Appendix C
Evaluation of Human Health Effects from Normal Operations

APPENDIX C
EVALUATION OF HUMAN HEALTH EFFECTS FROM NORMAL OPERATIONS

C.1 Introduction

This appendix presents detailed information on the potential impacts on humans associated with incident-free (normal) releases of radioactivity from the U.S. Department of Energy (DOE) facilities proposed in this *Versatile Test Reactor Environmental Impact Statement* (VTR EIS). This appendix also presents information on the calculation of worker doses that would be received as a result of performing facility modifications and operation of the Versatile Test Reactor (VTR) and associated facilities. Chapter 2 of this VTR EIS presents descriptions of the alternatives and the fuel preparation and fabrication options that contribute to the doses evaluated in this appendix. Appendix B provides descriptions of the VTR facilities: the VTR building, fuel preparation and fabrication facilities, post-irradiation examination facilities, and spent fuel treatment and temporary storage facilities. The analysis in this appendix supports the human health risk assessments described in Chapter 4, Section 4.10. Site-specific input data used in the evaluation of these human health impacts are provided or referenced, as appropriate. Resulting impacts can be compared to criteria invoked in DOE Order 458.1 for protection of the public (10 millirem per year from airborne pathways and 100 millirem per year total from all pathways) and Title 10 of the *Code of Federal Regulations* (CFR), Part 835, for protection of workers (5,000 millirem per year) at the three sites considered as alternative locations for VTR-related activities: the Idaho National Laboratory (INL) Site, Oak Ridge National Laboratory (ORNL), and Savannah River Site (SRS). Worker doses would be monitored and controlled below the regulatory limit to ensure that individual doses are less than 2,000 millirem per year and as low as reasonably achievable (ALARA).

The rest of this section provides information to aid the reader in understanding the impacts from the radiological dose assessments. The text box on the following page presents basic information about the sources, types, and nature of radiation and units of measurement. Subsequent subsections address the sources of radiation protection guidelines, radiation exposure limits applicable to DOE operations, and the assessment of health effects from exposure to radiation.

C.1.1 Radiation Protection Guides

Various organizations have issued radiation protection guides. The two organizations most directly responsible for the development of radiological requirements and exposure criteria associated with the operation of DOE facilities are DOE and the U.S. Environmental Protection Agency (EPA).

DOE. Radiological protection of the public and site workers from the operation of DOE facilities is primarily the responsibility of DOE. DOE establishes and enforces requirements for radiological protection at DOE sites in regulations and orders. Requirements for worker protection are included in "Occupational Radiation Protection Program" (10 CFR Part 835). Radiological protection of the public and environment is addressed in "Radiation Protection of the Public and the Environment" (DOE Order 458.1).

EPA. The EPA has published a series of documents under the title *Radiation Protection Guidance to Federal Agencies*. This guidance is used as a benchmark by a number of Federal agencies, including DOE, for the purpose of ensuring that regulation of public and occupational workforce exposures is protective, reflects the best available scientific information, and is carried out in a consistent manner. In addition, the EPA has established a regulatory limit of 10 millirem per year for exposure of the public to emissions from DOE facilities (40 CFR Part 61, Subpart H).

Radiation Basics

What is radiation? Radiation is energy emitted from unstable (radioactive) atoms in the form of atomic particles or electromagnetic waves. This type of radiation is also known as ionizing radiation because it can produce charged particles (ions) in matter.

What is radioactivity? Radioactivity is produced by the process of radioactive atoms trying to become stable (a process termed "decay"), the splitting of atoms (fission), and the combination of atoms (fusion). Radiation is emitted in the process. In the United States, radioactivity is commonly measured in units called curies, where 1 curie is equal to 3.7×10^{10} disintegrations (decay transformations) per second. Internationally, radioactivity is generally measured in units called becquerels, where 1 becquerel is equal to 1 disintegration per second (1 curie = 3.7×10^{10} becquerels).

What is radioactive material? Radioactive material is any material containing unstable atoms that emit radiation.

What are the four basic types of ionizing radiation?

> ***Alpha particles*** — Alpha particles consist of two protons and two neutrons. They can travel only a few centimeters in air and can be stopped easily by a sheet of paper or by the skin's surface.
>
> ***Beta particles*** — Beta particles are smaller and lighter than alpha particles and have the mass of a single electron. A high-energy beta particle can travel a few meters in the air. Beta particles can pass through a sheet of paper, but may be stopped by a thin sheet of aluminum foil or glass.
>
> ***Gamma rays*** — Gamma rays (and x-rays), unlike alpha or beta particles, are waves of pure energy. Gamma radiation is very penetrating and can travel several hundred feet in the air. Gamma radiation requires a thick wall of material such as concrete, lead, or steel to stop it.
>
> ***Neutrons*** — A neutron is an atomic particle that has about one-quarter the weight of an alpha particle. Like gamma radiation, it can easily travel several hundred feet in the air. Neutron radiation is most effectively stopped by materials with high hydrogen content, such as water or plastic.

What are the sources of radiation?

> ***Natural sources of radiation*** — Sources include cosmic radiation from the sun and outer space, natural radioactive elements in the Earth's crust, natural radioactive elements in the human body, and radon gas from the radioactive decay of uranium that is naturally present in the soil.
>
> ***Man-made sources of radiation*** — Sources include medical radiation (x-rays, medical isotopes), consumer products (TVs, luminous dial watches, smoke detectors), nuclear technology (nuclear power plants, industrial x-ray machines), and worldwide fallout from past nuclear weapons tests or accidents.

What is radiation dose? Radiation dose is the amount of energy in the form of ionizing radiation absorbed per unit mass of any material. For people, radiation dose is the amount of energy absorbed in human tissue. In the United States, radiation dose is commonly measured in units called rem; a smaller fraction of the rem is the millirem (1/1,000 of 1 rem). Internationally, radiation dose is generally measured in units called sieverts, where 1 rem = 0.01 sieverts.

Person-rem (or person-sievert) is a unit of collective radiation dose applied to populations or groups of individuals; it is the sum of the doses received by all the individuals of a specified population.

What is the average annual radiation dose from natural and man-made sources? Globally, humans are exposed constantly to radiation from the solar system and the Earth's rocks and soil. This natural radiation contributes to the natural background radiation that always surrounds us. Man-made sources of radiation also exist, including medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants. The average individual in the United States annually receives about 625 millirem of radiation dose from all background sources, of which about half is received from natural sources such as cosmic and terrestrial radiation and radon-220 and -222 in homes. Most of the remaining radiation dose from man-made sources is received from diagnostic x-rays and nuclear medicine (NCRP 2009).

What are the effects of radiation on humans? Radiation can cause a variety of adverse health effects in humans. Health impacts of radiation exposure, whether from external or internal sources, generally are identified as somatic (i.e., affecting the exposed individual) or genetic (i.e., affecting descendants of the exposed individual). Radiation is more likely to produce somatic than genetic effects. The somatic risks of most importance are induced cancers. Except for leukemia, which can have an induction period (time between exposure to the carcinogen and cancer diagnosis) of 2 to 7 years, most cancers have an induction period of more than 20 years.

For uniform irradiation of the body, cancer incidence varies among organs and tissues; the thyroid and skin demonstrate a greater sensitivity than other organs. Such cancers, however, also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because fatal cancer is the most serious effect of environmental and occupational radiation exposures, estimates of cancer fatalities, rather than cancer incidence, are presented as a measure of impact in this document. These estimates are referred to as "latent cancer fatalities" (LCFs), because the cancer may take many years to develop.

Several organizations, in addition to DOE and EPA, continually evaluate the impacts of radiation and provide radiation protection guidance. The responsibilities of the main radiation safety organizations, particularly those that affect policies in the United States, are summarized below.

International Commission on Radiological Protection (ICRP). The ICRP is responsible for providing guidance in matters of radiation safety.

National Council on Radiation Protection and Measurements. In the United States, this council is the national organization that formulates and disseminates guidance and recommendations on radiation protection and measurements that represent the consensus of leading scientific thinking.

National Research Council/National Academy of Sciences. The National Research Council integrates the broad science and technology community with the Academy's mission to further knowledge and advise the Federal Government. The National Research Council's Biological Effects of Ionizing Radiation (BEIR) Committee prepares reports to advise the Federal Government on the health consequences of radiation exposure.

U.S. Nuclear Regulatory Commission (NRC). NRC regulates nuclear power plants and the use of source materials, special nuclear materials, and byproduct materials by commercial and certain governmental entities.

C.1.2 Radiation Exposure Limits

Radiation exposure limits for members of the public and radiation workers are derived from ICRP recommendations. The EPA considers NCRP and ICRP recommendations in setting specific annual exposure limits (usually lower than those specified by the ICRP) in its radiation protection guidance to Federal agencies. The various exposure limits set by DOE and EPA for radiation workers and members of the public are given in **Table C–1**.

Table C–1. Radiation Exposure Limits for Members of the Public and Radiation Workers

Regulation/DOE Order/Standard (organization)	*Public Exposure Limits at the Site Boundary*	*Worker Exposure Limits*
10 CFR Part 835 (DOE)	–	5,000 millirem per year [a]
DOE-STD-1098-2017 (DOE)	–	2,000 millirem per year [b]
DOE Order 458.1 (DOE) [c]	100 millirem per year (all pathways) 10 millirem per year (all air pathways) 4 millirem per year (drinking-water pathway)	–
40 CFR Part 61, Subpart H (EPA)	10 millirem per year (all air pathways)	–
40 CFR Part 141 (EPA)	4 millirem per year (drinking-water pathway)	–

CFR = Code of Federal Regulations; EPA = U.S. Environmental Protection Agency.

[a] Although this measurement is a limit (or level) that is enforced by DOE, worker doses must be managed in accordance with as low as reasonably achievable principles. Refer to footnote b.

[b] This is an administrative control level; exceeding this level generally requires approval of senior management. DOE established this level to assist in achieving its goal of maintaining radiation doses as low as reasonably achievable. DOE recommends that facilities adopt a more limiting Administrative Control Level (DOE 2017). Facility operators must make reasonable attempts to maintain individual worker doses below these levels.

[c] Consistent with 10 CFR Part 20.

C.1.3 Human Health Effects Due to Exposure to Radiation

This section discusses the basic concepts used in the evaluation of radiation effects. Radiation can cause a variety of damaging health effects in humans, both somatic and genetic. Somatic effects (those that affect the exposed individual) are more probable. The most significant effect is induced cancer fatalities. These are called LCFs because the onset of cancer may take many years to develop after the radiation dose is received. In this VTR EIS, LCFs are used as the measure of estimated risk due to radiation exposure.

Cancer is a group of diseases characterized by the uncontrolled growth and spread of abnormal cells. Cancer is caused by both external factors (e.g., tobacco, excessive body weight, infectious organisms, alcohol consumption, and radiation) and internal factors (inherited mutations, hormones, immune conditions, and mutations that occur from metabolism). For the U.S. population of about 310 million, the American Cancer Society estimates that, in 2020, about 1.8 million new cancer cases would be diagnosed and about 606,520 cancer deaths would occur. Just under 20 percent of U.S. cancer deaths are estimated to be caused by tobacco use and slightly less are related to excess weight or obesity, physical inactivity, and poor nutrition. The average U.S. resident has about 4 chances in 10 of developing an invasive cancer over his or her lifetime (40 percent probability for males, 39 percent for females) (American Cancer Society 2020). About 21 percent of all deaths in the United States are due to cancer (CDC 2020).

In 2002, the Interagency Steering Committee on Radiation Standards (ISCORS) recommended that Federal agencies use conversion factors of 0.0006 fatal cancers per rem for mortality and 0.0008 cancers per rem for morbidity (incidences of cancer) when making qualitative or semi-quantitative estimates of risk from radiation exposure to members of the general public. No separate values were recommended for workers. The DOE Office of Environmental and Policy Guidance subsequently recommended that DOE personnel and contractors use the risk factors recommended by ISCORS, stating that, for most purposes, the value for the general population (0.0006 fatal cancers per rem) could be used for both workers and members of the public in National Environmental Policy Act analyses (DOE 2003a).

