APPENDIX I
DECOMMISSIONING RADIOLOGICAL AND HAZARDOUS CHEMICAL HUMAN HEALTH IMPACTS EVALUATION

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I.1 Introduction

This appendix provides a brief general discussion on radiation and its health effects. It also describes the methodologies and assumptions used for estimating potential impacts on and risks to individuals and the general public from exposure to radioactive and hazardous chemical material releases during normal operations and hypothetical accidents during the short-term preparation for the decommissioning phase of the decommissioning alternatives. Long-term radioactive and hazardous chemical release consequences are presented in Appendix H.

This appendix presents numerical information using scientific, or exponential, notation. For example, the number 100,000 can also be expressed as 1×10^5. The number 0.001 can be expressed as 1×10^{-3}. The following chart defines the equivalent numerical notations that may be used in this appendix.

Fractions and Multiples of Units

Multiple	*Decimal Equivalent*	*Prefix*	*Symbol*
1×10^6	1,000,000	mega-	M
1×10^3	1,000	kilo-	k
1×10^2	100	hecto-	h
1×10	10	deka-	da
1×10^{-1}	0.1	deci-	d
1×10^{-2}	0.01	centi-	c
1×10^{-3}	0.001	milli-	m
1×10^{-6}	0.000001	micro-	μ

I.2 Human Health Radiological Impacts

Because radiation exposure and its consequences are of interest to the general public, this environmental impact statement (EIS) provides information about the nature of radiation, explains basic concepts used to evaluate radiation health effects, and presents radiation exposure consequences.

I.2.1 Nature of Radiation and Its Effects on Humans

What Is Radiation?

Radiation is energy transferred in the form of particles or waves. Globally, human beings are exposed constantly to radiation from the solar system and the Earth's rocks and soil. This radiation contributes to the natural background radiation that always surrounds us. Manmade sources of radiation also exist, including medical and dental x-rays and household smoke detectors.

All matter in the universe is composed of atoms. Radiation comes from the activity of tiny particles within an atom. An atom consists of a positively charged nucleus (central part of an atom) with a number of negatively charged electron particles in various orbits around the nucleus. There are two types of particles in the nucleus:

neutrons that are electrically neutral, and protons that are positively charged. Atoms are categorized as different stable elements based on the number of protons in the nucleus. There are more than 100 natural and manmade elements. An element has equal numbers of electrons and protons. When atoms of an element differ in their number of neutrons, they are called isotopes of that element. All elements have three or more isotopes, some or all of which could be unstable.

Unstable isotopes undergo spontaneous change, known as radioactive disintegration or radioactive decay. The process of continuously undergoing spontaneous disintegration is called radioactivity. The radioactivity of a material decreases with time. The time it takes a material to lose half of its original radioactivity is its half-life. An isotope's half-life is a measure of its decay rate. For example, an isotope with a half-life of 8 days will lose one-half of its radioactivity in that amount of time. In 8 more days, one-half of the remaining radioactivity will be lost, and so on. Each radioactive element has a characteristic half-life. The half-lives of various radioactive elements may vary from millionths of a second to billions of years.

As unstable isotopes change into more stable forms, they emit particles and/or energy. An emitted particle may be an alpha particle (a helium nucleus), a beta particle (an electron), or a neutron, with various levels of kinetic energy. Sometimes these particles are emitted in conjunction with gamma rays. The particles and gamma rays are referred to as "ionizing radiation." Ionizing radiation refers to the fact that the radiation can ionize, or electrically charge, an atom by stripping off one or more of its electrons. Gamma rays, even though they do not carry an electric charge, can ionize atoms as they pass through an element by ejecting electrons. Thus, they cause ionization indirectly. Ionizing radiation can cause a change in the chemical composition of many things, including living tissue (organs), which can affect the way they function.

When a radioactive isotope of an element emits a particle, it changes to an entirely different element or isotope, one that may or may not be radioactive. Eventually a stable element is formed. This transformation, which may take several steps, is known as a decay chain. For example, the isotope radium-226, which is a member of the radioactive decay chain of uranium, has a half-life of 1,622 years. It emits an alpha particle and becomes the isotope radon-222, a radioactive gas with a half-life of only 3.8 days. Radon decays first to polonium; then, through a series of further decay steps, to bismuth; and ultimately to a stable isotope of lead. Meanwhile, the decay products will build up and eventually die away as time progresses.

Characteristics of various forms of ionizing radiation are briefly described below and in the box to the right.

Radiation Type	***Typical Travel Distance in Air***	***Barrier***
α	Few centimeters	Sheet of paper or skin's surface
β	Few meters	Thin sheet of aluminum foil or glass
γ	Very large	Thick wall of concrete, lead, or steel
n	Very large	Water, paraffin, graphite

Alpha (α) – Alpha particles are the heaviest type of ionizing radiation consisting of two protons and two neutrons. They can travel only a few centimeters in air. Alpha particles lose their energy almost as soon as they collide with anything. They can be stopped easily by a sheet of paper or by the skin's surface.

Beta (β) – Beta particles, consisting of an electron, are much (7,330 times) lighter than alpha particles. They can travel a longer distance than alpha particles in the air. A high-energy beta particle can travel a few meters in the air. Beta particles can pass through a sheet of paper, but can be stopped by a thin sheet of aluminum foil or glass.

Gamma (γ) – Gamma rays (and x-rays), unlike alpha or beta particles, are waves of pure energy. Gamma rays travel at the speed of light. Gamma radiation is very penetrating and requires a large mass such as a thick wall of concrete, lead, or steel to stop it.

Neutrons (n) – The most prolific source of neutrons is a nuclear reactor. Neutrons produce ionizing radiation indirectly by collision with hydrogen nuclei (protons) and when gamma rays and alpha particles are emitted following neutron capture in matter. A neutron has about one-quarter the weight of an alpha particle. It will travel in the air until it is absorbed in another nucleus.

I.2.2 Radiation Measuring Units

During the early days of radiological experimentation, there was no precise unit for radiation measure. Therefore, a variety of units were used to measure radiation. These units determined the amount, type, and intensity of radiation. Just as heat can be measured in terms of its intensity or effects using units of calories or degrees, amounts of radiation or its effects can be measured in units of curies, radiation absorbed dose (rad), or dose equivalent (roentgen equivalent man, or rem). The following summarizes these units.

Curie— The curie, named after French scientists Marie and Pierre Curie, describes the "intensity" of a sample of radioactive material. The decay rate of 1 gram of radium was the basis of this unit of measure. Because the measured decay rate kept changing slightly as measurement techniques became more accurate, the curie was subsequently defined as exactly 3.7×10^{10} disintegrations (decays) per second.

Rad—The rad is the unit of measurement for the physical absorption of radiation. The total energy absorbed per unit quantity of tissue is referred to as "absorbed dose" (or simply dose). As sunlight heats pavement by giving up an amount of energy to it, radiation similarly gives up energy to objects in its path. One rad is equal to the amount of radiation that leads to the deposition of 0.01 joule of energy per kilogram of absorbing material.

Radiation Units and Conversions to International System of Units

1 curie	= 3.7×10^{10} disintegrations per second
	= 3.7×10^{10} becquerels
1 becquerel	= 1 disintegration per second
1 rad	= 0.01 gray
1 rem	= 0.01 sievert
1 gray	= 1 joule per kilogram

Rem—The rem is a measurement of the dose equivalent from radiation based on its biological effects. The rem is used in measuring effects of radiation on the body. One rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other kind of radiation. This allows comparison of the biological effects of radionuclides that emit different types of radiation. One-thousandth of a rem is called a millirem.

Person-rem—The term used for reporting the collective dose, the sum of individual doses received in a given time period by a specified population from exposure to a specified radiation source.

The units of radiation measure in the International System of Units are: becquerel (a measure of source intensity [activity]), gray (a measure of absorbed dose), and sievert (a measure of dose equivalent). In accordance with U.S. Department of Energy (DOE) convention, all units presented in this EIS are in terms of curies, rad, rem, and person-rem.

An individual may be exposed to ionizing radiation externally (from a radioactive source outside the body) or internally (from ingesting or inhaling radioactive material). The external dose is different from the internal dose because an external dose is delivered only during the actual time of exposure to the external radiation source, while an internal dose continues to be delivered as long as the radioactive source is in the body. The dose from internal exposure is calculated over 50 years following the initial exposure. Both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time.

I.2.3 Radiation Sources

The average American receives a total of approximately 360 millirem per year from all radiation sources, both natural and manmade, of which approximately 300 millirem per year are from natural sources. Radiation sources can be divided into six different categories: (1) cosmic radiation, (2) terrestrial radiation, (3) internal radiation, (4) consumer products, (5) medical diagnosis and therapy, and (6) other sources (NCRP 1987). These categories are discussed in the following paragraphs.

Cosmic Radiation – Cosmic radiation is ionizing radiation resulting from energetic charged particles from space continuously hitting Earth's atmosphere where they create secondary particles and protons. These particles and the secondary particles and photons they create compose cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with the altitude above sea level. The average dose to people in the United States from this source is approximately 27 millirem per year.

External Terrestrial Radiation – External terrestrial radiation is radiation emitted from radioactive materials in Earth's rocks and soils. The average individual dose from external terrestrial radiation is approximately 28 millirem per year.

Internal Radiation – Internal radiation results from the human body metabolizing natural radioactive material that has entered the body by inhalation or ingestion. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, potassium, rubidium, and carbon. The major contributors to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon, which contribute approximately 200 millirem per year. The average individual dose from other internal radionuclides is approximately 39 millirem per year.

Consumer Products – Consumer products also contain sources of ionizing radiation. In some products, such as smoke detectors and airport x-ray machines, the radiation source is essential to the product's operation. In other products, such as televisions and tobacco, radiation occurs as the products function. The average dose from consumer products is approximately 10 millirem per year.

Medical Diagnosis and Therapy – Radiation is an important diagnostic medical tool and cancer treatment. Diagnostic x-rays result in an average exposure of 39 millirem per year. Nuclear medical procedures result in an average exposure of 14 millirem per year.

Other Sources – There are a few additional sources of radiation that contribute minor doses to individuals in the United States. The average dose from nuclear fuel cycle facilities (e.g., uranium mines, mills, and fuel processing plants) and nuclear power plants has been estimated to be less than 1 millirem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions from certain mineral extraction facilities, and transportation of radioactive materials contribute less than 1 millirem per year to the average dose to an individual. Air travel contributes approximately 1 millirem per year to the average dose.

I.2.4 Exposure Pathways

As stated earlier, an individual may be exposed to ionizing radiation both externally and internally. The different ways that could result in radiation exposure to an individual are called exposure pathways. Each type of exposure is discussed separately in the following paragraphs.

External Exposure—External radiation exposure can result from several different pathways, including exposure to a cloud of radioactive particles passing over the receptor (an exposed individual), standing on ground contaminated with radioactivity, and swimming or boating in contaminated water. If the receptor

leaves the source of radiation exposure, the dose rate will be reduced if not eliminated. Dose from external radiation is based on time spent exposed to a radiation source. The appropriate dose measure is called the effective dose equivalent.

Internal Exposure—Internal exposure results from a radiation source entering the human body through either inhalation of contaminated air or ingestion of contaminated food or water. In contrast to external exposure, once a radiation source enters the body, it remains there for a period of time that varies, depending on decay and biological half-life.[1] The absorbed dose to each organ of the body is calculated for a period of 50 years following intake, in accordance with DOE safety analysis application guidance. The calculated absorbed dose is called the committed dose equivalent. Various organs have different susceptibilities to damage from radiation. The committed effective dose equivalent takes these different susceptibilities into account and provides a broad indicator of the health risk to an individual from radiation. The committed effective dose equivalent is a weighted sum of the committed dose equivalent in each major organ or tissue. The concept of committed effective dose equivalent applies only to internal pathways.

I.2.5 Radiation Protection Guides

Several organizations have issued radiation protection guides. 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)—ICRP has responsibility for providing guidance in matters of radiation safety. ICRP's operating policy is to prepare recommendations to address basic principles of radiation protection, leaving the various national protection committees to introduce detailed technical regulations, recommendations, or codes of practice best suited to the needs of their countries.

National Council on Radiation Protection and Measurements—In the United States, this Council has responsibility for adapting and providing detailed technical guidelines for implementing ICRP recommendations. The Council consists of expert radiation protection specialists and scientists.

National Research Council/National Academy of Sciences—The National Research Council, which provides science and policy research supporting the National Academy of Sciences, associates the broad science and technology community with the Academy's purposes of furthering knowledge and advising the Federal Government. The Council's Nuclear Radiation Studies Board prepares reports to advise the Federal Government on issues related to radiation protection and radioactive materials. The Committee on the Biological Effects of Ionizing Radiation (BEIR), which has issued a number of studies on radiation exposure health conveyances, operates under the Nuclear Radiation Studies Board.

U.S. Environmental Protection Agency (EPA)—EPA has published a series of documents, *Radiation Protection Guidance to Federal Agencies*, used as a regulatory benchmark by a number of Federal agencies, including DOE, to limit public and occupational workforce exposures to the greatest extent possible.

The Interagency Steering Committee on Radiation Standards (ISCORS)—ISCORS technical reports serve as guidance to Federal agencies to assist them in preparing and reporting analyses results and implementing radiation protection standards in a consistent and uniform manner. ISCORS issued a technical report entitled *A Method for Estimating Radiation Risk from TEDE* (DOE 2002). This report provides dose-to-risk conversion factors using total effective dose equivalent (TEDE) to estimate dose. It is recommended for use by DOE personnel and contractors when computing potential radiation risk from calculated radiation dose for comparison purposes. However, for radiation risk assessments required in risk management decisions, the

[1] *Biological half-life is the time for one-half of a radioactive source that has entered the body to be removed from the body by natural processes.*

radionuclide-specific risk coefficients in EPA's Federal Guidance Report No. 13, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999b), should be used.

I.2.6 Radiation Exposure Limits

Exposure limits for members of the public and radiation workers are generally consistent with ICRP recommendations. EPA also considers National Council on Radiation Protection and Measurements and ICRP recommendations and sets specific annual exposure limits (usually less than those specified by ICRP) in *Radiation Protection Guidance to Federal Agencies* documents. Each regulatory organization then establishes its own set of radiation standards. Examples of exposure limits set by DOE, EPA and the U.S. Nuclear Regulatory Commission (NRC) for radiation workers and members of the public are shown in **Table I–1**.

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

Guidance Criteria (Organization)	*Public Exposure Limits at the Site Boundary*	*Worker Exposure Limits*
10 CFR 835.202 (DOE)	–	5 rem per year [a]
10 CFR 835.1002 (DOE)	–	1 rem per year [b]
40 CFR 61 (EPA)	0.01 rem per year (all air pathways)	–
40 CFR 141 (EPA)	0.004 rem per year (drinking water pathways)	–
DOE Order 5400.5 (DOE) [c]	0.01 rem per year (all air pathways) 0.004 rem per year (drinking water pathway) 0.1 rem per year (all pathway)	–
10 CFR 20.1301 (NRC)	0.1 rem per year (all pathways)	–
10 CFR 20.1201 (NRC)	–	5 rem per year
New York State Department of Environmental Conservation DSHM-RAD-05-01	0.01 rem per year after cleanup (all pathways)	–

CFR = *Code of Federal Regulations*, EPA = U.S. Environmental Protection Agency, NRC = U.S. Nuclear Regulatory Commission.

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

[b] This is an objective by DOE for the design of new facilities or modifications of existing facilities, to control personnel exposures from external sources of radiation. DOE recommends that facilities adopt an Administrative Control Level for occupational doses that should not exceed 2 rem per year, although DOE believes that an Administrative Control Level of 0.5 rem per year would be achievable for most facilities (DOE 1999b). Reasonable attempts must be made by the site to maintain individual worker doses below these levels.

[c] Derived from 40 CFR Part 61, 40 CFR Part 141, and 10 CFR Part 20.

I.3 Health Effects

To provide background information for discussions of radiation exposure impacts, this section explains basic concepts used to evaluate radiation effects.

Radiation can cause a variety of damaging health effects in humans. The most significant effects are induced cancer fatalities. These effects are referred to as "latent cancer fatalities" because the cancer may take many years to develop. In the discussions that follow, all fatal cancers are considered latent; therefore, the term "latent cancer fatalities" and "fatal cancers" are used interchangeably in this appendix.

The National Research Council's Committee on the BEIR has prepared a series of reports to advise the Federal Government on radiation exposure health consequences. *Health Effects of Exposure to Low Levels of Ionizing Radiation*, BEIR V (National Research Council 1990), provides current estimates for excess mortality from leukemia and other cancers expected to result from exposure to ionizing radiation. BEIR V provides estimates consistently higher than those in its predecessor, BEIR III. This increase is attributed to several factors,

including use of a linear dose response model for cancers other than leukemia, revised dosimetry for the Japanese atomic bomb survivors, and additional followup studies of the atomic bomb survivors and associated others. BEIR III employs constant, relative, and absolute risk models, with separate coefficients for each of several sex and age-at-exposure groups. Absolute risks are total population fatal cancer risks directly related to radiation dose. Relative risks account for differences in risk between the different age and sex of exposure groups. BEIR V develops models in which excess relative risk is expressed as a function of age at exposure, time after exposure, and sex for each of several cancer categories. The BEIR III models were based on the assumption that absolute risks are comparable between the atomic bomb survivors and the U.S. population. BEIR V models were based on the assumption that the relative risks are comparable. For a disease such as lung cancer, where baseline risks in the United States are much larger than those in Japan, the BEIR V approach leads to larger risk estimates than the BEIR III approach. The BEIR VII report, issued three years ago, is still being studied and incorporated into U.S. regulations and guidance. At this point, it appears that the BEIR VII report will not result in a change in mortality estimates. Therefore, fatal cancer estimates based on BEIR V are expected to remain valid. However, the BEIR VII report does result in an increase in morbidity estimates. Therefore, morbidity estimates, which are presented in Appendix H, are expected to increase when BEIR VII is incorporated into U.S. regulations and guidance.

