APPENDIX C
HUMAN HEALTH IMPACTS

This appendix contains information in addition to that presented in Chapter 4 on the human health analyses conducted for this environmental impact statement (EIS).

C.1 RADIATION AND HUMAN HEALTH

Radiation is the emission and propagation of energy through space or through a material in the form of waves or bundles of energy called photons, or in the form of high-energy subatomic particles. Radiation generally results from atomic or subatomic processes that occur naturally. The most common kind of radiation is electromagnetic radiation, which is transmitted as photons. Electromagnetic radiation is emitted over a range of wavelengths and energies. We are most commonly aware of visible light, which is part of the spectrum of electromagnetic radiation. Radiation of longer wavelengths and lower energy includes infrared radiation, which heats material when the material and the radiation interact, and radio waves. Electromagnetic radiation of shorter wavelengths and higher energy (which are more penetrating) includes ultraviolet radiation, which causes sunburn, X-rays, and gamma radiation.

Ionizing radiation is radiation that has sufficient energy to displace electrons from atoms or molecules to create ions. It can be electromagnetic (for example, X-rays or gamma radiation) or subatomic particles (for example, alpha and beta radiation). The ions have the ability to interact with other atoms or molecules; in biological systems, this interaction can cause damage in the tissue or organism.

Radioactivity is the property or characteristic of an unstable atom to undergo spontaneous transformation (to disintegrate or decay) with the emission of energy as radiation. Usually the emitted radiation is ionizing radiation. The result of the process, called radioactive decay, is the transformation of an unstable atom (a radionuclide) into a different atom, accompanied by the release of energy (as radiation) as the atom reaches a more stable, lower energy configuration. Radioactive decay produces three main types of ionizing radiation—alpha particles, beta particles, and gamma or X-rays—but our senses cannot detect them. These types of ionizing radiation can have different characteristics and levels of energy and, thus, varying abilities to penetrate and interact with atoms in the human body. Because each type has different characteristics, each requires different amounts of material to stop (shield) the radiation. Alpha particles are the least penetrating and can be stopped by a thin layer of material such as a single sheet of paper. However, if radioactive atoms (called radionuclides) emit alpha particles in the body when they decay, there is a concentrated deposition of energy near the point where the radioactive decay occurs. Shielding for beta particles requires thicker layers of material such as several reams of paper or several inches of wood or water. Shielding from gamma rays, which are highly penetrating, requires very thick material such as several inches to several feet of heavy material (for example, concrete or lead). Deposition of the energy by gamma rays is dispersed across the body in contrast to the local energy deposition by an alpha particle. In fact, some gamma radiation will pass through the body without interacting with it.

Radiation that originates outside of an individual's body is called external or direct radiation. Such radiation can come from an X-ray machine or from radioactive materials (materials or substances that contain radionuclides), such as radioactive waste or radionuclides in soil. Internal radiation originates inside a person's body following intake of radioactive material or radionuclides through ingestion or inhalation. Once in the body, the fate of a radioactive material is determined by its chemical behavior and how it is metabolized. If the material is soluble, it might be dissolved in bodily fluids and transported to and deposited in various body organs; if it is insoluble, it might move rapidly through the gastrointestinal tract or be deposited in the lungs.

Exposure to ionizing radiation is expressed in terms of absorbed dose, which is the amount of energy imparted to matter per unit mass. Often simply called dose, it is a fundamental concept in measuring and quantifying the effects of exposure to radiation. The unit of absorbed dose is the rad. The different types of radiation mentioned above have different effects in damaging the cells of biological systems. Dose equivalent is a concept that considers the absorbed dose and the relative effectiveness of the type of ionizing radiation in damaging biological systems, using a radiation-specific quality factor. The unit of dose equivalent is the rem. In quantifying the effects of radiation on humans, other types of concepts are also used. The concept of effective dose equivalent is used to quantify effects of radionuclides in the body. It involves estimating the susceptibility of the different tissue in the body to radiation to produce a tissue-specific weighting factor. The weighting factor is based on the susceptibility of that tissue to cancer. The sum of the products of each affected tissue's estimated dose equivalent multiplied by its specific weighting factor is the effective dose equivalent. The potential effects from a one-time ingestion or inhalation of radioactive material are calculated over a period of 50 years to account for radionuclides that have long half-lives and long residence time in the body. The result is called the committed effective dose equivalent. The unit of effective dose equivalent is also the rem. Total effective dose equivalent is the sum of the committed effective dose equivalent from radionuclides in the body plus the dose equivalent from radiation sources external to the body (also in rem). All estimates of dose presented in this EIS, unless specifically noted as something else, are total effective dose equivalents, which are quantified in terms of rem or millirem (mrem), which is one one-thousandth of a rem.

More detailed information on the concepts of radiation dose and dose equivalent are presented in publications of the National Council on Radiation Protection and Measurements (NCRP 1993) and the International Commission on Radiological Protection (ICRP 1991).

The factors used to convert estimates of radionuclide intake (by inhalation or ingestion) to dose are called dose conversion factors. The International Commission on Radiological Protection and federal agencies such as the U.S. Environmental Protection Agency (EPA) publish these factors (Eckerman and Ryman 1993; Eckerman et al. 1988). They are based on original recommendations of the International Commission on Radiological Protection (ICRP 1977).

The radiation dose to an individual or to a group of people can be expressed as the total dose received or as a dose rate, which is dose per unit time (usually an hour or a year). Collective dose is the total dose to an exposed population. Person-rem is the unit of collective dose. Collective dose is calculated by summing the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, the collective dose would be 10 person-rem (100×0.1 rem).

Exposures to radiation or radionuclides are often characterized as being acute or chronic. Acute exposures occur over a short period of time, typically 24 hours or less. Chronic exposures occur over longer periods of time (months to years); they are usually assumed to be continuous over a period, even though the dose rate might vary. For a given dose of radiation, chronic radiation exposure is usually less harmful than acute exposure because the dose rate (dose per unit time, such as rem per hour) is lower, providing more opportunity for the body to repair damaged cells.

On average, members of the public nationwide are exposed to approximately 300 mrem per year from natural sources (NCRP 1987). The largest natural sources are radon-222 and its radioactive decay products in homes and buildings, which contribute about 200 mrem per year. Additional natural sources include radioactive material in the earth (primarily the uranium and thorium decay series, and potassium-40) and cosmic rays from space filtered through the atmosphere. With respect to exposures resulting from human activities, the combined doses from weapons testing fallout, consumer and industrial products, and air travel (cosmic radiation) account for the remaining approximate 3 percent of the total annual dose. Nuclear fuel cycle facilities contribute less than 0.1 percent (0.05 mrem per year) of the total dose.

Cancer is the principal potential risk to human health from exposure to low or chronic levels of radiation. This EIS expresses radiological health impacts as the incremental changes in the number of expected fatal cancers (latent cancer fatalities) for populations and as the incremental increases in lifetime probabilities of contracting a fatal cancer for an individual. The estimates are based on the dose received and on dose-to-health effect conversion factors recommended by the International Commission on Radiological Protection (1991). The Commission estimated that, for the general population, a collective dose of 1 person-rem would yield 5×10^{-4} excess latent cancer fatality. For radiation workers, a collective dose of 1 person-rem would yield an estimated 4×10^{-4} excess latent cancer fatality. The higher risk factor for the general population is primarily due to the inclusion of children in the population group, while the radiation worker population includes only people older than 18.

Other health effects such as nonfatal cancers and genetic effects can occur as a result of chronic exposure to radiation. Inclusion of the incidence of nonfatal cancers and severe genetic effects from radiation exposure increases the total detriment by 40 to 50 percent (Table C-1), compared to the change for latent cancer fatalities (ICRP 1991). As is the general practice for any U.S. Department of Energy (DOE) EIS, estimates of the total change have not been included in this EIS.

Table C-1. Risk of Latent Cancer Fatalities and Other Health Effects from Exposure to Radiation

Population	Latent Cancer Fatality (per rem)	Nonfatal Cancer (per rem)	Genetic Effects (per rem)	Total Detriment (per rem)
Workers	4.0×10^{-4}	8.0×10^{-5}	8.0×10^{-5}	5.6×10^{-4}
General Population	5.0×10^{-4}	1.0×10^{-4}	1.3×10^{-4}	7.3×10^{-4}

Source: ICRP 1991.

Exposures to high levels of radiation at high dose rates over a short period (less than 24 hours) can result in acute radiation effects. Minor changes in blood characteristics might be noted at doses in the range of 25 to 50 rad. The external symptoms of radiation sickness begin to appear following acute exposures of about 50 to 100 rad and can include anorexia, nausea, and vomiting. More severe symptoms occur at higher doses and can include death at doses higher than 200 to 300 rad of total body irradiation, depending on the level of medical treatment received. Information on the effects of acute exposures on humans was obtained from studies of the survivors of the Hiroshima and Nagasaki bombings and from studies following a multitude of acute accidental exposures. Factors to relate the level of acute exposure to health effects exist but are not applied in this EIS because expected exposures during normal operations and accidents would be well below 50 rem.

C.2 RADIOLOGICAL ASSESSMENT

When radioactivity is released into the environment, it has the potential to affect persons who come in contact with it. Mechanisms for transporting radiation include air, water, soil and food. The many ways an individual or population can come into contact with radiation are known as pathways. Pathway analysis is useful in quantifying the effective dose equivalent to an individual or population that is affected by the release. If radiation is released into the environment, an individual can come directly into contact with it via the external and inhalation pathways, or indirectly via the ingestion pathway. Submersion in an air or water plume can be directly quantified by dose conversion factors based on the concentration in the medium of interest.

Gaseous effluents released to the atmosphere were modeled with a straight line gaussian plume. The receptors were assumed to be downwind at a location that maximized their dose. The total dose to the individual at that location is the sum of all pathways (external, inhalation, and ingestion). At the location of the receptor, the external dose was calculated by multiplying the time-integrated concentration in air by the length of exposure and then multiplying that product by the appropriate external dose conversion factor for air, for each radionuclide, and then those doses were summed across all radionuclides. Radionuclides deposited on the ground also provide an external dose component and are assessed in a similar manner using the appropriate external ground dose conversion factors.

Internal exposure via inhalation for each radionuclide was quantified at the receptor location by multiplying the estimated concentration of the radionuclide by the intake of air (breathing rate times length of exposure) multiplied by the appropriate inhalation dose conversion factor for all nuclides.

