APPENDIX J
ENVIRONMENTAL JUSTICE

This appendix provides an assessment of the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations resulting from implementation of the alternatives described in Chapter 2 of this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

J.1 INTRODUCTION

Environmental justice is defined as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group[s,] should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies" (EPA 1998).

The purpose of this appendix is to identify the various populations that could be affected by U.S. Department of Energy (DOE)–proposed actions at the Hanford Site (Hanford) and Idaho National Laboratory (INL), and to present a comparison of the impacts on subpopulations with potential for environmental justice concerns to the impacts on the remainder of the population to identify any disproportionately high and adverse impacts under the alternatives evaluated in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*.

Executive Order 12898, *Federal Actions to Address Environmental ustice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address, as appropriate, disproportionately high and adverse human health and environmental effects of their programs, policies, and activities on minority populations and low-income populations.

The Council on Environmental Quality (CEQ) has oversight responsibility for documentation prepared in compliance with the National Environmental Policy Act (NEPA). In December 1997, the CEQ released its guidance for analyzing environmental justice issues under NEPA (CEQ 1997). The CEQ guidance was adopted as the basis for analysis of environmental justice in this environmental impact statement (EIS).

J.2 DEFINITIONS

J.2.1 Minority Individuals and Populations

The following definitions of minority individuals and populations were used in this analysis of environmental justice:

Minority individuals. Individuals who are members of the following population groups: Hispanic or Latino, American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, or two or more races. This definition is similar to that given in the CEQ environmental justice guidance (CEQ 1997), except that it has been modified to reflect "Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity" (62 FR 58782) and recent guidance published by the Office of Management and Budget. These revisions were adopted and used by the U.S. Census Bureau in collecting data for the 2000 census (OMB 2000). When data from the 1990 census are used, a minority individual is defined as someone self-identified as: Hispanic; American Indian, Eskimo, or Aleut; Asian or Pacific Islander; or Black. As discussed below, racial and ethnic data from the 1990 census cannot be directly compared with that from the 2000 census.

The Office of Management and Budget also recommends counting a person self-identified as multiracial as a minority individual if at least one of the races is a minority race (OMB 2000). During the 2000 census, approximately 2 percent of the population identified themselves as members of more than one race (Grieco and Cassidy 2001). Approximately two-thirds of those designated themselves as members of at least one minority race.

> **Minority populations.** Minority populations should be identified where either (1) the minority population of the affected area exceeds 50 percent or (2) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider a community as either a group of individuals living in geographic proximity to one another or a geographically dispersed and transient set of individuals (such as migrant workers or American Indians/Alaska Natives), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction or a neighborhood, census tract, or other similar unit that is chosen to avoid artificially diluting or inflating the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds.

Data for the analysis of minority populations in 2000 were extracted from the Census Bureau's Summary File 1 (Census 2007a). The CEQ guidance recommends that impacts on the minority population be examined, as well as those specific to American Indian tribes (CEQ 1997). Due to the large number of minority Hispanics, impacts on that specific population were also examined.

In the discussions of environmental justice in this *TC & WM EIS*, people self-designated as Hispanic or Latino are included in the total Hispanic population, regardless of race. For example, the Asian population is composed of people self-designated as Asian regardless of whether they indicated Hispanic or Latino origin. Asians who designated themselves as having Hispanic or Latino origins are also included in the total Hispanic population.

J.2.2 Low-Income Populations and Individuals

Executive Order 12898 specifically addresses disproportionately high and adverse effects on low-income populations. The CEQ recommends that poverty thresholds be used to identify low-income individuals (CEQ 1997).

The following definition of low-income population was used in this analysis:

> "Low-income population: Low-income populations in an affected area should be identified with the annual statistical poverty thresholds from the Bureau of Census' Current Population Reports, Series P-60 on Income and Poverty. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another or a set of individuals (such as migrant workers or American Indians), where either type of group experiences common conditions of environmental exposure or effect (CEQ 1997)."

Thresholds used in the analysis in this EIS are from the Census Bureau's Current Population Reports, Series P60-210 on Consumer Income, Poverty in the United States: 1999 (Dalaker and Proctor 2000).

Data for the analysis of low-income populations were extracted from the Census Bureau's Summary File 3 (Census 2007b).

J.2.3 Disproportionately High and Adverse Human Health Effects

Adverse health effects are measured in risks and rates that could result in latent cancer fatalities (LCFs), as well as other fatal or nonfatal adverse impacts on human health. Adverse health effects may include bodily impairment, infirmity, illness, or death. Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant (as defined by NEPA) and appreciably exceeds the risk or exposure rate for the general population or another appropriate comparison group (CEQ 1997).

J.2.4 Disproportionately High and Adverse Environmental Effects

A disproportionately high environmental impact refers to an impact or the risk of an impact on the natural or physical environment in a low-income or minority community that is significant (as defined by NEPA) or appreciably exceeds the environmental impact on the larger community. Such effects may include ecological, cultural, human health, economic, or social impacts. An adverse environmental impact is an impact that is determined to be both harmful and significant (as defined by NEPA). In assessing cultural and aesthetic environmental impacts, impacts that uniquely affect geographically dislocated or dispersed minority or low-income populations, including American Indian tribes, are also considered (CEQ 1997).

J.3 SPATIAL RESOLUTION

For the purposes of enumeration and analysis, the Census Bureau has defined a variety of areal units. Areal units of concern in this document include (in order of increasing spatial resolution) states, counties, census tracts, block groups, and blocks. The block is the smallest geographic entity for which the Census Bureau collects and tabulates data and, therefore, offers the finest spatial resolution. This term refers to a relatively small geographical area bounded on all sides by visible features such as streets or streams or by invisible boundaries such as city limits and property lines. During the 2000 census, the Census Bureau subdivided the United States and its territories into 8,205,582 blocks (Census 2007c). For comparison, the number of counties, census tracts, and block groups used in the 2000 census were 3,141; 65,443; and 208,790; respectively. While blocks offer the finest spatial resolution, economic data required for the identification of low-income populations are not available at the block level of spatial resolution. In the analysis below, block-group-level resolution was used to identify minority and low-income populations.

During preparation of this *TC & WM EIS*, consequences and risks from normal operations and accidents were evaluated for the following potential release locations at Hanford: the Supplemental Treatment Technology Site in the 200-East Area and the 200-West Area (STTS-East and STTS-West), the Waste Treatment Plant (WTP) facilities, in the 200-East Area, and the Fast Flux Test Facility (FFTF) in the 400 Area. The location of the WTP is approximately 600 meters (1,979 feet) northeast of STTS-East. A potential release location at INL, the Materials and Fuels Complex (MFC), was also evaluated. In the analysis of health impacts of normal operations and accidents, all persons living within 80 kilometers (50 miles) of these facilities were assumed to be potentially affected. The same 80-kilometer (50-mile) regions of influence were used in this analysis of environmental justice to identify potentially affected minority and low-income populations.

In general, the boundary of a circle with an 80-kilometer (50-mile) radius centered on the facility site would not coincide with boundaries used by the Census Bureau for enumeration of the population in the potentially affected area. Some blocks or block groups lie completely inside or outside of the radius used for health effects calculation, while others are only partially included. As a result of these partial inclusions, uncertainties were introduced into the estimate of the potentially affected population.

To estimate the populations in the partially included block groups, it was assumed that populations are uniformly distributed throughout the area of each block group. For example, if 30 percent of the area of a block group lies within 80 kilometers (50 miles) of the facility site, it was assumed that 30 percent of the population residing in that block group would be potentially affected.

J.4 MAP DEVELOPMENT

The geographic information system (GIS) statistics maps and diagrams provided in Chapter 3 of this *TC & WM EIS* and Section J.5 were developed using ArcMap 9.0. ArcMap 9.0 allows standard base maps to be projected in a variety of projection systems. In this document, maps and diagrams were developed using the North American Standard 1983 projection. Standard GIS geospatially attributed data sets, known as shapefiles, were downloaded from two public access websites: the Census Bureau, http://www.census.gov,[1] and the Environmental Systems Research Institute, http://www.esri.com/data/download/census2000_tigerline/index.html.[2]

The downloaded shapefiles were re-projected to the North American Standard 1983 projection to prevent potential data misalignment. Additional shapefiles either were developed as necessary using ArcMap 9.0 and actual geographic coordinates (e.g., the facility sites) or were provided by Hanford personnel to show specific site landmarks (e.g., the fence lines of limited-access areas).

Each shapefile stores nontopological geometry and tabular attribute information for spatial features (point, line, or polygon) in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates; the attributes, as tabular files in dBASE® format. Each feature in the shapefile represents a single geographic feature and its attributes; that is, each shape record has a one-to-one relationship with an attribute record. Maps and diagrams were developed by importing all shapefiles into the Hanford GIS project. The development of each map involved different combinations of the shapefiles to visually display data on a standard base map of Oregon and Washington.

J.5 ENVIRONMENTAL JUSTICE ANALYSIS

This analysis of environmental justice is based on assessment of the impacts reported in Chapter 4. This analysis was performed to identify any disproportionately high and adverse human health or environmental impacts on minority or low-income populations surrounding the facility sites. Demographic information obtained from the Census Bureau was used to identify the minority populations and low-income communities surrounding the sites (Census 2007a, 2007b). Minority populations and low-income communities were identified where the percentage of minority and low-income population in the impacted areas significantly exceeded the general population percentage in other reasonable geographic areas of comparison, defined here as the potentially affected counties and states in which the impacted areas are located. The U.S. Nuclear Regulatory Commission considers such percentages "significant" when the total minority or low-income population percentage exceeds the general population by 20 points, or when either the minority or low-income population percentage exceeds 50 percent (69 FR 52040). Table J–1 displays the thresholds used to determine minority and low-income populations.

Table J–1. Thresholds for Identifying Minority Populations and Low-Income Communities

Site	Minority (percent)	Low-Income (percent)
Hanford Site	50.0	36.2
Idaho National Laboratory	32.7	33.6

[1] Block Data, Block Group Data, Key Geographical Locations, Landmark Locations, Hydrography, Railroads, County Roads, Federal Lands.

[2] Data for Washington and Oregon.

Chapter 3, Sections 3.2.11 and 3.3.11 discuss the affected environment to be included in the environmental justice analysis. Potentially affected minority and low-income populations are shown graphically within each facility site's 80-kilometer (50-mile) region of influence (see Section J.3). Tables show the potentially affected populations by county, as well as the percentage of the minority or low-income population considered to be potentially affected. In addition, figures are presented that identify minority and low-income populations by block group, and graphs showing cumulative populations by distance are used to visually locate concentrations of minority and low-income populations.

J.5.1 Minority and Low-Income Populations Surrounding the 200-West Area Supplemental Treatment Technology Site

Figure J–1 shows minority and nonminority populations living in block groups surrounding STTS-West. There are 372 block groups within the 80-kilometer (50-mile) potentially affected radius. Out of these block groups, 130 were determined to contain minority populations. The potentially affected counties include eight counties in the state of Washington (Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Walla Walla, and Yakima) and two counties in Oregon (Morrow and Umatilla). As indicated in Table J–2, approximately one-half of the potentially affected minority population resides in Yakima County, and over 90 percent of the potentially affected minority population lives in four Washington counties: Benton, Franklin, Grant, and Yakima.

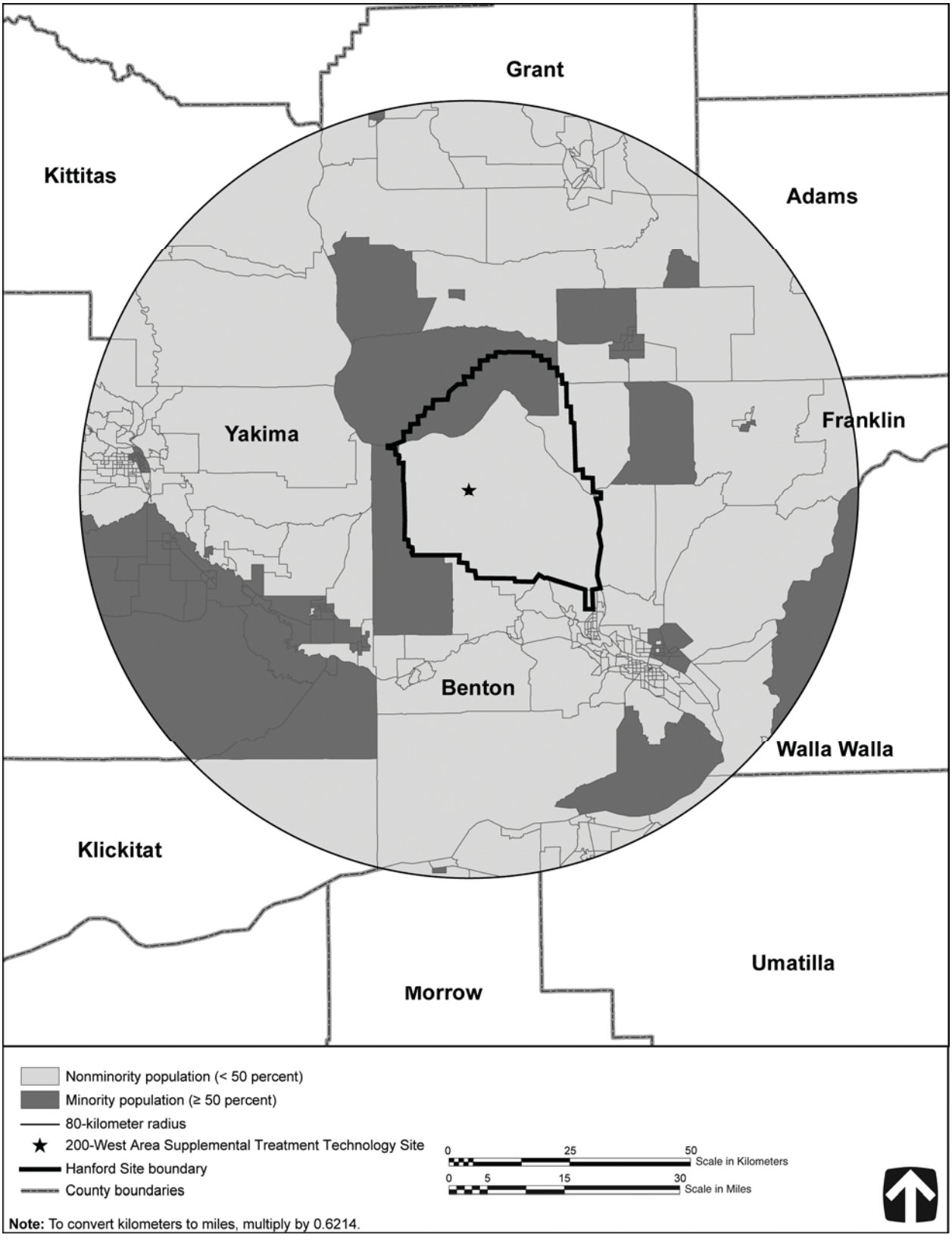


Figure J–1. Minority and Nonminority Populations Living in Potentially Affected Block Groups Surrounding the 200-West Area Supplemental Treatment Technology Site (2000)

Table J–2. Minority Populations Living in Potentially Affected Counties Surrounding the 200-West Area Supplemental Treatment Technology Site (2000)

County (State)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Population Total
Adams (Washington)	16,428	8,062	12,296	7,750	4.3
Benton (Washington)[b]	142,475	26,018	142,464	26,027	14.4
Franklin (Washington)	49,347	25,877	49,039	25,845	14.3
Grant (Washington)	74,698	25,815	55,421	22,775	12.6
Kittitas (Washington)	33,362	3,537	3,643	365	0.2
Klickitat (Washington)	19,161	2,832	264	78	0.0
Walla Walla (Washington)	55,180	11,678	4,213	769	0.4
Yakima (Washington)	222,581	96,848	203,306	91,164	50.4
Morrow (Oregon)	10,995	3,084	6,224	2,323	1.3
Umatilla (Oregon)	70,548	15,878	12,027	3,698	2.0
Total	**694,775**	**219,629**	**488,897**	**180,794**	**100.0**

[a] Census 2007d.

[b] Potentially affected populations may not equal total populations due to rounding.

Figures J–2 and J–3 show cumulative minority populations as a function of distance from STTS-West. Values along the vertical axis of these figures show minority populations living within a given distance from STTS-West. Moving outward from the facilities, the cumulative minority populations increase sharply near the outskirts of the population centers of Richland, Kennewick/Pasco, and Yakima. Approximately 18 percent of the potentially affected minority population lives within about 40 kilometers (25 miles) of the facility, and 55 percent resides within about 56 kilometers (35 miles). The potentially affected total minority population surrounding STTS-West is approximately 181,000 persons, accounting for approximately 37 percent of the total potentially affected population of approximately 489,000. Approximately 84 percent of the minority population surrounding STTS-West is Hispanic or Latino.

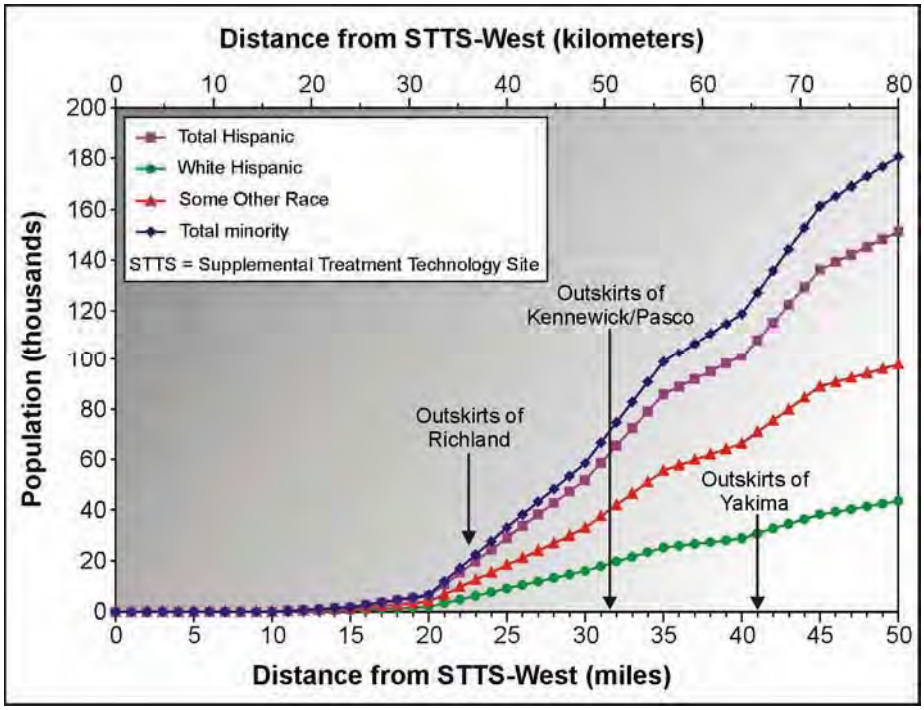


Figure J–2. Cumulative Larger-Scale Minority Populations as a Function of Distance from the 200-West Area Supplemental Treatment Technology Site

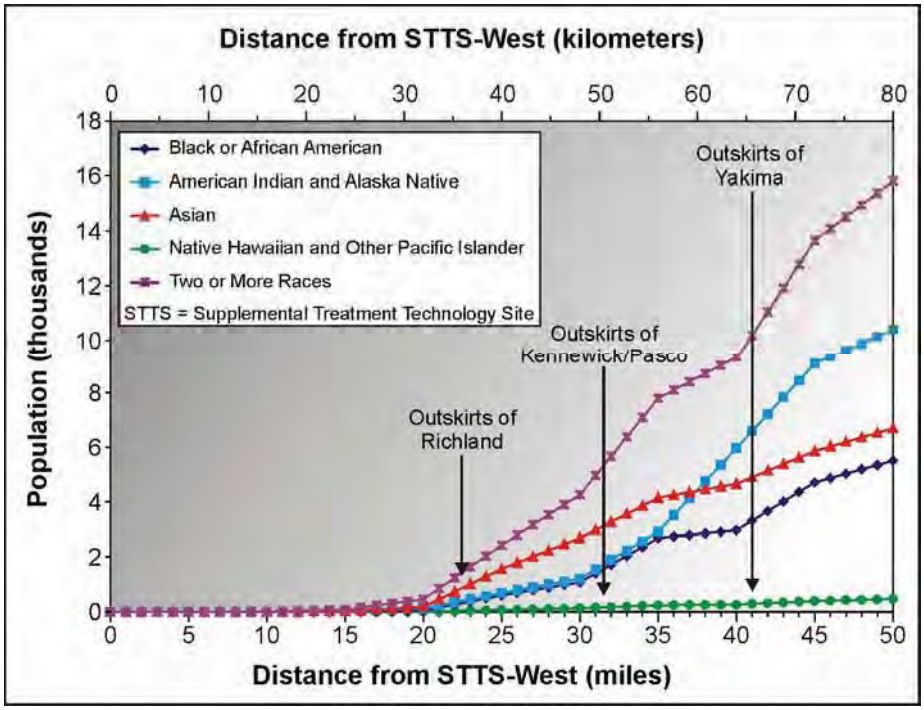


Figure J–3. Cumulative Smaller-Scale Minority Populations as a Function of Distance from the 200-West Area Supplemental Treatment Technology Site

Figure J–4 shows block groups surrounding STTS-West and low-income and non-low-income populations living in the potentially affected area. Of the 372 block groups surrounding STTS-West, an estimated 27 block groups contain low-income populations. As indicated in Table J–3, approximately one-half of the potentially affected low-income population lives in Yakima County, and over 90 percent of the potentially affected low-income population lives in the counties of Benton, Franklin, Grant, and Yakima. Low-income persons compose approximately 17 percent of the total population living in the potentially affected area.

Table J–3. Low-Income Populations Living in Potentially Affected Counties Surrounding the 200-West Area Supplemental Treatment Technology Site (2000)

County (State)	Total County Population[a]	Total Low-Income Population[a]	Potentially Affected Total Population	Potentially Affected Low-Income Population	Percentage of the Potentially Affected Low-Income Population Total
Adams (Washington)	16,217	2,951	12,222	2,403	3.0
Benton (Washington)	141,232	14,517	141,219	14,515	18.2
Franklin (Washington)	48,307	9,280	48,006	9,230	11.5
Grant (Washington)	73,591	12,809	54,826	9,888	12.4
Kittitas (Washington)	31,177	6,122	3,657	365	0.5
Klickitat (Washington)	18,983	3,236	251	55	0.1
Walla Walla (Washington)	50,245	7,567	4,208	334	0.4
Yakima (Washington)	218,966	43,070	199,747	40,444	50.6
Morrow (Oregon)	10,919	1,617	6,190	1,198	1.5
Umatilla (Oregon)	67,329	8,524	11,024	1,532	1.9
Total	**676,966**	**109,693**	**481,350**	**79,964**	**100.0**

[a] Census 2007e.

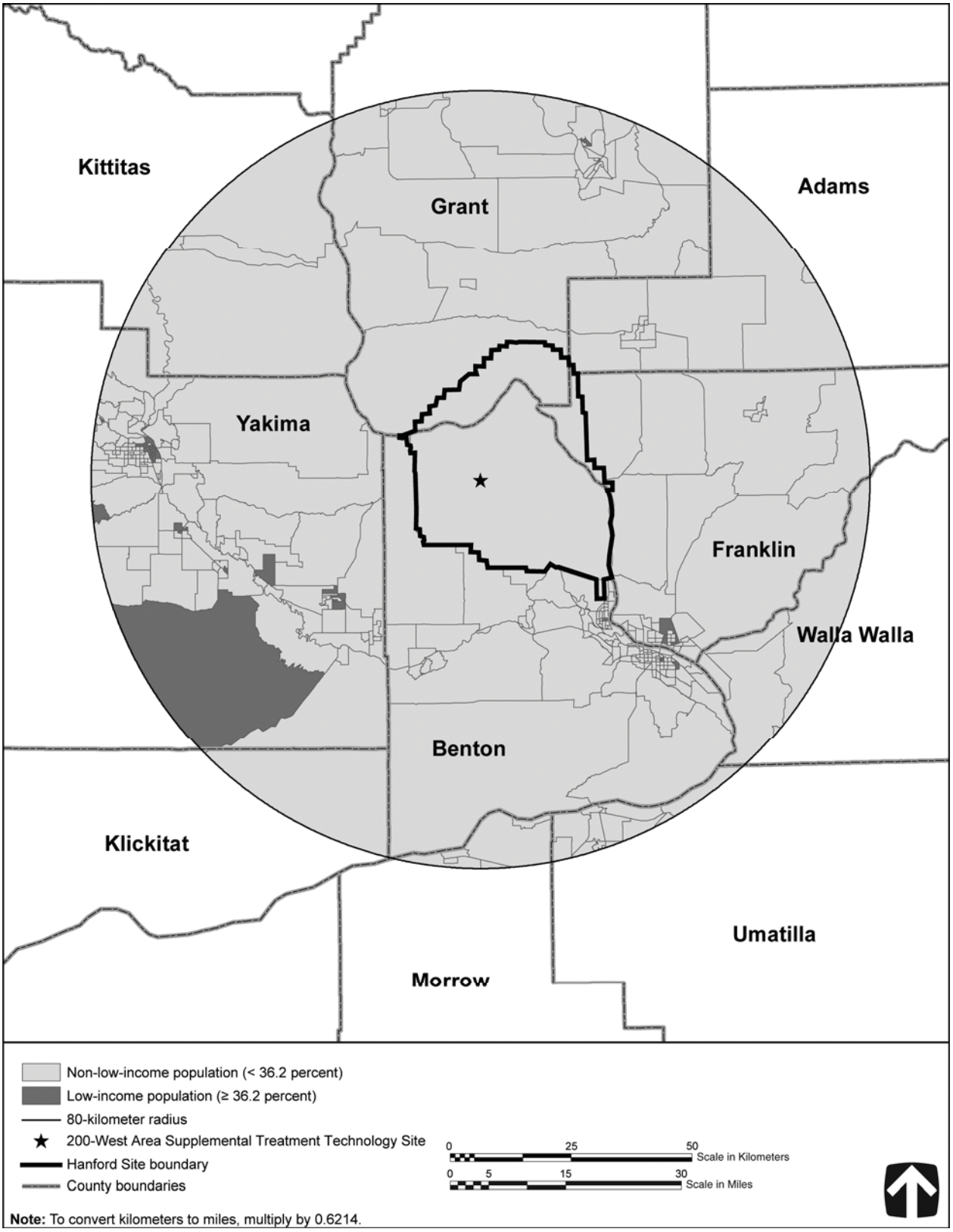


Figure J–4. Low-Income and Non-Low-Income Populations Living in Potentially Affected Block Groups Surrounding the 200-West Area Supplemental Treatment Technology Site (2000)

Figure J–5 shows cumulative low-income populations as a function of distance from STTS-West. Low-income populations surrounding STTS-West are concentrated in the Tri-Cities area and Yakima County.

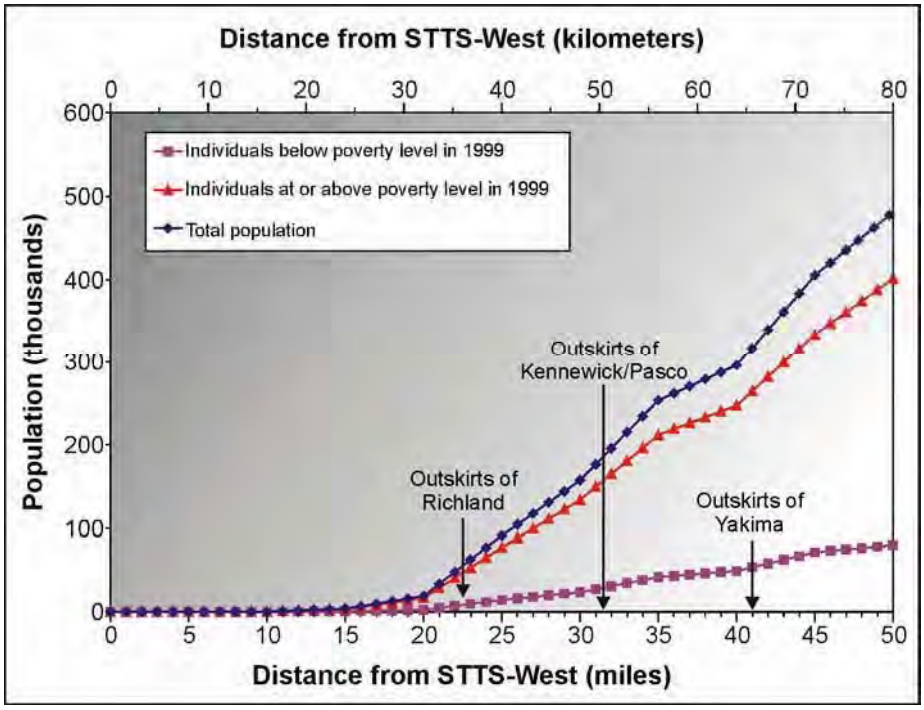


Figure J–5. Cumulative Low-Income Populations as a Function of Distance from the 200-West Area Supplemental Treatment Technology Site

J.5.2 Minority and Low-Income Populations Surrounding the Waste Treatment Plant

Figure J–6 shows minority and nonminority populations living in block groups surrounding the WTP. Of the 360 block groups that surround the WTP, an estimated 84 contain minority populations. Potentially affected counties include eight counties in Washington (Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Walla Walla, and Yakima) and two counties in Oregon (Morrow and Umatilla).

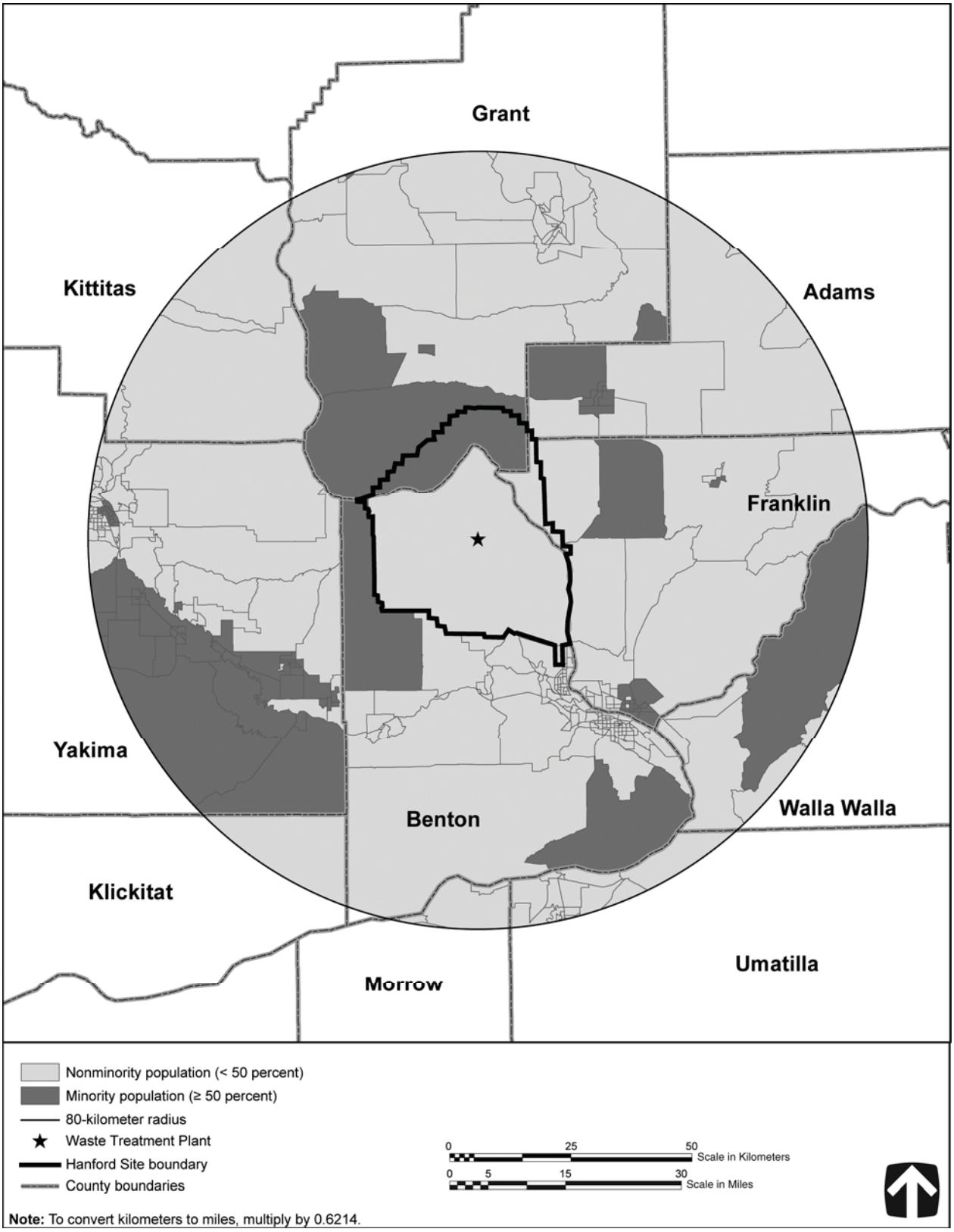


Figure J–6. Minority and Nonminority Populations Living in Potentially Affected Block Groups Surrounding the Waste Treatment Plant (2000)

As indicated in Table J–4, approximately one-half of the potentially affected minority population resides in Yakima County, and over 90 percent of the potentially affected minority population lives in four Washington counties: Benton, Franklin, Grant, and Yakima.

Table J–4. Minority Populations Living in Potentially Affected Counties Surrounding the Waste Treatment Plant (2000)

County (State)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Population Total
Adams (Washington)	16,428	8,062	12,574	7,791	4.5
Benton (Washington)	142,475	26,018	142,456	26,000	15.0
Franklin (Washington)	49,347	25,877	49,139	25,855	14.9
Grant (Washington)	74,698	25,815	53,849	21,314	12.3
Kittitas (Washington)	33,362	3,537	2,546	262	0.2
Klickitat (Washington)	19,161	2,832	162	48	0.0
Walla Walla (Washington)	55,180	11,678	5,068	1,087	0.6
Yakima (Washington)	222,581	96,848	159,157	83,793	48.4
Morrow (Oregon)	10,995	3,084	4,588	1,370	0.8
Umatilla (Oregon)	70,548	15,878	17,815	5,527	3.2
Total	**694,775**	**219,629**	**447,354**	**173,047**	**100.0**

[a] Census 2007d.

Figures J–7 and J–8 show cumulative minority populations as a function of distance from the WTP. Values along the vertical axis of this figure show minority populations living within a given distance from the WTP. Moving outward from the facilities, the cumulative minority populations increase sharply near the outskirts of the population centers of Richland, Kennewick/Pasco, and Yakima. Approximately 20 percent of the potentially affected minority population lives within about 39 kilometers (24 miles) of the facility, and 50 percent resides within about 53 kilometers (33 miles). The potentially affected total minority population surrounding the WTP is approximately 173,000 persons, accounting for approximately 39 percent of the total potentially affected population of approximately 447,000. Approximately 84 percent of the minority population surrounding the WTP is Hispanic or Latino.

Figure J–9 shows block groups surrounding the WTP as well as low-income and non-low-income populations living in the potentially affected area. Of the 360 block groups that surround WTP, an estimated 30 contain low-income populations.

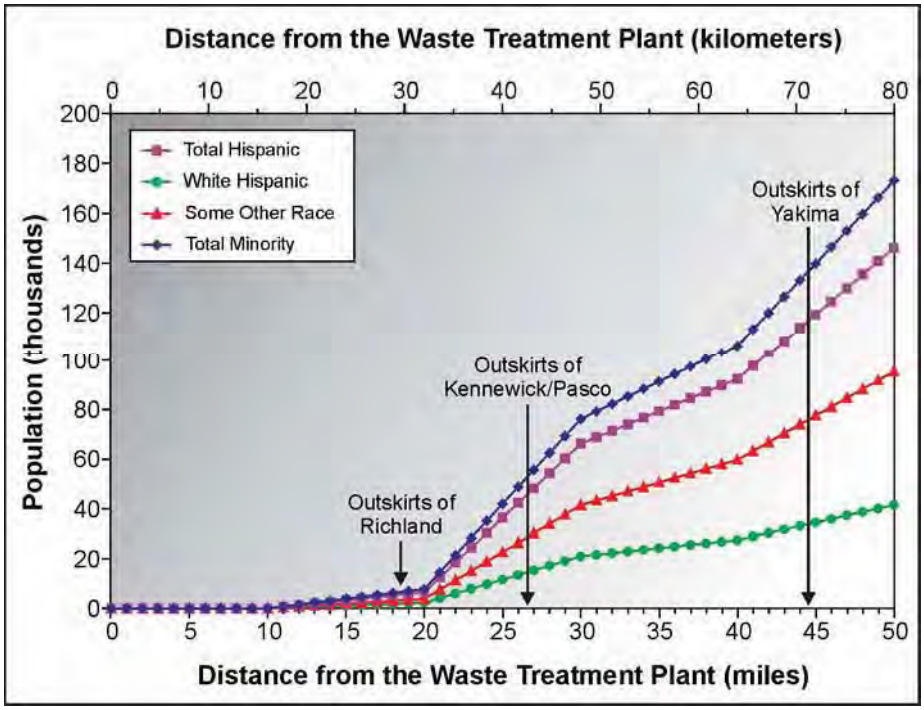


Figure J–7. Cumulative Larger-Scale Minority Populations as a Function of Distance from the Waste Treatment Plant

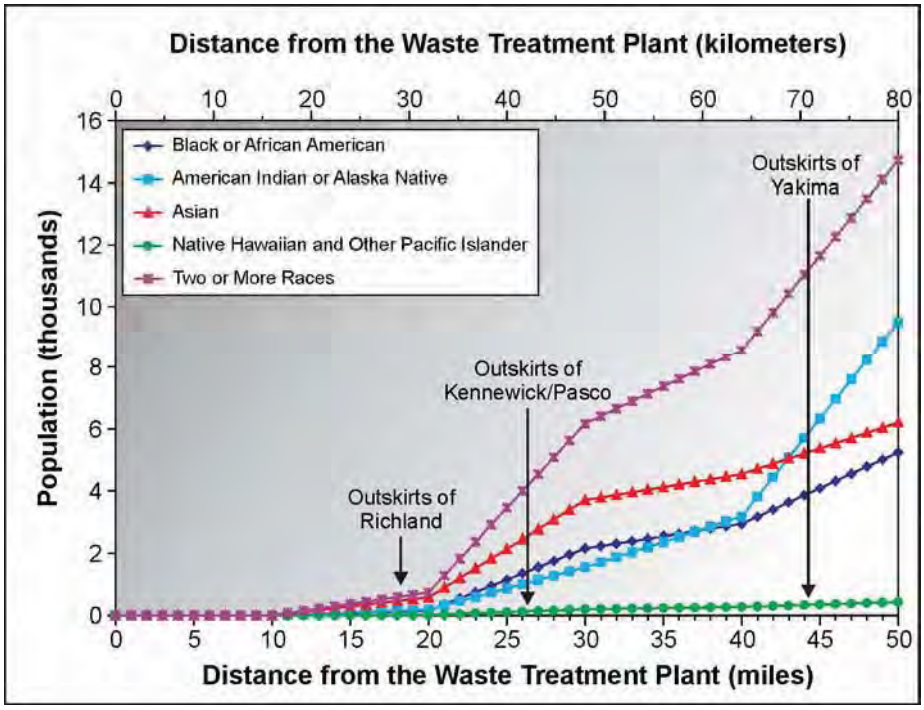


Figure J–8. Cumulative Smaller-Scale Minority Populations as a Function of Distance from the Waste Treatment Plant

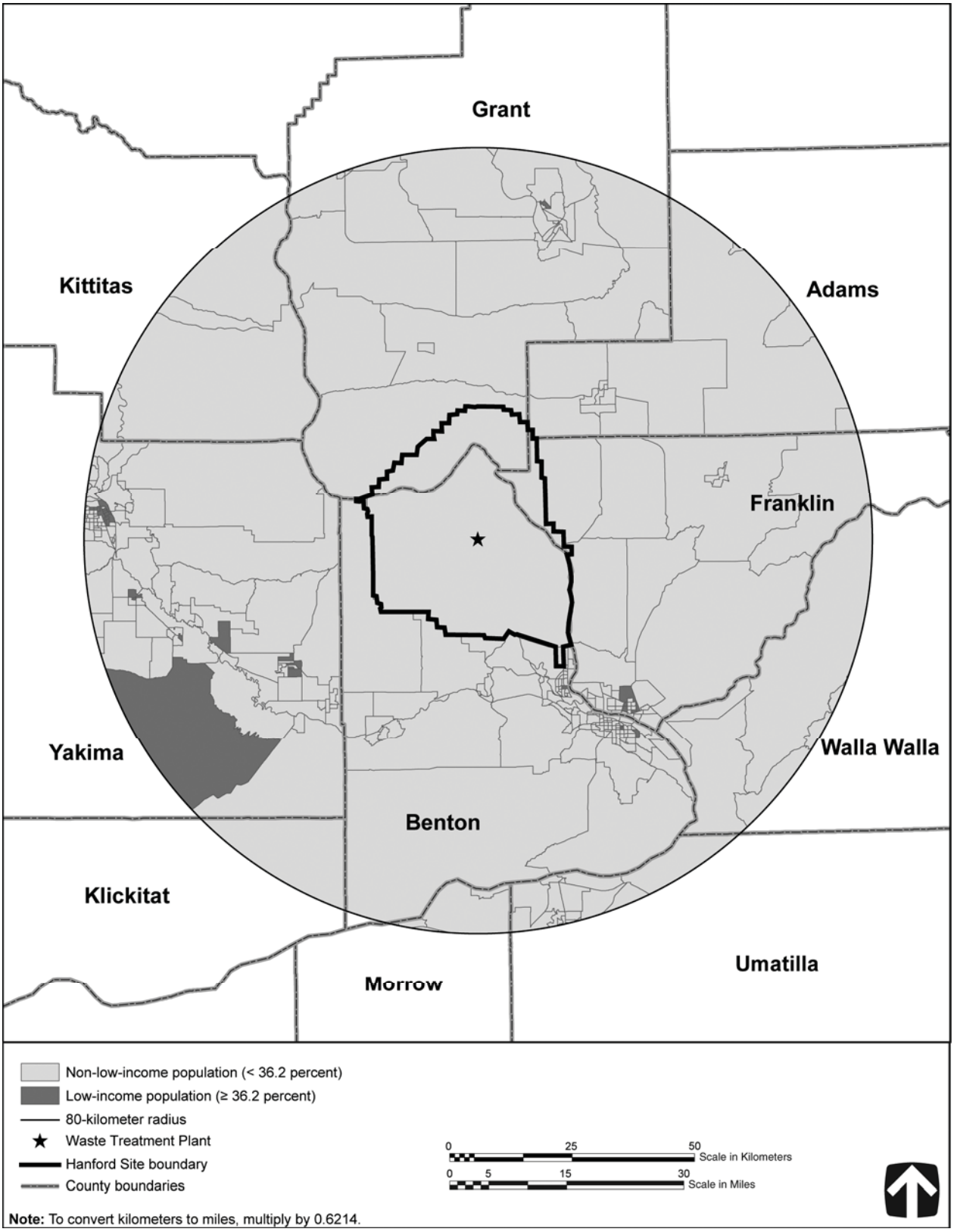


Figure J–9. Low-Income and Non-Low-Income Populations Living in Potentially Affected Block Groups Surrounding the Waste Treatment Plant (2000)

As indicated in Table J–5, approximately one-half of the potentially affected low-income population lives in Yakima County, and over 90 percent of the potentially affected low-income population lives in the counties of Benton, Franklin, Grant, and Yakima. Low-income persons compose approximately 17 percent of the total population living in the potentially affected area.

Table J–5. Low-Income Populations Living in Potentially Affected Counties Surrounding the Waste Treatment Plant (2000)

County (State)	Total County Population[a]	Total Low-Income Population[a]	Potentially Affected Total Population	Potentially Affected Low-Income Population	Percentage of the Potentially Affected Low-Income Population Total
Adams (Washington)	16,217	2,951	12,506	2,433	3.2
Benton (Washington)	141,232	14,517	141,217	14,513	18.8
Franklin (Washington)	48,307	9,280	48,104	9,245	12.0
Grant (Washington)	73,591	12,809	53,292	9,496	12.3
Kittitas (Washington)	31,177	6,122	2,559	251	0.3
Klickitat (Washington)	18,983	3,236	154	34	0.0
Walla Walla (Washington)	50,245	7,567	5,052	475	0.6
Yakima (Washington)	218,966	43,070	156,394	37,462	48.6
Morrow (Oregon)	10,919	1,617	4,559	832	1.1
Umatilla (Oregon)	67,329	8,524	16,746	2,305	3.0
Total	**676,966**	**109,693**	**440,583**	**77,046**	**100.0**

[a] Census 2007e.

Figure J–10 shows cumulative low-income populations as a function of distance from the WTP. Low-income populations surrounding the WTP are concentrated in the Tri-Cities area and Yakima County.

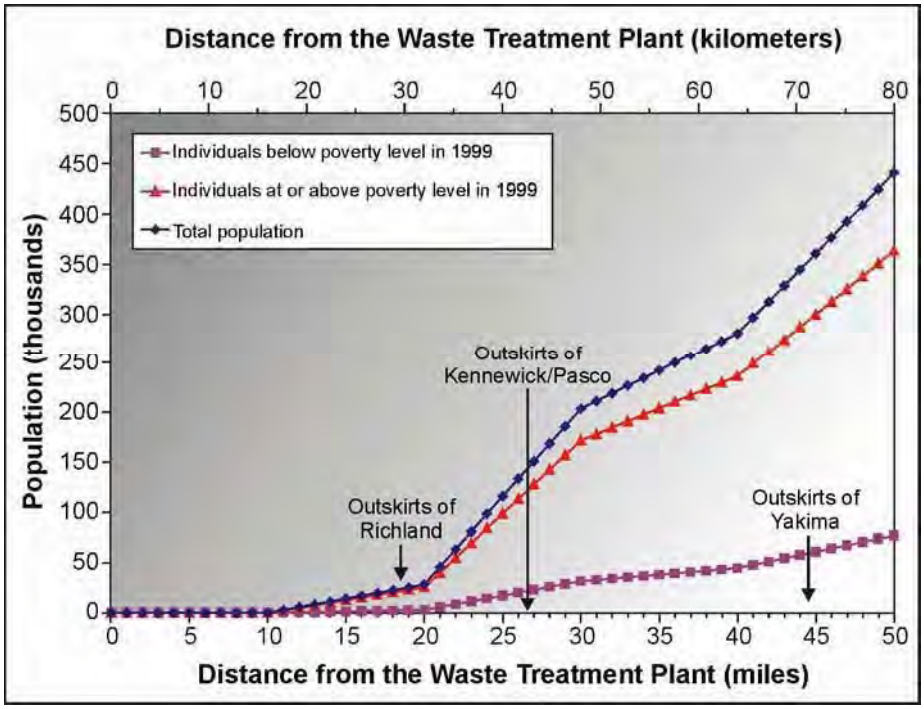


Figure J–10. Cumulative Low-Income Populations as a Function of Distance from the Waste Treatment Plant

J.5.3 Minority and Low-Income Populations Surrounding the 200-East Area Supplemental Treatment Technology Site

Figure J–11 shows minority and nonminority populations living in block groups surrounding STTS-East. Of the 364 block groups that surround STTS-East, an estimated 86 contain minority populations. STTS-East is located within approximately 600 meters (1,969 feet) of the WTP, and the populations surrounding STTS-East are nearly the same as those surrounding the WTP. Counties that would be potentially affected by activities at STTS-East include eight counties in Washington (Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Walla Walla, and Yakima) and two counties in Oregon (Morrow and Umatilla).

As indicated in Table J–6, approximately one-half of the potentially affected minority population resides in Yakima County, and over 90 percent of the potentially affected minority population lives in four Washington counties: Benton, Franklin, Grant, and Yakima. Due to the close proximity of the WTP and STTS-East, data for minority populations surrounding STTS-East are nearly identical to those shown for WTP minority populations in Figures J–7 and J–8, respectively, in Section J.5.2.

Table J–6. Minority Populations Living in Potentially Affected Counties Surrounding the 200-East Area Supplemental Treatment Technology Site (2000)

County (State)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Population Total
Adams (Washington)	16,428	8,062	12,550	7,789	4.5
Benton (Washington)	142,475	26,018	142,442	26,001	15.0
Franklin (Washington)	49,347	25,877	49,137	25,855	14.9
Grant (Washington)	74,698	25,815	52,071	20,293	11.7
Kittitas (Washington)	33,362	3,537	2,510	260	0.1
Klickitat (Washington)	19,161	2,832	173	51	0.0
Walla Walla (Washington)	55,180	11,678	5,090	1,087	0.6
Yakima (Washington)	222,581	96,848	160,443	84,050	48.4
Morrow (Oregon)	10,995	3,084	5,373	1,808	1.0
Umatilla (Oregon)	70,548	15,878	21,777	6,635	3.8
Total	**694,775**	**219,629**	**451,556**	**173,829**	**100.0**

[a] Census 2007d.

Figure J–12 shows block groups surrounding STTS-East and low-income and non-low-income populations living in the potentially affected area. Of the 364 block groups that surround STTS-East, an estimated 32 contain low-income populations.

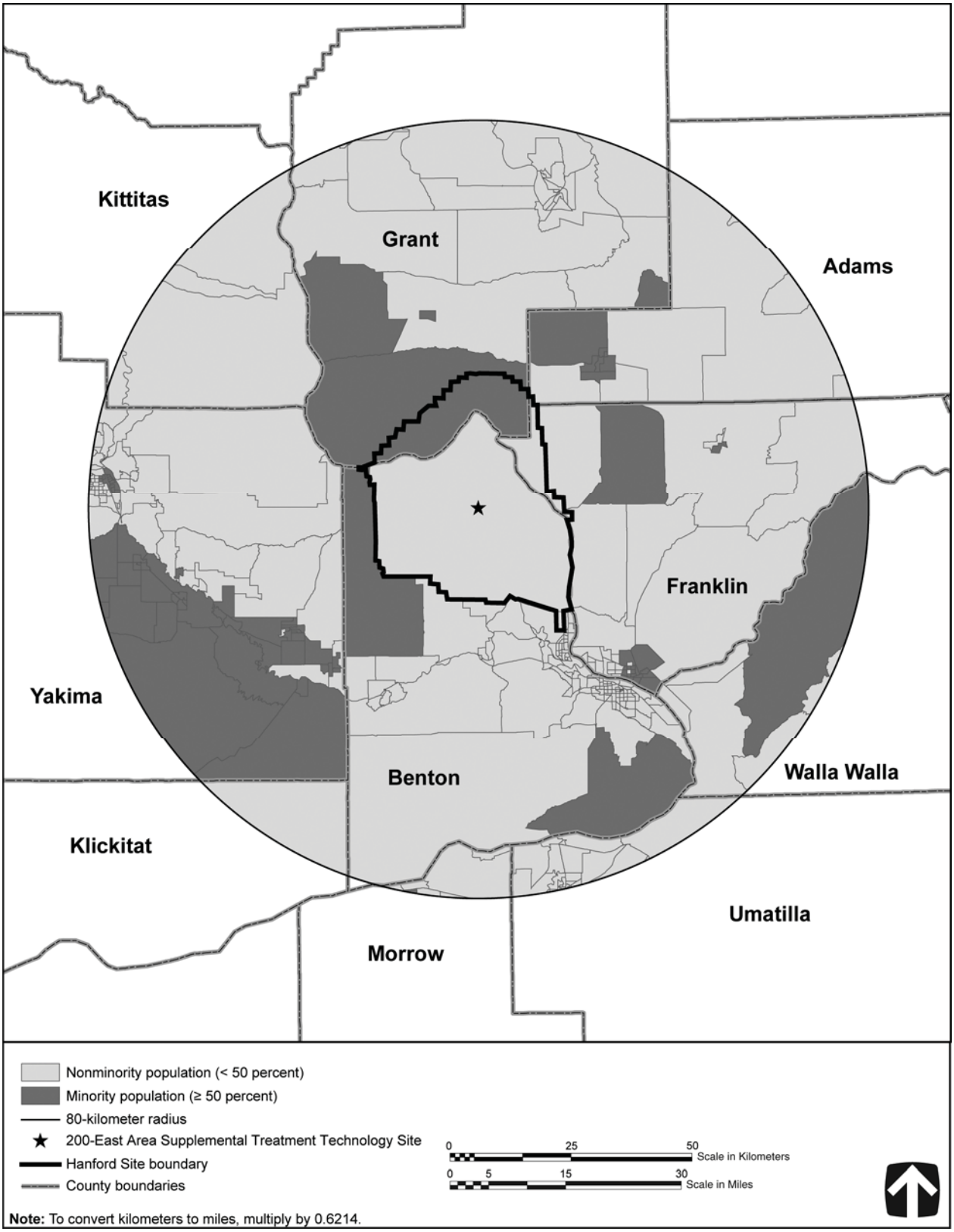


Figure J–11. Minority and Nonminority Populations Living in Potentially Affected Block Groups Surrounding the 200-East Area Supplemental Treatment Technology Site (2000)

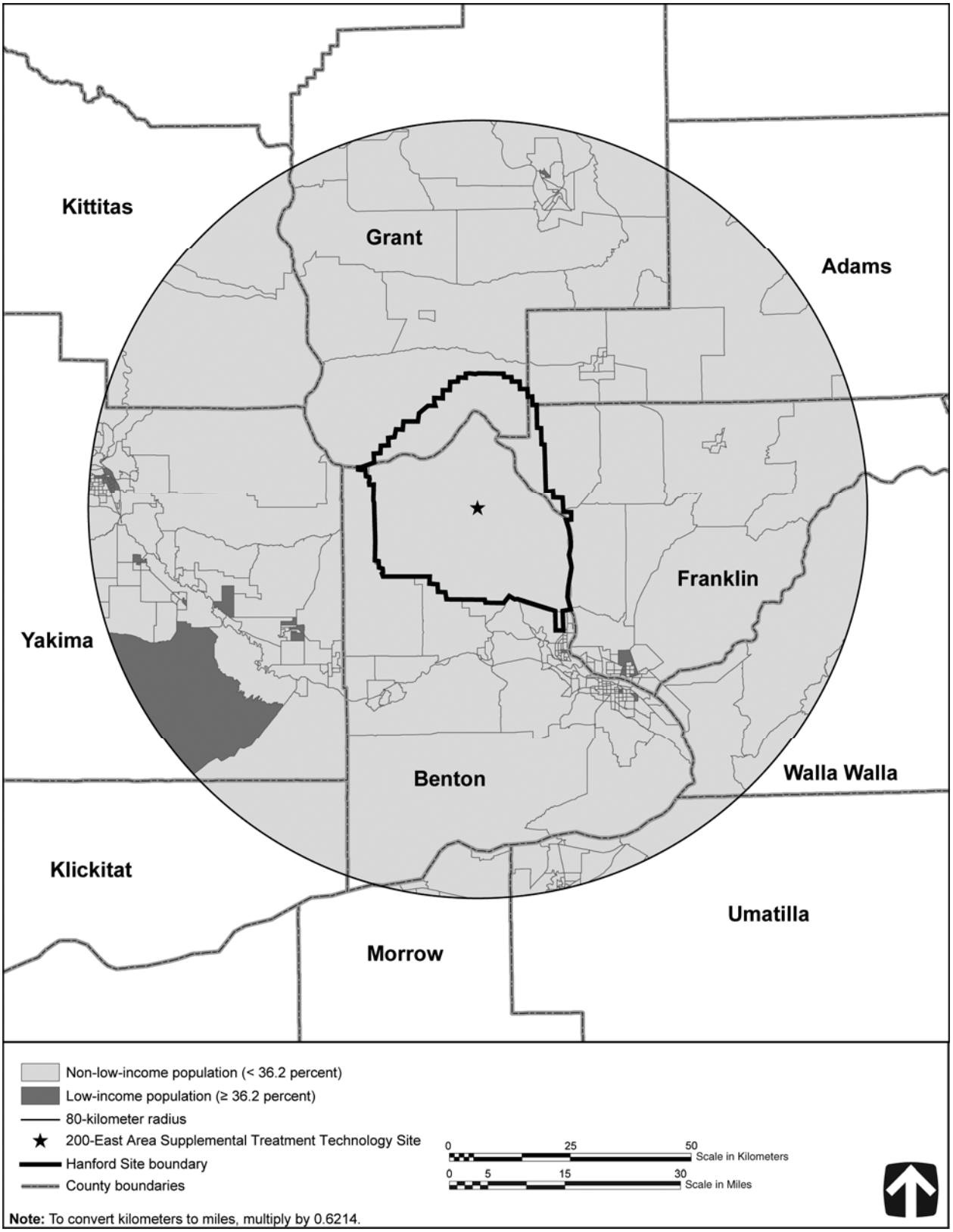


Figure J–12. Low-Income and Non-Low-Income Populations Living in Potentially Affected Block Groups Surrounding the 200-East Area Supplemental Treatment Technology Site (2000)

As indicated in Table J–7, approximately one-half of the potentially affected low-income population lives in Yakima County, and over 90 percent of the potentially affected low-income population lives in the counties of Benton, Franklin, Grant, and Yakima. Low-income persons compose approximately 17 percent of the total population living in the potentially affected area. Due to the close proximity of the WTP and STTS-East, data for the low-income population as a function of distance from STTS-East are nearly identical to those for the low-income population as a function of distance from the WTP in Figure J–10 in Section J.5.2. Low-income populations surrounding STTS-East are concentrated in the Tri-Cities area and Yakima County.

Table J–7. Low-Income Populations Living in Potentially Affected Counties Surrounding the 200-East Area Supplemental Treatment Technology Site (2000)

County (State)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Population Total
Adams (Washington)	16,217	2,951	12,485	2,429	3.1
Benton (Washington)	141,232	14,517	141,203	14,512	18.7
Franklin (Washington)	48,307	9,280	48,097	9,247	11.9
Grant (Washington)	73,591	12,809	51,502	9,141	11.8
Kittitas (Washington)	31,177	6,122	2,528	248	0.3
Klickitat (Washington)	18,983	3,236	164	37	0.0
Walla Walla (Washington)	50,245	7,567	5,078	476	0.6
Yakima (Washington)	218,966	43,070	157,596	37,585	48.5
Morrow (Oregon)	10,919	1,617	5,341	1,003	1.3
Umatilla (Oregon)	67,329	8,524	20,795	2,859	3.7
Total	**676,966**	**109,693**	**444,789**	**77,537**	**100.0**

[a] Census 2007e.

J.5.4 Minority and Low-Income Populations Surrounding the Fast Flux Test Facility

Figure J–13 shows minority and nonminority populations living in block groups surrounding FFTF, which is located in the 400 Area at Hanford. Of the 298 block groups that surround FFTF, an estimated 60 contain minority populations. Potentially affected counties include eight counties in Washington (Adams, Benton, Franklin, Grant, Kittitas, Klickitat, Walla Walla, and Yakima) and two counties in Oregon (Morrow and Umatilla).

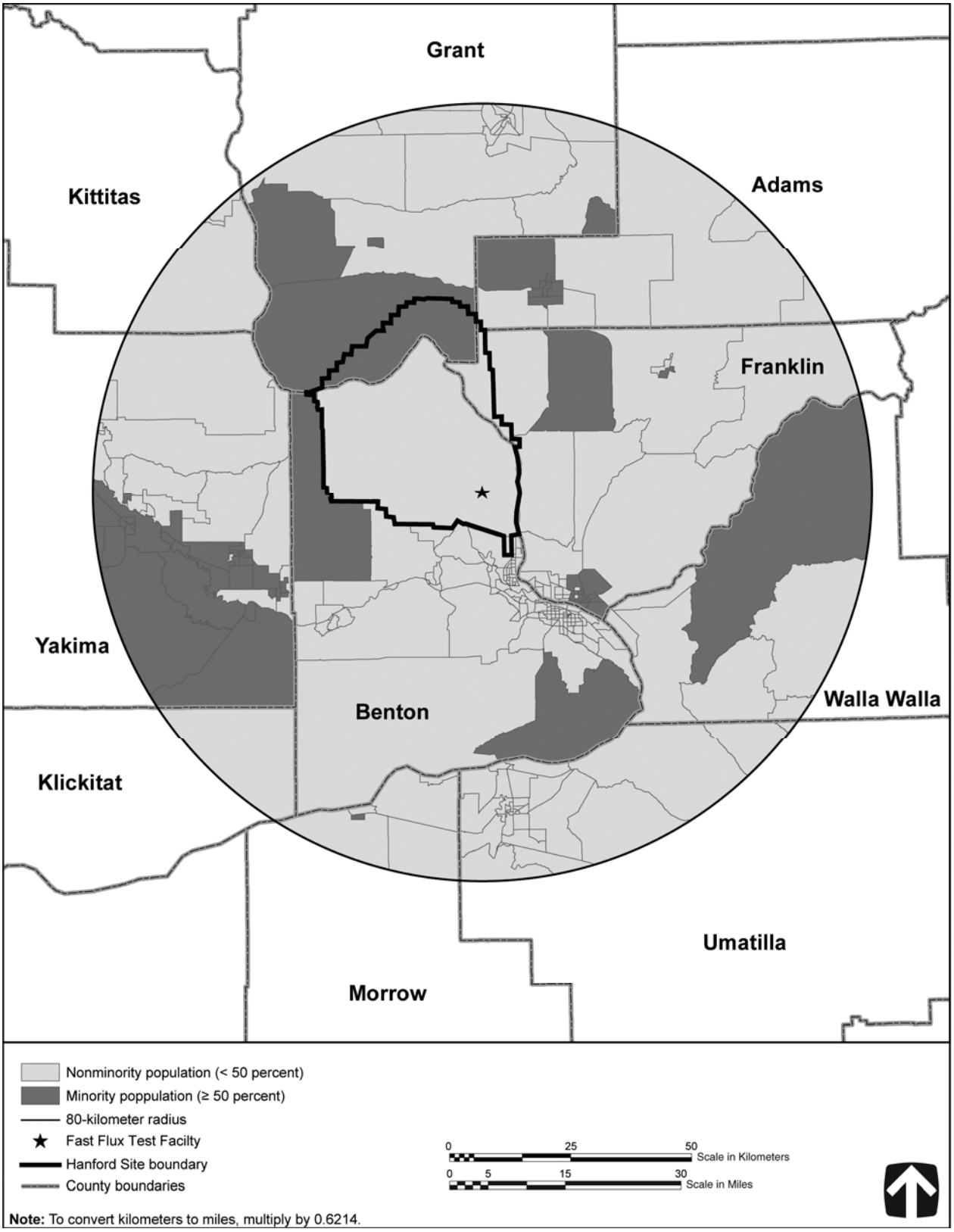


Figure J–13. Minority and Nonminority Populations Living in Potentially Affected Block Groups Surrounding the Fast Flux Test Facility (2000)

As indicated in Table J–8, approximately 33 percent of the potentially affected minority population resides in Yakima County, and over 90 percent of the potentially affected minority population lives in five counties: Benton, Franklin, Grant, and Yakima Counties in Washington and Umatilla County in Oregon.