Models and risk coefficients in BEIR V were derived through analyses of relevant epidemiologic data that included the Japanese atomic bomb survivors, ankylosis spondylitis patients, Canadian and Massachusetts fluoroscopy (breast cancer) patients, New York postpartum mastitis (breast cancer) patients, Israeli tinea capitis (thyroid cancer) patients, and Rochester thymus (thyroid cancer) patients. Models for leukemia, respiratory cancer, digestive cancer, and other cancers used only the atomic bomb survivor data, although the ankylosis spondylitis patient analysis results were considered. Atomic bomb survivor analyses were based on revised dosimetry, with an assumed relative biological effectiveness of 20 for neutrons, and were restricted to doses less than 400 rad. Estimates of fatal cancer (other than leukemia) risks were obtained by totaling estimates for breast, respiratory, digestive, and other cancers.

The National Council on Radiation Protection and Measurements, based on radiation risk estimates provided in BEIR V and ICRP Publication 60 recommendations (ICRP 1991), estimated the total detriment resulting from low-dose or low-dose rate exposure to ionizing radiation to be 0.00056 per rem for the working population and 0.00073 per rem for the general population (NCRP 1993). The total detriment includes fatal and nonfatal cancers, as well as severe hereditary (genetic) effects. The major contribution to the total detriment is from fatal cancer, estimated to be 0.0004 and 0.0005 per rem for radiation workers and the general population, respectively. The difference in radiation risk between workers and the public is due to the age of workers as compared to the population which includes children and elderly who are more sensitive to radiation. The risk estimator breakdowns for both workers and the general population are shown in **Table I–2**. Nonfatal cancers and genetic effects are less probable radiation exposure consequences.

Table I–2 Nominal Health Risk Estimators Associated with Exposure to 1 rem of Ionizing Radiation

Exposed Individual	*Fatal Cancer* [a, b]	*Nonfatal Cancer* [c]	*Genetic Disorders* [c]	*Total*
Worker	0.0004	0.00008	0.00008	0.00056
Public	0.0005	0.0001	0.00013	0.00073

[a] For fatal cancer, the health effect coefficient is the same as the probability coefficient. When applied to an individual, the unit is the lifetime probability of a cancer fatality per rem of radiation dose. When applied to a population of individuals, the unit is the excess number of fatal cancers per person-rem of radiation dose.

[b] For high individual exposures (greater than or equal to 20 rem) over a time period of up to one year, the health factors are multiplied by a factor of 2.

[c] In determining a means of assessing radiation exposure health effects, the ICRP has developed a weighting method for nonfatal cancers and genetic effects.

Source: NCRP 1993.

The EPA, in coordination with other Federal agencies involved in radiation protection, issued the September 1999 Federal Guidance Report No. 13*: Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999b). This document is a compilation of risk factors for doses from external gamma radiation and internal intake of radionuclides. Federal Guidance Report No. 13 is the basis of radionuclide risk coefficients used in the EPA *Health Effects Assessment Summary Tables* (EPA 2001a) and in computer dose codes such as the DOE Argonne Residual Radiation (RESRAD) code. However, DOE and other agencies regularly conduct dose assessments with models and codes that calculate radiation dose from exposure or intake using dose conversion factors and do not compute risk directly. In these cases, where it is necessary or desirable to estimate risk for comparative purposes (e.g., comparing risk associated with alternative actions), it is common practice to simply multiply the calculated TEDE by a risk-to-dose factor. DOE previously recommended TEDE-to-fatal-cancer risk factors of 5×10^{-4} per rem for the public and 4×10^{-4} per rem for working-age populations. These values were based upon former Committee on Interagency Radiation Research and Policy Coordination 1992 recommendations, which were superceded by ISCORS guidance. ISCORS recommends that agencies use a conversion factor of 6×10^{-4} fatal cancers per TEDE (rem) for mortality and 8×10^{-4} cancers per rem for morbidity when making qualitative or semi-quantitative estimates of radiation exposure risk to members of the general public[2] (DOE 2002).

The TEDE-to-risk factor provided in *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)*, ISCORS Technical Report No. 1, is based upon a static population with characteristics consistent with the U.S. population. There are no separate ISCORS recommendations for workers, but the report does specify the use of the same fatal cancer risk factor as for the general population. For workers (adults), a fatal cancer risk of 5×10^{-4} per rem and a morbidity risk of 7×10^{-4} per rem may be used. However, given the risk estimate uncertainties, for most estimates the value for the general population of 6×10^{-4} per rem could be used for workers (DOE 2002). The DOE Office of Environmental Policy and Guidance recommends these values, but it should be emphasized that they are principally suited for comparative analyses and where it would be impractical to calculate risk using Federal Guidance Report No. 13. If risk estimates for specific radionuclides are needed, cancer risk coefficients in Federal Guidance Report No. 13 should be used (DOE 2002).

The ISCORS report notes that the recommended risk coefficients used with TEDE dose estimates generally produce conservative radiation risk estimates (i.e., they overestimate risk).[3] For the ingestion pathway of 11 radionuclides compared, risks would be overestimated compared with Federal Guidance Report No. 13 values for about 8 radionuclides, and significantly overestimated (by up to a factor of 6) for 4 of these. The DOE Office of Environmental Policy and Guidance also compared the risks obtained using the risk conversion factor with the risks in Federal Guidance Report No. 13 for the inhalation pathway, and found a bias toward overestimation of risk, although it was not as severe as for ingestion. For 16 radionuclides/chemical states evaluated, 7 were significantly overestimated (by more than a factor of 2), 5 were significantly underestimated, and the remainder agreed within about a factor of 2. Generally, these differences are within the uncertainty of transport and uptake portions of dose or risk modeling and, therefore, the approach recommended is fully acceptable for comparative assessments. That notwithstanding, it is strongly recommended that, wherever possible, the more rigorous approach with Federal Guidance Report No. 13 cancer risk coefficients be used (DOE 2002).

The values in Table I–2 are "nominal" cancer and genetic disorder probability coefficients. They are based on an idealized population receiving a uniform whole-body dose. Recent EPA studies, based on age-dependent dose coefficients for members of the public, indicate that the product of the effective dose and the probability coefficient could over- or underestimate radiological risk (EPA 1999b). In support of risk results provided in Federal Guidance Report No. 13, EPA performed an uncertainty analysis on uniform whole-body exposure

[2]*Such estimates should not be stated with more than 1 significant digit.*

[3]*This statement presumes that using the radionuclide-specific risk factors in Federal Guidance Report No. 13 would be a more accurate measure of potential risk than multiplying the TEDE by a single average risk factor.*

effects. The analysis resulted in an estimated nominal risk coefficient increase from 0.051 fatal cancers per gray (0.00051 fatal cancers per rad) to 0.0575 fatal cancers per gray (0.000575 fatal cancers per rad) (EPA 1999a). This result indicates a nominal risk coefficient increase of about 20 percent over that provided in *Risk Estimates for Radiation Protection* (NCRP 1993) for the public.

Based on review of recent EPA reports, ISCORS recommended that a risk factor of 0.06 fatal cancers per sievert (0.0006 fatal cancers per rem) be used for estimating risks when using calculated dose (DOE 2002). DOE recommended that 0.0006 fatal cancers per rem be used for both workers and members of the public (DOE 2003a).

Numerical fatal cancer estimates presented in this EIS were obtained using a linear no-threshold extrapolation from the nominal risk estimated for lifetime total cancer mortality that results from a dose of 0.1 gray (10 rad). Other methods of extrapolation to the low-dose region could yield higher or lower numerical fatal cancer estimates. Studies of human populations exposed to low doses are inadequate to demonstrate the actual risk level. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation, and the possibility of no risk cannot be excluded (CIRRPC 1992). The risk factor of 0.0006 fatal cancers per rem was used as the conversion factor for all radiological exposures due to accidents, including those in the low-dose region. For normal operations radiological exposure, lifetime fatal cancer risk was calculated using radionuclide-specific risk factors.

EIS Health Effect Risk Estimators

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 carcinogen and cancer diagnosis) of as little as 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 in this appendix. The numbers of fatal cancers can be used to compare risks among the various alternatives. (Note that cancer incidence [latent cancer morbidity] is analyzed in Appendix H, Long-Term Performance Assessment Results, to enable comparison of the potential long-term impacts for the alternatives with the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] risk range.)

Based on the preceding discussion, the number of fatal cancers to workers and the general public for postulated accidents in which individual doses are less than 20 rem, is calculated using a health risk estimator of 0.0006 per person-rem. (Risk estimators are lifetime probabilities that an individual would develop a fatal cancer per rem of radiation received.) Risk estimators associated with total cancer incidence among the public is 0.0008 per person-rem (DOE 2002). Federal Guidance Report No. 13 individual radioisotope risk factors are used to calculate lifetime fatal cancer risk for normal operations.

Recent EPA analyses (EPA 1999a, 1999b) addressed the effects of low-dose and low-dose-rate exposure to ionizing radiation. Consistent with the conclusion in *Risk Estimates for Radiation Protection* (NCRP 1993), the risk to individuals receiving doses of 20 rem or more is double that associated with doses of less than 20 rem.

The fatal cancer estimators are used to calculate the statistical expectation of the effects of exposing a population to radiation. For example, if 100,000 people were each exposed to a one-time radiation dose of 100 millirem (0.1 rem), the collective dose would be 10,000 person-rem. The exposed population would then be expected to experience 6 additional cancer fatalities from the radiation (10,000 person-rem × 0.0006 lifetime probability of cancer fatalities per person-rem = 6 cancer fatalities).

Calculations of the number of excess fatal cancers associated with radiation exposure do not always yield whole numbers. These calculations may yield numbers less than one, especially in environmental impact applications. For example, if a population of 100,000 was exposed to a total dose of only 0.001 rem per person, the collective dose would be 100 person-rem (100,000 persons × 0.001 rem = 100 person-rem). The corresponding estimated number of cancer fatalities would be 0.06 (100 person-rem × 0.0006 cancer fatalities per person-rem = 0.06 cancer fatalities). The 0.06 means that there is 1 chance in 16.6 that the exposed population would experience 1 fatal cancer. In other words, 0.06 cancer fatalities are the *expected* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. In most groups, no person would incur a fatal cancer from the 0.001 rem dose each member received. In a small fraction of the groups, 1 cancer fatality would result; in exceptionally few groups, 2 or more cancer fatalities would occur. The *average* expected number of deaths over all the groups would be 0.06 cancer fatalities (just as the average of 0, 0, and 0, added to 1 is ¼, or 0.25). The most likely outcome is no cancer fatalities.

The same concept is applied to estimate radiation exposure effects on an individual member of the public. Consider the effects of an individual's exposure to a 360-millirem (0.36 rem) annual dose from all radiation sources. The probability that the individual would develop a fatal cancer from continuous exposure to this radiation over an average life of 72 years (presumed) is 0.016 (one person × 0.36 rem per year × 72 years × 0.0006 cancer fatalities per person-rem = 0.016). This corresponds to 1 chance in 64.

I.4 Normal Operations Radiological Impacts During Implementation of Alternatives

Normal operations involving release of radionuclides to the environment were analyzed with the GENII computer code.

I.4.1 GENII Computer Code Generic Description

Radiological impacts of releases during normal operations were calculated using Version 2 of the GENII computer code (PNNL 2007). GENII is designed to model long-term atmospheric and liquid releases of radionuclides are their human health consequences. Site-specific input data were used, including location, meteorology, population, and source terms. This section briefly describes GENII, and outlines the approach used for normal operations.

Code Description

The GENII computer model, developed by Pacific Northwest National Laboratory, is an integrated system of computer modules that analyzes environmental contamination resulting from acute or chronic releases to, or initial contamination in, air, water, or soil. The model calculates radiation doses to individuals and populations. The GENII computer model is well documented for assumptions, technical approach, method, and quality assurance issues. The GENII computer model has gone through extensive quality assurance and quality control steps, including comparing results from model computations with those from hand calculations and performing internal and external peer reviews (PNNL 2007).

Available release scenarios include chronic and acute releases to water or to air (ground level or elevated sources), and initial contamination of soil or surfaces. GENII implements NRC models in LADTAP for surface water doses. Exposure pathways include direct exposure via water (swimming, boating, and fishing), soil, air, inhalation, and ingestion pathways. GENII Version 1 implemented dosimetry models recommended by the ICRP in Publications 26, 30, and 48, and approved for use by DOE Order 5400.5. GENII Version 2 implements these models plus those of ICRP Publications 56 through 72, and the related risk factors published in Federal Guidance Report No. 13. Risk factors in the form of EPA developed "slope factors" are also included (these are a special subset of the Federal Guidance Report No. 13 values). These dosimetry and risk models are considered to be "state of the art" by the international radiation protection community and have been adopted by most national and international organizations as their standard dosimetry methodology (PNNL 2007).

GENII Version 2 consists of four independent atmospheric models, one surface water model, three independent environmental accumulation models, one exposure module, and one dose/risk module, each with a specific user interface code. The computer programs are of several types: user interfaces (i.e., interactive, menu-driven programs to assist the user with scenario generation and data input), internal and external dose factor libraries, environmental dosimetry programs, and file-viewing routines. The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) program serves as the interface for operating GENII. For maximum flexibility, the code has been divided into several interrelated, but separate, exposure and dose calculations (PNNL 2007).

I.4.2 GENII Input Data

To perform dose assessments for this EIS, different types of data were collected and generated. This section discusses the various data, along with assumptions made for performing the dose assessments.

Dose assessments were performed for members of the general public at the West Valley Demonstration Project (WVDP) to determine incremental doses that would be associated with the alternatives addressed in this EIS. Incremental doses for members of the public were calculated (via GENII) for two different types of receptors:

- Maximally exposed individual (MEI) – The MEI for air releases was assumed to be an individual member of the public located at a position on the site boundary, including public roads inside the site, that would yield the highest impacts during normal operations. For this EIS, the MEI for air releases is located approximately 1.3 kilometers (0.8 miles) in the north-northwest direction. For liquid releases, there are two MEI locations on Cattaraugus Creek near the site and on the lower reaches of Cattaraugus Creek for a member of the Seneca Nation of Indians. These MEI locations are presented in **Figure I–1**.

- Population – The general population living within 80 kilometers (50 miles) of the facility (approximately 1.7 million for this EIS). An average dose to a member of this population was also calculated.

