and external exposure to contaminated ground.

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## 4.0 SUMMARY

This report describes four offsite and three onsite scenarios for exposure of representative members of the public to atmospheric releases from operations at the ICPP facility and from ANP/IET tests that took place at INEL in the late 1950s. The exposure scenarios were developed for the purpose of performing a detailed dose reconstruction of the doses to the members of the public, and thus they pertain only to radionuclides that have been identified as potentially important in the screening process. The scenarios were developed based on site-specific information collected from detailed documents about the INEL site and surrounding regions, from individuals living in the area and from members of the Idaho Health Effects Subcommittee.

The offsite scenarios include a rural resident, an urban resident, and a migrant farm worker (Table 3). Because of potentially important releases of radioactive iodine (which accumulates in milk), two separate scenarios are defined for the rural resident according to the type of milk consumed: (1) a rural resident on a diet of backyard-cow milk and (2) a rural resident on a diet of goat milk.

The onsite scenarios include a farmer who lives in Howe (Figure 1 and Figure 3), takes care of cattle, and cultivates crops near the Big and Little Lost River sink area (about 13 km southeast of Howe); a hunter who consumes the meat of deer, elk or pronghorn antelopes grazing on the INEL property; and a visitor to the INEL facilities. For the hunter scenario, we analyze the doses to both an individual living far from the INEL site who hunts occasionally around the site, and an individual who lives in the vicinity of INEL and relies on hunting for his subsistence. The visitor scenario includes a one-time visitor (e.g., visiting scientist or high-school student) and a regular visitor (e.g., a delivery worker who regularly comes onsite, but is not an INEL employee).

All scenarios refer to exposures during the late 1950s, when the releases took place. Exposures after 1960 to long-lived radionuclides deposited onto the ground are also included. For the offsite scenarios, doses will be estimated for adults and for children, while for the onsite scenarios, only adults are assumed to be exposed, with the exception of the “one-time visitor” scenario, in which high school students are assumed to take a tour of the site.

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## APPENDIX A: ACRONYMS OF THE FACILITIES AND OPERATIONS AT INEL

ANL-W	Argonne National Laboratory - West
ANP	Aircraft Nuclear Propulsion Program
ARA	Auxiliary Reactor Area
ATR	Advanced Test Reactor
A1W	Large Ship Reactor A & B
BORAX	Boiling Water Reactor Experiment
CFA	Central Facilities Area
CFSGF	Coal Fired Steam Generating Facility
CTF	Core Test Facility
EBR-I	Experimental Breeder Reactor I
EBR-II	Experimental Breeder Reactor II
ECF	Expeded Core Facility
EFS	Experimental Field Station
EOCR	Experimental Organic Cooled Reactor (mothballed before startup)
ETR	Engineering Test Reactor
FAST	Fluorine and Fuel Storage Facility
ICPP	Idaho Chemical Processing Plant
IET	Initial Engine Test Facility
MTR	Materials Testing Reactor
NRF	Naval Reactors Facility
NWCF	New Waste Calcining Facility
PBF	Power Burst Facility
PREPP	Process Experimental Pilot Plant
RWMC	Radioactive Waste Management Center
SPERT	Special Power Excursion Reactor Test
S5G	Natural Circulation Reactor
STSL	Semi Scale Support Laboratory
S1W	Submarine Thermal Reactor
SWEPP	Stored Waste Examination Pilot Plant
TAN	Test Area North
TRA	Test Reactor Area
TREAT	Transient Reactor Test Facility
TSF	Technical Services Facility
WERF	Waste Experimental Reduction Facility
WRRTF	Water Reactor Research Test Facility
ZPPR	Zero Power Physics Reactor

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