Table J–8. Minority Populations Living in Potentially Affected Counties Surrounding the Fast Flux Test Facility (2000)

County (State)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Population Total
Adams (Washington)	16,428	8,062	12,579	7,793	5.9
Benton (Washington)	142,475	26,018	142,465	26,016	19.7
Franklin (Washington)	49,347	25,877	49,232	25,864	19.6
Grant (Washington)	74,698	25,815	39,353	16,172	12.3
Kittitas (Washington)	33,362	3,537	787	99	0.1
Klickitat (Washington)	19,161	2,832	215	65	0.0
Walla Walla (Washington)	55,180	11,678	6,984	1,570	1.2
Yakima (Washington)	222,581	96,848	66,206	42,819	32.5
Morrow (Oregon)	10,995	3,084	6,749	2,485	1.9
Umatilla (Oregon)	70,548	15,878	32,821	8,903	6.8
Total	**694,775**	**219,629**	**357,391**	**131,786**	**100.0**

[a] Census 2007d.

The total population of the potentially affected area surrounding FFTF is estimated to be approximately 357,000. The significant reduction in population compared to other areas at Hanford that are analyzed in this EIS can be attributed to Yakima City's location beyond the reach of the 80-kilometer (50-mile) radius of the potentially affected area. Figures J–14 and J–15 show cumulative minority populations as a function of distance from FFTF. Values along the vertical axis of this figure show minority populations living within a given distance from FFTF. Moving outward from the facilities, sharp increases in the cumulative minority populations can still be seen near the outskirts of the population centers of Richland and Kennewick/Pasco, Washington; however they occur roughly 16 kilometers (10 miles) closer than similar increases observed toward the outer rim of the potentially affected area surrounding the 200 Area facilities. An additional population spurt can be observed approximately 64 kilometers (40 miles) from FFTF, most likely attributed to the population center of Hermiston, Oregon. Additional increases in population are attributed to the outlying areas in Yakima County, Washington. Approximately 30 percent of the potentially affected minority population lives within about 32 kilometers (20 miles) of the facility, and 50 percent resides within about 47 kilometers (29 miles). The potentially affected total minority population surrounding FFTF is approximately 132,000 persons, accounting for approximately 37 percent of the total population. Approximately 86 percent of the minority population surrounding FFTF is Hispanic or Latino.

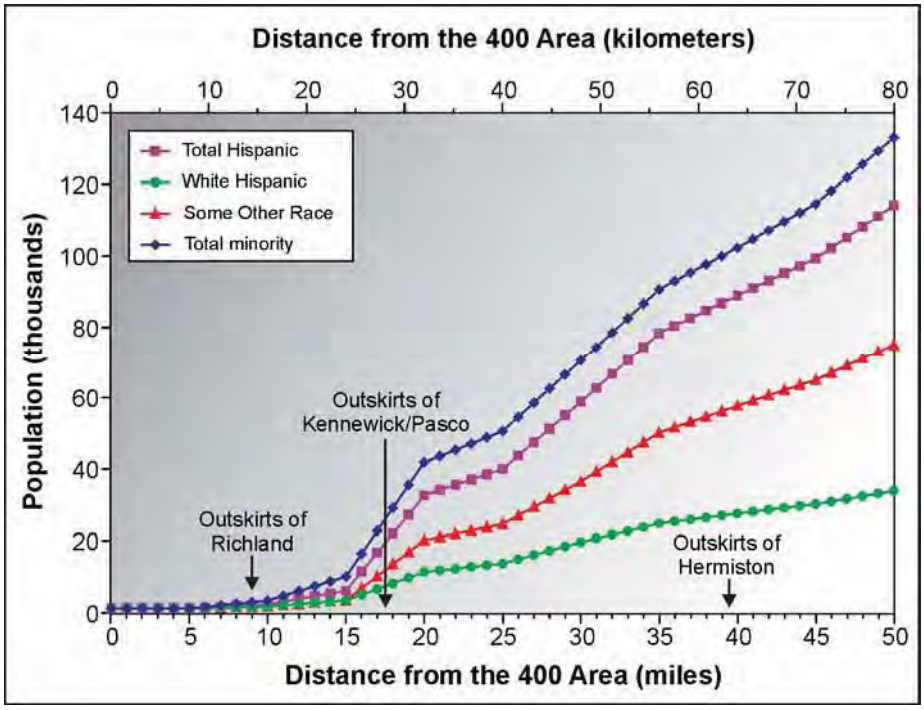


Figure J–14. Cumulative Larger-Scale Minority Populations as a Function of Distance from the Fast Flux Test Facility

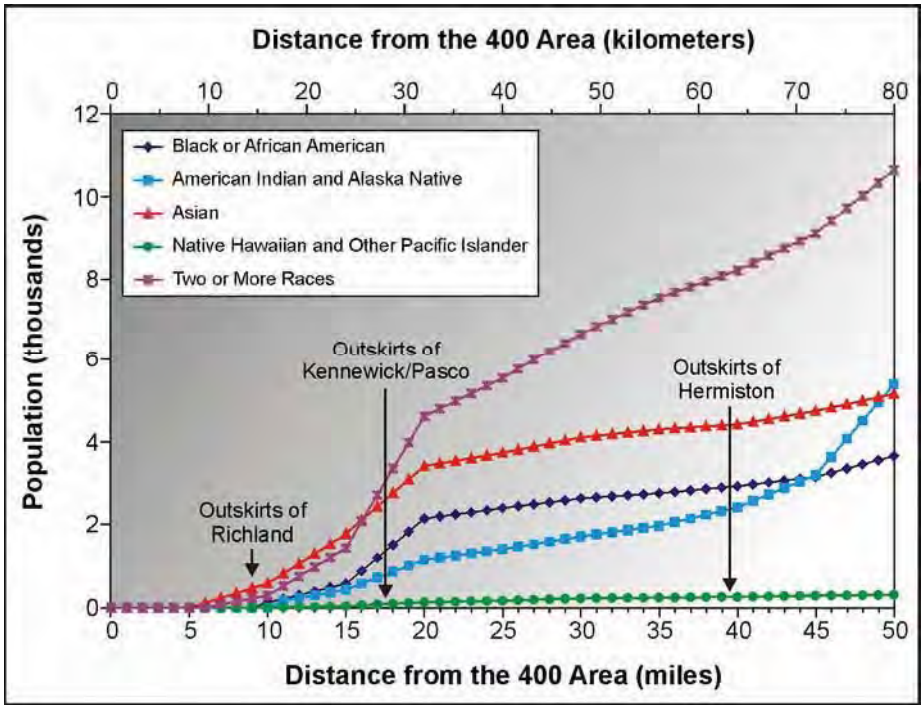


Figure J–15. Cumulative Smaller-Scale Minority Populations as a Function of Distance from the Fast Flux Test Facility

Figure J–16 shows block groups surrounding FFTF and low-income and non-low-income populations living in the potentially affected area. Of the 298 block groups that surround FFTF, an estimated 17 contain low-income populations.

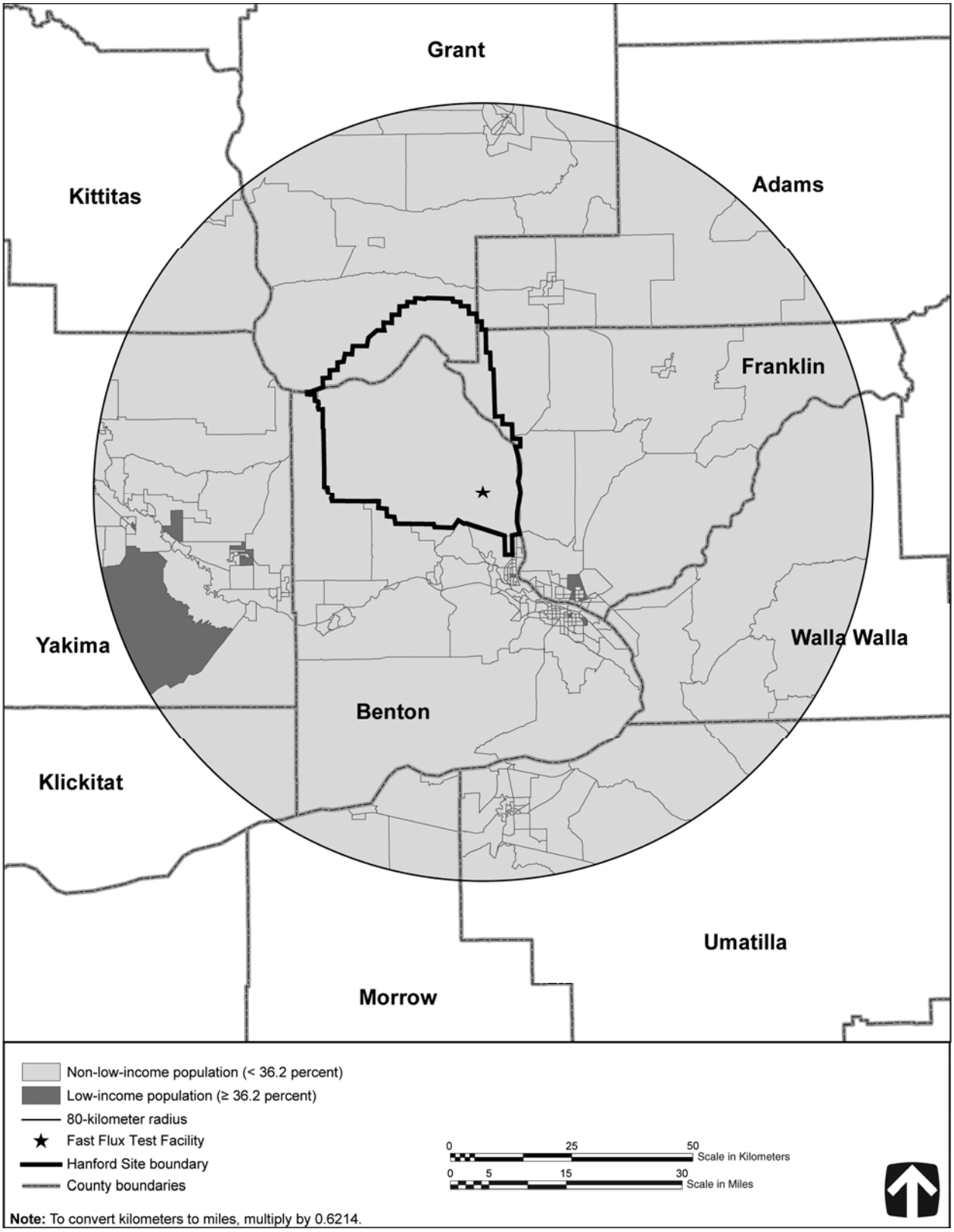


Figure J–16. Low-Income and Non-Low-Income Populations Living in Potentially Affected Block Groups Surrounding the Fast Flux Test Facility (2000)

As indicated in Table J–9, approximately 30 percent of the potentially affected low-income population lives in Yakima County, and over 90 percent of the potentially affected low-income population lives in five counties: Benton, Franklin, Grant, and Yakima Counties in Washington and Umatilla County in Oregon. Low-income persons compose approximately 16 percent of the total population living in the potentially affected area.

Table J–9. Low-Income Populations Living in Potentially Affected Counties Surrounding the Fast Flux Test Facility (2000)

County (State)	Total County Population[a]	Total Low-Income Population[a]	Potentially Affected Total Population	Potentially Affected Low-Income Population	Percentage of the Potentially Affected Low-Income Population Total
Adams (Washington)	16,217	2,951	12,508	2,431	4.4
Benton (Washington)[b]	141,232	14,517	141,219	14,521	26.3
Franklin (Washington)	48,307	9,280	48,183	9,256	16.8
Grant (Washington)	73,591	12,809	38,966	6,376	11.5
Kittitas (Washington)	31,177	6,122	799	67	0.1
Klickitat (Washington)	18,983	3,236	204	45	0.1
Walla Walla (Washington)	50,245	7,567	6,955	748	1.4
Yakima (Washington)	218,966	43,070	65,394	16,747	30.3
Morrow (Oregon)	10,919	1,617	6,718	1,242	2.2
Umatilla (Oregon)	67,329	8,524	30,940	3,801	6.9
Total	**676,966**	**109,693**	**351,886**	**55,234**	**100.0**

[a] Census 2007e.

[b] Potentially affected populations may not equal total populations due to rounding.

Figure J–17 shows cumulative low-income populations as a function of distance from FFTF. Low-income populations surrounding FFTF are concentrated in the Tri-Cities area and Yakima County in Washington and in Hermiston, Oregon.

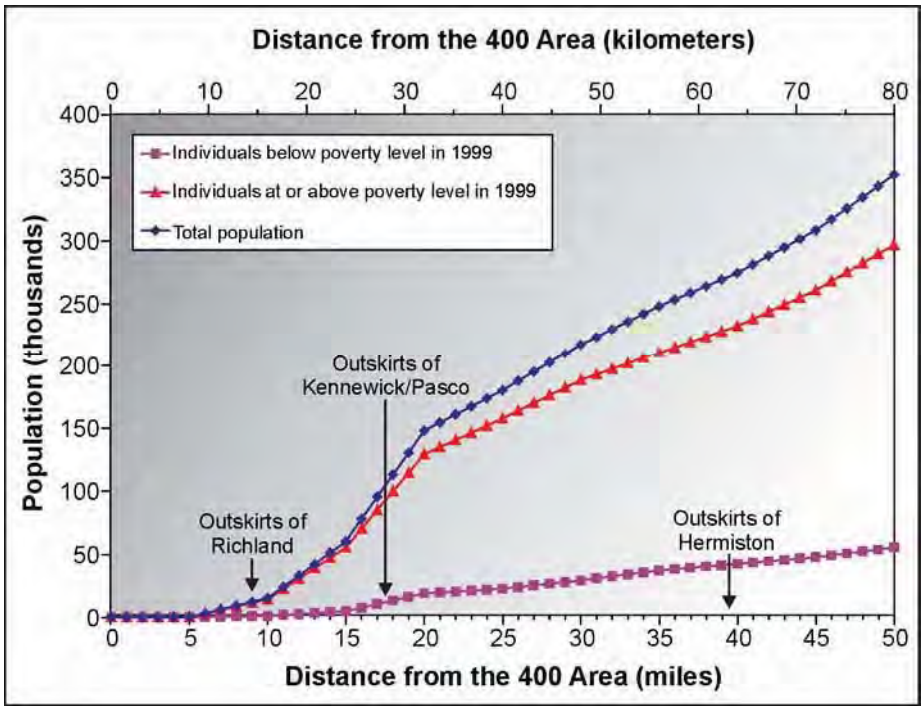


Figure J–17. Cumulative Low-Income Populations as a Function of Distance from the Fast Flux Test Facility

J.5.5 Minority and Low-Income Populations Surrounding Idaho National Laboratory

Figure J–18 shows minority and nonminority populations living in block groups surrounding INL. Of the 189 block groups that surround INL, an estimated 12 contain minority populations. Potentially affected counties include 14 counties in Idaho (Bannock, Bingham, Blaine, Bonneville, Butte, Caribou, Clark, Custer, Fremont, Jefferson, Lemhi, Madison, Minidoka, and Power). As indicated in Table J–10, approximately 66 percent of the potentially affected minority population resides in Bingham and Bonneville County, while another 30 percent of the potentially affected minority population lives in Bannock, Jefferson, and Madison Counties.

Table J–10. Minority Populations Living in Potentially Affected Counties Surrounding the Materials and Fuels Complex (2000)

County (Idaho)	Total County Population[a]	Total Minority Population[a]	Potentially Affected Total Population	Potentially Affected Minority Population	Percentage of the Potentially Affected Minority Population Total
Bannock	75,565	7,929	32,697	3,875	15.4
Bingham	41,735	8,911	40,557	8,724	34.7
Blaine	18,991	2,460	275	42	0.2
Bonneville	82,522	8,061	81,520	8,029	31.9
Butte	2,899	193	2,742	182	0.7
Caribou	7,304	375	0	0	0.0
Clark	1,022	369	625	233	0.9
Custer	4,342	242	160	8	0.0
Fremont	11,819	1,499	1,237	177	0.7
Jefferson	19,155	2,200	18,928	2,181	8.7
Lemhi	7,806	354	24	1	0.0
Madison	27,467	1,611	26,730	1,582	6.3
Minidoka	20,174	5,622	18	9	0.0
Power	7,538	1,946	449	132	0.5
Total	**328,339**	**41,772**	**205,962**	**25,175**	**100.0**

[a] Census 2007d.

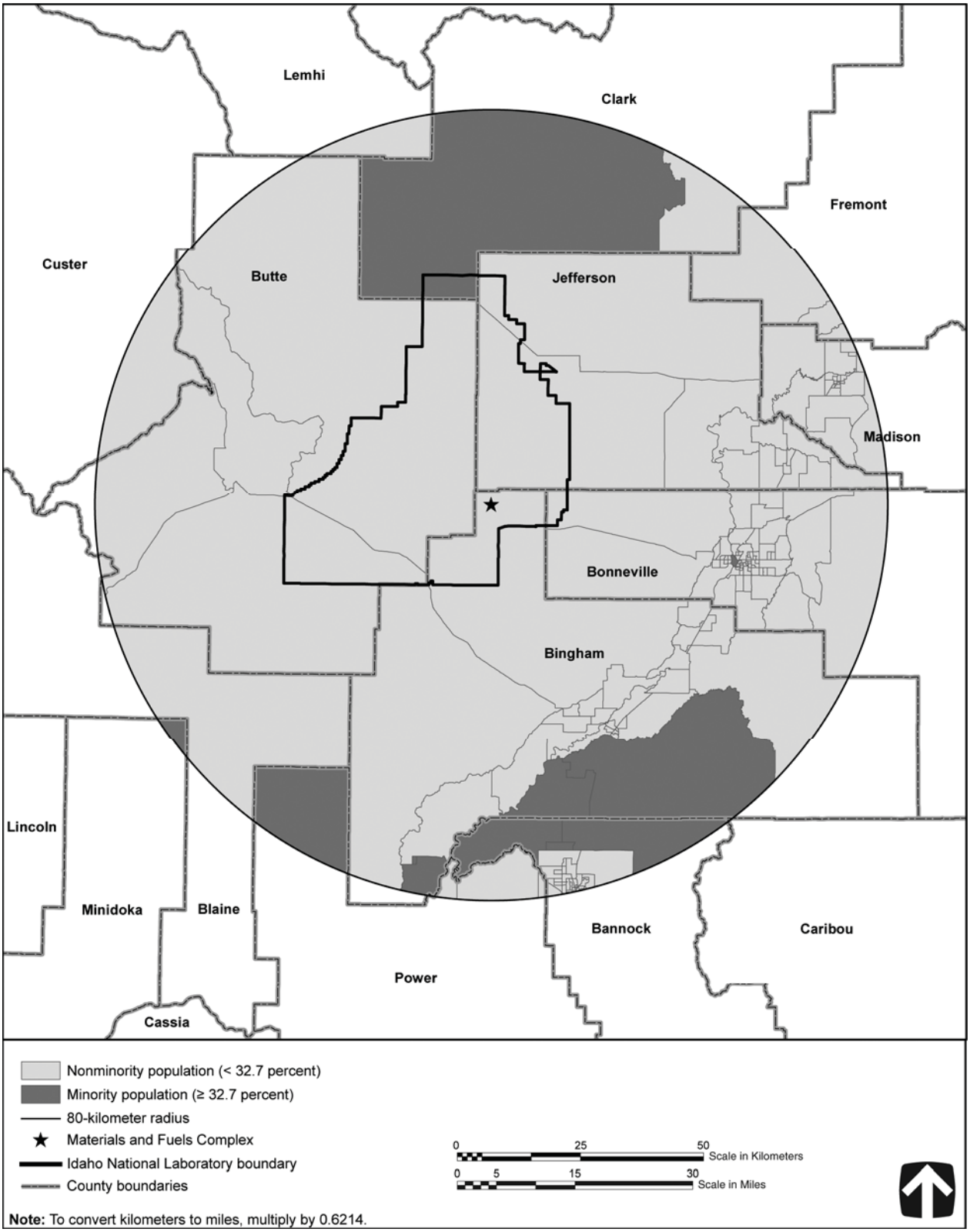


Figure J–18. Minority and Nonminority Populations Living in Potentially Affected Block Groups Surrounding the Materials and Fuels Complex (2000)

Figures J–19 and J–20 show cumulative minority populations as a function of distance from the MFC at INL. Values along the vertical axis of this figure show minority populations living within a given distance from the MFC. Moving outward from the MFC, the cumulative minority populations increase sharply near the outskirts of large population centers. Unlike the candidate facilities at Hanford, these large spikes do not occur until a distance of approximately 48 kilometers (30 miles), where Idaho Falls is located. The next significant jump in population occurs at approximately 72 kilometers (45 miles), near Pocatello. Approximately 10 percent of the potentially affected minority population lives within about 45 kilometers (28 miles) of the MFC, and 50 percent resides within about 56 kilometers (35 miles). The potentially affected total minority population surrounding the MFC is approximately 25,000 persons, accounting for approximately 12 percent of the total population. Approximately 65 percent of the minority population surrounding the MFC is Hispanic or Latino.

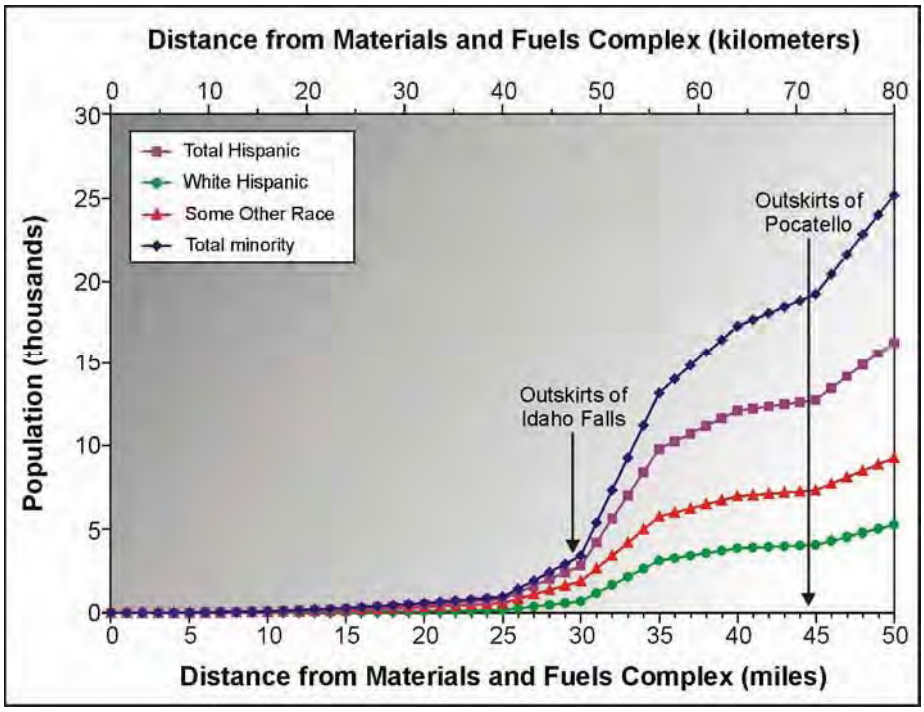


Figure J–19. Cumulative Larger-Scale Minority Populations as a Function of Distance from the Materials and Fuels Complex

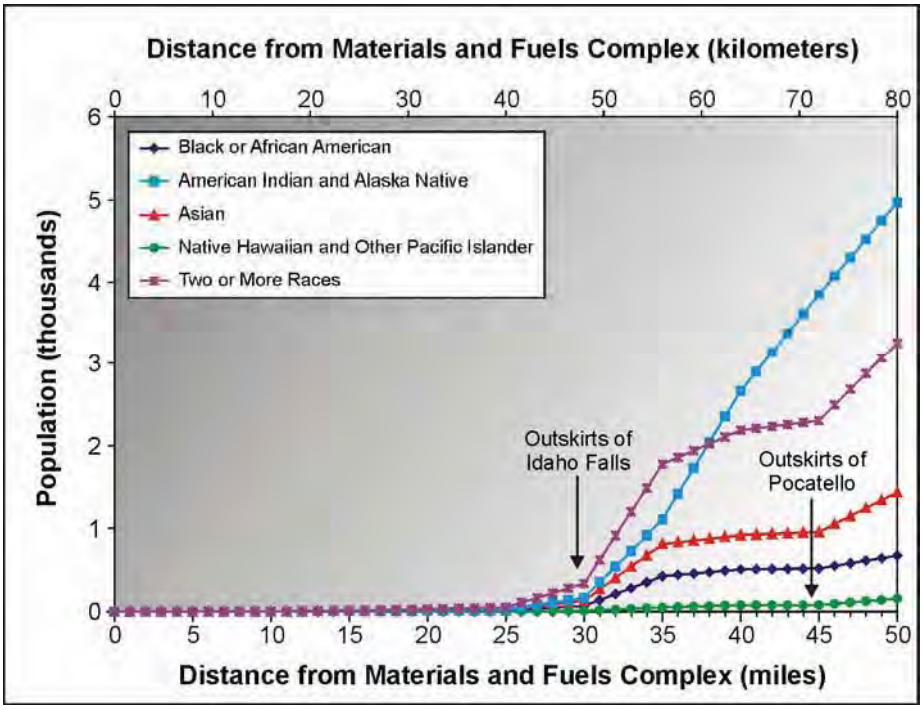


Figure J–20. Cumulative Smaller-Scale Minority Populations as a Function of Distance from the Materials and Fuels Complex

Figure J–21 shows the block groups surrounding INL and the low-income and non-low-income populations living in the potentially affected area. Of the 189 block groups that surround the MFC, it is estimated that 9 contain low-income populations. As indicated in Table J–11, approximately 60 percent of the potentially affected low-income population lives in Bonneville and Madison Counties. Another 30 percent of the potentially affected low-income population lives in Bannock and Bingham Counties. Low-income persons compose approximately 14 percent of the total population living in the potentially affected area. Figure J–22 shows cumulative low-income populations as a function of distance from the MFC. Low-income populations surrounding INL are concentrated in the Idaho Falls and Pocatello areas.

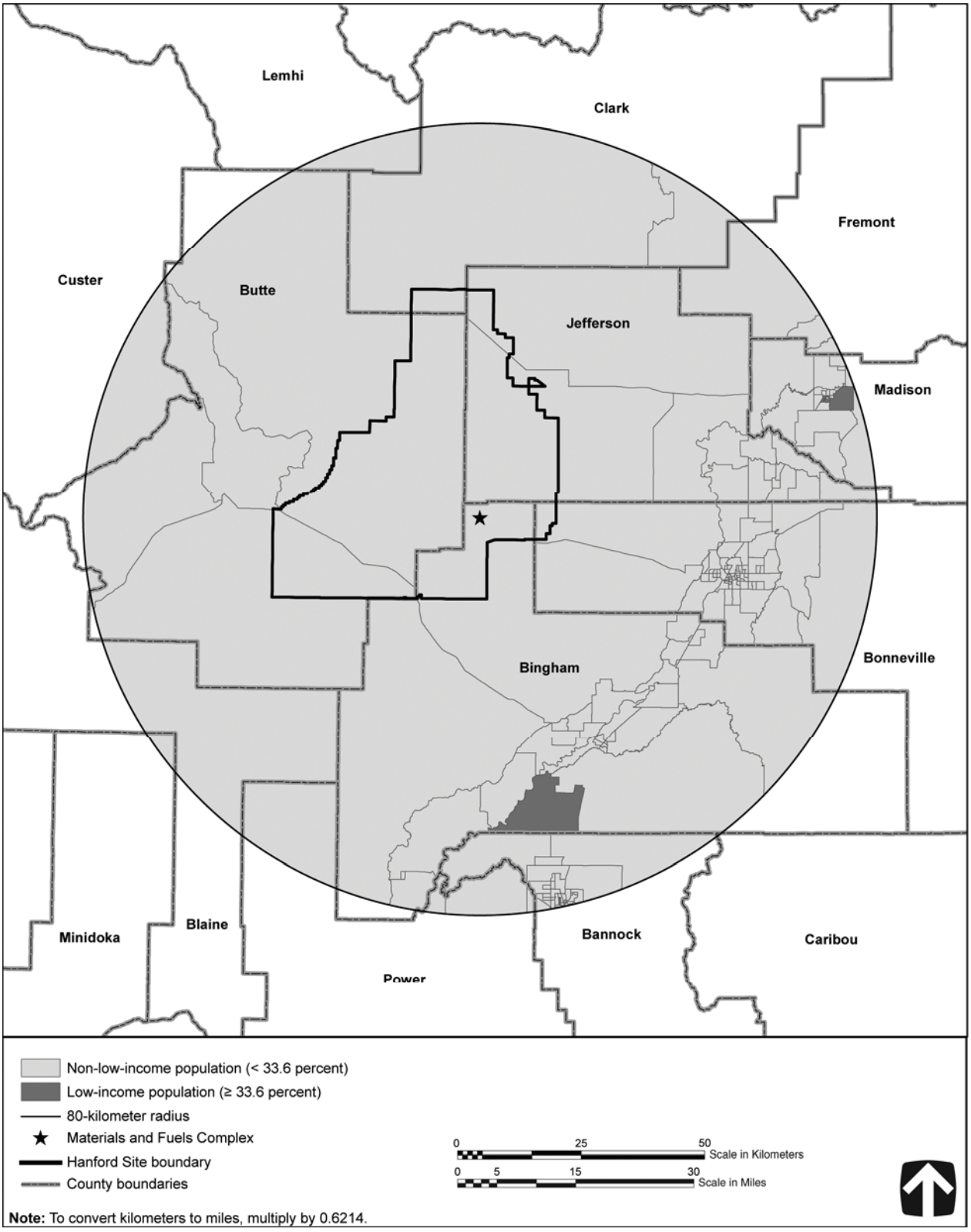


Figure J–21. Low-Income and Non-Low-Income Populations Living in Potentially Affected Block Groups Surrounding the Materials and Fuels Complex (2000)

Table J–11. Low-Income Populations Living in Potentially Affected Counties Surrounding the Materials and Fuels Complex (2000)

County (Idaho)	Total County Population[a]	Total Low-Income Population[a]	Potentially Affected Total Population	Potentially Affected Low-Income Population	Percentage of the Potentially Affected Low-Income Population Total
Bannock	73,414	10,181	32,435	3,719	13.5
Bingham	41,342	5,137	40,136	4,997	18.1
Blaine	18,868	1,469	274	24	0.1
Bonneville	81,532	8,260	80,521	8,178	29.6
Butte	2,869	522	2,707	498	1.8
Caribou	7,226	694	0	0	0.0
Clark	1,017	202	621	119	0.4
Custer	4,330	619	160	22	0.1
Fremont	11,530	1,633	1,218	106	0.4
Jefferson	19,090	1,984	18,867	1,946	7.0
Lemhi	7,736	1,185	24	5	0.0
Madison	26,051	7,948	25,297	7,922	28.7
Minidoka	19,992	2,960	20	4	0.0
Power	7,446	1,200	438	66	0.2
Total	**322,443**	**43,994**	**202,718**	**27,606**	**100.0**

[a] Census 2007e.

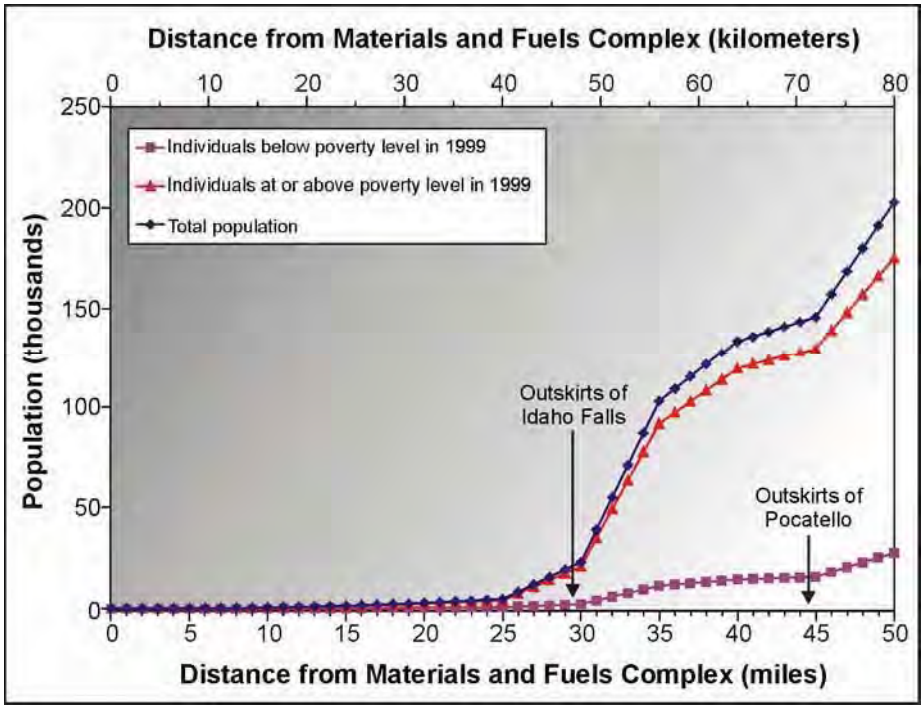


Figure J–22. Cumulative Low-Income Populations as a Function of Distance from the Materials and Fuels Complex

J.5.6 Impacts on Minority and Low-Income Populations

This environmental justice analysis is based on assessment of the impacts reported in Chapter 4 of this *TC & WM EIS*. Initially, all resource areas were examined to identify those with the potential for disproportionately high and adverse health or environmental impacts on minority and low-income populations. Access to Hanford is restricted, so the majority of impacts would be associated with onsite activities and would not affect populations residing off site; thus the potential for environmental justice concerns is small. Resource areas that could be impacted and that may affect populations residing off site include public health and safety due to normal operations and facility accidents, air quality, groundwater resources, and long-term human health. These areas were further analyzed because they do have the potential to pose environmental justice concerns.

J.5.6.1 Normal Operations and Facility Accidents

Radiological impacts of normal operations on minority, Hispanic, American Indian, and low-income populations were determined by applying the same methodology used to determine impacts of normal operations on the general public (total population). Concentrations of radiological air emissions originating from the appropriate facilities under each alternative were modeled using meteorological data and population distributions relative to the release sites to determine the impacts on each subset population. This approach is discussed in detail in Appendix K, Sections K.2.1.1.1, K.2.2.1.1, and K.2.3.1.1. Note that the exposure scenarios used to model the minority, Hispanic, American Indian, and low-income populations assume that these individuals would be exposed in the same manner as the general population, that is, by external exposure to the plume and deposited radioactive materials and by internal exposure from inhalation of contaminated air and deposited radioactive materials and ingestion of contaminated food, including homegrown produce and animal products from regional livestock.

For purposes of evaluating the potential for disproportionately high and adverse impacts caused by radiological emissions from normal operations, the average dose to an individual of the minority or low-income population is compared to the average dose to an individual of the remainder of the population. Table J–12 shows the population values used for this environmental justice analysis. The maximum annual dose (the maximum estimated dose in a single year of a particular alternative) and the project lifetime dose (the estimated dose received over the duration of a particular alternative) are used for this comparison. A maximum annual dose and a project lifetime dose were calculated for each subset of the population being evaluated (minority, Hispanic, American Indian, and low-income). The average dose to an individual of the population subset being evaluated is derived by dividing the population dose for the subset by the number of people in the subset.

$$D_{is} = \frac{D_{ps}}{n_s}$$

where:

D_{is} = average dose to an individual in the population subset s, millirem,
D_{ps} = population dose received by the population subset s, person-rem, and
n_s = number of people in the population subset s

Table J–12. Potentially Affected Populations[a]

Facility Site	Total Population[b]	Total Minority Population	Hispanic Population[c]	American Indian Population	Low-Income Population[d]
WTP	447,354	173,047	146,208	9,496	77,046
STTS-East	451,556	173,829	146,755	9,544	77,537
STTS-West	488,897	180,794	151,487	10,418	79,964
FFTF	357,391	131,786	112,899	5,383	55,234
INL	205,962	25,175	16,329	4,972	27,606

a Reflects populations living within an 80-kilometer (50-mile) radius of the indicated facility sites.

b Total population values used to compare with low-income populations are based on sample data. The values are 440,583; 444,789; 481,350; 351,886; and 202,718 for the WTP, STTS-East, STTS-West, FFTF, and INL, respectively.

c Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

d Low-income population values are based on sample data.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

The result is then compared to the average dose to an individual who is not a member of the subset being evaluated. The average dose to a member of the remaining population is derived by dividing the population dose to the remainder of the population (population dose to the total population minus the population dose to the subset population) by the number of people in the remainder of the population (living within 80 kilometers [50 miles]) of the candidate facilities that are not in the population subset).

$$D_{ir} \quad \frac{D_{pr}}{n_r}$$

where:

D_{ir} = average dose to an individual in the remainder of the population (not a member of population subset *s*), millirem

D_{pr} =population dose received by the remainder of the population (the population that is not a member of subset *s*), and person-rem

n_r =number of people in the remainder of the population (total population minus population of subset *s*)

J.5.6.1.1 Tank Closure Alternatives

Table J–13 compares average individual doses to minority and nonminority populations under each Tank Closure alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a minority individual and a nonminority individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–13. Tank Closure Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.2	7.1×10^{-3}	1.1	6.4×10^{-3}	2.1	7.6×10^{-3}
STTS-West	3.1	6.3×10^{-3}	9.9×10^{-1}	5.5×10^{-3}	2.1	6.8×10^{-3}
Total	**6.3**	**1.3×10^{-2}**	**2.1**	**1.2×10^{-2}**	**4.2**	**1.4×10^{-2}**
Alternative 2A						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	5.3×10^{-7}	1.2×10^{-9}	1.8×10^{-7}	1.0×10^{-9}	3.5×10^{-7}	1.3×10^{-9}
STTS-West	0	0	0	0	0	0
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**3.9×10^{1}**	**1.4×10^{-1}**
Alternative 2B						
WTP	7.6×10^{1}	1.7×10^{-1}	2.6×10^{1}	1.5×10^{-1}	4.9×10^{1}	1.8×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	5.6×10^{-2}	3.2×10^{-4}	1.1×10^{-1}	4.0×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	5.1×10^{-2}	2.8×10^{-4}	1.1×10^{-1}	3.6×10^{-4}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**2.6×10^{1}**	**1.5×10^{-1}**	**5.0×10^{1}**	**1.8×10^{-1}**
Alternative 3A						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	1.5×10^{-1}	8.5×10^{-4}	2.8×10^{-1}	1.0×10^{-3}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	1.4×10^{-1}	7.9×10^{-4}	3.0×10^{-1}	9.8×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**4.0×10^{1}**	**1.5×10^{-1}**
Alternative 3B						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	6.2×10^{-5}	1.4×10^{-7}	2.1×10^{-5}	1.2×10^{-7}	4.1×10^{-5}	1.5×10^{-7}
STTS-West	1.8×10^{-3}	3.7×10^{-6}	5.8×10^{-4}	3.2×10^{-6}	1.2×10^{-3}	4.0×10^{-6}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**3.9×10^{1}**	**1.4×10^{-1}**
Alternative 3C						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	1.5×10^{-1}	8.5×10^{-4}	2.8×10^{-1}	1.0×10^{-3}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	1.4×10^{-1}	7.9×10^{-4}	3.0×10^{-1}	9.8×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**4.0×10^{1}**	**1.5×10^{-1}**
Alternative 4						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	2.3×10^{-2}	5.2×10^{-5}	7.9×10^{-3}	4.6×10^{-5}	1.5×10^{-2}	5.6×10^{-5}
STTS-West	2.3×10^{-2}	4.8×10^{-5}	7.4×10^{-3}	4.1×10^{-5}	1.6×10^{-2}	5.2×10^{-5}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**3.9×10^{1}**	**1.4×10^{-1}**
Alternative 5						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	3.0×10^{-5}	6.6×10^{-8}	1.0×10^{-5}	5.8×10^{-8}	2.0×10^{-5}	7.0×10^{-8}
STTS-West	5.6×10^{-1}	1.2×10^{-3}	1.8×10^{-1}	1.0×10^{-3}	3.8×10^{-1}	1.2×10^{-3}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**4.0×10^{1}**	**1.5×10^{-1}**

Table J–13. Tank Closure Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses in Year of Maximum Impact *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 6A, Base Case						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	9.7×10^{-2}	2.2×10^{-4}	3.3×10^{-2}	1.9×10^{-4}	6.4×10^{-2}	2.3×10^{-4}
STTS-West	7.6×10^{-2}	1.6×10^{-4}	2.4×10^{-2}	1.3×10^{-4}	5.2×10^{-2}	1.7×10^{-4}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**3.9×10^{1}**	**1.4×10^{-1}**
Alternative 6A, Option Case						
WTP	6.0×10^{1}	1.3×10^{-1}	2.1×10^{1}	1.2×10^{-1}	3.9×10^{1}	1.4×10^{-1}
STTS-East	1.6×10^{-1}	3.6×10^{-4}	5.6×10^{-2}	3.2×10^{-4}	1.1×10^{-1}	3.9×10^{-4}
STTS-West	1.4×10^{-1}	2.9×10^{-4}	4.6×10^{-2}	2.5×10^{-4}	9.7×10^{-2}	3.2×10^{-4}
Total	**6.0×10^{1}**	**1.4×10^{-1}**	**2.1×10^{1}**	**1.2×10^{-1}**	**4.0×10^{1}**	**1.4×10^{-1}**
Alternative 6B, Base Case						
WTP	7.4×10^{1}	1.6×10^{-1}	2.6×10^{1}	1.5×10^{-1}	4.8×10^{1}	1.8×10^{-1}
STTS-East	1.3	2.9×10^{-3}	4.5×10^{-1}	2.6×10^{-3}	8.8×10^{-1}	3.2×10^{-3}
STTS-West	1.1	2.3×10^{-3}	3.6×10^{-1}	2.0×10^{-3}	7.7×10^{-1}	2.5×10^{-3}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**2.6×10^{1}**	**1.5×10^{-1}**	**5.0×10^{1}**	**1.8×10^{-1}**
Alternative 6B, Option Case						
WTP	7.4×10^{1}	1.7×10^{-1}	2.6×10^{1}	1.5×10^{-1}	4.8×10^{1}	1.8×10^{-1}
STTS-East	2.2	4.8×10^{-3}	7.4×10^{-1}	4.2×10^{-3}	1.4	5.2×10^{-3}
STTS-West	1.8	3.7×10^{-3}	5.7×10^{-1}	3.2×10^{-3}	1.2	4.0×10^{-3}
Total	**7.8×10^{1}**	**1.7×10^{-1}**	**2.7×10^{1}**	**1.6×10^{-1}**	**5.1×10^{1}**	**1.9×10^{-1}**
Alternative 6C						
WTP	7.4×10^{1}	1.6×10^{-1}	2.6×10^{1}	1.5×10^{-1}	4.8×10^{1}	1.8×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	5.6×10^{-2}	3.2×10^{-4}	1.1×10^{-1}	4.0×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	5.1×10^{-2}	2.8×10^{-4}	1.1×10^{-1}	3.6×10^{-4}
Total	**7.4×10^{1}**	**1.7×10^{-1}**	**2.6×10^{1}**	**1.5×10^{-1}**	**4.8×10^{1}**	**1.8×10^{-1}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–14 compares average individual doses to American Indian and non–American Indian populations under each Tank Closure alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–14. Tank Closure Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.2	7.1×10^{-3}	3.9×10^{-2}	4.0×10^{-3}	3.2	7.2×10^{-3}
STTS-West	3.1	6.3×10^{-3}	3.9×10^{-2}	3.8×10^{-3}	3.1	6.4×10^{-3}
Total	**6.3**	**1.3×10^{-2}**	**7.8×10^{-2}**	**7.8×10^{-3}**	**6.2**	**1.4×10^{-2}**
Alternative 2A						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	5.3×10^{-7}	1.2×10^{-9}	6.2×10^{-9}	6.5×10^{-10}	5.2×10^{-7}	1.2×10^{-9}
STTS-West	0	0	0	0	0	0
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**7.8×10^{-1}**	**8.2×10^{-2}**	**5.9×10^{1}**	**1.4×10^{-1}**
Alternative 2B						
WTP	7.6×10^{1}	1.7×10^{-1}	9.8×10^{-1}	1.0×10^{-1}	7.5×10^{1}	1.7×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	1.9×10^{-3}	2.0×10^{-4}	1.7×10^{-1}	3.7×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	2.0×10^{-3}	1.9×10^{-4}	1.6×10^{-1}	3.3×10^{-4}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**9.8×10^{-1}**	**1.0×10^{-1}**	**7.5×10^{1}**	**1.7×10^{-1}**
Alternative 3A						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	4.9×10^{-3}	5.2×10^{-4}	4.2×10^{-1}	9.5×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	5.5×10^{-3}	5.3×10^{-4}	4.4×10^{-1}	9.2×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**7.9×10^{-1}**	**8.3×10^{-2}**	**6.0×10^{1}**	**1.4×10^{-1}**
Alternative 3B						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	6.2×10^{-5}	1.4×10^{-7}	7.1×10^{-7}	7.5×10^{-8}	6.1×10^{-5}	1.4×10^{-7}
STTS-West	1.8×10^{-3}	3.7×10^{-6}	2.2×10^{-5}	2.2×10^{-6}	1.8×10^{-3}	3.8×10^{-6}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**7.8×10^{-1}**	**8.2×10^{-2}**	**5.9×10^{1}**	**1.4×10^{-1}**
Alternative 3C						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	4.9×10^{-3}	5.2×10^{-4}	4.2×10^{-1}	9.5×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	5.5×10^{-3}	5.3×10^{-4}	4.4×10^{-1}	9.2×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**7.9×10^{-1}**	**8.3×10^{-2}**	**6.0×10^{1}**	**1.4×10^{-1}**
Alternative 4						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	2.3×10^{-2}	5.2×10^{-5}	2.7×10^{-4}	2.8×10^{-5}	2.3×10^{-2}	5.2×10^{-5}
STTS-West	2.3×10^{-2}	4.8×10^{-5}	2.9×10^{-4}	2.8×10^{-5}	2.3×10^{-2}	4.8×10^{-5}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**7.8×10^{-1}**	**8.2×10^{-2}**	**5.9×10^{1}**	**1.4×10^{-1}**
Alternative 5						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	6.0×10^{1}	1.4×10^{-1}
STTS-East	3.0×10^{-5}	6.6×10^{-8}	3.4×10^{-7}	3.6×10^{-8}	2.9×10^{-5}	6.6×10^{-8}
STTS-West	5.6×10^{-1}	1.2×10^{-3}	7.0×10^{-3}	6.7×10^{-4}	5.6×10^{-1}	1.2×10^{-3}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**7.9×10^{-1}**	**8.3×10^{-2}**	**6.0×10^{1}**	**1.4×10^{-1}**

Table J–14. Tank Closure Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses in Year of Maximum Impact *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 6A, Base Case						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	9.7×10^{-2}	2.2×10^{-4}	1.1×10^{-3}	1.2×10^{-4}	9.6×10^{-2}	2.2×10^{-4}
STTS-West	7.6×10^{-2}	1.6×10^{-4}	9.3×10^{-4}	9.0×10^{-5}	7.5×10^{-2}	1.6×10^{-4}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**7.8×10^{-1}**	**8.2×10^{-2}**	**6.0×10^{1}**	**1.4×10^{-1}**
Alternative 6A, Option Case						
WTP	6.0×10^{1}	1.3×10^{-1}	7.8×10^{-1}	8.2×10^{-2}	5.9×10^{1}	1.4×10^{-1}
STTS-East	1.6×10^{-1}	3.6×10^{-4}	1.9×10^{-3}	2.0×10^{-4}	1.6×10^{-1}	3.7×10^{-4}
STTS-West	1.4×10^{-1}	2.9×10^{-4}	1.8×10^{-3}	1.7×10^{-4}	1.4×10^{-1}	2.9×10^{-4}
Total	**6.0×10^{1}**	**1.4×10^{-1}**	**7.8×10^{-1}**	**8.2×10^{-2}**	**6.0×10^{1}**	**1.4×10^{-1}**
Alternative 6B, Base Case						
WTP	7.4×10^{1}	1.6×10^{-1}	9.5×10^{-1}	1.0×10^{-1}	7.3×10^{1}	1.7×10^{-1}
STTS-East	1.3	2.9×10^{-3}	1.5×10^{-2}	1.6×10^{-3}	1.3	3.0×10^{-3}
STTS-West	1.1	2.3×10^{-3}	1.4×10^{-2}	1.3×10^{-3}	1.1	2.3×10^{-3}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**9.8×10^{-1}**	**1.0×10^{-1}**	**7.5×10^{1}**	**1.7×10^{-1}**
Alternative 6B, Option Case						
WTP	7.4×10^{1}	1.7×10^{-1}	9.5×10^{-1}	1.0×10^{-1}	7.3×10^{1}	1.7×10^{-1}
STTS-East	2.2	4.8×10^{-3}	2.5×10^{-2}	2.6×10^{-3}	2.2	4.9×10^{-3}
STTS-West	1.8	3.7×10^{-3}	2.2×10^{-2}	2.1×10^{-3}	1.8	3.7×10^{-3}
Total	**7.8×10^{1}**	**1.7×10^{-1}**	**1.0**	**1.0×10^{-1}**	**7.7×10^{1}**	**1.8×10^{-1}**
Alternative 6C						
WTP	7.4×10^{1}	1.6×10^{-1}	9.5×10^{-1}	1.0×10^{-1}	7.3×10^{1}	1.7×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	1.9×10^{-3}	2.0×10^{-4}	1.7×10^{-1}	3.7×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	2.0×10^{-3}	1.9×10^{-4}	1.6×10^{-1}	3.3×10^{-4}
Total	**7.4×10^{1}**	**1.7×10^{-1}**	**9.5×10^{-1}**	**1.0×10^{-1}**	**7.3×10^{1}**	**1.7×10^{-1}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–15 compares average individual doses to Hispanic and non-Hispanic populations under each Tank Closure alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a Hispanic individual and a non-Hispanic individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on Hispanic populations surrounding each facility site.