The ingestion pathway is significant for some radionuclides that are released into the air or into water used for irrigation. For those radionuclides in the air, as the plume carrying the radionuclides travels away from the source, the radionuclides are deposited on the ground. Some radionuclides move from the soil into vegetation with water. The outside of plants will also intercept radionuclides from air and water. These plants can be either consumed directly by humans, or ingested by an animal (beef or poultry) that will then be consumed by humans or that will produce milk or eggs. The rates at which radionuclides accumulate in plant and animal product food stuffs are described by radionuclide transfer factors.

The following are pathways for liquid effluents released into surface water. The receptor can come into contact with liquid effluents that are released into surface water through direct external submersion in the contaminated water, boating over contaminated water and by spending time on shorelines where contaminated water is present. These are all external pathways. Internal pathways are primarily from drinking contaminated water, eating fish and wildlife that use the water, and by eating produce and animal products that were irrigated using the contaminated surface water.

C.2.1 Normal Operations

The GENII computer code (Napier et al. 1988) was used to estimate the radiation doses from releases during normal operations. For releases of radioactive material to the atmosphere, two receptors were evaluated: the maximally exposed individual, who was considered to be a nearby resident, and the population within 80 kilometers (50 miles) of the WVDP site. People were assumed to inhale radioactive material and be exposed to external radiation from the radioactive material released during normal operations. People were also assumed to ingest radioactive material through foodstuffs such as leafy vegetables, produce, meat, and milk.

Releases to the atmosphere could be from ground level or from a stack. Annual average atmospheric conditions were used to estimate radiation doses. Site-specific meteorological data from 1994 through 1998 (WVNS 2000a) were used to determine these atmospheric conditions.

The values of parameters used in GENII are listed in Table C-2.

C.2.2 Facility Accidents

The GENII computer code (Napier et al. 1988) was also used to estimate radiation doses from accidents. For accidents where radioactive material would be released to the atmosphere, three receptors were evaluated: (1) a worker at the onsite evaluation point located 640 meters (3,000 feet) from the accident, (2) the maximally exposed individual located at the WVDP site boundary, and (3) the population within

Table C-2. Parameters Used in GENII Radiological Assessments

Parameter	Individual Value	Population Value
Leafy Vegetable Consumption Rate	64 kg/yr	23 kg/yr
Other Produce Consumption Rate	217 kg/yr	80 kg/yr
Fruit Consumption Rate	114 kg/yr	42 kg/yr
Cereal Consumption Rate	125 kg/yr	46 kg/yr
Leafy Vegetable Growing Time	90 d	60 d
Other Produce Growing Time	90 d	60 d
Fruit Growing Time	90 d	60 d
Cereal Growing Time	90 d	60 d
Leafy Vegetable Holdup Time	1 d	14 d
Other Produce Holdup Time	60 d	14 d
Fruit Holdup Time	60 d	14 d
Cereal Holdup Time	90 d	14 d
Leafy Vegetable Yield	2 kg/m^2	2 kg/m^2
Other Produce Yield	2 kg/m^2	2 kg/m^2
Fruit Yield	2 kg/m^2	2 kg/m^2
Cereal Yield	2 kg/m^2	2 kg/m^2
Beef Consumption Rate	73 kg/yr	63 kg/yr
Poultry Consumption Rate	37 kg/yr	31 kg/yr
Milk Consumption Rate	310 L/yr	110 L/yr
Egg Consumption Rate	100 kg/yr	20 kg/yr
Beef Holdup Time	20 d	20 d
Poultry Holdup Time	1 d	1 d
Milk Holdup Time	0 d	4 d
Egg Holdup Time	0 d	3 d
Stored Feed Diet Fraction (beef)	0.25	0.25
Stored Feed Diet Fraction (poultry)	0.25	0.25
Stored Feed Diet Fraction (milk cow)	0.25	0.25
Stored Feed Diet Fraction (laying hen)	0.25	0.25
Stored Feed Grow Time (beef)	90 d	90 d
Stored Feed Grow Time (poultry)	90 d	90 d
Stored Feed Grow Time (milk cow)	45 d	45 d
Stored Feed Grow Time (laying hen)	90 d	90 d
Stored Feed Yield (beef)	2 kg/m^2	1 kg/m^2
Stored Feed Yield (poultry)	2 kg/m^2	2 kg/m^2
Stored Feed Yield (milk cow)	2 kg/m^2	2 kg/m^2
Stored Feed Yield (laying hen)	2 kg/m^2	2 kg/m^2
Stored Feed Storage Time (beef)	90 d	90 d
Stored Feed Storage Time (poultry)	90 d	90 d
Stored Feed Storage Time (milk cow)	90 d	90 d
Stored Feed Storage Time (laying hen)	90 d	90 d
Fresh Forage Diet Fraction (beef)	0.25	0.25
Fresh Forage Diet Fraction (milk cow)	0.75	0.75
Fresh Forage Grow Time (beef)	45 d	45 d
Fresh Forage Grow Time (milk cow)	30 d	30 d
Fresh Forage Yield (beef)	0.70 kg/m^2	2 kg/m^2
Fresh Forage Yield (milk cow)	1 kg/m^2	0.7 kg/m^2
Fresh Forage Storage Time (beef)	90 d	90 d
Fresh Forage Storage Time (milk cow)	0	0
Immersion Exposure Time (Chronic)	8,760 hr/yr	8,760 hr/yr

Table C-2. Parameters Used in GENII Radiological Assessments (cont)

Parameter	Individual Value	Population Value
Inhalation Exposure Time (Chronic)	2,000 hr/yr	2,000 hr/yr
Ground Surface Exposure Time (Chronic)	2,000 hr/yr	2,000 hr/yr
Immersion Exposure Time (Acute)	Duration of plume passage	Duration of plume passage
Inhalation Exposure Time (Acute)	Duration of plume passage	Duration of plume passage
Ground Surface Exposure Time (Acute)	2 hr	2 hr
Mass Loading	1×10^{-4} g/m^3	1×10^{-4} g/m^3
Swimming Time	12 hr/yr	8.3 hr/yr
Boating Time	12 hr/yr	8.3 hr/yr
Other Shoreline Activities Time	12 hr/yr	8.3 hr/yr
Transit Time for aquatic recreation	2.3 hr	0 hr
Irrigation Rate	43 in/yr	36 in/yr
Irrigation Duration	6 mo/yr	6 mo/yr
Fish Consumption Rate	21 kg/yr	0.1 kg/yr
Fish Holdup Time	1 d	10 d
Fish Transit Time	2.3 hr	160 hr
Mixing Ratio	0.125	4×10^{-3}
Average River Flow Rate	13.6 m^3/s	23.1 m^3/s
Transit Time to Irrigation Withdrawal	3.8 hr	0
Drink Water Consumption Rate	0	370 L/yr
Drinking Water Holdup Time	0	1 d
Breathing Rate (Chronic)	270 cm^3/s	270 cm^3/s
Breathing Rate (Acute)	330 cm^3/s	330 cm^3/s

Source: WVNS 2000a.
Acronyms: kg/yr = kilograms per year; d = day; kg/m^2 = kilograms per square meter; L/yr = liters per year; hr/yr = hours per year; g/m^3 = grams per cubic meter; in/yr = inches per year; mo/yr = months per year; m^3/s = cubic meters per second; cm^3/s = cubic centimeters per second

80 kilometers (50 miles) of the WVDP site. The maximally exposed individual was assumed to be at the WVDP site boundary because radiation doses were higher at the boundary than at the actual locations of nearby residents.

People were assumed to inhale radioactive material and be exposed to external radiation from radioactive material released during the accident. This radioactive material could be released from ground level or from a stack, depending on the accident. Two types of atmospheric conditions were used to estimate radiation doses, 50 percent atmospheric conditions and 95 percent atmospheric conditions. Fifty percent atmospheric conditions are conditions that are not exceeded 50 percent of the time and provide a realistic estimate of the likely atmospheric conditions that would exist during an accident. Ninety-five percent atmospheric conditions are conditions that are not exceeded 95 percent of the time and provide an upper bound on the atmospheric conditions that would exist during an accident. Site-specific meteorological data from 1994 through 1998 (WVNS 2000a) were used to determine 50 percent and 95 percent atmospheric conditions.

C.3 RADIONUCLIDE RELEASES FOR NORMAL OPERATIONS

Under all alternatives, it is assumed that current levels of maintenance, surveillance, heating, ventilation, and other routine operations would continue to be required while the actions proposed under each alternative were performed. For this EIS, these actions are called ongoing operations. Because ongoing operations would not vary among the proposed alternatives, the releases from these actions would be the same across all alternatives. These releases are listed in the WVDP Annual Site Environmental Reports for 1995 through 1999 (WVNS 1996, 1997, 1998, 1999a, 2000b).

The No Action Alternative and Alternative A would have no additional airborne or liquid releases. For Alternative B, airborne releases would result from the interim stabilization of high-level waste (HLW) tanks 8D-1 and 8D-2. These releases would emanate from the stack at the Waste Tank Farm (Table C-3). The releases are based on 0.1 percent of the mobile inventory in the tanks becoming airborne during interim stabilization and being released after being filtered through two banks of high-efficiency particulate air (HEPA) filters with efficiencies of 99.97 percent. These releases are listed in Table C-4.

Table C-3. Stack Parameters for Normal Operations Releases

Stack	Height (meters)[a]	Diameter (meters)	Discharge Rate (cubic meters per second)[b]	Exit Velocity (meters per second)
Process Building (ANSTACK)	63.4	1.35	23.6	16.49
Vitrification Facility (ANVITSK)	22.86	0.91	11.8	17.98
Waste Tank Farm (ANSTSK)	10.06	0.47	2.12	12.24
01/14 Building (ANCSSTK)	22.25	0.6	4.58	16.19

Source: WVNS 1999b.
a. To convert meters to feet, multiply by 3.2808.
b. To convert cubic meters to cubic feet, multiply by 0.028317.