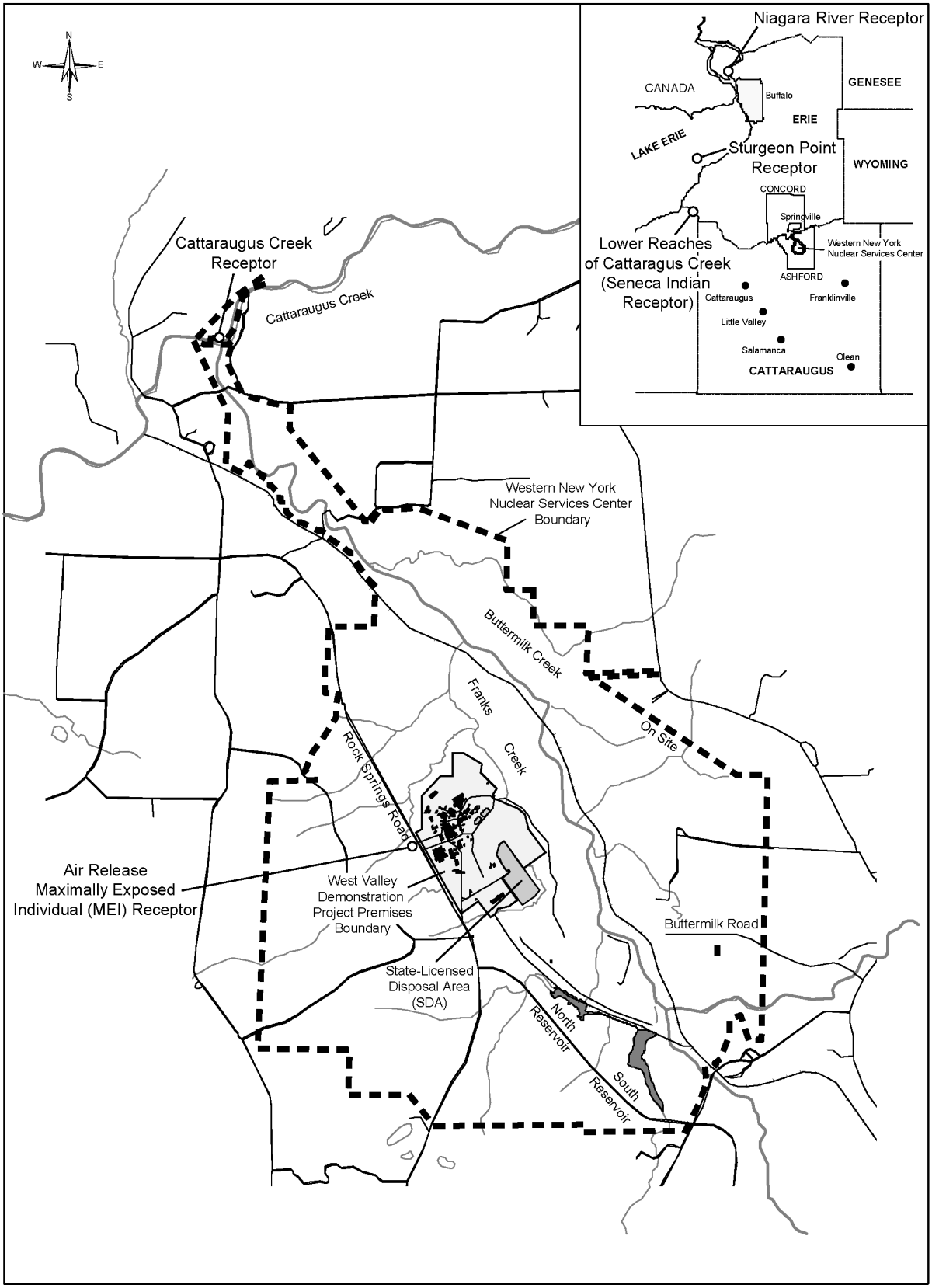

Figure I–1 Location of Maximally Exposed Individual for Normal Operations

I.4.3 Meteorological Data

The meteorological data used for all normal operational scenarios discussed in this EIS were in the form of joint frequency data files. A joint frequency data file is a table listing the fractions of time the wind blows in a certain direction, at a certain speed, and within a certain atmospheric stability class. The joint frequency data files were based on measurements taken over a period of 5 years (1998 to 2002) at WVDP.

I.4.3.1 Population Data

Population distributions were based on U.S. Department of Commerce state population census numbers and Canadian population census data (DOC 2008, ESRI 2008, Statistics Canada 2008). Area population trends have shown a decreasing population over time. Therefore, for conservatism, the 2000 U.S. census (supplemented by the 2001 Canadian census) site-specific population was used in the impact assessments. The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 80 kilometers (50 miles). The grid was centered at the location from which the radionuclides were assumed to be released. The 2000/2001 census total population from the WVDP out to 80 kilometers (50 miles) is approximately 1.7 million.

I.4.3.2 Source Term Data

Source term(s) (that is, the quantities of radioactive material released to the environment over a given period) for the No Action Alternative normal operational releases were based on release quantities identified in Annual Site Environmental Reports, which can be found on the Internet at www.wv.doe.gov and are summarized in a technical report (WSMS 2008e). These reports identified both airborne and liquid lifetime radiological releases. Source terms for each of the three decommissioning alternatives (Sitewide Removal, Sitewide Close-In-Place, and Phased Decisionmaking) were developed based on specific activities provided in the technical reports for these alternatives and their concomitant airborne and liquid radiological releases (WSMS 2008b, 2008c, 2008d). Projected airborne radiological releases for each alternative are presented in **Table I–3**, and liquid releases are provided in **Table I–4**. Tables I–3 and I–4 also present the estimated peak annual releases. The peak annual airborne and liquid releases were determined by evaluating annual releases for each radionuclide. The peak annual release for each radionuclide did not occur during the same year for some alternatives. Therefore, the year when the annual radiological release would result in the highest calculated population dose was selected. In some cases, this year does not result in the highest annual radiological release rate for every radionuclide.

Source terms used to calculate impacts of postulated accidents are provided in Section I.7.

I.4.3.3 Food Production and Consumption Data

Generic food consumption rates are available as default values in GENII. The default values are comparable to those established in NRC Regulatory Guide 1.109 (NRC 1977). This Regulatory Guide provides guidance for evaluating ingestion doses from consuming contaminated plant and animal food products using a standard set of assumptions for crop and livestock growth and harvesting characteristics.

Food consumption parameters used to evaluate each alternative are presented in **Tables I–5** and **I–6**.

Table I–3 Airborne Radiological Releases by Alternative

Alternative (duration in years)	*Tritium*	*Cobalt-60*	*Strontium-90*	*Iodine-129*	*Cesium-137*	*Transuranic* [a]	*Total* [b]
Average Airborne Radiological Releases (curies per year)							
Sitewide Removal (64)	3.3×10^{-2}	2.6×10^{-4}	1.0×10^{-2}	1.5×10^{-3}	2.3×10^{-3}	4.2×10^{-4}	4.7×10^{-2}
Sitewide Close-In-Place (7)	1.0×10^{-5}	9.0×10^{-5}	5.5×10^{-3}	1.9×10^{-6}	5.0×10^{-3}	2.5×10^{-4}	1.1×10^{-2}
Phased Decisionmaking (8)	2.7×10^{-4}	1.6×10^{-4}	1.7×10^{-2}	4.7×10^{-5}	1.5×10^{-2}	6.5×10^{-3}	3.9×10^{-2}
No Action [c] (100)	2.0×10^{-4}	1.4×10^{-9}	7.2×10^{-7}	3.3×10^{-6}	1.3×10^{-6}	2.7×10^{-8}	2.1×10^{-4}
Peak Annual Airborne Radiological Releases (curies per year)							
Sitewide Removal	7×10^{-2}	3×10^{-4}	1×10^{-1}	1×10^{-5}	3×10^{-3}	9×10^{-4}	1.7×10^{-1}
Sitewide Close-In-Place	1.4×10^{-5}	4.0×10^{-4}	1×10^{-2}	1.3×10^{-5}	1×10^{-2}	6×10^{-4}	2.1×10^{-2}
Phased Decisionmaking	8×10^{-5}	3×10^{-4}	3×10^{-2}	1.2×10^{-5}	3×10^{-2}	1.2×10^{-2}	7.2×10^{-2}
No Action [d]	4.1×10^{-1}	2.0×10^{-6}	4.8×10^{-4}	7.4×10^{-3}	8.6×10^{-4}	4.8×10^{-6}	4.2×10^{-1}

[a] Transuranic radioisotopes were represented by using plutonium-239.
[b] Yearly total presented. The activity released over the life of the alternative is the total (curies per year) times the duration (year).
[c] Also includes 6.1×10^{-8} curies of americium-241, 5.1×10^{-9} curies of europium-154, 7.5×10^{-9} curies of uranium isotopes represented by uranium-238, and 2×10^{-8} curies of plutonium-238.
[d] Also includes 2.8×10^{-6} curies of americium-241, 4.7×10^{-4} curies of europium-154, 3×10^{-7} curies of uranium isotopes represented by uranium-238, and 8.7×10^{-7} curies of plutonium-238.
Note: Alternative durations are presented in years. There is no decommissioning for the No Action Alternative; for this alternative, a 100-year period of site monitoring and maintenance is analyzed as adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c)
Sources: Steiner 2008; WSMS 2008b, 2008c, 2008d, 2008e.

Table I–4 Total Liquid Radiological Releases by Alternative

Alternative (duration in years)	*Tritium*	*Cobalt-60*	*Strontium-90*	*Cesium-137*	*Transuranic* [a]	*Total* [b]
Average Liquid Radiological Releases (curies per year)						
Sitewide Removal (64)	4.5	4.3×10^{-7}	6.1×10^{-3}	7.6×10^{-4}	6.5×10^{-6}	4.5
Sitewide Close-In-Place (7)	4.1×10^{1}	3.6×10^{-7}	4.3×10^{-2}	2.2×10^{-3}	4.9×10^{-5}	4.1×10^{1}
Phased Decisionmaking (8)	7.5×10^{-3}	1.3×10^{-9}	2.4×10^{-4}	4.1×10^{-7}	7.8×10^{-10}	7.7×10^{-3}
No Action (100) [c]	8.8×10^{-3}	4.3×10^{-6}	5.4×10^{-4}	2.7×10^{-4}	6.0×10^{-7}	9.6×10^{-3}
Peak Annual Liquid Radiological Releases (curies per year)						
Sitewide Removal	9×10^{-2}	5×10^{-6}	1.1×10^{-2}	1×10^{-3}	8×10^{-6}	1×10^{-1}
Sitewide Close-In-Place	7.2×10^{2}	6.3×10^{-7}	7.5×10^{-2}	3.8×10^{-3}	8.5×10^{-5}	7.2×10^{2}
Phased Decisionmaking	1.3×10^{-2}	2.6×10^{-9}	6.0×10^{-5}	9×10^{-7}	1.6×10^{-9}	1.3×10^{-2}
No Action [d]	7.2	2.3×10^{-3}	9.9×10^{-3}	6.6×10^{-2}	5.2×10^{-5}	7.3

[a] Transuranic radioisotopes were represented by using plutonium-239.
[b] Yearly total presented. The activity released over the life of the alternative is the total (curies per year) times the duration (year).
[c] Also includes: 3.6×10^{-5} curies of carbon-14, 7.4×10^{-5} curies of potassium-40, 1.1×10^{-4} curies of technetium-99, 8.1×10^{-6} curies of iodine-129, and 8.2×10^{-5} curies of uranium isotopes (represented by uranium-238).
[d] Also includes: 1.9×10^{-2} curies of carbon-14, 1.3×10^{-2} curies of potassium-40, 9.6×10^{-2} curies of technetium-99, 1.7×10^{-3} curies of iodine-129, and 1.1×10^{-2} curies of uranium isotopes (represented by uranium-238).
Note: Alternative durations are presented in years. There is no decommissioning for the No Action Alternative; for this alternative, a 100-year period of site monitoring and maintenance is analyzed as adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c).
Sources: Steiner 2008; WSMS 2008b, 2008c, 2008d, 2008e.

Table I–5 GENII Usage Parameters for Consumption of Plant Food (Normal Operations)

Food Type	*Agriculture Characteristics*		*Maximally Exposed Individual*		*General Population*	
	Growing Time (Days)	*Yield (kilograms per square meter)*	*Holdup Time (days)*	*Consumption Rate (kilograms per year)*	*Holdup Time (days)*	*Consumption Rate (kilograms per year)*
Leafy Vegetables	90	1.5	1	30	14	15
Root Vegetables	90	4	5	220	14	140
Fruit	90	2	5	330	14	64
Grains/Cereals	90	0.8	180	80	180	72

Note: To convert kilograms to pounds, multiply by 2.2046; square meters to square feet, multiply by 10.8.
Source: PNNL 2007.

Table I–6 GENII Usage Parameters for Consumption of Animal Products (Normal Operations)

Food Type	*Stored Feed*				*Fresh Forage*			
	Diet Fraction	*Growing Time (days)*	*Yield (kilograms per square meter)*	*Storage Time (days)*	*Diet Fraction*	*Growing Time (days)*	*Yield (kilograms per square meter)*	*Storage Time (days)*
Beef	0.25	90	0.8	180	0.75	45	2	100
Poultry	1	90	0.8	180	—	—	—	—
Milk	0.25	45	2	100	0.75	30	1.5	0
Eggs	1	90	0.8	180	—	—	—	—

Food Type	*Maximally Exposed Individual*		*General Population*	
	Consumption Rate (kilograms per year)	*Holdup Time (days)*	*Consumption Rate (kilograms per year)*	*Holdup Time (days)*
Beef	80	15	70	34
Poultry	18	1	8.5	34
Milk	270	1	230	3
Eggs	30	1	20	18

Note: To convert kilograms to pounds, multiply by 2.2046; square meters to square feet, multiply by 10.8.
Source: PNNL 2007.

Calculations of the population and MEI doses from liquid releases into the local streams and creeks (eventually reaching Buttermilk Creek, Cattaraugus Creek, and Lake Erie) included doses resulting from use of the creek water as a source of drinking water and from the ingestion of fish taken from the creek. (These waters are not a source of irrigation for local crops.) All receptors were assumed to drink 730 liters (193 gallons) of water per year. The populations considered in estimating the doses from drinking water were the customers of Lake Erie Water Treatment Plants Downstream of Cattaraugus Creek (565,000 individuals) and the Niagara River Water Treatment Plants (386,000 individuals). Fish consumption for the general population was determined to be approximately 0.1 kilograms per year (0.2 pounds per year) based upon estimates of the quantity of fish harvested from local waters, and the MEI was assumed to consume 9 kilograms per year (20 pounds per year). An additional receptor, a member of the Seneca Nations of Indians, was identified who could consume a greater quantity of fish than that identified for the MEI. This receptor was assumed to consume 62 kilograms per year (137 pounds per year) of fish harvested from local waters.

I.4.3.4 GENII Basic Assumptions

Other key assumptions used in GENII are delineated below:

- Public population distribution of an 80-kilometer (50-mile) radius in all 16 compass directions for specific distance rings (0 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, 5 to 10, 10 to 20, 20 to 30, 30 to 40, and 40 to 50 miles) based on 2000 U.S. and 2001 Canadian census data.

- MEI location at the WVDP Site for all 16 azimuthal compass directions, which constitutes the closest public boundary to the site in each of these directions.

- Agricultural and food consumption data for the land within 80 kilometers (50 miles) and the population residing within 80 kilometers (50 miles) of the WVDP Site.

- Radiological airborne emissions were released to the atmosphere at a height of either 0 or 24 meters (0 or 79 feet) to represent the range of structure heights for decommissioning operations. The largest height is that of the Main Plant Process Building in Waste Management Area (WMA) 1. This range of lowest and highest airborne emission height results in enveloping public radiation dose calculation results.

- For normal operations calculations, emission of the plume was assumed to continue throughout the year. Plume and ground deposition exposure parameters used in the GENII model for the exposed offsite individual and the general population are provided in **Table I–7**.

- The exposed individual or population was assumed to have adult human characteristics and habits.

- No evacuation or sheltering was assumed, though individuals were assumed to spend some time indoors.

- A Pasquill-Gifford plume model was used for the air immersion doses.

Table I–7 GENII Parameters for Exposure to Plumes (Normal Operations)

Maximally Exposed Individual				*General Population*			
External Exposure		*Inhalation of Plume*		*External Exposure*		*Inhalation of Plume*	
Plume (hours) [a]	*Ground Contamination (hours)* [b]	*Exposure Time (hours)*	*Breathing Rate (cubic centimeters per second)*	*Plume (hours)*	*Ground Contamination (hours)* [b]	*Exposure Time (hours)*	*Breathing Rate (cubic centimeters per second)*
6,132	8,760	8,760	270	4,383	8,760	8,760	270

[a] Assumes 70 percent outdoor exposure, with the balance indoors.
[b] Assumes 70 percent shielding for time indoors.
Note: To convert cubic centimeters to cubic inches, multiply by 0.061024.
Sources: PNNL 2007, NRC 1977.

I.4.3.5 Radiological Consequences from Normal Operations

The following tables provide the impacts, in terms of dose (person-rem) and increased risk of latent cancer fatalities (LCFs), to the public from radiological releases associated with normal operations for each of the four alternatives. **Table I–8** provides the yearly average, peak annual and total population impacts associated with airborne radiological releases from normal operations for the duration of the implementation of each alternative. **Table I–9** provides this information for liquid radiological releases. The peak annual population

doses presented in Tables I–8 and I–9 are based on the peak annual releases that are presented in Tables I–3 and I–4. The basis for these peak annual releases is also discussed in Section I.4.3.2.

Table I–8 Population Impacts from Normal Operational Airborne Radiological Releases

Alternative	*Yearly Average*		*Peak Annual*		*Duration Total*	
	Population Dose [a] (person-rem)	*Increased Risk of LCF [b]*	*Population Dose [a] (person-rem)*	*Increased Risk of LCF [b]*	*Population Dose [a] (person-rem)*	*Increased Risk of LCF [b]*
Sitewide Removal	6.1×10^{-1}	9.1×10^{-5}	1.8	5.0×10^{-4}	3.9×10^{1}	5.8×10^{-3}
Sitewide Close-In-Place	3.3×10^{-1}	7.3×10^{-5}	7.2×10^{-1}	1.5×10^{-4}	2.3	5.1×10^{-4}
Phased Decisionmaking (Phase 1)	5.2	7.0×10^{-4}	9.7	1.3×10^{-3}	4.2×10^{1}	5.6×10^{-3}
No Action	4.3×10^{-4}	2.0×10^{-8}	7.9×10^{-1}	2.5×10^{-5}	4.3×10^{-2} [c]	2.0×10^{-6} [c]

LCF = latent cancer fatality.
[a] Based on population of 1,704,000.
[b] Federal Guidance Report No. 13 individual radioisotope risk factors are used to calculate lifetime fatal cancer risk for normal operations.
[c] Although the duration of the No Action Alternative is in perpetuity, a 100-year time period is analyzed for this table. The 100-year period was adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c). The radionuclides that contribute to the majority of the calculated airborne and liquid release doses (tritium, cobalt-60, strontium-90, and cesium-137) would have decayed by a factor of 10 to 500,000 after 100 years.
Note: All population results for air releases are obtained directly from GENII 2 output.