Table J–15. Tank Closure Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.2	7.1×10^{-3}	9.2×10^{-1}	6.3×10^{-3}	2.3	7.5×10^{-3}
STTS-West	3.1	6.3×10^{-3}	8.1×10^{-1}	5.4×10^{-3}	2.3	6.7×10^{-3}
Total	**6.3**	**1.3×10^{-2}**	**1.7**	**1.2×10^{-2}**	**4.6**	**1.4×10^{-2}**
Alternative 2A						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	5.3×10^{-7}	1.2×10^{-9}	1.5×10^{-7}	1.0×10^{-9}	3.8×10^{-7}	1.2×10^{-9}
STTS-West	0	0	0	0	0	0
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**1.7×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 2B						
WTP	7.6×10^{1}	1.7×10^{-1}	2.2×10^{1}	1.5×10^{-1}	5.4×10^{1}	1.8×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	4.7×10^{-2}	3.2×10^{-4}	1.2×10^{-1}	3.9×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	4.2×10^{-2}	2.7×10^{-4}	1.2×10^{-1}	3.5×10^{-4}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**2.2×10^{1}**	**1.5×10^{-1}**	**5.4×10^{1}**	**1.8×10^{-1}**
Alternative 3A						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	1.2×10^{-1}	8.5×10^{-4}	3.0×10^{-1}	9.9×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	1.2×10^{-1}	7.8×10^{-4}	3.3×10^{-1}	9.7×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**1.8×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 3B						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	6.2×10^{-5}	1.4×10^{-7}	1.7×10^{-5}	1.2×10^{-7}	4.4×10^{-5}	1.4×10^{-7}
STTS-West	1.8×10^{-3}	3.7×10^{-6}	4.8×10^{-4}	3.2×10^{-6}	1.3×10^{-3}	4.0×10^{-6}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**1.7×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 3C						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	1.2×10^{-1}	8.5×10^{-4}	3.0×10^{-1}	9.9×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	1.2×10^{-1}	7.8×10^{-4}	3.3×10^{-1}	9.7×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**1.8×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 4						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	2.3×10^{-2}	5.2×10^{-5}	6.6×10^{-3}	4.5×10^{-5}	1.7×10^{-2}	5.5×10^{-5}
STTS-West	2.3×10^{-2}	4.8×10^{-5}	6.2×10^{-3}	4.1×10^{-5}	1.7×10^{-2}	5.1×10^{-5}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**1.7×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 5						
WTP	6.0×10^{1}	1.3×10^{-1}	1.8×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	3.0×10^{-5}	6.6×10^{-8}	8.4×10^{-6}	5.7×10^{-8}	2.1×10^{-5}	7.0×10^{-8}
STTS-West	5.6×10^{-1}	1.2×10^{-3}	1.5×10^{-1}	9.9×10^{-4}	4.1×10^{-1}	1.2×10^{-3}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**1.8×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 6A, Base Case						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	9.7×10^{-2}	2.2×10^{-4}	2.8×10^{-2}	1.9×10^{-4}	7.0×10^{-2}	2.3×10^{-4}
STTS-West	7.6×10^{-2}	1.6×10^{-4}	2.0×10^{-2}	1.3×10^{-4}	5.6×10^{-2}	1.7×10^{-4}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**1.8×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**

Table J–15. Tank Closure Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses in Year of Maximum Impact *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 6A, Option Case						
WTP	6.0×10^{1}	1.3×10^{-1}	1.7×10^{1}	1.2×10^{-1}	4.3×10^{1}	1.4×10^{-1}
STTS-East	1.6×10^{-1}	3.6×10^{-4}	4.6×10^{-2}	3.2×10^{-4}	1.2×10^{-1}	3.9×10^{-4}
STTS-West	1.4×10^{-1}	2.9×10^{-4}	3.8×10^{-2}	2.5×10^{-4}	1.1×10^{-1}	3.1×10^{-4}
Total	**6.0×10^{1}**	**1.4×10^{-1}**	**1.8×10^{1}**	**1.2×10^{-1}**	**4.3×10^{1}**	**1.4×10^{-1}**
Alternative 6B, Base Case						
WTP	7.4×10^{1}	1.6×10^{-1}	2.1×10^{1}	1.5×10^{-1}	5.2×10^{1}	1.7×10^{-1}
STTS-East	1.3	2.9×10^{-3}	3.7×10^{-1}	2.6×10^{-3}	9.6×10^{-1}	3.1×10^{-3}
STTS-West	1.1	2.3×10^{-3}	3.0×10^{-1}	2.0×10^{-3}	8.3×10^{-1}	2.5×10^{-3}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**2.2×10^{1}**	**1.5×10^{-1}**	**5.4×10^{1}**	**1.8×10^{-1}**
Alternative 6B, Option Case						
WTP	7.4×10^{1}	1.7×10^{-1}	2.1×10^{1}	1.5×10^{-1}	5.2×10^{1}	1.7×10^{-1}
STTS-East	2.2	4.8×10^{-3}	6.1×10^{-1}	4.2×10^{-3}	1.6	5.1×10^{-3}
STTS-West	1.8	3.7×10^{-3}	4.7×10^{-1}	3.1×10^{-3}	1.3	3.9×10^{-3}
Total	**7.8×10^{1}**	**1.7×10^{-1}**	**2.3×10^{1}**	**1.5×10^{-1}**	**5.5×10^{1}**	**1.8×10^{-1}**
Alternative 6C						
WTP	7.4×10^{1}	1.6×10^{-1}	2.1×10^{1}	1.5×10^{-1}	5.2×10^{1}	1.7×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	4.7×10^{-2}	3.2×10^{-4}	1.2×10^{-1}	3.9×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	4.2×10^{-2}	2.7×10^{-4}	1.2×10^{-1}	3.5×10^{-4}
Total	**7.4×10^{1}**	**1.7×10^{-1}**	**2.2×10^{1}**	**1.5×10^{-1}**	**5.3×10^{1}**	**1.7×10^{-1}**

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–16 compares average individual doses to low-income and non-low-income populations under each Tank Closure alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a low-income individual and a non-low-income individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–16. Tank Closure Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.2	7.1×10^{-3}	4.8×10^{-1}	6.2×10^{-3}	2.7	7.3×10^{-3}
STTS-West	3.1	6.3×10^{-3}	4.2×10^{-1}	5.3×10^{-3}	2.7	6.5×10^{-3}
Total	**6.3**	**1.3×10^{-2}**	**9.0×10^{-1}**	**1.1×10^{-2}**	**5.4**	**1.4×10^{-2}**
Alternative 2A						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	5.3×10^{-7}	1.2×10^{-9}	7.9×10^{-8}	1.0×10^{-9}	4.5×10^{-7}	1.2×10^{-9}
STTS-West	0	0	0	0	0	0
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**9.3**	**1.2×10^{-1}**	**5.1×10^{1}**	**1.4×10^{-1}**

Table J–16. Tank Closure Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses in Year of Maximum Impact *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 2B						
WTP	7.6×10^{1}	1.7×10^{-1}	1.2×10^{1}	1.5×10^{-1}	6.4×10^{1}	1.7×10^{-1}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	2.5×10^{-2}	3.2×10^{-4}	1.4×10^{-1}	3.8×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	2.2×10^{-2}	2.7×10^{-4}	1.4×10^{-1}	3.4×10^{-4}
Total	**7.6×10^{1}**	**1.7×10^{-1}**	**1.2×10^{1}**	**1.5×10^{-1}**	**6.4×10^{1}**	**1.7×10^{-1}**
Alternative 3A						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	6.2×10^{-2}	8.0×10^{-4}	3.6×10^{-1}	9.7×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	6.0×10^{-2}	7.4×10^{-4}	3.9×10^{-1}	9.4×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**9.4**	**1.2×10^{-1}**	**5.2×10^{1}**	**1.4×10^{-1}**
Alternative 3B						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	6.2×10^{-5}	1.4×10^{-7}	9.1×10^{-6}	1.2×10^{-7}	5.3×10^{-5}	1.4×10^{-7}
STTS-West	1.8×10^{-3}	3.7×10^{-6}	2.5×10^{-4}	3.1×10^{-6}	1.6×10^{-3}	3.9×10^{-6}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**9.3**	**1.2×10^{-1}**	**5.1×10^{1}**	**1.4×10^{-1}**
Alternative 3C						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	4.2×10^{-1}	9.4×10^{-4}	6.2×10^{-2}	8.0×10^{-4}	3.6×10^{-1}	9.7×10^{-4}
STTS-West	4.5×10^{-1}	9.1×10^{-4}	6.0×10^{-2}	7.4×10^{-4}	3.9×10^{-1}	9.4×10^{-4}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**9.4**	**1.2×10^{-1}**	**5.2×10^{1}**	**1.4×10^{-1}**
Alternative 4						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	2.3×10^{-2}	5.2×10^{-5}	3.5×10^{-3}	4.5×10^{-5}	2.0×10^{-2}	5.3×10^{-5}
STTS-West	2.3×10^{-2}	4.8×10^{-5}	3.1×10^{-3}	3.9×10^{-5}	2.0×10^{-2}	4.9×10^{-5}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**9.3**	**1.2×10^{-1}**	**5.1×10^{1}**	**1.4×10^{-1}**
Alternative 5						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	3.0×10^{-5}	6.6×10^{-8}	4.4×10^{-6}	5.6×10^{-8}	2.5×10^{-5}	6.8×10^{-8}
STTS-West	5.6×10^{-1}	1.2×10^{-3}	7.5×10^{-2}	9.4×10^{-4}	4.9×10^{-1}	1.2×10^{-3}
Total	**6.1×10^{1}**	**1.4×10^{-1}**	**9.4**	**1.2×10^{-1}**	**5.2×10^{1}**	**1.4×10^{-1}**
Alternative 6A, Base Case						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	9.7×10^{-2}	2.2×10^{-4}	1.4×10^{-2}	1.9×10^{-4}	8.3×10^{-2}	2.2×10^{-4}
STTS-West	7.6×10^{-2}	1.6×10^{-4}	1.0×10^{-2}	1.3×10^{-4}	6.6×10^{-2}	1.6×10^{-4}
Total	**6.0×10^{1}**	**1.3×10^{-1}**	**9.3**	**1.2×10^{-1}**	**5.1×10^{1}**	**1.4×10^{-1}**
Alternative 6A, Option Case						
WTP	6.0×10^{1}	1.3×10^{-1}	9.3	1.2×10^{-1}	5.1×10^{1}	1.4×10^{-1}
STTS-East	1.6×10^{-1}	3.6×10^{-4}	2.4×10^{-2}	3.1×10^{-4}	1.4×10^{-1}	3.7×10^{-4}
STTS-West	1.4×10^{-1}	2.9×10^{-4}	1.9×10^{-2}	2.4×10^{-4}	1.2×10^{-1}	3.0×10^{-4}
Total	**6.0×10^{1}**	**1.4×10^{-1}**	**9.3**	**1.2×10^{-1}**	**5.1×10^{1}**	**1.4×10^{-1}**

Table J–16. Tank Closure Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses in Year of Maximum Impact *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 6B, Base Case						
WTP	7.4×10^{1}	1.6×10^{-1}	1.1×10^{1}	1.5×10^{-1}	6.2×10^{1}	1.7×10^{-1}
STTS-East	1.3	2.9×10^{-3}	2.0×10^{-1}	2.5×10^{-3}	1.1	3.0×10^{-3}
STTS-West	1.1	2.3×10^{-3}	1.5×10^{-1}	1.9×10^{-3}	9.7×10^{-1}	2.4×10^{-3}
Total	**7.6×1^{1}**	**1.7×10^{-1}**	**1.2×10^{1}**	**1.5×10^{-1}**	**6.5×10^{1}**	**1.7×10^{-1}**
Alternative 6B, Option Case						
WTP	7.4×10^{1}	1.7×10^{-1}	1.1×10^{1}	1.5×10^{-1}	6.3×10^{1}	1.7×10^{-1}
STTS-East	2.2	4.8×10^{-3}	3.2×10^{-1}	4.2×10^{-3}	1.9	5.0×10^{-3}
STTS-West	1.8	3.7×10^{-3}	2.4×10^{-1}	3.0×10^{-3}	1.6	3.8×10^{-3}
Total	**7.8×10^{1}**	**1.7×10^{-1}**	**1.2×10^{1}**	**1.5×10^{-1}**	**6.6×10^{1}**	**1.8×10^{-1}**
Alternative 6C						
WTP	7.4×10^{1}	1.6×10^{-1}	1.1×10^{1}	1.5×10^{-1}	6.2×10^{1}	1.7×10^{-3}
STTS-East	1.7×10^{-1}	3.7×10^{-4}	2.5×10^{-2}	3.2×10^{-4}	1.4×10^{-1}	3.8×10^{-4}
STTS-West	1.6×10^{-1}	3.3×10^{-4}	2.2×10^{-2}	2.7×10^{-4}	1.4×10^{-1}	3.4×10^{-4}
Total	**7.4×10^{1}**	**1.7×10^{-1}**	**1.1×10^{1}**	**1.5×10^{-1}**	**6.3×10^{1}**	**1.7×10^{-1}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–17 compares the average individual doses to minority and nonminority populations under each Tank Closure alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a minority individual and a nonminority individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–17. Tank Closure Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.1×10^{2}	6.8×10^{-1}	1.1×10^{2}	6.1×10^{-1}	2.0×10^{2}	7.2×10^{-1}
STTS-West	2.9×10^{2}	6.0×10^{-1}	9.4×10^{1}	5.2×10^{-1}	2.0×10^{2}	6.5×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**2.0×10^{2}**	**1.1**	**4.0×10^{2}**	**1.4**
Alternative 2A						
WTP	4.5×10^{2}	1.0	1.5×10^{2}	8.9×10^{-1}	2.9×10^{2}	1.1
STTS-East	3.2×10^{2}	7.1×10^{-1}	1.1×10^{2}	6.4×10^{-1}	2.1×10^{2}	7.5×10^{-1}
STTS-West	3.1×10^{2}	6.3×10^{-1}	9.8×10^{1}	5.4×10^{-1}	2.1×10^{2}	6.8×10^{-1}
Total	**1.1×10^{3}**	**2.3**	**3.6×10^{2}**	**2.1**	**7.1×10^{2}**	**2.5**
Alternative 2B						
WTP	4.5×10^{2}	1.0	1.6×10^{2}	9.0×10^{-1}	3.0×10^{2}	1.1
STTS-East	6.0	1.3×10^{-2}	2.0	1.2×10^{-2}	4.0	1.4×10^{-2}
STTS-West	5.7	1.2×10^{-2}	1.8	1.0×10^{-2}	3.9	1.3×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**1.6×10^{2}**	**9.2×10^{-1}**	**3.0×10^{2}**	**1.1**

Table J–17. Tank Closure Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses Over the Life of the Project *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 3A						
WTP	3.6×10^{2}	8.1×10^{-1}	1.3×10^{2}	7.3×10^{-1}	2.4×10^{2}	8.7×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	3.5×10^{1}	2.0×10^{-1}	6.6×10^{1}	2.4×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	3.3×10^{1}	1.8×10^{-1}	7.1×10^{1}	2.3×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**1.9×10^{2}**	**1.1**	**3.7×10^{2}**	**1.3**
Alternative 3B						
WTP	3.6×10^{2}	8.1×10^{-1}	1.3×10^{2}	7.3×10^{-1}	2.4×10^{2}	8.7×10^{-1}
STTS-East	7.2	1.6×10^{-2}	2.4	1.4×10^{-2}	4.8	1.7×10^{-2}
STTS-West	5.6	1.1×10^{-2}	1.8	9.8×10^{-3}	3.8	1.2×10^{-2}
Total	**3.8×10^{2}**	**8.4×10^{-1}**	**1.3×10^{2}**	**7.5×10^{-1}**	**2.5×10^{2}**	**9.0×10^{-1}**
Alternative 3C						
WTP	3.6×10^{2}	8.1×10^{-1}	1.3×10^{2}	7.3×10^{-1}	2.4×10^{2}	8.7×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	3.5×10^{1}	2.0×10^{-1}	6.6×10^{1}	2.4×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	3.3×10^{1}	1.8×10^{-1}	7.1×10^{1}	2.3×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**1.9×10^{2}**	**1.1**	**3.7×10^{2}**	**1.3**
Alternative 4						
WTP	3.7×10^{2}	8.2×10^{-1}	1.3×10^{2}	7.3×10^{-1}	2.4×10^{2}	8.7×10^{-1}
STTS-East	1.2×10^{1}	2.6×10^{-2}	4.8	2.7×10^{-2}	6.8	2.5×10^{-2}
STTS-West	1.1×10^{2}	2.3×10^{-1}	3.4×10^{1}	1.9×10^{-1}	7.6×10^{1}	2.5×10^{-1}
Total	**4.9×10^{2}**	**1.1**	**1.7×10^{2}**	**9.5×10^{-1}**	**3.2×10^{2}**	**1.1**
Alternative 5						
WTP	3.6×10^{2}	7.9×10^{-1}	1.2×10^{2}	7.1×10^{-1}	2.3×10^{2}	8.5×10^{-1}
STTS-East	6.0	1.3×10^{-2}	2.0	1.2×10^{-2}	4.0	1.4×10^{-2}
STTS-West	9.5×10^{1}	2.0×10^{-1}	3.0×10^{1}	1.7×10^{-1}	6.5×10^{1}	2.1×10^{-1}
Total	**4.6×10^{2}**	**1.0**	**1.6×10^{2}**	**8.9×10^{-1}**	**3.0×10^{2}**	**1.1**
Alternative 6A, Base Case						
WTP	4.6×10^{2}	1.0	1.6×10^{2}	9.3×10^{-1}	3.0×10^{2}	1.1
STTS-East	9.3×10^{1}	2.1×10^{-1}	5.2×10^{1}	3.0×10^{-1}	4.2×10^{1}	1.5×10^{-1}
STTS-West	1.8	3.7×10^{-3}	3.9×10^{-1}	2.2×10^{-3}	1.4	4.6×10^{-3}
Total	**5.6×10^{2}**	**1.2**	**2.1×10^{2}**	**1.2**	**3.5×10^{2}**	**1.3**
Alternative 6A, Option Case						
WTP	4.6×10^{2}	1.0	1.6×10^{2}	9.3×10^{-1}	3.0×10^{2}	1.1
STTS-East	1.5×10^{2}	3.3×10^{-1}	8.8×10^{1}	5.1×10^{-1}	6.2×10^{1}	2.2×10^{-1}
STTS-West	1.5×10^{2}	3.1×10^{-1}	1.3×10^{1}	6.9×10^{-2}	1.4×10^{2}	4.5×10^{-1}
Total	**7.6×10^{2}**	**1.7**	**2.6×10^{2}**	**1.5**	**5.0×10^{2}**	**1.8**
Alternative 6B, Base Case						
WTP	4.5×10^{2}	1.0	1.5×10^{2}	8.9×10^{-1}	2.9×10^{2}	1.1
STTS-East	7.5×10^{1}	1.7×10^{-1}	4.5×10^{1}	2.6×10^{-1}	3.0×10^{1}	1.1×10^{-1}
STTS-West	7.5×10^{1}	1.5×10^{-1}	5.2	2.9×10^{-2}	7.0×10^{1}	2.3×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**2.1×10^{2}**	**1.2**	**3.9×10^{2}**	**1.4**
Alternative 6B, Option Case						
WTP	4.5×10^{2}	1.0	1.6×10^{2}	9.0×10^{-1}	2.9×10^{2}	1.1
STTS-East	1.3×10^{2}	2.9×10^{-1}	8.2×10^{1}	4.7×10^{-1}	5.0×10^{1}	1.8×10^{-1}
STTS-West	1.3×10^{2}	2.7×10^{-1}	6.5	3.6×10^{-2}	1.2×10^{2}	4.0×10^{-1}
Total	**7.1×10^{2}**	**1.6**	**2.4×10^{2}**	**1.4**	**4.7×10^{2}**	**1.6**
Alternative 6C						
WTP	4.5×10^{2}	1.0	1.5×10^{2}	8.9×10^{-1}	2.9×10^{2}	1.1
STTS-East	6.0	1.3×10^{-2}	2.0	1.2×10^{-2}	4.0	1.4×10^{-2}
STTS-West	5.70	1.2×10^{-2}	1.8	1.0×10^{-2}	3.9	1.3×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**1.6×10^{2}**	**9.2×10^{-1}**	**3.0×10^{2}**	**1.1**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–18 compares the average individual doses to American Indian and non–American Indian populations under each Tank Closure alternative over the lifetime of the project, to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–18. Tank Closure Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.1×10^{2}	6.8×10^{-1}	3.7	3.9×10^{-1}	3.0×10^{2}	6.9×10^{-1}
STTS-West	2.9×10^{2}	6.0×10^{-1}	3.8	3.6×10^{-1}	2.9×10^{2}	6.1×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**7.5**	**7.5×10^{-1}**	**5.9×10^{2}**	**1.3**
Alternative 2A						
WTP	4.5×10^{2}	1.0	5.7	6.0×10^{-1}	4.4×10^{2}	1.0
STTS-East	3.2×10^{2}	7.1×10^{-1}	3.8	4.0×10^{-1}	3.2×10^{2}	7.2×10^{-1}
STTS-West	3.1×10^{2}	6.3×10^{-1}	3.9	3.8×10^{-1}	3.0×10^{2}	6.3×10^{-1}
Total	**1.1×10^{3}**	**2.3**	**1.3×10^{1}**	**1.4**	**1.1×10^{3}**	**2.4**
Alternative 2B						
WTP	4.5×10^{2}	1.0	5.8	6.1×10^{-1}	4.5×10^{2}	1.0
STTS-East	6.0	1.3×10^{-2}	6.6×10^{-2}	7.0×10^{-3}	5.9	1.3×10^{-2}
STTS-West	5.7	1.2×10^{-2}	7.0×10^{-2}	6.7×10^{-3}	5.7	1.2×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**5.9**	**6.2×10^{-1}**	**4.6×10^{2}**	**1.0**
Alternative 3A						
WTP	3.6×10^{2}	8.1×10^{-1}	4.6	4.9×10^{-1}	3.6×10^{2}	8.2×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	1.2	1.2×10^{-1}	1.0×10^{2}	2.3×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	1.3	1.2×10^{-1}	1.0×10^{2}	2.1×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**7.1**	**7.3×10^{-1}**	**5.6×10^{2}**	**1.3**
Alternative 3B						
WTP	3.6×10^{2}	8.1×10^{-1}	4.6	4.9×10^{-1}	3.6×10^{2}	8.2×10^{-1}
STTS-East	7.2	1.6×10^{-2}	8.1×10^{-2}	8.5×10^{-3}	7.1	1.6×10^{-2}
STTS-West	5.6	1.1×10^{-2}	6.8×10^{-2}	6.5×10^{-3}	5.5	1.2×10^{-2}
Total	**3.8×10^{2}**	**8.4×10^{-1}**	**4.8**	**5.0×10^{-1}**	**3.7×10^{2}**	**8.5×10^{-1}**
Alternative 3C						
WTP	3.6×10^{2}	8.1×10^{-1}	4.6	4.9×10^{-1}	3.6×10^{2}	8.2×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	1.2	1.2×10^{-1}	1.0×10^{2}	2.3×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	1.3	1.2×10^{-1}	1.0×10^{2}	2.1×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**7.1**	**7.3×10^{-1}**	**5.6×10^{2}**	**1.3**
Alternative 4						
WTP	3.7×10^{2}	8.2×10^{-1}	4.7	4.9×10^{-1}	3.6×10^{2}	8.2×10^{-1}
STTS-East	1.2×10^{1}	2.6×10^{-2}	1.6×10^{-1}	1.7×10^{-2}	1.1×10^{1}	2.6×10^{-2}
STTS-West	1.1×10^{2}	2.3×10^{-1}	1.3	1.3×10^{-1}	1.1×10^{2}	2.3×10^{-1}
Total	**4.9×10^{2}**	**1.1**	**6.2**	**6.4×10^{-1}**	**4.8×10^{2}**	**1.1**

Table J–18. Tank Closure Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses Over the Life of the Project *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 5						
WTP	3.6×10^{2}	7.9×10^{-1}	4.5	4.8×10^{-1}	3.5×10^{2}	8.0×10^{-1}
STTS-East	6.0	1.3×10^{-2}	6.8×10^{-2}	7.1×10^{-3}	6.0	1.3×10^{-2}
STTS-West	9.5×10^{1}	2.0×10^{-1}	1.2	1.1×10^{-1}	9.4×10^{1}	2.0×10^{-1}
Total	**4.6×10^{2}**	**1.0**	**5.8**	**6.0×10^{-1}**	**4.5×10^{2}**	**1.0**
Alternative 6A, Base Case						
WTP	4.6×10^{2}	1.0	5.9	6.2×10^{-1}	4.6×10^{2}	1.0
STTS-East	9.3×10^{1}	2.1×10^{-1}	1.7	1.8×10^{-1}	9.2×10^{1}	2.1×10^{-1}
STTS-West	1.8	3.7×10^{-3}	1.5×10^{-2}	1.5×10^{-3}	1.8	3.7×10^{-3}
Total	**5.6×10^{2}**	**1.2**	**7.7**	**8.1×10^{-1}**	**5.5×10^{2}**	**1.3**
Alternative 6A, Option Case						
WTP	4.6×10^{2}	1.0	5.9	6.2×10^{-1}	4.6×10^{2}	1.0
STTS-East	1.5×10^{2}	3.3×10^{-1}	3.0	3.2×10^{-1}	1.5×10^{2}	3.3×10^{-1}
STTS-West	1.5×10^{2}	3.1×10^{-1}	4.9×10^{-1}	4.7×10^{-2}	1.5×10^{2}	3.1×10^{-1}
Total	**7.6×10^{2}**	**1.7**	**9.4**	**9.9×10^{-1}**	**7.5×10^{2}**	**1.7**
Alternative 6B, Base Case						
WTP	4.5×10^{2}	1.0	5.7	6.0×10^{-1}	4.4×10^{2}	1.0
STTS-East	7.5×10^{1}	1.7×10^{-1}	1.5	1.6×10^{-1}	7.3×10^{1}	1.7×10^{-1}
STTS-West	7.5×10^{1}	1.5×10^{-1}	2.0×10^{-1}	1.9×10^{-2}	7.5×10^{1}	1.6×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**7.5**	**7.8×10^{-1}**	**5.9×10^{2}**	**1.3**
Alternative 6B, Option Case						
WTP	4.5×10^{2}	1.0	5.7	6.0×10^{-1}	4.4×10^{2}	1.0
STTS-East	1.3×10^{2}	2.9×10^{-1}	2.8	2.9×10^{-1}	1.3×10^{2}	2.9×10^{-1}
STTS-West	1.3×10^{2}	2.7×10^{-1}	2.6×10^{-1}	2.5×10^{-2}	1.3×10^{2}	2.7×10^{-1}
Total	**7.1×10^{2}**	**1.6**	**8.8**	**9.2×10^{-1}**	**7.0×10^{2}**	**1.6**
Alternative 6C						
WTP	4.5×10^{2}	1.0	5.7	6.0×10^{-1}	4.4×10^{2}	1.0
STT-East	6.0	1.3×10^{-2}	6.6×10^{-2}	7.0×10^{-3}	5.9	1.3×10^{-2}
STTS-West	5.7	1.2×10^{-2}	7.0×10^{-2}	6.7×10^{-3}	5.7	1.2×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**5.9**	**6.2×10^{-1}**	**4.5×10^{2}**	**1.0**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–19 compares the average individual doses to Hispanic and non-Hispanic populations under each Tank Closure alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a Hispanic individual and a non-Hispanic individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on Hispanic populations surrounding each facility site.

Table J–19. Tank Closure Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.1×10^{2}	6.8×10^{-1}	8.8×10^{1}	6.0×10^{-1}	2.2×10^{2}	7.2×10^{-1}
STTS-West	2.9×10^{2}	6.0×10^{-1}	7.8×10^{1}	5.1×10^{-1}	2.2×10^{2}	6.4×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**1.7×10^{2}**	**1.1**	**4.4×10^{2}**	**1.4**
Alternative 2A						
WTP	4.5×10^{2}	1.0	1.3×10^{2}	8.9×10^{-1}	3.2×10^{2}	1.1
STTS-East	3.2×10^{2}	7.1×10^{-1}	9.1×10^{1}	6.2×10^{-1}	2.3×10^{2}	7.5×10^{-1}
STTS-West	3.1×10^{2}	6.3×10^{-1}	8.1×10^{1}	5.3×10^{-1}	2.3×10^{2}	6.7×10^{-1}
Total	**1.1×10^{3}**	**2.3**	**3.0×10^{2}**	**2.0**	**7.7×10^{2}**	**2.5**
Alternative 2B						
WTP	4.5×10^{2}	1.0	1.3×10^{2}	9.0×10^{-1}	3.2×10^{2}	1.1
STTS-East	6.0	1.3×10^{-2}	1.7	1.1×10^{-2}	4.3	1.4×10^{-2}
STTS-West	5.7	1.2×10^{-2}	1.5	9.8×10^{-3}	4.3	1.3×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**1.3×10^{2}**	**9.2×10^{-1}**	**3.3×10^{2}**	**1.1**
Alternative 3A						
WTP	3.6×10^{2}	8.1×10^{-1}	1.1×10^{2}	7.2×10^{-1}	2.6×10^{2}	8.5×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	3.0×10^{1}	2.0×10^{-1}	7.2×10^{1}	2.4×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	2.8×10^{1}	1.8×10^{-1}	7.6×10^{1}	2.3×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**1.6×10^{2}**	**1.1**	**4.1×10^{2}**	**1.3**
Alternative 3B						
WTP	3.6×10^{2}	8.1×10^{-1}	1.1×10^{2}	7.2×10^{-1}	2.6×10^{2}	8.5×10^{-1}
STTS-East	7.2	1.6×10^{-2}	2.0	1.4×10^{-2}	5.2	1.7×10^{-2}
STTS-West	5.6	1.1×10^{-2}	1.5	9.6×10^{-3}	4.2	1.2×10^{-2}
Total	**3.8×10^{2}**	**8.4×10^{-1}**	**1.1×10^{2}**	**7.5×10^{-1}**	**2.7×10^{2}**	**8.8×10^{-1}**
Alternative 3C						
WTP	3.6×10^{2}	8.1×10^{-1}	1.1×10^{2}	7.2×10^{-1}	2.6×10^{2}	8.5×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	3.0×10^{1}	2.0×10^{-1}	7.2×10^{1}	2.4×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	2.8×10^{1}	1.8×10^{-1}	7.6×10^{1}	2.3×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**1.6×10^{2}**	**1.1**	**4.1×10^{2}**	**1.3**
Alternative 4						
WTP	3.7×10^{2}	8.2×10^{-1}	1.1×10^{2}	7.3×10^{-1}	2.6×10^{2}	8.6×10^{-1}
STTS-East	1.2×10^{1}	2.6×10^{-2}	4.0	2.7×10^{-2}	7.7	2.5×10^{-2}
STTS-West	1.1×10^{2}	2.3×10^{-1}	2.9×10^{1}	1.9×10^{-1}	8.2×10^{1}	2.4×10^{-1}
Total	**4.9×10^{2}**	**1.1**	**1.4×10^{2}**	**9.5×10^{-1}**	**3.5×10^{2}**	**1.1**

Table J–19. Tank Closure Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses Over the Life of the Project *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 5						
WTP	3.6×10^{2}	7.9×10^{-1}	1.0×10^{2}	7.1×10^{-1}	2.5×10^{2}	8.4×10^{-1}
STTS-East	6.0	1.3×10^{-2}	1.7	1.1×10^{-2}	4.3	1.4×10^{-2}
STTS-West	9.5×10^{1}	2.0×10^{-1}	2.5×10^{1}	1.7×10^{-1}	7.0×10^{1}	2.1×10^{-1}
Total	**4.6×10^{2}**	**1.0**	**1.3×10^{2}**	**8.9×10^{-1}**	**3.3×10^{2}**	**1.1**
Alternative 6A, Base Case						
WTP	4.6×10^{2}	1.0	1.3×10^{2}	9.2×10^{-1}	3.3×10^{2}	1.1
STTS-East	9.3×10^{1}	2.1×10^{-1}	4.3×10^{1}	2.9×10^{-1}	5.1×10^{1}	1.7×10^{-1}
STTS-West	1.8	3.7×10^{-3}	3.3×10^{-1}	2.1×10^{-3}	1.5	4.4×10^{-3}
Total	**5.6×10^{2}**	**1.2**	**1.8×10^{2}**	**1.2**	**3.8×10^{2}**	**1.3**
Alternative 6A, Option Case						
WTP	4.6×10^{2}	1.0	1.3×10^{2}	9.2×10^{-1}	3.3×10^{2}	1.1
STTS-East	1.5×10^{2}	3.3×10^{-1}	7.3×10^{1}	5.0×10^{-1}	7.7×10^{1}	2.5×10^{-1}
STTS-West	1.5×10^{2}	3.1×10^{-1}	1.0×10^{1}	6.8×10^{-2}	1.4×10^{2}	4.1×10^{-1}
Total	**7.6×10^{2}**	**1.7**	**2.2×10^{2}**	**1.5**	**5.4×10^{2}**	**1.8**
Alternative 6B, Base Case						
WTP	4.5×10^{2}	1.0	1.3×10^{2}	8.9×10^{-1}	3.2×10^{2}	1.1
STTS-East	7.5×10^{1}	1.7×10^{-1}	3.8×10^{1}	2.6×10^{-1}	3.7×10^{1}	1.2×10^{-1}
STTS-West	7.5×10^{1}	1.5×10^{-1}	4.3	2.8×10^{-2}	7.1×10^{1}	2.1×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**1.7×10^{2}**	**1.2**	**4.2×10^{2}**	**1.4**
Alternative 6B, Option Case						
WTP	4.5×10^{2}	1.0	1.3×10^{2}	8.9×10^{-1}	3.2×10^{2}	1.1
STTS-East	1.3×10^{2}	2.9×10^{-1}	6.8×10^{1}	4.6×10^{-1}	6.4×10^{1}	2.1×10^{-1}
STTS-West	1.3×10^{2}	2.7×10^{-1}	5.4	3.6×10^{-2}	1.3×10^{2}	3.7×10^{-1}
Total	**7.1×10^{2}**	**1.6**	**2.0×10^{2}**	**1.4**	**5.1×10^{2}**	**1.6**
Alternative 6C						
WTP	4.5×10^{2}	1	1.3×10^{2}	8.9×10^{-1}	3.2×10^{2}	1.1
STTS-East	6.0	1.3×10^{-2}	1.70	1.1×10^{-2}	4.3	1.4×10^{-2}
STTS-West	5.7	1.2×10^{-2}	1.50	9.8×10^{-3}	4.3	1.3×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**1.3×10^{2}**	**9.1×10^{-1}**	**3.3×10^{2}**	**1.1**

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–20 compares average individual doses to low-income and non-low-income populations under each Tank Closure alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a low-income individual and a non-low-income individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–20. Tank Closure Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	3.1×10^{2}	6.8×10^{-1}	4.6×10^{1}	5.9×10^{-1}	2.6×10^{2}	7.0×10^{-1}
STTS-West	2.9×10^{2}	6.0×10^{-1}	4.0×10^{1}	5.0×10^{-1}	2.5×10^{2}	6.2×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**8.6×10^{1}**	**1.1**	**5.2×10^{2}**	**1.3**
Alternative 2A						
WTP	4.5×10^{2}	1.0	6.7×10^{1}	8.8×10^{-1}	3.8×10^{2}	1.0
STTS-East	3.2×10^{2}	7.1×10^{-1}	4.8×10^{1}	6.2×10^{-1}	2.7×10^{2}	7.3×10^{-1}
STTS-West	3.1×10^{2}	6.3×10^{-1}	4.2×10^{1}	5.2×10^{-1}	2.7×10^{2}	6.5×10^{-1}
Total	**1.1×10^{3}**	**2.3**	**1.6×10^{2}**	**2.0**	**9.2×10^{2}**	**2.4**
Alternative 2B						
WTP	4.5×10^{2}	1.0	6.8×10^{1}	8.8×10^{-1}	3.8×10^{2}	1.0
STTS-East	6.0	1.3×10^{-2}	8.8×10^{-1}	1.1×10^{-2}	5.1	1.4×10^{-2}
STTS-West	5.7	1.2×10^{-2}	7.8×10^{-1}	9.8×10^{-3}	5.0	1.2×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**7.0×10^{1}**	**9.1×10^{-1}**	**3.9×10^{2}**	**1.1**
Alternative 3A						
WTP	3.6×10^{2}	8.1×10^{-1}	5.5×10^{1}	7.1×10^{-1}	3.1×10^{2}	8.3×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	1.5×10^{1}	1.9×10^{-1}	8.7×10^{1}	2.3×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	1.4×10^{1}	1.7×10^{-1}	9.0×10^{1}	2.2×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**8.4×10^{1}**	**1.1**	**4.8×10^{2}**	**1.3**
Alternative 3B						
WTP	3.6×10^{2}	8.1×10^{-1}	5.5×10^{1}	7.1×10^{-1}	3.1×10^{2}	8.3×10^{-1}
STTS-East	7.2	1.6×10^{-2}	1.1	1.4×10^{-2}	6.1	1.6×10^{-2}
STTS-West	5.6	1.1×10^{-2}	7.6×10^{-1}	9.6×10^{-3}	4.8	1.2×10^{-2}
Total	**3.8×10^{2}**	**8.4×10^{-1}**	**5.7×10^{1}**	**7.4×10^{-1}**	**3.2×10^{2}**	**8.6×10^{-1}**
Alternative 3C						
WTP	3.6×10^{2}	8.1×10^{-1}	5.5×10^{1}	7.1×10^{-1}	3.1×10^{2}	8.3×10^{-1}
STTS-East	1.0×10^{2}	2.2×10^{-1}	1.5×10^{1}	1.9×10^{-1}	8.7×10^{1}	2.3×10^{-1}
STTS-West	1.0×10^{2}	2.1×10^{-1}	1.4×10^{1}	1.7×10^{-1}	9.0×10^{1}	2.2×10^{-1}
Total	**5.7×10^{2}**	**1.2**	**8.4×10^{1}**	**1.1**	**4.8×10^{2}**	**1.3**
Alternative 4						
WTP	3.7×10^{2}	8.2×10^{-1}	5.5×10^{1}	7.2×10^{-1}	3.1×10^{2}	8.4×10^{-1}
STTS-East	1.2×10^{1}	2.6×10^{-2}	2.1	2.7×10^{-2}	9.5	2.5×10^{-2}
STTS-West	1.1×10^{2}	2.3×10^{-1}	1.4×10^{1}	1.8×10^{-1}	9.6×10^{1}	2.3×10^{-1}
Total	**4.9×10^{2}**	**1.1**	**7.2×10^{1}**	**9.2×10^{-1}**	**4.2×10^{2}**	**1.1**
Alternative 5						
WTP	3.6×10^{2}	7.9×10^{-1}	5.4×10^{1}	7.0×10^{-1}	3.0×10^{2}	8.1×10^{-1}
STTS-East	6.0	1.3×10^{-2}	8.9×10^{-1}	1.2×10^{-2}	5.1	1.4×10^{-2}
STTS-West	9.5×10^{1}	2.0×10^{-1}	1.3×10^{1}	1.6×10^{-1}	8.3×10^{1}	2.0×10^{-1}
Total	**4.6×10^{2}**	**1.0**	**6.7×10^{1}**	**8.7×10^{-1}**	**3.9×10^{2}**	**1.0**
Alternative 6A, Base Case						
WTP	4.6×10^{2}	1.0	7.0×10^{1}	9.1×10^{-1}	3.9×10^{2}	1.1
STTS-East	9.3×10^{1}	2.1×10^{-1}	2.2×10^{1}	2.9×10^{-1}	7.1×10^{1}	1.9×10^{-1}
STTS-West	1.8	3.7×10^{-3}	1.7×10^{-1}	2.1×10^{-3}	1.6	4.0×10^{-3}
Total	**5.6×10^{2}**	**1.2**	**9.3×10^{1}**	**1.2**	**4.7×10^{2}**	**1.3**

Table J–20. Tank Closure Alternatives – Total, Low-Income, and Non-Low-Income Population and Individual Average Doses *(continued)*

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 6A, Option Case						
WTP	4.6×10^{2}	1.0	7.0×10^{1}	9.1×10^{-1}	3.9×10^{2}	1.1
STTS-East	1.5×10^{2}	3.3×10^{-1}	3.9×10^{1}	5.0×10^{-1}	1.1×10^{2}	3.0×10^{-1}
STTS-West	1.5×10^{2}	3.1×10^{-1}	5.4	6.7×10^{-2}	1.4×10^{2}	3.5×10^{-1}
Total	**7.6×10^{2}**	**1.7**	**1.1×10^{2}**	**1.5**	**6.5×10^{2}**	**1.7**
Alternative 6B, Base Case						
WTP	4.5×10^{2}	1.0	6.8×10^{1}	8.8×10^{-1}	3.8×10^{2}	1.0
STTS-East	7.5×10^{1}	1.7×10^{-1}	2.0×10^{1}	2.5×10^{-1}	5.5×10^{1}	1.5×10^{-1}
STTS-West	7.5×10^{1}	1.5×10^{-1}	2.2	2.8×10^{-2}	7.3×10^{1}	1.8×10^{-1}
Total	**6.0×10^{2}**	**1.3**	**8.9×10^{1}**	**1.2**	**5.1×10^{2}**	**1.4**
Alternative 6B, Option Case						
WTP	4.5×10^{2}	1.0	6.8×10^{1}	8.8×10^{-1}	3.8×10^{2}	1.0
STTS-East	1.3×10^{2}	2.9×10^{-1}	3.6×10^{1}	4.6×10^{-1}	9.6×10^{1}	2.6×10^{-1}
STTS-West	1.3×10^{2}	2.7×10^{-1}	2.8	3.5×10^{-2}	1.3×10^{2}	3.1×10^{-1}
Total	**7.1×10^{2}**	**1.6**	**1.1×10^{2}**	**1.4**	**6.0×10^{2}**	**1.6**
Alternative 6C						
WTP	4.5×10^{2}	1.0	6.8×10^{1}	8.8×10^{-1}	3.8×10^{2}	1.0
STTS-East	6.0	1.3×10^{-2}	8.8×10^{-1}	1.1×10^{-2}	5.1	1.4×10^{-2}
STTS-West	5.7	1.2×10^{-2}	7.9×10^{-1}	9.8×10^{-3}	5.0	1.2×10^{-2}
Total	**4.6×10^{2}**	**1.0**	**6.9×10^{1}**	**9.0×10^{-1}**	**3.9×10^{2}**	**1.1**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

As discussed in Appendix K, Section K.2.1.1.1.1, normal operations would result in impacts on a maximally exposed individual (MEI) directly east of the 200 Areas in most cases and east-southeast along the Ringold section of the Columbia River and across the river from the Hanford 300 Area in a few cases. To explore potential American Indian environmental justice concerns associated with normal operations, impacts on a hypothetical individual residing at the boundary of the Yakama Reservation were evaluated. Table J–21 presents the maximum annual dose and cancer fatality risk to an MEI located there.

The results of this analysis show that the probability for an individual at this location to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the maximum annual dose to an MEI residing at the reservation boundary would be approximately one order of magnitude less than the maximum annual dose to an MEI at the Hanford boundary.

Table J–21. Tank Closure Alternatives – Maximum Annual Dose and Risk to the Maximally Exposed Individual Located at the Boundary of the Yakama Reservation

Alternative	WTP	STTS-East	STTS-West	Total	Risk[a]
	Dose (millirem)				
1	0	3.6×10^{-3}	4.2×10^{-3}	7.9×10^{-3}	5×10^{-9}
2A	1.3×10^{-1}	5.5×10^{-10}	0	1.3×10^{-1}	8×10^{-8}
2B	1.6×10^{-1}	2.8×10^{-4}	3.2×10^{-4}	1.6×10^{-1}	1×10^{-7}
3A	1.3×10^{-1}	1.0×10^{-3}	1.1×10^{-3}	1.3×10^{-1}	8×10^{-8}
3B	1.3×10^{-1}	9.5×10^{-8}	3.0×10^{-6}	1.3×10^{-1}	8×10^{-8}
3C	1.3×10^{-1}	1.0×10^{-3}	1.1×10^{-3}	1.3×10^{-1}	8×10^{-8}
4	1.3×10^{-1}	3.1×10^{-5}	3.6×10^{-5}	1.3×10^{-1}	8×10^{-8}
5	1.3×10^{-1}	4.6×10^{-8}	1.4×10^{-3}	1.3×10^{-1}	8×10^{-8}
6A Base	1.3×10^{-1}	1.4×10^{-4}	1.4×10^{-4}	1.3×10^{-1}	8×10^{-8}
6A Option	1.3×10^{-1}	2.2×10^{-4}	2.3×10^{-4}	1.3×10^{-1}	8×10^{-8}
6B Base	1.5×10^{-1}	2.1×10^{-3}	2.1×10^{-3}	1.6×10^{-1}	9×10^{-8}
6B Option	1.5×10^{-1}	3.1×10^{-3}	3.0×10^{-3}	1.6×10^{-1}	1×10^{-7}
6C	1.5×10^{-1}	2.8×10^{-4}	3.2×10^{-4}	1.5×10^{-1}	9×10^{-8}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem (DOE 2003).

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–22 presents the dose and cancer fatality risk over the lifetime of the project to an MEI located at the boundary of the Yakama Reservation.

Table J–22. Tank Closure Alternatives – Dose and Risk to the Maximally Exposed Individual Located at the Boundary of the Yakama Reservation Over the Life of the Project

Alternative	Duration of Exposure (years)	WTP	STTS-East	STTS-West	Total	Risk[a]
		Dose (millirem)				
1	102	0	3.4×10^{-1}	3.9×10^{-1}	7.3×10^{-1}	4×10^{-7}
2A	188	8.4×10^{-1}	3.6×10^{-1}	4.2×10^{-1}	1.6	1×10^{-6}
2B	40	7.4×10^{-1}	8.1×10^{-3}	9.5×10^{-3}	7.6×10^{-1}	5×10^{-7}
3A	37	6.5×10^{-1}	2.3×10^{-1}	2.6×10^{-1}	1.1	7×10^{-7}
3B	37	6.5×10^{-1}	1.1×10^{-2}	1.1×10^{-2}	6.8×10^{-1}	4×10^{-7}
3C	37	6.5×10^{-1}	2.3×10^{-1}	2.6×10^{-1}	1.1	7×10^{-7}
4	40	6.6×10^{-1}	1.8×10^{-2}	2.7×10^{-1}	9.5×10^{-1}	6×10^{-7}
5	31	6.6×10^{-1}	9.3×10^{-3}	2.4×10^{-1}	9.1×10^{-1}	5×10^{-7}
6A Base	163	7.6×10^{-1}	1.2×10^{-1}	2.7×10^{-3}	8.8×10^{-1}	5×10^{-7}
6A Option	163	8.7×10^{-1}	2.2×10^{-1}	2.5×10^{-1}	1.3	8×10^{-7}
6B Base	95	8.4×10^{-1}	1.2×10^{-1}	1.4×10^{-1}	1.1	7×10^{-7}
6B Option	95	8.4×10^{-1}	1.8×10^{-1}	2.1×10^{-1}	1.2	7×10^{-7}
6C	40	7.3×10^{-1}	8.1×10^{-3}	9.5×10^{-3}	7.5×10^{-1}	4×10^{-7}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem **(**DOE 2003).

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

The results of this analysis show that the probability for an individual at this location to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the dose to an MEI residing at the reservation boundary over the life of the project would be approximately one order of magnitude less than the dose to an MEI at the Hanford boundary over the life of the project.

In addition, a scenario was analyzed for an individual living at or near the Hanford boundary who subsists predominantly on the consumption of homegrown produce, animal products from a family farm, and foodstuffs harvested from the wild (e.g., fruits, vegetables, fish, and game) to determine a maximum potential dose. For this scenario, the hypothetical individual was assumed to live at the same location as

the MEI analyzed for the general public and could represent a member of a minority group who lives a subsistence lifestyle. This individual was assumed to get all of his or her food from the sources listed above. It was further conservatively assumed that all food came from an environment that was radiologically contaminated from air deposition. Irrigation water for crops and livestock and drinking water was assumed to come from radiologically contaminated surface waters. In contrast, the general population MEI was assumed to consume only a portion of his or her diet from regional food contaminated by radiological emissions. Table J–23 presents comparative data on the food consumption rates for the subsistence consumer and the general population MEI.

Table J–23. Comparative Food Consumption Rates for Subsistence Consumer and the General Population Maximally Exposed Individual

Ingestion Exposure Pathway	General Population MEI[a] (kilograms per year except as noted)	Subsistence Consumer (kilograms per year except as noted)	Reference
Leafy vegetable	65	65	Beyeler et al. 1999; DOE and Ecology 1996
Other vegetable	120	120	DOE 1995; DOE and Ecology 1996
Fruit	120	120	DOE 1995; DOE and Ecology 1996
Grain	90	90	Beyeler et al. 1999
Meat/game	27.8	125	DOE 1995; DOE and Ecology 1996
Eggs	19	19	Beyeler et al. 1999
Fish	0	62	EPA 1997
Dairy	110 liters	219 liters	DOE 1995; DOE and Ecology 1996
Surface water	0	730 liters	DOE 1995

[a] From Appendix K of this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Note: To convert kilograms to pounds, multiply by 2.2046; liters to gallons, by 0.26417.

Key: MEI=maximally exposed individual.

For the purposes of analysis and comparison, the dose to this subsistence consumer was analyzed for radiological airborne releases under Alternative 2B, which resulted in the highest MEI dose of 1.7 millirem in the year of maximum impact. This dose would only be applicable to the one year in which cesium and strontium capsules are processed. The dose to this individual exposed to the same releases under Alternative 2B for the whole year would be 3.1 millirem. Both of these doses are well below the National Emission Standards for Hazardous Air Pollutants limit of 10 millirem per year (40 CFR 61.90–61.97). Considering that both the MEI and this individual would also be receiving a dose in excess of 300 millirem per year from natural background radiation, there would be no appreciable differences between these two doses. The alternatives analyzed in this EIS would therefore not pose a disproportionately high and adverse impact on an individual with a subsistence diet.

Appendix K, Section K.3.4 discusses the radiological and chemical consequences of facility accidents under each Tank Closure alternative. Examination of the risks under each alternative shows that there would be essentially no LCFs per year for the offsite population, including minority and low-income populations, from radiological emissions. Hazardous chemical impacts are not expected to affect offsite populations. Therefore, these alternatives would not pose disproportionately high and adverse impacts on the minority and low-income populations.

J.5.6.1.2 FFTF Decommissioning Alternatives

Table J–24 compares average individual doses to minority and nonminority populations under each FFTF Decommissioning alternative to examine the potential for disproportionately high and adverse impacts. The Idaho Option under Alternatives 2 and 3 would result in the average dose to a minority individual slightly exceeding the average dose to a nonminority individual. However, the values show that there are no appreciable differences between average doses. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–24. FFTF Decommissioning Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	9.9×10^{-4}	7.5×10^{-6}	2.3×10^{-3}	1.0×10^{-5}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	2.9×10^{-5}	1.6×10^{-7}	6.1×10^{-5}	2.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{1.0\times10^{-3}}$	$\mathbf{7.6\times10^{-6}}$	$\mathbf{2.4\times10^{-3}}$	$\mathbf{1.0\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	3.0×10^{-7}	2.3×10^{-9}	7.0×10^{-7}	3.1×10^{-9}
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	2.8×10^{-5}	1.1×10^{-6}	1.9×10^{-4}	1.0×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{2.9\times10^{-5}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{1.9\times10^{-4}}$	$\mathbf{1.0\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	9.9×10^{-4}	7.5×10^{-6}	2.3×10^{-3}	1.0×10^{-5}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	2.9×10^{-5}	1.6×10^{-7}	6.1×10^{-5}	2.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{1.0\times10^{-3}}$	$\mathbf{7.6\times10^{-6}}$	$\mathbf{2.4\times10^{-3}}$	$\mathbf{1.0\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	2.8×10^{-5}	1.1×10^{-6}	1.9×10^{-4}	1.0×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{2.8\times10^{-5}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{1.9\times10^{-4}}$	$\mathbf{1.0\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–25 compares average individual doses to American Indian and non–American Indian populations under each FFTF Decommissioning alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–25. FFTF Decommissioning Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	2.9×10^{-5}	5.4×10^{-6}	3.3×10^{-3}	9.3×10^{-6}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	1.1×10^{-6}	1.1×10^{-7}	8.9×10^{-5}	1.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{3.0\times10^{-5}}$	$\mathbf{5.5\times10^{-6}}$	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.5\times10^{-6}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	8.8×10^{-9}	1.6×10^{-9}	9.9×10^{-7}	2.8×10^{-9}
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	5.0×10^{-6}	1.0×10^{-6}	2.1×10^{-4}	1.1×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{5.0\times10^{-6}}$	$\mathbf{1.0\times10^{-6}}$	$\mathbf{2.1\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	2.9×10^{-5}	5.4×10^{-6}	3.3×10^{-3}	9.3×10^{-6}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	1.1×10^{-6}	1.1×10^{-7}	8.9×10^{-5}	1.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{3.0\times10^{-5}}$	$\mathbf{5.5\times10^{-6}}$	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.5\times10^{-6}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	5.0×10^{-6}	1.0×10^{-6}	2.1×10^{-4}	1.1×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{5.0\times10^{-6}}$	$\mathbf{1.0\times10^{-6}}$	$\mathbf{2.1\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–26 compares average individual doses to Hispanic and non-Hispanic populations under each FFTF Decommissioning alternative to examine the potential for disproportionately high and adverse impacts. The Idaho Option under Alternatives 2 and 3 would result in the average dose to a Hispanic individual slightly exceeding the average dose to a non-Hispanic individual. However, the values show that there are no appreciable differences between average doses. Therefore, these alternatives would not pose disproportionately high and adverse impacts on Hispanic or Latino populations surrounding each facility site.

Table J–26. FFTF Decommissioning Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	8.0×10^{-4}	7.1×10^{-6}	2.5×10^{-3}	1.0×10^{-5}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	2.4×10^{-5}	1.6×10^{-7}	6.6×10^{-5}	2.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{8.2\times10^{-4}}$	$\mathbf{7.2\times10^{-6}}$	$\mathbf{2.6\times10^{-3}}$	$\mathbf{1.0\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	2.4×10^{-7}	2.1×10^{-9}	7.6×10^{-7}	3.1×10^{-9}
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.0×10^{-6}	2.0×10^{-5}	1.2×10^{-6}	2.0×10^{-4}	1.0×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.0\times10^{-6}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{1.2\times10^{-6}}$	$\mathbf{2.0\times10^{-4}}$	$\mathbf{1.0\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	8.0×10^{-4}	7.1×10^{-6}	2.5×10^{-3}	1.0×10^{-5}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	2.4×10^{-5}	1.6×10^{-7}	6.6×10^{-5}	2.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{8.2\times10^{-4}}$	$\mathbf{7.2\times10^{-6}}$	$\mathbf{2.6\times10^{-3}}$	$\mathbf{1.0\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	2.0×10^{-5}	1.2×10^{-6}	2.0×10^{-4}	1.0×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{1.2\times10^{-6}}$	$\mathbf{2.0\times10^{-4}}$	$\mathbf{1.0\times10^{-6}}$

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–27 compares average individual doses to low-income and non-low-income populations under each FFTF Decommissioning alternative to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to a low-income individual and a non-low-income individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–27. FFTF Decommissioning Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	4.3×10^{-4}	7.7×10^{-6}	2.9×10^{-3}	9.5×10^{-6}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	1.2×10^{-5}	1.5×10^{-7}	7.8×10^{-5}	1.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{4.4\times10^{-4}}$	$\mathbf{7.9\times10^{-6}}$	$\mathbf{3.0\times10^{-3}}$	$\mathbf{9.7\times10^{-6}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	1.3×10^{-7}	2.4×10^{-9}	8.7×10^{-7}	2.9×10^{-9}
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	2.9×10^{-5}	1.0×10^{-6}	1.9×10^{-4}	1.1×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{2.9\times10^{-5}}$	$\mathbf{1.0\times10^{-6}}$	$\mathbf{1.9\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	3.3×10^{-3}	9.2×10^{-6}	4.3×10^{-4}	7.7×10^{-6}	2.9×10^{-3}	9.5×10^{-6}
200-West Area	9.0×10^{-5}	1.8×10^{-7}	1.2×10^{-5}	1.5×10^{-7}	7.8×10^{-5}	1.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{3.4\times10^{-3}}$	$\mathbf{9.4\times10^{-6}}$	$\mathbf{4.4\times10^{-4}}$	$\mathbf{7.9\times10^{-6}}$	$\mathbf{3.0\times10^{-3}}$	$\mathbf{9.7\times10^{-6}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	2.2×10^{-4}	1.1×10^{-6}	2.9×10^{-5}	1.6×10^{-6}	1.9×10^{-4}	1.1×10^{-6}
Total	$\mathbf{2.2\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{2.9\times10^{-5}}$	$\mathbf{1.6\times10^{-6}}$	$\mathbf{1.9\times10^{-4}}$	$\mathbf{1.1\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–28 compares average individual doses to minority and nonminority populations under each FFTF Decommissioning alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. The Idaho Option under Alternatives 2 and 3 would result in the average dose to a minority individual slightly exceeding the average dose to a nonminority individual. However, the values show that there are no appreciable differences between average doses. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–28. FFTF Decommissioning Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	2.2×10^{-3}	1.6×10^{-5}	5.0×10^{-3}	2.2×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	4.3×10^{-5}	2.4×10^{-7}	9.7×10^{-5}	3.1×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{2.2\times10^{-3}}$	$\mathbf{1.7\times10^{-5}}$	$\mathbf{5.1\times10^{-3}}$	$\mathbf{2.3\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	3.0×10^{-7}	2.3×10^{-9}	7.0×10^{-7}	3.1×10^{-9}
200-Area West	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	5.8×10^{-5}	2.3×10^{-6}	3.7×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{5.9\times10^{-5}}$	$\mathbf{2.3\times10^{-6}}$	$\mathbf{3.7\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	2.2×10^{-3}	1.6×10^{-5}	5.0×10^{-3}	2.2×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	4.3×10^{-5}	2.4×10^{-7}	9.7×10^{-5}	3.1×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{2.2\times10^{-3}}$	$\mathbf{1.7\times10^{-5}}$	$\mathbf{5.1\times10^{-3}}$	$\mathbf{2.3\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	5.8×10^{-5}	2.3×10^{-6}	3.7×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{5.8\times10^{-5}}$	$\mathbf{2.3\times10^{-6}}$	$\mathbf{3.7\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–29 compares average individual doses to American Indian and non–American Indian populations under each FFTF Decommissioning alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–29. FFTF Decommissioning Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	6.4×10^{-5}	1.2×10^{-5}	7.1×10^{-3}	2.0×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	1.7×10^{-6}	1.6×10^{-7}	1.4×10^{-4}	2.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{6.5\times10^{-5}}$	$\mathbf{1.2\times10^{-5}}$	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.1\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	8.8×10^{-9}	1.6×10^{-9}	9.9×10^{-7}	2.8×10^{-9}
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	1.0×10^{-5}	2.1×10^{-6}	4.2×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{1.0\times10^{-5}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{4.2\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	6.3×10^{-5}	1.2×10^{-5}	7.1×10^{-3}	2.0×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	1.7×10^{-6}	1.6×10^{-7}	1.4×10^{-4}	2.9×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{6.5\times10^{-5}}$	$\mathbf{1.2\times10^{-5}}$	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.1\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	1.0×10^{-5}	2.1×10^{-6}	4.2×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{1.0\times10^{-5}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{4.2\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–30 compares average individual doses to Hispanic and non-Hispanic populations under each FFTF Decommissioning alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. The Idaho Option under Alternatives 2 and 3 would result in the average dose to a Hispanic individual slightly exceeding the average dose to a non-Hispanic individual. However, the values show that there are no appreciable differences between average doses. Therefore, these alternatives would not pose disproportionately high and adverse impacts on Hispanic or Latino populations surrounding each facility site.

Table J–30. FFTF Decommissioning Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	1.8×10^{-3}	1.6×10^{-5}	5.4×10^{-3}	2.2×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	3.6×10^{-5}	2.4×10^{-7}	1.0×10^{-4}	3.1×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{1.8\times10^{-3}}$	$\mathbf{1.6\times10^{-5}}$	$\mathbf{5.6\times10^{-3}}$	$\mathbf{2.3\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	2.4×10^{-7}	2.1×10^{-9}	7.6×10^{-7}	3.1×10^{-9}
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	4.1×10^{-5}	2.5×10^{-6}	3.9×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{4.1\times10^{-5}}$	$\mathbf{2.5\times10^{-6}}$	$\mathbf{3.9\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	1.8×10^{-3}	1.6×10^{-5}	5.4×10^{-3}	2.2×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	3.6×10^{-5}	2.4×10^{-7}	1.0×10^{-4}	3.1×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{1.8\times10^{-3}}$	$\mathbf{1.6\times10^{-5}}$	$\mathbf{5.6\times10^{-3}}$	$\mathbf{2.3\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	4.1×10^{-5}	2.5×10^{-6}	3.9×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{4.1\times10^{-5}}$	$\mathbf{2.5\times10^{-6}}$	$\mathbf{3.9\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–31 compares average individual doses to low-income and non-low-income populations under each FFTF Decommissioning alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. The Idaho Option under Alternatives 2 and 3 would result in the average dose to a low-income individual slightly exceeding the average dose to a non-low-income individual. However, the values show that there are no appreciable differences between average doses. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–31. FFTF Decommissioning Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	9.4×10^{-4}	1.7×10^{-5}	6.3×10^{-3}	2.1×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	1.8×10^{-5}	2.3×10^{-7}	1.2×10^{-4}	3.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{9.6\times10^{-4}}$	$\mathbf{1.7\times10^{-5}}$	$\mathbf{6.4\times10^{-3}}$	$\mathbf{2.1\times10^{-5}}$
Alternative 2 Idaho National Laboratory						
FFTF	1.0×10^{-6}	2.8×10^{-9}	1.3×10^{-7}	2.4×10^{-9}	8.7×10^{-7}	2.9×10^{-9}
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	5.9×10^{-5}	2.2×10^{-6}	3.7×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{6.0\times10^{-5}}$	$\mathbf{2.2\times10^{-6}}$	$\mathbf{3.7\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$
Alternative 3 Hanford Site						
FFTF	7.2×10^{-3}	2.0×10^{-5}	9.3×10^{-4}	1.7×10^{-5}	6.3×10^{-3}	2.1×10^{-5}
200-West Area	1.4×10^{-4}	2.9×10^{-7}	1.8×10^{-5}	2.3×10^{-7}	1.2×10^{-4}	3.0×10^{-7}
INL	0	0	0	0	0	0
Total	$\mathbf{7.3\times10^{-3}}$	$\mathbf{2.0\times10^{-5}}$	$\mathbf{9.6\times10^{-4}}$	$\mathbf{1.7\times10^{-5}}$	$\mathbf{6.4\times10^{-3}}$	$\mathbf{2.1\times10^{-5}}$
Alternative 3 Idaho National Laboratory						
FFTF	0	0	0	0	0	0
200-West Area	0	0	0	0	0	0
INL	4.3×10^{-4}	2.1×10^{-6}	5.9×10^{-5}	2.1×10^{-6}	3.7×10^{-4}	2.1×10^{-6}
Total	$\mathbf{4.3\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{5.9\times10^{-5}}$	$\mathbf{2.1\times10^{-6}}$	$\mathbf{3.7\times10^{-4}}$	$\mathbf{2.1\times10^{-6}}$

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory.

Table J–32 presents the maximum annual dose and cancer fatality risk to an MEI located at the appropriate reservation boundary. The results of this analysis show that the probability of such an individual to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the maximum annual dose to an MEI residing at a reservation boundary would be approximately one order of magnitude less than the maximum annual dose to an MEI at each respective site boundary under all FFTF Decommissioning alternatives.

Appendix K, Section K.2.2.1.1 discusses the approach used to model the FFTF Decommissioning alternatives. The same MEIs modeled under the Tank Closure alternatives are used for emissions from the 200 Area. An offsite MEI was identified for emissions from the 400 Area. This MEI is located to the southeast, across the river from the 300 Area. Similar to the Tank Closure alternatives, an MEI at the boundary of the Yakama Reservation is analyzed to explore potential environmental justice concerns surrounding Hanford. Some FFTF Decommissioning alternatives include options to process materials at the INL MFC. An offsite MEI from this location is identified to be south-southeast of the MFC. To explore potential American Indian environmental justice concerns associated with normal operations under these alternatives, impacts to a hypothetical individual residing at the boundary of the Fort Hall Reservation were evaluated.

Table J–32. FFTF Decommissioning Alternatives – Maximum Annual Dose and Risk to a Maximally Exposed Individual Located at the Appropriate Reservation Boundary

	Yakama Reservation				Fort Hall Reservation	
	FFTF	STTS-West	Hanford Site Total	Risk[a]	INL	Risk[a]
Alternative	Dose (millirem)					
1	0	0	0	0	0	0
2 Hanford Site	3.0×10^{-6}	1.6×10^{-7}	3.1×10^{-6}	1.9×10^{-12}	0	0
2 INL	7.9×10^{-10}	0	7.9×10^{-10}	4.7×10^{-16}	2.9×10^{-6}	2.0×10^{-12}
3 Hanford Site	3.0×10^{-6}	1.6×10^{-7}	3.1×10^{-6}	1.9×10^{-12}	0	0
3 INL	0	0	0	0	2.9×10^{-6}	2.0×10^{-12}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem (DOE 2003).

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; STTS-West=200-West Area Supplemental Treatment Technology Site.

Table J–33 presents the dose and cancer fatality risk over the lifetime of the project to an MEI located at the appropriate reservation boundary. The results of this analysis show that the probability of such an individual to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the dose to an MEI residing at a reservation boundary over the life of the project would be approximately one order of magnitude less than the dose to an MEI at each respective site boundary over the life of the project.

Table J–33. FFTF Decommissioning Alternatives – Dose and Risk to a Maximally Exposed Individual Located at the Appropriate Reservation Boundary Over the Life of the Project

Alternative	Duration of Exposure (years)	Yakama Reservation				Fort Hall Reservation	
		FFTF	STTS-West	Hanford Total	Risk[a]	INL	Risk[a]
		Dose (millirem)					
1	0[b]	0	0	0	0	0	0
2 Hanford Site	3	6.6×10^{-6}	2.4×10^{-7}	6.8×10^{-6}	4.1×10^{-12}	0	0
2 INL	4	7.9×10^{-10}	0	7.9×10^{-10}	4.7×10^{-16}	5.9×10^{-6}	3.5×10^{-12}
3 Hanford Site	3	6.6×10^{-6}	2.4×10^{-7}	6.8×10^{-6}	4.1×10^{-12}	0	0
3 INL	4	0	0	0	0	5.9×10^{-6}	3.5×10^{-12}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem (DOE 2003).

[b] There would be no incremental radiological air releases above current facility operations reported as part of the baseline in the affected environment section of this *TC & WM EIS*.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; STTS-West=200-West Area Supplemental Treatment Technology Site.

Appendix K, Section K.3.5 discusses the radiological and chemical consequences of facility accidents under each FFTF Decommissioning alternative. Examination of the risks under each alternative shows that there would be essentially no LCFs per year for the offsite population, including minority and low-income populations, due to radiological emissions. The most severe chemical impacts would be the result of a Hanford sodium storage tank failure scenario, which could result in a hazardous plume slightly exceeding the site boundary to the east of the 400 Area; however it is not be expected to reach the far side of the Columbia River. The potentially affected area is located in Franklin County, Washington, census tract 206.01, block group 2. This block group has not been identified to contain minority or low-income populations. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority or low-income populations.

J.5.6.1.3 Waste Management Alternatives

Table J–34 compares average individual doses to minority and nonminority populations under each Waste Management alternative to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to a minority individual and a nonminority individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–34. Waste Management Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	5.6×10^{-6}	3.1×10^{-8}	1.2×10^{-5}	4.0×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**5.6×10^{-6}**	**3.1×10^{-8}**	**1.2×10^{-5}**	**4.0×10^{-8}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	5.6×10^{-6}	3.1×10^{-8}	1.2×10^{-5}	4.0×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**5.6×10^{-6}**	**3.1×10^{-8}**	**1.2×10^{-5}**	**4.0×10^{-8}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–35 compares average individual doses to American Indian and non–American Indian populations under each Waste Management alternative to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–35. Waste Management Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non-American Indian Population Dose (person-rem)	Non-American Indian Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	2.2×10^{-7}	2.1×10^{-8}	1.8×10^{-5}	3.7×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**2.2×10^{-7}**	**2.1×10^{-8}**	**1.8×10^{-5}**	**3.7×10^{-8}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	2.2×10^{-7}	2.1×10^{-8}	1.8×10^{-5}	3.7×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**2.2×10^{-7}**	**2.1×10^{-8}**	**1.8×10^{-5}**	**3.7×10^{-8}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–36 compares average individual doses to Hispanic and non-Hispanic populations under each Waste Management alternative to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to a Hispanic individual and a non-Hispanic individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on Hispanic or Latino populations surrounding each facility site.

Table J–36. Waste Management Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	4.6×10^{-6}	3.1×10^{-8}	1.3×10^{-5}	4.0×10^{-8}
Total	$\mathbf{1.8\times10^{-5}}$	$\mathbf{3.7\times10^{-8}}$	$\mathbf{4.6\times10^{-6}}$	$\mathbf{3.1\times10^{-8}}$	$\mathbf{1.3\times10^{-5}}$	$\mathbf{4.0\times10^{-8}}$
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×1^{-8}	4.6×10^{-6}	3.1×10^{-8}	1.3×10^{-5}	4.0×10^{-8}
Total	$\mathbf{1.8\times10^{-5}}$	$\mathbf{3.7\times1^{-8}}$	$\mathbf{4.6\times10^{-6}}$	$\mathbf{3.1\times10^{-8}}$	$\mathbf{1.3\times10^{-5}}$	$\mathbf{4.0\times10^{-8}}$

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–37 compares average individual doses to low-income and non-low-income populations under each Waste Management alternative to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to a low-income individual and a non-low-income individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–37. Waste Management Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses in Year of Maximum Impact

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0.	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	2.3×10^{-6}	2.9×10^{-8}	1.6×10^{-5}	3.8×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**2.3×10^{-6}**	**2.9×10^{-8}**	**1.6×10^{-5}**	**3.8×10^{-8}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	1.8×10^{-5}	3.7×10^{-8}	2.3×10^{-6}	2.9×10^{-8}	1.6×10^{-5}	3.8×10^{-8}
Total	**1.8×10^{-5}**	**3.7×10^{-8}**	**2.3×10^{-6}**	**2.9×10^{-8}**	**1.6×10^{-5}**	**3.8×10^{-8}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–38 compares the average individual doses to minority and nonminority populations under each Waste Management alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to a minority individual and a nonminority individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority populations surrounding each facility site.