Table C-4. Airborne Releases from Interim Stabilization Normal Operations

Nuclide	MAR (curies)[a]	DR	ARF	RF	LPF	ST (curies)[b]
Carbon-14	1.0×10^{-3}	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.8×10^{-13}
Cobalt-60	0.50	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	9.0×10^{-11}
Nickel-63	4.1	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	7.4×10^{-10}
Strontium-90	820	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.5×10^{-7}
Technetium-99	0.12	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	2.2×10^{-11}
Cesium-137	21,000	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	3.8×10^{-6}
Plutonium-241	6.3	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.1×10^{-9}
Curium-242	0.060	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.1×10^{-11}
Neptunium-237	7.0×10^{-3}	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.3×10^{-12}
Plutonium-238	0.70	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.3×10^{-10}
Plutonium-239	0.30	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	5.4×10^{-11}
Americium-241	5.4	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	9.7×10^{-10}
Americium-243	0.090	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	1.6×10^{-11}
Curium-244	1.1	1.0	1.0×10^{-3}	1.0	9.0×10^{-8}	2.0×10^{-10}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = Airborne Release Fraction; RF = respirable fraction; LPF = leakpath factor; ST = source term
a. MAR is based in the mobile inventory in Tank 8D-2 (WVNS 2001a).
b. ST is based on releases from two tanks, 8D-1 and 8D-2.

C.4 RADIONUCLIDE RELEASES FOR ACCIDENTS

The amount of radioactive material released during an accident is known as the source term. The units of the source term are usually curies. It is the product of several factors, including:

$$\text{Source Term} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF}$$

where:

MAR = Material at risk
DR = Damage ratio
ARF = Airborne release fraction
RF = Respirable fraction
LPF = Leakpath factor

The material at risk is the amount of radioactive material (in grams or curies of radioactivity for each radionuclide) available to be acted on by a given physical stress.

The damage ratio is the fraction of the material at risk impacted by the actual accident-generated conditions under evaluation.

The airborne release fraction is the coefficient used to estimate the amount of a radioactive material that can be suspended in air and made available for airborne transport under a specific set of induced physical stresses. It is applicable to events and situations that are completed during the course of the event.

The respirable fraction is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particulate matter less than or equal to 10 micrometers in diameter.

The leakpath factor is the fraction of airborne materials transported from containment or confinement deposition or filtration mechanism (for example, fraction of airborne material in a glovebox leaving the glovebox under static conditions, fraction of material passing through a HEPA filter).

C.4.1 Class A LLW Drum Puncture

This accident assumed that a drum containing Class A low-level waste (LLW) was punctured during handling by a fork of the forktruck. The accident could take place under the No Action Alternative, Alternative A, or Alternative B.

The material at risk for this accident is based on a Class A LLW drum filled with the intermediate radionuclide mix from Marschke (2001). The values for the damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-5 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-5. Source Term for Class A LLW Drum Puncture

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	6.7×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	6.7×10^{-8}
Cesium-137	8.6×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	8.6×10^{-8}
Plutonium-238	2.7×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	2.7×10^{-8}
Plutonium-239	3.8×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	3.8×10^{-8}
Plutonium-240	2.7×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	2.7×10^{-8}
Plutonium-241	1.1×10^{-2}	0.10	1.0×10^{-3}	1.0	1.0	1.1×10^{-6}
Americium-241	2.8×10^{-5}	0.10	1.0×10^{-3}	1.0	1.0	2.8×10^{-9}
Americium-243	8.3×10^{-7}	0.10	1.0×10^{-3}	1.0	1.0	8.3×10^{-11}
Curium-244	4.0×10^{-7}	0.10	1.0×10^{-3}	1.0	1.0	4.0×10^{-11}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.2 Class A LLW Pallet Drop

This accident assumed that a pallet containing six Class A LLW drums was dropped during handling and the 6 drums were punctured. The accident could take place under the No Action Alternative, Alternative A, or Alternative B.

The material at risk for this accident is based on a Class A LLW drum filled with the intermediate radionuclide mix from Marschke (2001). The values for the damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-6 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-6. Source Term for Class A LLW Pallet Drop

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	4.0×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	4.0×10^{-7}
Cesium-137	5.2×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	5.2×10^{-7}
Plutonium-238	1.6×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	1.6×10^{-7}
Plutonium-239	2.3×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	2.3×10^{-7}
Plutonium-240	1.6×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	1.6×10^{-7}
Plutonium-241	0.063	0.10	1.0×10^{-3}	1.0	1.0	6.3×10^{-6}
Americium-241	1.7×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	1.7×10^{-8}
Americium-243	5.0×10^{-6}	0.10	1.0×10^{-3}	1.0	1.0	5.0×10^{-10}
Curium-244	2.4×10^{-6}	0.10	1.0×10^{-3}	1.0	1.0	2.4×10^{-10}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.3 Class A LLW Box Puncture

This accident assumed that a B-25 box containing 90 cubic feet of Class A LLW was punctured during handling by a fork of the forktruck. The accident could take place under the No Action Alternative, Alternative A, or Alternative B.

The material at risk for this accident is based on a Class A LLW box filled with the intermediate radionuclide mix from Marschke (2001). The values for the damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-7 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-7. Source Term for Class A LLW Box Puncture

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	8.3×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	8.3×10^{-7}
Cesium-137	0.011	0.10	1.0×10^{-3}	1.0	1.0	1.1×10^{-6}
Plutonium-238	3.3×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	3.3×10^{-7}
Plutonium-239	4.6×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	4.6×10^{-7}
Plutonium-240	3.3×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	3.3×10^{-7}
Plutonium-241	0.13	0.10	1.0×10^{-3}	1.0	1.0	1.3×10^{-5}
Americium-241	3.4×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	3.4×10^{-8}
Americium-243	1.0×10^{-5}	0.10	1.0×10^{-3}	1.0	1.0	1.0×10^{-9}
Curium-244	4.9×10^{-6}	0.10	1.0×10^{-3}	1.0	1.0	4.9×10^{-10}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.4 Collapse of Tank 8D-2 Vault (Wet)

For this accident, it is assumed that the occurrence of a severe earthquake greater than six times the design basis (0.1 g) causes the roof of Tank 8D-2 and its vault to collapse, exposing the tank contents to the atmosphere. In this accident, the contents of the tank were assumed to be wet. The material at risk for Tank 8D-2 was a heel made up of two components, the mobile inventory and the fixed inventory (WVNS 2001a). The mobile inventory consisted of the liquid at the bottom of the tank. This liquid was assumed to have an airborne release fraction of 1×10^{-8}. The fixed inventory was assumed to be scoured from the sides of the tank by debris falling into the tank during the collapse and have an airborne release fraction of 1×10^{-7}. Because of its physical form (particles as opposed to liquid), the zeolite inventory was assumed to not be released during the accident.

This accident could take place under the No Action Alternative or Alternative A, or under Alternative B until tank interim stabilization occurred. The frequency of this accident was estimated to be in the range of 10^{-4} to 10^{-6} per year (WVNS 2002a). Table C-8 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-8. Source Term for Tank 8D-2 Collapse (Wet)

Nuclide	Mobile MAR (curies)	Fixed MAR (curies)	DR	Mobile ARF	Fixed ARF	RF	LPF	ST (curies)
Carbon-14	1.0×10^{-3}	4.0×10^{-3}	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	4.1×10^{-10}
Cobalt-60	0.50	1.2	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.3×10^{-7}
Nickel-63	4.1	9.7	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.0×10^{-6}
Strontium-90	820	39,000	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	3.9×10^{-3}
Technetium-99	0.12	0.68	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	6.9×10^{-8}
Cesium-137	21,000	4,600	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	6.7×10^{-4}
Plutonium-241	6.3	1,000	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.0×10^{-4}
Curium-242	0.060	1.4	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.4×10^{-7}
Neptunium-237	7.0×10^{-3}	0.32	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	3.2×10^{-8}
Plutonium-238	0.70	120	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.2×10^{-5}
Plutonium-239	0.30	48	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	4.8×10^{-6}
Americium-241	5.4	170	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	1.7×10^{-5}
Americium-243	0.090	2.1	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	2.1×10^{-7}
Curium-244	1.1	25	1.0	1.0×10^{-8}	1.0×10^{-7}	1.0	1.0	2.5×10^{-6}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.5 Collapse of Tank 8D-2 Vault (Dry)

For this accident, it is assumed that the occurrence of a severe earthquake greater than six times the design basis (0.1 g) causes the roof of Tank 8D-2 and its vault to collapse, exposing the tank contents to the atmosphere. In this accident, the contents of the tank were assumed to be dry. The material at risk for Tank 8D-2 was a heel made up of two components, the mobile and zeolite inventory, and the fixed inventory (WVNS 2001a). The mobile and zeolite inventory was assumed to have dried out at the bottom of the tank. This dry material was assumed to have an airborne release factor of 4×10^{-7}. The fixed inventory was assumed to be scoured from the sides of the tank by debris falling into the tank during the collapse and have an airborne release factor of 1×10^{-7}.

Two phenomena were assumed to control the release of radioactive material following a tank collapse. The impact stresses imposed by the falling debris entrain some of the radioactive material in the air during the collapse. For the material on the walls of the tank, the fraction airborne was estimated using Equation 5-1 in DOE (1994). Using a fall height of 8 meters (27 feet) and a particle density of 2 grams per cubic meter, an airborne release fraction of 3×10^{-5} was estimated.

For the solid debris on the bottom of the tank, Section 4.4.3.3.2 of DOE (1994) summarizes experiments that have been run to estimate the release fractions when debris falls into various powders. According to Volume 2 of DOE (1994), there is only one experiment in which objects were actually dropped on powders; Table A-42 of that document summarizes those results. Based on the values listed in the "< 10 : m Inhal. PMS Probe" column, the average airborne release fraction is 1.4×10^{-4}.

The two airborne release fractions derived above were multiplied by 3×10^{-3} to obtain the final release fractions of 1.0×10^{-7} and 4×10^{-7}. The factor of 3×10^{-3} accounts for the effectiveness of the falling debris to remove entrained respirable particulates. The basis for this removal fraction is a series of experiments performed to determine the release fraction of respirable material following an explosion in a cell used to assemble nuclear weapons. These cells have roofs consisting of several feet of overburden that falls into the cell following an explosion. These experiments show that the falling debris removes 99.7 percent of the respirable particles.