Publications by both the BEIR Committee and the ICRP support the continued use of the ISCORS-recommended risk values. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2* (National Research Council 2006) reported fatal cancer risk factors of 0.00048 per rem for males and 0.00066 per rem for females in a population with an age distribution similar to that of the entire U.S. population (average value of 0.00057 per rem for a population with equal numbers of males and females). ICRP Publication 103 (Valentin 2007) recommends nominal cancer risk coefficients of 0.00041 and 0.00055 per rem for adults and the general population, respectively.

Accordingly, a risk factor of 0.0006 LCFs per rem was used in this VTR EIS to estimate risk impacts due to radiation doses from normal operations and accidents. For high, acute individual doses (greater than or equal to 20 rem), the health risk factor is multiplied by 2 (NCRP 1993). The presentation of risks from radiation exposure associated with VTR EIS activities are the increased risks of developing a cancer; that is, they are in addition to the risk of cancer from all other causes.

Using the risk factors discussed above, a calculated dose can be used to estimate the risk of an LCF. For example, if each member of a population of 100,000 people were exposed to a one-time dose of 100 millirem (0.1 rem), the collective dose would be 10,000 person-rem (100,000 persons times 0.1 rem). Using the risk factor of 0.0006 LCFs per person-rem, this collective dose is expected to cause 6 additional LCFs in this population (10,000 person-rem times 0.0006 LCFs per person-rem).

Calculations of the number of LCFs sometimes do not yield whole numbers and may yield a number less than one. For example, if each individual of a population of 100,000 people were to receive an annual dose of 1 millirem (0.001 rem), the collective dose would be 100 person-rem, and the corresponding risk of an LCF would be 0.06 (100,000 persons times 0.001 rem times 0.0006 LCFs per person-rem). A fractional result should be interpreted as a statistical estimate. That is, 0.06 is the average number of LCFs expected if many groups of 100,000 people were to experience the same radiation exposure situation. For most groups, no LCFs would occur; in a few groups, one LCF would occur; in a very small number of groups, two or more LCFs would occur. The average number of LCFs over all of the groups would be 0.06. In this VTR EIS, LCFs calculated for a population are presented as both the rounded whole number, representing the most likely outcome for that population, and the calculated statistical estimate of risk, which is presented in parentheses.

The numerical estimates of LCFs presented in this VTR EIS were obtained using a linear extrapolation from the nominal risk estimated for lifetime total cancer mortality resulting from a dose of 0.1 grays (10 rad). This results in the use of a “linear no-threshold” model. Other methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of LCFs. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation. Studies of human populations exposed to low doses are inadequate to demonstrate the actual level of risk. However, the latest recommendations of the National Research Council support use of a “linear no-threshold” risk model in which the risk of cancer proceeds in a linear fashion at lower doses without a threshold i.e., any non-zero dose results in an increased risk of cancer (National Research Council 2006).

C.2 Assessment Approach

The dose assessments performed for this VTR EIS were based on site-specific environmental data, facility-specific data, and assumptions related to various exposure parameters. The GENII Version 2 (GENII Environmental Dosimetry System, Version 2) computer code (Version 2.10) was used to calculate the projected doses from normal operations at the INL site, ORNL, and SRS. The GENII computer code complies with quality assurance plans based on the American National Standards Institute Standard NQA-1. This code is one of the toolbox models that meets DOE Order 414.1C, and is overseen by DOE’s Office of Quality Assurance Policy and Assistance. All steps of code development were documented and tested, and hand calculations verified the code’s implementation of major transport and exposure pathways for a subset of the radionuclide library. The code was reviewed by the EPA Science Advisory Board and a separate, EPA-sponsored, independent peer review panel. The quality assurance of GENII Version 2 has been reviewed by DOE (DOE 2003b) and continues to be rigorously reviewed with each updated version released by Pacific Northwest National Laboratory, the developer of the code.

C.2.1 Meteorological Data

The meteorological data used in the INL, ORNL, and SRS dose assessments are joint frequency distribution (JFD) files created from site-specific meteorological data. A JFD file is a table listing the percentage of time the wind blows from a certain direction, within a certain range of speeds, and within a certain stability class. JFD data for the INL Site were based on measurements taken from the National Oceanographic and Aeronautics Administration/INL Mesonet tower at the Materials and Fuels Complex (MFC) over a 5-year period (2015 through 2019) at a height of 15 meters. JFD data for ORNL were based on measurements taken at ORNL Meteorological Tower A over a 5 year period (2015 through 2019) at a height of 15 meters. JFD data for SRS were based on measurements taken at the H Tower over a 5-year period (2007 through 2011) at a height of 10 meters. Meteorological station parameters and wind-speed midpoints were used in the normal operational assessments. **Tables C–2** through **C–4** present the JFD data used in the INL, ORNL, and SRS analyses, respectively.

Table C–2. Idaho National Laboratory Site Joint Frequency Distribution Data [a]

Average Wind Speed (m/s)	***Stability Class***	***Direction From Which the Wind Blows***															
		N	***NNE***	***NE***	***ENE***	***E***	***ESE***	***SE***	***SSE***	***S***	***SSW***	***SW***	***WSW***	***W***	***WNW***	***NW***	***NNW***
1.23	A	0.06	0.05	0.08	0.03	0.03	0.02	0.00	0.03	0.02	0.04	0.06	0.07	0.09	0.11	0.09	0.07
	B	0.63	0.60	0.49	0.24	0.13	0.11	0.06	0.11	0.13	0.20	0.26	0.38	0.39	0.36	0.44	0.64
	C	0.11	0.11	0.09	0.06	0.03	0.03	0.02	0.03	0.05	0.09	0.07	0.07	0.09	0.06	0.07	0.07
	D	0.59	0.52	0.59	0.47	0.28	0.19	0.20	0.24	0.30	0.37	0.30	0.25	0.24	0.22	0.27	0.34
	E	0.36	0.40	0.39	0.24	0.13	0.09	0.08	0.11	0.13	0.20	0.19	0.17	0.11	0.14	0.17	0.30
	F	0.62	0.86	1.31	1.11	0.75	0.50	0.53	0.74	0.74	0.83	0.64	0.48	0.36	0.33	0.32	0.41
2.92	A	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00
	B	0.12	0.21	0.36	0.12	0.04	0.02	0.03	0.09	0.20	0.38	0.39	0.27	0.12	0.04	0.05	0.05
	C	0.64	1.40	1.39	0.34	0.08	0.07	0.07	0.21	0.30	0.56	0.54	0.52	0.23	0.17	0.21	0.33
	D	0.97	1.76	2.67	2.02	0.65	0.29	0.43	1.09	1.66	1.71	1.46	0.78	0.42	0.32	0.34	0.51
	E	0.10	0.24	0.51	0.44	0.16	0.06	0.08	0.17	0.30	0.29	0.19	0.10	0.07	0.04	0.05	0.06
	F	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
4.94	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.01	0.04	0.11	0.03	0.01	0.01	0.00	0.02	0.11	0.23	0.20	0.04	0.01	0.00	0.01	0.01
	C	0.10	0.26	0.45	0.10	0.03	0.01	0.01	0.09	0.28	0.60	0.52	0.17	0.05	0.05	0.07	0.07
	D	0.62	1.07	1.36	1.09	0.41	0.24	0.44	2.06	2.03	2.87	2.25	0.73	0.21	0.19	0.29	0.51
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.38	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.09	0.01	0.00	0.00	0.00	0.00
	D	0.40	1.00	0.96	0.34	0.08	0.08	0.08	0.67	1.91	3.80	4.19	0.92	0.10	0.13	0.15	0.31
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.34	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.09	0.01	0.00	0.00	0.00	0.00
	D	0.23	0.38	0.21	0.02	0.01	0.00	0.00	0.05	0.55	1.52	2.69	0.56	0.04	0.03	0.01	0.06
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.11	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.00	0.00	0.00
	D	0.06	0.09	0.04	0.00	0.00	0.00	0.00	0.00	0.09	0.34	1.01	0.18	0.00	0.00	0.01	0.01
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.42	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.24	0.03	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

E = east; ENE = east-northeast; ESE = east-southeast; INL = Idaho National Laboratory; m/s = meters per second; MFC = Materials and Fuels Complex; N = north; NE = northeast; NNE = north-northeast; NNW = north-northwest; NW = northwest; S = south; SE = southeast; SSE = south-southeast; SSW = south-southwest; SW = southwest; W = west; WNW = west-northwest; WSW = west-southwest.

[a] MFC: 15 meter tower height. Based on 2015 to 2019 meteorological data.

Note: To convert meters per second to miles per hour, multiply by 2.2369; meters to feet, by 3.2808.

Table C–3. Oak Ridge National Laboratory Joint Frequency Distribution Data [a]

Average Wind-speed (m/s)	Stability Class	Direction From Which the Wind Blows															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.55	A	0.03	0.02	0.05	0.08	0.10	0.04	0.03	0.06	0.06	0.07	0.06	0.06	0.02	0.01	0.02	0.01
	B	0.11	0.14	0.23	0.23	0.21	0.20	0.16	0.19	0.24	0.32	0.31	0.29	0.18	0.13	0.10	0.09
	C	0.02	0.04	0.07	0.13	0.07	0.02	0.01	0.01	0.01	0.03	0.07	0.11	0.07	0.04	0.01	0.00
	D	0.31	0.45	0.90	1.30	0.52	0.21	0.18	0.17	0.23	0.41	0.61	1.12	0.75	0.41	0.27	0.27
	E	0.16	0.26	0.50	0.73	0.34	0.17	0.15	0.15	0.24	0.25	0.42	0.72	0.58	0.27	0.15	0.18
	F	0.93	1.51	2.38	2.42	1.34	0.86	0.61	0.71	0.86	0.92	1.17	2.19	1.99	0.79	0.65	0.69
	G	0.32	0.44	0.76	0.94	0.71	0.51	0.52	0.50	0.48	0.44	0.58	0.70	0.64	0.26	0.20	0.18
1.44	A	0.12	0.18	0.27	0.30	0.25	0.22	0.18	0.21	0.29	0.57	0.58	0.36	0.21	0.12	0.06	0.09
	B	0.12	0.21	0.55	0.69	0.43	0.18	0.16	0.16	0.33	0.60	0.89	0.60	0.37	0.21	0.18	0.13
	C	0.03	0.04	0.13	0.37	0.12	0.04	0.02	0.03	0.02	0.17	0.38	0.37	0.20	0.07	0.03	0.03
	D	0.11	0.16	0.79	1.30	0.23	0.06	0.04	0.05	0.09	0.32	0.69	1.11	0.72	0.21	0.12	0.07
	E	0.18	0.23	0.63	0.83	0.31	0.21	0.15	0.16	0.25	0.50	0.76	0.84	0.72	0.49	0.28	0.18
	F	0.08	0.18	0.77	1.33	0.16	0.05	0.03	0.05	0.13	0.24	0.45	0.97	0.54	0.13	0.06	0.04
	G	0.00	0.01	0.10	0.15	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.09	0.01	0.01	0.00
2.42	A	0.02	0.02	0.08	0.08	0.06	0.03	0.00	0.00	0.03	0.14	0.18	0.06	0.03	0.04	0.02	0.02
	B	0.04	0.08	0.25	0.26	0.10	0.03	0.02	0.02	0.03	0.26	0.43	0.19	0.10	0.11	0.09	0.03
	C	0.05	0.09	0.30	0.53	0.15	0.04	0.02	0.03	0.08	0.48	0.89	0.43	0.36	0.28	0.08	0.05
	D	0.12	0.15	0.64	0.76	0.14	0.03	0.03	0.05	0.12	0.57	1.24	0.82	0.87	0.64	0.24	0.13
	E	0.03	0.08	0.21	0.25	0.02	0.01	0.00	0.01	0.04	0.07	0.10	0.07	0.06	0.13	0.14	0.07
	F	0.01	0.01	0.07	0.11	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.01	0.00	0.02	0.01	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.58	A	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
	B	0.01	0.02	0.14	0.14	0.03	0.00	0.00	0.00	0.01	0.19	0.26	0.05	0.03	0.07	0.07	0.02
	C	0.02	0.05	0.17	0.16	0.03	0.00	0.00	0.00	0.04	0.30	0.42	0.14	0.15	0.21	0.07	0.02
	D	0.02	0.05	0.32	0.20	0.02	0.02	0.00	0.02	0.07	0.50	0.89	0.34	0.50	0.52	0.24	0.06
	E	0.01	0.01	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.08	0.02
	F	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.06	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.01	0.01	0.00
	C	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.09	0.09	0.01	0.03	0.03	0.04	0.01
	D	0.01	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.04	0.19	0.20	0.09	0.11	0.18	0.12	0.01
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.49	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03	0.01	0.02	0.03	0.02	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

m/s = meters per second.