Table J–38. Waste Management Alternatives – Total, Minority, and Nonminority Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Minority Population Dose (person-rem)	Minority Individual Average Dose (millirem)	Nonminority Population Dose (person-rem)	Nonminority Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	2.1×10^{-4}	1.2×10^{-6}	4.6×10^{-4}	1.5×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**2.1×10^{-4}**	**1.2×10^{-6}**	**4.6×10^{-4}**	**1.5×10^{-6}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	2.1×10^{-4}	1.2×10^{-6}	4.6×10^{-4}	1.5×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**2.1×10^{-4}**	**1.2×10^{-6}**	**4.6×10^{-4}**	**1.5×10^{-6}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–39 compares the average individual doses to American Indian and non–American Indian populations under each Waste Management alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to an American Indian individual and a non–American Indian individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–39. Waste Management Alternatives – Total, American Indian, and Non–American Indian Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	American Indian Population Dose (person-rem)	American Indian Individual Average Dose (millirem)	Non–American Indian Population Dose (person-rem)	Non–American Indian Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	8.3×10^{-6}	8.0×10^{-7}	6.6×10^{-4}	1.4×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**8.3×10^{-6}**	**8.0×10^{-7}**	**6.6×10^{-4}**	**1.4×10^{-6}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0.	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	8.3×10^{-6}	8.0×10^{-7}	6.6×10^{-4}	1.4×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**8.3×10^{-6}**	**8.0×10^{-7}**	**6.6×10^{-4}**	**1.4×10^{-6}**

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–40 compares the average individual doses to Hispanic and non-Hispanic populations under each Waste Management alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of the disposal groups. There are no appreciable differences between the average dose to a Hispanic individual and a non-Hispanic individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on American Indian populations surrounding each facility site.

Table J–40. Waste Management Alternatives – Total, Hispanic, and Non-Hispanic Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Hispanic Population Dose[a] (person-rem)	Hispanic Individual Average Dose[a] (millirem)	Non-Hispanic Population Dose (person-rem)	Non-Hispanic Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	1.8×10^{-4}	1.2×10^{-6}	4.9×10^{-4}	1.5×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**1.8×10^{-4}**	**1.2×10^{-6}**	**4.9×10^{-4}**	**1.5×10^{-6}**
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	1.8×10^{-4}	1.2×10^{-6}	4.9×10^{-4}	1.5×10^{-6}
Total	**6.7×10^{-4}**	**1.4×10^{-6}**	**1.8×10^{-4}**	**1.2×10^{-6}**	**4.9×10^{-4}**	**1.5×10^{-6}**

[a] Includes all individuals, regardless of race, who identified themselves as Hispanic or Latino.

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–41 compares the average individual doses to low-income and non-low-income populations under each Waste Management alternative over the lifetime of the project to examine the potential for disproportionately high and adverse impacts. These impacts would be the same regardless of disposal group. There are no appreciable differences between the average dose to a low-income individual and a non-low-income individual under any of the alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on low-income populations surrounding each facility site.

Table J–41. Waste Management Alternatives – Total, Low-Income, and Non-Low-Income Population and Average Individual Doses Over the Life of the Project

Facility Site	Total Population Dose (person-rem)	Individual Average Dose (millirem)	Low-Income Population Dose (person-rem)	Low-Income Individual Average Dose (millirem)	Non-Low-Income Population Dose (person-rem)	Non-Low-Income Individual Average Dose (millirem)
Alternative 1						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Alternative 2						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	8.9×10^{-5}	1.1×10^{-6}	5.8×10^{-4}	1.4×10^{-6}
Total	$\mathbf{6.7\times10^{-4}}$	$\mathbf{1.4\times10^{-6}}$	$\mathbf{8.9\times10^{-5}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{5.8\times10^{-4}}$	$\mathbf{1.4\times10^{-6}}$
Alternative 3						
WTP	0	0	0	0	0	0
STTS-East	0	0	0	0	0	0
STTS-West	6.7×10^{-4}	1.4×10^{-6}	8.9×10^{-5}	1.1×10^{-6}	5.8×10^{-4}	1.4×10^{-6}
Total	$\mathbf{6.7\times10^{-4}}$	$\mathbf{1.4\times10^{-6}}$	$\mathbf{8.9\times10^{-5}}$	$\mathbf{1.1\times10^{-6}}$	$\mathbf{5.8\times10^{-4}}$	$\mathbf{1.4\times10^{-6}}$

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–42 presents the maximum annual dose and cancer fatality risk to an MEI located at the boundary of the Yakama Reservation. The results of this analysis show that the probability of an individual at this location to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the maximum annual dose to a MEI residing at the reservation boundary would be approximately one order of magnitude less than the maximum annual dose to an MEI at the Hanford boundary under all Waste Management alternatives.

Table J–42. Waste Management Alternatives – Maximum Annual Dose and Risk to the Maximally Exposed Individual at the Boundary of the Yakama Reservation

Alternative	WTP	STTS-East	STTS-West	Total	Risk[a]
	Dose (millirem)				
1	0	0	0	0	0
2	0	0	2.1×10^{-8}	2.1×10^{-8}	1×10^{-14}
3	0	0	2.1×10^{-8}	2.1×10^{-8}	1×10^{-14}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem (DOE 2003).

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table J–43 presents the dose and cancer fatality risk over the lifetime of the project to an MEI located at the boundary of the Yakama Reservation. The results of this analysis show that the probability of an individual at this location to develop an LCF from radioactive releases during normal operations would essentially be zero. In addition, the dose to an MEI residing at the reservation boundary over the life of the project would be approximately one order of magnitude less than the dose to an MEI at the Hanford boundary over the life of the project under all Waste Management alternatives.

Table J–43. Waste Management Alternatives – Dose and Risk to the Maximally Exposed Individual Located at the Boundary of the Yakama Reservation Over the Life of the Project

Alternative	Duration of Exposure (years)	WTP	STTS-East	STTS-West	Total	Risk[a]
		Dose (millirem)				
1	0[b]	0	0	0	0	0
2	39	0	0	8.1×10^{-7}	8.1×10^{-7}	5×10^{-13}
3	39	0	0	8.1×10^{-7}	8.1×10^{-7}	5×10^{-13}

[a] Cancer risk is the probability of developing a latent cancer fatality, which is estimated by multiplying the dose by the risk factor of 0.0006 latent cancer fatalities per rem (DOE 2003).

[b] There would be no incremental radiological air releases above current facility operations reported as part of the baseline in the affected environment section of this *TC & WM EIS*.

Key: STTS-East=200-East Area Supplemental Treatment Technology Site; STTS-West=200-West Area Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Appendix K, Section K.3.6 discusses the radiological and chemical consequences of facility accidents under each Waste Management alternative. Examination of the risks under each alternative shows that there would be essentially no LCFs per year for the offsite population, including minority and low-income populations due to radiological emissions. Potential risks from hazardous chemical impacts from reasonably foreseeable accidents would be encompassed by those discussed in Section J.5.6.2.2 under the FFTF Decommissioning alternatives. Therefore, these alternatives would not pose disproportionately high and adverse impacts on minority or low-income populations.

J.5.6.2 Air Quality

Air quality impacts were not analyzed separately for each subset population because the results would be similar to those for radiological impacts (see Section J.5.6.2); because there were no disproportionately high and adverse health or environmental impacts on minority, American Indian, Hispanic, or low-income populations due to radiological air releases during normal operations, the same would be true for nonradioactive air emissions.

J.5.6.3 Groundwater Resources: Long-Term Human Health Impacts

Appendix Q, Section Q.3 evaluated groundwater impacts and associated potential long-term human health effects for each Tank Closure, FFTF Decommissioning, and Waste Management alternative. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differs from that of the American Indian resident farmer. The American Indian hunter-gatherer does not cultivate crops but gathers food from indigenous plants, harvests fish from the Columbia River, and is exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix O, Section O.1.2.2 and Appendix Q, Section Q.2.2.

J.5.6.3.1 Tank Closure Alternatives

Results of the analysis of groundwater contamination under the Tank Closure alternatives for the American Indian receptors are presented in Appendix Q, Tables Q–20 through Q–208. Long-term human health impacts of Tank Closure actions would be greatest under Tank Closure Alternative 1. Radiological releases under this alternative would result in the doses at the A and B Barriers and the Core Zone Boundary exceeding regulatory limits for the resident farmer, American Indian resident farmer, and the American Indian hunter-gatherer; the dose at the S Barrier would exceed regulatory limits for the American Indian resident farmer and American Indian hunter-gatherer; at the T Barrier, for the American Indian hunter-gatherer. None of the hypothetical receptors at the Columbia River nearshore or surface-water locations would be exposed to a dose in excess of regulatory limits. Nonradiological releases under this alternative would result in exceedance of the Hazard Index for chromium and nitrate at all onsite locations analyzed for the resident farmer, American Indian resident farmer, and American Indian hunter-gatherer. The analysis determined that the greatest impact of any alternative on long-term human health would result in radiological doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the A, B, S, T, or U Barriers, the Core Zone Boundary, or the Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected within a reasonably foreseeable timeframe because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore location is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the Tank Closure alternatives would pose a disproportionately high and adverse long-term human health risk to the American Indian population at offsite locations. The greatest risk would be to the American Indian resident farmer at the

Core Zone Boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.4 rem. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index greater than 1. The adverse impacts would also be applicable to the non–American Indian receptors at the same locations, but to a lesser extent.

J.5.6.3.2 FFTF Decommissioning Alternatives

Results of the analysis of groundwater contamination under the FFTF Decommissioning alternatives for the American Indian receptors are presented in Appendix Q, Tables Q–213 through Q–218. Long-term human health impacts of FFTF decommissioning actions would be greatest under FFTF Decommissioning Alternative 1. Under this alternative, none of the hypothetical receptors at any of the assessment boundaries would receive a radiological dose in excess of regulatory limits or a chemical exposure with a Hazard Index greater than 1. The greatest risk would be to the American Indian resident farmer at the FFTF boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.8 millirem, compared to the regulatory limit of 100 millirem from all sources. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index less than 1. Therefore, none of the FFTF Decommissioning alternatives would pose a disproportionately high and adverse long-term human health risk to the American Indian population at offsite locations.

J.5.6.3.3 Waste Management Alternatives

Results of the analysis of groundwater contamination under the Waste Management alternatives for the American Indian receptors are presented in Appendix Q, Tables Q–220 through Q–358. Long-term human health impacts of waste management actions would be greatest under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D. Radiological releases under this alternative would result in the doses at the 200-East Area Integrated Disposal Facility (IDF-East) Barrier and the Core Zone Boundary exceeding regulatory limits for the resident farmer and the American Indian resident farmer. None of the hypothetical receptors at the River Protection Project Disposal Facility Barrier, the Columbia River nearshore, or the Columbia River surface-water location would be exposed to a dose in excess of regulatory limits. Nonradiological releases under this alternative would result in exceedance of the Hazard Index for chromium at the IDF-East Barrier, Core Zone Boundary, and Columbia River nearshore for the resident farmer and the American Indian resident farmer. The analysis determined that the greatest impact of any alternative on long-term human health would result in radiological doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the IDF-East Barrier, the Core Zone Boundary, or the Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected within a reasonably foreseeable timeframe because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore location is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the Waste Management alternatives would pose a disproportionately high and adverse long-term human health risk to the American Indian population. The greatest risk would be to the American Indian resident farmer at the IDF-East boundary. During the year of peak dose, this receptor would receive a radiological dose of 281 millirem. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index greater than 1. The adverse impacts would also be applicable to non-American Indian receptors at the same locations, but to a lesser extent.

J.6 REFERENCES

Beyeler, W.E., W.A. Hareland, F.A. Durán, T.J. Brown, E. Kalinina, D.P. Gallegos, and P.A. Davis, 1999, *Residual Radioactive Contamination from Decommissioning, Parameter Analysis, Draft Report for Comment*, NUREG/CR-5512, Vol. 3, U.S. Nuclear Regulatory Commission, Washington, D.C., October.

Census (U.S. Census Bureau), 2007a, *Summary File 1, 2000 Census of Population and Housing: Technical Documentation*, SF1/14 (RV), Washington, D.C., July.

Census (U.S. Census Bureau), 2007b, *Summary File 3, 2000 Census of Population and Housing: Technical Documentation*, SF3/18 (RV), Washington, D.C., July.

Census (U.S. Census Bureau), 2007c, *200 TIGER/Line Files: Technical Documentation*, 2nd ed., Washington, D.C., February.

Census (U.S. Census Bureau), 2007d, *Summary File 1 (SF 1) – 100 Percent Data*, Census 2000 Data Releases, accessed through http://www.census.gov/.

Census (U.S. Census Bureau), 2007e, *Summary File 3 (SF 3) – Sample Data*, Census 2000 Data Releases, accessed through http://www.census.gov/, November 1.

CEQ (Council on Environmental Quality), 1997, *Environmental ustice Guidance Under the National Environmental Policy Act*, Executive Office of the President, Washington, D.C., December 10.

Dalaker, J., and B.D. Proctor, 2000, *Poverty in the United States: 1999*, Current Population Reports: Consumer Income, Series P60-210, U.S. Census Bureau, Washington, D.C., September.

DOE (U.S. Department of Energy), 1995, *Hanford Site Risk Assessment Methodology*, DOE/RL-91-45, Rev. 3, Richland Operations Office, Richland, Washington, May.

DOE (U.S. Department of Energy), 1999, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, DOE/EIS-0222-F, Richland Operations Office, Richland, Washington, September.

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

DOE and Ecology (U.S. Department of Energy, Richland Operations Office, Richland, Washington, and Washington State Department of Ecology, Olympia, Washington), 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, DOE/EIS-0189, August.

EPA (U.S. Environmental Protection Agency), 1997, *Exposure Factors Handbook*, Vol. II, *Food Ingestion Factors*, EPA/600/P-95/002Fa, b & c, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., August.

EPA (U.S. Environmental Protection Agency), 1998, *Final Guidance for Incorporating Environmental ustice Concerns in EPA's NEPA Compliance Analyses*, accessed through http://www.epa.gov/compliance/resources/policies/ej/ej_guidance_nepa_epa0498.pdf, April.

Grieco, E.M., and R.C. Cassidy, 2001, *Overview of Race and Hispanic Origin*, Census 2000 Brief C2KBR/01-1, U.S. Census Bureau, Washington, D.C., March.

OMB (U.S. Office of Management and Budget), 2000, *Guidance on Aggregation and Allocation of Data on Race for Use in Civil Rights Monitoring and Enforcement*, OMB Bulletin No. 00-02, Washington, D.C., accessed through http://www.whitehouse.gov/omb/bulletins/b00-02.html, March 9.

Code of Federal Regulations

40 CFR 61.90–61.97, U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants," Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities."

Executive Orders

Executive Order 12898, *Federal Actions to Address Environmental ustice in Minority Populations and Low-Income Populations*, February 11, 1994.

Federal Register

62 FR 58782, Office of Management and Budget, 1997, "Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity," October 30.

69 FR 52040, U.S. Nuclear Regulatory Commission, 2004, "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions," August 24.

APPENDIX K
HUMAN HEALTH RISK ANALYSIS

This appendix presents the methodologies and assumptions used for estimating potential impacts on, and risks to, individuals and the general public from exposure to releases of radioactive and hazardous chemical materials during normal operations and as a result of hypothetical accidents. It also presents the methodology that was used to assess industrial safety. This information is intended to support the public and occupational health and safety assessments described in Chapter 4 of this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. Section K.1 presents background information on the nature and hazards of radiation and chemicals. Section K.2 presents the methodology used in the assessment of normal radiological impacts, followed by the results of the radiological impact analyses. Section K.3 presents the assumptions and methodologies used in the assessment of facility accidents, followed by presentation of the impacts of accidental radioactive material and hazardous chemical releases. Section K.4 discusses the method used for assessment of industrial safety.

K.1 BACKGROUND

K.1.1 Radiation

Radiation exposure and its consequences are topics of interest to the general public. For this reason, this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* provides the reader with information regarding the consequences of exposure to radiation, provides the reader with information about the nature of radiation, and explains the basic concepts used to evaluate radiation health effects.

K.1.1.1 What Is Radiation?

Radiation is energy and/or mass transferred in the form of particles or waves. Globally, human beings are exposed constantly to radiation from cosmic sources (outer space); terrestrial sources, such as the Earth's rocks and soils; and radionuclides naturally present in the body. This radiation contributes to the natural background radiation that always surrounds us. Manmade sources of radiation also exist, including medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants.

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, which are electrically neutral, and protons, which are positively charged. Atoms with different numbers of protons are known as "elements." 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 (i.e., change over time).

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 millions of years.

As unstable isotopes change into more-stable forms, they emit energy and/or particles (mass). A particle may be either 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 means that the particles and gamma rays can ionize, or electrically charge, an atom by stripping off one or more of its electrons. Even though gamma rays do not carry an electric charge, they can ionize atoms by ejecting electrons as they pass through an element. Thus, they cause ionization indirectly. Ionizing radiation can change 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, radium, a member of the radioactive decay chain of uranium, has a half-life of 1,622 years. It emits an alpha particle and becomes radon, 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. The characteristics of various forms of ionizing radiation are briefly described below.

Alpha (α) particles—Alpha particles are the heaviest type of ionizing radiation. 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.

eta (β) particles—Beta particles are much (7,300 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 may be stopped by a thin sheet of aluminum foil or glass.

Gamma (γ) rays—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)—Neutrons are particles that contribute to radiation exposure both directly and indirectly. The most prolific source of neutrons is a nuclear reactor. Indirect radiation exposure occurs 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 by another element.

K.1.1.1.1 Measurement Units for Radiation

During the early days of radiological experimentation, there was no precise measurement unit for radiation. Therefore, a variety of units were used to determine 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 paragraphs describe the basis for these units.

Curie—The curie, named after the scientists Marie and Pierre Curie, describes the "intensity" or activity of a sample of radioactive material. The rate of decay 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 37 billion disintegrations (decays) per second.

Rad—The rad is used to measure 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.

Rem—A rem is used to measure dose equivalent. The dose equivalent in rem equals the absorbed dose in rads in tissue multiplied by the appropriate quality factor (the biological effectiveness of a given type of radiation) and possibly other modifying factors. The rem is used in measuring the effects of radiation on the body similar to the way degrees Celsius or Fahrenheit (°C or °F) are used in measuring the effects of sunlight heating pavement. Thus, 1 rem from one type of radiation is presumed to have the same biological effects as 1 rem from 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—A person-rem used to measure collective radiation dose, i.e., the sum of the individual doses received by a population or group from exposure to a specified source of radiation.

Equivalent Radiation Units in the International System of Units

Traditional Unit	International System Unit
1 curie	3.7×10^{10} becquerel (Bq)
1 rad	0.01 gray (Gy)
1 rem	0.01 sieverts (Sv)

The units of measure for radiation in the International System of Units are becquerels (used to measure source intensity [activity]), grays (used to measure absorbed dose), and sieverts (used to measure dose equivalent).

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 typically 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.

Doses projected from normal operations and from accidents are reported in terms of total effective dose equivalent, the sum of the effective dose equivalent due to penetrating radiation from sources external to the body and the committed effective dose equivalent from internal deposition of radionuclides. The committed effective dose equivalent is an estimate of the radiation dose to a person resulting from inhalation or ingestion of radioactive material that takes into account the radiation sensitivities of different organs and the time (up to 50 years) a particular substance stays in the body (further discussed in Section K.1.1.1.3).

K.1.1.1.2 Sources of Radiation

The average American receives a total dose of approximately 365 millirem per year from all sources of radiation, both natural and manmade; approximately 300 millirem per year of this total are from natural sources (NCRP 1987). The sources of radiation 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. These categories are discussed in the following paragraphs.

Cosmic radiation—Cosmic radiation is ionizing radiation resulting from energetic charged particles from space continuously hitting the Earth's atmosphere. These particles, and the secondary particles and photons they create, constitute 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 a person in the United States from this source is approximately 30 millirem per year.

External terrestrial radiation—External terrestrial radiation is the radiation emitted from the radioactive materials in the Earth's rocks and soils. The average individual dose from external terrestrial radiation is approximately 30 millirem per year.

Internal radiation—Internal radiation results from inhalation or ingestion of natural radioactive material. 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 40 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, the 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 dose of 39 millirem per year. Nuclear medical procedures result in an average dose of 14 millirem per year.[1]

Other sources—There are a few additional sources of radiation that contribute minor doses to individuals in the United States. The 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.

K.1.1.1.3 Exposure Pathways

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

External exposure—External exposure results from exposure to radiation outside the body via any of several different pathways, including exposure to a cloud of radiation passing over the receptor (an exposed individual), standing on ground that is contaminated with radioactivity, and swimming or boating in contaminated water. If the receptor departs from the source of radiation exposure, the dose rate will decrease. It was assumed that external exposure occurs uniformly during the year. The appropriate dose measure for external pathways 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 its biological half-life (the time required for a radioactive material taken in by a living organism to be reduced to half the initial quantity by a combination of biological elimination

[1] Exposures from nuclear diagnostic and medical procedures vary over a wide range depending on the procedure. The reported values are average annual doses in the U.S. population (NCRP 1987).

processes and radioactive decay). The absorbed dose to each organ of the body is calculated for a period of 50 years following the intake. The calculated absorbed dose is called the "committed dose equivalent." Various organs have different susceptibilities to harm from radiation. The quantity that takes these different susceptibilities into account is called the "committed effective dose equivalent"; it provides a broad indicator of the risk to the health of 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.

K.1.1.1.4 Radiation Protection Guides

Various organizations have issued radiation protection guides. The responsibilities of the main radiation safety organizations, particularly those that affect policies in the United States, are summarized below.

International Commission on Radiological Protection (ICRP)—The ICRP is responsible for providing guidance in matters of radiation safety. The operating policy of this organization is to prepare recommendations that address basic principles of radiation protection, leaving to the various national protection committees the responsibility to prepare 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 is the national organization responsible for adapting and providing detailed technical guidelines to implement ICRP recommendations. The council consists of technical experts who are specialists in radiation protection and scientists who are experts in disciplines that form the basis for radiation protection.

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

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

U.S. Nuclear Regulatory Commission (NRC)—NRC regulates source materials, special nuclear materials, and byproduct materials used by commercial entities, such as nuclear power plants, either directly or through state agreements. NRC has promulgated "Standards for Protection Against Radiation" in Title 10 of the *Code of Federal Regulations* (CFR), Part 20 (10 CFR 20), which apply to commercial uses of the materials listed above.

U.S. Department of Energy (DOE)—DOE establishes requirements for radiological protection at DOE sites in regulations and orders. Requirements for worker protection are included in 10 CFR 835. Radiological protection of the public and environment are addressed in DOE Order 5400.5.

K.1.1.2 Limits of Radiation Exposure

Limits of exposure to members of the public and radiation workers are derived from ICRP recommendations. EPA uses National Council on Radiation Protection and Measurements and ICRP recommendations to set specific annual exposure limits (usually less than those specified by the ICRP) in its radiation protection guidance to federal agencies documents. Each regulatory organization then

establishes its own set of radiation standards. The various exposure limits set by DOE and EPA for radiation workers and members of the public are given in Table K–1.

Table K–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 (DOE)	–	5,000 millirem per year[a]
10 CFR 835.1002 (DOE)	–	1,000 millirem per year[b]
DOE Order 5400.5 (DOE)[c]	10 millirem per year (all air pathways) 4 millirem per year (drinking-water pathways) 100 millirem per year (all pathways)	–
40 CFR 61.90–61.97 (EPA)	10 millirem per year (all air pathways)	–
40 CFR 141 (EPA)	4 millirem per year (drinking-water pathways)	–

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

[b] This measurement is a control level. It was established by DOE to assist in achieving its goal to maintain radiological doses as low as is reasonably achievable. DOE recommends that facilities adopt a more-limiting 500 millirem per year Administrative Control Level (DOE Standard 1098-99). Reasonable attempts have to be made by the site to maintain individual worker doses below these levels.

[c] Derived from or consistent with 40 CFR 61.90–61.97; 40 CFR 141; and 10 CFR 20.

Key: CFR=*Code of Federal Regulations*; DOE=U.S. Department of Energy; EPA=U.S. Environmental Protection Agency.

K.1.1.3 Health Effects due to Exposure to Radiation

To provide the background for discussions of impacts, this section explains the basic concepts used in the evaluation of radiation effects. Radiation can cause a variety of damaging health effects in people. The most significant effects are induced cancer fatalities, called "latent cancer fatalities" (LCFs) because the onset of cancer may take many years to develop after the radiation dose is received. In this *TC & WM EIS*, LCFs are used to measure the estimated risk due to radiation exposure.

The National Research Council's BEIR Committee has prepared a series of reports to advise the Federal Government on the health consequences of radiation exposure. Based on its 1990 report, *Health Effects of Exposure to Low Levels of Ionizing Radiation, EIR V* (National Research Council 1990), the former Committee on Interagency Radiation Research and Policy Coordination recommended cancer risk factors of 0.0005 per rem for the public and 0.0004 per rem for working-age populations (CIRRPC 1992). In 2002, the Interagency Steering Committee on Radiation Standards (ISCORS) recommended that Federal agencies use conversion factors of 0.0006 fatal cancers per rem for mortality and 0.0008 cancers per rem for morbidity when making qualitative or semiquantitative estimates of risk from radiation exposure to members of the general public. No separate values were recommended for workers. The DOE Office of Environmental and Policy Guidance subsequently recommended that DOE personnel and contractors use the risk factors recommended by ISCORS, stating that, for most purposes, the value for the general population (0.0006 fatal cancers per rem) could be used for both workers and members of the public in National Environmental Policy Act (NEPA) analyses (DOE 2003).

Recent publications by both the BEIR Committee and the ICRP support the continued use of the ISCORS-recommended risk values. *Health Risks from Exposure to Low Levels of Ionizing Radiation: EIR VII Phase 2* (National Research Council 2006) reported fatal cancer risk factors of 0.00048 per rem for males and 0.00066 per rem for females in a population with an age distribution similar to that of the entire U.S. population (average value of 0.00057 per rem for a population with equal numbers of males and females). ICRP Publication 103 (Valentin 2007) recommends nominal cancer risk coefficients of 0.00041 and 0.00055 per rem for adults and the general population, respectively, and estimates the risk from heritable effects to be about 3 to 4 percent of the nominal fatal cancer risk (see Table K–2).

Table K–2. Nominal Health Risk Estimators Associated with Exposure to Ionizing Radiation[a]

Exposed Population	Cancer[b]	Genetic Effects	Total
Worker (Adult)[c]	0.00041	0.00001	0.00042
Whole	0.00055	0.00002	0.00057

a Risk per rem (individual dose) or person-rem (population dose). For individual doses equal to or greater than 20 rem, the health risk estimators are multiplied by 2.

b Risk of all cancers, adjusted for lethality and quality-of-life impacts.

c Ages 18–64 years.

Source: Valentin 2007, Table A.4.4.

Accordingly, a risk factor of 0.0006 LCFs per rem was used in this *TC & WM EIS* to estimate risk due to radiation doses from normal operations and accidents. For high individual doses (greater than or equal to 20 rem), the health risk factor was multiplied by 2. In addition, nuclide-specific risk coefficients were developed using techniques accounting for gender, age, and exposure pathway (Eckerman et al. 1999). These coefficients, documented in the Health Effects Assessment Summary Tables database, were adopted for use in evaluation of impacts occurring in the long-term period following stabilization or closure of the high-level radioactive waste (HLW) tanks.

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

Sometimes, calculations of the number of LCFs do not yield whole numbers, and may yield a number less than 1. For example, if each individual of a population of 100,000 people were to receive an annual dose of 1 millirem (0.001 rem), the collective dose would be 100 person-rem, and the corresponding risk of an LCF would be 0.06 (100,000 persons times 0.001 rem times 0.0006 LCFs per person-rem). A fractional result should be interpreted as a statistical estimate. That is, 0.06 is the average number of LCFs expected if many groups of 100,000 people were to experience the same radiation exposure situation. For most groups, no LCFs would occur; in a few groups, 1 LCF would occur; in a very small number of groups, 2 or more LCFs would occur. The average number of LCFs over all of the groups would be 0.06 (just like the average of 0, 0, 0, and 1 is 1 divided by 4, or 0.25). In the preceding example, the most likely outcome for any single group would be 0 LCFs. In this *TC & WM EIS*, LCFs calculated for a population are presented as both the rounded whole number, representing the most likely outcome for that population, and the calculated statistical estimate of risk, presented in parentheses.

The numerical estimates of LCFs presented in this environmental impact statement (EIS) were obtained using a linear 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 estimates of LCFs. Studies of human populations exposed to low doses are inadequate to demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation. However, comprehensive review of available biological and biophysical data supports a "linear-no-threshold" risk model—in which the risk of cancer proceeds in a linear fashion at lower doses without a threshold—and that the smallest dose has the potential to cause a small increase in risk to humans (National Research Council 2006).

K.1.2 Chemicals

The reprocessing of nuclear fuels, the manufacture of nuclear materials, and the processing of fuel cycle waste entail the use of chemicals. Some of the more-hazardous chemicals could pose risks to human health, even to the point of being fatal, if they are accidentally released to the environment or if they come

into contact with workers in an occupational setting. The risks from exposure are of two general types: toxic, noncarcinogenic (non-cancer-causing) effects and cancer-inducing effects. In addition, the presence of some chemicals may pose a physical hazard to humans, such as chemical burns to the skin or internal organs, explosions or thermal hazards, displacement of oxygen, or runaway chemical reactions that cause high-energy release events.

K.1.2.1 What is a Toxic or Hazardous Chemical?

Nearly every chemical that exists can be detrimental to human health under specific exposure conditions. A large number, both carcinogenic (cancer-causing) and noncarcinogenic, are specifically addressed in Occupational Safety and Health Administration (OSHA) regulations. The exposure limit or guideline for any given substance depends on the basic toxic or hazardous properties of the material, its physical properties (solid, liquid, gas, or vapor), the circumstances of exposure (inhalation, consumption of water or food, or contact with soil or contaminated surfaces), and whether the exposure occurs at a low rate during normal operations or at a high rate as a result of an accident. Occupational exposure limitations and other controls for specific toxic or hazardous chemicals are provided in various sections of the "Occupational Safety and Health Standards" (29 CFR 1910). Acute exposure concentration guidelines for more than 3,000 chemicals have been developed by DOE and others for use in hazards analyses and emergency planning and response (DOE 2008).

K.1.2.2 Usage of Chemicals

Chemical usage can be categorized by either process chemicals or chemicals that support and maintain waste management operations. Process chemicals are those required in the direct processing of wastes. The specific chemicals used depend upon the specific processes chosen. The waste being processed, with its various chemical constituents, also falls into the category of process chemicals. Nonprocess chemicals that support and maintain waste management operations are typically cleaning fluids and lubricants.

K.1.2.3 Exposure Pathways

To cause toxic effects on human biological systems, chemicals must make contact with or be introduced into the body. There are three general means of entry into the body: inhalation, ingestion, and dermal (skin) contact. The effects through a particular pathway will depend essentially on the properties of the toxic chemical, its concentration in one or more environmental media (air, water, and soil), and human behavior. Exposure may be dominated by contact with chemicals in a single medium or may reflect concurrent contacts with multiple media.

K.1.2.4 Chemical Exposure Limits and Criteria

Exposure to chemicals in occupational settings is limited to levels within applicable OSHA Permissible Exposure Limits (29 CFR 1910) or the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (ACGIH 2002). Exposures are typically maintained below the levels specified in these references by either engineered controls or the use of protective equipment.

The flammable and explosive hazards associated with chemicals are typically controlled through standards promulgated by OSHA (29 CFR 1910.106). These standards address the storage, labeling, and information required to be provided to the worker.

For accidental airborne releases of hazardous chemicals into the environment, DOE has specified criteria to be used as indicators of human health impacts resulting from acute exposures (DOE Guide 151.1–2). For each specific hazardous chemical of concern, criteria are drawn from one of the following systems (listed in order of preference): the Acute Exposure Guideline Levels (AEGLs) promulgated by EPA; the Emergency Response Planning Guidelines (ERPGs), published by the American Industrial Hygiene

Association; and the Temporary Emergency Exposure Limits (TEELs), developed by DOE. The system of AEGLs includes values for five exposure periods, ranging from 10 minutes to 8 hours. However, the ERPG and TEEL systems provide values only for exposures of 1 hour. To allow the systems to be used together, DOE has specified that the 1-hour (60-minute) AEGL values are to be used. For the chemicals addressed by each system, three exposure levels (i.e., thresholds), expressed in terms of airborne concentrations, have been developed. Although the specific definitions vary slightly between the systems, the levels of human health impact associated with exposure for 1 hour to each airborne concentration level can be paraphrased as follows: exposures of up to 1 hour at or below level 1 may result in mild, transient, adverse health effects; exposures of up to one hour above level 1 and up to level 2 should not result in irreversible or other serious health effects or symptoms that could impair a person's ability to take protective actions; exposures of up to 1 hour above level 2 and up to level 3 should not result in an experience or development of life-threatening health effects; and exposures of up to 1 hour above level 3 could result in life-threatening health effects or death. DOE has specified that level 2 is the threshold above which unacceptable human health effects may be experienced. At concentrations above level 2, action should be taken to avoid, reduce, or mitigate human exposure. Level 3 has been identified as the threshold above which severe human health effects are expected.

K.1.2.5 Health Effects of Hazardous Chemical Exposure

Various chemicals invoke different types of damage to human biological systems. The harm may even vary according to the sensitivity of each individual person exposed. Hazardous chemical releases from routine operations generally are expected to result in concentrations below levels that would cause acute toxic health effects. Acute toxic health effects generally result from short-term exposure to relatively high concentrations of the toxic contaminant, such as those resulting from accidental releases. Long-term exposure to lower concentrations can produce adverse chronic health effects, both carcinogenic and noncarcinogenic. Excess incidences of cancer are the endpoint of carcinogenic effects. However, a spectrum of chemical-specific noncancer health effects (e.g., headaches, skin irritation, neurotoxicity, immunotoxicity, reproductive and genetic toxicity, liver/kidney toxicity, and developmental toxicity) could be observed due to exposure to noncarcinogenic compounds.

K.1.2.6 Hazardous Chemical Impact Assessment

Illness, injury, and death resulting from industrial accidents in occupational settings (i.e., routine operations) are assessed in the "Industrial Safety" sections of Chapter 4 (see Sections 4.1.15, 4.2.15, 4.3.15**,** and 4.4.13**)** and summarized in Chapter 2 (see Sections 2.8.1.15, 2.8.15, and 2.8.3.15. These industrial safety impacts are included in the general industry incidence rates. The remainder of this discussion pertains to the assessment of impacts on populations other than direct facility workers. The results of these assessments for each alternative may be found in Chapter 4, Sections 4.1.11, 4.2.11, and 4.3.11, "Public and Occupational Health and Safety—Facility Accidents." Additional information is also provided in Appendix G, "Air Quality Analysis," and Appendix P, "Ecological Resources and Risk Analysis."

The exposure assessment for accidents estimated how chemicals could travel to a receptor, how these chemicals could come into contact with a receptor's body, and whether the chemicals present in the environmental medium were likely to be of sufficient concentration to cause significant adverse effects. The exposure assessment assumes inhalation to be the only pathway and air the only medium. This simplification was based principally on the volatility of the chemicals released. Normal human behavior also was considered (i.e., an individual was assumed to perform activities under normal conditions). To maximize the impact of the exposure, the analysis also assumed that the released chemicals would remain in the air with no or negligible partitioning to other media (i.e., water and ground). Thus, no dermal contact or ingestion is considered in this assessment.

To determine long-term impacts (see Appendix Q), noncancer health effects were estimated by comparing the annual concentrations of contaminants to the reference concentrations published in the *Integrated Risk Information System* (EPA 2008). The potential toxic effects on an individual from exposure to a toxic chemical were evaluated by dividing the estimated inhalation concentration of that chemical by its reference concentration value to obtain a noncancer Hazard Quotient (EPA 1989). For exposure to multiple compounds, Hazard Quotients were calculated for each toxic chemical and then summed to generate a Hazard Index as shown in the following equation

$$HI \quad \sum_i \frac{CA_i}{RfC_i}$$

where:

HI	=	Hazard Index
CA_i	=	concentration of the chemical *i* in the air, micrograms per cubic meter
RfC_i	=	reference concentration for chemical *i,* micrograms per cubic meter

The Hazard Index is the estimate of the total noncancer toxicity impact. According to the EPA risk assessment guidelines, if the Hazard Index value is less than or equal to 1, the exposure is unlikely to produce adverse toxic effects. However, if it exceeds 1, adverse toxic effects may result from exposure to the considered chemicals.

The risks from exposure to carcinogenic chemicals were evaluated using chemical-specific unit risk factors, which are estimates of the maximum lifetime probability of an individual developing cancer from exposure to the chemical and the chemical concentration in the air. The unit risk factors for carcinogenic chemicals were taken from EPA's *Integrated Risk Information System* database. Therefore, for carcinogenic chemicals, the risk was estimated by the following equation (EPA 1989):

$$\text{Risk} = 1 - e^{(-CA \times URF)}$$

where :

e	=	~2.718
CA	=	contaminant concentration in the air, micrograms per cubic meter
URF	=	unit risk factor for inhalation specific to the contaminant obtained from the Integrated Risk Information System, cancers per micrograms per cubic meter

As the value in the parentheses is generally small (less than 0.01), the equation is simplified to:

$$\text{Risk} = CA \times URF$$

CA	=	contaminant concentration in the air, micrograms per cubic meter
URF	=	unit risk factor for inhalation specific to the contaminant obtained from the Integrated Risk Information System, cancers per micrograms per cubic meter

K.2 NORMAL OPERATIONS

This section describes the methodology used to evaluate the impacts of radiological emissions from tank closure, Fast Flux Test Facility (FFTF) decommissioning, and waste management activities on the public and workers. Dose assessments were performed for members of the general public near Hanford Site (and Idaho National Laboratory [INL] for selected FFTF decommissioning options) to estimate the incremental doses and related risks that would be associated with the alternatives addressed in this *TC & WM EIS*. Incremental doses for members of the public were calculated using the Hanford

Environmental Radiation Dosimetry Software System (Generation II) (GENII) computer code (Napier et al. 1988) for the following receptors:

- *Population*—The general public living within 80 kilometers (50 miles) of the facilities.
- *Maximally exposed individual (MEI)* The MEI is a hypothetical individual member of the public located at the position near the site boundary that would yield the highest impacts during normal operations.
- *Onsite MEI*—The onsite MEI is a member of the public who works at Hanford but is not associated with DOE facilities or operations. The Columbia Generating Station and the Laser Interferometer Gravitational-Wave Observatory were the two worksites considered. This receptor would only be exposed during a normal work shift.

Impacts were also evaluated for two classes of workers: (1) radiation workers, involved workers who might be exposed to radiation while performing activities associated with the alternatives; and (2) noninvolved workers, onsite workers who may be incidentally exposed as a result of the actions taken to implement a project, but who are not directly involved in the project. Radiological impacts were determined for both radiation workers and noninvolved workers.

K.2.1 Tank Closure Alternatives

K.2.1.1 Impacts on the Public During Normal Operations

This section describes the methodology used to evaluate the impacts of radiological emissions from waste treatment and tank closure activities on the population near Hanford. Later sections of this appendix address any differences in the methodology as it was applied to radiological impacts analysis for FFTF decommissioning and waste management.

K.2.1.1.1 Approach

Under normal operations, radiological releases would occur during activities associated with tank farm operations, including waste retrieval, pretreatment, and treatment and tank farm closure. Small amounts of radioactivity from normal operations may be released in liquid effluents. The liquid effluents would be routed to the Treated Effluent Disposal Facility or the Liquid Effluent Retention Facility/Effluent Treatment Facility, which are existing, state-permitted facilities. Effluents are sampled prior to release and treated, as necessary, using best available technologies to ensure they meet state discharge limits. Based on a previous environmental assessment (DOE 1992), discharges from these facilities were determined to be of no significant impact and therefore are not expected to make a distinguishable difference in the calculated doses to members of the public.

For purposes of evaluating the impacts of radiological air emissions, the activities and facilities associated with each Tank Closure alternative are treated as originating from one of three locations: the Waste Treatment Plant (WTP), the 200-East Area, or the 200-West Area. Releases modeled as originating from the WTP included those from the vitrification and pretreatment facilities. All other activities and facilities in the 200-East Area were modeled as if they were located at the 200-East Area Supplemental Treatment Technology Site (STTS-East) in the southeast corner of the 200-East Area (see Figure K–1). This location has been identified for supplemental technologies (e.g., bulk vitrification, cast stone, or steam reforming) if they are deployed in the 200-East Area. This location was selected because the emissions of the supplemental technologies would be substantially higher for most radionuclides than those associated with other project-related, 200-East Area activities, such as normal tank farm operations or waste retrieval. Similarly, emissions from the 200-West Area were modeled as if they arose from the 200-West Area STTS (STTS-West) in the southeast corner of the 200-West Area (see Figure K–1), the site for

deployment of supplemental technologies in the 200-West Area. Although tank farms are located at a number of positions within the 200-East and 200-West Areas (all tank farms are within 2.6 kilometers [1.6 miles] of STTS-East and -West), the simplifying assumption that radiological emissions other than those from the WTP would come from these STTSs added a level of conservatism to the analysis because the STTSs would be located closer to the principal receptors in the predominant downwind direction, the population centers of Richland, Pasco, and Kennewick, and closer to the MEI, located eastward.

The activities associated with each of these emission source locations are summarized as follows:

WTP:

- HLW vitrification
- Low-activity waste (LAW) vitrification
- Cesium and strontium de-encapsulation and processing
- Waste pretreatment
- Sulfate removal

STTS-East:

- Tank farm operations
- Tank waste retrieval
- Tank farm facilities deactivation
- Bulk vitrification
- Cast stone
- Steam reforming
- Remote-handled transuranic (TRU) waste treatment
- Contact-handled TRU waste treatment
- Tank removal
- Soil removal

STTS-West:

- Tank farm operations
- Tank waste retrieval
- Tank farm facilities deactivation
- Bulk vitrification
- Cast stone
- Steam reforming
- Contact-handled TRU waste treatment
- Tank removal
- Soil removal

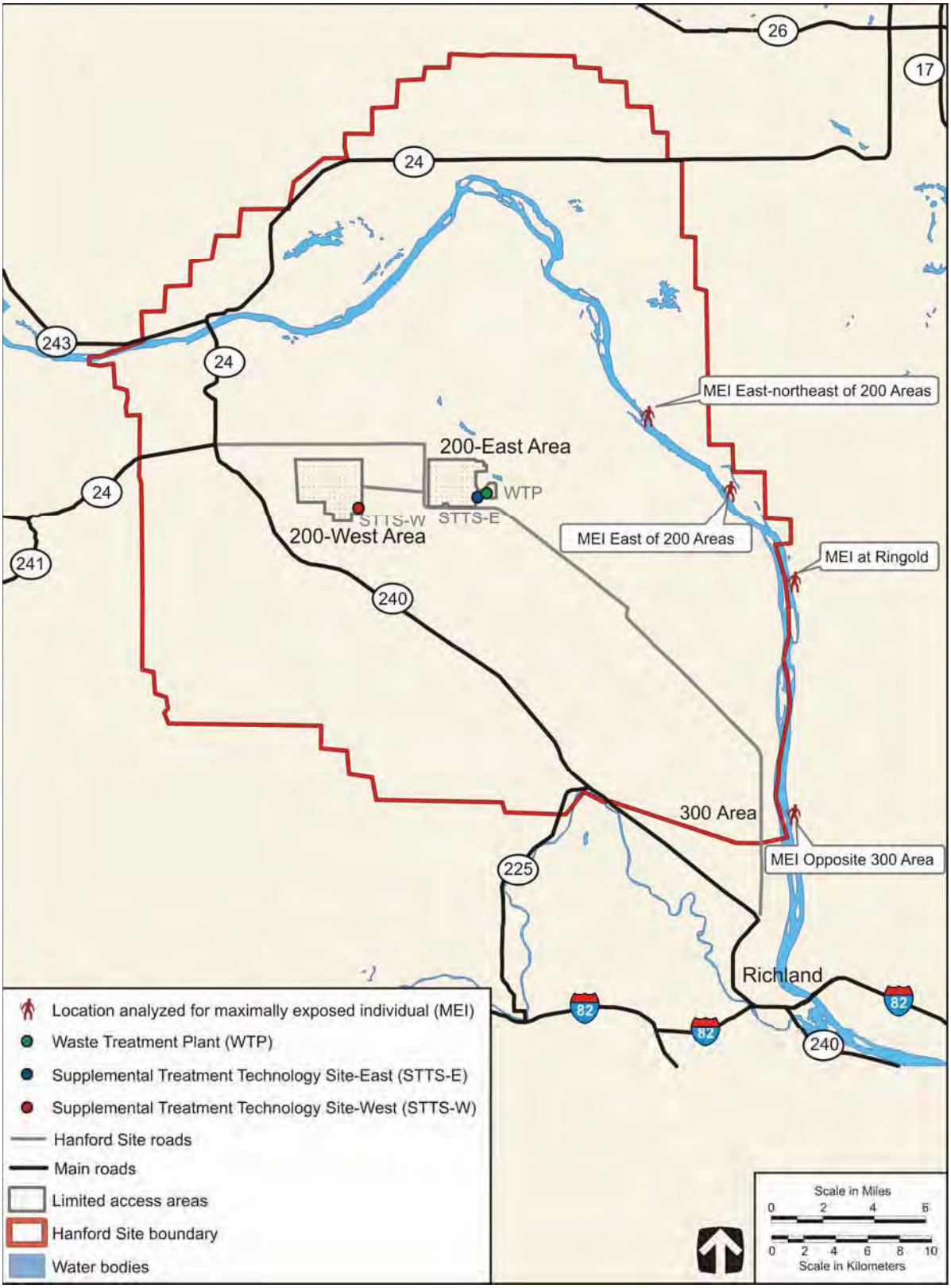


Figure K–1. Locations Assumed to Be Sources of Radiological Air Emissions and Possible Locations of the Maximally Exposed Individual

K.2.1.1.1.1 Exposure Scenarios

The analysis of radioactive releases from normal operations evaluated the impacts on three public receptors: the general population living within 80 kilometers (50 miles) of the release locations, a hypothetical MEI, and an onsite MEI. The general population, the MEI, and the onsite MEI would receive external as well as internal doses from radioactive releases.

The population living within 80 kilometers (50 miles) of the release locations would be exposed to atmospheric releases of radioactive materials that are carried by the wind. Therefore, the meteorological conditions at Hanford and the population distribution around the site would affect the dose received by the population. Details of the population distribution and the meteorological conditions are presented in Section K.2.1.1.3, "Input Parameters." Members of the general population would receive an external exposure to radiation from the radioactive plume as it passes and from materials that are deposited on the ground. They would also receive an internal dose from the inhalation and ingestion of radionuclides. Members of the population would receive an internal dose through inhalation of contaminated air as the plume passes and inhalation of resuspended materials that are deposited on the ground. They were also assumed to receive an internal dose by consuming produce grown in a family garden and animal products from regional livestock contaminated by deposition and uptake of radioactive materials. The assumed respiration rate and the amount of contaminated food consumed are discussed in Section K.2.1.1.3.

For the purpose of analyzing the impacts of radiological releases to the air from normal operations, the MEI was assumed to be an individual who lives near the Hanford boundary in the location that results in the maximum impact. The GENII computer code (Napier et al. 1988), which was used to project the impacts of radiological releases from normal operations, was also used to evaluate possible locations of the MEI. Using the joint frequency distribution of meteorological data for the Hanford 200 Areas, the assumed emission source locations (the WTP, STTS-East, and STTS-West), and the release inventories, MEI analyses were performed for multiple locations on the bank of the Columbia River opposite Hanford (see Figure K–1). These analyses showed that the MEI would be located at one of the following locations: (1) a point about 11 kilometers (6.8 miles) east-northeast of the WTP, (2) a point about 13.1 kilometers (8.1 miles) east of the WTP, or (3) a point along the Ringold section of the Columbia River about 18.2 kilometers (11.3 miles) east-southeast of the WTP. A point across the river from the Hanford 300 Area, about 22 kilometers (13.7 miles) southeast of the WTP, was also considered but never yielded the maximum result. As the relative emissions from the three source locations change, the location of the MEI would also change. Generally, the more the emissions are dominated by elevated releases from the WTP (modeled as coming from the 61-meter-[200-foot-] high stack), the more likely the MEI would be to the east or east-southeast. Although it is expected that the supplemental treatment technologies would have elevated releases (e.g., from stack emissions), no detailed design information for the associated facilities was available to use in the analysis. Therefore, it was assumed that the emissions from the supplemental treatment facilities at STTS-East and -West would be at ground level. Emissions modeled as arising from ground-level sources would not disperse as much as those from elevated release points. As reduced dispersal would mean more-concentrated plumes, this assumption resulted in a conservative analysis that overestimated the dose impact.

The MEI would be exposed in the same manner as the general population, that is, by external exposure to the plume and deposited radioactive materials and by internal exposure from inhalation of radioactive materials and ingestion of contaminated food. The MEI was assumed to consume a larger quantity of produce grown in a family garden.

The onsite MEI, a member of the public whose workday is spent at the Columbia Generating Station or Laser Interferometer Gravitational-Wave Observatory at Hanford, would receive an external dose from the plume and material deposited on the ground and an internal dose from inhalation of the plume and resuspended radioactive materials deposited on the ground.

K.2.1.1.2 Modeling

The radiological impacts of releases during normal operations of the facilities used to retrieve and treat tank waste and to deactivate and close tank farm facilities were calculated using Version 1.485 of the GENII computer code (Napier et al. 1988). Site-specific input data were used, including location, meteorology, population, and source terms. This section briefly describes GENII and outlines the approach used for estimating impacts of normal operations.

K.2.1.1.2.1 Description of the GENII Code

The GENII computer code, developed by Pacific Northwest National Laboratory, is an integrated system of models (referred to as "modules") that analyzes environmental contamination resulting from acute or chronic releases to, or initial contamination in, air, water, or soil. The GENII computer code calculates radiation doses to individuals and populations. Its assumptions, technical approach, method, and quality assurance are well documented. The code has gone through an extensive quality assurance and quality control process, which included comparing results from model computations with those from manual calculations and performing internal and external peer reviews (Napier et al. 1988).

The GENII code consists of several modules for various applications, as described in the code manual (Napier et al. 1988). For this *TC & WM EIS*, only the ENVIN, ENV, and DOSE modules were used. The output of one module is stored in a file that can be used by the next module in the system. The functions of the three modules used in this EIS are discussed below.

ENVIN

The ENVIN module of the GENII code controls the reading of input files and organizes input for optimal use in the environmental transport and exposure module, ENV. The ENVIN module interprets the basic input, reads the basic GENII data libraries and other optional input files, and organizes the input into sequential segments based on radionuclide decay chains.

A standardized file that contains scenario, control, and inventory parameters is used as input to ENVIN. Radionuclide inventories can be entered as functions of releases to air or water, concentrations in basic environmental media (air, soil, or water), or concentrations in foods. If certain atmospheric dispersion options have been selected, this module generates tables of atmospheric dispersion parameters that are used in later calculations. The ENVIN module prepares the data transfer files that are used as input by the ENV module; ENVIN generates the first portion of the calculation documentation, the run input parameters report.

ENV

The ENV module calculates the environmental transfer, uptake, and human exposure to radionuclides that result from the chosen scenario for the user-specified source term. The module reads the input files from ENVIN and then, for each radionuclide chain, sequentially performs the preliminary calculations to establish the conditions at the start of the exposure scenario. Environmental concentrations of radionuclides at the start are established by assuming decay of pre-existing sources, considering biotic transport of existing subsurface contamination, and defining soil contamination from continuing atmospheric or irrigation depositions. For each year of postulated exposure, the module then estimates the concentrations of each radionuclide in the chain in air, surface soil, deep soil, groundwater, and surface water. Human exposure and intake of each radionuclide are calculated for (1) pathways of external exposure from finite or infinite atmospheric plumes; (2) external exposure from contaminated soil, sediments, and water; (3) external exposure from special geometries (e.g., a shoreline exposure); (4) internal exposure from inhalation; and (5) internal exposure from consumption of terrestrial foods, aquatic foods, drinking water, and animal products, and inadvertent intake of soil. The intermediate

information on annual media concentrations and intake rates is written to data transfer files. Although these may be accessed directly, they are usually used as input to the DOSE module of GENII.

DOSE

The DOSE module reads the intake and exposure rates defined by the ENV module and converts the data to radiation dose.

K.2.1.1.3 Input Parameters

Site-specific and scenario-dependent data are used as input to the GENII computer code. The following paragraphs describe the development of data that were used in the analyses of doses to the general public and the MEI near Hanford.

K.2.1.1.3.1 Meteorological Data

The GENII computer code uses a data set of the joint frequency distribution of windspeed, direction, and Pasquill atmospheric stability class as input to modeling the atmospheric transport of radioactive emissions. Tables K–3 and K–4 present the joint frequency distribution data for the Hanford 200 Areas for the 61-meter (200-foot) and 9-meter (30-foot) heights, respectively. These data represent the 10-year averages of data collected from 1997 through 2006 at the 200 Area Hanford Meteorological Station (Burk 2007). Wind rose representations of these data are included in Chapter 3, Section 3.2.4.1.

In the current *TC & WM EIS* analysis, the meteorological data from the 61-meter (200-foot) height were used in evaluating the impacts of releases from the WTP. This height is consistent with the current WTP design in which most emissions would be from a 61-meter (200-foot) height. The 9-meter (30-foot) height joint frequency data were used as input to model the transport of releases from STTS-East and -West.

Table K–3. Joint Frequency Distribution for the Hanford Site 200 Areas at a 61-Meter Height

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.78	A	0.11	0.12	0.14	0.12	0.12	0.1	0.08	0.07	0.07	0.04	0.05	0.04	0.04	0.06	0.07	0.08
	B	0.05	0.06	0.07	0.06	0.06	0.04	0.04	0.04	0.02	0.03	0.03	0.03	0.04	0.03	0.04	0.06
	C	0.05	0.06	0.06	0.04	0.04	0.05	0.05	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.03	0.05
	D	0.41	0.41	0.39	0.33	0.33	0.25	0.38	0.3	0.19	0.18	0.17	0.17	0.2	0.24	0.32	0.41
	E	0.21	0.18	0.17	0.18	0.2	0.2	0.33	0.23	0.18	0.15	0.16	0.15	0.18	0.22	0.23	0.25
	F	0.17	0.15	0.12	0.14	0.13	0.13	0.18	0.17	0.12	0.13	0.15	0.15	0.2	0.15	0.19	0.18
	G	0.05	0.06	0.05	0.06	0.06	0.05	0.08	0.08	0.08	0.07	0.06	0.06	0.09	0.11	0.1	0.08
2.5	A	0.58	0.64	0.5	0.47	0.62	0.4	0.5	0.46	0.27	0.24	0.24	0.16	0.18	0.24	0.48	0.77
	B	0.17	0.17	0.14	0.12	0.13	0.11	0.16	0.1	0.08	0.09	0.08	0.07	0.07	0.11	0.21	0.26
	C	0.14	0.12	0.1	0.09	0.08	0.09	0.12	0.08	0.06	0.05	0.06	0.04	0.04	0.07	0.14	0.19
	D	0.64	0.47	0.41	0.37	0.43	0.37	0.49	0.39	0.23	0.2	0.24	0.27	0.34	0.57	1.09	1
	E	0.32	0.27	0.19	0.2	0.26	0.26	0.37	0.33	0.19	0.17	0.27	0.34	0.57	0.81	0.91	0.55
	F	0.26	0.15	0.14	0.1	0.15	0.15	0.31	0.3	0.21	0.2	0.26	0.41	0.66	0.82	0.86	0.57
	G	0.07	0.05	0.05	0.05	0.05	0.06	0.07	0.12	0.08	0.1	0.17	0.22	0.33	0.33	0.29	0.16
4.5	A	0.29	0.3	0.2	0.1	0.14	0.09	0.08	0.07	0.09	0.18	0.28	0.3	0.14	0.26	0.74	0.44
	B	0.08	0.09	0.03	0.01	0.02	0.02	0.01	0.02	0.03	0.05	0.08	0.09	0.06	0.12	0.27	0.1
	C	0.07	0.04	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.05	0.06	0.04	0.09	0.21	0.08
	D	0.18	0.13	0.08	0.06	0.12	0.09	0.08	0.11	0.1	0.16	0.28	0.32	0.35	0.82	1.34	0.35
	E	0.14	0.1	0.11	0.09	0.15	0.13	0.09	0.2	0.1	0.16	0.31	0.53	1.06	1.85	1.5	0.35
	F	0.09	0.05	0.03	0.03	0.04	0.05	0.06	0.21	0.1	0.07	0.19	0.47	1.02	1.63	1.41	0.39
	G	0.02	0	0	0	0.01	0	0.01	0.05	0.03	0.03	0.07	0.17	0.38	0.47	0.47	0.15
7.0	A	0.08	0.14	0.08	0.02	0.02	0.01	0	0.01	0.03	0.09	0.27	0.34	0.1	0.23	0.52	0.1
	B	0.02	0.03	0.01	0	0	0	0	0.01	0.01	0.02	0.06	0.09	0.04	0.09	0.11	0.02
	C	0.01	0.01	0.01	0	0.01	0	0	0.01	0.01	0.01	0.05	0.06	0.02	0.06	0.09	0.01
	D	0.06	0.07	0.05	0.01	0.01	0	0.01	0.05	0.1	0.16	0.33	0.4	0.35	1	0.96	0.07
	E	0.04	0.06	0.03	0.01	0.02	0.01	0.02	0.1	0.11	0.16	0.41	0.77	0.98	2.58	1.56	0.11
	F	0.02	0.03	0.02	0.01	0.01	0	0.01	0.06	0.03	0.02	0.07	0.29	0.42	1.19	1.18	0.09
	G	0	0	0	0	0	0	0	0.03	0.01	0.01	0.01	0.05	0.08	0.17	0.63	0.05

Table K–3. Joint Frequency Distribution for the Hanford Site 200 Areas at a 61-Meter Height *(continued)*

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9.6	A	0.01	0.02	0.03	0	0	0	0	0	0	0.04	0.17	0.2	0.05	0.12	0.35	0.02
	B	0	0.01	0.01	0	0	0	0	0	0	0.01	0.05	0.05	0.01	0.03	0.07	0
	C	0	0.01	0.01	0	0	0	0	0	0	0.01	0.03	0.03	0	0.02	0.06	0
	D	0.01	0.03	0.02	0	0	0	0	0.02	0.06	0.15	0.33	0.26	0.14	0.65	0.65	0.01
	E	0.01	0.03	0.04	0.01	0	0	0	0.05	0.13	0.17	0.36	0.34	0.21	1	0.91	0.01
	F	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.04	0.12	0.16	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.08	0
12.5	A	0	0	0	0	0	0	0	0	0	0.01	0.11	0.09	0.02	0.04	0.18	0
	B	0	0	0	0	0	0	0	0	0	0	0.04	0.02	0.01	0.01	0.05	0
	C	0	0	0	0	0	0	0	0	0	0.01	0.02	0.02	0.01	0.01	0.04	0
	D	0	0	0.01	0	0	0	0	0.01	0.06	0.14	0.28	0.15	0.03	0.3	0.45	0
	E	0	0.01	0.01	0	0	0	0	0.02	0.05	0.12	0.18	0.11	0.03	0.3	0.26	0
	F	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.9	A	0	0	0	0	0	0	0	0	0	0.01	0.04	0.02	0.01	0	0.03	0
	B	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0.01	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0.01	0
	D	0	0	0	0	0	0	0	0	0.01	0.08	0.11	0.03	0.01	0.02	0.04	0
	E	0	0	0	0	0	0	0	0	0	0.03	0.06	0.04	0.01	0.03	0.04	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.8	A	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.02	0.02	0.02	0.01	0	0	0
	E	0	0	0	0	0	0	0	0	0	0.01	0.04	0.01	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: To convert meters to feet, multiply by 3.281.
Source: Burk 2007.