This accident could take place under the No Action Alternative or Alternative A, or under Alternative B until tank interim stabilization occurred. The frequency of this accident was estimated to be in the range of 10^{-4} to 10^{-6} per year (WVNS 2002a). Table C-9 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-9. Source Term for Tank 8D-2 Collapse (Dry)

Nuclide	Dry MAR (curies)	Fixed MAR (curies)	DR	Dry ARF	Fixed ARF	RF	LPF	ST (curies)
Carbon-14	1.0×10^{-3}	4.0×10^{-3}	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	8.0×10^{-10}
Cobalt-60	0.50	1.2	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	3.2×10^{-7}
Nickel-63	4.1	9.7	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	2.6×10^{-6}
Strontium-90	990	39,000	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	4.3×10^{-3}
Technetium-99	0.12	0.68	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	1.2×10^{-7}
Cesium-137	130,000	4,600	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	0.054
Plutonium-241	8.3	1,000	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	1.0×10^{-4}
Curium-242	0.060	1.4	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	1.6×10^{-7}
Neptunium-237	7.0×10^{-3}	0.32	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	3.5×10^{-8}
Plutonium-238	0.93	120	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	1.2×10^{-5}
Plutonium-239	0.40	48	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	5.0×10^{-6}
Americium-241	5.4	170	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	1.9×10^{-5}
Americium-243	0.090	2.1	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	2.4×10^{-7}
Curium-244	1.1	25	1.0	4.0×10^{-7}	1.0×10^{-7}	1.0	1.0	2.9×10^{-6}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.6 Drum Cell Drop

This accident assumed that two drums containing solidified LLW from the Drum Cell were dropped. The accident could take place under Alternative A or Alternative B.

The material at risk for this accident is based on a 71-gallon drum filled with solidified LLW (WVNS 1993b). The airborne release fraction (DOE 1994) assumed that the cement in the drum was solid with a density of 1.8 grams per cubic centimeter (0.065 pound per cubic inch). The fall height for the drums was assumed to be 200 centimeters (79 inches), which yields an airborne release fraction of 7.1×10^{-6}. The damage ratio, respirable fraction, and leakpath factor were assumed to equal one for this accident. The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-10 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-10. Source Term for Drum Cell Drop

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	0.30	1.0	7.1×10^{-6}	1.0	1.0	2.1×10^{-6}
Cesium-137	2.0	1.0	7.1×10^{-6}	1.0	1.0	1.4×10^{-5}
Plutonium-238	0.076	1.0	7.1×10^{-6}	1.0	1.0	5.4×10^{-7}
Plutonium-239	0.015	1.0	7.1×10^{-6}	1.0	1.0	1.0×10^{-7}
Plutonium-240	0.011	1.0	7.1×10^{-6}	1.0	1.0	7.8×10^{-8}
Plutonium-241	0.74	1.0	7.1×10^{-6}	1.0	1.0	5.2×10^{-6}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.7 Class C LLW Drum Puncture

This accident assumed that a drum containing Class C LLW was punctured during handling by a fork of the forktruck. The accident could take place under Alternative A or Alternative B.

The material at risk, damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-11 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-11. Source Term for Class C LLW Drum Puncture

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	0.14	0.10	1.0×10^{-3}	1.0	1.0	1.4×10^{-5}
Cesium-137	0.15	0.10	1.0×10^{-3}	1.0	1.0	1.5×10^{-5}
Plutonium-238	7.5×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	7.5×10^{-7}
Plutonium-239	2.1×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	2.1×10^{-7}
Plutonium-240	1.5×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	1.5×10^{-7}
Plutonium-241	0.099	0.10	1.0×10^{-3}	1.0	1.0	9.9×10^{-6}
Americium-241	5.7×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	5.7×10^{-7}
Americium-243	5.0×10^{-5}	0.10	1.0×10^{-3}	1.0	1.0	5.0×10^{-9}
Curium-244	6.0×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	6.0×10^{-8}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.8 Class C LLW Pallet Drop

This accident assumed that a pallet containing six Class C LLW drums was dropped during handling and the 6 drums were punctured. The accident could take place under Alternative A or Alternative B.

The material at risk, damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-12 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-12. Source Term for Class C LLW Pallet Drop

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	0.84	0.10	1.0×10^{-3}	1.0	1.0	8.4×10^{-5}
Cesium-137	0.90	0.10	1.0×10^{-3}	1.0	1.0	9.0×10^{-5}
Plutonium-238	0.045	0.10	1.0×10^{-3}	1.0	1.0	4.5×10^{-6}
Plutonium-239	0.013	0.10	1.0×10^{-3}	1.0	1.0	1.3×10^{-6}
Plutonium-240	9.0×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	9.0×10^{-7}
Plutonium-241	0.59	0.10	1.0×10^{-3}	1.0	1.0	5.9×10^{-5}
Americium-241	0.034	0.10	1.0×10^{-3}	1.0	1.0	3.4×10^{-6}
Americium-243	3.0×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	3.0×10^{-8}
Curium-244	3.6×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	3.6×10^{-7}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.9 Class C LLW Box Puncture

This accident assumed that a B-25 box containing 90 cubic feet of Class C LLW was punctured during handling by a fork of the forktruck. The accident could take place under Alternative A or Alternative B.

The material at risk, damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-13 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-13. Source Term for Class C LLW Box Puncture

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Strontium-90	1.4	0.10	1.0×10^{-3}	1.0	1.0	1.4×10^{-4}
Cesium-137	1.5	0.10	1.0×10^{-3}	1.0	1.0	1.5×10^{-4}
Plutonium-238	0.075	0.10	1.0×10^{-3}	1.0	1.0	7.5×10^{-6}
Plutonium-239	0.021	0.10	1.0×10^{-3}	1.0	1.0	2.1×10^{-6}
Plutonium-240	0.015	0.10	1.0×10^{-3}	1.0	1.0	1.5×10^{-6}
Plutonium-241	0.99	0.10	1.0×10^{-3}	1.0	1.0	9.9×10^{-5}
Americium-241	0.057	0.10	1.0×10^{-3}	1.0	1.0	5.7×10^{-6}
Americium-243	5.0×10^{-4}	0.10	1.0×10^{-3}	1.0	1.0	5.0×10^{-8}
Curium-244	6.0×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	6.0×10^{-7}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.10 High-Integrity Container Drop

This accident assumed that a high-integrity container holding radioactive sludge and resin was dropped during handling, spilling its contents. The accident could take place under Alternative A or Alternative B.

The material at risk, damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (2002a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-14 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-14. Source Term for High-Integrity Container Drop

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Americium-241	0.18	1.0	4.0×10^{-5}	1.0	1.0	7.2×10^{-6}
Plutonium-239	0.15	1.0	4.0×10^{-5}	1.0	1.0	6.1×10^{-6}
Plutonium-240	0.12	1.0	4.0×10^{-5}	1.0	1.0	4.6×10^{-6}
Plutonium-241	5.7	1.0	4.0×10^{-5}	1.0	1.0	2.3×10^{-4}
Plutonium-238	0.043	1.0	4.0×10^{-5}	1.0	1.0	1.7×10^{-6}
Cesium-137	210	1.0	4.0×10^{-5}	1.0	1.0	8.4×10^{-3}
Cobalt-60	5.2	1.0	4.0×10^{-5}	1.0	1.0	2.1×10^{-4}
Strontium-90	2.2	1.0	4.0×10^{-5}	1.0	1.0	8.7×10^{-5}
Cesium-134	4.5	1.0	4.0×10^{-5}	1.0	1.0	1.8×10^{-4}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.11 CH-TRU Drum Puncture

This accident assumed that a drum containing contact-handled transuranic (CH-TRU) waste was punctured during handling by a fork of the forktruck. The accident could take place under Alternative A or Alternative B.

The material at risk for this accident is from WVNS (2002a). The damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (1993a). The frequency of this accident was estimated to be in the range of 0.1 to 0.01 per year (WVNS 2002a). Table C-15 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-15. Source Term for CH-TRU Drum Puncture

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Plutonium-238	3.3	0.10	1.0×10^{-3}	1.0	1.0	3.3×10^{-4}
Strontium-90	520	0.10	1.0×10^{-3}	1.0	1.0	0.052
Plutonium-239	0.85	0.10	1.0×10^{-3}	1.0	1.0	8.5×10^{-5}
Plutonium-240	0.64	0.10	1.0×10^{-3}	1.0	1.0	6.4×10^{-5}
Americium-241	0.62	0.10	1.0×10^{-3}	1.0	1.0	6.2×10^{-5}
Plutonium-241	32	0.10	1.0×10^{-3}	1.0	1.0	3.2×10^{-3}
Curium-244	0.14	0.10	1.0×10^{-3}	1.0	1.0	1.4×10^{-5}
Americium-243	0.045	0.10	1.0×10^{-3}	1.0	1.0	4.5×10^{-6}
Cesium-137	570	0.10	1.0×10^{-3}	1.0	1.0	0.057
Uranium-232	0.015	0.10	1.0×10^{-3}	1.0	1.0	1.5×10^{-6}
Americium-242m	7.6×10^{-3}	0.10	1.0×10^{-3}	1.0	1.0	7.6×10^{-7}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.12 Fire in Loadout Bay

This accident involved a diesel fuel fire in the Remote-Handled Waste Facility as a result of a leak in the fuel tank or fuel line of a truck. This fire would involve CH-TRU and remote-handled transuranic

(RH-TRU) waste. The frequency of this accident was estimated to be in the range of 10^{-4} to 10^{-6} per year WVNS (2000c). This accident could take place under Alternative A or Alternative B.

The material at risk, damage ratio, airborne release fraction, respirable fraction, and leakpath factor are from WVNS (2000c). Table C-16 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-16. Source Term for Fire in Loadout Bay

Nuclide	MAR (curies)	DR	ARF	RF	LPF	ST (curies)
Plutonium-238	11	1.0	6.0×10^{-3}	0.010	1.0	6.8×10^{-4}
Americium-241	3.9	1.0	6.0×10^{-3}	0.010	1.0	2.3×10^{-4}
Plutonium-239	3.2	1.0	6.0×10^{-3}	0.010	1.0	1.9×10^{-4}
Plutonium-240	2.4	1.0	6.0×10^{-3}	0.010	1.0	1.5×10^{-4}
Plutonium-241	71	1.0	6.0×10^{-3}	0.010	1.0	4.2×10^{-3}
Cesium-137	180	1.0	6.0×10^{-3}	1.0	1.0	11
Strontium-90	170	1.0	6.0×10^{-3}	0.010	1.0	9.9×10^{-3}
Curium-244	0.35	1.0	6.0×10^{-3}	0.010	1.0	2.1×10^{-5}
Americium-243	0.17	1.0	6.0×10^{-3}	0.010	1.0	1.0×10^{-5}
Uranium-232	0.051	1.0	6.0×10^{-3}	0.010	1.0	3.0×10^{-6}
Americium-242	0.027	1.0	6.0×10^{-3}	0.010	1.0	1.6×10^{-6}
Thorium-228	0.051	1.0	6.0×10^{-3}	0.010	1.0	3.1×10^{-6}
Americium-242m	0.027	1.0	6.0×10^{-3}	0.010	1.0	1.6×10^{-6}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.4.13 Containment System Failure During Interim Stabilization of Tank 8D-2

This accident involved containment system failure during the interim stabilization of Tank 8D-2. During interim stabilization, Tanks 8D-1 and 8D-2 would be filled with about 102 centimeters (40 inches) of grout. The material at risk for this accident was the mobile inventory contained in Tank 8D-2 (WVNS 2001a).