Table I–9 Population Impacts from Normal Operational Liquid Radiological Releases

Alternative	*Yearly Average*		*Peak Annual*		*Duration Total*	
	Population Dose [a] (person-rem)	*Increased Risk of LCF [b]*	*Population Dose [a] (person-rem)*	*Increased Risk of LCF [b]*	*Population Dose [a] (person-rem)*	*Increased Risk of LCF [b]*
Lake Erie Downstream of Cattaraugus Creek Water Consumer [a]						
Sitewide Removal	5.1×10^{-1}	1.8×10^{-4}	6.7×10^{-1}	2.5×10^{-4}	3.3×10^{1}	1.2×10^{-2}
Sitewide Close-In-Place	3.4	1.2×10^{-3}	2.2×10^{1}	7.4×10^{-3}	2.4×10^{1}	8.7×10^{-3}
Phased Decisionmaking (Phase 1)	1.2×10^{-2}	4.6×10^{-6}	3.4×10^{-3}	1.3×10^{-6}	9.6×10^{-2}	3.7×10^{-5}
No Action	7.5×10^{-2}	2.4×10^{-5}	1.3×10^{1}	4.1×10^{-3}	7.5 [c]	2.4×10^{-3} [c]
Niagara River Water Consumer [a]						
Sitewide Removal	8.4×10^{-3}	3.0×10^{-6}	1.1×10^{-2}	4.1×10^{-6}	5.4×10^{-1}	1.9×10^{-4}
Sitewide Close-In-Place	5.6×10^{-2}	2.0×10^{-5}	3.7×10^{-1}	1.2×10^{-4}	4.0×10^{-1}	1.4×10^{-4}
Phased Decisionmaking (Phase 1)	2.0×10^{-4}	7.5×10^{-8}	5.5×10^{-5}	2.1×10^{-8}	1.6×10^{-3}	6.0×10^{-7}
No Action	1.2×10^{-3}	3.9×10^{-7}	2.1×10^{-1}	6.7×10^{-5}	1.2×10^{-1} [c]	3.9×10^{-5} [c]

LCF = latent cancer fatality.
[a] Affected populations: Lake Erie Treatment Plants Downstream of Cattaraugus Creek, 565,000; Niagara River Treatment Plants 386,000.
[b] Federal Guidance Report No. 13 individual radioisotope risk factors are used to calculate lifetime fatal cancer risk for normal operations.
[c] Although the duration of the No Action Alternative is in perpetuity, a 100-year time period is analyzed for this table. The 100-year period was adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c). The radionuclides that contribute to the majority of the calculated airborne and liquid release doses (tritium, cobalt-60, strontium-90, and cesium-137) would have decayed by a factor of 10 to 500,000 after 100 years.

The following tables provide the individual impacts, in terms of individual yearly dose (in millirem) and increased risk of an LCF, associated with radiological releases associated with normal operations for the implementation phase of each alternative. Three individuals have been identified for analysis. Typically the MEI would be a person at the site boundary (closest location to the point of release) in the direction that yields the highest individual dose from an airborne release, a result of a combination of distance and meteorological conditions. However, this is not the individual who could be the MEI from liquid releases. Therefore, two additional individuals were identified. One lives near the site; the second, a member of the Seneca Nation of Indians, has a significantly higher consumption of fish taken from local waters. **Table I–10** provides the yearly average, peak annual, and the total individual impacts associated with airborne radiological releases from normal operations for the duration of the implementation of each alternative. **Table I–11** provides this information for liquid radiological releases.

Table I–10 Individual Impacts from Normal Operational Airborne Radiological Releases

Alternative	*Yearly Average*		*Peak Annual*		*Duration Total*	
	Dose Rate (millirem per year)	*Increased Risk of LCF* [a]	*Total Rate (millirem)*	*Increased Risk of LCF* [a]	*Total Dose (millirem)*	*Increased Risk of LCF per Year* [a]
Maximally Exposed Individual (WVDP Site Boundary)						
Sitewide Removal	7.6×10^{-2}	1.3×10^{-8}	2.6×10^{-1}	8.4×10^{-8}	4.9	8.3×10^{-7}
Sitewide Close-In-Place	4.0×10^{-2}	1.1×10^{-8}	8.4×10^{-2}	2.1×10^{-8}	2.8×10^{-1}	7.7×10^{-8}
Phased Decisionmaking (Phase 1)	4.8×10^{-1}	7.1×10^{-8}	8.4×10^{-1}	1.1×10^{-7}	3.8	5.7×10^{-7}
No Action	6.6×10^{-5}	3.7×10^{-12}	1.3×10^{-1}	4.0×10^{-9}	6.6×10^{-3} [b]	3.7×10^{-10} [b]
Individual on Cattaraugus Creek Near Site						
Sitewide Removal	4.5×10^{-2}	6.8×10^{-9}	1.4×10^{-1}	3.9×10^{-8}	2.9	4.0×10^{-7}
Sitewide Close-In-Place	2.4×10^{-2}	5.6×10^{-9}	5.2×10^{-2}	1.1×10^{-8}	1.7×10^{-1}	3.9×10^{-8}
Phased Decisionmaking (Phase 1)	3.5×10^{-1}	4.8×10^{-8}	6.5×10^{-1}	8.9×10^{-8}	2.8	3.8×10^{-7}
No Action	3.3×10^{-5}	1.5×10^{-12}	6.4×10^{-2}	2.0×10^{-9}	3.3×10^{-3} [b]	1.5×10^{-10} [b]
Individual on Lower Reaches of Cattaraugus Creek						
Sitewide Removal	1.2×10^{-3}	1.8×10^{-10}	3.5×10^{-3}	9.4×10^{-10}	7.7×10^{-2}	1.2×10^{-8}
Sitewide Close-In-Place	6.6×10^{-4}	1.4×10^{-10}	1.4×10^{-3}	2.9×10^{-10}	4.6×10^{-3}	9.8×10^{-10}
Phased Decisionmaking (Phase 1)	1.1×10^{-2}	1.4×10^{-9}	2.0×10^{-2}	2.7×10^{-9}	8.8×10^{-2}	1.1×10^{-8}
No Action	8.0×10^{-7}	3.8×10^{-14}	1.5×10^{-3}	4.7×10^{-11}	8.0×10^{-5} [b]	3.8×10^{-12} [b]

LCF = latent cancer fatality, WVDP = West Valley Demonstration Project.

[a] Federal Guidance Report No. 13 individual radioisotope risk factors are used to calculate lifetime fatal cancer risk for normal operations.

[b] Although the duration of the No Action Alternative is in perpetuity, a 100-year time period is analyzed for this table. The 100-year period was adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c). The radionuclides that contribute to the majority of the calculated airborne and liquid release doses (tritium, cobalt-60, strontium-90, and cesium-137) would have decayed by a factor of 10 to 500,000 after 100 years.

Table I–11 Individual Impacts from Normal Operational Liquid Radiological Releases

Alternative	*Yearly Average*		*Peak Annual*		*Duration Total*	
	Individual Dose (millirem)	***Increased Risk of LCF*** [a]	***Individual Dose (millirem)***	***Increased Risk of LCF*** [a]	***Individual Dose (millirem)***	***Increased Risk of LCF*** [a]
Individual on Cattaraugus Creek Near Site						
Sitewide Removal	3.7×10^{-3}	1.3×10^{-9}	5.4×10^{-3}	2.0×10^{-9}	2.4×10^{-1}	8.6×10^{-8}
Sitewide Close-In-Place	2.1×10^{-2}	7.8×10^{-9}	8.8×10^{-2}	3.0×10^{-8}	1.5×10^{-1}	5.4×10^{-8}
Phased Decisionmaking (Phase 1)	8.0×10^{-5}	3.0×10^{-11}	2.2×10^{-5}	8.4×10^{-12}	6.4×10^{-4}	2.4×10^{-10}
No Action	7.4×10^{-4}	2.5×10^{-10}	1.7×10^{-1}	5.7×10^{-8}	7.4×10^{-2} [b]	2.5×10^{-8} [b]
Individual on Lower Reaches of Cattaraugus Creek						
Sitewide Removal	8.7×10^{-3}	3.2×10^{-9}	1.3×10^{-2}	4.7×10^{-9}	5.6×10^{-1}	2.0×10^{-7}
Sitewide Close-In-Place	4.1×10^{-2}	1.5×10^{-8}	1.1×10^{-1}	3.8×10^{-8}	2.9×10^{-1}	1.1×10^{-7}
Phased Decisionmaking (Phase 1)	1.4×10^{-4}	5.2×10^{-11}	4.0×10^{-5}	1.5×10^{-11}	1.1×10^{-3}	4.2×10^{-10}
No Action	2.3×10^{-3}	7.9×10^{-10}	6.1×10^{-1}	2.1×10^{-7}	2.3×10^{-1} [b]	7.9×10^{-8} [b]

LCF = latent cancer fatality.

[a] Federal Guidance Report No. 13 individual radioisotope risk factors are used to calculate lifetime fatal cancer risk for normal operations.

[b] Although the duration of the No Action Alternative is in perpetuity, a 100-year time period is analyzed for this table. The 100-year period was adapted from the recommendations in DOE Manual 435.1-1 regarding analytical assumptions for institutional controls (DOE 1999c). The radionuclides that contribute to the majority of the calculated airborne and liquid release doses (tritium, cobalt-60, strontium-90, and cesium-137) would have decayed by a factor of 10 to 500,000 after 100 years.

I.4.3.6 Analysis Uncertainties

The sequence of analyses performed to generate normal operations radiological impact estimates includes selection of normal operational modes, estimation of source terms, estimation of environmental transport and uptake of radionuclides, calculation of radiation doses to exposed individuals, and estimation of health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way the physical systems being analyzed are represented by the computational models and in the data required to exercise the models (due to measurement, sampling, or natural variability).

In principle, one can estimate the uncertainty associated with each source and predict the remaining uncertainty in the results of each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final results. However, conducting such a full-scale quantitative uncertainty analysis is neither practical nor standard practice for this type of study. Instead, the analysis is designed to ensure—through judicious selection of release scenarios, models, and parameters—that the results conservatively represent the potential risks. This is accomplished by making conservative assumptions in the calculations at each step. The models, parameters, and release scenarios used in the calculations are selected in such a way that most intermediate results and, consequently, final impact estimates are greater than expected. As a result, even though the range of uncertainty in a quantity might be large, the value calculated for the quantity would be close to one of the extremes in the range of possible values, so the chance of the actual quantity being greater than the calculated value would be low. Conservative assumptions in this analysis bound all uncertainties. Key conservative assumptions in this analysis that bound all uncertainties include:

1. Inhalation population radiological exposure continuously for 365 days and 24 hours per day causing the highest possible inhalation radiation dose;

2. A range of the lowest (i.e. ground-level) and highest (i.e. existing ventilation stack) possible airborne release plume heights resulting in the largest possible radionuclide air concentration from atmospheric dispersion;

3. Use of the 2000 Census population data causing the highest population dose since census data for all counties within 80 kilometers (50 miles) of the Western New York Nuclear Service Center (WNYNSC) shows a decrease in population since 2000;

4. Location of the MEI at the closest public boundary during all radiological releases resulting in the largest possible MEI radiation doses;

5. The annual airborne release rate of radionuclides was not reduced to account for the radioactive decay of relatively short half-life radionuclides such as cobalt-60, tritium, cesium-137, and strontium-90, which would significantly reduce the release rates and calculated dose especially for the longer time periods of the Sitewide Removal and No Action Alternatives.

Routine normal activities may have different human health impacts on specific populations such as American Indians or Hispanics whose cultural heritage can result in special exposure pathways that are different than those modeled to evaluate doses to the general population and MEI. The analyses performed to evaluate public impacts of the alternatives did include normally significant pathways and were designed to be conservative. Higher fish consumption for a member of the Seneca Nation of Indians was analyzed to calculate impacts on this population group. A qualitative evaluation of potential impacts on other specific population groups was performed based on the radionuclides emitted and an understanding of the most significant pathways.

Parameter selection and population and MEI practices were chosen to be conservative. For example, it was assumed that the population breathed contaminated air all the time (spent no time away from the local area) and that all food was produced in the potentially affected area (no food from outside the local area). The dose to a member of the public was dominated by internal exposures from inhalation and ingestion. Typically, about one-third of the dose was from inhalation and two-thirds was from ingestion. Inhalation of ambient air and the resulting dose would be about the same for all members of the population surrounding the locations of interest.

I.5 Impacts of Accidents During Alternative Implementation

I.5.1 Accident Relationship to Environmental Impact Statement Alternative

Each alternative considered in this EIS has specific aspects that may affect which accidents are analyzed for that alternative. This section evaluates the alternatives in terms of their applicable accident scenarios. Accident scenarios have been identified for radioactive waste packages, the radioactive waste tanks in WMA 3, the Main Plant Process Building in WMA 1, the NRC-licensed Disposal Area (NDA) in WMA 7, and the State-licensed Disposal Area (SDA) in WMA 8. **Table I–12** lists those aspects of the four alternatives that affect accident analyses.

Table I–12 shows that accidents involving the Main Plant Process Building, radioactive waste tanks, and the Low-Level Waste Treatment Facility could occur under all alternatives, and that the same radioactive waste packages would not be transported under each alternative. The No Action Alternative monitoring of facility and structure residual radioactivity does not preclude an accident in which this radioactivity could be released to the environment.

Based on the preparation for decommissioning actions and affected facilities for each alternative described in Table I–12, **Table I–13** was developed to correlate the accident scenarios with each specific alternative. The

greatest difference, for accidents, between the alternatives is that the No Action Alternative does not have any remote-handled transuranic, Greater-Than-Class C, or high-integrity container (HIC) package accident scenarios.

Table I–12 Environmental Impact Statement Alternative Parameters Affecting Accident Analysis Scenarios

Alternative	*Sitewide Removal Alternative*	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Main Plant Process Building	Demolish and exhume	Demolish to floor slab	Demolish and exhume	Monitor and maintain
Radioactive Waste Tanks in the Waste Tank Farms	Demolish and exhume	Fill and cap	Monitor and maintain	Monitor and maintain
Radioactive Waste Package Transportation	Yes	Yes	Yes	Yes
Low-Level Waste Treatment Facility	Demolish and exhume	Demolish and exhume	Demolish and exhume	Monitor and maintain
Lagoons, trenches, groundwater plume, Cesium Prong	Exhume	Manage in place	Remove lagoons, monitor others	Monitor and maintain
NRC-licensed Disposal Area	Exhume	Remove leachate and fill	Monitor and maintain	Monitor and maintain
State-licensed Disposal Area	Exhume	Remove leachate and fill	Monitor and maintain	Monitor and maintain

Table I–13 Accident Scenarios Applicable to Each Alternative

Accident Category	*Sitewide Removal Alternative*	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Main Plant Process Building	Yes	Yes	Yes	Yes
Radioactive Waste Tanks	Yes	Yes	Yes	Yes
Radioactive Waste Package Transportation	Yes (most)	Yes	Yes	Yes (least)
NRC-licensed Disposal Area Exhumation	Yes	No	No	No
State-licensed Disposal Area Exhumation	Yes	No	No	No

I.5.2 Radiological Source Term Methodology

The accident source term is the amount of respirable radioactive material released to the air or particles released to the water, in terms of curies or grams, assuming the occurrence of a postulated accident. The airborne source term is typically estimated by the following equation:

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

where:

MAR = material at risk
DR = damage ratio
ARF = airborne release fraction
RF = respirable fraction
LPF = leak path factor

The MAR is the amount of radionuclides (in curies of activity or grams for each radionuclide) available for release when acted upon by a given physical stress or accident. The MAR is specific to a given process in the

facility of interest. It is not necessarily the total quantity of material present, but is that amount of material in the scenario of interest postulated to be available for release.

The DR is the fraction of material exposed to the effects of the energy, force, or stress generated by the postulated event. For the accident scenarios discussed in this analysis, the DR value varies from 0.1 to 1.0.

The ARF is the fraction of material that becomes airborne due to the accident. In this analysis, ARFs were obtained from the *WVDP Waste Management EIS* (DOE 2003c), *Plutonium Residue EIS* (DOE 1998), or *DOE Handbook* on ARFs (DOE 1994).

The RF is the fraction of material with a 10-micrometer (0.0004 inches) or less aerodynamic-equivalent-diameter particle size that could be retained in the respiratory system following inhalation. The RF values are also taken from the *WVDP Waste Management EIS* (DOE 2003c), *Plutonium Residue EIS* (DOE 1998), or *DOE Handbook* on ARFs (DOE 1994).

The LPF accounts for the action of removal mechanisms – for example, containment systems, filtration, and deposition – to reduce the amount of airborne radioactivity ultimately released to occupied spaces in the facility or environment. An LPF of 1.0 (no reduction) is assigned in accident scenarios involving a major failure of confinement barriers. LPFs were obtained from the *WVDP Waste Management EIS* (DOE 2003c), *Plutonium Residue EIS* (DOE 1998), and site-specific evaluations.