[a] ORNL: Tower A, 15 meter tower height. Based on 2015 to 2019 meteorological data.

Note: To convert meters per second to miles per hour, multiply by 2.2369; meters to feet, by 3.2808.

Table C–4. Savannah River Site Joint Frequency Distribution Data [a]

Average Wind-speed (m/s)	*Stability Class*	*Direction From Which the Wind Blows*															
		S	*SSW*	*SW*	*WSW*	*W*	*WNW*	*NW*	*NNW*	*N*	*NNE*	*NE*	*ENE*	*E*	*ESE*	*SE*	*SSE*
1.14	A	0.05	0.08	0.10	0.12	0.12	0.12	0.08	0.11	0.10	0.10	0.09	0.08	0.08	0.08	0.09	0.07
	B	0.00	0.01	0.01	0.03	0.01	0.04	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	C	0.03	0.02	0.04	0.06	0.05	0.04	0.05	0.04	0.04	0.04	0.09	0.06	0.04	0.05	0.04	0.04
	D	0.16	0.17	0.16	0.12	0.18	0.13	0.12	0.15	0.18	0.22	0.28	0.26	0.20	0.17	0.19	0.16
	E	0.26	0.30	0.22	0.24	0.25	0.22	0.21	0.17	0.15	0.18	0.33	0.30	0.26	0.27	0.24	0.30
	F	0.77	0.90	0.75	0.68	0.50	0.51	0.52	0.52	0.49	0.55	0.69	0.33	0.26	0.36	0.44	0.68
2.07	A	0.31	0.32	0.40	0.55	0.55	0.38	0.28	0.21	0.21	0.25	0.27	0.35	0.37	0.29	0.27	0.26
	B	0.06	0.08	0.12	0.16	0.13	0.14	0.06	0.05	0.05	0.07	0.11	0.16	0.12	0.10	0.08	0.07
	C	0.14	0.17	0.20	0.30	0.18	0.21	0.10	0.08	0.07	0.10	0.25	0.24	0.20	0.15	0.12	0.08
	D	0.60	0.43	0.63	0.68	0.58	0.57	0.41	0.29	0.37	0.58	1.18	0.96	0.75	0.59	0.46	0.39
	E	1.47	1.46	1.31	1.27	1.11	0.78	0.49	0.34	0.34	0.44	0.80	0.88	0.86	0.82	0.93	1.05
	F	0.26	0.37	0.20	0.21	0.13	0.13	0.05	0.06	0.15	0.32	0.08	0.02	0.02	0.07	0.10	0.13
3.19	A	0.08	0.07	0.09	0.18	0.23	0.11	0.05	0.06	0.04	0.05	0.07	0.11	0.12	0.09	0.04	0.04
	B	0.16	0.21	0.30	0.61	0.57	0.33	0.10	0.10	0.10	0.12	0.25	0.40	0.38	0.26	0.16	0.05
	C	0.42	0.49	0.59	0.99	0.70	0.51	0.20	0.13	0.21	0.34	0.81	0.73	0.49	0.25	0.22	0.16
	D	2.09	1.33	1.54	1.52	1.62	1.32	0.60	0.34	0.52	0.87	1.85	1.56	1.20	0.90	0.97	1.36
	E	0.59	0.42	0.40	0.29	0.16	0.10	0.05	0.03	0.07	0.14	0.04	0.10	0.12	0.09	0.11	0.23
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.85	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.16	0.22	0.31	0.63	0.66	0.57	0.18	0.05	0.09	0.14	0.40	0.34	0.10	0.05	0.06	0.07
	D	0.70	0.60	0.55	0.61	0.84	1.18	0.27	0.09	0.21	0.27	0.27	0.17	0.10	0.07	0.13	0.66
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.59	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.02	0.01	0.00	0.04	0.07	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

m/s = meters per second.

[a] SRS: Tower H, 10 meter tower height. Based on 2007 to 2011 meteorological data.

Note: To convert meters per second to miles per hour, multiply by 2.2369; meters to feet, by 3.2808.

C.2.2 Population Data

The INL Site, ORNL, and SRS population distributions were based on data from the 2010 census and the 2017 five-year American Community Survey update for areas within 50 miles of the locations for the proposed facilities. The 2010 populations derived from the census were projected to the year 2050, which was selected as the representative year for full-scale operations, by calculating a linear trend developed using data from the 2000 and 2010 decennial censuses and the 2017 American Community Survey (Census 2020a, 2020b, 2020c). The populations were spatially distributed on a circular grid with 16 directions and 10 radial distances out to 50 miles. The grids were centered at the proposed location for the VTR at the INL Site (just east of the Zero Power Physics Reactor [ZPPR] in the MFC), at the proposed location for the VTR at ORNL (less than a mile north-east of the High Flux Isotope Reactor [HFIR]), and at the K-Reactor Building in the K Area Complex (K Area) at SRS; the locations from which radionuclides were assumed to be released during incident-free operations at INL,[1] ORNL, and SRS, respectively. During the population distribution allocation process, those individuals who were geographically situated within a sector that was entirely on the INL Site, ORNL, or SRS property were moved (for the analysis) to an adjoining sector to ensure that no individuals were assessed as if they were living on DOE property. **Tables C–5**, **C–6**, and **C–7** present the population data used for the dose assessments.

Potential maximally exposed individual (MEI) locations at each site boundary for all 16 compass directions were evaluated to determine the boundary location with the highest total dose for all facilities associated with the alternatives evaluated in this VTR EIS. (This location differs from locations for the MEI from current operations.) This analysis was performed using population estimates for the year 2050. With an increasing population, an individual could live closer to the border than the current MEI (e.g., INL identifies the MEI as living 1.4 miles south of the INL border and northeast of the East Butte [a farm and cattle operation]). Therefore, a location at the site boundary was used. It was determined that an INL Site boundary location 3.1 miles south of the proposed VTR location at the MFC, yielded the highest annual MEI dose. For ORNL, the boundary location is 1.6 miles to the southeast of the proposed VTR location, on the east bank of Melton Valley Lake. For SRS (K Area), the boundary location is 6.6 miles south-southwest of the K Area. These are the distances and compass directions to this MEI location used in the GENII Version 2 modeling.

Table C–5. Estimated Population Within 50 Miles of INL-MFC in the Year 2050

Direction	Distance (miles)									
	0–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
E	0	0	0	0	0	73	223	1,974	20,268	55,812
ENE	0	0	0	0	0	0	286	409	512	738
ESE	0	0	0	0	0	94	398	10,151	126,556	7,896
N	0	0	0	0	0	0	0	104	42	63
NE	0	0	0	0	0	0	287	378	311	51
NNE	0	0	0	0	0	0	281	319	123	51
NNW	0	0	0	0	0	0	35	36	51	72
NW	0	0	0	0	0	0	33	143	328	367
S	0	0	0	8	4	38	153	7,320	13,636	45,759
SE	0	0	0	0	12	112	736	9,092	34,303	1,275
SSE	0	0	0	8	4	58	433	3,622	5,604	698
SSW	0	0	0	0	0	51	147	181	1,937	7,133
SW	0	0	0	0	0	0	178	175	234	573
W	0	0	0	0	0	0	34	35	52	139
WNW	0	0	0	0	0	0	0	158	283	425
WSW	0	0	0	0	0	0	114	56	105	220
Total Population										**363,570**

Note: Centered on 43.592755 degrees latitude N, 112.651649 degrees longitude W.
Source: Census 2020a, 2020b, 2020c.

[1] Additional sources of VTR-related releases at the INL Site include the Hot Fuel Examination Facility, Fuel Manufacturing Facility, Fuel Conditioning Facility, and Zero Power Physics Reactor. All of these facilities are located within the MFC, relatively close to the proposed location of the VTR. Separate population distributions centered on these facilities were not generated.

Table C–6. Estimated Population Surrounding Oak Ridge National Laboratory in the Year 2050

Direction	Distance (miles)									
	0–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
E	0	19	215	369	523	18,661	138,371	113,771	74,799	94,315
ENE	0	109	62	270	397	10,735	90,465	105,804	25,278	29,539
ESE	0	22	253	480	810	26,451	53,546	52,846	19,227	49,227
N	0	0	0	92	985	8,820	1,302	1,894	3,254	6,286
NE	0	46	0	7	0	5,957	22,494	15,732	12,145	11,378
NNE	0	0	0	0	402	16,223	9,824	20,221	17,109	6,882
NNW	0	0	0	328	1,150	5,732	1,997	1,528	9,190	9,257
NW	0	0	0	22	340	2,245	9,316	3,057	3,125	9,136
S	0	8	45	231	354	15,643	17,236	16,269	11,975	3,622
SE	0	76	255	478	1,458	18,195	30,638	51,497	962	1,741
SSE	0	27	180	300	701	10,067	11,359	11,586	2,873	4,354
SSW	0	0	25	188	246	3,381	16,525	19,607	32,906	17,150
SW	0	0	0	112	151	1,238	4,177	5,272	10,244	15,883
W	0	0	0	0	0	1,503	12,370	7,538	18,003	36,793
WNW	0	0	0	0	0	1,441	6,713	3,150	10,299	12,036
WSW	0	0	0	20	73	1,994	12,510	7,482	10,446	11,916
Total Population										**1,617,562**

Note: Centered on 35.925707 degrees latitude N, 84.290790 degrees longitude W.
Source: Census 2020a, 2020b, 2020c.

Table C–7. Estimated Population Surrounding Savannah River Site K Area in the Year 2050

Direction	Distance (miles)									
	0–1	1–2	2–3	3–4	4–5	5–10	10–20	20–30	30–40	40–50
E	0	0	0	0	0	0	4,912	2,575	4,444	3,774
ENE	0	0	0	0	0	6	2,299	4,411	5,750	22,437
ESE	0	0	0	0	0	51	1,026	1,942	2,194	3,221
N	0	0	0	0	0	0	15,044	45,274	8,158	16,239
NE	0	0	0	0	0	0	1,975	4,101	4,021	15,810
NNE	0	0	0	0	0	0	2,845	3,787	7,060	28,309
NNW	0	0	0	0	0	0	10,997	51,820	21,221	8,431
NW	0	0	0	0	0	94	6,368	124,148	177,640	11,342
S	0	0	0	0	0	62	523	1,607	5,153	7,461
SE	0	0	0	0	0	66	352	1,931	4,974	6,788
SSE	0	0	0	0	0	95	252	436	1,793	2,110
SSW	0	0	0	0	0	80	1,325	2,037	3,951	6,506
SW	0	0	0	0	0	168	1,026	1,905	1,974	2,430
W	0	0	0	0	0	186	2,642	4,954	4,223	4,376
WNW	0	0	0	0	0	152	3,953	75,035	76,496	20,717
WSW	0	0	0	0	0	242	2,558	7,519	1,756	5,364
Total Population										**888,904**

Note: Centered on 33.211800 degrees latitude N, 81.663915 degrees longitude W.
Source: Census 2020a, 2020b, 2020c.

Population distributions for use in the Environmental Justice analysis were developed in the same manner as described above for the total populations. These population distributions are presented in Attachment C1 to this appendix.

C.2.3 Agricultural Data

Ingestion exposures from atmospheric transport include ingestion of farm products and inadvertent ingestion of soil. Farm products include leafy vegetables, other vegetables, cereal grains, fruit, cow's milk, beef, poultry, and eggs. The concentration in plants at the time of harvest was evaluated as the sum of contributions from deposition onto plant surfaces, as well as uptake through the roots. Pathways by which animal products may become contaminated include animal ingestion of contaminated plants, water, and soil. Site-specific agricultural data were not developed. This analysis used the generic agricultural production data and the human consumption rates provided in the GENII code for both the population and MEI calculations.