The airborne release fraction is based on the assumption that 0.1 percent of the mobile inventory would become airborne during stabilization and that stabilization would take place over 40 hours. Normally, this airborne radioactivity would be filtered by HEPA filters. This accident assumed a brief (1-hour) unfiltered release of radioactivity occurred during stabilization because of either a ventilation duct failure before filtration or a filter failure. The 1-hour time limitation assumed that the failure would be detected by either the effluent monitors or the filter differential pressure monitors and that mitigating actions (for example, shutdown of exhaust fans or isolation of ducts) would take place. The airborne release fraction for this 1-hour release would be 2.5×10^{-5}:

$$0.001 \times 1 \text{ hr}/40 \text{ hrs} = 0.000025$$

Interim stabilization would take place under Alternative B. The frequency of this accident was estimated to be in the range of 10^{-6} to 10^{-8} per year and could take place under Alternative B but not under the No Action Alternative or Alternative A. Table C-17 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-17. Source Term for Containment System Failure During Interim Stabilization of Tank 8D-2

Nuclide	MAR[a] (curies)	DR	ARF	RF	LPF	ST (curies)
Carbon-14	1.0×10^{-3}	1.0	2.5×10^{-5}	1.0	1.0	2.5×10^{-8}
Cobalt-60	0.50	1.0	2.5×10^{-5}	1.0	1.0	1.3×10^{-5}
Nickel-63	4.1	1.0	2.5×10^{-5}	1.0	1.0	1.0×10^{-4}
Strontium-90	820	1.0	2.5×10^{-5}	1.0	1.0	0.020
Technetium-99	0.12	1.0	2.5×10^{-5}	1.0	1.0	3.0×10^{-6}
Cesium-137	21,000	1.0	2.5×10^{-5}	1.0	1.0	0.53
Plutonium-241	6.3	1.0	2.5×10^{-5}	1.0	1.0	1.6×10^{-4}
Curium-242	0.060	1.0	2.5×10^{-5}	1.0	1.0	1.5×10^{-6}
Neptunium-237	7.0×10^{-3}	1.0	2.5×10^{-5}	1.0	1.0	1.8×10^{-7}
Plutonium-238	0.70	1.0	2.5×10^{-5}	1.0	1.0	1.8×10^{-5}
Plutonium-239	0.30	1.0	2.5×10^{-5}	1.0	1.0	7.5×10^{-6}
Americium-241	5.4	1.0	2.5×10^{-5}	1.0	1.0	1.4×10^{-4}
Americium-243	0.090	1.0	2.5×10^{-5}	1.0	1.0	2.3×10^{-6}
Curium-244	1.1	1.0	2.5×10^{-5}	1.0	1.0	2.7×10^{-5}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

a. The MAR for this accident is the mobile inventory in Tank 8D-2 (WVNS 2001a).

C.4.14 Collapse of Tank 8D-2 Vault (Grouted)

For this accident, it is assumed that the occurrence of a severe earthquake greater than six times the design basis (0.1 g) causes the roof of Tank 8D-2 and its vault to collapse, exposing the tank contents to the atmosphere. In this accident, the contents of the tank were assumed to be dry. The material at risk for Tank 8D-2 was a heel made up of two components, the mobile and zeolite inventory, and the fixed inventory (WVNS 2001a). The mobile and zeolite inventory was assumed to have been grouted in place at the bottom of the tank and are not available for release (airborne release fraction = 0). The fixed inventory was assumed to be scoured from the sides of the tank by debris falling into the tank during the collapse and have an airborne release fraction of 1×10^{-7}. In addition, the fixed inventory below the level of the grout [1 meter (40 inches)] was assumed to be unavailable for release. The fixed inventory is proportional to the interior tank surface area; because 44 percent of the interior tank surface area would be below 1 meter of grout, the damage ratio for the fixed inventory was 0.56 (1 – 0.44).

This accident could take place only under Alternative B, after tank interim stabilization occurred. The frequency of this accident was estimated to be in the range of 10^{-4} to 10^{-6} per year (WVNS 2002a). Table C-18 lists the material at risk, damage ratio, airborne release fraction, respirable fraction, leakpath factor, and source term for this accident.

Table C-18. Source Term for Tank 8D-2 Collapse (Grouted)

Nuclide	Dry MAR (curies)	Fixed MAR (curies)	DR	Dry ARF	Fixed ARF	RF	LPF	ST (curies)
Carbon-14	1.0×10^{-3}	4.0×10^{-3}	0.56	0	1.0×10^{-7}	1.0	1.0	2.2×10^{-10}
Cobalt-60	0.50	1.2	0.56	0	1.0×10^{-7}	1.0	1.0	6.7×10^{-8}
Nickel-63	4.1	9.7	0.56	0	1.0×10^{-7}	1.0	1.0	5.4×10^{-7}
Strontium-90	990	39,000	0.56	0	1.0×10^{-7}	1.0	1.0	2.2×10^{-3}
Technetium-99	0.12	0.68	0.56	0	1.0×10^{-7}	1.0	1.0	3.8×10^{-8}
Cesium-137	130,000	4,600	0.56	0	1.0×10^{-7}	1.0	1.0	2.6×10^{-4}
Plutonium-241	8.3	1,000	0.56	0	1.0×10^{-7}	1.0	1.0	5.7×10^{-5}
Curium-242	0.060	1.4	0.56	0	1.0×10^{-7}	1.0	1.0	7.8×10^{-8}
Neptunium-237	7.0×10^{-3}	0.32	0.56	0	1.0×10^{-7}	1.0	1.0	1.8×10^{-8}
Plutonium-238	0.93	120	0.56	0	1.0×10^{-7}	1.0	1.0	6.5×10^{-6}
Plutonium-239	0.40	48	0.56	0	1.0×10^{-7}	1.0	1.0	2.7×10^{-6}
Americium-241	5.4	170	0.56	0	1.0×10^{-7}	1.0	1.0	9.5×10^{-6}
Americium-243	0.090	2.1	0.56	0	1.0×10^{-7}	1.0	1.0	1.2×10^{-7}
Curium-244	1.1	25	0.56	0	1.0×10^{-7}	1.0	1.0	1.4×10^{-6}

Acronyms: MAR = material at risk; DR = damage ratio; ARF = airborne release fraction; RF = respirable fraction; LPF = leakpath factor; ST = Source Term

C.5 ATMOSPHERIC DATA

Hourly meteorological data collected at West Valley are shown in Tables C-19 and C-20 for 10-meter (33-foot) and 60-meter (197-foot) heights. These data were collected over a 5-year period from 1994 through 1998 (WVNS 2000a). They are arranged according to direction, atmospheric stability class, and wind speed. When the wind was calm (wind speed = 0 meters per second), the data were assigned to stability classes weighted by the frequency of each stability class. The "greater than 12 meters per second" data were included with the "9.0-12.0 meters per second" data.

C.6 LOCATIONS OF RECEPTORS

Locations of receptors near the WVDP site are listed in Table C-21. To provide a realistic estimate of maximally exposed individual radiation doses from airborne releases during normal operations, radiation doses were evaluated at the locations of nearby residences. For releases from the Process Building, the location that yielded the largest radiation dose was at 1,800 meters (5,900 feet) northwest of the WVDP site. For airborne releases from the Vitrification Facility, the Waste Tank Farm, and the 01/14 Building, the location that yielded the largest radiation dose was at 1,900 meters (6,200 feet) north-northwest of the WVDP site. Population radiation doses from airborne releases during normal operations included contributions from all directions for distances from 0 to 80 kilometers (0 to 50 miles) of the WVDP site.

To provide a conservative estimate of maximally exposed individual radiation doses from airborne releases during accidents, radiation doses were evaluated at the WVDP site boundary because radiation doses at the site boundary were slightly larger than at nearby residences. For ground-level releases, the location that yielded the largest radiation dose was at 1,051 meters (3,448 feet) west-northwest of the WVDP site for 95-percent meteorology and at 1,223 meters (4,012 feet) north-northwest for 50-percent meteorology. For elevated releases, the location that yielded the largest radiation dose was at 1,806 meters (5,925 feet) south-southwest of the WVDP site for 95-percent meteorology and 50-percent meteorology.

Table C-19. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 10-meter (33-foot) Height for 1994-1998 at the WVDP Site[a]

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
S	N	A	4	9	21	1	0	0
SSW	NNE	A	2	11	16	0	0	0
SW	NE	A	1	16	14	0	0	0
WSW	ENE	A	2	10	3	0	0	0
W	E	A	1	11	3	0	0	0
WNW	ESE	A	0	22	40	0	0	0
NW	SE	A	1	46	242	2	0	0
NNW	SSE	A	0	19	67	6	0	0
N	S	A	0	21	20	0	0	0
NNE	SSW	A	0	18	12	0	0	0
NE	SW	A	0	13	10	0	0	0
ENE	WSW	A	0	11	12	0	0	0
E	W	A	0	16	9	0	0	0
ESE	WNW	A	0	7	6	0	0	0
SE	NW	A	0	9	10	0	0	0
SSE	NNW	A	2	6	10	0	0	0
	Calms	A	0					
S	N	B	0	23	42	3	0	0
SSW	NNE	B	2	34	26	0	0	0
SW	NE	B	1	50	27	0	0	0
WSW	ENE	B	0	26	10	0	0	0
W	E	B	1	34	14	0	0	0
WNW	ESE	B	1	67	61	1	0	0
NW	SE	B	0	119	241	1	0	0
NNW	SSE	B	0	34	95	2	0	0
N	S	B	0	24	18	0	0	0
NNE	SSW	B	2	28	15	0	0	0
NE	SW	B	3	22	10	0	0	0
ENE	WSW	B	2	13	4	0	0	0
E	W	B	0	15	7	0	0	0
ESE	WNW	B	0	10	4	0	0	0
SE	NW	B	1	15	16	2	0	0
SSE	NNW	B	2	19	40	0	0	0
	Calms	B	1					
S	N	C	5	68	74	0	0	0
SSW	NNE	C	3	74	29	0	0	0
SW	NE	C	3	102	30	0	0	0
WSW	ENE	C	3	48	19	0	0	0
W	E	C	2	71	21	0	0	0
WNW	ESE	C	8	143	72	2	0	0