I.5.3 Accident Scenario Development Methodology

The methodology used to develop accident scenarios and their associated parameters involved several steps. First, other relevant EISs and the *DOE Handbook* on ARFs (DOE 1994) were evaluated to develop a list of likely accident scenarios. This evaluation examined the types of structures and equipment at the WVDP expected to contain any significant residual radioactivity in the form of fixed or mobile chemical or physical forms of radionuclides. Experience from previous EISs involving nonreactor facilities was also used to establish accident scenarios. This first step led to the conclusion that accidents at a facility like the WVDP could fall into one of the following categories:

- Drops
- Punctures
- Spills
- Leaks
- Seismic induced structural failures
- Fires
- Explosions
- Seismic induced structural failures followed by fires and/or explosions
- Nuclear criticality events
- Chemical reactions

Evaluation of systems, components, and facilities at the WVDP that would be subject to decommissioning activities resulted in elimination of explosion, nuclear criticality, and chemical reaction as accident event scenarios. No explosive materials exist at the WVDP, and explosives would not be used for decommissioning activities. Any fissionable radionuclides at the WVDP are in quantities and concentrations too small to

constitute any nuclear criticality risk or cause any nuclear criticality accident. Chemicals at the WVDP or intended for decommissioning activities are not capable of reaction with chemicals already at the WVDP or with each other in such a way that could initiate any accident releasing radionuclides. However, it was determined that drops, punctures, spills, leaks, seismic-induced structural failures, fires, and seismic-induced structural failures followed by fires are all possible accident scenarios during decommissioning activities at the WVDP. Further evaluation of fires eliminated them for large structures because of the absence of combustible materials and the distributed nature of radioactive contamination over large surface areas and room volumes. Although it would be possible for a fire to occur in an individual room or cell, the lack of combustible materials throughout a facility such as the Main Plant Process Building would preclude a facility-wide fire and would therefore limit the release of radionuclides to one room. Fires are still considered for radioactive waste package handling.

Several accidents were postulated at the WVDP during decommissioning activities. These involve the high-level radioactive waste tanks, which contain both mobile and fixed residual radionuclide contamination, and the Main Plant Process Building, which contains both mobile and fixed residual radionuclide contamination, because these structures appear to contain the largest residual radioactivity available for release to the environment during an accident.

The seismic-induced structural failure of one high-level radioactive waste tank is another accident analyzed for this EIS. In this accident, a seismic event occurs, which causes failure of tank supports or other tank structures, thereby resulting in direct exposure of the tank radionuclide inventory to the environment. The seismic event is also assumed to fail any isolating or confinement covers around the high-level radioactive waste tanks. Fires in and around the radioactive waste tanks in the Waste Tank Farm were dismissed because of lack of combustible material, thereby resulting in an extremely low probability (i.e., less than the screening limit of 1.0×10^{-6} per year). Although this postulated accident would result in both an airborne and liquid release, the relatively slow dispersion of a liquid, the ability to contain a liquid release, and the relatively longer timeframe which allows for emergency response would result in protection of the public from radiation doses due to liquids. The risk and consequence dominant release from this accident scenario is the airborne release.

The Main Plant Process Building consists of a number of cells and other enclosed areas. Five accidents were postulated for this structure, which involve either the single cell having the largest residual radionuclide contamination inventory or the entire Main Plant Process Building and its concomitant total residual radionuclide contamination inventory. As in the case of the high-level radioactive waste tanks, these accidents involve either a fire or seismic structural collapse of either the hottest cell or the entire Main Plant Process Building, with failure of any confinement enclosure. The fifth accident assumes a seismic event that causes both structural collapse and a fire in the Main Plant Process Building. As in the case of the radioactive waste tanks, this last accident scenario was dismissed from detailed analysis because its estimated frequency of occurrence is less than the screening limit of 1×10^{-6} per year. Furthermore, as the Main Plant Process Building, as a whole, contains the bounding radionuclide inventory (i.e., MAR), accidents involving the hottest process cell were eliminated from analysis. Lack of combustible material in and around the Main Plant Process Building eliminated the fire accident scenario. The Main Plant Process Building accident scenario that was analyzed is the seismic induced complete collapse of the entire Main Plant Process Building.

Ten different types of radioactive waste transportation packages were identified as being used under one or more of the four alternatives considered in this EIS. As in the WVDP Waste Management EIS (DOE 2003c), drops and/or fires resulting in package confinement failure were postulated for each of these packages. Eleven accident scenarios involving all 10 of these packages were analyzed for this EIS and are described in Sections I.5.4 and I.5.5.

The exhumation, removal, and backfill of contaminated areas such as the lagoons in WMA 2; NRC-licensed trenches, holes, and lagoons in WMA 7; State-licensed disposal area trenches and lagoons in WMA 8; the

North Plateau Groundwater Plume; and the Cesium Prong involve handling large quantities of soil, sediment, and other solid materials and their subsequent shipment offsite to a suitable waste facility. The magnitude of contamination per unit mass or volume for these areas is much smaller than that of the high-level radioactive waste tanks, radioactive waste shipping packages, and Main Plant Process Building.

Two accident scenarios were postulated to occur during exhumation of the waste in the NDA and the SDA. The radioactive waste in these areas consists of a wide range of materials including solvents, soil, filters, fuel rod segments, and clothing. Each scenario involves the ignition of flammable solvent or diesel fuel spill from exhumation equipment. The fire affects 0.3 cubic meters (11 cubic feet) of exposed contaminated waste. This release fraction is based on a conservative assumption that the waste consists of uncontained combustible material that contains radioactive contamination. For the NDA, combination waste is assumed for the radioisotope composition; and, for the SDA, Trench 10 was assumed for the accident scenario. Both the NDA and SDA scenarios use the largest respirable radioisotope inventory of all the buried waste categories and trenches. These scenarios were analyzed as either a plume with no energy or one with the energy associated with a postulated concomitant fire.

An accident scenario involving any liquid releases (e.g., leachate from transfer piping, used to transfer groundwater from the NDA interceptor trench sump) would involve smaller quantities of radionuclides and, being in a liquid form, would pose a much smaller risk to the public and workers. All accidental liquid releases are amenable to mitigation because public and worker radiation doses are dependent upon ingestion or immersion in the liquid. Emergency response to such a liquid release would preclude contaminated water ingestion or exposure in a timeframe sufficient to avoid radiological doses. The timing and nature of airborne releases from a postulated accident make it more difficult to mitigate and preclude radiation doses to workers and the public. Hence, the near-term consequences and risks of postulated accidents involving liquid releases are bounded by accidents that were analyzed involving the airborne release of radionuclides.

Accidents to workers involving exposure to radiologically contaminated liquids and volatile compounds could result in significant health impacts due to external exposure, inhalation, and ingestion. However, the EIS does not calculate any specific impacts to workers with regard to an accident scenario because of the wide range of locations and actions of such workers. All accident consequences and risks are calculated for the MEI and population. The most severe consequences may occur to workers for some of the accidents already analyzed in the EIS. For example, seismic collapse of the waste tank or main plant process building could be postulated to lead to fatalities of nearby workers due the seismic event and associated structural collapse. No liquid release or volatile chemical exposure can result in a higher worker consequence than a fatality. Furthermore, worker exposure to radiologically contaminated liquids, volatile chemicals and other hazardous or chemical substances are considered as part of the category of occupational hazards (Occupational Safety and Health Administration regulations) and not a lower probability accident as is analyzed in this appendix. In any industrial or waste cleanup situation, there are numerous possible opportunities for spills or mishaps that are not considered bounding conservative accidents.

A postulated accident involving a drop, puncture, or fire involving packages containing vitrified high-level radioactive waste would not release respirable particles of radioactive material. The physical properties of vitrified high-level radioactive waste preclude the generation of respirable size particles under these accident conditions. Moreover, the vitrified high-level radioactive waste packaging design provides a greater confinement than the packagings used for smaller quantities of radioactive materials. Therefore, although considered, no accident involving vitrified high-level radioactive waste packaging was analyzed because no release of respirable particles would occur under postulated accident conditions (DOE 1994).

The MEI location for postulated accident scenarios is based on the closest location to the accident scene at which a member of the public could be present. The MEI location for each accident scenario is: 183 meters (600 feet) for radioactive waste packages, 259 meters (850 feet) for the radioactive waste tanks, 244 meters

(800 feet) for the Main Plant Process Building, 366 meters (1,200 feet) for the NDA, and 549 meters (1,800 feet) for the SDA. Analysis of the maximum public individual dose rate for each accident scenario using the MACCS computer code showed that the NDA and SDA exhumation fire accident scenarios resulted in a higher MEI dose at a distance of 2,500 meters (8,200 feet) than at the nearest geographically determined distance. This greater distance is due to the plume rise associated with fire energy postulated for these two accidents. The highest MEI dose, regardless of location outside the site, was presented for all accident scenarios.

I.5.4 Accident Source Term

To calculate accident source terms, the MAR was first determined for key facilities at the WVDP, which contains significant residual radioactive contamination inventories. These were identified as the radioactive waste tanks in the Waste Tank Farm and Main Plant Process Building. Their respective radionuclide inventories are presented in **Tables I–14** and **I–15** (WSMS 2005a, WVNSCO 2005)**.** Waste tanks have mobile and fixed inventories. Mobile inventories at the starting point of this EIS as described in Chapter 2 are physically present in the remaining liquid heel in these tanks. Fixed inventories are radionuclides physically attached to surfaces inside the tanks. The peak residual inventory varies between Tanks 8D-1 and -2 for individual radioisotopes and is delineated below for the conservative case. A bounding tank was synthesized from the two highest inventory tanks to represent the highest total inventory of any one tank and assigned the designation of Bounding Tank 8D-B. Bounding Tank 8D-B is now the MAR for accidents involving the Waste Tank Farm area at West Valley based on the highest individual radionuclide value for either Tank 8D-1 or -2.

Table I–14 Waste Management Area 3 High-Level Radioactive Waste Tank Material at Risk [a]

Radionuclide	*Tank 8D-1 (curies)*	*Tank 8D-2 (curies)*	*Bounding Tank 8D-B (curies)*
Carbon-14	2.0×10^{-2}	2.7×10^{-3}	2.0×10^{-2}
Strontium-90	2.3×10^{3}	3.0×10^{4}	3.4×10^{4}
Technetium-99	5.4	2.9	5.4
Iodine-129	6.8×10^{-3}	3.8×10^{-3}	6.8×10^{-3}
Cesium-137	2.5×10^{5}	8.6×10^{4}	2.5×10^{5}
Uranium-232	6.0×10^{-1}	1.2×10^{-1}	6.0×10^{-1}
Uranium-233	2.6×10^{-1}	5.9×10^{-2}	2.6×10^{-1}
Uranium-234	1.0×10^{-1}	2.2×10^{-2}	1.0×10^{-1}
Uranium-235	3.4×10^{-3}	1.1×10^{-3}	3.4×10^{-3}
Uranium-238	3.1×10^{-2}	5.2×10^{-3}	3.1×10^{-2}
Neptunium-237	2.3×10^{-2}	5.0×10^{-1}	5.0×10^{-1}
Plutonium-238	5.6	1.5×10^{2}	1.5×10^{2}
Plutonium-239	1.5	3.6×10^{1}	3.6×10^{1}
Plutonium-240	1.1	2.6×10^{1}	2.6×10^{1}
Plutonium-241	4.4×10^{1}	7.4×10^{2}	7.4×10^{2}
Americium-241	3.8×10^{-1}	3.8×10^{2}	3.8×10^{2}
Curium-243	1.1×10^{-3}	3.6	3.6
Curium-244	5.0×10^{-2}	8.0×10^{1}	8.0×10^{1}

[a] Consistent with the starting point of this EIS as defined in Chapter 2.
Source: WVNSCO 2005.

Table I–15 Main Plant Process Building Total Residual Radioactivity Material at Risk

Radionuclide	*Total Process Building Residual Activity (curies)*	*Radionuclide*	*Total Process Building Residual Activity (curies)*
Carbon-14	1.3×10^{1}	Neptunium-237	5.7×10^{-1}
Strontium-90	2.4×10^{3}	Uranium-238	9.0×10^{-2}
Technetium-99	5.0	Plutonium-238	2.1×10^{2}
Iodine-129	6.3×10^{-1}	Plutonium-239	6.4×10^{1}
Cesium-137	3.2×10^{3}	Plutonium-240	4.7×10^{1}
Uranium-232	8.1×10^{-1}	Plutonium-241	1.5×10^{3}
Uranium-233	4.2×10^{-1}	Americium-241	2.7×10^{2}
Uranium-234	2.0×10^{-1}	Curium-243	3.4×10^{-1}
Uranium-235	3.0×10^{-1}	Curium-244	8.4

Source: WSMS 2008a.

Numerous waste packages would be transported offsite under each alternative. Accidents are postulated to occur with these packages, including drops, punctures, and fires. The MAR for each type of waste package is presented in **Table I–16**.

Table I–16 Waste Package [a] Material at Risk (curies)

Isotope	*Truck Class B/C (HIC)*	*GTCC Cat-2 (Drum)*	*TRU (RH) (Drum)*	*LSA Container per cubic meters (7.306 each)*	*Fuel and Hardware (Drum)*	*Class A Drum*	*Class C-R-D Drum*	*Class B/C Box*	*Class A Box*
Tritium	73.5	2.00	0.0	0.0284	3.11	0.0114	0.0	37.2	0.124
Carbon-14	0.545	0.0148	1.6×10^{-6}	0.00163	0.425	8.44×10^{-5}	1.42×10^{-6}	0.276	9.18×10^{-4}
Iron-55	0.330	0.00898	0.0	0.0	0.0	5.12×10^{-5}	0.0	0.167	5.57×10^{-4}
Cobalt-60	9.49	0.258	0.0	0.0	27.3	0.00147	0.0	4.8	0.016
Nickel-63	36.7	0.999	0.0	0.0	0.0	0.00569	0.0	18.6	0.062
Strontium-90	0.403	1.85	49.3	9.2×10^{-4}	1,330	4.12×10^{-4}	2.16	0.204	4.49×10^{-3}
Yttrium-90	0.403	1.85	49.3	9.2×10^{-4}	1,330	4.12×10^{-4}	2.16	0.204	4.49×10^{-3}
Cesium-137	26.0	2.35	88.2	0.00152	1,730	0.00403	640	13.2	0.0439
Thorium-234	0.341	0.0268	8.93×10^{-6}	0.0	0.131	5.29×10^{-5}	2.85×10^{-5}	0.173	5.76×10^{-4}
Neptunium-237	0.0	0.0	6.64×10^{-4}	0.0	0.00794	0.0	2.79×10^{-5}	0.0	0.0
Uranium-238	0.341	0.00928	8.93×10^{-6}	0.0	0.131	5.29×10^{-5}	2.85×10^{-5}	0.173	5.76×10^{-4}
Plutonium-238	0.200	26.7	0.183	1.1×10^{-6}	10.5	3.09×10^{-5}	0.00401	0.101	3.73×10^{-4}
Plutonium-239	0.328	0.0363	0.0458	1.1×10^{-6}	41.2	5.08×10^{-5}	7.59×10^{-4}	0.166	5.53×10^{-4}
Plutonium-240	0.195	0.188	0.0332	1.1×10^{-6}	22.1	3.02×10^{-5}	5.46×10^{-4}	0.0985	3.28×10^{-4}
Plutonium-241	69.1	10.5	0.985	1.1×10^{-6}	671.0	0.00107	0.0451	3.5	0.0117
Americium-241	0.780	0.116	0.481	1.1×10^{-6}	79.9	1.21×10^{-4}	0.0115	0.395	1.23×10^{-3}
Curium-244	0.0	0.0	0.0997	0.0	0.626	0.0	0.00202	0.0	0.0

HIC = high-integrity container, GTCC = Greater-Than-Class C waste, Cat. = Category, TRU = transuranic (waste), RH = remote-handled, LSA = low specific activity, Class C-R-D = remote-handled Class C (waste).

[a] Vitrified high-level waste canisters were not included because their physical form would preclude the release of respirable particles in the event of a postulated accident.

Note: To convert cubic meters to cubic feet, multiply by 35.3.

Source: Karimi 2005.

The MAR for the SDA and NDA is presented in **Table I-17**.

Table I–17 NRC-licensed Disposal Area and State-licensed Disposal Area Material at Risk

Radionuclide	***NRC-licensed Disposal Area Material At Risk (curies per cubic foot)***	***Radionuclide***	***State-licensed Disposal Area Material At Risk (curies per cubic foot)***
Tritium	4.1×10^{-4}	Tritium	2.0×10^{-2}
Cobalt-60	1.2×10^{-4}	Carbon-14	1.2×10^{-4}
Nickel-63	3.4×10^{-4}	Cobalt-60	4.5×10^{-5}
Strontium-90	1.8×10^{-1}	Nickel-63	2.4×10^{-5}
Cesium-137	2.2×10^{-1}	Strontium-90	3.9×10^{-5}
Promethium-147	4.2×10^{-4}	Cesium-137	1.8×10^{-4}
Samarium-151	2.5×10^{-3}	Thorium-234	4.0×10^{-5}
Europium-154	1.5×10^{-3}	Protactinium-234m	4.0×10^{-5}
Europium-155	2.2×10^{-4}	Uranium-234	2.2×10^{-5}
Plutonium-238	2.2×10^{-3}	Uranium-238	4.0×10^{-5}
Plutonium-239	3.0×10^{-3}	Plutonium-238	3.5×10^{-2}
Plutonium-240	2.1×10^{-3}	Plutonium-239	8.2×10^{-6}
Plutonium-241	9.0×10^{-2}	Plutonium-241	9.6×10^{-6}
Americium-241	9.7×10^{-3}	Americium-241	3.2×10^{-5}

Note: To convert cubic feet to cubic meters, multiply by 0.028317.
Sources: URS 2000, 2002.