C.2.4 Source Term Data

Table C–8 presents the stack parameters for INL, ORNL, and SRS facilities. Stack heights, sizes, velocities, temperatures, and release locations were provided in the responses to the facility data requests supporting this VTR EIS (INL 2020a; SRNS 2020). These parameters affect the distribution of radioactive emissions from the stacks. **Table C–9** identifies the VTR-related activities associated with each facility identified in Table C–8.

Table C–8. Stack Parameters

Stack Parameter	*VTR (Radwaste HVAC)*	*VTR (RVACS exhaust)*	*HFEF*	*FMF*	*FCF*	*ZPPR*	*ORNL Hot Cell Facility* [a]	*K-Reactor Building* [b]
Height (feet)	99	98	95	46	200	75	95	124
Area (square feet)	3.1	38 [c]	17.4	7.1	19.6	3.0	20	7.1
Flow Velocity (feet/second)	450 [d]	3.9 [d]	40.7	15.1 [d]	29.6	27.9	44	42
Average Temperature (°F)	105	<500	72.3	64	72 [e]	68	72.3	72

FCF = Fuel Conditioning Facility; FMF = Fuel Manufacturing Facility; HFEF = Hot Fuel Examination Facility; HVAC = heating, ventilation, and air conditioning; RVACS = Reactor Vessel Auxiliary Cooling System; VTR = Versatile Test Reactor, ZPPR = Zero Power Physics Reactor.

[a] Parameters for this facility were estimated based on the HFEF stack parameters and adjusted for the larger size of the facility

[b] Final height, area, and location would be refined when a design is finalized. Some parameters are estimated based on existing K-Reactor Building stack.

[c] RVACS has four stacks, exhaust area is for each stack.

[d] Calculated based on area and flow rates provided.

[e] Discharge is at ambient temperature.

Table C–9. Locations used for VTR-Related Activity Stack Emissions

Activity	*Facility Location*		
	INL	*ORNL*	*SRS*
VTR Operation [a]	VTR	VTR	–
Post-Irradiation Examination	HFEF	Hot Cell Facility	–
Spent Fuel Treatment	FCF	Hot Cell Facility	–
Feedstock Preparation	FCF	–	K Area
Fuel Fabrication	FMF/ZPPR	–	K Area

FCF = Fuel Conditioning Facility; FMF = Fuel Manufacturing Facility; HFEF = Hot Fuel Examination Facility; VTR = Versatile Test Reactor; ZPPR = Zero Power Physics Reactor.

[a] Most emissions are from the facility HVAC stack. However, activated argon is in the air emitted from the RVACS stack.

As discussed in Appendix B, at INL the final fuel assembly fabrication step would be performed in ZPPR. At ZPPR fuel assemblies would be fabricated using fuel rods produced at FMF. Few if any emissions would result from this portion of the fuel assembly fabrication process. At INL, irradiated test articles would be transferred to the Hot Fuel Examination Facility (HFEF) for decontamination, initial examination, and preparation for transfer to additional examination facilities. While other MFC facilities would be used for further examination, the emissions from HFEF are used to represent the total post-irradiation examination emissions. Similarly, at ORNL where additional existing facilities would be used for post-irradiation examination, the post-irradiation examination releases are modeled as coming from the new hot cell facility.

Tables C–10 through **C–14,** respectively, present the estimated incident-free radiological releases (source terms), based on the following activities: VTR operation, test article post-irradiation examination, VTR spent fuel treatment, VTR feedstock preparation, and reactor fuel fabrication. The source terms were provided in responses to facility data requests supporting this VTR EIS (INL 2020a; SRNS 2020). The source terms are based on emissions from INL and SRS facilities or proposed projects and scaled to adjust for the types and quantities of expected emissions from VTR facilities.

All releases, except for the argon released from the VTR RVACS, would be filtered through high efficiency particulate air (HEPA) filters. The real-world performance of multiple stages of HEPA filters has been well demonstrated and experimental testing confirms the performance of HEPA filters for uranium and plutonium particles. The independent Defense Nuclear Facilities Safety Board thoroughly evaluated the use of HEPA filters by DOE) and has issued multiple reports on the performance of HEPA filters within the DOE complex. HEPA filters used in support of the VTR activities would conform to the latest version of DOE Standard "Specifications for HEPA Filters Used by DOE Contractors," DOE-STD-3020-2015. Performance testing required by this standard for all HEPA filters credited for safety would ensure that the filters meet or exceed the performance requirements assumed in safety evaluations.

For the post-irradiation examination operational releases (Table C–11), the isotopes in bold are those that contributed at least 0.1 percent of the total offsite dose from MFC operations in 2018 based on the INL Annual Site Environmental Report (INL 2019). Other isotopes listed are those with releases greater than 10^{-10} curies. Spent fuel treatment releases, Table C–12, are limited to those with releases greater than 10^{-10} curies per year.

Source terms were determined to be independent of the location for the VTR and its associated facilities, feedstock preparation, and fuel fabrication, e.g., the VTR source term would be the same whether the VTR were located at the INL Site or ORNL.

Table C–10. Annual Radiological Releases from Versatile Test Reactor Operation

Isotope	*Curies*	*Isotope*	*Curies*
Argon-41	27.1 [a]	Krypton-88	8.9×10^{-6}
Cesium-135	9.0×10^{-16}	Xenon-131m	1.6×10^{-2}
Cesium-137	1.2×10^{-12}	Xenon-133	1.0×10^{-3}
Cesium-138	2.0×10^{-6}	Xenon-133m	5.4×10^{-7}
Hydrogen-3 (Tritium)	1.2	Xenon-135	4.2×10^{-5}
Krypton-83m	1.8×10^{-6}	Xenon-135m	1.5×10^{-6}
Krypton-85	0.70	Xenon-137	7.4×10^{-7}
Krypton-85m	3.5×10^{-6}	Xenon-138	4.4×10^{-6}
Krypton-87	4.8×10^{-6}		

[a] Argon is released through both the VTR plant stack (0.14 curies) and the RVACS stacks (27 curies due to air activation).

Source: INL 2020a, 2020b.

Table C–11. Annual Radiological Releases from Post-Irradiation Examination Operations

Isotope	Release (curies)	Isotope	Release (curies)
Antimony-125	3.2×10^{-5}	Krypton-85	4.4×10^{-3}
Americium-241	**8.4×10^{-12}**	Neptunium-237	3.2×10^{-9}
Carbon-14	**3.1×10^{-4}**	Phosphorus-32	2.6×10^{-5}
Cadmium-109	5.2×10^{-4}	Phosphorus-33	4.9×10^{-9}
Cadmium-115m	1.0×10^{-7}	**Plutonium-238**	**1.2×10^{-10}**
Chlorine-36	1.0×10^{-5}	**Plutonium-239**	**9.5×10^{-8}**
Cobalt-60	**7.9×10^{-13}**	**Plutonium-240**	**3.0×10^{-12}**
Cesium-134	8.0×10^{-7}	Plutonium-242	1.8×10^{-9}
Cesium-137	**2.5×10^{-2}**	Sodium-22	3.2×10^{-6}
Hydrogen-3 (Tritium)	**3.7×10^{-2}**	Sodium-24	1.7×10^{-8}
Iodine-129	**1.8×10^{-5}**	Sulfur-35	1.2×10^{-4}
Iodine-131	8.9×10^{-3}	**Strontium-90**	**3.8×10^{-7}**

Source: INL 2020a, 2020b.

Table C–12. Annual Radiological Releases from Spent Fuel Treatment

Isotope	Curies	Isotope	Curies
Cadmium-113m	4.2×10^{-10}	Nickel-63	2.8×10^{-10}
Cerium-144	1.4×10^{-6}	Promethium-147	1.3×10^{-7}
Cesium-134	2.6×10^{-7}	Plutonium-238	1.2×10^{-10}
Cesium-137	2.0×10^{-6}	Plutonium-239	2.8×10^{-9}
Cobalt-60	2.1×10^{-9}	Plutonium-240	1.9×10^{-10}
Europium-154	1.7×10^{-10}	Plutonium-241	1.2×10^{-9}
Europium-155	2.1×10^{-9}	Ruthenium-106	5.7×10^{-6}
Iron-55	5.5×10^{-8}	Antimony-125	1.6×10^{-7}
Hydrogen-3 (Tritium)	5.1×10^{2}	Samarium-151	9.0×10^{-10}
Krypton-85	8.3×10^{3}	Strontium-90	3.5×10^{-8}

Source: INL 2020a, 2020b.

Table C–13. Annual Radiological Releases from Feedstock Preparation

Isotope	Curies	Isotope	Curies
Americium-241	6.6×10^{-4}	Uranium-232	5.8×10^{-12}
Plutonium-238	9.5×10^{-6}	Uranium-234	1.7×10^{-9}
Plutonium-239	9.6×10^{-6}	Uranium-235	1.5×10^{-11}
Plutonium-240	1.4×10^{-5}	Uranium-236	2.2×10^{-10}
Plutonium-241	2.0×10^{-4}	Uranium-238	4.3×10^{-11}
Plutonium-242	2.2×10^{-8}		

Source: Adapted from SRNS 2020.

Table C–14. Annual Radiological Releases from Fuel Fabrication

Isotope	Curies	Isotope	Curies
Americium-241	3.3×10^{-4}	Uranium-232	7.3×10^{-12}
Plutonium-238	2.3×10^{-6}	Uranium-234	2.2×10^{-9}
Plutonium-239	3.7×10^{-6}	Uranium-235	1.9×10^{-11}
Plutonium-240	2.4×10^{-6}	Uranium-236	2.8×10^{-10}
Plutonium-241	5.7×10^{-5}	Uranium-238	5.4×10^{-11}
Plutonium-242	1.7×10^{-9}		

Source: Adapted from SRNS 2020.

Because activities associated with spent fuel storage only involve movement and storage of materials within certified containers, no significant airborne radiological emissions would result from these activities.

C.2.5 Other Calculation Assumptions

To estimate the radiological impacts of incident-free operation of the VTR facilities, the following additional assumptions and factors were considered, in accordance with the guidelines established in NRC Regulatory Guide 1.109 (NRC 1977):

- All receptors were assumed to be exposed to radioactive material deposited on the ground from facility emissions. Exposure pathways include direct exposure from air immersion and ground exposure, inhalation, and translocation through the food chain.
- The annual exposure time to the plume (for inhalation and immersion) and soil contamination was assumed to be 0.7 years for the MEI.
- The annual exposure time to the plume (for inhalation and immersion) and soil contamination was assumed to be 0.5 years for the population.
- The annual exposure time to the plume (for inhalation and immersion) was assumed to be 1 year for the MEI, average individual and general population.
- Noninvolved worker exposure was limited to the plume and resuspension pathways; ingestion exposure pathways were not considered. The annual exposure time to the plume (for inhalation and immersion) was assumed to be 2,500 hours.
- All receptors were assumed to have the characteristics and habits (e.g., inhalation and ingestion rates) of adult humans.
- The GENII model uses a finite plume (i.e., Gaussian) model for air immersion doses. Other pathways evaluated were ground exposure, inhalation, ingestion of food crops, and ingestion of animal products.
- The calculated internal doses were assumed to be the 50-year committed effective dose equivalent from 1 year of emissions.
- At the INL Site all releases relating to post-irradiation examination were modeled as being emitted from the HFEF. Most post-irradiation examination releases are anticipated to be from this facility.
- Two release points exist for the VTR, the HVAC exhaust and the RVACS stack. Only one release point was modeled, the HVAC exhaust. The release from the RVACS stack (argon-41) was combined with the other radionuclides released from the HVAC exhaust.

In addition to the calculation assumptions listed above, a risk estimator of 0.0006 latent cancer fatalities per rem or person-rem (600 cancer deaths per 1 million rem or person-rem) received by workers or members of the public is used in the impact assessments (DOE 2003a).

C.3 Results for Idaho National Laboratory

The following subsections present the potential incident-free radiological impacts that could occur from VTR operation, feedstock preparation, and reactor fuel fabrication at the INL Site. Radiological impacts from VTR operation include impacts from operation of the VTR, test article post-irradiation examination, and spent fuel treatment and storage. Human health risks from construction and normal operations are evaluated for several individuals, including a noninvolved worker, a hypothetical MEI at the site boundary, and an average member of the public. Human health risk from construction and normal operations are also evaluated for the offsite population within 50 miles of the MFC.