Table C-19. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 10-meter (33-foot) Height for 1994-1998 at the WVDP Site[a] (cont)

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
NW	SE	C	7	203	341	4	0	0
NNW	SSE	C	4	95	118	5	0	0
N	S	C	1	71	30	0	0	0
NNE	SSW	C	9	39	11	0	0	0
NE	SW	C	5	33	11	0	0	0
ENE	WSW	C	3	18	6	0	0	0
E	W	C	2	17	20	4	0	0
ESE	WNW	C	3	22	14	0	0	0
SE	NW	C	5	39	44	2	0	0
SSE	NNW	C	2	39	42	9	0	0
	Calms	C	0					
S	N	D	284	929	615	25	0	0
SSW	NNE	D	294	938	283	1	0	0
SW	NE	D	257	729	181	1	0	0
WSW	ENE	D	251	501	96	0	0	0
W	E	D	340	827	214	0	0	0
WNW	ESE	D	429	1,441	739	1	0	0
NW	SE	D	370	2,575	1,816	8	0	0
NNW	SSE	D	147	630	492	4	0	0
N	S	D	131	421	126	0	0	0
NNE	SSW	D	139	261	46	0	0	0
NE	SW	D	91	170	29	0	0	0
ENE	WSW	D	90	142	117	8	0	0
E	W	D	103	161	128	1	0	0
ESE	WNW	D	140	314	202	2	0	0
SE	NW	D	191	660	698	114	4	0
SSE	NNW	D	180	534	797	270	29	3
	Calms	D	46					
S	N	E	810	895	315	10	0	0
SSW	NNE	E	446	288	39	0	0	0
SW	NE	E	280	59	3	0	0	0
WSW	ENE	E	267	41	3	0	0	0
W	E	E	290	66	3	0	0	0
WNW	ESE	E	317	183	2	0	0	0
NW	SE	E	175	267	28	0	0	0
NNW	SSE	E	60	34	3	0	0	0
N	S	E	38	8	1	0	0	0
NNE	SSW	E	38	8	0	0	0	0
NE	SW	E	32	9	0	0	0	0
ENE	WSW	E	54	8	0	0	0	0

Table C-19. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 10-meter (33-foot) Height for 1994-1998 at the WVDP Site[a] (cont)

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
E	W	E	95	15	4	0	0	0
ESE	WNW	E	114	73	7	0	0	0
SE	NW	E	275	433	199	3	0	0
SSE	NNW	E	575	692	476	94	11	0
	Calms	E	219					
S	N	F	632	98	0	0	0	0
SSW	NNE	F	276	9	0	0	0	0
SW	NE	F	166	1	0	0	0	0
WSW	ENE	F	111	4	0	0	0	0
W	E	F	68	7	0	0	0	0
WNW	ESE	F	28	2	0	0	0	0
NW	SE	F	20	6	0	0	0	0
NNW	SSE	F	23	4	0	0	0	0
N	S	F	16	0	0	0	0	0
NNE	SSW	F	10	1	0	0	0	0
NE	SW	F	20	0	0	0	0	0
ENE	WSW	F	17	0	0	0	0	0
E	W	F	42	1	0	0	0	0
ESE	WNW	F	96	14	1	0	0	0
SE	NW	F	223	72	3	0	0	0
SSE	NNW	F	711	136	10	0	0	0
	Calms	F	537					
S	N	G	696	22	0	0	0	0
SSW	NNE	G	168	0	0	0	0	0
SW	NE	G	89	0	0	0	0	0
WSW	ENE	G	51	1	0	0	0	0
W	E	G	16	1	0	0	0	0
WNW	ESE	G	4	0	0	0	0	0
NW	SE	G	8	0	0	0	0	0
NNW	SSE	G	9	0	0	0	0	0
N	S	G	5	0	0	0	0	0
NNE	SSW	G	4	0	0	0	0	0
NE	SW	G	6	0	0	0	0	0
ENE	WSW	G	12	0	0	0	0	0
E	W	G	16	0	0	0	0	0
ESE	WNW	G	53	3	0	0	0	0
SE	NW	G	260	27	0	0	0	0
SSE	NNW	G	1,197	85	0	0	0	0
	Calms	G	611					

Source: WVNS 2000a.

a. Total hours recorded (1994-1998) for wind blowing from the direction and at the speed range indicated.

Table C-20. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 60-meter (197-foot) Height for 1994-1998 at the WVDP Site[a]

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
S	N	A	0	2	15	7	1	0
SSW	NNE	A	0	2	22	5	0	0
SW	NE	A	0	5	21	12	0	0
WSW	ENE	A	0	5	11	5	0	0
W	E	A	1	4	16	4	1	0
WNW	ESE	A	1	7	87	70	2	0
NW	SE	A	0	8	122	59	3	0
NNW	SSE	A	0	9	41	21	1	0
N	S	A	0	7	34	2	0	0
NNE	SSW	A	0	3	26	0	0	0
NE	SW	A	0	3	19	0	0	0
ENE	WSW	A	0	6	17	0	0	0
E	W	A	1	9	19	0	0	0
ESE	WNW	A	0	4	6	0	0	0
SE	NW	A	1	2	13	1	0	0
SSE	NNW	A	1	3	8	1	0	0
	Calms	A	1					
S	N	B	0	8	34	7	2	0
SSW	NNE	B	1	3	45	15	1	0
SW	NE	B	1	5	72	12	0	0
WSW	ENE	B	0	9	42	10	1	0
W	E	B	0	16	38	19	0	0
WNW	ESE	B	0	31	159	55	6	0
NW	SE	B	0	31	168	51	1	0
NNW	SSE	B	0	23	72	7	0	0
N	S	B	3	14	22	0	0	0
NNE	SSW	B	0	21	21	0	0	0
NE	SW	B	1	19	16	0	0	0
ENE	WSW	B	0	8	10	0	0	0
E	W	B	0	7	14	0	0	0
ESE	WNW	B	2	9	4	1	0	0
SE	NW	B	0	7	15	5	0	0
SSE	NNW	B	2	6	29	12	0	0
	Calms	B	0					
S	N	C	4	15	61	11	0	0
SSW	NNE	C	2	28	107	9	0	0
SW	NE	C	2	30	121	17	0	0
WSW	ENE	C	1	29	71	13	0	0
W	E	C	0	35	115	14	2	0
WNW	ESE	C	1	48	266	79	12	0

Table C-20. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 60-meter (197-foot) Height for 1994-1998 at the WVDP Site[a] (cont)

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
NW	SE	C	3	53	260	41	1	0
NNW	SSE	C	4	53	98	15	0	0
N	S	C	2	52	45	0	0	0
NNE	SSW	C	1	36	22	0	0	0
NE	SW	C	4	28	17	0	0	0
ENE	WSW	C	1	14	14	1	0	0
E	W	C	1	14	21	7	3	0
ESE	WNW	C	3	14	15	4	0	0
SE	NW	C	1	27	40	4	1	1
SSE	NNW	C	0	16	38	14	6	
	Calms	C	0					
S	N	D	42	162	475	278	54	5
SSW	NNE	D	24	242	908	204	6	0
SW	NE	D	29	408	1,334	296	2	0
WSW	ENE	D	46	438	1,066	181	2	0
W	E	D	49	528	1,737	506	24	0
WNW	ESE	D	49	585	2,320	748	32	0
NW	SE	D	70	524	1,425	322	8	0
NNW	SSE	D	67	311	469	46	0	0
N	S	D	82	312	262	14	0	0
NNE	SSW	D	84	234	167	1	0	0
NE	SW	D	74	193	99	6	0	0
ENE	WSW	D	76	105	195	10	3	0
E	W	D	62	126	214	12	1	0
ESE	WNW	D	85	219	281	33	0	0
SE	NW	D	86	371	671	226	53	6
SSE	NNW	D	38	227	685	323	204	45
	Calms	D	24					
S	N	E	65	178	523	226	28	1
SSW	NNE	E	39	174	728	136	0	0
SW	NE	E	38	153	589	69	0	0
WSW	ENE	E	30	200	249	6	0	0
W	E	E	32	184	299	7	0	0
WNW	ESE	E	42	165	286	10	1	0
NW	SE	E	47	134	201	6	0	0
NNW	SSE	E	56	65	62	0	0	0
N	S	E	55	72	10	0	0	0
NNE	SSW	E	43	34	4	0	0	0
NE	SW	E	36	32	7	0	0	0
ENE	WSW	E	40	35	14	0	0	0

Table C-20. Hours for Combinations of Direction, Stability Class, and Wind Speed Range at 60-meter (197-foot) Height for 1994-1998 at the WVDP Site[a] (cont)

Direction		Stability Class	Wind Speed Range (in meters per second)					
From	To		0.0-1.5	1.5-3.0	3.0-6.0	6.0-9.0	9.0-12.0	> 12.0
E	W	E	55	59	14	6	0	0
ESE	WNW	E	111	121	42	1	0	0
SE	NW	E	224	507	455	50	0	0
SSE	NNW	E	166	337	536	207	76	14
	Calms	E	59					
S	N	F	72	100	140	1	0	0
SSW	NNE	F	19	87	115	0	0	0
SW	NE	F	26	46	66	0	0	0
WSW	ENE	F	27	56	30	1	0	0
W	E	F	18	50	22	0	0	0
WNW	ESE	F	26	55	25	0	0	0
NW	SE	F	43	52	35	0	0	0
NNW	SSE	F	44	34	13	0	0	0
N	S	F	42	8	0	0	0	0
NNE	SSW	F	20	4	0	0	0	0
NE	SW	F	28	3	0	0	0	0
ENE	WSW	F	28	3	0	0	0	0
E	W	F	39	7	0	0	0	0
ESE	WNW	F	72	35	6	0	0	0
SE	NW	F	374	390	162	3	0	0
SSE	NNW	F	457	286	134	8	0	0
	Calms	F	77					
S	N	G	99	172	122	1	0	0
SSW	NNE	G	36	114	166	1	0	0
SW	NE	G	25	87	49	0	0	0
WSW	ENE	G	32	68	7	0	0	0
W	E	G	20	37	8	0	0	0
WNW	ESE	G	21	25	6	0	0	0
NW	SE	G	31	44	6	0	0	0
NNW	SSE	G	24	16	1	0	0	0
N	S	G	15	2	0	0	0	0
NNE	SSW	G	19	1	0	0	0	0
NE	SW	G	28	0	0	0	0	0
ENE	WSW	G	17	2	0	0	0	0
E	W	G	27	1	0	0	0	0
ESE	WNW	G	63	12	2	0	0	0
SE	NW	G	317	369	89	0	0	0
SSE	NNW	G	554	511	110	0	0	0
	Calms	G	44					

Source: WVNS 2000a.

a. Total hours recorded (1994-1998) for wind blowing from the direction and at the speed range indicated.