Table K–4. Joint Frequency Distribution for the Hanford Site 200 Areas at a 9-Meter Height

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.78	A	0.29	0.31	0.34	0.27	0.28	0.25	0.19	0.17	0.13	0.12	0.12	0.1	0.1	0.13	0.17	0.22
	B	0.12	0.11	0.12	0.09	0.08	0.09	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.1
	C	0.09	0.09	0.1	0.05	0.06	0.07	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.06
	D	0.68	0.56	0.57	0.44	0.4	0.39	0.42	0.39	0.3	0.24	0.26	0.3	0.35	0.41	0.55	0.67
	E	0.36	0.29	0.27	0.24	0.27	0.32	0.47	0.4	0.35	0.34	0.48	0.53	0.55	0.52	0.57	0.46
	F	0.24	0.16	0.17	0.17	0.17	0.19	0.27	0.25	0.33	0.34	0.39	0.38	0.41	0.39	0.38	0.3
	G	0.09	0.07	0.1	0.09	0.08	0.08	0.11	0.1	0.1	0.11	0.1	0.1	0.13	0.13	0.14	0.11
2.5	A	0.72	0.53	0.42	0.36	0.46	0.47	0.45	0.28	0.24	0.24	0.32	0.25	0.2	0.29	0.66	0.78
	B	0.18	0.14	0.11	0.11	0.1	0.13	0.13	0.07	0.08	0.08	0.09	0.08	0.08	0.13	0.27	0.28
	C	0.16	0.11	0.09	0.08	0.07	0.1	0.1	0.08	0.04	0.04	0.07	0.06	0.05	0.09	0.21	0.22
	D	0.62	0.36	0.29	0.27	0.37	0.4	0.49	0.34	0.23	0.23	0.31	0.39	0.52	0.96	1.56	1.08
	E	0.25	0.15	0.13	0.14	0.23	0.31	0.38	0.38	0.33	0.32	0.63	1.13	2.04	2.26	1.69	0.56
	F	0.12	0.06	0.06	0.06	0.09	0.14	0.3	0.45	0.42	0.5	0.89	1.78	2.15	2.12	1.55	0.44
	G	0.04	0.02	0.02	0.03	0.03	0.03	0.08	0.19	0.2	0.24	0.37	0.75	0.62	0.69	0.59	0.11
4.5	A	0.21	0.22	0.16	0.06	0.08	0.04	0.02	0.04	0.05	0.14	0.27	0.4	0.2	0.35	0.76	0.27
	B	0.05	0.07	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.09	0.13	0.08	0.13	0.23	0.06
	C	0.03	0.03	0.01	0	0.01	0	0.01	0.01	0.01	0.02	0.06	0.08	0.04	0.09	0.18	0.04
	D	0.12	0.12	0.07	0.03	0.05	0.03	0.03	0.08	0.11	0.21	0.36	0.53	0.58	1.18	1.36	0.18
	E	0.05	0.05	0.04	0.02	0.02	0.01	0.04	0.12	0.15	0.19	0.46	0.91	1.24	2.28	1.57	0.11
	F	0	0	0	0.01	0.01	0	0.01	0.07	0.04	0.03	0.12	0.39	0.31	0.53	0.52	0.03
	G	0	0	0	0	0	0	0	0.02	0.01	0.01	0.04	0.2	0.04	0.17	0.21	0.01
7.0	A	0.02	0.06	0.05	0.01	0	0	0	0	0.01	0.05	0.25	0.37	0.09	0.2	0.5	0.07
	B	0	0.01	0.01	0	0	0	0	0	0.01	0.02	0.06	0.09	0.03	0.04	0.12	0.01
	C	0	0	0.01	0	0	0	0	0	0.01	0.01	0.04	0.06	0.02	0.04	0.09	0
	D	0.01	0.03	0.04	0.01	0	0	0	0.02	0.1	0.2	0.43	0.39	0.2	0.7	0.92	0.02
	E	0.01	0.03	0.03	0.01	0	0	0	0.05	0.14	0.21	0.39	0.29	0.17	0.57	0.76	0.01
	F	0	0	0	0	0	0	0	0	0.01	0	0.01	0.01	0.01	0.01	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table K–4. Joint Frequency Distribution for the Hanford Site 200 Areas at a 9-Meter Height *(continued)*

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9.6	A	0	0	0	0	0	0	0	0	0	0.01	0.1	0.13	0.04	0.05	0.16	0
	B	0	0	0	0	0	0	0	0	0	0	0.04	0.03	0.01	0.01	0.04	0
	C	0	0	0	0	0	0	0	0	0	0	0.02	0.02	0.01	0.01	0.03	0
	D	0	0	0.01	0	0	0	0	0	0.04	0.11	0.22	0.13	0.03	0.1	0.23	0
	E	0	0	0.01	0	0	0	0	0.01	0.01	0.04	0.08	0.06	0.02	0.06	0.1	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5	A	0	0	0	0	0	0	0	0	0	0.01	0.02	0.02	0	0	0.02	0
	B	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.03	0.03	0.03	0.01	0.01	0	0
	E	0	0	0	0	0	0	0	0	0	0.01	0.02	0.01	0	0	0.01	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.9	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.8	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: To convert meters to feet, multiply by 3.281.
Source: Burk 2007.

K.2.1.1.3.2 Population Data

The analysis considered the impacts on the populations residing within an 80-kilometer (50-mile) radius of the sources of emissions on the 200 Area plateau, the WTP, STTS-East, and STTS-West: 447,354; 451,556; and 488,897 people, respectively. The population data used in the analysis were taken from the 2000 census. Data from this year were used to provide a common basis for comparing impacts among the alternatives. Projections of future population growth were not been made because the long duration of some alternatives would make such projections extremely speculative. Population distributions within 80 kilometers (50 miles) of the WTP, STTS-East, and STTS-West are shown in Figures K–2 through K–4 respectively. These figures illustrate the population distribution used in the calculations conducted with the GENII computer code. Concentric circles shown in each figure are centered on the locations discussed above and have the following radii: 1.6 kilometers (1 mile), 3.2 kilometers (2 miles), 4.8 kilometers (3 miles), 6.4 kilometers (4 miles), 8.0 kilometers (5 miles), 16 kilometers (10 miles), 32 kilometers (20 miles), 48 kilometers (30 miles), 64 kilometers (40 miles), and 80 kilometers (50 miles). The population in each sector was calculated using data from the 2000 census (Census 2007a, 2007b). All sectors located within 8.0 kilometers (5 miles) and many of the sectors located within 16 kilometers (10 miles) of the center points have zero populations because no one is allowed to reside on the Hanford Site.

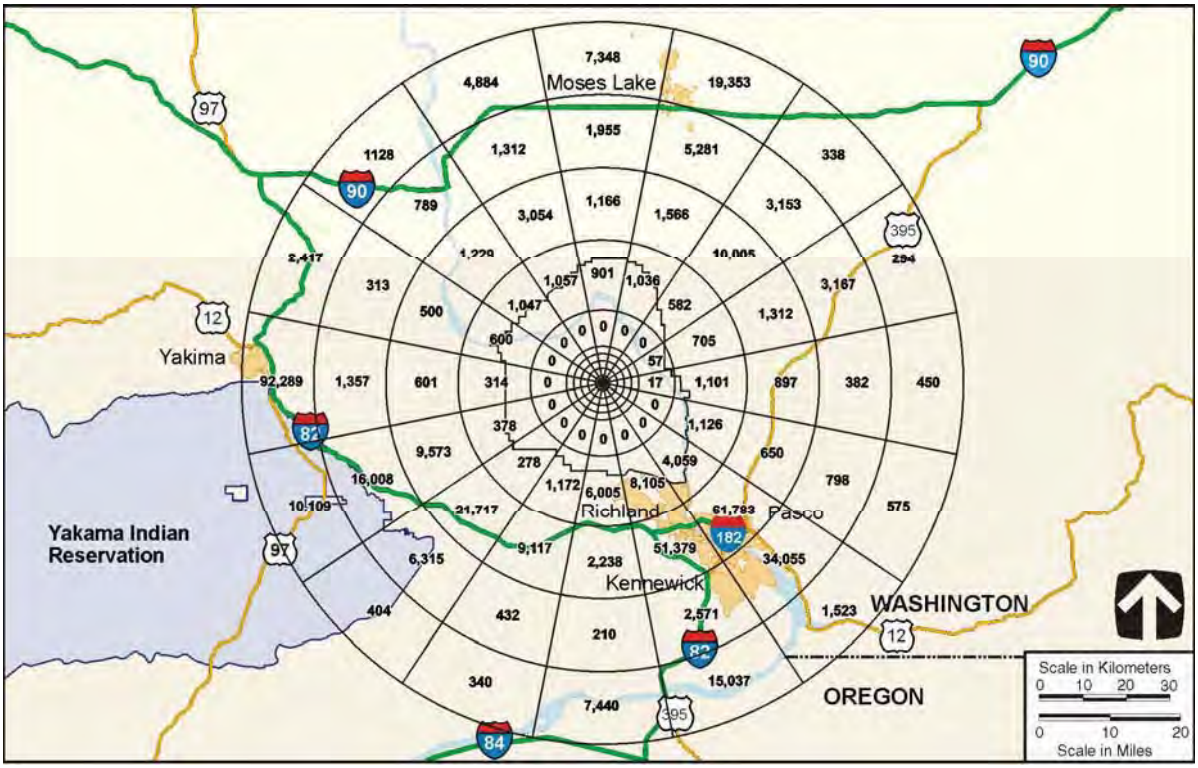


Figure K–2. Population Distribution Within 80 Kilometers (50 Miles) of the Waste Treatment Plant

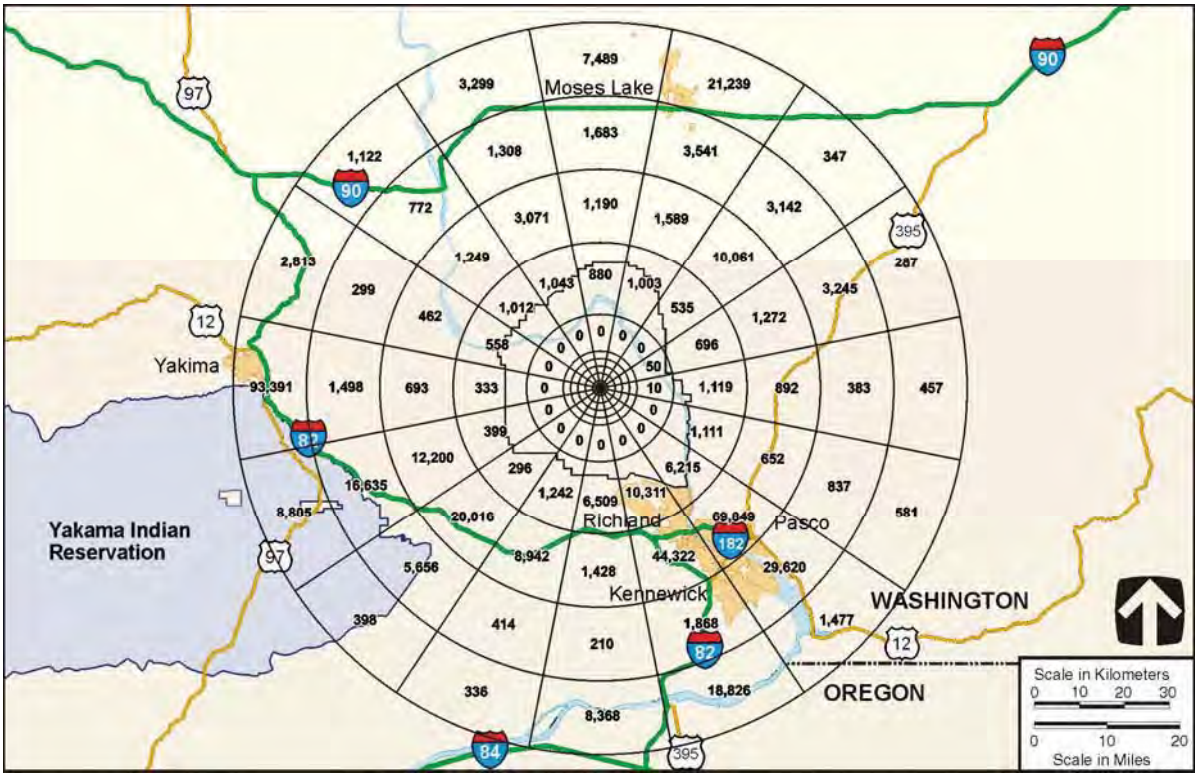


Figure K–3. Population Distribution Within 80 Kilometers (50 Miles) of the 200-East Area Supplemental Treatment Technology Site

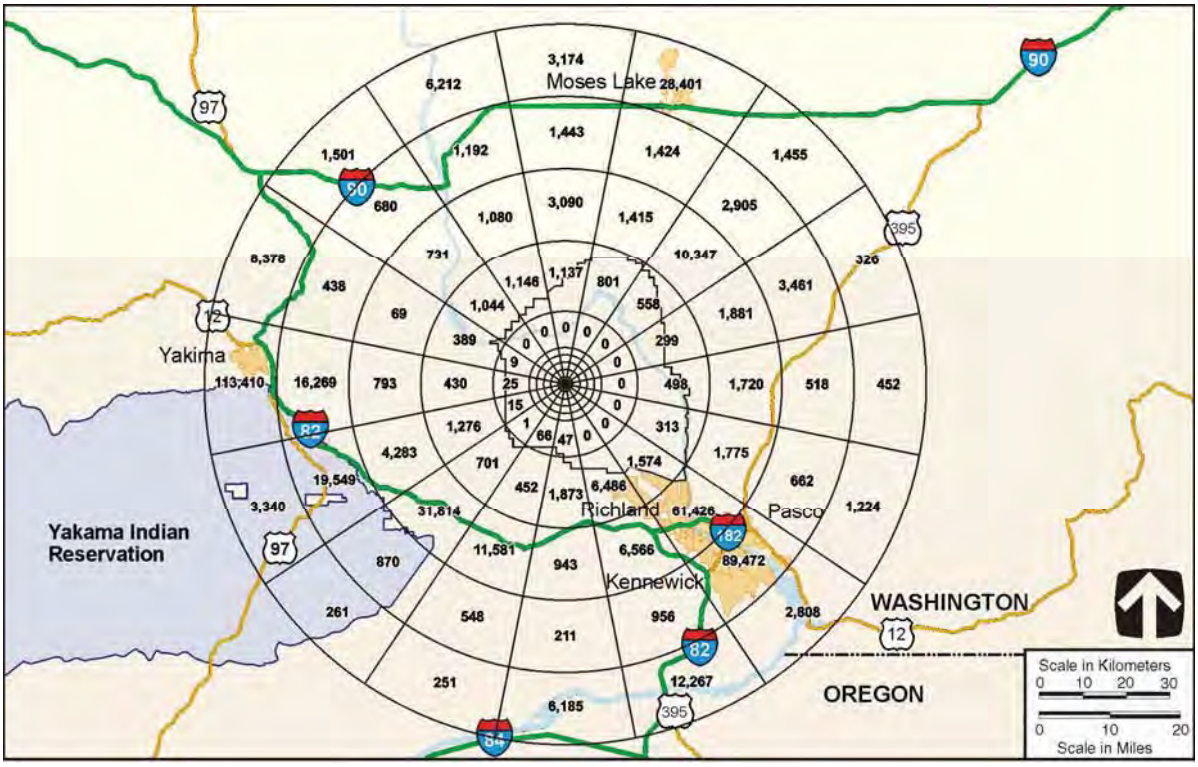


Figure K–4. Population Distribution Within 80 Kilometers (50 Miles) of the 200-West Area Supplemental Treatment Technology Site

K.2.1.1.3.3 Exposure Data

During normal operations of managing, retrieving, pretreating, and treating tank waste and deactivating and closing tanks and tank farm facilities, the general population would be exposed to atmospheric emissions. Exposure parameters for evaluating dose to the general population, the MEI, and the onsite MEI were primarily based on parameters from the *Hanford Site Risk Assessment Methodology (HSRAM)* (DOE 1995). As discussed below, the *HSRAM* parameters were modified, combined, or replaced where there was a reasonable basis for doing so. The parameters used for the general population, the MEI, and the onsite MEI are shown in Table K–5. Certain inputs to the GENII computer code required the number of hours per year that an exposure could occur. A full year was defined as 8,766 hours, or 365.25 days, to account for leap years.

Table K–5. Exposure Input Parameters for Members of the Public

Medium	Exposure Pathway	Rate	Reference
Population			
Air (plume)	External	8,766 hours per year	Napier et al. 1988
	Internal – inhalation	20 cubic meters per day	DOE 1995
Soil	External	2,192 hours per year	Napier et al. 1988
	Internal – ingestion	120 milligrams per day	EPA 2000a
Food[a]	Internal – ingestion of:		
	Leafy vegetable	21 kilograms per year	Beyeler et al. 1999
	Other vegetable	29.2 kilograms per year	DOE 1995
	Fruit	15.3 kilograms per year	DOE 1995
	Grain	14 kilograms per year	Beyeler et al. 1999
	Meat	27.8 kilograms per year	DOE 1995
	Dairy	110 kilograms per year	DOE 1995
	Poultry	28.5 kilograms per year	Beyeler et al. 1999
	Eggs	19 kilograms per year	Beyeler et al. 1999
Maximally Exposed Individual			
Air (plume)	External	8,766 hours per year	Napier et al. 1988
	Internal – inhalation	20 cubic meters per day	DOE 1995
Soil	External	4,380 hours per year	Napier et al. 1988
	Internal – ingestion	120 milligrams per day	EPA 2000a
Food[a]	Internal – ingestion of:		
	Leafy vegetable	65 kilograms per year	Beyeler et al. 1999, DOE and Ecology 1996
	Other vegetable	120 kilograms per year	DOE and Ecology 1996
	Fruit	120 kilograms per year	DOE and Ecology 1996
	Grain	90 kilograms per year	Beyeler et al. 1999
	Meat	27.8 kilograms per year	DOE and Ecology 1996
	Dairy	110 kilograms per year	DOE 1995
	Poultry	28.5 kilograms per year	Beyeler et al. 1999
	Eggs	19 kilograms per year	Beyeler et al. 1999
Onsite Maximally Exposed Individual			
Air (plume)	External	2,000 hours per year	DOE 1995
	Internal – inhalation	2,000 hours per year	DOE 1995
Soil	External	1,168 hours per year	DOE 1995
	Internal – ingestion	50 milligrams per day	DOE 1995

[a] Food consumption rates represent the portion of the diet consisting of contaminated food.

Note: To convert cubic meters to cubic feet, multiply by 35.315; milligrams to ounces, by 0.00003527; kilograms to pounds, by 2.2046.

Members of the public would be exposed via two pathways by the passing plume. They would receive an external dose 24 hours per day from direct exposure to the passing plume. They also would receive an internal dose from breathing 20 cubic meters (706 cubic feet) of contaminated air per day (DOE 1995). Respiration of resuspended radionuclides that have been deposited on the ground was also included in the dose from inhalation.

Radionuclides deposited on the ground represent another means of exposure because they may cause an external exposure to individuals near the contamination. In this analysis, it was assumed that an average member of the public would be exposed 25 percent of the time, 2,192 hours, during the entire year, and the MEI would be exposed 50 percent of the time, 4,380 hours per year. Soil could also be inadvertently ingested, resulting in an internal dose. The *HSRAM* assumes ingestion rates of 200 milligrams (0.71 ounces) per day for children and 100 milligrams (0.35 ounces) per day for adults. In this analysis, a single rate of 120 milligrams (0.42 ounces) per day was used (EPA 2000a). This is the weighted average of the values in the *HSRAM*—ingestion of 200 milligrams (0.71 ounces) per day over a 6-year period and ingestion of 100 milligrams (0.35 ounces) per day over a 24-year period.

Exposure of members of the public was also assumed to occur as a result of a portion of their diet coming from fruits and vegetables grown in a family garden. These fruits and vegetables could become contaminated by the deposition of radioactive materials. When consumed, the radioactive materials would result in an internal dose. Consistent with the *HSRAM*, members of the general public were assumed to consume 15.3 kilograms (33.7 pounds) of fruit and 29.2 kilograms (64.2 pounds) of non-leafy vegetables per year that have become contaminated by deposition of radioactive material (DOE 1995). Additionally, individuals were assumed to consume 21 kilograms (46.2 pounds) per year of leafy vegetables and 14 kilograms (30.8 pounds) per year of grains that have become contaminated (Beyeler et al. 1999). The MEI was assumed to consume a larger portion of his or her diet from fruits and vegetables grown in a family garden. Annual consumption was assumed to be 120 kilograms (264 pounds) of fruit, 120 kilograms (264 pounds) of non-leafy vegetables, 65 kilograms (143 pounds) of leafy vegetables, and 90 kilograms (198 pounds) of grains (Beyeler et al. 1999; DOE and Ecology 1996).

Analysis of the radiological impact on members of the public was based on an assumption that a portion of their diet would come from animal products from livestock raised in the area. Consuming forage that has been contaminated through the deposition of radioactive material would expose the animals. A person was assumed to consume 27.8 kilograms (61.2 pounds) of meat per year, consisting of 27.4 kilograms (60.3 pounds) of beef and 0.4 kilograms (0.9 pounds) of venison (DOE 1995). The consumption rate of contaminated dairy products was assumed to be 110 kilograms (242 pounds) per year (DOE 1995). The entire annual intake of 28.5 kilograms (62.7 pounds) of poultry and 19 kilograms (41.8 pounds) of eggs was assumed to come from local sources (Beyeler et al. 1999). The MEI consumption of meat, poultry, eggs, and dairy products was assumed to be the same as consumption by the members of the public.

Exposure parameter values for the onsite MEI dose analysis are shown in Table K–5. The onsite MEI was assumed to be exposed during the workday. Exposure to the passing plume and inhalation were assumed to occur for a normal 40-hour work week, or about 2,000 hours per year. Exposure to deposited materials on the ground was assumed to occur for only a portion of this time, about 1,168 hours per year. Ingestion of resuspended soil would result in consumption of 50 milligrams (0.0018 ounces) per day.

K.2.1.1.3.4 Source Terms

Doses and risks to the public from the atmospheric release of radionuclides during normal operations were estimated for the year of maximum impact and for the life of the project for each Tank Closure alternative. The atmospheric releases were evaluated as arising from three locations: the WTP, STTS-East, and STTS-West. Therefore, six sets of source terms were developed for each Tank Closure alternative.

Radionuclides that would dominate the dose to the public through the air pathway were selected for detailed analysis. These were the radionuclides that are known to be the main contributors to the air pathway dose or that are of specific interest. To ensure that no major radionuclides were eliminated from the detailed analysis, a screening analysis was performed. In the screening analysis, it was assumed that one millionth of the tank farms' Best-Basis Inventory would enter an air stream through a treatment system that would remove 99.95 percent of the particulates. Exceptions were hydrogen-3 (tritium), carbon-14, and iodine-129, all of which would likely be in a gaseous state, are easily volatilized, and are poorly captured in air treatment systems. In the screening analysis, the entire Best-Basis Inventory of these three radionuclides was assumed to be released. Inhalation dose conversion factors (Eckerman, Wolburst, and Richardson 1988) were multiplied by the released inventory to determine the radionuclides in the tank farm inventory of greatest potential impact. Table K–6 lists the radionuclides considered in the detailed dose analysis. These radionuclides account for 99.99 percent of the dose estimated from the screening analysis. A second screening analysis was done that assumed that the air treatment system removed 99 percent of the iodine-129. This assumption is consistent with the way iodine-129 releases from the WTP, Bulk Vitrification Facilities, and Cast Stone Facilities were modeled in the dose analysis. This second screening also showed that the radionuclides selected for detailed analysis were responsible for 99.99 percent of the estimated dose.

Table K–6. Radionuclides Included in Air Pathway Dose Analysis

Radionuclide	Symbol
Hydrogen-3 (tritium)	H-3
Carbon-14	C-14
Cobalt-60	Co-60
Strontium-90	Sr-90
Technetium-99	Tc-99
Iodine-129	I-129
Cesium-137	Cs-137
Uranium[a]	U
Plutonium-238	Pu-238
Plutonium-239 and -240	Pu-239, Pu-240
Plutonium-241	Pu-241
Americium-241	Am-241

[a] Uranium inventories include the isotopes uranium-233, uranium-234, uranium-235, and uranium-238.

Estimates of the release of radionuclides associated with the Tank Closure alternatives evaluated in this *TC & WM EIS* were derived from data packages that defined the various activities needed to execute the tank closure project. These data packages defined the resource and labor requirements, radiological and nonradiological air emissions, worker dose, waste generation, and scope and duration of activities, such as installing risers (access ports into the underground tanks), retrieving waste from tanks (determined by retrieval technology), processing waste, removing and filling tanks, and other closure activities. Various combinations of these activities form the Tank Closure alternatives.

The data package activities had to be scaled to correspond to the Tank Closure alternatives evaluated in this EIS. Scaling is proportionally adjusting the values in the data packages to account for differences in the assumptions or basis of each alternative. Scaling accounts for a number of differences, including the duration of an activity and the number of actions performed as part of an activity. For example, the amount of a radionuclide emitted from processing 99 percent of the tank waste would remain essentially the same for a given treatment technology under any of the alternatives, but the annual release might change depending on the number of years taken to process the waste under a specific alternative. Scaling was used to adjust the emissions to account for the number of years of operations for a particular alternative compared with the duration assumed in the data packages. Similarly, if a data package activity was developed based on the installation of 50 new risers but the alternative requires 75 new risers, the

resource requirements, emissions, and other data associated with the activity would be increased by 50 percent to scale the data to match the alternative. The scaled data are included in the scaled data sets.

Estimated emissions for the treatment facilities (e.g., the Pretreatment Facility and WTP) presented in the scaled data sets (SAIC 2007a, 2008) were conservatively based on a reduction factor of 2,000 for particulate emissions. This factor represents the reduction associated with a single stage of high-efficiency particulate air (HEPA) filters. The air treatment equipment currently proposed for the WTP includes a number of other technologies that would further reduce emissions to the atmosphere, including, for example, scrubbers, high-efficiency mist eliminators, and a second stage of HEPA filters. The source terms from the treatment facilities were adjusted by a factor of 100 for particulates and iodine-129 to take credit equivalent to that provided by a second set of HEPA filters (for particulates) or caustic scrubbers and other treatments (for iodine). This adjustment still resulted in an overestimation of the radionuclides in the treatment facility air discharges because no credit was taken for other air treatment technologies that would be employed. No reduction factors were applied to tritium and carbon-14 emissions. They are treated as gaseous emissions that would not be abated by the air treatment technologies.

The source terms for the WTP and STTS-East and -West were based on the estimated annual emissions from the scaled data sets (SAIC 2007a, 2008). Then the radiological emissions, or a portion thereof, were assigned to one of the three locations. Emissions associated with pretreatment or vitrification of tank waste, de-encapsulation and vitrification of cesium and strontium, or deactivation of the associated facilities were attributed to the WTP. Radiological emissions from all other activities are divided between STTS-East and -West, based on the actions and facilities involved. For example, emissions from tank waste retrieval via a particular technology were divided between the two locations based on the proportion of tanks in the 200-East and 200-West Areas on which the technology would be used. Similarly, emissions from supplemental treatment technologies such as bulk vitrification, cast stone, or steam reforming were assigned to the appropriate area to reflect the assumptions employed in developing a specific alternative.

The timeframe over which each activity would occur was determined for all of the activities associated with an alternative. The total annual emissions for each of the three locations were determined by summing the emissions from each activity that would be ongoing during a year. In most cases, the year of maximum impact was immediately apparent because the emissions from the WTP and supplemental treatment technologies would contribute most to variability in the release of radionuclides and these activities would operate simultaneously; when necessary to distinguish which year would result in the maximum impact, emissions from different years were evaluated. Tables K–7 through K–19 present the emissions for the year of maximum impact (based on the population and MEI doses in Tables K–20 through K–45) and the year in which those emissions would occur under each Tank Closure alternative.

Total emissions over the operational life of the project were also calculated for the WTP, the 200-East Area, and the 200-West Area for each Tank Closure alternative. The total emissions were calculated by summing the releases for each location across all the years of release. The results are also presented in Tables K–7 through K–19. For the life-of-project emissions, the timespan presented in the tables reflects the portion of the project in which radiological emissions were projected to occur. Except for Tank Closure Alternatives 6A and 6B, which include clean closure of all of the tank farms, each alternative would have an administrative control period or a postclosure care period. Under Tank Closure Alternatives 1 and 2A, which do not include any closure, life-of-project emissions would include those that occur over the administrative control period. The postclosure care periods were not included in the timespan for the life-of-project emissions for the other Tank Closure alternatives because no radiological emissions are expected to occur.

Table K–7. Tank Closure Alternative 1 Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2107) (curies)			Annual Emissions in Year of Maximum Impact (2008) (curies)		
	Waste Treatment Plant[a]	200-East Area STTS	200-West Area STTS	Waste Treatment Plant[a]	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	0	6.1×10^{4}	5.9×10^{4}	0	6.1×10^{2}	5.9×10^{2}
Carbon-14	0	0	0	0	0	0
Cobalt-60	0	2.9	2.8	0	2.9×10^{-2}	2.8×10^{-2}
Strontium-90	0	3.3×10^{-1}	3.2×10^{-1}	0	6.4×10^{-3}	6.2×10^{-3}
Technetium-99	0	0	0	0	0	0
Iodine-129	0	7.3×10^{-1}	7.1×10^{-1}	0	1.4×10^{-2}	1.3×10^{-2}
Cesium-137	0	4.0	3.9	0	7.9×10^{-2}	7.5×10^{-2}
Uranium	0	1.9	1.8	0	1.9×10^{-2}	1.8×10^{-2}
Plutonium-238	0	0	0	0	0	0
Plutonium-239, -240	0	6.5×10^{-8}	6.1×10^{-8}	0	1.7×10^{-9}	1.2×10^{-9}
Plutonium-241	0	0	0	0	0	0
Americium-241	0	5.0×10^{-8}	4.6×10^{-8}	0	1.5×10^{-9}	9.6×10^{-10}

[a] There would be no emissions from the Waste Treatment Plant because it would not operate under this alternative.

Key: STTS=Supplemental Treatment Technology Site.

Table K–8. Tank Closure Alternative 2A Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2193) (curies)			Annual Emissions in Year of Maximum Impact (2093) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	6.1×10^{4}	5.9×10^{4}	0	0	0
Carbon-14	3.1×10^{3}	0	0	0	0	0
Cobalt-60	4.0×10^{-2}	2.9	2.8	0	0	0
Strontium-90	4.0×10^{2}	6.0×10^{-1}	5.8×10^{-1}	1.0×10^{2}	0	0
Technetium-99	1.5×10^{-1}	0	0	0	0	0
Iodine-129	4.8×10^{-1}	1.3	1.3	0	0	0
Cesium-137	5.8×10^{2}	7.3	7.1	2.4×10^{2}	0	0
Uranium	4.7×10^{-3}	1.9	1.8	0	0	0
Plutonium-238	2.4×10^{-2}	1.2×10^{-7}	3.2×10^{-7}	0	0	0
Plutonium-239, -240	4.1×10^{-1}	1.6×10^{-5}	4.1×10^{-5}	0	1.0×10^{-9}	0
Plutonium-241	6.2×10^{-1}	0	0	0	0	0
Americium-241	7.2×10^{-1}	1.6×10^{-6}	3.5×10^{-6}	0	0	0

Key: STTS=Supplemental Treatment Technology Site.

Table K–9. Tank Closure Alternative 2B Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2045) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	0	0	4.6×10^{2}	0	0
Carbon-14	3.1×10^{3}	0	0	1.2×10^{2}	0	0
Cobalt-60	4.1×10^{-2}	0	0	1.6×10^{-3}	0	0
Strontium-90	4.2×10^{2}	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{2}	3.2×10^{-3}	3.1×10^{-3}
Technetium-99	1.5×10^{-1}	0	0	5.7×10^{-3}	0	0
Iodine-129	4.8×10^{-1}	2.7×10^{-1}	2.6×10^{-1}	1.8×10^{-2}	7.0×10^{-3}	6.7×10^{-3}
Cesium-137	5.8×10^{2}	1.5	1.4	2.5×10^{2}	3.9×10^{-2}	3.8×10^{-2}
Uranium	4.7×10^{-3}	0	0	1.8×10^{-4}	0	0
Plutonium-238	2.4×10^{-2}	5.6×10^{-7}	7.6×10^{-7}	9.3×10^{-4}	1.5×10^{-7}	1.5×10^{-7}
Plutonium-239, -240	4.1×10^{-1}	7.2×10^{-5}	9.7×10^{-5}	1.6×10^{-2}	1.9×10^{-5}	1.9×10^{-5}
Plutonium-241	6.3×10^{-1}	0	0	2.4×10^{-2}	0	0
Americium-241	7.2×10^{-1}	5.9×10^{-6}	7.8×10^{-6}	2.8×10^{-2}	1.5×10^{-6}	1.5×10^{-6}

Key: STTS=Supplemental Treatment Technology Site.

Table K–10. Tank Closure Alternative 3A Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2042) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	3.5×10^{3}	4.6×10^{3}	3.9×10^{3}	0	2.1×10^{1}	1.8×10^{1}
Carbon-14	9.6×10^{2}	1.2×10^{3}	9.9×10^{2}	0	5.3	4.5
Cobalt-60	3.3×10^{-2}	3.5×10^{-3}	3.4×10^{-3}	0	1.6×10^{-5}	1.5×10^{-5}
Strontium-90	4.0×10^{2}	1.8×10^{-1}	2.4	1.0×10^{2}	2.1×10^{-5}	1.1×10^{-2}
Technetium-99	4.4×10^{-2}	5.4×10^{-4}	4.8×10^{-2}	0	2.6×10^{-4}	2.1×10^{-4}
Iodine-129	1.4×10^{-1}	4.2×10^{-1}	3.8×10^{-1}	0	8.3×10^{-4}	7.0×10^{-4}
Cesium-137	5.6×10^{2}	2.5	2.3×10^{1}	2.4×10^{2}	5.2×10^{-3}	1.0×10^{-1}
Uranium	4.3×10^{-3}	1.1×10^{-4}	1.5×10^{-4}	0	4.9×10^{-7}	6.8×10^{-7}
Plutonium-238	2.1×10^{-2}	6.8×10^{-5}	3.0×10^{-4}	0	7.5×10^{-10}	1.3×10^{-6}
Plutonium-239, -240	3.7×10^{-1}	8.0×10^{-4}	5.4×10^{-3}	0	1.4×10^{-8}	2.4×10^{-5}
Plutonium-241	5.6×10^{-1}	1.2×10^{-3}	8.0×10^{-3}	0	2.0×10^{-8}	3.6×10^{-5}
Americium-241	6.0×10^{-1}	2.4×10^{-3}	7.0×10^{-3}	0	3.6×10^{-8}	3.2×10^{-5}

Key: STTS=Supplemental Treatment Technology Site.

Table K–11. Tank Closure Alternative 3B Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2042) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	3.5×10^{3}	4.6×10^{-2}	3.9×10^{-2}	0	2.1×10^{-4}	1.8×10^{-4}
Carbon-14	9.6×10^{2}	1.2×10^{-2}	9.9×10^{-3}	0	5.3×10^{-5}	4.5×10^{-5}
Cobalt-60	3.3×10^{-2}	7.7×10^{-5}	6.7×10^{-5}	0	3.1×10^{-7}	3.0×10^{-7}
Strontium-90	4.0×10^{2}	1.9×10^{-1}	1.5×10^{-1}	1.0×10^{2}	4.1×10^{-7}	2.1×10^{-4}
Technetium-99	1.0×10^{-1}	4.6×10^{-5}	9.5×10^{-4}	0	5.1×10^{-8}	4.3×10^{-6}
Iodine-129	1.4×10^{-1}	2.4×10^{-1}	2.3×10^{-1}	0	8.3×10^{-9}	7.0×10^{-9}
Cesium-137	5.6×10^{2}	1.4	1.7	2.4×10^{2}	1.0×10^{-4}	2.0×10^{-3}
Uranium	4.3×10^{-3}	6.7×10^{-6}	3.4×10^{-6}	0	9.7×10^{-9}	1.4×10^{-8}
Plutonium-238	2.1×10^{-2}	6.9×10^{-5}	7.1×10^{-6}	0	1.5×10^{-11}	2.7×10^{-8}
Plutonium-239, -240	3.7×10^{-1}	8.2×10^{-4}	2.8×10^{-4}	0	1.3×10^{-9}	4.8×10^{-7}
Plutonium-241	5.6×10^{-1}	1.2×10^{-3}	1.7×10^{-4}	0	4.0×10^{-10}	7.2×10^{-7}
Americium-241	6.0×10^{-1}	2.4×10^{-3}	1.6×10^{-4}	0	7.3×10^{-10}	6.3×10^{-7}

Key: STTS=Supplemental Treatment Technology Site.

Table K–12. Tank Closure Alternative 3C Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2042) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	3.5×10^{3}	4.6×10^{3}	3.9×10^{3}	0	2.1×10^{1}	1.8×10^{1}
Carbon-14	9.6×10^{2}	1.2×10^{3}	9.9×10^{2}	0	5.3	4.5
Cobalt-60	3.3×10^{-2}	3.5×10^{-3}	3.4×10^{-3}	0	1.6×10^{-5}	1.5×10^{-5}
Strontium-90	4.0×10^{2}	1.9×10^{-1}	2.4	1.0×10^{2}	2.1×10^{-5}	1.1×10^{-2}
Technetium-99	1.0×10^{-1}	5.7×10^{-2}	4.8×10^{-2}	0	2.6×10^{-4}	2.1×10^{-4}
Iodine-129	1.4×10^{-1}	4.2×10^{-1}	3.8×10^{-1}	0	8.3×10^{-4}	7.0×10^{-4}
Cesium-137	5.6×10^{2}	2.5	2.3×10^{1}	2.4×10^{2}	5.2×10^{-3}	1.0×10^{-1}
Uranium	4.3×10^{-3}	1.1×10^{-4}	1.5×10^{-4}	0	4.9×10^{-7}	6.8×10^{-7}
Plutonium-238	2.1×10^{-2}	6.9×10^{-5}	3.0×10^{-4}	0	7.5×10^{-10}	1.3×10^{-6}
Plutonium-239, -240	3.7×10^{-1}	8.0×10^{-4}	5.4×10^{-3}	0	1.4×10^{-8}	2.4×10^{-5}
Plutonium-241	5.6×10^{-1}	1.2×10^{-3}	8.0×10^{-3}	0	2.0×10^{-8}	3.6×10^{-5}
Americium-241	6.0×10^{-1}	2.4×10^{-3}	7.0×10^{-3}	0	3.6×10^{-8}	3.2×10^{-5}

Key: STTS=Supplemental Treatment Technology Site.

Table K–13. Tank Closure Alternative 4 Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2045) (curies)			Annual Emissions in Year of Maximum Impact (2043) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	3.6×10^{3}	4.8×10^{-2}	3.9×10^{3}	0	2.8×10^{-6}	2.8×10^{-6}
Carbon-14	9.7×10^{2}	1.2×10^{-2}	1.0×10^{3}	0	2.7×10^{-7}	2.7×10^{-7}
Cobalt-60	3.4×10^{-2}	2×10^{-4}	3.6×10^{-3}	0	2.2×10^{-7}	2.2×10^{-7}
Strontium-90	4.0×10^{2}	2.1	4.9	1.0×10^{2}	5.8×10^{-3}	5.8×10^{-3}
Technetium-99	4.4×10^{-2}	1.6×10^{-3}	4.8×10^{-2}	0	2.0×10^{-6}	2.0×10^{-6}
Iodine-129	1.4×10^{-1}	2.6×10^{-1}	4.1×10^{-1}	0	3.7×10^{-9}	3.7×10^{-9}
Cesium-137	5.6×10^{2}	2.5	2.5×10^{1}	2.4×10^{2}	4.7×10^{-3}	4.7×10^{-3}
Uranium	4.4×10^{-3}	5.6×10^{-5}	2.0×10^{-4}	0	2.5×10^{-7}	2.5×10^{-7}
Plutonium-238	2.1×10^{-2}	1.3×10^{-4}	3.6×10^{-4}	0	4.6×10^{-7}	4.6×10^{-7}
Plutonium-239, -240	3.7×10^{-1}	2.8×10^{-3}	8.0×10^{-3}	0	2.6×10^{-5}	2.6×10^{-5}
Plutonium-241	5.7×10^{-1}	2.1×10^{-3}	9.0×10^{-3}	0	4.4×10^{-6}	4.4×10^{-6}
Americium-241	6.1×10^{-1}	4.4×10^{-3}	9.8×10^{-3}	0	5.5×10^{-6}	5.5×10^{-6}

Key: STTS=Supplemental Treatment Technology Site.

Table K–14. Tank Closure Alternative 5 Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2036) (curies)			Annual Emissions in Year of Maximum Impact (2034) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	5.8×10^{3}	1.6×10^{-2}	3.5×10^{3}	3.6	1.0×10^{-4}	2.2×10^{1}
Carbon-14	1.5×10^{3}	4.1×10^{-3}	9.0×10^{2}	9.1	2.5×10^{-5}	5.6
Cobalt-60	4.1×10^{-2}	3.1×10^{-5}	3.1×10^{-3}	5.4×10^{-5}	1.5×10^{-7}	1.9×10^{-5}
Strontium-90	3.8×10^{2}	1.6×10^{-1}	2.2	1.0×10^{2}	2.0×10^{-7}	1.3×10^{-2}
Technetium-99	2.1×10^{-1}	4.3×10^{-4}	4.3×10^{-2}	8.8×10^{-4}	2.4×10^{-6}	2.7×10^{-4}
Iodine-129	2.3×10^{-1}	2.0×10^{-1}	3.3×10^{-1}	1.4×10^{-6}	4.0×10^{-9}	8.8×10^{-4}
Cesium-137	5.4×10^{2}	1.1	2.3×10^{1}	2.4×10^{2}	4.9×10^{-5}	1.4×10^{-1}
Uranium	4.3×10^{-3}	4.8×10^{-6}	1.4×10^{-4}	1.7×10^{-6}	4.6×10^{-9}	8.6×10^{-7}
Plutonium-238	1.9×10^{-2}	6.2×10^{-5}	2.7×10^{-4}	2.6×10^{-9}	7.1×10^{-12}	1.7×10^{-6}
Plutonium-239, -240	3.4×10^{-1}	6.8×10^{-4}	4.9×10^{-3}	4.5×10^{-8}	1.1×10^{-9}	3.0×10^{-5}
Plutonium-241	5.1×10^{-1}	1.1×10^{-3}	7.3×10^{-3}	6.8×10^{-8}	1.9×10^{-10}	4.5×10^{-5}
Americium-241	5.5×10^{-1}	2.2×10^{-3}	6.4×10^{-3}	1.3×10^{-7}	3.5×10^{-10}	3.9×10^{-5}

Key: STTS=Supplemental Treatment Technology Site.

Table K–15. Tank Closure Alternative 6A, Base Case, Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2168) (curies)			Annual Emissions in Year of Maximum Impact (2163) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	6.0×10^{1}	5.7×10^{-1}	0	7.7×10^{-2}	7.7×10^{-2}
Carbon-14	3.1×10^{3}	1.1×10^{1}	1.0×10^{-1}	0	1.4×10^{-2}	1.4×10^{-2}
Cobalt-60	4.1×10^{-2}	2.7×10^{-3}	7.6×10^{-5}	0	2.7×10^{-6}	2.7×10^{-6}
Strontium-90	4.3×10^{2}	2.2×10^{1}	6.9×10^{-1}	1.0×10^{2}	2.1×10^{-2}	2.1×10^{-2}
Technetium-99	1.5×10^{-1}	3.8×10^{-2}	3.7×10^{-4}	0	5.0×10^{-5}	5.0×10^{-5}
Iodine-129	4.8×10^{-1}	1.2	8.0×10^{-3}	0	1.9×10^{-4}	1.9×10^{-4}
Cesium-137	6.4×10^{2}	7.0×10^{1}	6.6×10^{-1}	2.4×10^{2}	8.3×10^{-2}	8.3×10^{-2}
Uranium	4.7×10^{-3}	2.2×10^{-3}	2.1×10^{-5}	0	2.8×10^{-6}	2.8×10^{-6}
Plutonium-238	2.4×10^{-2}	1.2×10^{-3}	1.2×10^{-5}	0	1.8×10^{-6}	1.5×10^{-6}
Plutonium-239, -240	4.1×10^{-1}	1.4×10^{-2}	6.5×10^{-4}	0	4.9×10^{-5}	1.2×10^{-5}
Plutonium-241	6.3×10^{-1}	8.2×10^{-3}	9.2×10^{-5}	0	1.0×10^{-5}	1.0×10^{-5}
Americium-241	7.3×10^{-1}	1.6×10^{-2}	8.8×10^{-4}	0	1.4×10^{-5}	1.1×10^{-5}

Key: STTS=Supplemental Treatment Technology Site.

Table K–16. Tank Closure Alternative 6A, Option Case, Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2168) (curies)			Annual Emissions in Year of Maximum Impact (2163) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	1.4×10^{3}	1.4×10^{3}	0	1.9	1.9
Carbon-14	3.1×10^{3}	1.4×10^{1}	1.4×10^{1}	0	1.9×10^{-2}	1.9×10^{-2}
Cobalt-60	4.1×10^{-2}	5.0×10^{-3}	5.0×10^{-3}	0	5.4×10^{-6}	5.4×10^{-6}
Strontium-90	4.3×10^{2}	2.6×10^{1}	2.6×10^{1}	1.0×10^{2}	2.3×10^{-2}	2.3×10^{-2}
Technetium-99	1.5×10^{-1}	5.6×10^{-2}	5.6×10^{-2}	0	7.3×10^{-5}	7.3×10^{-5}
Iodine-129	4.8×10^{-1}	1.3	1.3	0	2.7×10^{-4}	2.7×10^{-4}
Cesium-137	6.4×10^{2}	7.2×10^{1}	7.2×10^{1}	2.4×10^{2}	8.5×10^{-2}	8.5×10^{-2}
Uranium	4.7×10^{-3}	3.0×10^{-3}	3.0×10^{-3}	0	3.8×10^{-6}	3.8×10^{-6}
Plutonium-238	2.4×10^{-2}	2.3×10^{-3}	2.3×10^{-3}	0	3.3×10^{-6}	3.0×10^{-6}
Plutonium-239, -240	4.1×10^{-1}	9.1×10^{-2}	9.1×10^{-2}	0	1.5×10^{-4}	1.1×10^{-4}
Plutonium-241	6.3×10^{-1}	6.3×10^{-2}	6.3×10^{-2}	0	8.1×10^{-5}	8.1×10^{-5}
Americium-241	7.3×10^{-1}	3.4×10^{-2}	3.4×10^{-2}	0	3.1×10^{-5}	2.8×10^{-5}

Key: STTS=Supplemental Treatment Technology Site.

Table K–17. Tank Closure Alternative 6B, Base Case, Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2100) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	5.9×10^{1}	5.9×10^{1}	4.6×10^{2}	7.7×10^{-1}	7.7×10^{-1}
Carbon-14	3.1×10^{3}	1.1×10^{1}	1.1×10^{1}	1.2×10^{2}	1.4×10^{-1}	1.4×10^{-1}
Cobalt-60	4.1×10^{-2}	2.7×10^{-3}	2.7×10^{-3}	1.6×10^{-3}	5.0×10^{-5}	3.9×10^{-5}
Strontium-90	4.1×10^{2}	2.2×10^{1}	2.2×10^{1}	1.1×10^{2}	4.3×10^{-1}	3.2×10^{-1}
Technetium-99	1.5×10^{-1}	3.8×10^{-2}	3.8×10^{-2}	5.7×10^{-3}	5.0×10^{-4}	5.0×10^{-4}
Iodine-129	4.8×10^{-1}	4.1×10^{-1}	4.0×10^{-1}	1.8×10^{-2}	8.9×10^{-3}	8.6×10^{-3}
Cesium-137	5.8×10^{2}	6.5×10^{1}	6.5×10^{1}	2.5×10^{2}	8.7×10^{-1}	8.7×10^{-1}
Uranium	4.7×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	1.8×10^{-4}	2.8×10^{-5}	2.8×10^{-5}
Plutonium-238	2.4×10^{-2}	1.2×10^{-3}	1.2×10^{-3}	9.3×10^{-4}	1.5×10^{-5}	1.5×10^{-5}
Plutonium-239, -240	4.1×10^{-1}	1.4×10^{-2}	1.4×10^{-2}	1.6×10^{-2}	3.0×10^{-4}	2.1×10^{-4}
Plutonium-241	6.3×10^{-1}	8.1×10^{-3}	8.1×10^{-3}	2.4×10^{-2}	1.1×10^{-4}	1.1×10^{-4}
Americium-241	7.2×10^{-1}	1.6×10^{-2}	1.7×10^{-2}	2.8×10^{-2}	4.3×10^{-4}	2.8×10^{-4}

Key: STTS=Supplemental Treatment Technology Site.

Table K–18. Tank Closure Alternative 6B, Option Case, Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2100) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	1.4×10^{3}	1.4×10^{3}	4.6×10^{2}	1.9×10^{1}	1.9×10^{1}
Carbon-14	3.1×10^{3}	1.4×10^{1}	1.4×10^{1}	1.2×10^{2}	1.9×10^{-1}	1.9×10^{-1}
Cobalt-60	4.1×10^{-2}	5.0×10^{-3}	5.0×10^{-3}	1.6×10^{-3}	8.6×10^{-5}	6.6×10^{-5}
Strontium-90	4.1×10^{2}	2.5×10^{1}	2.5×10^{1}	1.1×10^{2}	5.3×10^{-1}	3.4×10^{-1}
Technetium-99	1.5×10^{-1}	5.6×10^{-2}	5.6×10^{-2}	5.7×10^{-3}	7.3×10^{-4}	7.3×10^{-4}
Iodine-129	4.8×10^{-1}	4.7×10^{-1}	4.6×10^{-1}	1.8×10^{-2}	9.7×10^{-3}	9.4×10^{-3}
Cesium-137	5.8×10^{2}	6.7×10^{1}	6.7×10^{1}	2.5×10^{2}	9.0×10^{-1}	8.9×10^{-1}
Uranium	4.7×10^{-3}	3.0×10^{-3}	3.0×10^{-3}	1.8×10^{-4}	3.8×10^{-5}	3.8×10^{-5}
Plutonium-238	2.4×10^{-2}	2.3×10^{-3}	2.3×10^{-3}	9.3×10^{-4}	3.0×10^{-5}	3.0×10^{-5}
Plutonium-239, -240	4.1×10^{-1}	9.1×10^{-2}	9.1×10^{-2}	1.6×10^{-2}	1.3×10^{-3}	1.2×10^{-3}
Plutonium-241	6.3×10^{-1}	6.3×10^{-2}	6.3×10^{-2}	2.4×10^{-2}	8.2×10^{-4}	8.1×10^{-4}
Americium-241	7.2×10^{-1}	3.3×10^{-2}	3.3×10^{-2}	2.8×10^{-2}	7.3×10^{-4}	4.4×10^{-4}

Key: STTS=Supplemental Treatment Technology Site.

Table K–19. Tank Closure Alternative 6C Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project (2006–2045) (curies)			Annual Emissions in Year of Maximum Impact (2040) (curies)		
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Waste Treatment Plant	200-East Area STTS	200-West Area STTS
Hydrogen-3 (tritium)	1.2×10^{4}	0	0	4.6×10^{2}	0	0
Carbon-14	3.1×10^{3}	0	0	1.2×10^{2}	0	0
Cobalt-60	4.1×10^{-2}	0	0	1.6×10^{-3}	0	0
Strontium-90	4.1×10^{2}	1.2×10^{-1}	1.2×10^{-1}	1.1×10^{2}	3.2×10^{-3}	3.1×10^{-3}
Technetium-99	1.5×10^{-1}	0	0	5.7×10^{-3}	0	0
Iodine-129	4.8×10^{-1}	2.7×10^{-1}	2.6×10^{-1}	1.8×10^{-2}	7.0×10^{-3}	6.7×10^{-3}
Cesium-137	5.8×10^{2}	1.5	1.4	2.5×10^{2}	3.9×10^{-2}	3.8×10^{-2}
Uranium	4.7×10^{-3}	0	0	1.8×10^{-4}	0	0
Plutonium-238	2.4×10^{-2}	5.6×10^{-7}	7.6×10^{-7}	9.3×10^{-4}	1.5×10^{-7}	1.5×10^{-7}
Plutonium-239, -240	4.1×10^{-1}	7.2×10^{-5}	9.6×10^{-5}	1.6×10^{-2}	1.9×10^{-5}	1.9×10^{-5}
Plutonium-241	6.3×10^{-1}	0	0	2.4×10^{-2}	0	0
Americium-241	7.2×10^{-1}	5.9×10^{-6}	7.8×10^{-6}	2.8×10^{-2}	1.5×10^{-6}	1.5×10^{-6}

Key: STTS=Supplemental Treatment Technology Site.

K.2.1.1.4 Results

The results of the dose analyses are presented in this section. Tables K–20 through K–32 show the estimated doses to the population living within 80 kilometers (50 miles) of the 200 Areas over the life of the project and during the year of maximum impact under each Tank Closure alternative. Tables K–33 through K–45 show the estimated doses to the MEI over the life of the project and during the year of maximum impact under each Tank Closure alternative. The year of maximum impact was determined by considering the combined impacts on the population or the MEI from the three emission source locations: the WTP, STTS-East, and STTS-West. For purposes of comparison, the National Emission Standards for Hazardous Air Pollutants annual dose limit to an individual member of the public is 10 millirem (0.01 rem) per year for all emission sources from a DOE site (40 CFR 61.90–61.97).

For activities that occur over a number of years, an average emission was assumed for each year. This approach can result in the peak impact spanning a number of years rather than occurring in a single year. Under all Tank Closure alternatives except Alternative 1, the year in which cesium and strontium would be de-encapsulated and processed at the WTP would result in the largest annual impacts.

Note that some of the alternatives would take much longer than others to complete; this difference would affect the population dose. As a result of the duration of some of the alternatives, the exposed population could include multiple generations. The radioactive inventories were not adjusted to account for the differences in the duration of the alternatives (radioactive decay over time would reduce the radioactivity of each radionuclide); however, the analyses still support a general comparison of the impacts on the offsite population and MEI.

Table K–20. Tank Closure Alternative 1 Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant[b]	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant[b]	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	0	2.6×10^{1}	2.5×10^{1}	5.0×10^{1}	0	2.6×10^{-1}	2.5×10^{-1}	5.0×10^{-1}
Carbon-14	0	0	0	0	0	0	0	0
Cobalt-60	0	1.3	1.3	2.6	0	1.3×10^{-2}	1.3×10^{-2}	2.6×10^{-2}
Strontium-90	0	2.2×10^{-1}	2.1×10^{-1}	4.4×10^{-1}	0	4.3×10^{-3}	4.1×10^{-3}	8.5×10^{-3}
Technetium-99	0	0	0	0	0	0	0	0
Iodine-129	0	1.4×10^{1}	1.3×10^{1}	2.7×10^{1}	0	2.7×10^{-1}	2.6×10^{-1}	5.2×10^{-1}
Cesium-137	0	2.1	2.1	4.2	0	4.2×10^{-2}	4.0×10^{-2}	8.2×10^{-2}
Uranium	0	2.6×10^{2}	2.5×10^{2}	5.2×10^{2}	0	2.6	2.5	5.2
Plutonium-238	0	0	0	0	0	0	0	0
Plutonium-239, -240	0	3.4×10^{-5}	3.2×10^{-5}	6.6×10^{-5}	0	9.2×10^{-7}	6.4×10^{-7}	1.6×10^{-6}
Plutonium-241	0	6.4×10^{-7}	6.0×10^{-7}	1.2×10^{-6}	0	0	0	0
Americium-241	0	2.7×10^{-5}	2.5×10^{-5}	5.2×10^{-5}	0	7.9×10^{-7}	5.2×10^{-7}	1.3×10^{-6}
Total	0	3.1×10^{2}	2.9×10^{2}	6×10^{2}	0	3.2	3.1	6.3
Number of latent cancer fatalities[c]				0 (4×10^{-1})				0 (4×10^{-3})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] There would be no emissions from the Waste Treatment Plant because it would not operate under this alternative.