In two other EISs, the nature and form of radionuclide source term available for release during an accident scenario were found to be similar to that of this EIS. These are the *Plutonium Residue EIS* (DOE 1998) and the *WVDP Waste Management EIS* (DOE 2003c). Further guidance on airborne source terms was also found in the *DOE Handbook on ARFs* (DOE 1994). After the spectrum of accidents was identified, it was necessary to estimate a release fraction for each of the accidents. Release fraction estimates were developed based on review of available information on facility design and operation, as well as information in the *DOE Handbook on ARFs* (DOE 1994), relevant EISs (DOE 1998, 2003c), and Safety Analysis Reports (DOE 2006; WVNSCO 2004, 2007). The release fractions selected were also reviewed against each other to ensure that the relative magnitude was considered reasonable. Based on evaluation of the nature of contamination present in WVDP, the following **Table I–18** lists values of the DR, ARF, RF, and LPF developed from the aforementioned references and used in this EIS. These values are based on the discussion and references in **Table I–19**.

The release fraction is the fraction of the material at risk which become airborne and can be inhaled by humans causing a radiation dose. It is calculated by multiplying the four factors DR, ARS, RF, and LPF. Table I–19 summarizes release fractions considered appropriate for the identified severe accidents and the rationale for their selection.

Table I–18 Accident Scenario Damage Ratio, Respirable Fraction, Airborne Release Fraction, and Leak Path Factor

Accident Scenario	*Damage Ratio (DR)*	*Leak Path Factor (LPF)*	*Airborne Release Fraction (ARF)*	*Respirable Fraction (RF)*	*DR × LPF × ARF × RF*
Main Plant Process Building					
Main Plant Process Building seismic collapse	1.0	0.1	1.0×10^{-3}	1.0×10^{-2}	1.0×10^{-6}
High-Level Waste Tanks					
High-level waste tank seismic collapse	1.0	1.0	$\sim 3.0 \times 10^{-5}$	$\sim 3.0 \times 10^{-3}$	1.0×10^{-7}
Radioactive Waste Package					
Transuranic remote-handled drum puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
Greater-Than-Class Class 2 drum puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
High-integrity container fire	1.0	1.0	6.0×10^{-3}	1.0×10^{-2}	6.0×10^{-5}
High-integrity container puncture	1.0	1.0	4.0×10^{-5}	1.0	4.0×10^{-5}
Class A box puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
Class A pallet drop	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
Low specific activity container puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
Fuel and hardware drum puncture [a]	0.1	1.0	1.0×10^{-3}	1.0×10^{-2}	1.0×10^{-6}
Class A drum puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
Class C-R-D drum puncture [a]	0.1	1.0	1.0×10^{-3}	1.0×10^{-2}	1.0×10^{-6}
Class B/C box puncture	0.1	1.0	1.0×10^{-3}	1.0	1.0×10^{-4}
NRC-licensed Disposal Area					
Exhumation plume release	1.0	1.0	1.0×10^{-4}	1.0	1.0×10^{-4}
State-licensed Disposal Area					
Exhumation plume release	1.0	1.0	1.0×10^{-4}	1.0	1.0×10^{-4}

[a] Radioactive waste in these packages is in the form of grout and has different dispersion properties during an accident.

Table I–19 Basis for Specific Accident Radionuclide Release Fraction

Accident	*Release Fraction (DR × RF × ARF × LPF)*	*Basis*
Main Plant Process Building collapse due to seismic event	1.0×10^{-6}	The *Plutonium Residue EIS* (DOE 1998) assumed a release fraction of 5×10^{-6} for release of material being processed through a canyon building. In the WVDP Main Plant Process Building, there is less material and it is not located in large quantities in process equipment. In many cases, easily removed material has already been removed. The largest inventories are in the lower cells of the facility and would have a much longer leak path than material from the actual process cells. A factor of 5 reduction in overall release fraction appears reasonable.
High-level radioactive waste tank collapse due to seismic event	1.0×10^{-7}	Factors similar to this were used in the *WVDP WM EIS* (DOE 2003c). Much of the inventory is fixed (not easily removed), and such a low release fraction appears reasonable.
Waste package puncture or drop, nonsolidified waste	1.0×10^{-4}	This release fraction has been used in the *WVDP WM EIS* and WVDP Safety Analysis Report (WVNSCO 2004) and is considered reasonable for contaminated material.
High-integrity container drop and puncture	4.0×10^{-5}	Factors similar to this were used in the *WVDP WM EIS* (DOE 2003c). Much of the inventory is fixed (not easily removed), and such a low release fraction appears reasonable. Also recommended in *DOE Handbook* (DOE 1994).

Accident	*Release Fraction (DR × RF × ARF × LPF)*	*Basis*
High-integrity container fire	6.0×10^{-5}	Factors similar to this were used in the *WVDP WM EIS* (DOE 2003c). Much of the inventory is fixed (not easily removed), and such a low release fraction appears reasonable. Also recommended in *DOE Handbook* (DOE 1994).
Waste package puncture or drop, solidified waste	1.0×10^{-6}	This number was used in the *WVDP WM EIS* (DOE 2003c), and a similar number was used in the WVDP Safety Analysis Report (WVNSCO 2004) for a dropped high-level radioactive waste canister.
NDA or SDA exhumation plume release	1.0×10^{-4}	The measured combustible contaminated waste ARF from experiments recommended in DOE Airborne Release Handbook (DOE 1994).

Puncture and high-integrity container drop accident source terms for all containers are listed in **Table I–20**. Pallet drop accident source terms are listed in **Table I–21**. The high-level radioactive waste tank and Main Plant Process Building accident source terms are presented in **Table I–22**. The NDA and SDA accident source terms are presented in **Table I–23**.

Table I–20 Waste Package Puncture and High-Integrity Container Drop Accident Source Terms (curies)

Isotope	*Truck Class B/C (HIC Drop)*	*GTCC Cat 2 (Drum)*	*TRU (RH) (Drum)*	*LSA Container*	*Fuel and Hardware (Drum)*	*Class A Drum*	*Class C-R-D Drum*	*Class B/C Box*	*Class A Box*
Tritium	2.9×10^{-3}	2.0×10^{-4}	0.0	2.1×10^{-5}	3.1×10^{-6}	1.1×10^{-6}	0.0	3.7×10^{-3}	1.2×10^{-5}
Carbon-14	2.2×10^{-5}	1.5×10^{-6}	1.6×10^{-10}	1.2×10^{-6}	4.2×10^{-7}	8.4×10^{-9}	1.4×10^{-12}	2.8×10^{-5}	9.2×10^{-8}
Iron-55	1.3×10^{-5}	9.0×10^{-7}	0.0	0.0	0.0	5.1×10^{-9}	0.0	1.7×10^{-5}	5.6×10^{-8}
Cobalt-60	3.8×10^{-4}	2.6×10^{-5}	0.0	0.0	2.7×10^{-5}	1.5×10^{-7}	0.0	4.8×10^{-4}	1.6×10^{-6}
Nickel-63	1.5×10^{-3}	1.0×10^{-4}	0.0	0.0	0.0	5.7×10^{-7}	0.0	1.9×10^{-3}	6.2×10^{-6}
Strontium-90	1.6×10^{-5}	1.8×10^{-4}	4.9×10^{-3}	6.7×10^{-7}	1.3×10^{-3}	4.1×10^{-8}	2.2×10^{-6}	2.0×10^{-5}	4.5×10^{-7}
Yttrium-90	1.6×10^{-5}	1.8×10^{-4}	4.9×10^{-3}	6.7×10^{-7}	1.3×10^{-3}	4.1×10^{-8}	2.2×10^{-6}	2.0×10^{-5}	4.5×10^{-7}
Cesium-137	1.0×10^{-3}	2.4×10^{-4}	8.8×10^{-3}	1.1×10^{-6}	1.7×10^{-3}	4.0×10^{-7}	6.4×10^{-4}	1.3×10^{-3}	4.4×10^{-6}
Thorium-234	1.4×10^{-5}	2.7×10^{-6}	8.9×10^{-10}	0.0	1.3×10^{-7}	5.3×10^{-9}	2.8×10^{-11}	1.7×10^{-5}	5.8×10^{-8}
Neptunium-237	0.0	0.0	6.6×10^{-8}	0.0	7.94×10^{-9}	0.0	2.8×10^{-11}	0.0	0.0
Uranium-238	1.4×10^{-5}	9.3×10^{-7}	8.9×10^{-10}	0.0	1.3×10^{-7}	5.3×10^{-9}	2.8×10^{-11}	1.7×10^{-5}	5.8×10^{-8}
Plutonium-238	8.0×10^{-6}	2.7×10^{-3}	1.8×10^{-5}	8.0×10^{-10}	1.0×10^{-5}	3.1×10^{-9}	4.0×10^{-9}	1.0×10^{-5}	3.7×10^{-8}
Plutonium-239	1.3×10^{-5}	3.6×10^{-6}	4.6×10^{-6}	8.0×10^{-10}	4.1×10^{-5}	5.1×10^{-9}	7.6×10^{-10}	1.7×10^{-5}	5.5×10^{-8}
Plutonium-240	7.8×10^{-6}	1.9×10^{-6}	3.3×10^{-6}	8.0×10^{-10}	2.2×10^{-5}	3.0×10^{-9}	5.5×10^{-10}	9.8×10^{-6}	3.3×10^{-8}
Plutonium-241	2.8×10^{-3}	1.0×10^{-3}	9.8×10^{-5}	8.0×10^{-10}	6.7×10^{-4}	1.1×10^{-7}	4.5×10^{-8}	3.5×10^{-4}	1.2×10^{-6}
Americium-241	3.1×10^{-5}	1.2×10^{-5}	4.8×10^{-5}	8.0×10^{-10}	8.0×10^{-5}	1.2×10^{-8}	1.2×10^{-8}	4.0×10^{-5}	1.2×10^{-7}
Curium-244	0.0	0.0	1.0×10^{-5}	0.0	6.3×10^{-7}	0.0	2.0×10^{-9}	0.0	0.0

HIC = high-integrity container, GTCC = Greater-Than-Class C waste, TRU = transuranic (waste), RH = remote-handled, LSA = low specific activity.

Table I–21 Waste Pallet High-integrity Container Drop Accident Source Terms (curies)

Isotope	*Class A Pallet Drop*	*Isotope*	*Class A Pallet Drop*
Tritium	6.84×10^{-6}	Uranium-238	3.17×10^{-8}
Carbon-14	5.06×10^{-8}	Plutonium-238	1.85×10^{-8}
Iron-55	3.07×10^{-8}	Plutonium-239	3.05×10^{-8}
Cobalt-60	8.82×10^{-7}	Plutonium-240	1.81×10^{-8}
Nickel-63	3.41×10^{-6}	Plutonium-241	6.42×10^{-7}
Strontium-90	2.47×10^{-7}	Americium-241	7.26×10^{-8}
Yttrium-90	2.47×10^{-7}	Neptunium-237	0.0
Cesium-137	2.42×10^{-6}	Curium-244	0.0
Thorium-234	3.17×10^{-8}		

Table I–22 High-level Radioactive Waste Tank and Main Plant Process Building Accident Source Terms

Radionuclide	*Tank Total Inventory or Material at Risk (curies)*	*Accident Source Term (curies)*	*Radionuclide*	*Main Plant Process Building Residual Activity or Material at Risk (curies)*	*Accident Source Term (curies)*
Carbon-14	2.0×10^{-2}	2.0×10^{-9}	Americium-241	2.7×10^{2}	2.7×10^{-4}
Strontium-90	3.4×10^{4}	3.4×10^{-3}	Carbon-14	1.3×10^{1}	1.3×10^{-5}
Technetium-99	5.4	5.4×10^{-7}	Curium-243	3.4×10^{-1}	3.4×10^{-7}
Iodine-129	6.8×10^{-3}	6.8×10^{-10}	Curium-244	8.4	8.4×10^{-6}
Cesium-137	2.5×10^{5}	2.5×10^{-2}	Cesium-137	3.2×10^{3}	3.2×10^{-3}
Uranium-232	6.0×10^{-1}	6.0×10^{-8}	Iodine-129	6.3×10^{-1}	6.3×10^{-7}
Uranium-233	2.6×10^{-1}	2.6×10^{-8}	Neptunium-237	5.7×10^{-1}	5.7×10^{-7}
Uranium-234	1.0×10^{-1}	1.0×10^{-8}	Plutonium-238	2.1×10^{2}	2.1×10^{-4}
Uranium-235	3.4×10^{-3}	3.4×10^{-10}	Plutonium-239	6.4×10^{1}	6.4×10^{-5}
Uranium-238	3.1×10^{-2}	3.1×10^{-9}	Plutonium-240	4.7×10^{1}	4.7×10^{-5}
Neptunium-237	5.0×10^{-1}	5.0×10^{-8}	Plutonium-241	1.5×10^{3}	1.5×10^{-3}
Plutonium-238	1.5×10^{2}	1.5×10^{-5}	Strontium-90	2.4×10^{3}	2.4×10^{-3}
Plutonium-239	3.6×10^{1}	3.6×10^{-6}	Technetium-99	5	5×10^{-6}
Plutonium-240	2.6×10^{1}	2.6×10^{-6}	Uranium-232	8.1×10^{-1}	8.1×10^{-7}
Plutonium-241	7.4×10^{2}	7.4×10^{-5}	Uranium-233	4.2×10^{-1}	4.2×10^{-7}
Americium-241	3.8×10^{2}	3.8×10^{-5}	Uranium-234	2×10^{-1}	2×10^{-7}
Curium-243	3.6	3.6×10^{-7}	Uranium-235	3×10^{-2}	3×10^{-8}
Curium-244	8.0×10^{1}	8.0×10^{-6}	Uranium-238	9×10^{-2}	9×10^{-8}

Table I–23 NRC-licensed Disposal Area and State-licensed Disposal Area Accident Source Terms

Radionuclide	*NRC-licensed Disposal Area (curies)*	*State-licensed Disposal Area Trench 10 (curies)*
Tritium	4.5×10^{-7}	2.2×10^{-5}
Carbon-14	1.7×10^{-9}	1.3×10^{-7}
Cobalt-60	1.3×10^{-7}	4.9×10^{-8}
Nickel-63	3.8×10^{-7}	2.7×10^{-8}
Strontium-90	1.9×10^{-4}	4.3×10^{-8}
Yttrium-90	1.9×10^{-4}	4.3×10^{-8}
Cesium-137	2.5×10^{-4}	2.0×10^{-7}
Samarium-151	2.8×10^{-6}	Not reported
Thorium-234	8.0×10^{-9}	4.4×10^{-8}
Uranium-233	7.4×10^{-8}	5.5×10^{-10}
Uranium-234	3.7×10^{-9}	2.5×10^{-8}
Uranium-235	7.1×10^{-10}	7.4×10^{-10}
Uranium-238	8.0×10^{-9}	4.4×10^{-8}
Plutonium-238	2.4×10^{-6}	3.9×10^{-5}
Plutonium-239	3.3×10^{-6}	9.0×10^{-9}
Plutonium-240	2.4×10^{-6}	1.8×10^{-10}
Plutonium-241	9.9×10^{-5}	1.1×10^{-8}
Americium-241	1.1×10^{-5}	3.5×10^{-8}

I.5.5 Accident Frequency

The annual frequency of each accident is used to calculate the annual risk of a fatal latent cancer associated with each accident. The annual accident risk is calculated by multiplying the accident risk of a fatal latent cancer by the annual frequency of the accident. Each specific accident's annual frequency is determined by data from operational experience or an analysis of the sequence of events necessary for the accident to occur. Accidents with an annual frequency of less than 1×10^{-6} per year or 1 in 1 million are not analyzed in this appendix because they are so unlikely to occur that their risks are extremely small. However, the consequences of intentional destructive acts, which have a lower frequency than 1×10^{-6} per year, are analyzed in Appendix N.

Radioactive waste accidents analyzed in the *WVDP Waste Management EIS* (DOE 2003c) and their frequencies are:

- Class A low-level radioactive waste drum puncture (0.1 to 0.01 per year)
- Class A low-level radioactive waste pallet drop (0.1 to 0.01 per year)
- Class A low-level radioactive waste box puncture (0.1 to 0.01 per year)
- Drum cell drop (0.1 to 0.01 per year)
- Class C low-level radioactive waste drum puncture (0.1 to 0.01 per year)
- Class C low-level radioactive waste pallet drop (0.1 to 0.01 per year)
- Class C low-level radioactive waste box puncture (0.1 to 0.01 per year)
- HIC drop (0.1 to 0.01 per year)
- Remote-handled transuranic waste drum puncture (0.1 to 0.01 per year)
- Loadout bay fire (1×10^{-4} to 1×10^{-6} per year).