Table C-21. Locations of Receptors at WVDP Site (in meters)[a]

Direction	Site Boundary Distance	Nearest Residence Distance
S	1,958	2,300
SSW	1,806	2,800
SW	1,538	2,100
WSW	1,405	2,200
W	1,051	1,800
WNW	1,051	1,200
NW	1,153	1,300
NNW	1,223	1,900
N	1,598	2,500
NNE	1,604	2,600
NE	1,604	1,900
ENE	1,615	2,000
E	1,856	2,500
ESE	2,430	2,600
SE	2,406	2,900
SSE	2,223	3,100

Sources: WVNS 2000a (site boundary); WVNS 2002b (nearest residence).
a. To convert meters to feet, multiply by 3.2808.

For accidents, radiation doses for workers were also evaluated at an onsite evaluation point located 640 meters (2,100 feet) from the accident. For ground-level releases, the north-northwest direction yielded the largest radiation dose for 95-percent meteorology and 50-percent meteorology. For elevated releases, the southwest direction yielded the largest radiation dose for 95-percent meteorology and 50-percent meteorology.

Population radiation doses from airborne releases during accidents were evaluated for the direction that yielded the largest population radiation dose. For ground-level and elevated releases, the north-northwest direction yielded the largest population radiation dose for 95-percent meteorology and 50-percent meteorology. For distances from 0 to 80 kilometers (0 to 50 miles) of the WVDP site, this direction had a population of about 680,000 people.

C.7 POPULATION DATA

The 2000 population within 80 kilometers (50 miles) of the WVDP site was 1,535,963 (Table C-22). This was an increase of about 15 percent since 1990, with most of the growth being in the southern suburbs of Buffalo, north and north-northwest of the WVDP site. The 2000 population within 10 kilometer (6.2 miles) of the WVDP site was 8,978; this was a decrease of about 2 percent since 1990.

C.8 RADIATION DOSES FROM CONTINUED MANAGEMENT FOR WVDP WORKERS AND THE PUBLIC

Using data from DOE Radiation Exposure Monitoring System (DOE 2001) for 1995 through 1999, the average collective radiation dose to workers at the WVDP site was about 15 person-rem per year (Table C-23). Over this same time period, the average individual radiation dose to workers at the WVDP site was about 59 millirem (mrem) per year. This radiation dose is well below the WVDP site administrative control level of 500 mrem per year (WVNS 2001b).

Table C-22. 2000 Population Distribution Around the WVDP Site

Direction	Distance (in kilometers)[a]										
	0 to 2	2 to 3	3 to 5	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 80	Total (0 to 80)
S	3	6	19	140	998	1,849	5,874	1,420	1,7190	6,109	33,608
SSW	4	3	44	205	540	1,957	2,669	691	437	15,236	21,786
SW	9	4	19	166	780	2,163	2,563	4,148	7,935	54,727	72,514
WSW	13	7	32	167	497	674	2,386	2,304	5,201	13,869	25,150
W	14	13	41	105	390	5,710	1,819	4,129	29,437	10,830	52,488
WNW	20	40	203	68	1,276	7,277	6,140	8,614	0	0	23,638
NW	8	32	58	236	915	5,206	19,405	1,407	0	0	27,267
NNW	1	6	40	2,554	1,518	8,536	59,778	106,966	294,784	213,344	687,527
N	5	10	53	2380	1,680	4,329	24,337	80,620	109,284	112,259	334,957
NNE	7	12	69	306	914	3,824	3,940	5,758	10,979	35,272	61,081
NE	8	14	47	160	1,343	1,649	2,155	2,596	10,031	17,803	35,806
ENE	7	16	40	122	4,082	3,586	1,419	2,218	5,687	26,411	43,588
E	7	12	95	171	1,323	1,376	1,752	4,048	1,600	11,020	21,404
ESE	10	23	64	175	1,411	578	1,127	2,668	4,521	17,611	28,188
SE	22	22	105	318	725	2,689	2,432	3,820	4,541	7,076	21,750
SSE	1	19	40	358	353	698	2,427	24,822	6,562	9,931	45,211
Total	139	239	969	7,631	18,745	52,101	140,223	256,229	508,189	551,498	1,535,963

a. To convert kilometers to miles, multiply by 0.62137.

Table C-23. Radiation Doses to WVDP Workers from Continued Management Activities

Year	Number of People Monitored	Number of People with Measurable Doses	Collective Dose (person-rem/yr)	Individual Dose (mrem/yr)
1999	1,064	243	12.5	52
1998	1,115	260	18.2	70
1997	1,206	174	6.9	40
1996	1,365	231	11.2	48
1995	1,518	311	26.9	87
Average	1,254	244	15	59

Source: DOE 2001.

Using data from the West Valley Annual Site Environmental Reports (WVNS 1996, 1997, 1998, 1999a, 2000b) for 1995 through 1999, the collective radiation dose to people living around the WVDP site from airborne releases was about 0.17 person-rem per year (Table C-24). The individual radiation dose from airborne releases was about 0.021 mrem per year.

Table C-24. Radiation Doses to WVDP Members of the Public from Continued Management Activities

Pathway	Individual Dose (mrem/yr)	Collective Dose (person-rem/yr)
Airborne		
1999	0.011	0.11
1998	0.034	0.26
1997	0.049	0.39
1996	8.7×10^{-3}	0.070
1995	4.3×10^{-4}	8.6×10^{-3}
Annual Average	0.021	0.17
Waterborne[a]		
1999	0.056	0.13
1998	0.031	0.067
1997	0.024	0.038
1996	0.067	0.084
1995	0.028	0.094
Annual Average	0.041	0.083
All-Pathways		
1999	0.068	0.24
1998	0.065	0.33
1997	0.073	0.43
1996	0.076	0.15
1995	0.028	0.10
Annual Average	0.062	0.25
Background		
1999	300	380,000
1998	300	380,000
1997	300	380,000
1996	300	390,000
1995	300	390,000
Annual Average	300	380,000

a. Includes effluents and North Plateau drainage.
Sources: WVNS 1996, 1997, 1998, 1999a, and 2000b

Over this same time period, radiation doses from waterborne releases, including effluents and North Plateau drainage, were estimated to be 0.041 mrem per year for individuals and 0.083 person-rem per year for the population within 80 kilometers (50 miles) of the WVDP site.

The collective radiation dose through all exposure pathways (air and water) to people living around the WVDP site was about 0.25 person-rem per year. The individual radiation dose through all exposure pathways to people living within 80 kilometers (50 miles) of the WVDP site was about 0.062 mrem per year. For perspective, the population radiation dose from background radiation to people living within 80 kilometers (50 miles) of the WVDP site was 380,000 person-rem per year, and the individual radiation dose from background radiation to people living within 80 kilometers of West Valley was about 300 mrem per year.

C.9 AIR QUALITY

New York State is divided into nine regions for assessing state ambient air quality. The WVDP site is located in Region 9, which is comprised of Niagara, Erie, Wyoming, Chatauqua, Cattaraugus, and Allegany counties. The WVDP site and the surrounding area in Cattaraugus County are in attainment with the National Primary and Secondary Ambient Air Quality Standards contained in 40 CFR 50 and

New York State air quality standards contained in 6 NYCRR 257. The city of Buffalo, located about 48 km (30 mi) from the WVDP site, is a marginal nonattainment area for ozone (EPA 2002).

Under all of the proposed alternatives, the primary impacts to air quality would be through the continued emission of four criteria pollutants—nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter—from the two Cleaver Brooks boilers at the WVDP site. These boilers are used to generate steam for heating and other processes at the site, and each have a capacity of 20.2 million British thermal units per hour. Together, these boilers use about 2 million cubic meters (70 million cubic feet) of natural gas and about 24,000 liters (6,300 gallons) of No. 2 fuel oil per year. The other two criteria pollutants, lead and ozone, are produced in insufficient quantities by the boilers for consideration in this analysis.

Emissions from the boilers are presented in Table C-25. These emissions were calculated using the emission factors from *Compilation of Air Pollutant Emission Factors* (EPA 1998) (Chapter 1.3 for fuel oil combustion and Chapter 1.4 for natural gas combustion and are for boilers with a capacity of less than 100 million British thermal units per hour). The particulate matter emissions include both filterable particulate matter and condensable particulate matter, and all particulate matter was assumed to have an aerodynamic diameter of less than 10 micrometers. Back-up generators at the WVDP site do not contribute significantly to these emissions. Other data used in the analysis are listed in Table C-26.

The SCREEN3 computer code (EPA 1995) was used to model the potential impacts to air quality from these emissions. Three analyses were performed: (1) a simple terrain analysis for flat terrain, (2) a simple elevated terrain analysis for terrain lower than the physical stack height, and (3) a complex terrain analysis for terrain higher than the physical stack height. The simple elevated terrain analysis and the complex terrain analysis were performed because of the many hills and valleys around the WVDP site. Many offsite locations were examined in these analyses. The nearest location was at 1,051 meters (3,450 feet) from the boiler stacks, which corresponds to the nearest the WVDP site boundary location. The furthest location was at 50,000 meters (30 miles) from the site. The simple elevated terrain analysis yielded the highest estimates of criteria pollutant concentrations (Table C-27). The highest concentrations occurred at 1,379 meters (4,524 feet) from the WVDP site. As shown in Table C-27, the concentrations of criteria pollutants from the WVDP site emissions are well below the National Primary and Secondary Ambient Air Quality Standards contained in 40 CFR 50 and the New York State air quality standards contained in 6 NYCRR 257. It should be noted that the background concentrations used in Table C-27 were from near Buffalo, New York; actual background concentrations near the WVDP site would be lower. WVDP emissions of nitrogen dioxide and sulfur dioxide are also well below the New York State Department of Environmental Conservation's annual emission cap of 90,700 kilograms (100 tons).