For the purposes of this VTR EIS, an involved worker[2] (worker) is a facility worker who is directly or indirectly involved with operations at a facility and might receive an occupational radiation exposure due to direct radiation (neutron, x-ray, beta, or gamma) or through radionuclides released as a part of normal VTR-related operations. Noninvolved workers are assumed to be outside of the facility would not be subject to direct radiation exposure due to building shielding and appreciable distances between operational facilities, but could be exposed to operational releases.

Materials released from VTR-related operations activities include both particulates and fission product gases. All material would be released through facility stacks. Particulates would be filtered through HEPA filters and gases would be absorbed by charcoal bed absorbers in the VTR exhaust system. Normal releases would be very small, in the millicurie to less than millicurie-per-year quantities, in most cases. But argon, tritium, and krypton would be released in curie quantities.

Materials released due to feedstock preparation and fuel fabrication would be particulates (primarily plutonium and uranium isotopes and americium-241) that would be released through tall stacks. Particulates would be filtered through HEPA filters before being released. These filter systems are designed to protect the onsite workforce and the public from normal and accidental releases. Normal releases from all facilities would be very small—in the microcurie to less than millicurie-per-year.

C.3.1 Construction

There would be no radiological risk to members of the public from potential construction of the VTR or modification of the INL MFC facilities. VTR construction would occur in an undeveloped area adjacent to the ZPPR at MFC where worker exposures would be to background radiation only. Modifications to equipment within facility hot cells (fuel and sampling equipment replacement within HFEF and the Fuel Conditioning Facility [FCF]) are anticipated. Modification work within the HFEF would not result in worker exposures beyond those currently being experienced. However, modification work in the FCF to support spent fuel treatment and in the Fuel Manufacturing Facility (FMF) and ZPPR to support reactor fuel fabrication occurs in an area where workers would be expected to receive an operational dose. Equipment would be designed, assembled, and tested in radiologically clean areas. Installation of the equipment within the hot cells would be performed remotely. To enable feedstock preparation and fuel fabrication, new gloveboxes and supporting equipment would be installed in the FMF and FCF, and new fuel pin handling and fuel assembly fabrication and handling equipment would be installed in ZPPR. Radiological and nonradiological worker impacts associated with these construction efforts are provided in Chapter 4.

C.3.2 Operations

Under the INL VTR Alternative and the INL reactor fuel production options, the following program activities could occur at the INL Site and could result in doses to the public and a noninvolved worker:

VTR Operation. Operation would include:

- *VTR Reactor Operations*. Multiple fuel cycles would be run each year. Reactor operation would be the principle source of potential normal releases. Fuel and test article handling, washing, and movement would also occur, but these activities would be performed within fuel and test article casks.

[2] Involved worker impacts are calculated for the VTR project. However, the analysis of worker dose (average individual and collective worker population dose) is performed simply based on the number of workers involved in VTR-related activities, and the expected exposure received during these activities. Involved worker doses are estimated based on existing environmental conditions at the sites or based upon analysis of worker activities resulting in exposure. Radiological impacts to involved workers are provided in Chapter 4 of this EIS.

- *Post-Irradiation Examination*. Test articles would be transferred to the HFEF for decontamination and initial post-irradiation examination. Test articles, in whole or in part, could be sent to additional INL facilities for further examination
- *Spent Fuel Treatment*. Fuel removed from the reactor core would be stored, for up to a year within the VTR reactor vessel and for at least 3 years on a storage pad. Fuel would then be transferred to the FCF for treatment (sodium bond removal and fuel downblending with a diluent) and repackaging. Treated spent fuel would be returned to the storage pad pending transfer to an offsite repository.

Feedstock Preparation. Non-metallic plutonium feed would be converted into metal and plutonium with unacceptable levels of impurities would be polished. All activities would be performed in gloveboxes designed and installed specifically for feedstock preparation within the FCF. The polished metallic plutonium product would be used as feed for fuel fabrication.

Fuel Fabrication. Fuel fabrication would include plutonium, uranium, and zirconium melting and alloying, casting of fuel pins, and fabrication of fuel assemblies. Melting, alloying and pin casting would all be performed in gloveboxes. All operations would take place in FMF and ZPPR.

Additional details about these operations are provided in Appendix B.

Tables C–15 through **C–17** present the projected incident-free radiological impacts on a noninvolved worker and the public from VTR-related operations at MFC.

Table C–15. Radiological Impacts on a Noninvolved Worker and the Public from the INL VTR Alternative

	Noninvolved Worker	***Maximally Exposed Individual***	***Population***	***Average Individual***
Annual dose	0.0021 millirem	0.0068 millirem	0.044 person-rem	1.2×10^{-4} millirem [a]
Regulatory dose limit [b]	--	10 millirem	--	10 millirem
Annual LCF risk [c]	1×10^{-9}	4×10^{-9}	0 (3×10^{-5})	Less than 1×10^{-10}
Percent of natural background radiation [d]	0.0006	0.002	3×10^{-5}	3×10^{-5}

FCF = Fuel Conditioning Facility; HFEF = Hot Fuel Examination Facility; LCF = latent cancer fatality; VTR = Versatile Test Reactor.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the INL facilities in 2050 (approximately 379,265 for MFC).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals; projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for the INL Site is 383 millirem for the average individual (INL 2019); the population within 50 miles of MFC in 2050 would receive a dose of about 145,000 person-rem.

Table C–16. Radiological Impacts on a Noninvolved Worker and the Public from the INL Feedstock Preparation Option

	Noninvolved Worker	*Maximally Exposed Individual*	*Population*	*Average Individual*
Annual dose	0.0017 millirem	0.0012 millirem	0.012 person-rem	3.2×10^{-5} millirem [a]
Regulatory dose limit [b]	--	10 millirem	--	10 millirem
Annual LCF risk [c]	1×10^{-9}	7×10^{-10}	0 (7×10^{-6})	Less than 1×10^{-10}
Percent of natural background radiation [d]	0.0004	0.0003	8×10^{-6}	8×10^{-6}

LCF = latent cancer fatality.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the INL facilities in 2050 (approximately 379,265 for MFC).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals; projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for the INL Site is 383 millirem for the average individual (INL 2019); the population within 50 miles of MFC in 2050 would receive a dose of about 145,000 person-rem.

Table C–17. Radiological Impacts on a Noninvolved Worker and the Public from the INL Fuel Fabrication Option

	Noninvolved Worker	*Maximally Exposed Individual*	*Population*	*Average Individual*
Annual dose	0.067 millirem	0.0016 millirem	0.0053 person-rem	1.5×10^{-5} millirem [a]
Regulatory dose limit [b]	--	10 millirem	--	10 millirem
Annual LCF risk [c]	1×10^{-7}	1×10^{-9}	0 (3×10^{-6})	Less than 1×10^{-10}
Percent of natural background radiation [d]	0.02	0.0004	4×10^{-6}	4×10^{-6}

FCF = Fuel Conditioning Facility; LCF = latent cancer fatality; ZPPR = Zero Power Physics Reactor.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the INL facilities in 2050 (approximately 379,265 for MFC).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals, projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for the INL Site is 383 millirem for the average individual (INL 2019); the population within 50 miles of MFC in 2050 would receive a dose of about 145,000 person-rem.

As indicated by the results for the MEI, the annual potential doses from normal releases (on the order of 0.0035 to 0.0057 millirem) are small fractions (less than or about 0.002 percent) of the natural background radiation dose of 383 millirem per year (see Chapter 3, Section 3.1.10). A conservative estimate of the dose to a noninvolved INL worker is also calculated. Assuming no shielding, a location within MFC near about 200 meters from the VTR INL fuel fabrication facility release point would result in the highest dose to the noninvolved worker, an incremental annual dose of about 0.067 millirem. (Doses to the noninvolved worker located 300 meters from VTR operations and 400 meters from feedstock preparation, would have lower annual doses from the operation of these facilities.) This dose is small relative to the dose from natural background radiation and much smaller than the dose an involved worker would receive.

Worker impacts for these operations are provided in Chapter 4.

C.4 Results for Oak Ridge National Laboratory

The following subsections present the potential incident-free radiological impacts that could occur from VTR operations at ORNL under the ORNL VTR Alternative. Human health risks from construction and normal operations are evaluated for several individual and population groups; including noninvolved workers, a hypothetical MEI at the site boundary, and an average member of the public. Human health risk from construction and normal operations are also evaluated for the offsite population within 50 miles of the proposed VTR location. As stated in Section C.4 the impacts to involved workers are discussed in Chapter 4.

Materials released from VTR-related operations activities include both particulates and fission product gases. All material would be released through facility stacks. Particulates would be filtered HEPA filters and gases would be absorbed by charcoal bed absorbers in the VTR exhaust system. Most material would be released in less than millicurie-per-year quantities, although argon, tritium, and krypton would be release in curie quantities.

C.4.1 Construction

There would be no radiological risk to members of the public or workers from construction of the VTR and the Hot Cell Facility at ORNL. Construction would occur in an undeveloped area where worker exposures would be to background radiation only. No radiological emissions that could impact the public would result from construction.

Nonradiological worker impacts for these operations are provided in Chapter 4.

C.4.2 Operations

Under the ORNL VTR Alternative the following program activities could occur at ORNL and could result in doses to the public:

- *VTR Reactor Operations*. Multiple fuel cycles would be run each year. Reactor operation would be the principle source of potential normal releases. Fuel and test article handling, washing, and movement would also occur, but these activities would be performed within fuel and test article casks.
- *Post-Irradiation Examination*. Test articles would be transferred to the Hot Cell Facility for decontamination and initial post-irradiation examination. Test articles, in whole or in part, could be sent to additional ORNL facilities for further examination
- *Spent Fuel Treatment*. Fuel removed from the reactor core would be stored for up to a year within the VTR reactor vessel and for at least 3 years on a storage pad. Fuel would then be transferred to the Hot Cell Facility for treatment (sodium bond removal and fuel downblending with a diluent) and repackaging. Treated spent fuel would be returned to the storage pad pending transfer to an offsite repository.

Additional details about these operations are provided in Appendix B.

Tables C–18 presents the projected incident-free radiological impacts on a noninvolved worker and the public from operations at the VTR and Hot Cell Facility.

As indicated by the results for the MEI, the annual potential doses from normal releases (on the order of 0.031 millirem) would be a small fraction (approximately 0.01 percent) of the natural background radiation dose of 300 millirem per year (see Chapter 3, Section 3.3.10). A conservative estimate of the dose to a noninvolved ORNL worker is also calculated. The proposed VTR site would not be within any of the currently developed areas of ORNL. The nearest continuously occupied area to the proposed VTR site would be the HFIR complex (about 4,700 feet), the 7000 area (about 3,700 feet), the ORNL main campus (about 5,400 feet) and the Energy System Test Complex (about 4,800 feet). Assuming no shielding, a location at the ORNL Energy System Test Complex would result in the highest dose to the noninvolved worker, an incremental annual dose of about 0.0048 millirem. This dose is small compared to the dose from natural background radiation and much smaller than the dose an involved worker would receive.

Worker impacts for these operations are provided in Chapter 4.

Table C–18. Radiological Impacts on a Noninvolved Worker and the Public from the ORNL VTR Alternative

	Noninvolved Worker	*Maximally Exposed Individual*	*Population*	*Average Individual*
Annual dose	0.0048 millirem	0.031 millirem	0.58 person-rem	3.6×10^{-4} millirem [a]
Regulatory dose limit [b]	--	10 millirem	--	10 millirem
Annual LCF risk [c]	3×10^{-9}	2×10^{-8}	0 (3×10^{-4})	2×10^{-10}
Percent of natural background radiation [d]	0.002	0.01	0.0001	0.0001

LCF = latent cancer fatality.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the ORNL facilities in 2050 (approximately 1,553,177 for the proposed VTR site).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals; projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for ORNL is 300 millirem for the average individual (ORO 2019); the population within 50 miles of the proposed VTR site in 2050 would receive a dose of about 466,000 person-rem.