[c] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–21. Tank Closure Alternative 2A Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	2.6×10^{1}	2.5×10^{1}	5.2×10^{1}	0	0	0	0
Carbon-14	7.2×10^{1}	0	0	7.2×10^{1}	0	0	0	0
Cobalt-60	5.7×10^{3}	1.3	1.3	2.6	0	0	0	0
Strontium-90	8.5×10^{1}	4.0×10^{-1}	3.9×10^{-1}	8.6×10^{1}	2.2×10^{1}	0	0	2.2×10^{1}
Technetium-99	1.8×10^{-3}	0	0	1.8×10^{-3}	0	0	0	0
Iodine-129	2.7	2.5×10^{1}	2.4×10^{1}	5.2×10^{1}	0	0	0	0
Cesium-137	9.3×10^{1}	3.9	3.7	1.0×10^{2}	3.8×10^{1}	0	0	3.8×10^{1}
Uranium	2.1×10^{-1}	2.6×10^{2}	2.5×10^{2}	5.2×10^{2}	0	0	0	0
Plutonium-238	3.7	5.9×10^{-5}	1.5×10^{-4}	3.7	0	0	0	0
Plutonium-239, -240	6.5×10^{1}	8.6×10^{-3}	2.2×10^{-2}	6.5×10^{1}	0	5.3×10^{-7}	0	5.3×10^{-7}
Plutonium-241	1.3	1.6×10^{-4}	4.0×10^{-4}	1.3	0	0	0	0
Americium-241	1.2×10^{2}	8.8×10^{-4}	1.9×10^{-3}	1.2×10^{2}	0	0	0	0
Total	4.5×10^{2}	3.2×10^{2}	3.1×10^{2}	1.1×10^{3}	6.0×10^{1}	5.3×10^{-7}	0	6.0×10^{1}
Number of latent cancer fatalities[b]				1 (0.6)				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–22. Tank Closure Alternative 2B Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	0	0	1.6	6.0×10^{-2}	0	0	6.0×10^{-2}
Carbon-14	7.2×10^{1}	0	0	7.2×10^{1}	2.7	0	0	2.7
Cobalt-60	5.7×10^{-3}	0	0	5.7×10^{-3}	2.2×10^{-4}	0	0	2.2×10^{-4}
Strontium-90	8.9×10^{1}	8.2×10^{-2}	7.9×10^{-2}	8.9×10^{1}	2.6×10^{1}	2.2×10^{-3}	2.1×10^{-3}	2.6×10^{1}
Technetium-99	1.8×10^{-3}	0	0	1.8×10^{-3}	6.8×10^{-5}	0	0	6.8×10^{-5}
Iodine-129	2.7	5.1	4.8	1.3×10^{1}	1.0×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	3.7×10^{-1}
Cesium-137	9.3×10^{1}	7.9×10^{-1}	7.6×10^{-1}	9.5×10^{1}	4.0×10^{1}	2.1×10^{-2}	2.0×10^{-2}	4.0×10^{1}
Uranium	2.1×10^{-1}	0	0	2.1×10^{-1}	7.9×10^{-3}	0	0	7.9×10^{-3}
Plutonium-238	3.7	2.7×10^{-4}	3.6×10^{-4}	3.7	1.4×10^{-1}	7.0×10^{-5}	7.0×10^{-5}	1.4×10^{-1}
Plutonium-239, -240	6.5×10^{1}	3.8×10^{-2}	5.1×10^{-2}	6.5×10^{1}	2.6	9.9×10^{-3}	9.9×10^{-3}	2.7
Plutonium-241	1.3	7.1×10^{-4}	9.6×10^{-4}	1.3	7.4×10^{-2}	0	0	7.4×10^{-2}
Americium-241	1.2×10^{2}	3.2×10^{-3}	4.2×10^{-3}	1.2×10^{2}	4.4	7.9×10^{-4}	7.9×10^{-4}	4.4
Total	4.5×10^{2}	6.0	5.7	4.6×10^{2}	7.6×10^{1}	1.7×10^{-1}	1.6×10^{-1}	7.6×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (5×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–23. Tank Closure Alternative 3A Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	4.6×10^{-1}	1.9	1.6	4.0	0	8.8×10^{-3}	7.4×10^{-3}	1.6×10^{-2}
Carbon-14	2.2×10^{1}	8.8×10^{1}	7.4×10^{1}	1.8×10^{2}	0	4.0×10^{-1}	3.3×10^{-1}	7.3×10^{-1}
Cobalt-60	4.7×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	7.7×10^{-3}	0	7.0×10^{-6}	6.8×10^{-6}	1.4×10^{-5}
Strontium-90	8.4×10^{1}	1.2×10^{-1}	1.6	8.6×10^{1}	2.2×10^{1}	1.4×10^{-5}	7.1×10^{-3}	2.2×10^{1}
Technetium-99	5.3×10^{-4}	2.2×10^{-5}	1.9×10^{-3}	2.4×10^{-3}	0	1.0×10^{-5}	8.6×10^{-6}	1.9×10^{-5}
Iodine-129	8.0×10^{-1}	8.0	7.3	1.6×10^{1}	0	1.6×10^{-2}	1.3×10^{-2}	2.9×10^{-2}
Cesium-137	8.9×10^{1}	1.3	1.2×10^{1}	1.0×10^{2}	3.8×10^{1}	2.7×10^{-3}	5.3×10^{-2}	3.8×10^{1}
Uranium	1.9×10^{-1}	1.6×10^{-2}	2.1×10^{-2}	2.3×10^{-1}	0	6.8×10^{-5}	9.6×10^{-5}	1.6×10^{-4}
Plutonium-238	3.1	3.3×10^{-2}	1.4×10^{-1}	3.3	0	3.6×10^{-7}	6.4×10^{-4}	6.4×10^{-4}
Plutonium-239, -240	5.9×10^{1}	4.2×10^{-1}	2.9	6.3×10^{1}	0	7.4×10^{-6}	1.3×10^{-2}	1.3×10^{-2}
Plutonium-241	1.1	7.9×10^{-3}	5.4×10^{-2}	1.2	0	2.0×10^{-7}	3.6×10^{-4}	3.6×10^{-4}
Americium-241	1.0×10^{2}	1.3	3.8	1.1×10^{2}	0	2.0×10^{-5}	1.7×10^{-2}	1.7×10^{-2}
Total	3.6×10^{2}	1.0×10^{2}	1.0×10^{2}	5.7×10^{2}	6.0×10^{1}	4.2×10^{-1}	4.5×10^{-1}	6.1×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–24. Tank Closure Alternative 3B Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	4.6×10^{-1}	2.0×10^{-5}	1.6×10^{-5}	4.6×10^{-1}	0	8.8×10^{-8}	7.4×10^{-8}	1.6×10^{-7}
Carbon-14	2.2×10^{1}	8.9×10^{-4}	7.4×10^{-4}	2.2×10^{1}	0	4.0×10^{-6}	3.3×10^{-6}	7.3×10^{-6}
Cobalt-60	4.7×10^{-3}	3.5×10^{-5}	3.0×10^{-5}	4.7×10^{-3}	0	1.4×10^{-7}	1.4×10^{-7}	2.8×10^{-7}
Strontium-90	8.4×10^{1}	1.2×10^{-1}	1.0×10^{-1}	8.5×10^{1}	2.2×10^{1}	2.8×10^{-7}	1.4×10^{-4}	2.2×10^{1}
Technetium-99	1.2×10^{-3}	1.8×10^{-6}	3.8×10^{-5}	1.2×10^{-3}	0	2.0×10^{-9}	1.7×10^{-7}	1.7×10^{-7}
Iodine-129	8.0×10^{-1}	4.5	4.3	9.7	0	1.6×10^{-7}	1.3×10^{-7}	2.9×10^{-7}
Cesium-137	8.9×10^{1}	7.4×10^{-1}	9.2×10^{-1}	9.1×10^{1}	3.8×10^{1}	5.5×10^{-5}	1.1×10^{-3}	3.8×10^{1}
Uranium	1.9×10^{-1}	9.3×10^{-4}	4.8×10^{-4}	1.9×10^{-1}	0	1.4×10^{-6}	1.9×10^{-6}	3.3×10^{-6}
Plutonium-238	3.1	3.3×10^{-2}	3.4×10^{-3}	3.2	0	7.2×10^{-9}	1.3×10^{-5}	1.3×10^{-5}
Plutonium-239, -240	5.9×10^{1}	4.4×10^{-1}	1.5×10^{-1}	6.0×10^{1}	0	6.7×10^{-7}	2.5×10^{-4}	2.5×10^{-4}
Plutonium-241	1.1	8.1×10^{-3}	2.8×10^{-3}	1.2	0	3.9×10^{-9}	7.2×10^{-6}	7.2×10^{-6}
Americium-241	1.0×10^{2}	1.3	8.4×10^{-2}	1.0×10^{2}	0	3.9×10^{-7}	3.4×10^{-4}	3.4×10^{-4}
Total	3.6×10^{2}	7.2	5.6	3.8×10^{2}	6.0×10^{1}	6.2×10^{-5}	1.8×10^{-3}	6.0×10^{1}
Number of latent cancer fatalities[b]				0 (2×10^{-1})				0 (4×10^{-2})

a The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

b The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–25. Tank Closure Alternative 3C Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	4.6×10^{-1}	1.9	1.6	4.0	0	8.8×10^{-3}	7.4×10^{-3}	1.6×10^{-2}
Carbon-14	2.2×10^{1}	8.8×10^{1}	7.4×10^{1}	1.8×10^{2}	0	4.0×10^{-1}	3.3×10^{-1}	7.3×10^{-1}
Cobalt-60	4.7×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	7.7×10^{-3}	0	7.0×10^{-6}	6.8×10^{-6}	1.4×10^{-5}
Strontium-90	8.4×10^{1}	1.3×10^{-1}	1.6	8.6×10^{1}	2.2×10^{1}	1.4×10^{-5}	7.1×10^{-3}	2.2×10^{1}
Technetium-99	1.2×10^{-3}	2.3×10^{-3}	1.9×10^{-3}	5.4×10^{-3}	0	1.0×10^{-5}	8.6×10^{-6}	1.9×10^{-5}
Iodine-129	8.0×10^{-1}	8.0	7.3	1.6×10^{1}	0	1.6×10^{-2}	1.3×10^{-2}	2.9×10^{-2}
Cesium-137	8.9×10^{1}	1.3	1.2×10^{1}	1.0×10^{2}	3.8×10^{1}	2.7×10^{-3}	5.3×10^{-2}	3.8×10^{1}
Uranium	1.9×10^{-1}	1.6×10^{-2}	2.1×10^{-2}	2.3×10^{-1}	0	6.8×10^{-5}	9.6×10^{-5}	1.6×10^{-4}
Plutonium-238	3.1	3.3×10^{-2}	1.4×10^{-1}	3.3	0	3.6×10^{-7}	6.4×10^{-4}	6.4×10^{-4}
Plutonium-239, -240	5.9×10^{1}	4.2×10^{-1}	2.9	6.3×10^{1}	0	7.4×10^{-6}	1.3×10^{-2}	1.3×10^{-2}
Plutonium-241	1.1	7.9×10^{-3}	5.4×10^{-2}	1.2	0	2.0×10^{-7}	3.6×10^{-4}	3.6×10^{-4}
Americium-241	1.0×10^{2}	1.3	3.8	1.1×10^{2}	0	2.0×10^{-5}	1.7×10^{-2}	1.7×10^{-2}
Total	3.6×10^{2}	1×10^{2}	1×10^{2}	5.7×10^{2}	6.0×10^{1}	4.2×10^{-1}	4.5×10^{-1}	6.1×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

a The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

b The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the ris k factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–26. Tank Closure Alternative 4 Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	4.7×10^{-1}	2.0×10^{-5}	1.7	2.1	0	1.2×10^{-9}	1.2×10^{-9}	2.4×10^{-9}
Carbon-14	2.2×10^{1}	9.0×10^{-4}	7.5×10^{1}	9.7×10^{1}	0	2.0×10^{-8}	2.0×10^{-8}	4.0×10^{-8}
Cobalt-60	4.7×10^{-3}	9.0×10^{-5}	1.6×10^{-3}	6.4×10^{-3}	0	1.0×10^{-7}	1.0×10^{-7}	2.0×10^{-7}
Strontium-90	8.5×10^{1}	1.4	3.3	9.0×10^{1}	2.2×10^{1}	3.9×10^{-3}	3.9×10^{-3}	2.2×10^{1}
Technetium-99	5.3×10^{-4}	6.4×10^{-5}	1.9×10^{-3}	2.5×10^{-3}	0	8.1×10^{-8}	8.1×10^{-8}	1.6×10^{-7}
Iodine-129	8.1×10^{-1}	4.9	7.7	1.3×10^{1}	0	7.0×10^{-8}	7.0×10^{-8}	1.4×10^{-7}
Cesium-137	9.0×10^{1}	1.3	1.3×10^{1}	1.0×10^{2}	3.8×10^{1}	2.5×10^{-3}	2.5×10^{-3}	3.8×10^{1}
Uranium	1.9×10^{-1}	7.9×10^{-3}	2.8×10^{-2}	2.3×10^{-1}	0	3.5×10^{-5}	3.5×10^{-5}	6.9×10^{-5}
Plutonium-238	3.2	6.4×10^{-2}	1.7×10^{-1}	3.4	0	2.2×10^{-4}	2.2×10^{-4}	4.4×10^{-4}
Plutonium-239, -240	6.0×10^{1}	1.5	4.2	6.5×10^{1}	0	1.4×10^{-2}	1.4×10^{-2}	2.7×10^{-2}
Plutonium-241	1.2	2.8×10^{-2}	7.9×10^{-2}	1.3	0	4.4×10^{-5}	4.4×10^{-5}	8.8×10^{-5}
Americium-241	1.0×10^{2}	2.4	5.3	1.1×10^{2}	0	3.0×10^{-3}	3.0×10^{-3}	6.0×10^{-3}
Total	3.7×10^{2}	1.2×10^{1}	1.1×10^{2}	4.9×10^{2}	6.0×10^{1}	2.3×10^{-2}	2.3×10^{-2}	6.0×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–27. Tank Closure Alternative 5 Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	7.6×10^{-1}	6.8×10^{-6}	1.5	2.2	4.7×10^{-4}	4.2×10^{-8}	9.2×10^{-3}	9.7×10^{-3}
Carbon-14	3.5×10^{1}	3.1×10^{-4}	6.8×10^{1}	1.0×10^{2}	2.1×10^{-1}	1.9×10^{-6}	4.2×10^{-1}	6.3×10^{-1}
Cobalt-60	5.8×10^{-3}	1.4×10^{-5}	1.4×10^{-3}	7.1×10^{-3}	7.5×10^{-6}	6.7×10^{-8}	8.5×10^{-6}	1.6×10^{-5}
Strontium-90	8.0×10^{1}	1.1×10^{-1}	1.5	8.2×10^{1}	2.2×10^{1}	1.3×10^{-7}	8.8×10^{-3}	2.2×10^{1}
Technetium-99	2.6×10^{-3}	1.7×19^{-5}	1.7×10^{-3}	4.3×10^{-3}	1.1×10^{-5}	9.8×10^{-8}	1.1×10^{-5}	2.1×10^{-5}
Iodine-129	1.3	3.7	6.3	1.1×10^{1}	8.2×10^{-6}	7.6×10^{-8}	1.7×10^{-2}	1.7×10^{-2}
Cesium-137	8.7×10^{1}	6.0×10^{-1}	1.2×10^{1}	1.0×10^{2}	3.8×10^{1}	2.6×10^{-5}	7.3×10^{-2}	3.8×10^{1}
Uranium	1.9×10^{-1}	6.8×10^{-4}	1.9×10^{-2}	2.1×10^{-1}	7.3×10^{-5}	6.5×10^{-7}	1.2×10^{-4}	1.9×10^{-4}
Plutonium-238	2.9	3.0×10^{-2}	1.3×10^{-1}	3.0	3.9×10^{-7}	3.4×10^{-9}	8.0×10^{-4}	8.0×10^{-4}
Plutonium-239, -240	5.4×10^{1}	3.6×10^{-1}	2.6	5.7×10^{1}	7.6×10^{-6}	6.0×10^{-7}	1.6×10^{-2}	1.6×10^{-2}
Plutonium-241	1.0	6.7×10^{-3}	4.9×10^{-2}	1.1	2.1×10^{-7}	1.9×10^{-9}	4.5×10^{-4}	4.5×10^{-4}
Americium-241	9.3×10^{1}	1.2	3.5	9.8×10^{1}	2.0×10^{-5}	1.9×10^{-7}	2.1×10^{-2}	2.1×10^{-2}
Total	3.6×10^{2}	6.0	9.5×10^{1}	4.6×10^{2}	6.0×10^{1}	3.0×10^{-5}	5.6×10^{-1}	6.1×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–28. Tank Closure Alternative 6A, Base Case, Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	2.5×10^{-2}	2.4×10^{-4}	1.6	0	3.2×10^{-5}	3.2×10^{-5}	6.5×10^{-5}
Carbon-14	7.2×10^{1}	7.9×10^{-1}	7.6×10^{-3}	7.3×10^{1}	0	1.0×10^{-3}	1.0×10^{-3}	2.1×10^{-3}
Cobalt-60	5.7×10^{-3}	1.2×10^{-3}	3.4×10^{-5}	6.9×10^{-3}	0	1.2×10^{-6}	1.2×10^{-6}	2.4×10^{-6}
Strontium-90	9.0×10^{1}	1.5×10^{1}	4.6×10^{-1}	1.1×10^{2}	2.2×10^{1}	1.4×10^{-2}	1.4×10^{-2}	2.2×10^{1}
Technetium-99	1.8×10^{-3}	1.5×10^{-3}	1.5×10^{-5}	3.3×10^{-3}	0	2.0×10^{-6}	2.0×10^{-6}	4.0×10^{-6}
Iodine-129	2.8	2.4×10^{1}	1.5×10^{-1}	2.6×10^{1}	0	3.6×10^{-3}	3.6×10^{-3}	7.3×10^{-3}
Cesium-137	1.0×10^{2}	3.7×10^{1}	3.5×10^{-1}	1.4×10^{2}	3.8×10^{1}	4.4×10^{-2}	4.4×10^{-2}	3.8×10^{1}
Uranium	2.1×10^{-1}	3.1×10^{-1}	2.9×10^{-3}	5.2×10^{-1}	0	4.0×10^{-4}	4.0×10^{-4}	7.9×10^{-4}
Plutonium-238	3.7	5.7×10^{-1}	6.0×10^{-3}	4.2	0	8.8×10^{-4}	7.4×10^{-4}	1.6×10^{-3}
Plutonium-239, -240	6.5×10^{1}	7.3	3.4×10^{-1}	7.3×10^{1}	0	2.6×10^{-2}	6.2×10^{-3}	3.2×10^{-2}
Plutonium-241	1.3	1.4×10^{-1}	6.4×10^{-3}	1.4	0	1.0×10^{-4}	1.0×10^{-4}	2.0×10^{-4}
Americium-241	1.2×10^{2}	8.9	4.7×10^{-1}	1.3×10^{2}	0	7.5×10^{-3}	5.9×10^{-3}	1.3×10^{-2}
Total	4.6×10^{2}	9.3×10^{1}	1.8	5.6×10^{2}	6.0×10^{1}	9.7×10^{-2}	7.6×10^{-2}	6.0×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–29. Tank Closure Alternative 6A, Option Case, Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	6.0×10^{-1}	6.0×10^{-1}	2.8	0	7.8×10^{-4}	7.8×10^{-4}	1.6×10^{-3}
Carbon-14	7.2×10^{1}	1.1	1.1	7.4×10^{1}	0	1.4×10^{-3}	1.4×10^{-3}	2.8×10^{-3}
Cobalt-60	5.7×10^{-3}	2.3×10^{-3}	2.3×10^{-3}	1.0×10^{-2}	0	2.4×10^{-6}	2.4×10^{-6}	4.9×10^{-6}
Strontium-90	9.0×10^{1}	1.8×10^{1}	1.8×10^{1}	1.3×10^{2}	2.2×10^{1}	1.5×10^{-2}	1.5×10^{-2}	2.2×10^{1}
Technetium-99	1.8×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	6.3×10^{-3}	0	2.9×10^{-6}	2.9×10^{-6}	5.8×10^{-6}
Iodine-129	2.8	2.5×10^{1}	2.4×10^{1}	5.1×10^{1}	0	5.1×10^{-3}	5.1×10^{-3}	1.0×10^{-2}
Cesium-137	1.0×10^{2}	3.8×10^{1}	3.8×10^{1}	1.8×10^{2}	3.8×10^{1}	4.5×10^{-2}	4.5×10^{-2}	3.8×10^{1}
Uranium	2.1×10^{-1}	4.1×10^{-1}	4.1×10^{-1}	1.0	0	5.4×10^{-4}	5.4×10^{-4}	1.1×10^{-3}
Plutonium-238	3.7	1.1	1.1	5.9	0	1.6×10^{-3}	1.4×10^{-3}	3.0×10^{-3}
Plutonium-239 -240	6.5×10^{1}	4.8×10^{1}	4.8×10^{1}	1.6×10^{2}	0	7.7×10^{-2}	5.8×10^{-2}	1.3×10^{-1}
Plutonium-241	1.3	9.0×10^{-1}	9.0×10^{-1}	3.1	0	8.0×10^{-4}	8.0×10^{-4}	1.6×10^{-3}
Americium-241	1.2×10^{2}	1.8×10^{1}	1.8×10^{1}	1.6×10^{2}	0	1.7×10^{-2}	1.5×10^{-2}	3.2×10^{-2}
Total	4.6×10^{2}	1.5×10^{2}	1.5×10^{2}	7.6×10^{2}	6.0×10^{1}	1.6×10^{-1}	1.4×10^{-1}	6.0×10^{1}
Number of latent cancer fatalities[b]				0 (5×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–30. Tank Closure Alternative 6B, Base Case, Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	2.5×10^{-2}	2.5×10^{-2}	1.6	6.0×10^{-2}	3.2×10^{-4}	3.2×10^{-4}	6.0×10^{-2}
Carbon-14	7.2×10^{1}	7.9×10^{-1}	7.9×10^{-1}	7.3×10^{1}	2.7	1.0×10^{-2}	1.0×10^{-2}	2.8
Cobalt-60	5.7×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	8.1×10^{-3}	2.2×10^{-4}	2.2×10^{-5}	1.8×10^{-5}	2.6×10^{-4}
Strontium-90	8.5×10^{1}	1.5×10^{1}	1.5×10^{1}	1.1×10^{2}	2.4×10^{1}	2.9×10^{-1}	2.2×10^{-1}	2.4×10^{1}
Technetium-99	1.8×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	4.8×10^{-3}	6.8×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	1.1×10^{-4}
Iodine-129	2.7	7.9	7.6	1.8×10^{1}	1.0×10^{-1}	1.7×10^{-1}	1.6×10^{-1}	4.4×10^{-1}
Cesium-137	9.3×10^{1}	3.5×10^{1}	3.5×10^{1}	1.6×10^{2}	4.0×10^{1}	4.6×10^{-1}	4.6×10^{-1}	4.1×10^{1}
Uranium	2.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	8.2×10^{-1}	7.9×10^{-3}	4.0×10^{-3}	4.0×10^{-3}	1.6×10^{-2}
Plutonium-238	3.7	5.7×10^{-1}	5.7×10^{-1}	4.8	1.4×10^{-1}	7.4×10^{-3}	7.4×10^{-3}	1.5×10^{-1}
Plutonium-239, -240	6.5×10^{1}	7.3	7.4	8.0×10^{1}	2.6	1.6×10^{-1}	1.1×10^{-1}	2.9
Plutonium-241	1.3	1.4×10^{-1}	1.4×10^{-1}	1.5	7.4×10^{-2}	1.1×10^{-3}	1.1×10^{-3}	7.6×10^{-2}
Americium-241	1.2×10^{2}	8.9	9.0	1.4×10^{2}	4.4	2.3×10^{-1}	1.5×10^{-1}	4.8
Total	4.5×10^{2}	7.5×10^{1}	7.5×10^{1}	6.0×10^{2}	7.4×10^{1}	1.3	1.1	7.6×10^{1}
Number of latent cancer fatalities[b]				0 (4×10^{-1})				0 (5×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–31. Tank Closure Alternative 6B, Option Case, Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	6.0×10^{-1}	6.0×10^{-1}	2.8	6.0×10^{-2}	7.8×10^{-3}	7.8×10^{-3}	7.5×10^{-2}
Carbon-14	7.2×10^{1}	1.1	1.1	7.4×10^{1}	2.7	1.4×10^{-2}	1.4×10^{-2}	2.8
Cobalt-60	5.7×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	1.0×10^{-2}	2.2×10^{-4}	3.9×10^{-5}	3.0×10^{-5}	2.9×10^{-4}
Strontium-90	8.5×10^{1}	1.7×10^{1}	1.7×10^{1}	1.2×10^{2}	2.4×10^{1}	3.6×10^{-1}	2.3×10^{-1}	2.4×10^{1}
Technetium-99	1.8×10^{-3}	2.2×10^{-3}	2.2×10^{-3}	6.3×10^{-3}	6.8×10^{-5}	2.9×10^{-5}	2.9×10^{-5}	1.3×10^{-4}
Iodine-129	2.7	9.0	8.8	2.0×10^{1}	1.0×10^{-1}	1.8×10^{-1}	1.8×10^{-1}	4.7×10^{-1}
Cesium-137	9.3×10^{1}	3.6×10^{1}	3.6×10^{1}	1.6×10^{2}	4.0×10^{1}	4.8×10^{-1}	4.7×10^{-1}	4.1×10^{1}
Uranium	2.1×10^{-1}	4.2×10^{-1}	4.2×10^{-1}	1.0	7.9×10^{-3}	5.4×10^{-3}	5.4×10^{-3}	1.9×10^{-2}
Plutonium-238	3.7	1.1	1.1	5.9	1.4×10^{-1}	1.5×10^{-2}	1.4×10^{-2}	1.7×10^{-1}
Plutonium-239, -240	6.5×10^{1}	4.8×10^{1}	4.8×10^{1}	1.6×10^{2}	2.5	7.1×10^{-1}	6.3×10^{-1}	3.8
Plutonium-241	1.3	9.0×10^{-1}	9.0×10^{-1}	3.1	7.4×10^{-2}	8.1×10^{-3}	8.1×10^{-3}	9.0×10^{-2}
Americium-241	1.2×10^{2}	1.8×10^{1}	1.8×10^{1}	1.6×10^{2}	4.7	4.0×10^{-1}	2.4×10^{-1}	5.3
Total	4.5×10^{2}	1.3×10^{2}	1.3×10^{2}	7.1×10^{2}	7.4×10^{1}	2.2	1.8	7.8×10^{1}
Number of latent cancer fatalities[b]				0 (4×10^{-1})				0 (5×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–32. Tank Closure Alternative 6C Impacts on the Population During Normal Operations

Radionuclides	Dose over Life of Project (person-rem)[a]				Dose in Year of Maximum Impact (person-rem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6	0	0	1.6	6.0×10^{-2}	0	0	6.0×10^{-2}
Carbon-14	7.2×10^{1}	0	0	7.2×10^{1}	2.7	0	0	2.7
Cobalt-60	5.7×10^{-3}	0	0	5.7×10^{-3}	2.2×10^{-4}	0	0	2.2×10^{-4}
Strontium-90	8.5×10^{1}	8.2×10^{-2}	7.9×10^{-2}	8.5×10^{1}	2.4×10^{1}	2.2×10^{-3}	2.1×10^{-3}	2.4×10^{1}
Technetium-99	1.8×10^{-3}	0	0	1.8×10^{-3}	6.8×10^{-5}	0	0	6.8×10^{-5}
Iodine-129	2.7	5.1	4.9	1.3×10^{1}	1.0×10^{-1}	1.3×10^{-1}	1.3×10^{-1}	3.7×10^{-1}
Cesium-137	9.3×10^{1}	7.9×10^{-1}	7.6×10^{-1}	9.5×10^{1}	4.0×10^{1}	2.1×10^{-2}	2.0×10^{-2}	4.0×10^{1}
Uranium	2.1×10^{-1}	0	0	2.1×10^{-1}	7.9×10^{-3}	0	0	7.9×10^{-3}
Plutonium-238	3.7	2.7×10^{-4}	3.6×10^{-4}	3.7	1.4×10^{-1}	7.0×10^{-5}	7.0×10^{-5}	1.4×10^{-1}
Plutonium-239, -240	6.5×10^{1}	3.8×10^{-2}	5.1×10^{-2}	6.5×10^{1}	2.6	9.9×10^{-3}	9.9×10^{-3}	2.7
Plutonium-241	1.3	7.1×10^{-4}	9.6×10^{-4}	1.3	7.4×10^{-2}	0	0	7.4×10^{-2}
Americium-241	1.2×10^{2}	3.2×10^{-3}	4.2×10^{-3}	1.2×10^{2}	4.4	7.9×10^{-4}	7.9×10^{-4}	4.4
Total	4.5×10^{2}	6.0	5.7	4.6×10^{2}	7.4×10^{1}	1.7×10^{-1}	1.6×10^{-1}	7.4×10^{1}
Number of latent cancer fatalities[b]				0 (3×10^{-1})				0 (4×10^{-2})

[a] The reported result is the collective dose for a population of approximately 463,000, the average of the populations of 447,354; 451,556; and 488,897 that live within 80 kilometers (50 miles) of the Waste Treatment Plant, 200-East Area STTS, and 200-West Area STTS, respectively. There is no regulatory standard for a population dose.

[b] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–33. Tank Closure Alternative 1 Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant[c]	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant[c]	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	0	1.0	5.2×10^{-1}	1.6	0	1.0×10^{-2}	5.2×10^{-3}	1.6×10^{-2}
Carbon-14	0	0	0	0	0	0	0	0
Cobalt-60	0	4.4×10^{-2}	2.2×10^{-2}	6.6×10^{-2}	0	4.4×10^{-4}	2.2×10^{-4}	6.6×10^{-4}
Strontium-90	0	1.3×10^{-2}	6.4×10^{-3}	1.9×10^{-2}	0	2.4×10^{-4}	1.2×10^{-4}	3.7×10^{-4}
Technetium-99	0	0	0	0	0	0	0	0
Iodine-129	0	5.5×10^{-1}	2.8×10^{-1}	8.3×10^{-1}	0	1.1×10^{-2}	5.4×10^{-3}	1.6×10^{-2}
Cesium-137	0	7.3×10^{-2}	3.8×10^{-2}	1.1×10^{-1}	0	1.4×10^{-3}	7.3×10^{-4}	2.1×10^{-3}
Uranium	0	6	3.1	9.1	0	6.0×10^{-2}	3.1×10^{-2}	9.1×10^{-2}
Plutonium-238	0	0	0	0	0	0	0	0
Plutonium-239, -240	0	7.8×10^{-7}	3.9×10^{-7}	1.2×10^{-6}	0	2.1×10^{-8}	7.7×10^{-9}	2.9×10^{-8}
Plutonium-241	0	0	0	0	0	0	0	0
Americium-241	0	6.6×10^{-7}	3.0×10^{-7}	9.5×10^{-7}	0	1.9×10^{-8}	6.3×10^{-9}	2.5×10^{-8}
Total	0	7.7	3.9	1.2×10^{1}	0	8.3×10^{-2}	4.2×10^{-2}	1.3×10^{-1}
Lifetime risk of a latent cancer fatality				7×10^{-6}				8×10^{-8}

[a] Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 8 millirem, with a corresponding lifetime risk of a latent cancer fatality of 5×10^{-6}.

[b] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

[c] There would be no emissions from the Waste Treatment Plant because it would not operate under this alternative.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–34. Tank Closure Alternative 2A Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	2.8×10^{-2}	1.0	5.2×10^{-1}	1.6	0	0	0	0
Carbon-14	1.7	0	0	1.7	0	0	0	0
Cobalt-60	8.1×10^{-5}	4.4×10^{-2}	2.2×10^{-2}	6.6×10^{-2}	0	0	0	0
Strontium-90	2.1	2.3×10^{-2}	1.2×10^{-2}	2.1	6.4×10^{-1}	0	0	6.4×10^{-1}
Technetium-99	6.2×10^{-5}	0	0	6.2×10^{-5}	0	0	0	0
Iodine-129	4.8×10^{-2}	9.9×10^{-1}	5.1×10^{-1}	1.5	0	0	0	0
Cesium-137	1.5	1.3×10^{-1}	6.8×10^{-2}	1.7	7.2×10^{-1}	0	0	7.2×10^{-1}
Uranium	2.1×10^{-3}	6.0	3.1	9.1	0	0	0	0
Plutonium-238	3.7×10^{-2}	1.4×10^{-6}	1.8×10^{-6}	3.7×10^{-2}	0	0	0	0
Plutonium-239, -240	6.9×10^{-1}	1.9×10^{-4}	2.6×10^{-4}	6.9×10^{-1}	0	7.8×10^{-9}	0	7.8×10^{-9}
Plutonium-241	2.0×10^{-2}	0	0	2.0×10^{-2}	0	0	0	0
Americium-241	1.2	2.1×10^{-5}	2.3×10^{-5}	1.2	0	0	0	0
Total	7.3	8.3	4.2	2.0×10^{1}	1.4	7.8×10^{-9}	0	1.4
Lifetime risk of a latent cancer fatality				1×10^{-5}				8×10^{-7}

[a] Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 7.4 millirem, with a corresponding lifetime risk of a latent cancer fatality of 4×10^{-6}.

[b] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–35. Tank Closure Alternative 2B Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	3.3×10^{-2}	0	0	3.3×10^{-2}	1.2×10^{-3}	0	0	1.2×10^{-3}
Carbon-14	2.2	0	0	2.2	8.2×10^{-2}	0	0	8.2×10^{-2}
Cobalt-60	1.0×10^{-4}	0	0	1.0×10^{-4}	3.9×10^{-6}	0	0	3.9×10^{-6}
Strontium-90	2.6	3.0×10^{-3}	1.7×10^{-3}	2.6	7.6×10^{-1}	7.9×10^{-5}	4.6×10^{-5}	7.6×10^{-1}
Technetium-99	7.4×10^{-5}	0	0	7.4×10^{-5}	2.8×10^{-6}	0	0	2.8×10^{-6}
Iodine-129	5.8×10^{-2}	1.3×10^{-1}	7.4×10^{-2}	2.6×10^{-1}	2.2×10^{-3}	3.4×10^{-3}	1.9×10^{-3}	7.6×10^{-3}
Cesium-137	1.7	1.8×10^{-2}	1.0×10^{-2}	1.8	7.4×10^{-1}	4.7×10^{-4}	2.7×10^{-4}	7.5×10^{-1}
Uranium	2.5×10^{-3}	0	0	2.5×10^{-3}	9.5×10^{-5}	0	0	9.5×10^{-5}
Plutonium-238	4.4×10^{-2}	3.9×10^{-6}	3.1×10^{-6}	4.4×10^{-2}	1.7×10^{-3}	1.0×10^{-6}	6.0×10^{-7}	1.7×10^{-3}
Plutonium-239, -240	8.1×10^{-1}	5.6×10^{-4}	4.4×10^{-4}	8.1×10^{-1}	3.1×10^{-2}	1.5×10^{-4}	8.6×10^{-5}	3.1×10^{-2}
Plutonium-241	2.4×10^{-2}	0	0	2.4×10^{-2}	9.1×10^{-4}	0	0	9.1×10^{-4}
Americium-241	1.4	4.6×10^{-5}	3.7×10^{-5}	1.4	5.5×10^{-2}	1.2×10^{-5}	6.9×10^{-6}	5.5×10^{-2}
Total	8.9	1.5×10^{-1}	8.6×10^{-2}	9.2	1.7	4.1×10^{-3}	2.4×10^{-3}	1.7
Lifetime risk of a latent cancer fatality				5×10^{-6}				1×10^{-6}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–36. Tank Closure Alternative 3A Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	8.1×10^{-3}	7.9×10^{-2}	3.5×10^{-2}	1.2×10^{-1}	0	2.3×10^{-4}	1.2×10^{-4}	3.5×10^{-4}
Carbon-14	5.4×10^{-1}	4.9	2.2	7.7	0	1.4×10^{-2}	7.1×10^{-3}	2.1×10^{-2}
Cobalt-60	6.7×10^{-5}	5.2×10^{-5}	2.6×10^{-5}	1.5×10^{-4}	0	1.5×10^{-7}	8.8×10^{-8}	2.4×10^{-7}
Strontium-90	2.0	7.1×10^{-3}	4.9×10^{-2}	2.1	6.4×10^{-1}	5.1×10^{-7}	1.6×10^{-4}	6.4×10^{-1}
Technetium-99	1.8×10^{-5}	1.7×10^{-6}	7.6×10^{-5}	9.6×10^{-5}	0	5.1×10^{-7}	2.6×10^{-7}	7.7×10^{-7}
Iodine-129	1.4×10^{-2}	3.2×10^{-1}	1.5×10^{-1}	4.9×10^{-1}	0	4.1×10^{-4}	2.0×10^{-4}	6.1×10^{-4}
Cesium-137	1.4	4.5×10^{-2}	2.3×10^{-1}	1.7	7.2×10^{-1}	6.2×10^{-5}	7.1×10^{-4}	7.2×10^{-1}
Uranium	1.9×10^{-3}	3.6×10^{-4}	2.6×10^{-4}	2.5×10^{-3}	0	9.7×10^{-7}	8.2×10^{-7}	1.8×10^{-6}
Plutonium-238	3.1×10^{-2}	7.5×10^{-4}	1.7×10^{-3}	3.4×10^{-2}	0	5.2×10^{-9}	5.5×10^{-6}	5.5×10^{-6}
Plutonium-239, -240	6.3×10^{-1}	9.6×10^{-3}	3.5×10^{-2}	6.7×10^{-1}	0	1.1×10^{-7}	1.1×10^{-4}	1.1×10^{-4}
Plutonium-241	1.8×10^{-2}	2.7×10^{-4}	9.6×10^{-4}	1.9×10^{-2}	0	3.0×10^{-9}	3.1×10^{-6}	3.1×10^{-6}
Americium-241	1.0	3.2×10^{-2}	4.6×10^{-2}	1.1	0	2.9×10^{-7}	1.5×10^{-4}	1.5×10^{-4}
Total	5.7	5.4	2.7	1.4×10^{1}	1.4	1.5×10^{-2}	8.6×10^{-3}	1.4
Lifetime risk of a latent cancer fatality				8×10^{-6}				8×10^{-7}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–37. Tank Closure Alternative 3B Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	9.5×10^{-3}	5.1×10^{-7}	2.6×10^{-7}	9.5×10^{-3}	0	2.3×10^{-9}	1.2×10^{-9}	3.5×10^{-9}
Carbon-14	6.6×10^{-1}	3.2×10^{-5}	1.6×10^{-5}	6.6×10^{-1}	0	1.4×10^{-7}	7.1×10^{-8}	2.1×10^{-7}
Cobalt-60	8.3×10^{-5}	7.5×10^{-7}	3.9×10^{-7}	8.4×10^{-5}	0	3.0×10^{-9}	1.8×10^{-9}	4.8×10^{-9}
Strontium-90	2.5	4.5×10^{-3}	2.3×10^{-3}	2.5	6.4×10^{-1}	1.0×10^{-8}	3.1×10^{-6}	6.4×10^{-1}
Technetium-99	5.0×10^{-5}	9.1×10^{-8}	1.1×10^{-6}	5.1×10^{-5}	0	1.0×10^{-10}	5.1×10^{-9}	5.2×10^{-9}
Iodine-129	1.7×10^{-2}	1.2×10^{-1}	6.6×10^{-2}	2.0×10^{-1}	0	4.1×10^{-9}	2.0×10^{-9}	6.1×10^{-9}
Cesium-137	1.7	1.7×10^{-2}	1.2×10^{-2}	1.7	7.2×10^{-1}	1.2×10^{-6}	1.4×10^{-5}	7.2×10^{-1}
Uranium	2.3×10^{-3}	1.3×10^{-5}	4.1×10^{-6}	2.3×10^{-3}	0	1.9×10^{-8}	1.6×10^{-8}	3.6×10^{-8}
Plutonium-238	3.8×10^{-2}	4.8×10^{-4}	2.9×10^{-5}	3.8×10^{-2}	0	1.0×10^{-10}	1.1×10^{-7}	1.1×10^{-7}
Plutonium-239, -240	7.4×10^{-1}	6.4×10^{-3}	1.3×10^{-3}	7.5×10^{-1}	0	9.8×10^{-9}	2.2×10^{-6}	2.2×10^{-6}
Plutonium-241	2.1×10^{-2}	1.8×10^{-4}	1.5×10^{-5}	2.2×10^{-2}	0	5.9×10^{-11}	6.2×10^{-8}	6.2×10^{-8}
Americium-241	1.2	1.9×10^{-2}	7.3×10^{-4}	1.2	0	5.7×10^{-9}	3.0×10^{-6}	3.0×10^{-6}
Total	6.8	1.6×10^{-1}	8.3×10^{-2}	7.1	1.4	1.4×10^{-6}	2.3×10^{-5}	1.4
Lifetime risk of a latent cancer fatality				4×10^{-6}				8×10^{-7}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–38. Tank Closure Alternative 3C Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	8.1×10^{-3}	7.9×10^{-2}	3.5×10^{-2}	1.2×10^{-1}	0	2.3×10^{-4}	1.2×10^{-4}	3.5×10^{-4}
Carbon-14	5.4×10^{-1}	4.9	2.2	7.7	0	1.4×10^{-2}	7.1×10^{-3}	2.1×10^{-2}
Cobalt-60	6.7×10^{-5}	5.2×10^{-5}	2.6×10^{-5}	1.5×10^{-4}	0	1.5×10^{-7}	8.8×10^{-8}	2.4×10^{-7}
Strontium-90	2.0	7.2×10^{-3}	4.9×10^{-2}	2.1	6.4×10^{-1}	5.1×10^{-7}	1.6×10^{-4}	6.4×10^{-1}
Technetium-99	4.2×10^{-5}	1.8×10^{-4}	7.6×10^{-5}	2.9×10^{-4}	0	5.1×10^{-7}	2.6×10^{-7}	7.7×10^{-7}
Iodine-129	1.4×10^{-2}	3.2×10^{-1}	1.5×10^{-1}	4.9×10^{-1}	0	4.1×10^{-4}	2.0×10^{-4}	6.1×10^{-4}
Cesium-137	1.4	4.5×10^{-2}	2.3×10^{-1}	1.7	7.2×10^{-1}	6.2×10^{-5}	7.1×10^{-4}	7.2×10^{-1}
Uranium	1.9×10^{-3}	3.6×10^{-4}	2.6×10^{-4}	2.5×10^{-3}	0	9.7×10^{-7}	8.2×10^{-7}	1.8×10^{-6}
Plutonium-238	3.1×10^{-2}	7.6×10^{-4}	1.7×10^{-3}	3.4×10^{-2}	0	5.2×10^{-9}	5.5×10^{-6}	5.5×10^{-6}
Plutonium-239, -240	6.3×10^{-1}	9.6×10^{-3}	3.5×10^{-2}	6.7×10^{-1}	0	1.1×10^{-7}	1.1×10^{-4}	1.1×10^{-4}
Plutonium-241	1.8×10^{-2}	2.7×10^{-4}	9.6×10^{-4}	1.9×10^{-2}	0	3.0×10^{-9}	3.1×10^{-6}	3.1×10^{-6}
Americium-241	1.0	3.2×10^{-2}	4.6×10^{-2}	1.1	0	2.9×10^{-7}	1.5×10^{-4}	1.5×10^{-4}
Total	5.7	5.4	2.7	1.4×10^{1}	1.4	1.5×10^{-2}	8.6×10^{-3}	1.4
Lifetime risk of a latent cancer fatality				8×10^{-6}				8×10^{-7}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–39. Tank Closure Alternative 4 Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	9.0×10^{-3}	6.7×10^{-7}	3.2×10^{-2}	4.1×10^{-2}	0	3.1×10^{-11}	1.9×10^{-11}	4.9×10^{-11}
Carbon-14	6.0×10^{-1}	4.2×10^{-5}	2.0	2.6	0	7.2×10^{-10}	4.2×10^{-10}	1.1×10^{-9}
Cobalt-60	7.8×10^{-5}	2.6×10^{-6}	2.6×10^{-5}	1.1×10^{-4}	0	2.2×10^{-9}	1.3×10^{-9}	3.5×10^{-9}
Strontium-90	2.3	6.7×10^{-2}	8.9×10^{-2}	2.5	6.4×10^{-1}	1.4×10^{-4}	8.7×10^{-5}	6.4×10^{-1}
Technetium-99	2.0×10^{-5}	4.2×10^{-6}	7.3×10^{-5}	9.7×10^{-5}	0	4.1×10^{-9}	2.4×10^{-9}	6.5×10^{-9}
Iodine-129	1.6×10^{-2}	1.7×10^{-1}	1.5×10^{-1}	3.3×10^{-1}	0	1.8×10^{-9}	1.1×10^{-9}	2.9×10^{-9}
Cesium-137	1.6	3.7×10^{-2}	2.2×10^{-1}	1.8	7.2×10^{-1}	5.6×10^{-5}	3.3×10^{-5}	7.2×10^{-1}
Uranium	2.1×10^{-3}	1.6×10^{-4}	3.3×10^{-4}	2.6×10^{-3}	0	4.9×10^{-7}	3.0×10^{-7}	7.9×10^{-7}
Plutonium-238	3.4×10^{-2}	1.3×10^{-3}	2.0×10^{-3}	3.7×10^{-2}	0	3.2×10^{-6}	1.9×10^{-6}	5.1×10^{-6}
Plutonium-239, -240	6.7×10^{-1}	2.8×10^{-2}	4.7×10^{-2}	7.5×10^{-1}	0	2.0×10^{-4}	1.2×10^{-4}	3.2×10^{-4}
Plutonium-241	1.9×10^{-2}	4.2×10^{-4}	1.0×10^{-3}	2.1×10^{-2}	0	6.7×10^{-7}	3.8×10^{-7}	1.0×10^{-6}
Americium-241	1.2	4.8×10^{-2}	6.0×10^{-2}	1.3	0	4.4×10^{-5}	2.6×10^{-5}	7.0×10^{-5}
Total	6.4	3.5×10^{-1}	2.6	9.3	1.4	4.5×10^{-4}	2.7×10^{-4}	1.4
Lifetime risk of a latent cancer fatality				6×10^{-6}				8×10^{-7}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–40. Tank Closure Alternative 5 Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	1.6×10^{-2}	1.8×10^{-7}	2.3×10^{-2}	3.9×10^{-2}	9.7×10^{-6}	1.1×10^{-9}	1.4×10^{-4}	1.5×10^{-4}
Carbon-14	1.1	1.1×10^{-5}	1.4	2.5	6.3×10^{-3}	6.8×10^{-8}	8.9×10^{-3}	1.5×10^{-2}
Cobalt-60	1.0×10^{-4}	3.0×10^{-7}	1.8×10^{-5}	1.2×10^{-4}	1.3×10^{-7}	1.4×10^{-9}	1.1×10^{-7}	2.5×10^{-7}
Strontium-90	2.3	3.9×10^{-3}	3.3×10^{-2}	2.4	6.4×10^{-1}	4.8×10^{-9}	1.9×10^{-4}	6.4×10^{-1}
Technetium-99	1.1×10^{-4}	8.5×10^{-7}	5.2×10^{-5}	1.6×10^{-4}	4.4×10^{-7}	4.9×10^{-9}	3.2×10^{-7}	7.7×10^{-7}
Iodine-129	2.8×10^{-2}	9.6×10^{-2}	9.6×10^{-2}	2.2×10^{-1}	1.7×10^{-7}	2.0×10^{-9}	2.5×10^{-4}	2.5×10^{-4}
Cesium-137	1.6	1.4×10^{-2}	1.7×10^{-1}	1.8	7.2×10^{-1}	5.9×10^{-7}	9.8×10^{-4}	7.2×10^{-1}
Uranium	2.3×10^{-3}	9.7×10^{-6}	1.7×10^{-4}	2.4×10^{-3}	8.9×10^{-7}	9.3×10^{-9}	1.0×10^{-6}	1.9×10^{-6}
Plutonium-238	3.4×10^{-2}	4.3×10^{-4}	1.1×10^{-3}	3.6×10^{-2}	4.6×10^{-9}	5.0×10^{-11}	6.8×10^{-6}	6.9×10^{-6}
Plutonium-239, -240	6.7×10^{-1}	5.3×10^{-3}	2.3×10^{-2}	7.0×10^{-1}	8.9×10^{-8}	8.8×10^{-9}	1.4×10^{-4}	1.4×10^{-4}
Plutonium-241	2.0×10^{-2}	1.6×10^{-4}	6.3×10^{-4}	2.0×10^{-2}	2.6×10^{-9}	2.8×10^{-11}	3.9×10^{-6}	3.9×10^{-6}
Americium-241	1.1	1.7×10^{-2}	3.0×10^{-2}	1.1	2.5×10^{-7}	2.7×10^{-9}	1.9×10^{-4}	1.9×10^{-4}
Total	6.9	1.4×10^{-1}	1.8	8.9	1.4	6.9×10^{-7}	1.1×10^{-2}	1.4
Lifetime risk of a latent cancer fatality				5×10^{-6}				8×10^{-7}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–41. Tank Closure Alternative 6A, Base Case, Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	3.3×10^{-2}	6.6×10^{-4}	3.8×10^{-6}	3.3×10^{-2}	0	8.5×10^{-7}	5.1×10^{-7}	1.4×10^{-6}
Carbon-14	2.2	2.8×10^{-2}	1.6×10^{-4}	2.2	0	3.7×10^{-5}	2.2×10^{-5}	5.9×10^{-5}
Cobalt-60	1.0×10^{-4}	2.6×10^{-5}	4.4×10^{-7}	1.3×10^{-4}	0	2.6×10^{-8}	1.6×10^{-8}	4.2×10^{-8}
Strontium-90	2.6	5.4×10^{-1}	1.0×10^{-2}	3.2	6.4×10^{-1}	5.1×10^{-4}	3.1×10^{-4}	6.4×10^{-1}
Technetium-99	7.4×10^{-5}	7.7×10^{-5}	4.4×10^{-7}	1.5×10^{-4}	0	9.9×10^{-8}	6.0×10^{-8}	1.6×10^{-7}
Iodine-129	5.8×10^{-2}	6.1×10^{-1}	2.3×10^{-3}	6.7×10^{-1}	0	9.4×10^{-5}	5.5×10^{-5}	1.5×10^{-4}
Cesium-137	1.9	8.4×10^{-1}	4.7×10^{-3}	2.8	7.2×10^{-1}	9.9×10^{-4}	5.9×10^{-4}	7.2×10^{-1}
Uranium	2.5×10^{-3}	4.4×10^{-3}	2.5×10^{-5}	6.9×10^{-3}	0	5.7×10^{-6}	3.4×10^{-6}	9.1×10^{-6}
Plutonium-238	4.4×10^{-2}	8.3×10^{-3}	5.1×10^{-5}	5.2×10^{-2}	0	1.3×10^{-5}	6.3×10^{-6}	1.9×10^{-5}
Plutonium-239, -240	8.2×10^{-1}	1.1×10^{-1}	3.0×10^{-3}	9.3×10^{-1}	0	3.8×10^{-4}	5.4×10^{-5}	4.4×10^{-4}
Plutonium-241	2.4×10^{-2}	1.2×10^{-3}	7.9×10^{-6}	2.5×10^{-2}	0	1.6×10^{-6}	8.9×10^{-7}	2.4×10^{-6}
Americium-241	1.5	1.3×10^{-1}	4.1×10^{-3}	1.6	0	1.1×10^{-4}	5.1×10^{-5}	1.6×10^{-4}
Total	9.2	2.3	2.5×10^{-2}	1.1×10^{1}	1.4	2.1×10^{-3}	1.1×10^{-3}	1.4
Lifetime risk of a latent cancer fatality				7×10^{-6}				8×10^{-7}

[a] Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 4.9 millirem, with a corresponding lifetime risk of a latent cancer fatality of 3×10^{-6}.

[b] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–42. Tank Closure Alternative 6A, Option Case, Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	2.8×10^{-2}	2.4×10^{-2}	1.3×10^{-2}	6.5×10^{-2}	0	2.1×10^{-5}	1.2×10^{-5}	3.3×10^{-5}
Carbon-14	1.8	6.0×10^{-2}	3.2×10^{-2}	1.8	0	5.0×10^{-5}	3.0×10^{-5}	8.0×10^{-5}
Cobalt-60	8.1×10^{-5}	7.5×10^{-5}	4.0×10^{-5}	2.0×10^{-4}	0	5.2×10^{-8}	3.1×10^{-8}	8.4×10^{-8}
Strontium-90	2.2	9.9×10^{-1}	5.3×10^{-1}	3.7	6.4×10^{-1}	5.5×10^{-4}	3.4×10^{-4}	6.4×10^{-1}
Technetium-99	6.2×10^{-5}	1.7×10^{-4}	9.0×10^{-5}	3.3×10^{-4}	0	1.5×10^{-7}	8.7×10^{-8}	2.3×10^{-7}
Iodine-129	4.8×10^{-2}	9.7×10^{-1}	5.0×10^{-1}	1.5	0	1.3×10^{-4}	7.8×10^{-5}	2.1×10^{-4}
Cesium-137	1.6	1.3	6.9×10^{-1}	3.6	7.2×10^{-1}	1.0×10^{-3}	6.0×10^{-4}	7.2×10^{-1}
Uranium	2.1×10^{-3}	9.5×10^{-3}	5.0×10^{-3}	1.7×10^{-2}	0	7.7×10^{-6}	4.6×10^{-6}	1.2×10^{-5}
Plutonium-238	3.7×10^{-2}	2.6×10^{-2}	1.4×10^{-2}	7.6×10^{-2}	0	2.3×10^{-5}	1.2×10^{-5}	3.6×10^{-5}
Plutonium-239, -240	7.0×10^{-1}	1.1	5.8×10^{-1}	2.4	0	1.1×10^{-3}	5.0×10^{-4}	1.6×10^{-3}
Plutonium-241	2.0×10^{-2}	1.4×10^{-2}	7.5×10^{-3}	4.2×10^{-2}	0	1.2×10^{-5}	7.0×10^{-6}	1.9×10^{-5}
Americium-241	1.2	4.4×10^{-1}	2.2×10^{-1}	1.9	0	2.4×10^{-4}	1.3×10^{-4}	3.7×10^{-4}
Total	7.6	4.9	2.6	1.5×10^{1}	1.4	3.2×10^{-3}	1.7×10^{-3}	1.4
Lifetime risk of a latent cancer fatality				9×10^{-6}				8×10^{-7}

a Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 6.5 millirem, with a corresponding lifetime risk of a latent cancer fatality of 4×10^{-6}.

b The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–43. Tank Closure Alternative 6B, Base Case, Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	3.0×10^{-2}	8.3×10^{-4}	4.9×10^{-4}	3.1×10^{-2}	1.2×10^{-3}	8.5×10^{-6}	5.1×10^{-6}	1.3×10^{-3}
Carbon-14	1.9	3.7×10^{-2}	2.1×10^{-2}	2.0	8.2×10^{-2}	3.7×10^{-4}	2.2×10^{-4}	8.3×10^{-2}
Cobalt-60	9.3×10^{-5}	3.4×10^{-5}	1.9×10^{-5}	1.5×10^{-4}	3.9×10^{-6}	4.8×10^{-7}	2.3×10^{-7}	4.6×10^{-6}
Strontium-90	2.3	6.9×10^{-1}	3.9×10^{-1}	3.4	7.0×10^{-1}	1.0×10^{-2}	4.8×10^{-3}	7.2×10^{-1}
Technetium-99	6.8×10^{-5}	1.0×10^{-4}	5.7×10^{-5}	2.3×10^{-4}	2.8×10^{-6}	1.0×10^{-6}	6.0×10^{-7}	4.4×10^{-6}
Iodine-129	5.3×10^{-2}	2.6×10^{-1}	1.5×10^{-1}	4.7×10^{-1}	2.2×10^{-3}	4.4×10^{-3}	2.5×10^{-3}	9.1×10^{-3}
Cesium-137	1.6	9.8×10^{-1}	5.9×10^{-1}	3.2	7.4×10^{-1}	1.0×10^{-2}	6.1×10^{-3}	7.6×10^{-1}
Uranium	2.3×10^{-3}	6.1×10^{-3}	3.5×10^{-3}	1.2×10^{-2}	9.5×10^{-5}	5.7×10^{-5}	3.4×10^{-5}	1.9×10^{-4}
Plutonium-238	3.9×10^{-2}	1.1×10^{-2}	6.4×10^{-3}	5.7×10^{-2}	1.7×10^{-3}	1.1×10^{-4}	6.3×10^{-5}	1.9×10^{-3}
Plutonium-239, -240	7.3×10^{-1}	1.4×10^{-1}	8.2×10^{-2}	9.5×10^{-1}	3.1×10^{-2}	2.3×10^{-3}	9.7×10^{-4}	3.4×10^{-2}
Plutonium-241	2.1×10^{-2}	1.6×10^{-3}	9.0×10^{-4}	2.4×10^{-2}	9.1×10^{-4}	1.6×10^{-5}	9.2×10^{-6}	9.3×10^{-4}
Americium-241	1.4	1.8×10^{-1}	1.0×10^{-1}	1.7	5.5×10^{-2}	3.4×10^{-3}	1.3×10^{-3}	6.0×10^{-2}
Total	8.1	2.3	1.3	1.2×10^{1}	1.6	3.2×10^{-2}	1.6×10^{-2}	1.7
Lifetime risk of a latent cancer fatality				7×10^{-6}				1×10^{-6}

a Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 8.7 millirem, with a corresponding lifetime risk of a latent cancer fatality of 5×10^{-6}.

b The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–44. Tank Closure Alternative 6B, Option Case, Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)[a]				Dose in Year of Maximum Impact (millirem per year)[b]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	2.8×10^{-2}	2.4×10^{-2}	1.3×10^{-2}	6.5×10^{-2}	1.2×10^{-3}	2.1×10^{-4}	1.2×10^{-4}	1.6×10^{-3}
Carbon-14	1.7	6.0×10^{-2}	3.2×10^{-2}	1.8	8.2×10^{-2}	5.0×10^{-4}	3.0×10^{-4}	8.3×10^{-2}
Cobalt-60	8.1×10^{-5}	7.5×10^{-5}	3.9×10^{-5}	2.0×10^{-4}	3.9×10^{-6}	8.4×10^{-7}	3.8×10^{-7}	5.1×10^{-6}
Strontium-90	2.1	9.7×10^{-1}	5.1×10^{-1}	3.5	7.0×10^{-1}	1.3×10^{-2}	5.1×10^{-3}	7.2×10^{-1}
Technetium-99	6.2×10^{-5}	1.7×10^{-4}	9.0×10^{-5}	3.3×10^{-4}	2.8×10^{-6}	1.5×10^{-6}	8.7×10^{-7}	5.2×10^{-6}
Iodine-129	4.8×10^{-2}	3.5×10^{-1}	1.8×10^{-1}	5.9×10^{-1}	2.2×10^{-3}	4.7×10^{-3}	2.7×10^{-3}	9.7×10^{-3}
Cesium-137	1.5	1.2	6.5×10^{-1}	3.3	7.4×10^{-1}	1.1×10^{-2}	6.3×10^{-3}	7.6×10^{-1}
Uranium	2.1×10^{-3}	9.5×10^{-3}	5.0×10^{-3}	1.7×10^{-2}	9.5×10^{-5}	7.7×10^{-5}	4.6×10^{-5}	2.2×10^{-4}
Plutonium-238	3.7×10^{-2}	2.6×10^{-2}	1.4×10^{-2}	7.6×10^{-2}	1.7×10^{-3}	2.1×10^{-4}	1.2×10^{-4}	2.0×10^{-3}
Plutonium-239, -240	6.9×10^{-1}	1.1	5.8×10^{-1}	2.4	3.1×10^{-2}	1.0×10^{-2}	5.4×10^{-3}	4.7×10^{-2}
Plutonium-241	2.0×10^{-2}	1.4×10^{-2}	7.5×10^{-3}	4.2×10^{-2}	9.1×10^{-4}	1.2×10^{-4}	7.0×10^{-5}	1.1×10^{-3}
Americium-241	1.2	4.3×10^{-1}	2.1×10^{-1}	1.9	5.5×10^{-2}	5.8×10^{-3}	2.1×10^{-3}	6.3×10^{-2}
Total	7.3	4.2	2.2	1.4×10^{1}	1.6	4.6×10^{-2}	2.2×10^{-2}	1.7
Lifetime risk of a latent cancer fatality				8×10^{-6}				1×10^{-6}

[a] Impacts are provided for comparison to other alternatives. The life-of-project dose would not be received by one individual person due to the duration of this alternative. The dose from 70 years of exposure at the average annual dose rate would be 10 millirem, with a corresponding lifetime risk of a latent cancer fatality of 6×10^{-6}.

[b] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

Table K–45. Tank Closure Alternative 6C Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Dose over Life of Project (millirem)				Dose in Year of Maximum Impact (millirem per year)[a]			
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources
Hydrogen-3 (tritium)	3.3×10^{-2}	0	0	3.3×10^{-2}	1.2×10^{-3}	0	0	1.2×10^{-3}
Carbon-14	2.2	0	0	2.2	8.2×10^{-2}	0	0	8.2×10^{-2}
Cobalt-60	1.0×10^{-4}	0	0	1.0×10^{-4}	3.9×10^{-6}	0	0	3.9×10^{-6}
Strontium-90	2.5	3.0×10^{-3}	1.7×10^{-3}	2.5	7.0×10^{-1}	7.9×10^{-5}	4.6×10^{-5}	7.0×10^{-1}
Technetium-99	7.4×10^{-5}	0	0	7.4×10^{-5}	2.8×10^{-6}	0	0	2.8×10^{-6}
Iodine-129	5.8×10^{-2}	1.3×10^{-1}	7.4×10^{-2}	2.6×10^{-1}	2.2×10^{-3}	3.4×10^{-3}	2.0×10^{-3}	7.6×10^{-3}
Cesium-137	1.7	1.8×10^{-2}	1.0×10^{-2}	1.8	7.4×10^{-1}	4.7×10^{-4}	2.7×10^{-4}	7.5×10^{-1}
Uranium	2.5×10^{-3}	0	0	2.5×10^{-3}	9.5×10^{-5}	0	0	9.5×10^{-5}
Plutonium-238	4.4×10^{-2}	3.9×10^{-6}	3.1×10^{-6}	4.4×10^{-2}	1.7×10^{-3}	1.0×10^{-6}	6.0×10^{-7}	1.7×10^{-3}
Plutonium-239, -240	8.1×10^{-1}	5.6×10^{-4}	4.4×10^{-4}	8.1×10^{-1}	3.1×10^{-2}	1.5×10^{-4}	8.6×10^{-5}	3.1×10^{-2}
Plutonium-241	2.4×10^{-2}	0	0	2.4×10^{-2}	9.1×10^{-4}	0	0	9.1×10^{-4}
Americium-241	1.4	4.6×10^{-5}	3.7×10^{-5}	1.4	5.5×10^{-2}	1.2×10^{-5}	6.9×10^{-6}	5.5×10^{-2}
Total	8.8	1.5×10^{-1}	8.6×10^{-2}	9.1	1.6	4.1×10^{-3}	2.4×10^{-3}	1.6
Lifetime risk of a latent cancer fatality				5×10^{-6}				1×10^{-6}

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding.

Key: STTS=Supplemental Treatment Technology Site.

An onsite MEI would receive a dose from emissions from the WTP, STTS-East, and STTS-West. Table K–46 presents the doses from each source location, the sum of those doses, and the associated risk of an LCF for the life of the project under each Tank Closure alternative. These data are provided for comparison among the alternatives, recognizing that some of the alternatives (Alternatives 1; 2A; 6A, Base and Option Cases; and 6B, Base and Option Cases) would span multiple generations. Table K–47 presents the doses and associated risks for the year or years of projected maximum impact. The location of the onsite MEI would be affected by the relative amounts of emissions from the three source areas, the WTP, STTS-East, and STTS-West.

Table K–46. Tank Closure Alternatives – Impacts on the Onsite Maximally Exposed Individual Over the Life of the Project During Normal Operations

Tank Closure Alternative	Dose (millirem)				Lifetime Risk of an LCF	Location
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources		
1[a]	0	1.1	6.5×10^{-1}	1.8	1×10^{-6}	CGS
2A[a]	0.76	1.1	6.5×10^{-1}	2.6	2×10^{-6}	CGS
2B	1.0	1.7×10^{-3}	2.2×10^{-4}	1.0	6×10^{-7}	LIGO
3A	0.90	2.2×10^{-2}	1.1×10^{-2}	9.3×10^{-1}	6×10^{-7}	LIGO
3B	0.90	2.4×10^{-3}	4.1×10^{-4}	9.0×10^{-1}	5×10^{-7}	LIGO
3C	0.90	2.2×10^{-2}	1.1×10^{-2}	9.3×10^{-1}	6×10^{-7}	LIGO
4	0.90	7.7×10^{-3}	1.5×10^{-2}	9.3×10^{-1}	6×10^{-7}	LIGO
5	0.83	2.0×10^{-3}	1.0×10^{-2}	8.4×10^{-1}	5×10^{-7}	LIGO
6A Base Case[a]	1.0	1.1×10^{-1}	9.5×10^{-4}	1.2	7×10^{-7}	LIGO
6A Option Case[a]	0.78	3.3×10^{-1}	2.0×10^{-1}	1.3	8×10^{-7}	CGS
6B Base Case[a]	1.0	1.1×10^{-1}	2.5×10^{-2}	1.2	7×10^{-7}	LIGO
6B Option Case[a]	0.76	3.3×10^{-1}	2.0×10^{-1}	1.3	8×10^{-7}	CGS
6C	1.0	1.7×10^{-3}	2.2×10^{-4}	1.0	6×10^{-7}	LIGO

[a] The life-of-project dose would not be received by one individual person due to the duration of these alternatives. The dose and lifetime risk of an LCF from 40 years of exposure at the average annual dose rate would be: Alternative 1 – 0.71 millirem, 4×10^{-7} LCF risk; Alternative 2A – 0.55 millirem, 3×10^{-7} LCF risk; Alternative 6A, Base Case – 0.28 millirem, 2×10^{-7} LCF risk; Alternative 6A, Option Case – 0.32 millirem, 2×10^{-7} LCF risk; Alternative 6B, Base Case – 0.49 millirem, 3×10^{-7} LCF risk; Alternative 6B, Option Case – 0.54 millirem, 3×10^{-7} LCF risk.