The *WVDP Waste Management EIS* (DOE 2003c) addressed the shipment of 46,839 radioactive waste packages over a 10-year time period for both its alternatives. Using the annual frequency value range of 0.1 to 0.01 per year for all waste package mishandling drop and puncture accidents, the accident frequency for handling each individual package is 2.1×10^{-5} to 2.1×10^{-6} per year. The larger value of 2.1×10^{-5} per package year was used with the individual alternative average annual radioactive waste package rate to calculate an annual frequency for each accident scenario which is delineated in **Table I–24**. For comparison purposes, a separate radioactive waste handling accident analysis performed for the Waste Isolation Pilot Plant resulted in a calculation of 7×10^{-6} per year for radioactive waste package puncture and drop accidents, which is within the range of 2.1×10^{-5} and 2.1×10^{-6} per year (DOE 2006). The accident frequency for the high-level radioactive waste tank, Main Plant Process Building, and HIC fire were all assumed at the identical value for all alternatives because package handling rate is not a factor. In all cases, the largest value of the range of possible accident frequencies was conservatively used for this EIS. Accident scenarios developed for the WVDP decommissioning activities are listed, along with their annual frequency, for each alternative in Table I–24.

Table I–24 Accident Scenario Annual Frequency

West Valley Demonstration Project Location and Accident Scenario	*Accident Initiator*	*Sitewide Removal Alternative Annual Frequency*	*Sitewide Close-In-Place Alternative Annual Frequency*	*Phased Decisionmaking Alternative (Phase 1) Annual Frequency*	*No Action Alternative Annual Frequency*
Radioactive waste tank collapse	Seismic event	0.0001	0.0001	0.0001	0.0001
Main Plant Process Building collapse	Seismic event	0.0001	0.0001	0.0001	0.0001
Transuranic (remote-handled) drum puncture	Mishandling or drop	0.08	0.008	0.1	Not applicable
Greater-Than-Class C Class 2 drum puncture	Mishandling or drop	0.08	Not applicable	0.1	Not applicable
High-integrity container fire	Human error	0.0001	0.0001	0.0001	Not applicable
High-integrity container puncture	Mishandling or drop	0.08	0.008	0.1	Not applicable
Class A box puncture	Mishandling or drop	0.08	0.008	0.1	0.003
Class A pallet drop	Mishandling or drop	0.08	0.008	0.1	0.003
Low specific activity container puncture	Mishandling or drop	0.08	0.008	0.1	0.003
Fuel and hardware drum puncture	Mishandling or drop	0.08	0.008	0.1	Not applicable
Class A drum puncture	Mishandling or drop	0.08	0.008	0.1	0.003
Class C-R-D drum puncture	Mishandling or drop	0.08	0.008	0.1	Not applicable
Class B/C box puncture	Mishandling or drop	0.08	0.008	0.1	Not applicable
NRC-licensed Disposal Area Exhumation Fire	Human error	0.0001	Not applicable	Not applicable	Not applicable
State-licensed Disposal Area Exhumation Fire	Human error	0.0001	Not applicable	Not applicable	Not applicable

Not applicable = these radioactive waste packages or decommissioning actions are not part of the alternative.

I.5.6 MACCS2 Code Description

The MACCS2 computer code V.1.13.1 (Chanin and Young 1997) is used to estimate the radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. MACCS was used to analyze health impacts of postulated accidents instead of GENII due to the following factors:

- MACCS uses actual hourly meteorological data (i.e., wind speed, wind direction, rainfall, atmospheric dispersion stability) from the site whereas GENII uses a statistically interpreted joint frequency distribution that averages this data. The use of actual hourly data is more accurate in calculating the probabilistic dose distribution for accident analyses;

- The GENII tritium model assumes equilibrium between tritium concentrations in the air and vegetation, which is a good assumption for long-term releases, but may over-predict short-duration releases (DOE 2003b);

- MACCS has the capability to model the effects of population evacuation or relocation during or after an accident. This capability is not in GENII; and

- GENII cannot be used to calculate 95th percentile radiation dose according to DOE Standard 3009-94 Appendix A (DOE 2003b) whereas MACCS can calculate this dose;

Conversely, GENII was used to analyze human health impacts from normal operations because:

- GENII can model liquid radiological releases whereas MACCS does not have this capability;

- GENII can model long-term radiological releases whereas MACCS is limited to a maximum plume release time of 24 hours

The specification of the release characteristics, designated a "source term," can consist of up to four Gaussian plumes that are often referred to simply as "plumes."

The radioactive materials released are modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, particulate material can be modeled as being deposited on the ground. The extent of this deposition can depend on precipitation. If contamination levels exceed a user-specified criterion, mitigating actions can be triggered to limit radiation exposures.

Atmospheric conditions during an accident scenario's release and subsequent plume transport are taken from the annual sequential hourly meteorological data file. Scenario initiation is assumed to be equally likely during any hour contained in the file's dataset, with plume transport governed by the succeeding hours. The model was applied by calculating the exposure to each receptor for accident initiation during each hour of the 8,760-hour dataset. The mean results of these samples, which include contributions from all meteorological conditions, are presented in this EIS.

Two aspects of the code's structure are important to understanding its calculations: (1) the calculations are divided into modules and phases; and (2) the region surrounding the facility is divided into a polar-coordinate grid. These concepts are described in the following sections.

MACCS2 is divided into three primary modules: ATMOS, EARLY, and CHRONC. Three phases are defined as the emergency, intermediate, and long-term phases. The relationship among the code's three modules and the three phases of exposure are summarized below.

The ATMOS module performs all of the calculations pertaining to atmospheric transport, dispersion, and deposition, as well as the radioactive decay that occurs before release and while the material is in the atmosphere. It uses a Gaussian plume model with Pasquill-Gifford dispersion parameters. The phenomena treated include building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay and in-growth. Local topography is not modeled for calculating atmospheric dispersion which results in conservatively higher plume concentrations, doses, and risks to the public. The results of the calculations are stored for subsequent use by EARLY and CHRONC. In addition to the air and ground concentrations, ATMOS stores information on wind direction, arrival and departure times, and plume dimensions.

It is noted that dispersion calculations such as used in MACCS2 are generally recognized to be less applicable within 100 meters (328 feet) of a release than they are to further downwind distances (DOE 2004); such close-in results frequently over-predict the atmospheric concentrations because they do not account for the initial momentum or size of the release, or for the impacts of structures and other obstacles on plume dispersion. Most of the results presented in this EIS are for distances at least 100 meters (328 feet) downwind from a hypothesized release source.

The EARLY module models the period immediately following a radioactive release. This period is commonly referred to as the emergency phase. The emergency phase begins at each successive downwind distance point when the first plume of the release arrives. The duration of the emergency phase is specified by the user, and it can range between 1 and 7 days. The exposure pathways considered during this period are direct external exposure to radioactive material in the plume (cloud shine), exposure from inhalation of radionuclides in the cloud (cloud inhalation), exposure to radioactive material deposited on the ground (ground shine), inhalation of resuspended material (resuspension inhalation), and skin dose from material deposited on the skin. Mitigating actions that can be specified for the emergency phase include evacuation, sheltering, and dose-dependent relocation.

The CHRONC module performs all of the calculations pertaining to the intermediate and long-term phases. CHRONC calculates the individual health effects that result from both direct exposures to contaminated ground and from inhalation of resuspended materials.

The intermediate phase begins at each successive downwind distance point upon conclusion of the emergency phase. The user can configure the calculations with an intermediate phase that has a duration as short as 0 or as long as 1 year. In the zero-duration case, there is essentially no intermediate phase, and a long-term phase begins immediately upon conclusion of the emergency phase.

Intermediate models are implemented on the assumption that the radioactive plume has passed and the only exposure sources (ground shine and resuspension inhalation) are from ground-deposited material.

The mitigating action model for the intermediate phase is very simple. If the intermediate phase dose criterion is satisfied, the resident population is assumed to be present and subject to radiation exposure from ground shine and resuspension for the entire intermediate phase. If the intermediate phase exposure exceeds the dose criterion, then the population is assumed to be relocated to uncontaminated areas for the entire intermediate phase.

The long-term phase begins at each successive downwind distance point upon conclusion of the intermediate phase. The exposure pathways considered during this period are ground shine and resuspension inhalation. The exposure pathways considered are those resulting from ground-deposited material. A number of protective measures, such as decontamination, temporary interdiction, and condemnation, can be modeled in the long-term phase to reduce doses to user-specified levels.

The decisions on mitigating action in the long-term phase are based on two sets of independent actions: (1) decisions related to whether land at a specific location and time is suitable for human habitation (habitability), and (2) decisions related to whether land at a specific location and time is suitable for agricultural production (ability to farm). For the EIS, no mitigation or special protective measures were assumed for the exposure calculations.

All of the calculations of MACCS2 are stored based on a polar-coordinate spatial grid with a treatment that differs somewhat between calculations of the emergency phase and calculations of the intermediate and long-term phases. The region potentially affected by a release is represented with a (r, Θ) grid system centered on the location of the release. Downwind distance is represented by the radius "r." The angle, "Θ", is the angular offset from the north, going clockwise.

The user specifies the number of radial divisions as well as their endpoint distances. The angular divisions used to define the spatial grid are fixed in the code. They correspond to the 16 points of the compass, each being 22.5 degrees wide. The 16 points of the compass are used in the United States to express wind direction. The compass sectors are referred to as the coarse grid.

Since emergency phase calculations use dose-response models for early fatalities and early injuries that can be highly nonlinear, these calculations are performed on a finer grid basis than the calculations of the intermediate and long-term phases. For this reason, the calculations of the emergency phase are performed with the 16 compass sectors divided into 3, 5, or 7 equal angular subdivisions. The subdivided compass sectors are referred to as the fine grid.

Lifetime doses are the conventional measure of detriment used for radiological protection. These are 50-year dose commitments to a weighted sum of tissue doses defined by the ICRP and referred to as "effective dose equivalent." Lifetime doses may be used to calculate the stochastic health effect risk resulting from exposure to radiation. The calculated lifetime dose was used in cancer risk calculations.

I.5.7 Radiological Accident Results

The MACCS-calculated results for all 15 analyzed accident scenarios are presented in **Table I–25**. Results are presented in terms of 80-kilometer (50-mile) radius population and MEI radiation dose, LCF, and annual risk. The LCF for all accidents was calculated using the 0.0006 LCF per rem risk factor discussed in Section I.3. Although the Main Plant Process Building and high-level radioactive waste tank accidents apply to all four alternatives, not all the radioactive waste package handling accidents are relevant to each alternative because the actions under each alternative do not necessarily require all the package types. In addition, the NDA and SDA exhumation accidents only apply to the Sitewide Removal Alternative. Therefore, the term, "Not Applicable" is placed under alternatives where a specific package, NDA, or SDA accident is not relevant.

Table I–25 MACCS Calculated Accident Risk and Consequences for Each Alternative

Bounding Accident	*Sitewide Removal Alternative*	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Main Plant Process Building				
Main Plant Process Building Seismic Collapse				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.68 person-rem 0.046 rem 4.1×10^{-8} 2.7×10^{-9}	0.68 person-rem 0.046 rem 4.1×10^{-8} 2.7×10^{-9}	0.68 person-rem 0.046 rem 4.1×10^{-8} 2.7×10^{-9}	**0.68 person-rem** **0.046 rem** **4.1×10^{-8}** **2.7×10^{-9}**
Radioactive Waste Tanks				
High Level Waste Tank Seismic Collapse				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.59 person-rem 0.014 rem 3.6×10^{-8} 8.3×10^{-10}	0.59 person-rem 0.014 rem 3.6×10^{-8} 8.3×10^{-10}	0.59 person-rem 0.014 rem 3.6×10^{-8} 8.3×10^{-10}	0.59 person-rem 0.014 rem 3.6×10^{-8} 8.3×10^{-10}
Radwaste Package				
Transuranic (remote-handled) Drum Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.27 person-rem 0.029 rem 1.3×10^{-5} 1.4×10^{-6}	0.27 person-rem 0.029 rem **1.3×10^{-6}** **1.4×10^{-7}**	0.27 person-rem 0.029 rem **1.6×10^{-5}** **1.7×10^{-6}**	Not Applicable
GTCC Drum Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	1.9 person-rem **0.68 rem** **9.1×10^{-5}** **3.3×10^{-5}**	Not Applicable	Not Applicable	Not Applicable
HIC Fire				
-Population dose -MEI dose -Population annual risk -MEI annual risk	**3.4 person-rem** 0.053 rem 2.0×10^{-7} 3.2×10^{-9}	**3.4 person-rem** **0.053 rem** 2.0×10^{-7} 3.2×10^{-9}	**3.4 person-rem** **0.053 rem** 2.0×10^{-7} 3.2×10^{-9}	Not Applicable
HIC Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.12 person-rem 0.033 rem 5.8×10^{-6} 1.6×10^{-6}	0.12 person-rem 0.033 rem 5.8×10^{-7} 1.6×10^{-7}	0.12 person-rem 0.033 rem 7.2×10^{-6} 2.0×10^{-6}	Not Applicable
Class A Box Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.00038 person-rem 9.1×10^{-5} rem 1.8×10^{-8} 4.4×10^{-9}	0.00038 person-rem 9.1×10^{-5} rem 1.8×10^{-9} 4.4×10^{-10}	0.00038 person-rem 9.1×10^{-5} rem 2.3×10^{-8} 5.5×10^{-9}	.00038 person-rem 9.1×10^{-5} rem 6.8×10^{-10} 1.6×10^{-10}
Class A Pallet Drop				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.00013 person-rem 2.1×10^{-5} rem 6.2×10^{-9} 1.0×10^{-9}	0.00013 person-rem 2.1×10^{-5} rem 6.2×10^{-10} 1.0×10^{-10}	0.00013 person-rem 2.1×10^{-5} rem 7.8×10^{-9} 1.3×10^{-9}	0.00013 person-rem 2.1×10^{-5} rem 2.3×10^{-10} 3.8×10^{-11}
LSA Container Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	2.8×10^{-5} person-rem 1.1×10^{-6} rem 1.3×10^{-9} 5.3×10^{-11}	2.8×10^{-5} person-rem 1.1×10^{-6} rem 1.3×10^{-10} 5.3×10^{-12}	2.8×10^{-5} person-rem 1.1×10^{-6} rem 1.7×10^{-9} 6.6×10^{-11}	2.8×10^{-5} person-rem 1.1×10^{-6} rem 5.0×10^{-11} 2.0×10^{-12}

Bounding Accident	*Sitewide Removal Alternative*	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Fuel and Hardware Drum Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.19 person-rem 0.054 rem 9.4×10^{-6} 2.6×10^{-6}	Not Applicable	Not Applicable	Not Applicable
Class A Drum Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	3.5×10^{-5} person-rem 8.6×10^{-6} rem 1.7×10^{-9} 4.1×10^{-10}	3.5×10^{-5} person-rem 8.6×10^{-6} rem 1.7×10^{-10} 4.1×10^{-11}	3.5×10^{-5} person-rem 8.6×10^{-6} rem 2.1×10^{-9} 5.2×10^{-10}	3.5×10^{-5} person-rem 8.6×10^{-6} rem 6.3×10^{-11} 1.5×10^{-11}
Class C-R-D Drum Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.013 person-rem 2.5×10^{-5} rem 6.2×10^{-7} 1.2×10^{-9}	0.013 person-rem 2.5×10^{-5} rem 6.2×10^{-8} 1.2×10^{-10}	0.013 person-rem 2.5×10^{-5} rem 7.8×10^{-7} 1.5×10^{-9}	Not Applicable
Class B/C Box Puncture				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.12 person-rem 0.028 rem 5.8×10^{-6} 1.3×10^{-6}	0.12 person-rem 0.028 rem 5.8×10^{-7} 1.3×10^{-7}	0.12 person-rem 0.028 rem 7.2×10^{-6} 1.7×10^{-6}	Not Applicable
NDA and SDA				
NDA Exhumation Release				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.038 person-rem 0.0023 rem 2.3×10^{-9} 1.4×10^{-10}	Not Applicable	Not Applicable	Not Applicable
SDA Exhumation Release				
-Population dose -MEI dose -Population annual risk -MEI annual risk	0.041 person-rem 0.0018 rem 2.5×10^{-9} 1.1×10^{-10}	Not Applicable	Not Applicable	Not Applicable

MEI = maximally exposed individual, GTCC = Greater-Than-Class C, HIC = high-integrity container, LSA = low specific activity waste, NDA = NRC-licensed Disposal Area, SDA = State-licensed Disposal Area.
Maximum accident consequence and risk for each alternative is displayed in bold.
Note: To convert from rem or person-rem to sieverts or person-sieverts, multiply by 0.01.