C.5 Results for Savannah River Site

The following subsections present the potential incident-free radiological impacts that could occur from feedstock preparation and reactor fuel fabrication at SRS. Human health risks from construction and normal operations are evaluated for several individuals, including a noninvolved worker, a hypothetical MEI at the site boundary, and an average member of the public. Human health risk from construction and normal operations are also evaluated for the offsite population within 50-miles of the SRS K Area. As stated in Section C.4 the impacts to involved workers are discussed in Chapter 4.

All of the materials released due to feedstock preparation and fuel fabrication would be particulates (primarily plutonium and uranium isotopes and americium-241) that would be released through a new facility stack. Particulates would be filtered through HEPA filters before being released. These filter systems are designed to protect the onsite workforce and the public from normal and accidental releases. Normal releases would be very small—in the microcurie to less than millicurie-per-year range.

C.5.1 Construction

There would be no radiological risk to members of the public from potential construction or modification of facilities at the K Area. Construction worker exposures to radiation derived from other activities at the site, past or present, would be kept ALARA. Construction workers would be monitored (badged), as appropriate. Limited demolition, removal, and decontamination actions within the K-Reactor buildings would be required to support installation of new equipment. Construction activities would include 3 years of decontamination and equipment removal from K Area. To enable feedstock preparation and fuel fabrication, new gloveboxes and supporting equipment would be installed in the K Area. Radiological and nonradiological worker impacts associated with this construction effort are provided in Chapter 4.

C.5.2 Operations

Under the fuel production options the following possible program activities could occur at SRS and would result in doses to the public:

- *Feedstock Preparation.* Non-metallic plutonium feed would be converted into metal and plutonium with unacceptable levels of impurities would be polished. All activities would be performed in gloveboxes designed and installed specifically for feedstock preparation located in the K Area. The polished metallic plutonium product would be used as feed for fuel fabrication.
- *Fuel Fabrication*. Fuel fabrication would include plutonium, uranium, and zirconium melting and alloying, casting of fuel pins, and fabrication of fuel assemblies. Melting, alloying, and pin casting would all be performed in gloveboxes. All operations would take place in the K Area.

Additional details about these operations are provided in Appendix B.

Tables C–19 and **C–20** present the projected incident-free radiological impacts on a noninvolved worker and the public from operations at the K Area.

Table C–19. Radiological Impacts on a Noninvolved Worker and the Public from the SRS Feedstock Preparation Option

	Noninvolved Worker	*Maximally Exposed Individual*	*Population*	*Average Individual*
Annual dose	0.0061 millirem	0.0015 millirem	0.042 person-rem	4.7×10^{-5} millirem [a]
Regulatory dose limit [b]	–	10 millirem	–	10 millirem
Annual LCF risk [c]	4×10^{-9}	9×10^{-10}	0 (2×10^{-5})	Less than 1×10^{-10}
Percent of natural background radiation [d]	0.002	0.0005	2×10^{-5}	2×10^{-5}

LCF = latent cancer fatality.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the SRS facilities in 2050 (approximately 885,150 for K Area).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals; projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for SRS is 311 millirem for the average individual (SRNS 2019); the population within 50 miles of K Area in 2050 would receive a dose of about 277,000 person-rem.

Table C–20. Radiological Impacts on a Noninvolved Worker and the Public from SRS Fuel Fabrication Option

	Noninvolved Worker	*Maximally Exposed Individual*	*Population*	*Average Individual*
Annual dose	0.0030 millirem	0.00071 millirem	0.020 person-rem	2.3×10^{-5} millirem [a]
Regulatory dose limit [b]	--	10 millirem	--	10 millirem
Annual LCF risk [c]	2×10^{-9}	4×10^{-10}	0 (1×10^{-5})	Less than 1×10^{-10}
Percent of natural background radiation [d]	0.001	0.0002	7×10^{-6}	7×10^{-6}

LCF = latent cancer fatality.

[a] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the SRS facilities in 2050 (approximately 885,150 for K Area).

[b] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

[c] LCF risk for individuals; projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[d] The annual natural background radiation dose assumed for SRS is 311 millirem for the average individual (SRNS 2019); the population within 50 miles of K Area in 2050 would receive a dose of about 277,000 person-rem.

As indicated by the results for the MEI, the annual potential doses from normal releases (between 0.00071 and 0.0015 millirem) would be small fractions (less than 0.001 percent) of the natural background radiation dose of 311 millirem per year (see Chapter 3, Section 3.3.10). A conservative estimate of the dose to a noninvolved SRS worker is also calculated. Assuming no shielding, a location 500 meters from the K-Reactor Building would result in the highest dose to the noninvolved worker, an incremental annual dose of between 0.003 and 0.006 millirem. This dose is small compared to the dose from natural background radiation and much smaller than the dose an involved worker would receive.

Worker impacts for these operations are provided in Chapter 4.

C.6 Environmental Justice Results

Tables C–21 through **C–23** present the results of the population and average individual impact assessments for minority and low-income populations. These impacts are calculated in the same manner as the impacts for the total populations. The population distributions for the Total Minority, African American, Native American, White Hispanic, Other Minority, and Low-Income groups (provided in Attachment C1 to this appendix) are used in place of the total population distributions. All other exposure parameters for the population from the general population analysis are used.

A separate MEI calculation was not performed for these groups. The MEI is assumed to be an individual located at the site boundary where the highest individual dose occurs. No specific attributes of a minority or low-income individual were identified that would indicate that the exposure parameters should be modified to address unique characteristics of a minority or low-income MEI.

Table C–21. Radiological Impacts on Minority and Low-Income Populations from VTR-Related Operations at INL – MFC

	Total Minority	*African American*	*Native American*	*White Hispanic*	*Other Minority*	*Low Income*
INL VTR Alternative						
Population						
Annual dose (person-rem)	0.0084	0.00027	0.00073	0.0028	0.0060	0.0062
Annual LCF [a]	0 (5×10^{-6})	0 (2×10^{-7})	0 (4×10^{-7})	0 (2×10^{-6})	0 (4×10^{-6})	0 (4×10^{-6})
Annual dose from natural background radiation [b] (person-rem)	29,000	830	1,700	7,800	18,000	21,000
Percent of natural background radiation	3×10^{-5}	3×10^{-5}	4×10^{-5}	4×10^{-5}	3×10^{-5}	3×10^{-5}
Average Individual [c]						
Annual dose (millirem) [d]	0.00011	0.00013	0.00017	0.00014	0.00013	0.00011
Annual LCF Risk [c]	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}
INL Feedstock Preparation Option						
Population						
Annual dose (person-rem)	0.0026	7.3×10^{-5}	0.00019	0.00072	0.0016	0.0016
Annual LCF [a]	0 (2×10^{-6})	0 (4×10^{-8})	0 (1×10^{-7})	0 (5×10^{-7})	0 (1×10^{-6})	0 (1×10^{-6})
Annual dose from natural background radiation [b] (person-rem)	29,000	830	1,700	7,800	18,000	21,000
Percent of natural background radiation	1×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Average Individual [c]						
Annual dose (millirem) [d]	3.5×10^{-5}	3.4×10^{-5}	4.4×10^{-5}	3.7×10^{-5}	3.4×10^{-5}	3.0×10^{-5}
Annual LCF Risk [c]	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}

	Total Minority	*African American*	*Native American*	*White Hispanic*	*Other Minority*	*Low Income*
INL Fuel Fabrication Option						
Population						
Annual dose (person-rem)	0.0012	3.3×10^{-5}	8.4×10^{-5}	0.00034	0.00073	0.00072
Annual LCF [a]	0 (7×10^{-7})	0 (2×10^{-8})	0 (5×10^{-8})	0 (2×10^{-7})	0 (4×10^{-7})	0 (4×10^{-7})
Annual dose from natural background radiation [b] (person-rem)	29,000	830	1,700	7,800	18,000	21,000
Percent of natural background radiation	4×10^{-6}	4×10^{-6}	5×10^{-6}	4×10^{-6}	4×10^{-6}	3×10^{-6}
Average Individual [c]						
Annual dose (millirem) [d]	1.6×10^{-5}	1.5×10^{-5}	1.9×10^{-5}	1.7×10^{-5}	1.5×10^{-5}	1.3×10^{-5}
Annual LCF Risk [c]	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}

LCF = latent cancer fatality.

[a] LCF risk for individuals, projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[b] The annual natural background radiation dose assumed for the INL Site is 383 millirem for the average individual (INL 2019).

[c] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the proposed INL VTR facilities at MFC in 2050 (populations are provided in Attachment C1 to this appendix).

[d] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

Table C–22. Radiological Impacts on Minority and Low-Income Populations from the ORNL VTR Alternative

	Total Minority	*African American*	*Native American*	*White Hispanic*	*Other Minority*	*Low Income*
Population						
Annual dose (person-rem)	0.093	0.023	0.0019	0.017	0.051	0.087
Annual LCF [a]	0 (6×10^{-5})	0 (1×10^{-5})	0 (1×10^{-6})	0 (1×10^{-5})	0 (3×10^{-5})	0 (5×10^{-5})
Annual dose from natural background radiation [b] (person-rem)	90,000	22,000	2,100	12,000	54,000	78,000
Percent of natural background radiation	1×10^{-4}	1×10^{-4}	9×10^{-5}	1×10^{-4}	1×10^{-4}	1×10^{-4}
Average Individual [c]						
Annual dose (millirem) [d]	0.00031	0.00033	0.00027	0.00042	0.00028	0.00034
Annual LCF Risk [a]	2×10^{-10}	2×10^{-10}	2×10^{-10}	3×10^{-10}	2×10^{-10}	2×10^{-10}

LCF = latent cancer fatality.

[a] LCF risk for individuals, projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[b] The annual natural background radiation dose assumed for ORNL is 300 millirem for the average individual (ORO 2019).

[c] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the proposed ORNL VTR facilities in 2050 (populations are provided in Attachment C1 to this appendix).

[d] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

Table C–23. Radiological Impacts on Minority and Low-Income Populations from the SRS Fuel Production Options

	Total Minority	***African American***	***Native American***	***White Hispanic***	***Other Minority***	***Low Income***
SRS Feedstock Preparation Option						
Population						
Annual dose (person-rem)	0.022	0.017	0.00011	0.0011	0.0034	0.0079
Annual LCF [a]	0 (1×10^{-5})	0 (1×10^{-5})	0 (7×10^{-8})	0 (7×10^{-7})	0 (2×10^{-6})	0 (5×10^{-6})
Annual dose from natural background radiation [b]	140,000	100,000	700	8,100	25,000	49,000
Percent of natural background radiation	2×10^{-5}	2×10^{-5}	2×10^{-5}	1×10^{-5}	1×10^{-5}	2×10^{-5}
Average Individual [c]						
Annual dose (millirem) [d]	5.0×10^{-5}	5.2×10^{-5}	5.0×10^{-5}	4.3×10^{-5}	4.2×10^{-5}	5.1×10^{-5}
Annual LCF Risk [a]	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}
SRS Fuel Fabrication Option						
Population						
Annual dose (person-rem)	0.011	0.0083	5.6×10^{-5}	0.00054	0.0017	0.0039
Annual LCF [a]	0 (6×10^{-6})	0 (5×10^{-6})	0 (3×10^{-8})	0 (3×10^{-7})	0 (1×10^{-6})	0 (2×10^{-6})
Annual dose from natural background radiation [b]	140,000	100,000	700	8,100	25,000	49,000
Percent of natural background radiation	8×10^{-6}	8×10^{-6}	8×10^{-6}	7×10^{-6}	7×10^{-6}	8×10^{-6}
Average Individual [c]						
Annual dose (millirem) [b]	2.4×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.1×10^{-5}	2.0×10^{-5}	2.5×10^{-5}
Annual LCF Risk [a]	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}	Less than 1×10^{-10}

LCF = latent cancer fatality.

[a] LCF risk for individuals, projected number of fatalities for the population. Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses.

[b] The annual natural background radiation dose assumed for SRS is 311 millirem for the average individual (SRNS 2019).