Key: CGS=Columbia Generating Station; LCF=latent cancer fatality; LIGO=Laser Interferometer Gravitational-Wave Observatory; STTS=Supplemental Treatment Technology Site.

Table K–47. Tank Closure Alternatives – Impacts on the Onsite Maximally Exposed Individual in the Year of Maximum Impact During Normal Operations

Tank Closure Alternative	Dose (millirem per year)[a]				Lifetime Risk of an LCF	Location
	Waste Treatment Plant	200-East Area STTS	200-West Area STTS	Combined Sources		
1	0	1.1×10^{-2}	6.5×10^{-3}	1.8×10^{-2}	1×10^{-8}	CGS
2A	5.8×10^{-2}	7.6×10^{-10}	0	5.8×10^{-2}	4×10^{-8}	LIGO
2B	9.7×10^{-2}	5.8×10^{-5}	1.4×10^{-5}	9.7×10^{-2}	6×10^{-8}	LIGO
3A	5.8×10^{-2}	8.6×10^{-5}	4.9×10^{-5}	5.8×10^{-2}	4×10^{-8}	LIGO
3B	5.8×10^{-2}	1.1×10^{-7}	7.5×10^{-7}	5.8×10^{-2}	4×10^{-8}	LIGO
3C	5.8×10^{-2}	8.6×10^{-5}	4.9×10^{-5}	5.8×10^{-2}	4×10^{-8}	LIGO
4	5.8×10^{-2}	3.3×10^{-5}	1.7×10^{-5}	5.8×10^{-2}	4×10^{-8}	LIGO
5	5.8×10^{-2}	5.0×10^{-5}	6.3×10^{-5}	5.8×10^{-2}	4×10^{-8}	LIGO
6A Base Case	5.8×10^{-2}	1.5×10^{-4}	2.3×10^{-5}	5.9×10^{-2}	4×10^{-8}	LIGO
6A Option Case	5.8×10^{-2}	2.3×10^{-4}	7.9×10^{-5}	5.9×10^{-2}	4×10^{-8}	LIGO
6B Base Case	9.4×10^{-2}	1.7×10^{-3}	3.8×10^{-4}	9.6×10^{-2}	6×10^{-8}	LIGO
6B Option Case	9.4×10^{-2}	2.7×10^{-3}	9.5×10^{-4}	9.8×10^{-2}	6×10^{-8}	LIGO
6C	9.4×10^{-2}	5.8×10^{-5}	1.4×10^{-5}	9.4×10^{-2}	6×10^{-8}	LIGO

Table K–47. Tank Closure Alternatives – Impacts on the Onsite Maximally Exposed Individual in the Year of Maximum Impact During Normal Operations *(continued)*

[a] The regulatory limit for exposure of an individual to radiological air emissions from U.S. Department of Energy facilities is 10 millirem per year (40 CFR 61.90–61.97).

Key: CGS=Columbia Generating Station; LCF=latent cancer fatality; LIGO=Laser Interferometer Gravitational-Wave Observatory; STTS=Supplemental Treatment Technology Site.

K.2.1.2 Impacts on Workers During Normal Operations

This section describes the methodologies used to evaluate the impacts of waste treatment and closure activities on Hanford workers. Two groups of workers were considered in the evaluation—project radiation workers who are engaged in the waste treatment and closure activities and nearby, noninvolved workers. Different methodologies were used to determine the radiological impacts on these two receptors.

K.2.1.2.1 Project Radiation Workers

Project radiation workers are exposed to radiation through the performance of activities related to the retrieval and processing of tank waste and the deactivation and closure of tank farm facilities. External exposure to radiation is the principal cause of doses to radiation workers.

Doses to radiation workers under each Tank Closure alternative were estimated using data provided in the scaled data sets developed to support this *TC & WM EIS* (SAIC 2007a, 2008). The data sets present conservative estimates of expected worker doses for a range of activities that make up the Tank Closure alternatives. Those estimates were based on a number of factors, including dose rates and doses associated with current tank farm operations, engineering studies of related activities, and conservative engineering estimates for accomplishing particular scopes of work. Scaled data sets representing the Tank Closure alternatives included in this *TC & WM EIS* include scaled estimates of the radiation worker labor hours required to accomplish the activities that make up an alternative and the associated radiation doses.

Total doses associated with each Tank Closure alternative were estimated by summing the dose estimates for each activity that is a component of the alternative, resulting in the project dose estimates shown in Table K–48. These results are presumed to overestimate the dose that would likely be received by the worker population. A number of factors contributed to the conservatism. Conservative dose estimates were included in the original data packages to ensure that they represented the upper range of expected doses associated with performing the activities. Linear scaling of the resources, labor hours, and doses to develop the alternatives added to the conservatism because there was no recognition of economies of scale or changes in annual resource needs commensurate with changes in the duration of activities. For example, the annual labor requirements for operating a facility to process a given amount of material were the same whether the processing period would be 30 years or 80 years. Consequently, the conservatism in the project doses may be greater for alternatives with long operating periods. Through the application of administrative and engineering controls to maintain exposure as low as is reasonably achievable, actual total radiation worker doses from executing an alternative would likely be lower than the estimates.

Data from the scaled data sets were used to develop an estimate of the average annual dose per work year for each Tank Closure alternative. Doses to radiation workers were calculated based on a full-time equivalent (FTE) worker, who was assumed to have a 2,080-hour work year for the purposes of this dose evaluation. The time and dose associated with the various activities that make up an alternative vary, resulting in comparatively low dose rates for some activities and high dose rates for others. In practice, DOE and its contractors would implement controls to limit the exposure of individual workers for all activities in accordance with regulations and guidance (10 CFR 835; DOE Standard 1098-99). Therefore, the average FTE doses calculated for each alternative are not necessarily representative of the actual

doses that would be received by individual workers. Rather, they represent an overestimation of the average dose that a worker would receive.

The average dose per FTE under an alternative was calculated by dividing the total radiation worker dose by the number of FTEs. The number of FTEs was determined by dividing the total radiation worker labor hours by 2,080 hours per work year. An average dose for an FTE radiation worker assumed to be involved with the project for an entire working career was also calculated for each alternative. The career dose was estimated by multiplying the average annual FTE dose by 40 years. The average dose per FTE and the average career dose are shown in Table K–48.

Table K–48. Tank Closure Alternatives – Radiation Worker Impacts and Labor Estimates

Alternative	Life-of-Project Collective Worker Impact		Life-of-Project Full-Time Equivalent Radiation Worker Labor		Average Annual Impact per Full-Time Equivalent Radiation Worker		Average Project Impact per Full-Time Equivalent Radiation Worker[a]	
	Dose (person-rem)	LCFs[b]	Hours	Years	Dose (millirem/year)	LCFs[c]	Dose (millirem)	LCFs
1	2.8×10^{2}	0 (0.2)	4.07×10^{6}	2,000	1.4×10^{2}	9×10^{-5}	5.7×10^{3}	3×10^{-3}
2A	2.3×10^{4}	13	2.72×10^{8}	131,000	1.7×10^{2}	1×10^{-4}	6.9×10^{3}	4×10^{-3}
2B	1.1×10^{4}	7	1.44×10^{8}	69,100	1.6×10^{2}	1×10^{-4}	6.4×10^{3}	4×10^{-3}
3A	1.0×10^{4}	6	1.36×10^{8}	65,600	1.6×10^{2}	1×10^{-4}	6.3×10^{3}	4×10^{-3}
3B	1.0×10^{4}	6	1.32×10^{8}	63,400	1.6×10^{2}	9×10^{-5}	6.3×10^{3}	4×10^{-3}
3C	1.1×10^{4}	6	1.41×10^{8}	67,600	1.6×10^{2}	1×10^{-4}	6.4×10^{3}	4×10^{-3}
4	4.3×10^{4}	26	1.74×10^{8}	83,800	5.2×10^{2}	3×10^{-4}	2.1×10^{4}	1×10^{-2}
5	8.8×10^{3}	5	1.24×10^{8}	59,400	1.5×10^{2}	9×10^{-5}	5.9×10^{3}	4×10^{-3}
6A Base Case	1.2×10^{5}	72	6.02×10^{8}	289,000	4.2×10^{2}	2×10^{-4}	1.7×10^{4}	1×10^{-2}
6A Option Case	1.2×10^{5}	75	6.47×10^{8}	311,000	4.0×10^{2}	2×10^{-4}	1.6×10^{4}	1×10^{-2}
6B Base Case	8.2×10^{4}	49	1.96×10^{8}	94,100	8.7×10^{2}	5×10^{-4}	3.5×10^{4}	2×10^{-2}
6B Option Case	8.5×10^{4}	51	2.25×10^{8}	108,000	7.9×10^{2}	5×10^{-4}	3.2×10^{4}	2×10^{-2}
6C	1.1×10^{4}	7	1.44×10^{8}	69,100	1.6×10^{2}	1×10^{-4}	6.4×10^{3}	4×10^{-3}

a Full-time equivalent radiation worker project dose and individual risk of an LCF from 40 years of occupational exposure.

b Increased number of LCFs for the worker population as a result of the radiation dose received under the alternative. If zero, the number in parentheses is the value calculated by multiplying the dose by the risk factor of 0.0006 LCFs per person-rem.

c The increased individual risk of an LCF from one year of occupational exposure.

Key: LCF=latent cancer fatality.

K.2.1.2.2 Noninvolved Workers

Doses were also estimated for a noninvolved worker, i.e., a person working at the site who is incidentally exposed due to the radiological emissions associated with the Tank Closure alternatives. The GENII model described in Section K.2.1.1.2 was used to estimate doses to noninvolved workers. The exposure parameters for a noninvolved worker were different from those used for an offsite member of the public. Because the worker was assumed to spend only a work shift at the site, exposure to and inhalation of the radioactive plume was assumed to occur only for a portion of the day. It was also assumed that a portion of the worker's job is performed outdoors, resulting in exposure to deposited material. The outdoor activity was assumed to result in ingestion of contaminated soil suspended by wind or work activities. Unlike doses to members of the offsite population, there was no assumption that any portion of the exposure associated with work would result from consumption of radioactively contaminated fruits, vegetables, or animal products. Table K–49 shows the parameters used for the dose analysis of noninvolved workers.

Table K–49. Dose Assessment Parameters for Noninvolved Workers

Medium	Exposure Pathway	Rate	Reference
Air (plume)	Internal – inhalation	20 cubic meters per day	DOE 1995
	Internal – inhalation	2,000 hours per year	DOE 1995
	External	2,000 hours per year	Consistent with inhalation exposure
Soil	External	1,168 hours per year	DOE 1995
	Internal – ingestion	50 milligrams per day	DOE 1995

Note: To convert cubic meters to cubic feet, multiply by 35.315; milligrams to ounces, by 0.00003527.

As discussed in Section K.2.1.1.1, for purposes of assessing the impacts of radiological emissions, all emissions were assigned to one of three sources; the WTP, STTS-East, or STTS-West.

Doses to a noninvolved worker were evaluated for a location in the 200-East Area and a location in the 200-West Area. The locations selected are near the assumed emission sources in facilities that are expected to be staffed on a daily basis. In the 200-East Area, the noninvolved worker was assumed to be at the 242-A Evaporator, about 0.7 kilometers (760 yards) west of the WTP and 0.6 kilometers (660 yards) north-northwest of STTS-East.

In the 200-West Area, two locations were considered for the noninvolved worker. The Environmental Restoration Disposal Facility (ERDF) was selected for detailed analysis after determining that the impact on a noninvolved worker located there would be higher than that on one located at the 222-S Laboratory. The ERDF is about 1.1 kilometers (1,200 yards) east of the STTS-West, while the 222-S Laboratory is southwest of the STTS-West.

Doses to a noninvolved worker at the 242-A Evaporator under each Tank Closure alternative were determined for releases from the STTS-East and the WTP, based on releases of 1 curie of each radionuclide identified in Table K–6. The dose to a noninvolved worker at the ERDF under each Tank Closure alternative was determined for releases from the STTS-West, based on 1-curie releases. The doses to noninvolved workers were scaled based on the estimated releases from the WTP, STTS-East, and STTS-West under each Tank Closure alternative (see Tables K–7 through K–19) over the life of the project and during the years of maximum impact. The doses to noninvolved workers in the year(s) of maximum impact are presented in Table K–50. Although the emissions that would impact a noninvolved worker or an MEI would be the same, the year(s) of maximum impact for these receptors may be different. The emissions from the STTSs would comprise a mix of sources, such as routine tank farm operations, tank waste retrieval activities, supplemental waste treatment, and tank closure, each of which would occur in a different time period during the project. The year(s) of maximum impact for a noninvolved worker at the ERDF would occur when the STTS-West emissions were largest. Similarly, the year(s) of maximum impact for a noninvolved worker at the 242-A Evaporator would be when emissions from the WTP, STTS-East, or both were largest. At a distance of more than 9.6 kilometers (6 miles), the MEI would be exposed to a combination of emissions from the WTP and STTS-East and -West; consequently, the combined impacts of all three emission sources could affect the year of maximum impact. However, the peak impacts on the MEI and noninvolved worker at the 242-A Evaporator would be dominated by the emissions from processing cesium and strontium at the WTP under all Tank Closure alternatives except Alternatives 1 and 2A. The alternatives have been conceptualized such that all of the cesium and strontium from capsules would be processed in a single year at the WTP, resulting in increased cesium and strontium emissions that year. Alternative 1 does not include cesium and strontium processing, and peak impacts under Alternative 2A would occur from continuing tank emissions during the period of administrative control and emissions occurring during deactivation of the WTP.

Table K–50. Tank Closure Alternatives – Impacts on Noninvolved Workers in the Year(s) of Maximum Impact During Normal Operations

Tank Closure Alternative	Noninvolved Worker at 242-A Evaporator					Noninvolved Worker at ERDF		
	Dose from 200-East Area STTS (millirem per year)	Dose from WTP (millirem per year)	Total Dose (millirem per year)	Lifetime Risk of a Latent Cancer Fatality	Year(s) of Maximum Impact	Dose from 200-West Area STTS (millirem per year)	Lifetime Risk of a Latent Cancer Fatality	Year(s) of Maximum Impact
1	2.5×10^{-1}	0	2.5×10^{-1}	2×10^{-7}	2008	7.1×10^{-1}	4×10^{-7}	2008
2A	2.5×10^{-1}	4.4×10^{-2}	3.0×10^{-1}	2×10^{-7}	2094–2095	7.1×10^{-1}	4×10^{-7}	2094–2193
2B	4.2×10^{-3}	2.9×10^{-1}	2.9×10^{-1}	2×10^{-7}	2040	4.2×10^{-3}	2×10^{-9}	2040
3A	1.5×10^{-3}	1.7×10^{-1}	1.8×10^{-1}	1×10^{-7}	2040	1.4×10^{-1}	9×10^{-8}	2018–2019
3B	9.9×10^{-7}	1.7×10^{-1}	1.7×10^{-1}	1×10^{-7}	2040	4.2×10^{-3}	3×10^{-9}	2018–2019
3C	1.5×10^{-3}	1.7×10^{-1}	1.8×10^{-1}	1×10^{-7}	2040	1.4×10^{-1}	9×10^{-8}	2018–2019
4	1.7×10^{-3}	1.7×10^{-1}	1.8×10^{-1}	1×10^{-7}	2043	2.0×10^{-1}	1×10^{-7}	2034–2039
5	0	1.7×10^{-1}	1.7×10^{-1}	1×10^{-7}	2034	1.8×10^{-1}	1×10^{-7}	2018–2019
6A Base Case	4.2×10^{-3}	1.7×10^{-1}	1.8×10^{-1}	1×10^{-7}	2163	7.5×10^{-2}	4×10^{-8}	2054–2061
6A Option Case	9.9×10^{-3}	1.7×10^{-1}	1.8×10^{-1}	1×10^{-7}	2163	2.0×10^{-1}	1×10^{-7}	2138–2140
6B Base Case	5.2×10^{-2}	2.8×10^{-1}	3.3×10^{-1}	2×10^{-7}	2040	1.1×10^{-1}	7×10^{-8}	2040
6B Option Case	1.2×10^{-1}	2.8×10^{-1}	4.0×10^{-1}	2×10^{-7}	2040	2.8×10^{-1}	2×10^{-7}	2040
6C	1.4×10^{-3}	2.8×10^{-1}	2.8×10^{-1}	2×10^{-7}	2040	4.2×10^{-3}	2×10^{-9}	2040

Note: Total may not equal the sum of the contributions due to rounding.

Key: ERDF=Environmental Restoration Disposal Facility; STTS=Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Table K–51. Tank Closure Alternatives – Impacts on Noninvolved Workers over the Life of the Project During Normal Operations

Tank Closure Alternative	Noninvolved Worker at 242-A Evaporator				Noninvolved Worker at ERDF		Years of Project Emissions
	Dose from 200-East Area STTS (millirem)	Dose from WTP (millirem)	Total Dose (millirem)	Lifetime Risk of a Latent Cancer Fatality	Dose from 200-West Area STTS (millirem)	Lifetime Risk of a Latent Cancer Fatality	
1[a]	2.5×10^{1}	0	2.5×10^{1}	2×10^{-5}	7.1×10^{1}	4×10^{-5}	2006–2107
2A[a]	2.5×10^{1}	3.0	2.8×10^{1}	2×10^{-5}	7.1×10^{1}	4×10^{-5}	2006–2193
2B	2.2×10^{-2}	3.0	3.0	2×10^{-6}	6.5×10^{-2}	4×10^{-8}	2006–2045
3A	5.1×10^{-1}	2.6	3.1	2×10^{-6}	3.2	2×10^{-6}	2006–2042
3B	2.2×10^{-2}	2.6	2.8	2×10^{-6}	1.2×10^{-1}	7×10^{-8}	2006–2042
3C	5.1×10^{-1}	2.6	3.1	2×10^{-6}	3.2	2×10^{-6}	2006–2042
4	4.3×10^{-1}	2.7	3.1	2×10^{-6}	4.2	3×10^{-6}	2006–2045
5	1.6×10^{-1}	2.4	2.6	2×10^{-6}	3.0	2×10^{-6}	2006–2036
6A Base Case[a]	2.6	3.1	5.6	3×10^{-6}	2.8×10^{-1}	2×10^{-7}	2006–2168
6A Option Case[a]	7.3	3.1	1.0×10^{1}	6×10^{-6}	2.1×10^{1}	1×10^{-5}	2006–2168
6B Base Case[a]	2.5	3.0	5.5	3×10^{-6}	7.3	4×10^{-6}	2006–2100
6B Option Case[a]	7.2	3.0	1.0×10^{1}	6×10^{-6}	2.1×10^{1}	1×10^{-5}	2006–2100
6C	2.2×10^{-2}	3.0	3.0	2×10^{-6}	6.5×10^{-2}	4×10^{-8}	2006–2045

[a] The life-of-project dose would not be received by one individual person due to the duration of these alternatives. The dose and lifetime risk of an LCF for the noninvolved worker with the larger impact from 40 years of exposure at the average annual dose rate would be: Alternative 1 – 28 millirem, 2×10^{-5} LCF risk; Alternative 2A – 15 millirem, 9×10^{-6} LCF risk; Alternative 6A, Base Case – 1.4 millirem, 8×10^{-7} LCF risk; Alternative 6A, Option Case – 5.2 millirem, 3×10^{-6} LCF risk; Alternative 6B, Base Case – 3.1 millirem, 2×10^{-6} LCF risk; Alternative 6B, Option Case – 8.8 millirem, 5×10^{-6} LCF risk.

Note: Total may not equal the sum of the contributions due to rounding.

Key: ERDF=Environmental Restoration Disposal Facility; LCF=latent cancer fatality; STTS=Supplemental Treatment Technology Site; WTP=Waste Treatment Plant.

Doses to noninvolved workers from emissions over the entire duration of each Tank Closure alternative are shown in Table K–51. Note that these project doses are presented for comparison purposes only. The duration of some of the alternatives (in particular, Alternatives 1; 2A; 6A, Base and Option Cases; and 6B, Base and Option Cases) would make it impossible for a single worker to receive the dose from the project's total emissions.

K.2.1.2.3 Chemical Risks to Workers

Workers involved in performing activities associated with the storage, retrieval, and processing of tank waste and the closure of the tank farm facilities could be exposed to chemical vapors. Chemical exposure is a concern because the tanks are continuously vented to the atmosphere, and workers would need to access parts of the tank farm system to monitor or retrieve the waste. The primary route of chemical exposure to workers during routine operations was assumed to be inhalation.

Exposures to tank farm vapors have been reported by workers since 1987. Between July 1987 and May 1993, 19 vapor exposure events involving 34 workers were reported (Osborne et al. 1995). These workers reported musty and foul odors, including the smell of ammonia, emanating from several single-shell tanks (SSTs) (Osborne and Huckaby 1994). They also reported effects such as headaches, burning sensations in the nose and throat, nausea, and impaired pulmonary functioning (Osborne et al. 1995).

In 1992, DOE and Westinghouse Hanford Company, which operated the tank farms at that time, determined that the tank farm vapor emissions had not been adequately characterized and represented a potential health risk to workers in the immediate vicinity of the tanks (Osborne and Huckaby 1994). To address this potential health risk, workers in certain areas of the tank farms (e.g., within the buffer zone of tank 214-C-103) were required to use supplied-air respirators (Osborne and Huckaby 1994). The Tank Vapor Issue Resolution Program was established in 1992 to characterize waste tank headspace vapors and understand their impact if they migrated into the workers' breathing zones (Osborne and Huckaby 1994).

In 1993, the Defense Nuclear Facilities Safety Board issued Recommendation 93-5, which indicated the need for better characterization of tank waste and headspace gases to understand the hazards present. As a result, an extensive tank waste characterization program was initiated that included process history and waste transfer records analysis, solid- and liquid-phase sampling and analysis, and vapor sampling and analysis (Cash 2004).

Between 1992 and 1997, headspace gas samples were collected from 109 SSTs (Stock and Huckaby 2000), primarily from SSTs that had passive ventilation. Some headspace vapor samples were also taken from double-shell tanks; however, all double-shell tanks have active ventilation, which greatly diminishes vapors (Cash 2004). Over 1,200 chemical species were identified as a result of this sampling effort (Stock and Huckaby 2000). By the end of 1996, the potential for hazardous vapor exposure had been analyzed, and acceptable controls were put in place. Based on the results of tank sample analysis and extensive reviews by outside oversight committees, including the Worker Health and Safety Subpanel of the DOE Tanks Advisory Panel, the vapor issue as known at that time was closed. Worker protection controls were implemented in the tank farms around those tanks known to contain larger amounts of noxious gases. The subpanel agreed that the implemented controls were adequate to protect the tank farm workers (Cash 2004).

Using sampling and monitoring data, a tank farm industrial hygiene program was implemented to prevent worker exposure to chemicals above occupational exposure limits. Among other actions designed to ensure worker protection, a tank farm health and safety plan was developed and implemented in 1993 and has been revised as necessary. The plan set action limits for organic chemical agents and ammonia that are below national occupational exposure limits. It further established case-by-case monitoring

requirements based on the specific tank located near where the work is to be performed and the nature of the work activity (CH2M HILL 2003a).

From 1997 until 1999, waste-disturbing activities were minimal. Interim stabilization of the SSTs resumed in 1999 under an enforceable consent decree with the State of Washington (Consent Decree No. CT-99-5076-EPS). This waste-disturbing activity increased during late 2001 and early 2002, and several negative evaluation reports were made by tank farm workers with concerns about odors in and around specific tank farms (Cash 2004).

In early 2002, workers were asked to report all smells or odors, and procedures were developed that required a medical evaluation of any worker exhibiting symptoms due to vapor exposure (CH2M HILL 2004a). In 2002, 19 workers reported vapor smells and received medical evaluations. Between January 1, 2003, and September 30, 2003, 40 workers reported vapor smells and received medical evaluations (CH2M HILL 2003a). Efforts to understand and address this increase were made in 2002 and were made the subject of a project in September 2003 to accelerate progress on resolving vapor issues (CH2M HILL 2004b).

A September 2003 report by the Government Accountability Project (GAP) (GAP 2003) stated that there had been an increase in the number of workers reporting deleterious effects of exposure to the chemical vapors in tank farms. The report was generally critical of the quality and adequacy of the exposure monitoring program and alleged that workers were sick and injured as a result of being exposed to vapors from HLW tanks and other toxic and carcinogenic substances. The GAP report and subsequent GAP statements also alleged that there were instances of improper medical record-keeping, including falsification of records and collusion to undermine worker compensation claims. Further, the GAP alleged that there had been instances in which injuries and illnesses had not been properly reported.

In February 2004, the Secretary of Energy directed the DOE Office of Independent Oversight and Performance Assurance (OA) to evaluate the GAP report allegations and assess past practices and current operations to determine whether additional actions were needed to ensure a safe work environment at Hanford. OA conducted an investigation of selected aspects of worker safety and health systems at Hanford from February through April 2004. The OA team consisted of 23 experts from various disciplines, including occupational medicine, industrial hygiene, radiological protection, nuclear engineering, waste management, environmental protection, chemistry, maintenance, operations, and management systems.

The April 2004 OA report (DOE 2004a) identified 18 individual findings, including deficiencies or weaknesses related to the following:

- Hazards analysis, exposure control, and exposure assessment
- Engineering practices and operational controls that threaten tank integrity and control of vapor emissions
- Processes for defining and investigating vapor exposure issues and managing corrective actions
- Classification and reporting of injury and illness cases
- DOE oversight and coordination of contractor industrial hygiene and occupational medicine programs

In its report, the OA team observed that there were no known instances of tank farm worker vapor exposures that exceeded regulatory limits. However, the team concluded that longstanding deficiencies in the characterization of tank farm vapors and the industrial hygiene program were such that the site could

not adequately assure that all exposures were below regulatory limits. Furthermore, to ensure that the vapor exposure issues would be fully addressed, OA reported that improvements were needed in various management systems, including engineering processes, industrial hygiene programs, integrated safety management implementation, communications, contractor feedback systems, and DOE Office of River Protection (ORP) line management oversight. The OA team identified an overarching weakness in that the strategy for protecting workers from vapors was not adequately defined and documented at a level that could be translated into a set of engineered controls, administrative controls, and personal protective equipment.

At the time of the assessment, the OA team determined that the contractor had adopted an "as low as is reasonably achievable" approach as the starting point for addressing this weakness, but had not yet characterized tank vapors (i.e., the chemicals of concern and conditions under which they are likely to be released) or established a technically sound industrial hygiene program that would provide for adequate sampling and monitoring of breathing zones and personnel air. The OA report also concluded that the Richland Operations Office had not established the necessary interfaces between prime contractors and the occupational medicine program to ensure the integration of occupational medicine program services as required by DOE directives and contractor requirements. Data on OSHA recordable accidents and in the Computerized Accident/Incident Reporting System (CAIRS) (see Section K.4) were found not to be as reliable as they should have been. Also, the CAIRS database was not being updated in a timely manner to reflect new information or the discovery of errors or omissions.

On the positive side, the OA report stated that the interim actions instituted by ORP and the contractor, which included respiratory protection for most work performed in tank farms, provided assurance that most of the immediate concerns were being addressed. Ongoing and planned actions regarding tank characterization, sampling, and personnel monitoring were seen as providing a good framework for developing longer-term solutions. The OA team found Hanford Environmental Health Foundation clinical practices and protocols to be consistent with standard occupational medical practices. The OA team found no substantiation of any of the health-related GAP allegations except for isolated instances of incomplete treatment information being provided to contractor record-keeping case managers. Although the need for some improvements was noted, OA concluded that the number and type of discrepancies identified in their investigation did not negate the overall usefulness of injury and illness metrics as a tool for monitoring safety performance and focusing attention on problem areas or trends. No indication of significant or pervasive underreporting of injuries and illnesses was noted, and most injury and illness events were found to be appropriately categorized. No egregious examples of misreporting were identified. This finding was consistent with a later Office of the Inspector General report of an independent review, which noted that the medical files were in good order (Friedman 2004).

Due to the increase in vapor exposure reports, mandatory respiratory protection for workers within the tank farm boundaries was implemented in March 2004 (Aromi 2004). In April 2004, a requirement for supplied-air respirators was implemented because of concerns about the amount of nitrous oxide in the tank vapors and the effectiveness of air-purifying respirators. Other actions taken to address vapor exposure issues included the following:

- Personal sampling devices were put into use to characterize tank farm worker breathing-zone vapor concentrations to better understand the exposure potential for various tasks. As of June 3, 2004, a total of 326 personal breathing-zone samples had been collected (124 for volatile organic compounds, 88 for ammonia, and 114 for nitrous oxide). Preliminary analysis of 79 of the nitrous oxide samples showed typical breathing-zone concentrations of less than 1 part per million (ppm) compared with the 50 ppm Threshold Limit Value established by ACGIH. Of the 29 ammonia samples for which analysis was complete, 17 showed less than detectable levels, while 12 showed levels ranging from 0.04 to 0.24 ppm, less than 1 percent of the 25 ppm Threshold Limit Value for ammonia.

- To better understand nitrous oxide emissions from tanks, samples were obtained from the breather filter openings for all 149 SSTs. Results of the sample analyses are provided in ***Results of Nitrous Oxide Monitoring Equipment Tests and adge Monitoring Non-personnel Area Tests Within Hanford Single Shell Tank Farms*** and are summarized as follows (Schofield 2004):

  – Results from 62 samples taken from 10 selected tanks believed to have high nitrous oxide concentrations in the tank headspace showed that the 24-hour time-weighted average concentrations at a distance of 0.9 to 1.5 meters (3 to 5 feet) from the breather filters were all below 1.0 ppm. Results from an additional 25 samples showed no 24-hour time-weighted average concentrations above 1.0 ppm at a distance of 46 centimeters (18 inches) from the breather filters on 5 selected tanks with high nitrous oxide concentrations in the tank headspace.

  – Results for 12-hour and 24-hour samples taken directly from the tank breather filter outlets showed, out of 343 samples, only 30 with time-weighted average concentrations above 1 ppm and 6 above 10 ppm. The highest value was 38 ppm, and the remaining 307 samples were less than 1.0 ppm.

- Tank headspace gas and vapor samples were obtained, and the 16 SSTs in the C tank farm were the first to be sampled. Data from these samples were used to monitor changes in vapor chemistry over time and determine appropriate protective measures (CH2M HILL 2004c).

- Other actions taken included installation of active ventilation systems, stack extensions to raise vapors above the worker breathing zone, and enhanced worker training (CH2M HILL 2004c).

An April 2005 assessment of the tank farms industrial hygiene program by ORP concluded that the program complied with applicable DOE and OSHA regulations and standards and was effective in protecting tank farm workers from industrial hazards (Schepens 2005). The assessment also sampled 57 of the 101 corrective actions arising from the April 2004 OA report (DOE 2004a) and verified adequate implementation for all 57. The assessment noted that the contractor had a plan to implement engineering controls in the tank farms to elevate exhaust points, and, in some cases, provide exhaust fans to minimize worker exposure. A number of key actions, including some engineering controls, had already been implemented, and all workers entering areas where they might be exposed to tank vapors were being required to use respiratory protection. It was also noted that the use of respiratory protection introduced several new hazards. From January 1, 2004, to March 30, 2005, about 33 percent of workplace injuries (mainly muscle strains, slips, and trips and falls) could be directly related to the use of a self-contained breathing apparatus (SCBA), which caused reduced visibility. Respiratory tract irritation from breathing the very dry air supplied by SCBAs was also noted (Schepens 2005).

On July 27, 2007, about 320 liters (85 gallons) of tank waste were spilled during a transfer from tank 241-S-102; the resulting Type A Accident Investigation Report identified several worker chemical exposure issues associated with the spill (DOE 2007a). A number of workers identified odors, experienced symptoms, or expressed concerns about their potential exposure to chemicals from the spill. Two individuals approached the spill location about 10 minutes after the leak and may have been exposed to tank vapors. One person noticed a strong odor and later reported symptoms, while the other, only a few feet away, did not. Others who reported symptoms were outside the tank farm fence, at least 40 meters (130 feet) from the leak location. Workers were sheltered for an extended time in a very warm mobile office building without ventilation, which may have contributed to the stress, concern, and symptoms (headaches) reported by some. There was no industrial hygiene sampling or monitoring for a chemical vapor release for more than 13 hours following the spill. However, any chemical vapors would have dissipated quickly and would have been difficult to measure quantitatively under the best of circumstances. Dispersion modeling conducted in the days following the spill indicated that, even in the maximum reasonably foreseeable case scenario with conservative assumptions, only individuals inside

the S tank farm fence would have been subjected to chemical concentrations at or above the applicable occupational exposure limit. The accident investigation report concluded that the contractor needed to better integrate industrial hygiene into its response to abnormal events that may involve chemical releases. It was also concluded that the Hanford fire department needed to improve the performance of its emergency medical technicians in the areas of documentation of patient encounters and communications with the site occupational medical services provider. The need for more-frequent review of patient records by physicians and enhanced documentation of patient encounters was also identified (DOE 2007a).

Estimates of worker exposure to chemicals and the resulting health effects are highly dependent on modeling assumptions. If a worker were assumed to be very close to the chemical emission point, the predicted consequences might vary from zero to extreme (severe, irreversible health effects), depending on the assumed duration of the release and exposure and the location of the worker with respect to the emission point and wind direction. Therefore, no attempt was made to estimate involved worker exposure to chemical releases associated with routine operations. Through compliance with applicable requirements and the scrutiny provided by internal and external review of chemical exposure issues, it is expected that involved worker exposure would be maintained below the thresholds identified by OSHA and ACGIH.

Because a noninvolved worker was assumed to be some distance away, it is possible to model exposures using average meteorological conditions at the site. Impacts on a noninvolved worker from carcinogenic and noncarcinogenic chemicals, ammonia, benzene, 1,3-butadiene, formaldehyde, mercury, toluene, and xylene were modeled. The modeling and risk assessment approach is described in Appendix G. The resulting toxic chemical concentrations and associated Hazard Quotients and risks are presented in Chapter 4, Section 4.1.4, for each Tank Closure alternative. The Hazard Index (the sum of the individual Hazard Quotients for all noncarcinogenic toxic chemicals) would be less than 1 under all alternatives, indicating that concentrations would be below a level requiring action to protect the noninvolved worker. The risk of cancer from exposure to the carcinogenic chemicals (benzene, 1,3-butadiene, and formaldehyde) would be on the order of 1 in 100,000 or less under all Tank Closure alternatives.

K.2.2 FFTF Decommissioning Alternatives

K.2.2.1 Impacts on the Public During Normal Operations

The methodology employed to evaluate impacts on the public and workers from decommissioning FFTF is similar to that discussed in Section K.2.1 for evaluating impacts of tank closure activities. Under FFTF Decommissioning Alternative 1: No Action, current impacts that are part of the Hanford baseline as presented in Chapter 3 would continue. The following sections address differences in scenarios and assumptions affecting human health impacts due to radiological emissions under FFTF Decommissioning Alternative 2: Entombment, and FFTF Decommissioning Alternative 3: Removal. Unless noted otherwise, assumptions described in Section K.2.1 also apply to the FFTF decommissioning radiological impacts analysis.

K.2.2.1.1 Approach

FFTF Decommissioning alternatives comprise three activities: (1) facility disposition (decommissioning of FFTF and auxiliary buildings), (2) disposition of remote-handled special components (RH-SCs), and (3) disposition of contaminated bulk sodium. Disposition of RH-SCs and bulk sodium would occur either at Hanford or the Materials and Fuels Complex (MFC) at INL; therefore, the three activities were evaluated separately.

Under normal operations, radiological releases could occur from any of the activities listed above. Deactivation activities were previously evaluated in the *Environmental Assessment, Sodium Residuals Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility (FFTF) Pro ect, Hanford Site, Richland, Washington* (DOE 2006). Based on the environmental assessment, DOE found no significant impact on the offsite population. The impact on an MEI was estimated to be 0.00026 millirem per year, assuming all of the tritium contamination was released to the environment (DOE 2006:4-2). Impacts of deactivation activities would be the same under all FFTF Decommissioning alternatives and were not included in the alternatives' dose estimates.

Impacts were evaluated for the same public receptors as the Tank Closure alternatives (described in the introduction to Section K.2): the offsite population, an MEI, and an onsite MEI. Impacts on an MEI due to FFTF emissions were evaluated for the dominant downwind directions; the MEI was identified as being about 9.1 kilometers (5.6 miles) to the southeast, across the river from the 300 Area. Ground-level radiological emissions were assumed for facility disposition activities or disposition of bulk sodium in a new facility at Hanford. This conservative assumption resulted in overestimation of the impacts. Emissions associated with the potential treatment of RH-SCs at Hanford would emanate from the 200-West Area near the T Plant complex. The same source location assumed for the 200-West Area tank closure emissions was assumed for the RH-SC emissions, i.e., STTS-West. This assumption resulted in conservative estimates of the impacts to members of the public.

FFTF Decommissioning Alternatives 2 and 3 include options for processing RH-SCs, bulk sodium, or both at the INL MFC. The MEI would be about 5.2 kilometers (3.2 miles) south-southeast of the MFC. A release height of 24 meters (78 feet) was assumed, based on the building and stack heights presented in the facility conceptual design report (ANL-W 2004:27, 53).

K.2.2.1.2 Modeling

The GENII computer code was used to evaluate impacts on the offsite populations of Hanford and INL.

K.2.2.1.3 Input Parameters

Input parameters for the GENII computer code included items that are a function of the location of the action being taken. For FFTF Decommissioning alternatives, the input parameters that were different than those used in evaluating Tank Closure alternatives were the meteorological data, population data, and radiological source terms.

K.2.2.1.3.1 Meteorological Data

FFTF Decommissioning alternatives could include activities that occur at FFTF (the Hanford 400 Area), the INL MFC, or the Hanford 200-West Area. Meteorological data for evaluating offsite impacts of activities that would occur in the Hanford 200-West Area were the same as those used in evaluating emissions from STTS-West for the Tank Closure alternatives (see Table K–4). Meteorological data for activities that would occur at FFTF (facility disposition or disposition of bulk sodium) are presented in Table K–52. These data represent 10-year averages of data collected from 1997 through 2006 at the 9-meter (30-foot) height at the FFTF Meteorological Station (Burk 2007). Wind rose representations of these data are included in Chapter 3, Section 3.2.4. Meteorological data for activities occurring at the INL MFC are presented in Table K–53. These data are based on meteorological data collected at the MFC Meteorological Station from 2000 through 2004.

Table K–52. Joint Frequency Distribution for the Hanford Site 400 Area (Fast Flux Test Facility) at a 9-Meter Height

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0.78	A	0.13	0.14	0.12	0.11	0.13	0.17	0.13	0.11	0.11	0.08	0.08	0.06	0.06	0.05	0.06	0.1
	B	0.04	0.05	0.07	0.04	0.05	0.05	0.07	0.05	0.05	0.04	0.03	0.02	0.03	0.03	0.02	0.04
	C	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03
	D	0.27	0.29	0.24	0.22	0.25	0.26	0.3	0.26	0.26	0.25	0.23	0.21	0.21	0.25	0.33	0.27
	E	0.27	0.22	0.21	0.21	0.21	0.2	0.25	0.3	0.36	0.35	0.35	0.33	0.36	0.35	0.41	0.3
	F	0.29	0.21	0.18	0.13	0.15	0.14	0.21	0.24	0.3	0.3	0.3	0.26	0.29	0.27	0.32	0.27
	G	0.09	0.08	0.06	0.06	0.05	0.06	0.07	0.08	0.1	0.12	0.1	0.09	0.1	0.11	0.09	0.11
2.5	A	0.43	0.49	0.41	0.34	0.4	0.48	0.57	0.55	0.64	0.43	0.22	0.14	0.15	0.13	0.18	0.28
	B	0.18	0.16	0.12	0.07	0.09	0.1	0.19	0.17	0.19	0.13	0.08	0.04	0.04	0.05	0.07	0.14
	C	0.14	0.12	0.07	0.06	0.08	0.09	0.15	0.1	0.15	0.1	0.03	0.03	0.02	0.04	0.07	0.11
	D	0.68	0.67	0.45	0.31	0.28	0.33	0.7	0.82	0.89	0.63	0.4	0.22	0.25	0.38	0.78	0.87
	E	0.66	0.55	0.37	0.21	0.19	0.27	0.63	1.03	1.18	1.19	0.62	0.46	0.47	0.66	1.08	0.95
	F	0.57	0.54	0.31	0.15	0.1	0.16	0.47	0.88	1.08	0.94	0.52	0.28	0.21	0.31	0.75	0.72
	G	0.28	0.24	0.13	0.04	0.03	0.05	0.14	0.31	0.32	0.27	0.17	0.08	0.06	0.12	0.31	0.31
4.5	A	0.4	0.46	0.24	0.07	0.09	0.12	0.21	0.25	0.83	0.74	0.28	0.17	0.16	0.13	0.19	0.27
	B	0.14	0.11	0.03	0.02	0.02	0.02	0.06	0.09	0.22	0.27	0.09	0.07	0.04	0.05	0.08	0.12
	C	0.08	0.07	0.03	0.01	0.01	0.01	0.04	0.05	0.15	0.19	0.05	0.03	0.04	0.03	0.05	0.09
	D	0.4	0.27	0.1	0.06	0.05	0.08	0.3	0.56	0.87	1.02	0.39	0.24	0.18	0.4	0.97	0.83
	E	0.23	0.18	0.1	0.03	0.01	0.03	0.36	0.98	0.99	1.19	0.54	0.28	0.27	0.57	1.43	0.96
	F	0.17	0.14	0.07	0.01	0.01	0.01	0.27	1.13	0.87	0.77	0.24	0.05	0.04	0.07	0.61	0.68
	G	0.06	0.06	0.03	0	0	0	0.13	0.46	0.27	0.17	0.04	0.01	0	0.01	0.23	0.29
7.0	A	0.1	0.16	0.06	0.01	0	0.01	0.02	0.02	0.23	0.66	0.4	0.19	0.12	0.12	0.19	0.09
	B	0.02	0.02	0.01	0	0	0	0.01	0.01	0.04	0.16	0.11	0.05	0.02	0.02	0.06	0.05
	C	0.02	0.01	0.01	0	0	0	0.01	0.01	0.04	0.15	0.08	0.05	0.02	0.01	0.05	0.02
	D	0.07	0.07	0.03	0.01	0	0	0.03	0.07	0.28	0.84	0.49	0.23	0.16	0.29	0.75	0.21
	E	0.04	0.05	0.03	0	0	0	0.05	0.1	0.31	0.77	0.56	0.18	0.12	0.3	0.67	0.1
	F	0.01	0.01	0.01	0	0	0	0.01	0.07	0.13	0.26	0.08	0.01	0.01	0.01	0.05	0.02
	G	0	0	0	0	0	0	0.01	0.09	0.05	0.07	0.04	0.01	0	0	0.01	0.01

Table K–52. Joint Frequency Distribution for the Hanford Site 400 Area (Fast Flux Test Facility) at a 9-Meter Height *(continued)*

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9.6	A	0	0.01	0.01	0.01	0	0	0	0	0.02	0.12	0.16	0.13	0.08	0.03	0.1	0.02
	B	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.03	0.02	0.01	0.02	0
	C	0	0	0	0	0	0	0	0	0	0.03	0.04	0.02	0.01	0	0.03	0
	D	0.01	0.02	0.02	0	0	0	0	0.01	0.04	0.23	0.27	0.12	0.06	0.08	0.23	0.02
	E	0.01	0.04	0.03	0	0	0	0.01	0.01	0.03	0.2	0.26	0.07	0.03	0.06	0.12	0.01
	F	0	0	0	0	0	0	0	0	0	0.02	0.02	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0.01	0.02	0	0	0	0	0
12.5	A	0	0	0	0	0	0	0	0	0	0.01	0.05	0.05	0.03	0	0.02	0
	B	0	0	0	0	0	0	0	0	0	0.01	0.03	0.01	0	0	0.01	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0.01	0
	D	0	0	0.01	0	0	0	0	0	0	0.06	0.14	0.05	0.02	0.01	0.04	0
	E	0	0	0.01	0	0	0	0	0	0	0.05	0.08	0.03	0.01	0.01	0.02	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.9	A	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.02	0.04	0.01	0.01	0	0	0
	E	0	0	0	0	0	0	0	0	0	0.01	0.02	0.01	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.8	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0
	E	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: To convert meters to feet, multiply by 3.281.
Source: Burk 2007.

Table K–53. Joint Frequency Distribution for the Idaho National Laboratory Materials and Fuels Complex at a 10-Meter Height

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
1.2	A	0.32	0.32	0.29	0.23	0.16	0.1	0.13	0.13	0.16	0.19	0.21	0.21	0.24	0.28	0.31	0.3
	B	0.04	0.05	0.07	0.05	0.02	0.01	0	0.01	0.02	0.01	0.01	0	0	0	0.01	0.06
	C	0.04	0.07	0.05	0.03	0.01	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.06
	D	0.06	0.07	0.09	0.1	0.06	0.02	0.01	0.09	0.11	0.04	0.01	0.01	0	0	0.01	0.05
	E	0.08	0.12	0.11	0.14	0.12	0.05	0.02	0.13	0.15	0.09	0.03	0.01	0	0	0.02	0.04
	F	0.52	0.62	0.73	0.81	0.75	0.66	0.58	0.69	0.67	0.57	0.45	0.37	0.2	0.27	0.35	0.4
1.9	A	0.49	0.55	0.36	0.21	0.13	0.07	0.1	0.12	0.13	0.19	0.3	0.29	0.3	0.3	0.3	0.42
	B	0.12	0.18	0.1	0.04	0.03	0	0.01	0.01	0.03	0.03	0.04	0.03	0.02	0.01	0.02	0.06
	C	0.07	0.17	0.19	0.07	0	0	0	0.01	0.02	0.03	0.03	0.03	0	0	0.01	0.05
	D	0.08	0.26	0.25	0.22	0.1	0.02	0.01	0.11	0.17	0.13	0.05	0.01	0	0	0	0.06
	E	0.11	0.18	0.21	0.23	0.11	0.03	0.02	0.12	0.26	0.19	0.1	0.05	0.01	0.01	0.09	0.08
	F	0.37	0.57	0.65	0.62	0.42	0.27	0.23	0.41	0.63	0.65	0.49	0.35	0.22	0.2	0.19	0.27
2.6	A	0.25	0.44	0.35	0.19	0.13	0.08	0.07	0.15	0.21	0.27	0.34	0.34	0.27	0.13	0.16	0.22
	B	0.12	0.21	0.14	0.04	0.03	0.01	0.01	0.01	0.04	0.06	0.08	0.09	0.05	0.03	0.02	0.04
	C	0.07	0.34	0.19	0.06	0.02	0.01	0.04	0.02	0.03	0.05	0.06	0.05	0.03	0.01	0.01	0.04
	D	0.15	0.68	0.75	0.58	0.16	0.05	0.04	0.31	0.5	0.53	0.27	0.13	0.03	0.01	0.03	0.08
	E	0.08	0.22	0.31	0.36	0.12	0.03	0.05	0.12	0.25	0.21	0.14	0.07	0.05	0.03	0.03	0.05
	F	0.11	0.23	0.3	0.28	0.13	0.08	0.07	0.18	0.26	0.28	0.25	0.18	0.09	0.1	0.08	0.1
3.5	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0.16	0.28	0.36	0.16	0.09	0.07	0.07	0.15	0.29	0.5	0.54	0.4	0.2	0.11	0.1	0.11
	C	0.07	0.32	0.23	0.07	0.02	0.02	0.02	0.09	0.08	0.12	0.14	0.12	0.03	0.03	0.02	0.03
	D	0.26	0.8	0.78	0.72	0.23	0.08	0.14	0.62	1.01	0.93	0.69	0.35	0.1	0.07	0.09	0.18
	E	0.07	0.2	0.22	0.33	0.17	0.06	0.08	0.36	0.34	0.29	0.14	0.08	0.04	0.05	0.03	0.07
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.7	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0.17	0.3	0.37	0.14	0.07	0.05	0.04	0.17	0.43	1.01	0.98	0.49	0.15	0.11	0.1	0.12
	D	0.33	0.72	0.8	0.42	0.16	0.1	0.13	1.09	0.93	1.49	1.46	0.56	0.11	0.11	0.1	0.2
	E	0	0.07	0.12	0.21	0.18	0.05	0.07	0.69	0.16	0.4	0.1	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table K–53. Joint Frequency Distribution for the Idaho National Laboratory Materials and Fuels Complex at a 10-Meter Height *(continued)*

Average Windspeed (meters per second)	Pasquill Atmospheric Stability Class	Percentage of Time Wind Blows from the Indicated Direction															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
6.9	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0.03	0.05	0.05	0.02	0	0.01	0.02	0.03	0.11	0.26	0.34	0.1	0.02	0.02	0.02	0.01
	D	0.45	0.71	0.77	0.21	0.06	0.05	0.04	0.62	1.35	3.49	4.44	1.5	0.14	0.16	0.13	0.23
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.7	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0.27	0.39	0.19	0.05	0.01	0	0.01	0.03	0.5	1.46	4.68	1.79	0.04	0.03	0.03	0.04
	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: To convert meters to feet, multiply by 3.281.

K.2.2.1.3.2 Population Data

The potentially exposed offsite population used for analysis depends on where an activity would occur. The population potentially exposed to emissions from disposition of FFTF and the auxiliary buildings would be within an 80-kilometer (50-mile) radius centered on the 400 Area. The population data represent results of the 2000 census. Under the Hanford Reuse Option of processing the bulk sodium at Hanford, the same population would be used because the Sodium Reaction Facility would be located in the 400 Area. The distribution of the 80-kilometer (50-mile) population around the 400 Area is shown in Figure K–5.

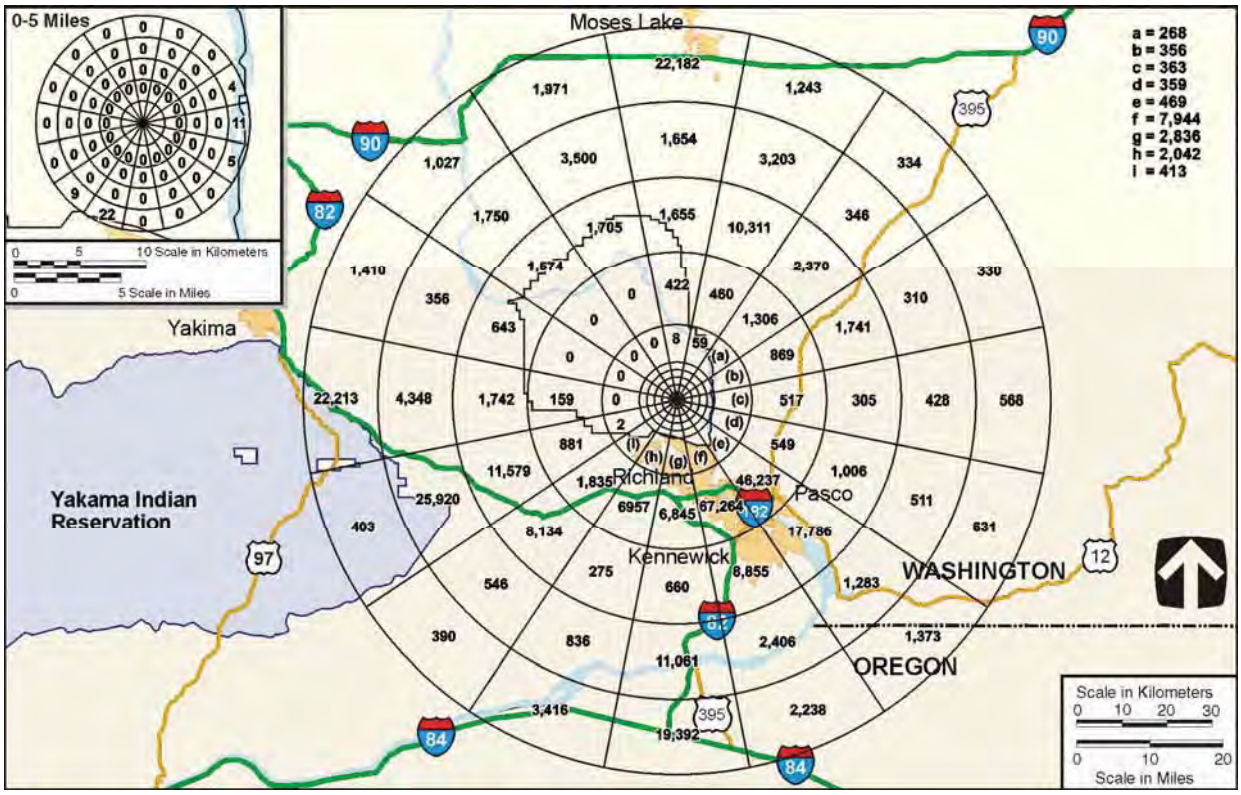


Figure K–5. Population Distribution Within 80 Kilometers (50 Miles) of the Fast Flux Test Facility

The Hanford Option for processing the RH-SCs would be to construct a facility adjacent to the T Plant in the 200-West Area. The same population distribution used for evaluating impacts of tank closure activities that would occur in the 200-West Area was used for evaluating impacts from processing RH-SCs (see Figure K–4). The center of the 80-kilometer (50-mile) region of influence, STTS-West in the southeast corner of 200-West Area, is closer than the T Plant to population centers in the dominant downwind directions, which contributed a degree of conservatism to the analysis.

FFTF Decommissioning Alternatives 2 and 3 include options for processing RH-SCs and bulk sodium in facilities at the INL MFC (the Idaho Option for disposition of RH-SCs and the Idaho Reuse Option for disposition of bulk sodium). The 80-kilometer (50-mile) population distribution used for analysis of impacts from these activities is shown in Figure K–6.

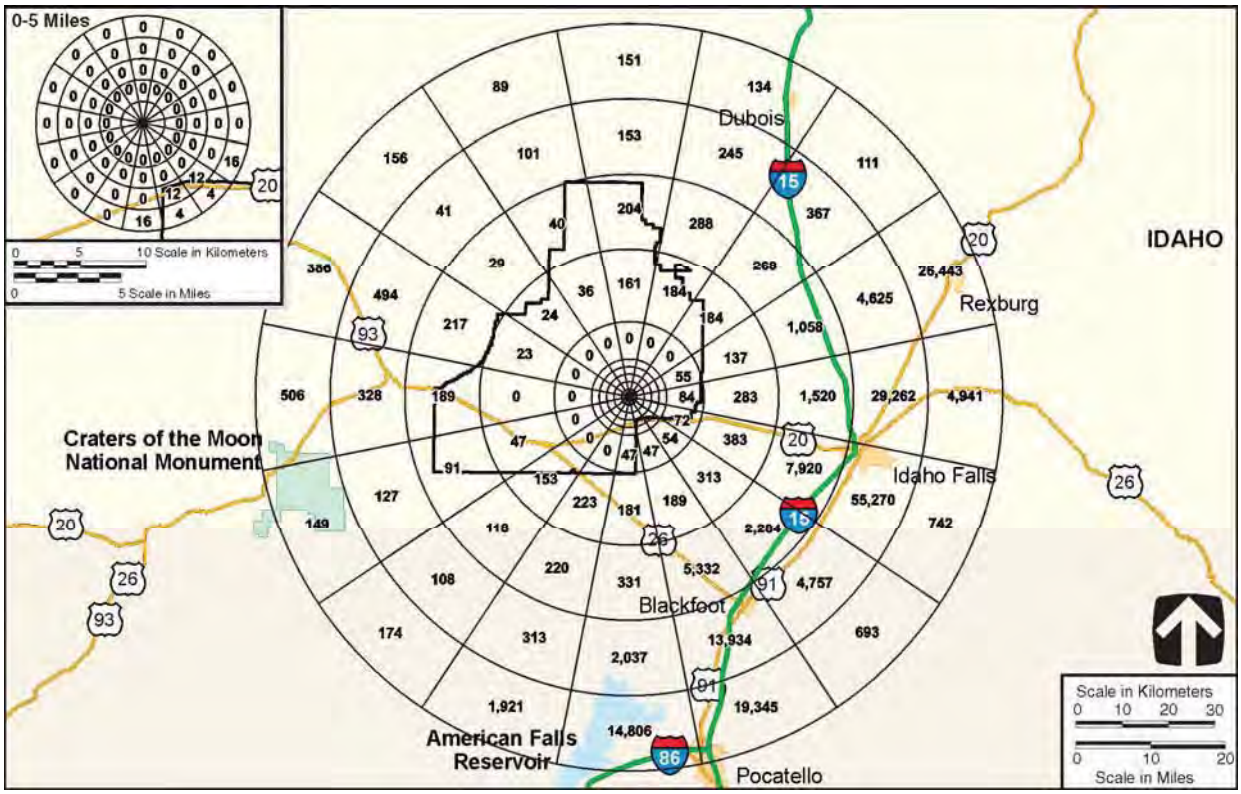


Figure K–6. Population Distribution Within 80 Kilometers (50 Miles) of the Idaho National Laboratory Materials and Fuels Complex

K.2.2.1.3.3 Source Terms

Radioactive emissions could be associated with each of the three activities that make up FFTF decommissioning. Emissions could result from activities to dispose of FFTF and the auxiliary buildings. FFTF Decommissioning Alternative 2 would require filling vessels and rooms that would remain in place prior to being covered by a barrier. Filling the voids could dislodge radioactive contaminants that would then be pushed out of the vessels and rooms as grout replaces the air in the voids. Under FFTF Decommissioning Alternative 3, the demolition practices employed, such as crimping or capping pipes and vessels, would control contamination such that negligible offsite emissions are expected.

Emissions from disposition of RH-SCs could occur at Hanford or INL, depending on which option is selected; the emissions would be the same regardless of location. Disposition of bulk sodium could occur at Hanford or INL. The total project emissions would be slightly higher under the Hanford Reuse Option because decommissioning the Sodium Reaction Facility is an additional activity. Deactivation of the Sodium Processing Facility (SPF) was assumed not to be required at INL because use of the facility would continue to support other activities. Table K–54 presents the source terms from radiological emissions assumed for each of the activities: facility disposition, disposition of RH-SCs, and disposition of bulk sodium.

Table K–54. FFTF Decommissioning Alternatives 2 and 3 – Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project		Annual Emissions in Year(s) of Maximum Impact	
	Curies	Year(s)	Curies	Year(s)
Facility Disposition[a]				
Cesium-137	1.5×10^{-6}	2017	1.5×10^{-6}	2017
Disposition of Remote-Handled Special Components – Hanford or Idaho Option				
Cesium-137	2.6×10^{-4}	2017–2018	1.7×10^{-4}	2017
Disposition of Bulk Sodium – Hanford Reuse Option				
Hydrogen-3 (tritium)	1.3×10^{1}	2017–2019	5.7	2017–2018
Cesium-137	7.3×10^{-4}		3.3×10^{-4}	
Uranium	2.1×10^{-7}		9.5×10^{-8}	
Disposition of Bulk Sodium – Idaho Reuse Option				
Tritium	1.1×10^{1}	2015–2016	5.7	2015–2016
Cesium-137	6.6×10^{-4}		3.3×10^{-4}	
Uranium	1.9×10^{-7}		9.5×10^{-8}	

a Emissions apply to Alternative 2 only.

Key: FFTF=Fast Flux Test Facility.

K.2.2.1.4 Results

The radiological impacts on the public due to the FFTF Decommissioning alternatives and options are presented in Table K–55 for the population, in Table K–56 for an MEI, and in Table K–57 for an onsite MEI at Hanford. Impacts under FFTF Decommissioning Alternative 1 are part of the Hanford baseline and are not addressed in this appendix. Impacts of FFTF Decommissioning Alternatives 2 and 3 would include the impacts of facility disposition, disposition of RH-SCs, and disposition of bulk sodium. Based on the calculated collective population dose, no LCFs are expected as a result of any of the alternatives or options; all calculated LCF values are much less than 1. The incremental risk of an LCF to an MEI would be extremely small in all cases; the largest risk over the life of the project would be about 2×10^{-10}, or less than 1 in a billion.

The incremental risk to an onsite MEI assumed to work at the Columbia Generating Station would be even smaller due to the shorter exposure time (a daily work shift) and typical wind direction.