Table C-25. Annual Criteria Pollutant Emissions from WVDP Boilers (in tons)[a]

Criteria Pollutant	Emissions from Natural Gas	Emissions from No. 2 Fuel Oil
Nitrogen Dioxide	3.5	0.063
Sulfur Dioxide	0.021	0.22
Carbon Monoxide	2.9	0.016
Particulate Matter	0.27	0.010

Source: EPA 1998.

a. To convert tons to kilograms, multiply by 907.18.

Note: Emissions are based on using 70 million cubic feet of natural gas and 6,300 gallons of No. 2 fuel oil per year. The boilers were assumed to operate 180 days per year. Emissions were calculated using the emission factors from AP-42, Chapter 1.3 for fuel oil combustion and AP-42, Chapter 1.4 for natural gas combustion, and are for boilers with a capacity of less than 100 million British thermal units per hour.

Table C-26. Data Used to Model Criteria Pollutant Emissions

Parameter	Value
Stack Height	7.62 meters (25 feet)
Stack Diameter	0.6096 meter (24 inches)
Stack Velocity	8 meters per second (26 feet per second)
Stack Temperature	154ºC (427ºK)
Ambient Temperature	20ºC (293ºK)
Boiler Capacity	20.2 million British thermal units per hour
Boiler Operating Time	180 days per year
Minimum site boundary distance	1,051 meters (3,450 feet)
Maximum distance	50,000 meters (30 miles)
Maximum sulfur content of No. 2 fuel oil	0.5 percent
Excess oxygen	3 percent
Fuel factor (natural gas)	8,710 dry standard cubic feet per million British thermal units
1-hour averaging time to 3-hour averaging time multiplying factor	0.9 (a)
1-hour averaging time to 8-hour averaging time multiplying factor	0.7 (a)
1-hour averaging time to 24-hour averaging time multiplying factor	0.4 (a)
1-hour averaging time to annual averaging time multiplying factor	0.08 (a)

Source: EPA 1992.

Table C-27 also shows the regional background concentrations of the criteria pollutants as measured near Buffalo, New York (EPA 2001). When combined with concentrations from WVDP emissions, the resulting total concentrations are also below the National Primary and Secondary Ambient Air Quality Standards contained in 40 CFR 50 and the New York State air quality standards contained in 6 NYCRR 257.

Air emissions of radionuclides from WVDP, are regulated by the EPA under the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations, 40 CFR Part 61, Subpart H, National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities. Annual reporting of the radionuclide emissions for calendar year 2000 was less than 0.1 percent of EPA's standards (WVNS, 2001).

Table C-27. Criteria Pollutant Concentrations from WVDP Boiler Emissions and Regional Background

Criteria Pollutant	Averaging Time	Standard[a,b]	Concentration From WVDP Emissions[b,c]	Background Concentration[b,d]	Total Concentration[b]	Percent of Standard
Nitrogen dioxide	Annual	100[g,h,i] (0.053 ppm)	1.5	41	42	42
Carbon monoxide	1 hour	40,000[g,i] (35 ppm)	15	5,800	5,800	14
Carbon monoxide	8 hours	10,000[g,i] (9 ppm)	11	3,200	3,200	32
Sulfur dioxide	Annual	80[g,i] (0.03 ppm)	0.10	17	17	22
Sulfur dioxide	24 hours	365[g,i] (0.14 ppm)	0.50	63	64	17
Sulfur dioxide	3 hours	1,300[h,i] (0.5 ppm)	1.1	160	160	12
Particulate matter[e]	Annual	50[g,h]	0.11	21	21	42
Particulate matter[f]	24 hours	150[g,h]	0.56	61	61	41
Ozone	1 hour	235[g,h] (0.12 ppm)	(--)	210	210	89
Lead	Quarterly	1.5[g,h]	(--)	0.03	0.03	2

a. Standards from 40 CFR 50, National Primary and Secondary Ambient Air Quality Standards and 6 NYCRR 257, Air Quality Standards. Comparisons to the standards for particulate matter with an aerodynamic diameter less than 2.5 micrometers and the 8-hour ozone standard were not made because these standards have been remanded to the U.S. Environmental Protection Agency by the U.S. Court of Appeals.
b. Units in micrograms per cubic meter. Parts per million not calculated for substances that do not exist as a gas or vapor at normal room temperature and pressure.
c. The maximum criteria pollutant concentrations from WVDP boiler emissions were located 1,379 meters (4,524 feet) from the WVDP site.
d. Source: EPA 2001. Background concentrations were measured near Buffalo, New York.
e. Annual state standard is 45 to 75 micrograms per cubic meter according to level designation.
f. 24-hour state standard is 250 micrograms per cubic meter.
g. National primary ambient air quality standard.
h. National secondary ambient air quality standard.
i. New York State air quality standard.

C.10 OFFSITE IMPACTS

This section describes how the data in Table 2-6 were derived from the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DOE 1997a) (WM PEIS), the *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement* (DOE 1997b) (WIPP SEIS-II), and the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 2002) (Yucca Mountain Repository EIS).

LLW and Mixed LLW Disposal at Hanford, NTS, or a Commercial Disposal Site such as Envirocare. In the WM PEIS, DOE analyzed the potential environmental impacts of managing (treating, storing, or disposing of) LLW, mixed LLW, TRU waste, HLW, and hazardous waste. For each waste type, DOE considered a Decentralized Alternative (DOE sites where waste was currently generated or stored), one or more Regionalized Alternatives (a few DOE sites at various locations across the nation), and one or more Centralized Alternatives (one DOE site). Of particular relevance to this WVDP Waste

Management EIS, the WM PEIS described human health impacts of disposing of 1.5 million cubic meters (53.5 million cubic feet) of LLW at Hanford (Centralized Alternative 3) or NTS (Centralized Alternative 4) and disposing of 219,000 cubic meters (7.8 million cubic feet) of mixed LLW at Hanford (Centralized Alternative) or NTS (Regionalized Alternative 3) (WM PEIS, Section 1.5 and Table 1-6.2).

For these two waste types, the WVDP waste represents less than 2 percent of the total waste volume from all DOE sites analyzed in the WM PEIS (for Class A waste, the WVDP represents 0.3 percent of the total LLW volume; for LLW, the WVDP waste represents 1.3 percent of the total LLW volume; and for mixed LLW, the WVDP waste represents 0.1 percent of the total mixed LLW volume). Because impacts, particularly human health impacts, are directly related to waste volume, the impacts of managing WVDP LLW and mixed LLW at either Hanford or NTS would be no more than 2 percent of the total impacts at those sites, as described in the WM PEIS. Table 2-6 shows the potential human health impacts of disposing of WVDP LLW and mixed LLW at Hanford or NTS. These impacts are 2 percent of the impacts described in the site data tables for those sites in Volume II of the WM PEIS. The impacts of the disposal of these waste types at Envirocare are assumed to be similar to impacts at Hanford.

TRU Waste Interim Storage at Hanford, INEEL, ORNL, or SRS. The WM PEIS also analyzed the treatment and interim storage of differing volumes of TRU waste from several DOE sites (including WVDP) at Hanford, INEEL, ORNL, or SRS (Regionalized Alternative 3). Table 2-6 shows the potential human health impacts of all TRU waste treatment and interim storage at those sites as stated in the WM PEIS. Because the WVDP TRU waste to be stored at those sites would not be treated and would be a smaller volume than that analyzed in the WM PEIS (and included in Table 2-6), the data in Table 2-6 substantially overstate the potential impacts of storing WVDP TRU waste at those sites.

TRU Waste Interim Storage at WIPP. The WM PEIS analyzed the treatment of TRU waste generated at most DOE sites at WIPP (Centralized Alternative). Table 2-6 shows the potential human health impacts of WVDP TRU waste interim storage at WIPP. These impacts are the impacts described in the WIPP SEIS-II for TRU waste treatment at WIPP. Because the volume of WVDP TRU waste is less than the volume analyzed in the WM PEIS, and because the impacts of interim storage at WIPP would be less than the impacts of TRU waste treatment at that site, the data in Table 2-6 substantially overstate the potential impacts of WVDP TRU waste interim storage at WIPP.

HLW Interim Storage at Hanford or SRS. With respect to HLW storage, the WM PEIS analyzed the interim storage of 340 canisters of WVDP HLW at Hanford (Regionalized Alternative 2) and SRS (Regionalized Alternative 1). Table 2-6 shows the potential human health impacts of WVDP HLW interim storage at these sites as originally reported in the site data tables for Hanford and SRS (Volume II of the WM PEIS). The impacts of interim storage of WVDP HLW would be slightly less because the volume of WVDP HLW (300 canisters) is slightly less than the volume of WVDP HLW analyzed in the WM PEIS (340 canisters).

TRU Waste Disposal at WIPP. The WIPP SEIS-II analyzed the potential environmental impacts of the shipment of all TRU waste to WIPP for treatment prior to disposal. TRU waste generated and stored at WVDP represents less than 1 percent of the total inventory to be disposed of at WIPP (175,580 cubic meters [6.2 million cubic feet]). Table 2-6 shows the expected human health impacts of disposing of WVDP TRU waste at WIPP. These impacts are 1 percent of the impacts reported in the WIPP SEIS-II (WIPP SEIS-II, Section 3.4, Table 3-18).

HLW Disposal at Yucca Mountain. The Yucca Mountain Repository EIS analyzed the potential environmental impacts of the disposal of 70,000 metric tons of heavy metal of HLW and spent nuclear fuel at the Yucca Mountain Repository. The 300 canisters of HLW (approximately 690 metric tons of heavy metal)[1] at WVDP represent approximately 1 percent of the total inventory of HLW and spent nuclear fuel to be disposed of at Yucca Mountain. Table 2-6 shows the expected human health impacts of disposing of WVDP HLW waste at the Yucca Mountain Repository. These impacts are 1 percent of the impacts reported in the Yucca Mountain Repository EIS (Yucca Mountain Repository EIS, Section 2.4.1, Table 2-7).

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[1] DOE estimates that each WVDP HLW canister contains 2.3 metric tons of heavy metal. Thus, 300 canisters would contain 690 metric tons of heavy metal. This volume is 1 percent of the 70,000 metric tons of heavy metal analyzed in the Yucca Mountain Repository EIS.

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