Table I–25 shows that the Sitewide Removal, Sitewide Close-In-Place, and Phased Decisionmaking (Phase 1) Alternatives have the same largest calculated accident dose consequence of 3.4 person-rem for the population (from the HIC Fire), and the Sitewide Removal Alternative has the highest MEI accident dose consequence of 0.68 rem (from the GTCC Class 2 Drum Puncture). The Sitewide Removal Alternative has the largest calculated accident annual risk of 9.1×10^{-5} for the population and 3.3×10^{-5} for the MEI, as compared to the other three alternatives. This alternative has the highest risk because it is the only alternative that handles Greater-Than-Class C Drums, which have a relatively large source term as shown in Tables I–17 and I–20. The Remote-Handled Transuranic Drum Puncture, Greater-Than-Class C Drum Puncture and HIC Fire accidents are dominant for dose and risk for the Sitewide Removal, Sitewide Close-In-Place, and Phased Decisionmaking (Phase 1) Alternatives. The highest calculated dose and risk for the No Action Alternative is the Main Plant Process Building Seismic Collapse accident. For all four alternatives, none of the accident population or MEI doses or risks will cause any fatality or serious injury due to radiation exposure.

To put the calculated doses from these accidents in some perspective, the largest MEI dose of 0.68 rem is two times the average annual background radiation dose of 0.36 rem (360 millirem) per person. The maximum MEI latent cancer risk (3.3×10^{-5}) means there is about 1 chance in 30,000 of an LCF to the MEI for the most severe accident. For comparison, the latest National Cancer Institute statistics (NCI 2005) indicate that the chance of a fatal latent cancer in all Americans over their lifetime is about 0.22, or about slightly greater than one chance in five.

The maximum accident population dose of 3.4 person-rem is a small percentage (less than 0.001 percent) of the annual background population dose of 613,000 person-rem that would be received by the approximately 1.7 million residents within an 80-kilometer (50-mile) radius of the WNYNSC. Another perspective on the population dose from this postulated bounding accident is that the risk to the average individual in the general population in terms of developing an LCF from this dose is 1.3×10^{-9} or 1 chance in 765 million. The maximum accident radiation dose to each individual in the 80-kilometer (50-mile) radius population is 0.0000021 rem, or less than 0.001 percent of the radiation received by using a computer monitor.

In considering the overall risk from accidents for an alternative, it is necessary to consider the number of years that decommissioning actions would occur. In addition, in the case of radioactive waste package handling accidents, the total number of packages and annual handling rate must also be considered. **Table I–26** presents a summary of the estimated number of years that each type of operation would occur for each alternative and the respective number of radioactive waste packages handled. This table shows that the largest number of radioactive waste packages would be handled by the Sitewide Removal Alternative, but Phase 1 of the Phased Decisionmaking Alternative has the largest radioactive waste package annual handling rate.

Table I–26 Risk Duration for Major Accident Scenarios

Parameter	*Removal Alternative*	*Close-In-Place Alternative*	*Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Years before initiating Main Plant Process Building removal or stabilization	7	1	1	No removal or stabilization
Years before radioactive waste tanks' removal or stabilization	24	2	No removal or stabilization	No removal or stabilization
Years of radioactive waste package handling during decommissioning actions	64	7	8	0 [a]
Number of radioactive waste packages handled	234,282	2,630	38,166	3,561 every 25 years [a]
Annual radioactive waste package handling rate	3,661	376	4,771	143 [a]

[a] Average over 25-year time intervals to account for periodic waste disposal along with annual expected waste disposal volumes, and assumes drums for Class A waste and the LSA container for LSA waste. This alternative does not involve preparation for decommissioning. The annual average includes a large spike when NDA/SDA covers are being replaced every 25 years.

Sources: WSMS 2008b, 2008c, 2008d, 2008e.

The combination of the annual risk estimate for various accident types and the activity duration estimates supports the development of an overall relative risk estimate for the four alternatives for accidents that would involve short-term releases of radionuclides to the atmosphere. Activity duration is used to qualitatively assess the time period when a specific facility or action would occur and therefore be vulnerable to a postulated accident. For example, the risk for a radioactive waste tank accident would be the largest for the No Action and Phased Decisionmaking (Phase 1) Alternatives because no removal or stabilization is planned for this facility. This overall relative risk is presented in **Table I–27**. The terms used in this table (highest, low, and lowest) are intended to convey a relative qualitative assessment of the accident risk between the alternatives. The absolute magnitude of accident consequences and risks for all alternatives is estimated to be very small and is not expected to present a significant health risk to the general population.

Table I–27 Relative Accident Risk Comparison Rating Between Alternatives for Entire Time Period

Sitewide Removal Alternative	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
Highest [a]	Low [a]	Low [a]	Lowest [a]

[a] These ratings are relative to each other between the alternatives. The absolute magnitude of accident risk for all alternatives is characterized as very small.

The Sitewide Removal Alternative has the greatest potential for an accident with the highest consequences and is expected to have the highest overall accident risk because it has the greatest number and duration of higher radioactivity content waste removal, packaging, and handling operations, and because it occurs over a longer period of time.

The most significant short-term accidents for the Sitewide Close-In-Place, Phased Decisionmaking (Phase 1), and No Action Alternatives have lower projected consequences than the dominant Sitewide Removal Alternative accident scenarios. The overall accident risk for these alternatives is estimated to be less than the overall accident risk for the Sitewide Removal Alternative. The overall accident risk for Phase 1 of the Phased Decisionmaking Alternative is slightly higher than the risk for the Sitewide Close-In-Place and No Action Alternatives as a result of the additional activity related to the Main Plant Process Building removal and the greater number of annual radioactive waste handling operations.

The most serious accident for the No Action Alternative, in terms of population dose, is smaller than the other three alternatives. The No Action Alternative does, however, have a higher risk of groundwater contamination over the long-term as a result of degradation or accidents involving the Main Plant Process Building and high-level radioactive waste tanks, since these facilities are not remediated under this alternative. It should also be noted that Phase 1 of the Phased Decisionmaking Alternative also has no plans for removal of the high-level radioactive waste tanks, and, depending on decisions made for Phase 2, could have similar long-term degradation and accident risks with regard to the high-level radioactive waste tanks. Long-term consequences for each alternative are presented in Appendix H.

I.5.8 Toxic Chemical Accidents

Data on toxic chemicals at the WVDP provide inventories of toxic metal elements such as lead and mercury and salts in the Waste Tank Farm and Main Plant Process Building (WSMS 2005a, 2005b). These inventories exist within equipment and individual components such as switches, lamps, and shielded windows and are not concentrated in one tank or physical location. Their physical and chemical forms are not conducive to an accident because of their highly dispersed distribution. No quantities of toxic chemicals of the same magnitude as in the Waste Tank Farm or Main Plant Process Building have been identified in a specific tank, drum, or pressurized component. Based on the type, form, and distribution of toxic chemicals at the WVDP, no credible hazardous chemical accidents can occur that would affect worker or public health.

Although no significant health effects from postulated accidents involving toxic chemicals are expected, an evaluation of the toxic chemical inventory was performed. **Table I–28** presents a tabulation of all the toxic chemicals present at the WVDP along with their quantities and relevant properties. EPA minimum release reportable quantities (EPA 2001b) and DOE health effect air concentration guidelines (DOE 2005) for each chemical are also presented in this table. In addition, Table I–28 presents the boiling point and vapor pressure (at 21 ^{o}C or 70 ^{o}F) of each toxic chemical. The purpose of providing the boiling point is to indicate that none of these chemicals could boil into vapor at expected temperatures during normal operations, and that only arsenic, cadmium, mercury, and selenium could vaporize if exposed to typical flame temperatures assumed for accidents of 800 ^{o}C (1475 ^{o}F) (10 CFR 71.73). The vapor pressure is used as another screening parameter in

eliminating toxic chemicals. Such screening methods in other EISs (DOE 1999a) eliminate chemicals with a vapor pressure of less than 0.5 millimeters mercury (Hg) or 0.01 pounds per square inch at normal temperatures. For example, water vapor pressure is 18 millimeter Hg or 0.35 pounds per square inch at 21 ^{o}C (70 ^{o}F).

Table I–28 Inventory, Properties, and Serious Health Effect Limits of the West Valley Demonstration Project Toxic Chemicals

Chemical	*Highest Total Main Plant Process Building Inventory* [a] *kilograms (pounds)*	*Highest Individual Tank Inventory kilograms (pounds)*	*EPA CERCLA Reportable Release Quantity* [b] *kilograms (pounds)*	*Chemical Boiling Point Temperature at Atmospheric Pressure*	*Chemical Vapor Pressure At 77 ^{o}F (25 ^{o}C), millimeter Hg*	*ERPG-3 TEEL3* [c] *milligrams per cubic meter*
Silver	26 (57.3)	1.98 (4.36)	454 (1,000)	2,162 °C 3,294 °F	0	10
Arsenic	51 (112.3)	3.92 (8.63)	0.454 (1)	614 °C 1,137 °F	0	5
Barium	70 (154.2)	17.5 (38.6)	None	1,870 °C 3,398 °F	0	125
Beryllium	5.1 (11.2)	0.608 (1.34)	4.54 (10)	2,469 °C 4,476 °F	0	0.1
Cadmium	17 (37.4)	1.66 (3.66)	4.54 (10)	767 °C 1,413 °F	0	7.5
Chromium	144 (317.2)	85.6 (188.6)	2,270 (5,000)	2,671 °C 4,840 °F	0	250
Mercury	0.81 (1.8)	1.15 (2.53)	0.454 (1)	357 °C 674 °F	0.0018	4.1
Nickel	457 (1006.7)	85.9 (189.2)	45.4 (100)	2,913 °C 5,275 °F	0	10
Lead	337 (742.3)	14.2 (31.3)	4.54 (10)	1,749 °C 3,180 °F	0	100
Antimony	18 (39.7)	9.76 (21.5)	2,270 (5,000)	1,587 °C 2,889 °F	0	50
Selenium	29 (63.9)	4.87 (10.7)	45.4 (100)	685 °C 1,265 °F	0	1
Thallium	6 (13.2)	9.68 (21.3)	454 (1,000)	1,473 °C 2,683 °F	0	15

EPA = U.S. Environmental Protection Agency, CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act, F = Fahrenheit, C = Celsius, ERPG-3 = Emergency Response Planning Guideline 3, TEEL3 = Temporary Emergency Exposure Limits 3.

[a] This total inventory represents the sum of the existence of this element distributed in components and structures throughout the Main Plant Process Building.

[b] For metals (silver, beryllium, cadmium, chromium, nickel, lead, antimony, selenium, and thallium) no reporting of solid form releases in these quantities is required unless the release is in the form of pieces with a mean diameter of 100 micrometers (100 microns) or smaller. For all materials, only particles of this size are reportable.

[c] Both the Emergency Response Planning Guideline 3 (ERPG-3) and Temporary Emergency Exposure Limits 3 (TEEL3) are the maximum concentration in air below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects. 1 millimeter Hg = 0.019 pounds per square inch.

Shading indicates that inventory is less than EPA CERCLA reportable release quantity.

Sources: DOE 2005; EPA 2001b; NYenvlaw 2002; Webelements 2006; WSMS 2005b, 2005c, 2008a, 2008b, 2008c.

Based on the ratio of individual toxic chemical inventory to ERPG-3 limit for those chemicals that are above the EPA CERCLA reportable release quantity, an accidental release of beryllium encompasses the impacts of the other toxic chemicals listed in Table I–28. Assuming an accident that would release toxic chemicals from the Main Plant Process Building or High-Level Waste Tanks having the same respirable particle release fraction that was used for the radiological accidents as presented in Table I–15, the higher inventory of toxic chemicals in the Main Plant Process Building would bound the inventory of the high-level waste tanks. The Main Plant Process Building Seismic Collapse accident scenario also results in a higher source term than the high-level waste tank accident scenario.

A postulated seismic collapse accident involving all 5.1 kilograms (11.2 pounds) of beryllium in the Main Plant Process Building results in a concentration of respirable particles of beryllium at 100 meters (328 feet) of 0.00043 milligrams per cubic meter (0.0000012 milligrams per cubic foot) for a 10-minute release time and average meteorology atmospheric dispersion conditions. This is a factor of more than 200 below or about 0.4 per cent of the ERPG-3 value of 0.1 milligrams per cubic meter (0.003 milligrams per cubic foot). If conservative meteorology atmospheric dispersion were to be assumed, the 100 meter (328 feet) air concentration would be 0.0021 milligrams per cubic meter, which is still significantly below the ERPG-3 limit of 0.1 milligrams per cubic meter (0.003 milligrams per cubic foot). The conservative meteorology 100-meter (328-foot) beryllium concentration is also below the ERPG-2 and ERPG-1 values of 0.025 milligrams per cubic meter and 0.005 milligrams per cubic meter (DOE 2005). Air concentrations below the ERPG-1 level do not cause any long-term or serious health effects. This calculation conservatively assumes that all the beryllium dispersed throughout the Main Plant Process Building would be affected by the Seismic Collapse accident scenario. It should also be noted that the distance of 100 meters (328 feet) is selected for the noninvolved worker and that the nearest public boundary is at a greater distance thereby resulting in an even lower concentration for public exposure to this postulated accident.

Since the beryllium accident release air concentration at 100 meters (328 feet) is below the ERPG-3, ERPG-2, and ERPG-1 levels, accident releases of all other toxic chemicals would be expected to be significantly less than their respective ERPG limits. Therefore, the risk to noninvolved workers and the public due to toxic chemicals released to the atmosphere from accidents is very small and insignificant as compared to the radiological accident risks presented in Section I.5.7.

The aforementioned evaluation is for accident releases of toxic chemicals into the atmosphere and short-term exposure for the public and noninvolved workers. The risks of cancer due to exposure from toxic chemicals have been extensively studied. EPA has developed an Integrated Risk Information System (IRIS) which presents chemical cancer risk data. Studies have shown that long-term exposure to certain chemicals is associated with an increase in the risk of specific organ cancer. For the chemicals listed in Table I–26 that are associated with cancer risk for long-term exposure, IRIS data shows that cadmium has the highest cancer risk level of 1×10^{-6} (a chance of one in one million) for lung cancer. This risk is from a long-term cadmium respirable particle air concentration of 6×10^{-4} micrograms per cubic meter (EPA 2006). Assuming that the entire cadmium inventory in the Main Plant Process Building was released as respirable particles over a 1-year period of time, the air concentration at 100 meters (328 feet) for the noninvolved worker would be less than this cancer risk level. The air concentration of cadmium at the nearest public boundary would be lower than that of the noninvolved worker. Accident short-term atmospheric release of toxic chemicals does not result in an air concentration that would cause a cancer risk to noninvolved workers or the public. Long-term atmospheric release of toxic chemicals at the WVDP results in air concentrations less than the value estimated to result in a cancer risk of 1×10^{-6} (a chance of one in one million) for the noninvolved worker or the nearest public member.

I.5.9 Accident Radiological and Chemical Impacts Conclusion

Radiological analyses of 15 different accidents involving the Main Plant Process Building, radioactive waste tanks, NDA, SDA, and radioactive waste packages for all four alternatives were performed using the MACCS computer code. Radiation doses were calculated for the MEI and the 80-kilometer (50-mile-) radius population. Doses were converted to LCFs and annual risk based on 0.0006 LCFs per rem and the annual frequency for each accident scenario. The largest accident consequence and risk for each alternative is summarized in **Table I–29** and compared to expected normal background radiation doses for expected cancer mortality.

The largest radiological accident risk is calculated for the Sitewide Removal Alternative, while the smallest calculated accident risk exists for the No Action Alternative. For all alternatives, the relative radiological accident risk is very small as compared to such risks as the normal lifetime fatal cancer risk of about one in five.

An evaluation of the nature and quantity of toxic chemicals was performed to determine if a postulated accident could result in the release of these chemicals resulting in a hazard to workers or the public. Although the annual frequency of a postulated accident involving the release of toxic chemicals is equivalent to the radiological release accidents, the relatively low quantity and physical characteristics of the toxic chemicals preclude any significant health hazards in the event of an accidental release of toxic liquids or gases.

Table I–29 Largest Accident [a] Radiological Consequence and Risk

Parameter	*Sitewide Removal Alternative*	*Sitewide Close-In-Place Alternative*	*Phased Decisionmaking Alternative (Phase 1)*	*No Action Alternative*
MEI dose (rem)	0.68	0.053	0.053	0.046
MEI LCF if the accident occurs	4.1×10^{-4}	3.2×10^{-5}	3.2×10^{-5}	2.7×10^{-5}
MEI annual risk	3.3×10^{-5} or 1 chance in 30,000	1.4×10^{-7} or 1 chance in 7.2 million	1.7×10^{-6} or 1 chance in 575,000	2.7×10^{-9} or 1 chance in 370 million
Population dose (person-rem)	3.4	3.4	3.4	0.68
Population LCF if the accident occurs	0.002	0.002	0.002	0.0004
Population annual risk	9.1×10^{-5} or 1 chance in 11,000	1.3×10^{-6} or 1 chance in 770,000	1.6×10^{-5} or 1 chance in 62,500	4.1×10^{-8} or 1 chance in 24 million
Population normal background radiation dose [b] (person-rem)	612,000	612,000	612,000	612,000
Population normal background radiation annual LCFs	368	368	368	368

LCF = latent cancer fatality, MEI = maximally exposed individual.

[a] Different accident scenarios are represented by the value in the table for each alternative.

[b] Based on an average of 0.36 rem per person annually and a population of 1.7 million.

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