[c] Obtained by dividing the population dose by the number of people projected to live within 50 miles of the proposed SRS fuel preparation facilities in 2050 (populations are provided in Attachment C1 to this appendix).

[d] 40 CFR Part 61, Subpart H, establishes an annual limit of 10 millirem via the air pathway to any member of the public from DOE operations.

C.7 References

American Cancer Society, 2020, *Cancer Facts & Figures 2020*, Atlanta, Georgia.

CDC (Centers for Disease Control and Prevention), 2020, Mortality in the United States 2018, NCHS Data Brief No. 355, National Center for Health Statistics, January.

Census (U.S. Census Bureau), 2020a, 2019 Tiger/Line Shapefiles: Block Groups (available at https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2019&layergroup=Block+Groups), March.

Census (U.S. Census Bureau), 2020b, American FactFinder, B03002 Hispanic or Latin Origin by Race (available at https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t#none), March.

Census (U.S. Census Bureau), 2020c, American FactFinder, C17002 Ratio of Income to Poverty Level in the past 12 Months (available at https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t#none), March.

DOE (U.S. Department of Energy), 2003a, *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE), ISCORS Technical Report No. 1,* DOE/EH-412/0015/0802, Rev. 1, Office of Environmental Policy and Guidance, Washington, DC, January.

DOE (U.S. Department of Energy), 2003b, *GENII Computer Code Application Guidance for Documented Safety Analysis, Interim Report*, DOE-EH-4.2.1.4-Interim-GENII, Rev. 1, Office of Environment, Safety and Health, Washington, DC, September.

DOE (U.S. Department of Energy), 2017, *Radiological Control*, DOE-STD-1098-2017, Change Notice 1, Washington, DC, May.

INL (Idaho National Laboratory), 2019, *Idaho National Laboratory Site Environmental Report Calendar Year 2018*, DOE/ID-12082(18), Environmental Surveillance, Education, and Research Program, Idaho Operations Office, Idaho Falls, Idaho, September.

INL (Idaho National Laboratory), 2020a, VTR Hazards and Impacts Information in Support of National Environmental Policy Act Data Needs, INL/EXT-19-55588, July.

INL (Idaho National Laboratory), 2020b, TEV-3976 Versatile Test Reactor (VTR Waste and Material Data for Environmental Impact Statement (EIS), Idaho Falls, Idaho. DRAFT

National Research Council, 2006, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*, Committee on the Biological Effects of Ionizing Radiation, National Academy Press, Washington, DC.

NCRP (National Council on Radiation Protection and Measurements), 1993, *Risk Estimates for Radiation Protection,* NCRP Report No. 115, Bethesda, Maryland, December 31.

NCRP (National Council on Radiation Protection and Measurements), 2009, *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 160, Bethesda, Maryland, March 3.

NRC (U.S. Nuclear Regulatory Commission), 1977, *Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10 CFR 50*, Appendix I, Regulatory Guide 1.109, Rev. 1, Office of Standards Development, Washington, DC, October.

ORO (U.S. Department of Energy - Oak Ridge Operations Office), 2019, *Oak Ridge Reservation Annual Site Environmental Report 2018*, DOE/ORO-2512, Oak Ridge, Tennessee, September.

SRNS (Savannah River Nuclear Solutions), 2019, *Savannah River Site Environmental Report 2018*, SRNS-RP-2019-00022, Aiken, South Carolina.

SRNS (Savannah River Nuclear Solutions), 2020, Savannah River Site Data Call Response for the Versatile Test Reactor Fuel Fabrication Facility, SRNS-RP-2020-00286, Rev. 2, Aiken, South Carolina, July 22.

Valentin, J., 2007, *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103, Elsevier Ltd.

Attachment C1:
Environmental Justice Population Distributions

Minority and Low-Income Populations

This attachment to Appendix C presents the projected 2050 population distributions for Total Minority, African American, Native American, Other Minority, White Hispanic, and low-income populations. The subject populations are presented in **Tables C–24** through **C–29** for the INL Site; **Tables C–30** through **C–35** for ORNL; and **Tables C–36** through **C–41** for SRS.

Table C–24. Estimated Total Minority Population Within 50 Miles of the Proposed VTR Complex at the INL–MFC in the Year 2050

	Distance (miles)									
Direction	***0-1***	***1-2***	***2-3***	***3-4***	***4-5***	***5-10***	***10-20***	***20-30***	***30-40***	***40-50***
E	0	0	0	0	0	23	87	470	2,016	8,285
ENE	0	0	0	0	0	0	110	127	115	41
ESE	0	0	0	0	0	30	149	1,992	29,643	754
N	0	0	0	0	0	0	0	34	26	22
NE	0	0	0	0	0	0	111	93	80	34
NNE	0	0	0	0	0	0	109	87	43	34
NNW	0	0	0	0	0	0	8	8	13	16
NW	0	0	0	0	0	0	8	10	13	21
S	0	0	0	1	0	5	20	2,637	4,479	8,578
SE	0	0	0	0	1	33	229	1,913	4,997	57
SSE	0	0	0	1	0	12	121	648	842	458
SSW	0	0	0	0	0	7	21	41	596	3,855
SW	0	0	0	0	0	0	29	41	67	411
W	0	0	0	0	0	0	8	8	13	18
WNW	0	0	0	0	0	0	0	17	11	10
WSW	0	0	0	0	0	0	22	13	15	93
Total Minority Population										**74,940**

Table C–25. Estimated African American Population Within 50 Miles of the Proposed VTR Complex at INL–MFC in the Year 2050

	Distance (miles)									
Direction	***0-1***	***1-2***	***2-3***	***3-4***	***4-5***	***5-10***	***10-20***	***20-30***	***30-40***	***40-50***
E	0	0	0	0	0	0	1	0	38	575
ENE	0	0	0	0	0	0	1	1	0	9
ESE	0	0	0	0	0	0	0	74	798	0
N	0	0	0	0	0	0	0	13	2	6
NE	0	0	0	0	0	0	1	0	0	1
NNE	0	0	0	0	0	0	1	1	0	1
NNW	0	0	0	0	0	0	7	8	12	15
NW	0	0	0	0	0	0	7	6	5	1
S	0	0	0	0	0	0	0	169	100	212
SE	0	0	0	0	0	0	0	10	11	0
SSE	0	0	0	0	0	0	0	1	1	1
SSW	0	0	0	0	0	0	0	0	0	1
SW	0	0	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	7	8	12	7
WNW	0	0	0	0	0	0	0	13	5	1
WSW	0	0	0	0	0	0	3	7	3	0
Total African American Population										**2,156**

Table C–26. Estimated Native American Population Within 50 Miles the Proposed VTR Complex at INL–MFC in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	0	1	4	27	17
ENE	0	0	0	0	0	0	2	1	0	3
ESE	0	0	0	0	0	0	0	7	200	53
N	0	0	0	0	0	0	0	2	10	6
NE	0	0	0	0	0	0	2	0	5	14
NNE	0	0	0	0	0	0	2	1	9	14
NNW	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	28	876	1,573
SE	0	0	0	0	0	0	0	58	17	0
SSE	0	0	0	0	0	0	0	11	218	364
SSW	0	0	0	0	0	0	0	0	227	704
SW	0	0	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0	0	0	0
Native American Total Population										**4,456**

Table C–27. Estimated Other Minority Population Within 50 Miles of the Proposed VTR Complex at INL–MFC in the Year 2050 [a]

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	14	40	230	1,649	5,065
ENE	0	0	0	0	0	0	45	50	39	19
ESE	0	0	0	0	0	28	147	954	22,419	240
N	0	0	0	0	0	0	0	7	6	4
NE	0	0	0	0	0	0	46	32	25	7
NNE	0	0	0	0	0	0	45	31	12	7
NNW	0	0	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0	0	11
S	0	0	0	0	0	1	5	1,671	1,899	3,834
SE	0	0	0	0	0	29	204	1,292	3,464	31
SSE	0	0	0	0	0	8	101	528	262	84
SSW	0	0	0	0	0	2	7	40	230	2,400
SW	0	0	0	0	0	0	17	41	65	407
W	0	0	0	0	0	0	0	0	0	3
WNW	0	0	0	0	0	0	0	0	1	5
WSW	0	0	0	0	0	0	13	5	3	78
Total Other Minority Population										**47,902**

[a] Includes people who identified as Asian, Native Hawaiian and other Pacific Islanders, Some other race, and two or more races.

Table C–28. Estimated White Hispanic Population Within 50 Miles of the Proposed VTR Complex at INL–MFC in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	9	45	236	302	2,628
ENE	0	0	0	0	0	0	62	75	76	10
ESE	0	0	0	0	0	2	2	957	6,226	461
N	0	0	0	0	0	0	0	12	8	6
NE	0	0	0	0	0	0	62	61	50	12
NNE	0	0	0	0	0	0	61	54	22	12
NNW	0	0	0	0	0	0	1	0	1	1
NW	0	0	0	0	0	0	1	4	8	9
S	0	0	0	1	0	4	15	769	1,604	2,959
SE	0	0	0	0	1	4	25	553	1,505	26
SSE	0	0	0	1	0	4	20	108	361	9
SSW	0	0	0	0	0	5	14	1	139	750
SW	0	0	0	0	0	0	12	0	2	4
W	0	0	0	0	0	0	1	0	1	8
WNW	0	0	0	0	0	0	0	4	5	4
WSW	0	0	0	0	0	0	6	1	9	15
Total White Hispanic Population										**20,426**

Table C–29. Estimated Low-Income Population Surrounding the Proposed VTR Complex at INL–MFC in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	11	22	394	1,749	17,511
ENE	0	0	0	0	0	0	23	35	28	33
ESE	0	0	0	0	0	25	124	1,039	17,198	382
N	0	0	0	0	0	0	0	10	9	9
NE	0	0	0	0	0	0	23	19	18	12
NNE	0	0	0	0	0	0	23	18	12	12
NNW	0	0	0	0	0	0	3	3	5	8
NW	0	0	0	0	0	0	3	32	71	76
S	0	0	0	0	0	1	3	1,049	2,677	6,481
SE	0	0	0	0	0	11	52	827	2,504	121
SSE	0	0	0	0	0	2	27	237	363	95
SSW	0	0	0	0	0	1	4	11	284	988
SW	0	0	0	0	0	0	6	11	17	11
W	0	0	0	0	0	0	3	3	5	21
WNW	0	0	0	0	0	0	0	30	49	49
WSW	0	0	0	0	0	0	5	5	18	27
Total Low-Income Population										**54,938**

Table C–30. Estimated Total Minority Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	4	7	26	2,318	37,033	39,778	26,086	37,756
ENE	0	1	1	4	33	1,292	15,132	15,969	1,287	3,704
ESE	0	0	4	56	153	4,043	9,009	6,806	2,388	27,373
N	0	0	0	29	315	2,052	10	65	88	411
NE	0	1	0	0	0	1,029	1,702	565	614	467
NNE	0	0	0	0	160	4,330	522	996	560	532
NNW	0	0	0	68	274	568	50	51	390	160
NW	0	0	0	4	60	133	2,464	73	66	397
S	0	0	0	1	3	4,027	1,105	1,410	1,472	167
SE	0	1	4	60	266	3,011	2,396	4,187	53	157
SSE	0	0	1	2	17	1,120	874	669	236	1,240
SSW	0	0	1	4	5	292	3,775	2,113	4,731	1,454
SW	0	0	0	1	1	48	488	578	859	1,343
W	0	0	0	0	0	114	989	644	1,162	3,503
WNW	0	0	0	0	0	225	292	124	227	583
WSW	0	0	0	0	0	85	997	478	441	2,013
Total Minority Population										**299,518**

Table C–31. Estimated African American Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	2	859	13,180	24,232	945	351
ENE	0	0	0	0	7	284	6,122	7,057	256	467
ESE	0	0	0	5	12	692	1,801	1,412	61	256
N	0	0	0	10	116	679	0	6	3	213
NE	0	0	0	0	0	85	339	119	141	0
NNE	0	0	0	0	68	801	151	105	54	188
NNW	0	0	0	16	44	100	30	0	232	33
NW	0	0	0	1	11	18	2,224	10	6	10
S	0	0	0	1	2	297	158	290	7	3
SE	0	0	0	6	13	312	378	945	0	0
SSE	0	0	1	2	1	55	16	0	0	9
SSW	0	0	0	0	0	40	508	610	796	362
SW	0	0	0	0	0	23	91	83	92	261
W	0	0	0	0	0	0	301	106	247	576
WNW	0	0	0	0	0	12	136	24	51	0
WSW	0	0	0	0	0	7	279	31	112	507
Total African American Population										**71,565**

Table C–32. Estimated Native American Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	37	471	268	62	261
ENE	0	0	0	0	0	16	216	352	95	44
ESE	0	0	0	0	0	13	227	318	73	199
N	0	0	0	0	0	10	3	4	9	17
NE	0	0	0	0	0	11	18	12	3	13
NNE	0	0	0	0	1	34	17	54	30	51
NNW	0	0	0	0	0	0	3	30	57	33
NW	0	0	0	0	0	0	7	8	1	3
S	0	0	0	0	0	0	0	120	535	28
SE	0	0	0	0	0	25	86	101	13	141
SSE	0	0	0	0	0	47	54	43	137	1,080
SSW	0	0	0	0	0	0	17	71	116	10
SW	0	0	0	0	0	6	83	40	2	30
W	0	0	0	0	0	43	117	0	76	492
WNW	0	0	0	0	0	0	3	11	14	124
WSW	0	0	0	0	0	41	29	12	22	200
Native American Total Population										**7,050**

Table C–33. Estimated Other Minority Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	1	2	16	1,130	18,536	12,380	23,833	34,492
ENE	0	0	0	1	20	608	6,664	6,714	665	1,945
ESE	0	0	1	40	123	2,254	5,513	2,817	1,793	25,976
N	0	0	0	19	198	1,131	6	43	58	131
NE	0	0	0	0	0	827	1,211	386	355	279
NNE	0	0	0	0	91	2,502	275	516	350	285
NNW	0	0	0	41	174	366	6	1	50	87
NW	0	0	0	2	35	74	159	14	48	341
S	0	0	0	0	1	2,083	244	376	704	64
SE	0	0	1	43	222	2,265	1,333	2,404	40	14
SSE	0	0	0	0	10	676	511	289	97	98
SSW	0	0	1	4	5	111	1,377	1,007	2,468	615
SW	0	0	0	1	1	11	223	345	631	570
W	0	0	0	0	0	62	518	394	459	1,190
WNW	0	0	0	0	0	154	141	36	106	350
WSW	0	0	0	0	0	37	553	398	155	703
Total Other Minority Population										**179,686**

[a] Includes people who identified as Asian, Native Hawaiian and other Pacific Islanders, Some other race, and two or more races.

Table C–34. Estimated White Hispanic Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	3	5	8	292	4,846	2,898	1,246	2,652
ENE	0	1	1	3	6	384	2,130	1,846	271	1,248
ESE	0	0	3	11	18	1,084	1,468	2,259	461	942
N	0	0	0	0	1	232	1	12	18	50
NE	0	1	0	0	0	106	134	48	115	175
NNE	0	0	0	0	0	993	79	321	126	8
NNW	0	0	0	11	56	102	11	20	51	7
NW	0	0	0	1	14	41	74	41	11	43
S	0	0	0	0	0	1,647	703	624	226	72
SE	0	1	3	11	31	409	599	737	0	2
SSE	0	0	0	0	6	342	293	337	2	53
SSW	0	0	0	0	0	141	1,873	425	1,351	467
SW	0	0	0	0	0	8	91	110	134	482
W	0	0	0	0	0	9	53	144	380	1,245
WNW	0	0	0	0	0	59	12	53	56	109
WSW	0	0	0	0	0	0	136	37	152	603
Total White Hispanic Population										**41,217**

Table C–35. Estimated Low-Income Population Within 50 Miles of the Proposed VTR Complex at ORNL in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	1	16	27	43	1,406	25,460	30,989	12,183	15,794
ENE	0	8	4	20	17	604	12,602	13,646	3,330	4,927
ESE	0	2	18	49	78	1,481	4,075	7,889	2,992	5,464
N	0	0	0	22	231	1,936	548	313	784	2,084
NE	0	3	0	1	0	288	3,076	2,126	2,630	2,099
NNE	0	0	0	0	119	2,844	1,800	2,807	4,067	2,066
NNW	0	0	0	30	82	798	533	367	2,359	2,574
NW	0	0	0	1	16	282	1,196	653	657	1,905
S	0	1	4	20	35	3,266	1,870	3,513	2,676	262
SE	0	6	19	51	61	593	2,787	6,168	109	247
SSE	0	2	15	24	45	781	1,053	1,196	260	793
SSW	0	0	5	36	46	471	2,859	4,255	6,329	2,833
SW	0	0	0	20	27	155	503	863	1,554	2,907
W	0	0	0	0	0	210	2,808	1,588	2,149	7,166
WNW	0	0	0	0	0	214	1,403	711	825	2,192
WSW	0	0	0	3	13	105	1,357	1,001	1,668	2,532
Total Low-Income Population										**259,087**

Table C–36. Estimated Total Minority Population Within 50 Miles of K Area at SRS in the Year 2050

	Distance (miles)									
Direction	**0-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-10**	**10-20**	**20-30**	**30-40**	**40-50**
E	0	0	0	0	0	0	2,870	700	3,121	1,846
ENE	0	0	0	0	0	3	1,171	3,360	3,900	15,350
ESE	0	0	0	0	0	33	701	1,702	951	1,199
N	0	0	0	0	0	0	4,292	20,399	3,174	8,835
NE	0	0	0	0	0	0	824	2,849	1,474	6,053
NNE	0	0	0	0	0	0	1,030	937	2,718	6,816
NNW	0	0	0	0	0	0	2,814	14,531	10,803	4,386
NW	0	0	0	0	0	39	2,217	83,785	60,303	3,506
S	0	0	0	0	0	27	219	681	2,316	2,049
SE	0	0	0	0	0	54	329	1,878	3,323	4,102
SSE	0	0	0	0	0	59	153	291	1,041	1,054
SSW	0	0	0	0	0	36	635	494	1,882	2,133
SW	0	0	0	0	0	94	566	912	830	989
W	0	0	0	0	0	110	1,165	2,210	1,731	1,863
WNW	0	0	0	0	0	72	2,113	66,490	41,438	8,343
WSW	0	0	0	0	0	143	1,704	4,662	984	3,726
Total Minority Population										**441,593**

Table C–37. Estimated African American Population Within 50 Miles of K Area at SRS in the Year 2050

	Distance (miles)									
Direction	**0-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-10**	**10-20**	**20-30**	**30-40**	**40-50**
E	0	0	0	0	0	0	2,618	642	2,790	1,484
ENE	0	0	0	0	0	3	1,087	3,078	3,646	12,330
ESE	0	0	0	0	0	30	656	1,664	794	1,030
N	0	0	0	0	0	0	2,291	15,980	2,396	5,898
NE	0	0	0	0	0	0	635	2,676	1,222	4,265
NNE	0	0	0	0	0	0	653	787	1,996	3,007
NNW	0	0	0	0	0	0	1,660	9,974	4,442	2,664
NW	0	0	0	0	0	31	1,559	71,050	34,343	2,362
S	0	0	0	0	0	27	214	588	1,898	1,505
SE	0	0	0	0	0	45	269	1,849	2,704	3,540
SSE	0	0	0	0	0	54	145	283	744	863
SSW	0	0	0	0	0	36	626	449	1,297	1,531
SW	0	0	0	0	0	93	563	853	579	894
W	0	0	0	0	0	108	949	1,805	1,389	1,534
WNW	0	0	0	0	0	60	1,808	58,300	27,145	5,341
WSW	0	0	0	0	0	140	1,668	4,097	782	3,353
Total African American Population										**331,871**

Table C–38. Estimated Native American Population Within 50 Miles of K Area at SRS in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	0	52	2	88	37
ENE	0	0	0	0	0	0	12	5	14	30
ESE	0	0	0	0	0	2	23	8	0	9
N	0	0	0	0	0	0	18	10	3	37
NE	0	0	0	0	0	0	4	26	17	48
NNE	0	0	0	0	0	0	22	6	36	78
NNW	0	0	0	0	0	0	1	41	39	33
NW	0	0	0	0	0	0	7	60	174	22
S	0	0	0	0	0	0	0	1	23	71
SE	0	0	0	0	0	7	47	12	6	16
SSE	0	0	0	0	0	3	5	0	8	13
SSW	0	0	0	0	0	0	0	22	217	63
SW	0	0	0	0	0	0	0	0	2	1
W	0	0	0	0	0	0	3	5	3	1
WNW	0	0	0	0	0	0	9	63	645	41
WSW	0	0	0	0	0	0	0	0	2	1
Native American Total Population										**2,254**

Table C–39. Estimated Other Minority Population Within 50 Miles of K Area at SRS in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	0	168	43	221	265
ENE	0	0	0	0	0	0	48	266	236	2,777
ESE	0	0	0	0	0	1	18	15	147	159
N	0	0	0	0	0	0	1,407	3,792	576	2,050
NE	0	0	0	0	0	0	169	117	199	1,393
NNE	0	0	0	0	0	0	93	56	508	2,571
NNW	0	0	0	0	0	0	680	2,678	5,897	1,547
NW	0	0	0	0	0	7	463	8,658	19,958	594
S	0	0	0	0	0	0	4	55	333	348
SE	0	0	0	0	0	2	10	14	517	503
SSE	0	0	0	0	0	2	1	4	178	153
SSW	0	0	0	0	0	0	9	4	87	381
SW	0	0	0	0	0	0	1	39	226	74
W	0	0	0	0	0	0	187	323	281	273
WNW	0	0	0	0	0	11	266	7,375	8,613	2,575
WSW	0	0	0	0	0	0	24	490	73	248
Total Other Minority Population										**81,461**

[a] Includes people who identified as Asian, Native Hawaiian and other Pacific Islanders, Some other race, and two or more races.

Table C–40. Estimated White Hispanic Population Within 50 Miles of K Area at SRS in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	0	32	13	22	60
ENE	0	0	0	0	0	0	24	11	4	213
ESE	0	0	0	0	0	0	4	15	10	1
N	0	0	0	0	0	0	576	617	199	850
NE	0	0	0	0	0	0	16	30	36	347
NNE	0	0	0	0	0	0	262	88	178	1,160
NNW	0	0	0	0	0	0	473	1,838	425	142
NW	0	0	0	0	0	1	188	4,017	5,828	528
S	0	0	0	0	0	0	1	37	62	125
SE	0	0	0	0	0	0	3	3	96	43
SSE	0	0	0	0	0	0	2	4	111	25
SSW	0	0	0	0	0	0	0	19	281	158
SW	0	0	0	0	0	1	2	20	23	20
W	0	0	0	0	0	2	26	77	58	55
WNW	0	0	0	0	0	1	30	752	5,035	386
WSW	0	0	0	0	0	3	12	75	127	124
Total White Hispanic Population										**26,007**

Table C–41. Estimated Low-Income Population Within 50 Miles of K Area at SRS in the Year 2050

Direction	Distance (miles)									
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
E	0	0	0	0	0	0	1,340	434	910	650
ENE	0	0	0	0	0	1	475	1,362	1,370	4,743
ESE	0	0	0	0	0	9	225	625	381	487
N	0	0	0	0	0	0	1,482	8,405	1,198	3,898
NE	0	0	0	0	0	0	389	1,541	740	3,323
NNE	0	0	0	0	0	0	624	849	1,544	5,590
NNW	0	0	0	0	0	0	874	7,898	2,326	1,198
NW	0	0	0	0	0	14	976	33,352	14,140	1,245
S	0	0	0	0	0	17	147	326	1,227	1,405
SE	0	0	0	0	0	16	94	548	899	1,068
SSE	0	0	0	0	0	19	58	65	239	485
SSW	0	0	0	0	0	22	420	436	1,341	1,232
SW	0	0	0	0	0	68	317	503	467	633
W	0	0	0	0	0	80	625	986	1,056	863
WNW	0	0	0	0	0	24	883	17,258	7,513	4,856
WSW	0	0	0	0	0	105	1,065	2,153	237	1,522
Total Low-Income Population										**155,896**