Table K–55. FFTF Decommissioning Alternatives 2 and 3 – Impacts on the Population During Normal Operations

Radionuclides	Life of Project		Year(s) of Maximum Impact	
	Dose (person-rem)	LCFs[a]	Dose (person-rem per year)	LCFs[a]
Alternative 2, Facility Disposition				
Cesium-137	1.0×10^{-6}	0 (6×10^{-10})	1.0×10^{-6}	0 (6×10^{-10})
Alternative 3, Facility Disposition				
	–	–	–	–
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Hanford Option				
Cesium-137	1.4×10^{-4}	0 (8×10^{-8})	9.0×10^{-5}	0 (5×10^{-8})
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Idaho Option				
Cesium-137	1.1×10^{-5}	0 (7×10^{-9})	7.3×10^{-6}	0 (4×10^{-9})

Table K–55. FFTF Decommissioning Alternatives 2 and 3 – Impacts on the Population During Normal Operations *(continued)*

Radionuclides	Life of Project		Year(s) of Maximum Impact	
	Dose (person-rem)	LCFs[a]	Dose (person-rem per year)	LCFs[a]
Alternative 2 or 3, Disposition of Bulk Sodium – Hanford Reuse Option				
Hydrogen-3 (tritium)	6.7×10^{-3}		3.0×10^{-3}	
Cesium-137	4.9×10^{-4}		2.2×10^{-4}	
Uranium	3.8×10^{-5}		1.7×10^{-5}	
Total	7.2×10^{-3}	0 (4×10^{-6})	3.3×10^{-3}	0 (2×10^{-6})
Alternative 2 or 3, Disposition of Bulk Sodium – Idaho Reuse Option				
Tritium	3.9×10^{-4}		1.9×10^{-4}	
Cesium-137	2.8×10^{-5}		1.4×10^{-5}	
Uranium	2.1×10^{-6}		1.0×10^{-6}	
Total	4.2×10^{-4}	0 (3×10^{-7})	2.1×10^{-4}	0 (1×10^{-7})

[a] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Key: FFTF=Fast Flux Test Facility; LCF=latent cancer fatality.

Table K–56. FFTF Decommissioning Alternatives 2 and 3 – Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Life of Project		Year(s) of Maximum Impact		Wind Direction	Distance (kilometers)
	Dose (millirem)	Lifetime Risk of an LCF	Dose (millirem per year)	Lifetime Risk of an LCF		
Alternative 2, Facility Disposition						
Cesium-137	3.0×10^{-8}	2×10^{-14}	3.0×10^{-8}	2×10^{-14}	SE	8.2
Alternative 3, Facility Disposition						
	–	–	–	–	–	–
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Hanford Option						
Cesium-137	2.5×10^{-6}	1×10^{-12}	1.6×10^{-6}	1×10^{-12}	ENE	22.2
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Idaho Option						
Cesium-137	2.1×10^{-6}	1×10^{-12}	1.4×10^{-6}	8×10^{-13}	SSE	5.2
Alternative 2 or 3, Disposition of Bulk Sodium – Hanford Reuse Option						
Hydrogen-3 (tritium)	2.4×10^{-4}		1.1×10^{-4}		SE	8.2
Cesium-137	1.5×10^{-5}		6.6×10^{-6}			
Uranium	7.5×10^{-7}		3.4×10^{-7}			
Total	2.5×10^{-4}	2×10^{-10}	1.2×10^{-4}	7×10^{-11}		
Alternative 2 or 3, Disposition of Bulk Sodium – Idaho Reuse Option						
Tritium	8.5×10^{-5}		4.2×10^{-5}		SSE	5.2
Cesium-137	5.3×10^{-6}		2.7×10^{-6}			
Uranium	2.7×10^{-7}		1.3×10^{-7}			
Total	9.0×10^{-5}	5×10^{-11}	4.5×10^{-5}	3×10^{-11}		

Note: To convert kilometers to miles, multiply by 0.6214.

Key: FFTF=Fast Flux Test Facility; LCF=latent cancer fatality.

Table K–57. FFTF Decommissioning Alternatives 2 and 3 – Impacts on the Hanford Onsite Maximally Exposed Individual During Normal Operations

Radionuclides	Life of Project		Year(s) of Maximum Impact		Wind Direction	Distance (kilometers)
	Dose (millirem)	Lifetime Risk of an LCF	Dose (millirem per year)	Lifetime Risk of an LCF		
Alternative 2, Facility Disposition						
Cesium-137	1.9×10^{-9}	1×10^{-15}	1.9×10^{-9}	1×10^{-15}	NNE	4.5
Alternative 3, Facility Disposition						
	–	–	–	–	–	–
Alternative 2 or 3, Disposition of Remote-Handled Special Components – Hanford Option						
Cesium-137	5.1×10^{-8}	3×10^{-14}	3.4×10^{-8}	2×10^{-14}	ESE	22.7
Alternative 2 or 3, Disposition of Bulk Sodium – Hanford Reuse Option						
Hydrogen-3 (tritium)	2.3×10^{-5}		1.0×10^{-5}		NNE	4.5
Cesium-137	9.4×10^{-7}		4.3×10^{-7}			
Uranium	5.0×10^{-7}		2.3×10^{-7}			
Total	2.4×10^{-5}	1×10^{-11}	1.1×10^{-5}	7×10^{-12}		

Note: To convert kilometers to miles, multiply by 0.6214.
Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality.

K.2.2.2 Impacts on Workers During Normal Operations

K.2.2.2.1 Project Radiation Workers

Workers would receive radiation doses from deactivation activities that were previously evaluated in the *Environmental Assessment, Sodium Residuals Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility (FFTF) Pro ect, Hanford Site, Richland, Washington* (DOE 2006). The collective dose to the worker population from deactivation activities would be 576 person-rem (DOE 2006:4-2). This dose would be incurred regardless of which FFTF Decommissioning alternative is selected.

Worker doses would result from maintaining administrative controls (under FFTF Decommissioning Alternative 1) or from facility disposition, disposition of RH-SCs, and disposition of bulk sodium (under FFTF Decommissioning Alternatives 2 and 3). Table K–58 presents the worker doses that would be received from these activities.

Table K–58. FFTF Decommissioning Alternatives – Radiation Worker Impacts and Labor Estimates

Alternative	Life of Project Collective Worker Impact		Life of Project Full-Time Equivalent Radiation Worker Labor		Average Annual Impact per Full-Time Equivalent Radiation Worker		Activity Duration
	Dose (person-rem)	LCFs[a]	Hours	Years	Dose (millirem per year)	Lifetime Risk of an LCF	Years
1	1	0 (6×10^{-4})	4.16×10^{4}	20	50	3×10^{-5}	2008–2107
2	**Facility Disposition**						
	0.37	0 (2×10^{-4})	7.68×10^{3}	4	100	6×10^{-5}	2017
3	**Facility Disposition**						
	6.3	0 (4×10^{-3})	1.31×10^{5}	63	100	6×10^{-5}	2013–2014
2 or 3	**Disposition of Remote-Handled Special Components – Hanford or Idaho Option**						
	1.2	0 (7×10^{-4})	1.25×10^{5}	60	20	1×10^{-5}	2017–2018
	Disposition of Bulk Sodium – Hanford Reuse Option						
	3.7	0 (2×10^{-3})	1.96×10^{5}	94	39	2×10^{-5}	2017–2019
	Disposition of Bulk Sodium – Idaho Reuse Option						
	3.6	0 (2×10^{-3})	1.91×10^{5}	92	39	2×10^{-5}	2014–2016

[a] Increased number of LCFs for the worker population as a result of the radiation dose received under the alternative. If zero, the number in parentheses is the value calculated by multiplying the dose by the risk factor of 0.0006 LCFs per person-rem.
Key: FFTF=Fast Flux Test Facility; LCF=latent cancer fatality.
Source: SAIC 2007b.

K.2.2.2.2 Noninvolved Workers

For the FFTF Decommissioning alternatives, the noninvolved worker that would be potentially affected by either facility disposition or disposition of bulk sodium was assumed to be located in the 300 Area, which is about 9.3 kilometers (5.8 miles) southeast of FFTF. For emissions from the T Plant in the 200-West Area that would result from disposition of RH-SCs at Hanford, the noninvolved worker was assumed to be located at a distance of 100 meters (110 yards) to the east-northeast. For emissions occurring at the INL MFC, the noninvolved worker was assumed to be located at the Experimental Breeder Reactor II (EBR-II) in the MFC, approximately 100 meters (110 yards) away. Table K–59 presents the doses and risks calculated for a noninvolved worker for facility disposition, disposition of bulk sodium, and disposition of RH-SCs. In all cases the doses would be small.

Table K–59. FFTF Decommissioning Alternatives – Impacts on the Noninvolved Worker During Normal Operations

Alternative	Noninvolved Worker Location	Life of Project		Year of Maximum Impact	
		Dose (millirem)	Lifetime Risk of an LCF	Dose (millirem)	Lifetime Risk of an LCF
Facility Disposition					
2	300 Area	6.6×10^{-10}	4×10^{-16}	6.6×10^{-10}	4×10^{-16}
3	300 Area	-	-	-	-
Disposition of Remote-Handled Special Components – Hanford Option					
2 or 3	100 meters east-northeast	2.8×10^{-4}	2×10^{-10}	1.9×10^{-4}	1×10^{-10}
Disposition of Remote-Handled Special Components – Idaho Option					
2 or 3	EBR-II	1.7×10^{-6}	1×10^{-12}	1.1×10^{-6}	7×10^{-13}
Disposition of Bulk Sodium – Hanford Reuse Option					
2 or 3	300 Area	8.0×10^{-6}	5×10^{-12}	3.7×10^{-6}	2×10^{-12}
Disposition of Bulk Sodium – Idaho Reuse Option					
2 or 3	EBR-II	1.1×10^{-4}	7×10^{-11}	5.5×10^{-5}	3×10^{-11}

Key: EBR-II=Experimental Breeder Reactor II; FFTF=Fast Flux Test Facility; LCF=latent cancer fatality.

K.2.3 Waste Management Alternatives

K.2.3.1 Impacts on the Public During Normal Operations

The methodology employed to evaluate the impacts of the Waste Management Alternatives on the public and workers was similar to that discussed in Section K.2.1 for evaluating the impacts of Tank Closure alternatives. Under Waste Management Alternative 1: No Action, currently approved operation of waste treatment facilities would continue; no impacts above those that are part of the current Hanford baseline would result. The scope of the expanded waste treatment activities is the same under Waste Management Alternatives 2 and 3; emissions from the expanded waste treatment activities could result in radiological impacts on the public and are addressed in this section. Differences between Waste Management Alternatives 2 and 3 are in the proposed locations and sizes of waste disposal facilities. As the facilities would receive packaged waste, they are not expected to contribute to offsite doses.

Unless noted otherwise, assumptions in Section K.2.1 also apply to the waste management radiological impacts analysis. The following sections address differences in scenarios and assumptions affecting human health impacts due to radiological emissions from waste management.

K.2.3.1.1 Approach

Waste Management alternatives include treatment, storage, and disposal activities. Existing emissions from the Waste Receiving and Processing Facility (WRAP) and from waste treatment at the T Plant complex would continue under Waste Management Alternative 1. Under Waste Management Alternatives 2 and 3, additional treatment capacity would be added at WRAP and the T Plant complex and additional waste volumes would be processed. These facilities would be located in the 200-West Area. For purposes of evaluating radiological impacts on the public, emissions from waste treatment activities were modeled as originating from a single location, the STTS-West in the southeast corner of 200-West Area, which was the same location used for modeling emissions from the 200-West Area under the Tank Closure and FFTF Decommissioning alternatives.

Waste storage capacity at the Central Waste Complex (CWC) would be expanded under Waste Management Alternatives 2 and 3. Under Waste Management Alternative 2, waste disposal would occur in the 200-East Area Integrated Disposal Facility (IDF-East) and the proposed River Protection Project Disposal Facility (RPPDF) to be located between the 200-East and 200-West Areas. Under Waste Management Alternative 3, in addition to IDF-East and RPPDF, a 200-West Area Integrated Disposal Facility (IDF-West) would be used for waste disposal. Stored waste and waste placed in the disposal facilities would be in packages or large roll-on, roll-off containers; therefore, no radiological emissions with the potential to cause offsite impacts are expected from waste storage and disposal.

K.2.3.1.2 Modeling

The GENII computer code was used to evaluate impacts on the offsite populations of Hanford.

K.2.3.1.3 Input Parameters

The waste treatment facilities would be in the 200-West Area, so many of the GENII input parameters would be the same as those used in modeling impacts from 200-West Area tank closure activities. Common input parameters include meteorological data (see Table K–4) and population distribution (see Figure K–4). The same pathway and exposure assumptions used in the tank closure analysis were used for evaluating waste management impacts (see Section K.2.1.1.3.3).

K.2.3.1.3.1 Source Terms

The emissions of the proposed waste treatment facilities were estimated based on emissions from current treatment facilities. Isotopic data reported in the *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 200* (Rokkan et al. 2007) for operation of WRAP and Buildings 2706-T/TA were used where available. If no specific alpha-emitting isotopes were reported, the reported gross alpha emissions were used and assumed to be plutonium-239. In the absence of specific beta-emitting isotopes, the reported gross beta emissions were used and assumed to be strontium-90. Emissions for the duration of the waste treatment activities and for the years of maximum impact are presented in Table K–60.

Table K–60. Waste Management Alternatives – Radiological Emissions During Normal Operations

Radionuclides	Emissions over Life of Project		Annual Emissions in Years of Maximum Impact	
	Curies	Years	Curies	Years
Waste Management Alternative 2 or 3				
Strontium-90	7.4×10^{-6}	2013–2051	2.0×10^{-7}	2019–2051
Plutonium-239	9.2×10^{-7}		2.4×10^{-8}	
Americium-241	3.2×10^{-7}		8.8×10^{-9}	

K.2.3.1.4 Results

The radiological impacts of Waste Management Alternative 1 on members of the public are accounted for in analyses of the impacts of ongoing Hanford waste management operations. The impacts of Waste Management Alternatives 2 and 3 would be the same because there are no differences in waste treatment activities between the alternatives. Estimated impacts on the offsite population are presented in Table K–61. Impacts on an MEI assumed to be on the far bank of the Columbia River to the east-northeast are presented in Table K–62. Impacts on an onsite MEI assumed to be at the Laser Interferometer Gravitational-Wave Observatory to the east-southeast of the 200-West Area are presented in Table K–63. Impacts at this location would exceed those at the Columbia Generating Station because it is in the same general direction, but closer to the emission source.

Table K–61. Waste Management Alternatives 2 and 3 – Impacts on the Population During Normal Operations

Radionuclides	Life of Project		Years of Maximum Impact	
	Dose (person-rem)	LCFs[a]	Dose (person-rem)	LCFs[a]
Waste Management Alternative 2 or 3				
Strontium-90	5.0×10^{-6}		1.3×10^{-7}	
Plutonium-239	4.9×10^{-4}		1.3×10^{-5}	
Americium-241	1.7×10^{-4}		4.7×10^{-6}	
Total	6.7×10^{-4}	0 (4×10^{-7})	1.8×10^{-5}	0 (1×10^{-8})

[a] The integer indicates the number of excess latent cancer fatalities that would be expected in the population based on the risk factor of 0.0006 latent cancer fatalities per person-rem; the value in parentheses is the value calculated from the dose and risk factor.

Key: LCF=latent cancer fatality.

Table K–62. Waste Management Alternatives 2 and 3 – Impacts on the Maximally Exposed Individual During Normal Operations

Radionuclides	Life of Project		Years of Maximum Impact		Wind Direction	Distance (kilometers)
	Dose (millirem)	Lifetime Risk of an LCF	Dose (millirem per year)	Lifetime Risk of an LCF		
Waste Management Alternative 2 or 3						
Strontium-90	1.5×10^{-7}		4.0×10^{-9}		ENE	18.2
Plutonium-239	5.9×10^{-6}		1.5×10^{-7}			
Americium-241	2.1×10^{-6}		5.7×10^{-8}			
Total	8.2×10^{-6}	5×10^{-12}	2.1×10^{-7}	1×10^{-13}		

Note: To convert kilometers to miles, multiply by 0.6214.

Key: LCF=latent cancer fatality.

Table K–63. Waste Management Alternatives 2 and 3 – Impacts on the Onsite Maximally Exposed Individual During Normal Operations

Radionuclides	Onsite Maximally Exposed Individual Doses and Risks					
	Life of Project		Years of Maximum Impact		Wind Direction	Distance (kilometers)
	Dose (millirem)	Lifetime Risk of an LCF	Dose (millirem per year)	Lifetime Risk of an LCF		
Waste Management Alternative 2 or 3						
Strontium-90	6.0×10^{-9}		1.6×10^{-10}		ESE	18.4
Plutonium-239	1.6×10^{-6}		4.1×10^{-8}			
Americium-241	5.8×10^{-7}		1.6×10^{-8}			
Total	2.2×10^{-6}	1×10^{-12}	5.7×10^{-8}	3×10^{-14}		

Note: To convert kilometers to miles, multiply by 0.6214.
Key: LCF=latent cancer fatality.

K.2.3.2 Impacts on Workers During Normal Operations

K.2.3.2.1 Project Radiation Workers

Impacts on workers would result from waste treatment and storage activities and from waste disposal operations. Under Waste Management Alternative 1, the impacts of currently operating treatment, storage, and disposal facilities would continue through 2035. Under Waste Management Alternatives 2 and 3, additional worker exposure would occur due to expanded treatment and storage operations beginning in 2013 and continuing through 2051. Waste Management Alternatives 2 and 3 include the same treatment and storage activities, so the worker dose would be the same under both alternatives. Radiation worker doses received from disposal operations would be comparable regardless of the Waste Management alternative, but the worker dose would be affected by the duration of disposal operations, which would depend on the disposal group selected. Disposal groups are based on which Tank Closure alternative is selected (see Chapter 2, Sections 2.5.4.2 and 2.5.4.3). Table K–64 shows the projected worker radiation doses for the Waste Management alternatives and the various disposal groups.

Table K–64. Waste Management Alternatives – Radiation Worker Impacts and Labor Estimates During Normal Operations

Alternative	Life-of-Project Collective Worker Impact		Life-of-Project Full-Time Equivalent Radiation Worker Labor		Average Annual Impact per Full-Time Equivalent Radiation Worker		Activity Duration
	Dose (person-rem)	LCFs[a]	Hours	Years	Dose (millirem per year)	Lifetime Risk of an LCF	Years
1	**Treatment, Storage, and Disposal Operations**						
	37	0 (2×10^{-2})	3.87×10^{5}	186	200	1×10^{-4}	2007–2035
2 or 3	**Treatment and Storage Operations**						
	3.0×10^{3}	2	3.13×10^{7}	15,054	200	1×10^{-4}	2013–2051
2	**Disposal Operations**						
	Disposal Group 1 (for Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C)						
	360	0 (2×10^{-1})	3.76×10^{6}	1,806	200	1×10^{-4}	2007–2050
	Disposal Group 2 (for Tank Closure Alternatives 2A and 6B)						
	3.6×10^{3}	2	3.69×10^{7}	17,720	200	1×10^{-4}	2007–2100
	Disposal Group 3 (for Tank Closure Alternative 6A)						
	6.4×10^{3}	4	6.67×10^{7}	32,061	200	1×10^{-4}	2007–2165

Table–64. Waste Management Alternatives – Radiation Worker Impacts and Labor Estimates During Normal Operations *(continued)*

Alternative	Life-of-Project Collective Worker Impact		Life-of-Project Full-Time Equivalent Radiation Worker Labor		Average Annual Impact per Full-Time Equivalent Radiation Worker		Activity Duration
	Dose (person-rem)	LCFs[a]	Hours	Years	Dose (millirem per year)	Lifetime Risk of an LCF	Years
3	**Disposal Operations**						
	Disposal Group 1 (for Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C)						
	360	0 (2×10^{-1})	3.75×10^{6}	1,803	200	1×10^{-4}	2007–2050
	Disposal Group 2 (for Tank Closure Alternatives 2A and 6B)						
	3.5×10^{3}	2	3.67×10^{7}	17,666	200	1×10^{-4}	2007–2100
	Disposal Group 3 (for Tank Closure Alternative 6A)						
	6.4×10^{3}	4	6.64×10^{7}	31,928	200	1×10^{-4}	2007–2165

[a] Increased number of LCFs for the worker population as a result of the radiation dose received under the alternative. If zero, the number in parentheses is the value calculated by multiplying the dose by the risk factor of 0.0006 LCFs per person-rem.

Key: LCF=latent cancer fatality.

Source: SAIC 2007c.

K.2.3.2.2 Noninvolved Workers

Radiological emissions from waste treatment activities could potentially impact noninvolved workers. Waste disposal operations are not expected to result in emissions during normal operations because the waste would be received and disposed of in packages. Under Waste Management Alternative 1: No Action, no additional impacts beyond those included in the baseline would occur. Differences between Waste Management Alternatives 2 and 3 are due to locations and operations of disposal facilities; therefore, the impacts on a noninvolved worker, which are based on treatment facility emissions, would be the same under Waste Management Alternatives 2 and 3.

Emissions from waste management facilities were treated as coming from a single source for purposes of evaluating potential impacts on a noninvolved worker. Additionally, a conservative assumption was made that the emission source would be at ground level. A noninvolved worker was assumed to be about 100 meters (110 yards) to the east-northeast of the emission source. The maximum annual dose to a noninvolved worker would be 2.3×10^{-4} millirem; the increased risk of an LCF from this dose would be less than 1 in 1 billion. Emissions from waste management treatment activities would occur from 2013 through 2051. If the same noninvolved worker were exposed over the duration of the waste treatment activities, the worker would receive a dose of 8.7×10^{-3}; this dose corresponds to an increased lifetime risk of an LCF of 5×10^{-9}, much less than 1 in a million.

K.3 ACCIDENT ANALYSIS

K.3.1 Introduction

Accident analyses for the *TC & WM EIS* alternatives were performed to estimate the impacts on workers and the public from reasonably foreseeable accidents. The analyses were performed in accordance with NEPA guidelines, including the process for the selection of accidents, definition of accident scenarios, and estimation of potential impacts. The sections that follow describe the methodology and assumptions used, as well as the accident selection process, selected accident scenarios, and consequences and risks of

the accidents evaluated. The accident scenario descriptions are intended to give the informed reader a general understanding of how the accident source terms were developed and how the releases from one event might compare to another.

K.3.2 Overview of Methodology and Assumptions

K.3.2.1 Modeling and Analysis of Airborne Radiological Releases

The radiological impacts of airborne releases from accidents at the facilities involved in the *TC & WM EIS* alternatives were calculated using the MELCOR Accident Consequences Code System (MACCS) computer code, Version 1.13.1 (MACCS2). A detailed description of the MACCS model is provided in *MELCOR Accident Consequences Code System (MACCS)* (NRC 1990). The enhancements incorporated in MACCS2 are described in the *Code Manual for MACCS2*, Vol. 1, *User's Guide* (Chanin and Young 1997). This section presents the MACCS2 data specific to the accident analyses.

MACCS2 description. The MACCS2 computer code is used to estimate the radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. The specific release characteristics can consist of up to four Gaussian plumes that are often referred to simply as "plumes"; these specifications are designated a "source term."

The radioactive materials released are modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, whether or not there is precipitation, particulate material can be modeled as being deposited on the ground. If contamination levels exceed a user-specified criterion, mitigating actions can be triggered to limit radiation exposures.

Two aspects of the code's structure are fundamental 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 paragraphs.

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

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; it can range from 1 to 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 exposure to

contaminated ground and inhalation of resuspended materials, as well as indirect health effects caused by the consumption of contaminated food and water by individuals who could reside both on and off the computational grid.

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 up to 1 year long. Alternatively, the user can configure the calculations with no intermediate phase, so that the long-term phase begins immediately upon conclusion of the emergency phase.

Intermediate phase models are implemented on the assumption that the radioactive plume has passed and the only exposure sources (ground shine and resuspension inhalation) are from material deposited on the ground. It is for this reason that MACCS2 requires that the total duration of a radioactive release be limited to 4 days. Potential doses from food and water during this period are not considered.

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, the population is assumed to have 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, resuspension inhalation, and ingestion of food and water.

The exposure pathways considered are those resulting from material deposited on the ground. 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 factors: (1) whether land at a specific location and time is suitable for human habitation (habitability) and (2) whether land at a specific location and time is suitable for agricultural production (ability to farm).

All of the calculations of MACCS2 are stored based on a polar coordinate spatial grid. Treatment 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. The radius, r, represents downwind distance. 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 division is 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."

Because 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 three, five, or seven equal, angular subdivisions. The subdivided compass sectors are referred to as the "fine grid."

Two types of doses may be calculated by the code: acute and lifetime.

Acute doses are calculated to estimate deterministic health effects that can result from high doses delivered at high dose rates. Such conditions may occur in the immediate vicinity of a nuclear facility following hypothetical severe accidents in which confinement and/or containment failure has occurred.

Examples of the health effects based on acute doses are early fatality, prodromal vomiting (a precursory symptom of disease), and hypothyroidism (insufficient production of the thyroid hormone).

Lifetime doses are the conventional measure of detriment used for radiological protection. These are 50-year dose commitments to specific tissues (e.g., red marrow and lungs) or a weighted sum of tissue doses defined by the ICRP and referred to as "effective dose." Lifetime doses may be used to calculate the stochastic (probabilistic) health effect risk resulting from exposure to radiation. MACCS2 uses the calculated lifetime dose in cancer risk calculations.

MACCS2 implementation. As implemented, the MACCS2 model evaluated doses due to inhalation of airborne material, as well as direct (external) exposure to the passing plume. These two modes of exposure represent the major portion of the dose that an individual would receive due to a *TC & WM EIS* alternative facility accident. The longer-term effects of airborne radioactive material deposited on the ground after a postulated accident, including the resuspension and subsequent inhalation of radioactive material and the ingestion of contaminated crops, were not modeled for this EIS. These pathways have been studied and found to contribute insignificantly to the total dose compared with inhalation of radioactive material in the passing plume; they are also controllable through cleanup and other mitigation measures. Hence, the deposition velocity of the radioactive material was set to zero, so that material that might otherwise be deposited on surfaces would remain airborne and available for inhalation. This method results in a higher degree of conservatism compared with dose results that would be obtained if deposition and resuspension were taken into account.

The impacts were assessed for the offsite population surrounding the 200-East and 200-West Areas, FFTF, and the INL MFC; the MEI; and a noninvolved worker. The impacts on involved workers were addressed qualitatively because no adequate method exists for calculating meaningful consequences at or near the location where an accident could occur. Involved workers are also fully trained in emergency procedures, including response to potential accidents.

The offsite population is defined as the general public residing within 80 kilometers (50 miles) of the site. The population distribution for each proposed site is based on U.S. Department of Commerce state population data (Census 2007a, 2007b). These data were fitted to a polar coordinate grid with 16 angular sectors aligned with the 16 compass directions, with radial intervals that extend outward to 80 kilometers (50 miles). The offsite populations within 80 kilometers (50 miles) of the 200-East and 200-West Areas were estimated to be 451,556 and 488,897 persons, respectively. The population within 80 kilometers (50 miles) of FFTF was estimated to be 357,391, and the INL MFC population was estimated to be 205,962. For this analysis, no credit was taken for emergency response evacuations or temporary relocation of the public.

The MEI is defined as a hypothetical individual member of the public who would receive the maximum dose from an accident. This individual is usually assumed to be located at a site boundary. However, because there are public access points within the Hanford boundary, the MEI could be at any of these onsite locations.

The MEI location was determined for each *TC & WM EIS* alternative. The MEI location at Hanford can vary based on the type and location of an accident. For this analysis, the MEI was assumed to be located 8.6 kilometers (5.4 miles) southwest of the 200-East Area facilities, 3.6 kilometers (2.3 miles) south of the 200-West Area facilities, and 6.8 kilometers (4.2 miles) east of FFTF. The MEI for the INL MFC was assumed to be located 5.5 kilometers (3.4 miles) to the south-southeast.

A noninvolved worker is defined as an onsite worker who is not directly involved in the facility activity pertaining to the accident. The noninvolved worker was assumed to be exposed to all or part of the

release without any protection. For some scenarios, workers would evacuate the area after becoming aware of the emergency, thereby reducing their exposure potential.

Doses to the offsite population, the MEI, and a noninvolved worker were calculated based on site-specific meteorological conditions. Site-specific meteorology was represented by 1 year of hourly windspeed, atmospheric stability, and rainfall data at each site. The MACCS2 calculations produced statistical distributions based on the meteorological conditions. For these analyses, the results presented were based on mean meteorological conditions, which produce more-realistic consequences than the 95th percentile condition sometimes used in accident analyses for safety analysis reports. The 95th percentile condition represents low-probability meteorological conditions that are not exceeded more than 5 percent of the time.

The health risk coefficient for determining the likelihood of an LCF for low doses or dose rates is 0.0006 LCFs per rem, applied to individual workers and members of the public (see Section K.1.1.3). For high doses or dose rates, a health risk coefficient of 0.0012 applies for individual workers and members of the public. The higher health risk coefficient applies when individual doses exceed 20 rem.

K.3.2.2 Modeling and Analysis of Airborne Chemical Releases

One of the computer models included in the DOE Safety Software Central Registry, the Emergency Prediction Information Code (EPIcode), was selected to obtain estimates of atmospheric dispersion and resultant downwind concentrations of hazardous chemicals (DOE 2004b; Homann 2003). The codes included in the central registry have been determined to be compliant with the DOE Safety Software Quality Assurance requirements. These codes are routinely used by DOE to perform calculations and develop data used to establish the safety basis for DOE facilities and their operation and to support the variety of safety analyses and evaluations developed for these facilities.

EPIcode uses the Gaussian dispersion model to determine plume dispersion. The Gaussian model computes airborne concentrations at a given distance based on: (1) amount released, (2) effective release height, (3) windspeed at the release height, (4) inversion layer, and (5) standard deviation of the integrated concentration distribution both in the crosswind direction (sigma-y) and the vertical direction (sigma-z). Both sigma-y and sigma-z depend on the Pasquill stability class (classification according to the degree of atmospheric turbulence, described below) and the terrain. EPIcode allows selection of either standard (rural) or urban terrain. The standard terrain assumes surface roughness lengths ranging from 0.01 to 0.1 meters (0.03 to 0.3 feet). The urban terrain accounts for increased dispersion due to large urban structures. Standard terrain was conservatively selected for all scenarios even though there are various large structures at Hanford. This choice resulted in higher downwind concentrations.

EPIcode accounts for plume depletion processes, by which very small particles and gases or vapors are deposited on or incorporated within surfaces as a result of turbulent diffusion and Brownian motion (random movement of small particles suspended in liquid or gas caused by collisions with molecules of the surrounding medium). Chemical reactions; impaction; and other biological, chemical, and physical processes combine to keep material that is deposited from becoming re-entrained. As this material is deposited, the plume above becomes depleted. EPIcode uses a source-depletion algorithm to adjust the air concentration in the plume to account for this removal of material. This integrated effect of all removal processes is represented in the plume depletion equation by a deposition velocity term. The code does not account for wind shifts, terrain steering effects, chemical reactions, dense gas effects, or radioactive materials (see Homann 2003).

EPIcode was used to model chemical concentrations in air at each receptor for each release scenario. Each chemical release was assumed to be at ground level. Seven Pasquill stability classes were defined, ranging from A (extremely unstable) to D (neutral) to G (extremely stable). A neutral atmospheric

stability (stability class D) and a windspeed of 5 meters (16.4 feet) per second were used for all EPIcode simulations in this document. The most frequent stability class at Hanford is D.

K.3.2.3 Accident Frequencies

Accident frequency or probability reflects the likelihood of occurrence of an unplanned event during operations that could potentially cause the release of hazardous materials and harm the public, workers, and environment. The unit of measure for accident frequency in this EIS is usually expressed as occurrences per unit of time.

Risk is the overall measure of an accident's potential for endangering the health and safety of workers and the public. As explained in Section K.3.7, an accident's risk is calculated by the mathematical product of the accident's frequency of occurrence and its consequences and is expressed in terms of LCFs per year.

Accident scenarios and frequencies used in this EIS were based on extensive studies that are documented in safety analysis reports and related documents. The accident frequencies in these reports typically reflect the effects of mitigating factors designed to prevent or minimize the magnitude of hazardous materials released. The accident frequencies used in this EIS were conservatively adjusted to reflect unmitigated conditions that result in higher releases of hazardous materials, and thus, higher consequences. Because of uncertainties in the factors that affect an accident's frequency, many were initially expressed as a range. For estimating risk, the higher, conservative end of the estimated frequency range was used in the multiplication of frequency and consequences.

K.3.2.4 Secondary Impacts

Secondary impacts occur due to deposition of radioactive material or chemicals from a plume released during an accident. Although further exposure to humans can occur from deposited material, the radiation dose or chemical exposure associated with the passing plume dominates human health impacts. However, for NEPA purposes, other impacts of deposition are also important. These impacts, discussed further in Section K.3.8 (for radiological releases) and Section K.3.9 (for chemical releases), may result in imposition of protective actions and temporary access restrictions to contaminated land or property.

For radiological releases, the MACCS2 code was used to estimate the level of ground contamination caused by deposition from a passing radioactive plume. The level of contamination is measured in units of microcuries per square meter at specified distances from the accident location. Releases were assumed to occur at ground level with no thermal lift. Mean meteorological conditions were assumed and the deposition velocity was set to 0.01 meters (0.03 feet) per second. The EPA level of concern was set to 0.1 microcuries per square meter. For the analyzed chemical release scenarios, a combination of quantitative and qualitative means was used to assess the secondary impacts in Section K.3.9.

K.3.3 Radiological Accident Analyses

In accordance with DOE NEPA guidelines, an EIS should contain a representative set of accidents that includes various types, such as fire, explosion, mechanical impact, criticality, spill, human error, natural phenomena, and external events. DOE's Office of NEPA Policy and Compliance provides guidance for preparing accident analyses in EISs in *Recommendations for Analyzing Accidents Under the National Environmental Policy Act* (DOE 2002). This document clarifies and supplements *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 2004c).

Facility accidents fall into three broad categories: (1) internally initiated operational events, (2) externally initiated events, and (3) natural phenomena. The first category, internally initiated operational events, includes accidents such as fires, explosions, criticalities, spills, floods, mechanical impacts, and human errors. The second category, externally initiated events, includes airplane crashes, land vehicle impacts,

and accidents at adjacent facilities that could impact DOE facilities. The third category, natural phenomena, includes earthquakes, tornados, lightning, high winds, floods, fires, and other naturally occurring events. Other accidents could be identified in each category specific to a facility's operations, design, location, and mission. Intentional acts by terrorists or saboteurs are not considered accidents in the context of NEPA; however, potential impacts of international destructive acts are addressed in Section K.3.11.

For this *TC & WM EIS*, a large number of potential accidents were considered in each category. The sources of these accident descriptions, which include identification, definition, and assessment of impacts, are documented in safety analysis reports for the WTP, Pretreatment Facility, LAW Vitrification Facility, and HLW Vitrification Facility. Other documents prepared in support of these safety analysis reports and related EISs were also referenced as needed.

From the large list of accident scenarios, a number were selected that were consistent with NEPA purposes and supportive of public interests and DOE decisions associated with this *TC & WM EIS*. Screening criteria for accident selection and further analysis included the following:

- Applicability (i.e., is the accident scenario applicable to this *TC & WM EIS*?)
- Likelihood of occurrence (i.e., is the accident's occurrence reasonably foreseeable?)
- Material at risk (MAR) (i.e., does the accident scenario involve a significant amount of hazardous MAR as a source term?)
- Magnitude of impacts (i.e., how would the accident's impacts illustrate the range of possible consequences and risks for workers and the public for a particular accident category such as fire or spill?)
- Differentiation of alternatives (i.e., would the accident's impacts help to differentiate between alternatives for decision making purposes?)
- Public interest (i.e., is the accident scenario one that is of particular interest and concern to the public?)

The results of the process of accident selection are provided in Sections K.3.4 for Tank Closure alternatives, K.3.5 for FFTF Decommissioning alternatives, and K.3.6 for Waste Management alternatives. These sections describe the accident scenarios and corresponding source terms developed for the *TC & WM EIS* alternatives. The spectrum of accidents discussed below was used to determine the range of consequences (public and worker doses) and associated risks. Additional assumptions were made when further information was required to clarify the accident condition, update various parameters, or facilitate the evaluation process. The assumptions are referenced in each accident description.

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

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

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 to be acted upon by a given physical stress. The MAR is specific to a given process in the facility of interest. It is not necessarily the total quantity of material present, but rather the 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 value of the DR ranges 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 applicable source documents or the DOE Handbook, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Vol. 1, *Analysis of Experimental Data* (DOE Handbook 3010-94).

The RF is the fraction of the material with a 10-micron (0.0004-inch) or less aerodynamic-equivalent diameter particle size that could be retained in the respiratory system following inhalation. The RF values are also taken from applicable source documents or the DOE Handbook (DOE Handbook 3010-94).

The LPF accounts for the action of removal mechanisms (e.g., containment systems, filtration, deposition) to reduce the amount of airborne radioactivity ultimately released to occupied spaces in the facility or the environment. The LPF values were taken from applicable sources when possible. Otherwise, an LPF of 1.0 (i.e., no reduction) was assigned. An LPF of 1.0 was also assigned in accident scenarios involving a major failure of confinement barriers.

For example, if for a particular waste process vessel accident, the MAR is 100 curies of a specified radionuclide in a fixed amount of tank waste, the DR is 0.5, the ARF is 0.01, the RF is 0.02, and the LPF is 0.05, the source term would be calculated as follows:

$$\text{Source term} = MAR \times DR \times ARF \times RF \times LPF = 100 \times 0.5 \times 0.01 \times 0.02 \times 0.05 = 0.0005 \text{ curies}$$

In other words, a process vessel contains 100 curies of a radionuclide that is at risk of being released to the environment. Because of an accident, for example, vessel failure, 50 percent (the DR is 0.5) of the vessel's contents are released to the immediate area, 1.0 percent (the ARF is 0.01) becomes airborne, and 2.0 percent (the RF is 0.02) of the airborne material is of respirable size. Depending on the nature of the accident, availability of filtration equipment, and other mitigating factors, 5 percent (the LPF is 0.05) of the respirable airborne material is released to the environment. The net effect is the release of 0.0005 curies of the radionuclide.

K.3.4 Tank Closure Accident Scenarios

This section describes the tank waste storage, retrieval, treatment, and handling accident scenarios applicable to the Tank Closure alternatives. The scenarios, selected in accordance with the process and criteria described in Section K.3.3, are organized according to facility or activity, and their applicability to the alternatives is shown in Table K–65. Many of the accident impacts are based on unmitigated releases, meaning that no credit is taken for HEPA filtration or other design features that may limit the amount of radioactive material released to the environment. Assessing accident impacts based on unmitigated releases is particularly applicable to accident scenarios initiated by seismic events, which were assumed to cause failure of the filtration systems or other mitigating features. In these cases, the lower frequency of the accident reflects the seismic initiating event's effects on mitigating features and accident risk. If these accident scenarios were initiated by events internal to the facility and operations, the HEPA filters and other mitigating features would have a high likelihood of functioning properly, thereby reducing the amount of radioactivity released to the environment. However, the frequency of accident occurrence in these cases would be higher, which would be reflected in the accident's resultant risk. The alphanumeric code following the accident's title (e.g., HL11) corresponds with the accident's description in the tables of this section and in Chapter 4, Section 4.1.11; it is provided to facilitate cross-referencing between tables and accident descriptions.

Table K–65. Tank Closure Alternatives – Applicability of Radiological Accident Scenarios

Accident Scenario[a]	Alternative										
	1	2A	2B	3A	3B	3C	4	5	6A	6B	6C
Spray release from jumper pit during waste retrieval–unmitigated (TK51)	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spray leak in transfer line during excavation–unmitigated (PT23)	–	Y	Y	Y	Y	Y	Y	Y	–	Y	Y
Pretreatment Facility waste feed receipt vessel or piping leak–unmitigated (PT22)	–	Y	Y	Y	Y	Y	Y	Y	–	Y	Y
Seismically induced failure of HLW melter feed preparation vessels–unmitigated (6 MTG/day) (HL11)	–	Y	Y	Y	Y	Y	Y	Y	–	Y	Y
Seismically induced failure of HLW melter feed preparation vessels–unmitigated (15 MTG/day) (HL11)	–	–	–	–	–	–	–	–	Y	–	–
HLW molten glass spill caused by HLW melter failure–unmitigated (6 MTG/day) (HL14)	–	Y	Y	Y	Y	Y	Y	Y	-	Y	Y
HLW molten glass spill caused by HLW melter failure–unmitigated (15 MTG/day) (HL14)	–	–	–	–	–	–	–	–	Y	–	–
Seismically induced LAW Vitrification Facility collapse and failure–unmitigated (30 MTG/day) (LA31)	–	Y	–	Y	Y	Y	Y	–	–	–	–
Seismically induced LAW Vitrification Facility collapse and failure–unmitigated (45 MTG/day) (LA31)	–	–	–	–	–	–	–	Y	–	–	–
Seismically induced LAW Vitrification Facility collapse and failure–unmitigated (90 MTG/day) (LA31)	–	–	Y	–	–	–	–	–	–	Y	Y
Seismically induced WTP collapse and failure–unmitigated (HLW 6 MTG/day; LAW 30 MTG/day) (WT41)	–	Y	–	Y	Y	Y	Y	–	–	–	–
Seismically induced WTP collapse and failure–unmitigated (HLW 6 MTG/day; LAW 45 MTG/day) (WT41)	–	–	–	–	–	–	–	Y	–	–	–
Seismically induced WTP collapse and failure–unmitigated (HLW 6 MTG/day; LAW 90 MTG/day) (WT41)	–	–	Y	–	–	–	–	–	–	Y	Y

Table K–65. Tank Closure Alternatives – Applicability of Radiological Accident Scenarios *(continued)*

Accident Scenario[a]	Alternative										
	1	2A	2B	3A	3B	3C	4	5	6A	6B	6C
Seismically induced WTP collapse and failure–unmitigated (HLW 15 MTG/day; LAW 0 MTG/day) (WT41)	–	–	–	–	–	–	–	–	Y	–	–
Cast stone feed receipt tank failure–unmitigated (200-East Area) (CS71)	–	–	–	–	Y	–	Y	Y	–	–	–
Cast stone feed receipt tank failure–unmitigated (200-West Area) (CS71)	–	–	–	–	Y	–	–	–	–	–	–
Mixed TRU waste/MLLW liquid sludge transfer line spray leak–unmitigated (200-East Area) (TR81)	–	–	–	Y	Y	Y	Y	Y	–	–	–
Mixed TRU waste/MLLW liquid sludge transfer line spray leak–unmitigated (200-West Area) (TR81)	–	–	–	Y	Y	Y	Y	Y	–	–	–
Bulk vitrification waste receipt tank failure–unmitigated (200-East Area) (BV61)	–	–	–	Y	–	–	–	–	–	–	–
Bulk vitrification waste receipt tank failure–unmitigated (200-West Area) (BV61)	–	–	–	Y	–	–	Y	Y	–	–	–
Steam reforming feed receipt tank failure–unmitigated (200-West Area) (SRF1)	–	–	–	–	–	Y	–	–	–	–	–
Steam reforming feed receipt tank failure–unmitigated (200-East Area) (SRF1)	–	–	–	–	–	Y	–	–	–	–	–
Seismically induced waste tank dome collapse–unmitigated (TK53)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IHLW glass canister drop–unmitigated (SH91)	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4 and Chapter 4, Section 4.1.11.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant; Y=yes.

K.3.4.1 HLW Vitrification Facility

K.3.4.1.1 Seismically Induced Failure of HLW Melter Feed Preparation Vessels—Unmitigated (HL11)

This accident scenario involves seismically induced structural failure of two HLW melter feed preparation vessels containing the most concentrated waste materials in the HLW Vitrification Facility. The resultant leaks would drain the tanks, creating internal pools of liquid 10 to 34 centimeters (about 4 to 13 inches) deep in each room, with subsequent entrainment of aerosols in the airflow across the liquid surface. HEPA filters were assumed to fail as a result of the seismic event. The MAR would be in 58,300 liters (15,400 gallons) of HLW (BNI 2005). An initial ARF of 0.00005 would apply to the vessels' contents as they spill to the floor. A continuing airborne release of 4×10^{-7} per hour of the spilled material due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface (Lindquist 2006a). The LPF would be 1.0 for the unmitigated case.

The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007a). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.1.2 HLW Melter Feed Preparation Vessel Failure—Mitigated (HL12)

This accident scenario involves structural failure of an HLW melter feed preparation vessel caused by internal release mechanisms. The resultant leak would drain the tank in 8 hours, creating an internal pool of liquid 10 to 34 centimeters (about 4 to 13 inches) deep in the room with subsequent entrainment of aerosols in the airflow across the liquid. HEPA filters were assumed to be operational. The MAR would be in the contents of a single vessel, 29,100 liters (7,700 gallons) of HLW received from the Pretreatment Facility (BNI 2005). An initial ARF of 0.00005 would apply to the vessel's contents as they spill to the floor. Continuing airborne release at a rate of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface. The LPF would be 2.5×10^{-5} (Lindquist 2006a). This accident's impacts would be less than those of the seismically induced failure of HLW melter feed preparation vessels (HL11) and were not analyzed further.

K.3.4.1.3 Overflow—Mitigated (HL13)

This accident scenario involves overflow of an HLW melter feed preparation vessel into the melter cave sumps and then into the bermed area of the melter cave; the overflow would be caused by excessive volume transfer from the pretreatment vessel or by transfer of material from the pretreatment vessel when the melter feed preparation vessel is full. The MAR would be in 29,100 liters (7,700 gallons) of HLW received from the Pretreatment Facility (BNI 2005). An initial ARF of 0.00005 would apply to the vessel's contents as they spill to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface. The LPF would be 2.5×10^{-5} (Lindquist 2006a). This accident's impacts would be less than those of the seismically induced failure of HLW melter feed preparation vessels (HL11) and were not analyzed further.

K.3.4.1.4 HLW Molten Glass Spill Caused by HLW Melter Failure—Unmitigated (HL14)

This accident scenario involves a seismically induced catastrophic failure of the HLW melter shell, causing molten glass at 1,150 °C (2,100 °F) to flow out into the HLW melter cave and pour tunnel. Rapid steam generation from the feed material would continue for 1 hour. The depth of the spilled molten glass would vary from 0.03 to 0.46 meters (0.09 to 1.51 feet), depending on the surface area. A depth of 1 centimeter (0.4 inches) was conservatively assumed to maximize the amount of cesium released from the glass as it cools (BNI 2004). HEPA filters were assumed to have failed as a result of the seismic event, resulting in an unfiltered release of radioactive material. The LPF was thereby assumed to be 1.0. The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.1.5 HLW Molten Glass Spill Caused by Failed Melter—Mitigated (HL15)

This accident scenario involves a catastrophic failure of the HLW melter shell, causing molten glass at 1,150 °C (2,100 °F) to flow out into the HLW melter cave and pour tunnel. Rapid steam generation from the feed material would continue for 1 hour. The depth of the spilled molten glass would vary from 0.03 to 0.46 meters (0.09 to 1.51 feet), depending on the surface area. A depth of 1 centimeter (0.4 inches) was conservatively assumed to maximize the amount of cesium released from the glass as it cools (BNI 2004). HEPA filters were assumed to be operational, resulting in a filtered release of radioactive material. The LPF was estimated to be 2.5×10^{-5} (Lindquist 2006a). This accident's impacts

would be less than those of the unmitigated scenario for the HLW melter failure (HL14) and were not analyzed further.

K.3.4.2 Pretreatment Facility

K.3.4.2.1 Dropped Ultrafilter Module—Mitigated (PT21)

This accident scenario involves a plugged ultrafilter module lifted for replacement using the hot cell crane. The module would be lifted to the maximum height and then a failure of the crane, hook, or lifting device would allow it to fall to the hot cell floor. The dropped module would create a radioactive aerosol that would be released into the hot cell with the potential for migrating into other areas and the environment. The MAR would be in 38.8 liters (10.2 gallons) of HLW. The ARF and RF were estimated to be 0.001 and 0.1, respectively (Woolfolk 2007b). The LPF was estimated to be 2.5×10^{-5} (Lindquist 2006a). This accident's impacts would be less than those of other Pretreatment Facility accidents and were not analyzed further.

K.3.4.2.2 Pretreatment Facility Waste Feed Receipt Vessel or Piping Leak—Unmitigated (PT22)

This accident scenario involves a seismically induced failure of one of four waste feed receipt process vessels or submerged transfer lines. Contributing failure mechanisms include corrosion, erosion, thermal cycling fatigue, faulty welds, or chemical/waste incompatibilities. The entire vessel's contents would spill from the vessel or piping to the floor of the cell due to failure of either the vessel's nozzles or the transfer line within the cell. HEPA filters were assumed to be inoperative, resulting in an unfiltered release of radioactive material. The MAR would be in 1.53 million liters (0.40 million gallons) of untreated waste. An initial ARF of 0.00005 would apply to the vessel's contents as they spill to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface (Woolfolk 2007b). The LPF would be 1.0 for the unmitigated case (the LPF would be 2.5×10^{-5} for the mitigated case) (Lindquist 2006a). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.2.3 Spray Leak in Transfer Line During Excavation—Unmitigated (PT23)

This accident scenario involves failure of the coaxial transfer piping that delivers waste from the tank farms to the Pretreatment Facility due to an excavation accident. The outer pipe wall was postulated to break so that the waste is released directly to the environment.

The MAR would be in a waste stream transferring 1,080 liters (285 gallons) per hour for 8 hours from the tank farms to the Pretreatment Facility. The release rate was estimated to be 0.30 liters (0.08 gallons) per second. The ARF and RF were estimated to be 0.0001 and 1.0, respectively. The LPF for the excavation case was estimated to be 1.0. The frequency of the accident was estimated to be 0.0001 per year (Woolfolk 2007b).

K.3.4.3 LAW Vitrification Facility

K.3.4.3.1 Seismically Induced LAW Vitrification Facility Collapse and Failure—Unmitigated (LA31)

This accident scenario involves a seismically induced failure of LAW vessels, product glass containers, melters, and HEPA filters. The MAR is the sum of the radionuclide inventories in 17 major process vessels (Medsker 2007). The product of ARF × RF was estimated to be 0.00005 (Lindquist 2006a). The

LPF was estimated to be 1.0. The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Medsker 2007). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.4 Waste Treatment Plant

K.3.4.4.1 Seismically Induced Waste Treatment Plant Collapse and Failure—Unmitigated (WT41)

This accident involves a seismically induced catastrophic failure of the WTP. The MAR is all radioactive materials in the WTP vessels, glass containers, melters, filters, transfer pipes, and other equipment. The material was postulated to spill or fall and to be subjected to impact by falling debris. The Pretreatment Facility MAR is the product of the vessel capacities (Woolfolk 2007b) and radionuclide concentrations (Hassan 2007) for 17 pretreatment process streams that contain significant amounts of radioactivity. The LAW Vitrification Facility MAR is the sum of the radionuclide inventories in 17 major process vessels (Medsker 2007). The HLW Vitrification Facility MAR is the product of the process vessel capacities (Woolfolk 2007a) and the radionuclide concentrations (BNI 2005) for seven process streams that contain significant amounts of radioactivity. To represent the different alternatives, the MAR values for the Pretreatment, LAW Vitrification, and HLW Vitrification Facilities were assumed to be proportional to the immobilized high-level radioactive waste (IHLW) and immobilized low-activity waste (ILAW) production rates. Total MAR values were calculated for WTP production rates (IHLW × ILAW) of 6 × 30, 6 × 90, 6 × 45, and 15 × 0 metric tons of glass per day. An initial airborne respirable release fraction (ARF × RF) of 0.00005 would apply to liquid waste that spills to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours (Lindquist 2006a). The HEPA filtration system was assumed to fail, resulting in unfiltered releases to the environment (an LPF of 1.0). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 was assumed.

K.3.4.5 Tank Waste Storage and Retrieval

K.3.4.5.1 Spray Release from Jumper Pit During Waste Retrieval—Unmitigated (TK51)

This accident scenario involves a spray release of pressurized liquid from a mispositioned jumper in an SST double-contained receiver tank pump pit that services the transfer from the double-contained receiver tank to the double-shell tank or pumps into or out of a receiver tank. A jumper is a short connection pipe that is used in a jumper or pump pit to route tank waste from one line to another when transferring waste to a specific location. It was postulated that a jumper is mispositioned and pinhole leaks develop at both ends of the jumper. All spray particles were assumed to evaporate to less than 10 microns before reaching the ground. All of the spray was considered respirable. The respirable release (MAR × ARF × RF) would be in 52 liters (14 gallons) of untreated tank waste (Shire et al. 1995). The frequency of this accident was estimated to be 0.011 per year (DOE and Ecology 1996).

K.3.4.5.2 Hydrogen Deflagration in Waste Storage Tanks—Mitigated (TK52)

This accident scenario involves hydrogen generated in tank waste that rises into the tank headspace and reaches the concentration necessary for combustion. Ignition would occur in the tank headspace during a 1-hour period when the gas concentration would exceed the lower flammability limit. Turbulence accompanying rapid combustion would suspend waste as aerosols, and pressure would drive some of the particulates out of the ventilation system into the environment. The MAR would be in 500,000 liters (130,000 gallons) of waste tank constituents. The product of ARF × RF was estimated to be 6.5×10^{-6}.

The LPF was estimated to be 0.75 due to mitigation of the aerosol by soil collapsing into the tank (Shire et al. 1995). The estimated impacts of this accident would be represented by other storage and retrieval accident impacts and have not been analyzed further.

K.3.4.5.3 Seismically Induced Waste Tank Dome Collapse—Unmitigated (TK53)

This accident scenario involves radiological and chemical contaminants in the tank headspace that were conservatively assumed to be available for release. The collapse of a portion of the dome and overburden would compress the vapor in the headspace as they descend, enhancing the vapor release rate by a sudden pressure difference. Assumptions for each tank included a respirable concentration of contaminants in the headspace of 10 milligrams per cubic meter, a liquid specific gravity of 1.0, and a headspace volume of 935 cubic meters (1,223 cubic yards). The MAR, representative of all tanks, would be in 0.1 liters (0.026 gallons) of vapor and 410,000 liters (108,000 gallons) of salt cake, sludge, and liquid. The product of ARF × RF was estimated to be 1.0 for aerosols in the headspace and 0.00002 for solids and liquids. The LPF was estimated to be 1.0. Entrainment from the material splashed out of the tank would contribute an additional 4.6×10^{-6} liters per second to the source term (Shire et al. 1995). The reference for this scenario (Shire et al. 1995) cites an earthquake with a frequency of 0.00004 per year as the possible initiator. However, for risk calculation purposes, a conservative frequency of 0.0005 per year was assumed, consistent with the frequency used for earthquake scenarios involving severe damage to the WTP.

K.3.4.5.4 Rapid Exothermic Ferrocyanide-Nitrate Reaction (TK54)

A postulated accident of concern is the occurrence of a sustainable, rapid exothermic ferrocyanide-nitrate (or nitrite) reaction in the stored waste. Such a sustainable, rapid exothermic reaction could produce sufficient heat and evolve gases to pressurize the tank headspace, releasing aerosolized waste from the tank vents and potentially damaging the tank's structure.

Waste tank operations at Hanford during the 1950s used ferrocyanide in a number of waste tanks to scavenge cesium-137 from waste supernatant, which led to the formation of ferrocyanide-containing sludge that settled in layers in a number of waste tanks. As a result of these operations, approximately 140 metric tons of ferrocyanide (as $Fe(CN)^{+4}$) were added to 18 SSTs at Hanford. Ferrocyanide, in sufficiently high concentrations and mixed with oxidizing material such as sodium nitrate/nitrite, can react exothermically or even explode when heated to high temperatures.

The risk posed by the continued storage of ferrocyanide wastes in Hanford underground storage tanks has been studied extensively. Waste sample data coupled with laboratory experiments show that the ferrocyanide has decomposed (aged) to inert chemicals through radiolysis and hydrolysis and that the wastes cannot combust or explode (WHC 1996). As a result, all 18 ferrocyanide tanks are categorized as safe and this event has not been analyzed further.

K.3.4.6 Supplemental Treatment—Bulk Vitrification

K.3.4.6.1 Bulk Vitrification Waste Receipt Tank Failure—Unmitigated (BV61)

This accident scenario involves a seismically induced failure of a waste receipt tank used in the bulk vitrification waste treatment process in either the 200-East or 200-West Area. Contributing failure mechanisms might include corrosion, erosion, thermal cycling fatigue, faulty welds, or chemical/waste incompatibilities. The entire vessel's contents would spill from the vessel or piping to the floor of the cell where the tank is located. HEPA filters were assumed to be inoperative, resulting in an unfiltered release of radioactive material. The MAR would be in 129,000 liters (34,100 gallons) of waste (CH2M HILL 2003b). An initial ARF of 0.00005 would apply to the vessel's contents as they spill to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for

24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface (DOE Handbook 3010-94). The LPF would be 1.0 for the unmitigated case (2.5×10^{-5} for the mitigated case) (Lindquist 2006a). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.7 Supplemental Treatment—Cast Stone

K.3.4.7.1 Cast Stone Feed Receipt Tank Failure—Unmitigated (CS71)

This accident scenario involves a seismically induced failure of a feed receipt and storage tank used in the cast stone waste treatment process in either the 200-East or 200-West Area. Contributing failure mechanisms may include corrosion, erosion, thermal cycling fatigue, faulty welds, or chemical/waste incompatibilities. The entire vessel's contents would spill from the vessel or piping to the floor of the cell where the tank is located. HEPA filters were assumed to be inoperative, resulting in an unfiltered release of radioactive material. The MAR would be in 129,000 liters (34,100 gallons) of waste (CH2M HILL 2003b). An initial ARF of 0.00005 would apply to the vessel's contents as they spilled to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface (DOE Handbook 3010-94). The LPF would be 1.0 for the unmitigated case (2.5×10^{-5} for the mitigated case) (Lindquist 2006a). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.8 Supplemental Treatment—Steam Reforming

K.3.4.8.1 Steam Reforming Feed Receipt Tank Failure—Unmitigated (SRF1)

This accident scenario involves a seismically induced failure of a feed receipt tank used in the steam reforming waste treatment process in either the 200-East or 200-West Area. Contributing failure mechanisms may include corrosion, erosion, thermal cycling fatigue, faulty welds, or chemical/waste incompatibilities. The entire vessel's contents would spill from the vessel or piping to the floor of the cell where the tank is located. HEPA filters were assumed to be inoperative, resulting in an unfiltered release of radioactive material. The MAR would be in 129,000 liters (34,100 gallons) of waste (CH2M HILL 2003b). An initial ARF of 0.00005 would apply to the vessel's contents as they spill to the floor. A continuing airborne release of 4×10^{-7} of the spilled material per hour due to entrainment from the pool surface was assumed to contribute to worker exposure for a period of 8 hours and to public exposure for 24 hours. The RFs would be 0.8 for aerosols formed as the waste spills and 1.0 for aerosols entrained from the pool surface (DOE Handbook 3010-94). The LPF would be 1.0 for the unmitigated case (2.5×10^{-5} for the mitigated case) (Lindquist 2006a). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.9 Supplemental Treatment—Remote-Handled TRU Waste

K.3.4.9.1 Mixed TRU Waste/Mixed Low-Level Radioactive Waste Liquid Sludge Transfer Line Spray Leak—Unmitigated (TR81)

This accident scenario involves a seismically induced break and spray leak in the TRU waste treatment system in the 200-East or 200-West Area. A spray leak could occur when waste slurry is transferred from the retrieval system to the feed receipt tanks. A small hole or orifice could develop in the transfer line, resulting in a spray leak. The MAR was based on a leak rate of 0.22 liters (0.06 gallons) per second for

the duration of the assumed exposure (8 hours for the noninvolved worker, 24 hours for the MEI and population). The ARF was estimated to be 0.0001. The RF and LPF were estimated to be 1.0 (Woolfolk 2007a). The frequency of the accident was estimated to be in the range of 0.00005 to 0.0005 per year (Woolfolk 2007b). For risk calculation purposes, a conservative frequency of 0.0005 per year was assumed.

K.3.4.10 Waste Product Storage and Handling

K.3.4.10.1 IHLW Glass Canister Drop (SH91)

An IHLW glass canister drop was postulated at the 200-East Area IHLW Interim Storage Facilities. The height of the drop was assumed to be 16.8 meters (55 feet). The MAR would be in 1,220 liters (322 gallons) of glass IHLW. The DR was conservatively assumed to be 1. The product of the ARF and RF was estimated to be 0.0000943. The LPF was estimated to be 0.1. The resulting source term for material released to the environment was based on 0.0115 liters (0.003 gallons) of respirable glass particles. The frequency of the initiating event was estimated to be in the range of 0.1 to 0.01 per year (Woolfolk 2007a). With credit given for controls that would lower the frequency of the initiating event and reduce the actual aerosol release, a frequency of 0.001 per year was assumed for risk calculation purposes. The impacts of this accident represent the upper end of the range of waste product storage and handling accidents.

K.3.4.10.2 ILAW Glass Canister Drop (SH92)

An ILAW glass canister drop was postulated at the 200-East Area ILAW Interim Storage Facilities. The height of the drop was assumed to be 9.5 meters (31 feet). The MAR would be in 6,000 kilograms (13,228 pounds) of waste. The DR was estimated to be 0.5, meaning that only 50 percent of the canister's contents would be damaged by the impact. The product of the ARF and RF was estimated to be 0.000048 (BNI 2002). The LPF was estimated to be 1.0. The resulting source term for material released to the environment was based on 0.145 kilograms (0.32 pounds) of waste. The frequency of the accident was assumed to be the same as that of the IHLW canister drop (SH91), 0.001 per year. The estimated impacts of this accident would be less than those of the IHLW glass canister drop (SH91) and were not analyzed further.

K.3.4.10.3 Bulk Vitrification Glass Canister Drop (SH93)

A bulk vitrification glass canister drop was postulated at the 200-East Area storage facility. The height of the drop was assumed to be 2 meters (6.6 feet). The MAR would be in 27,600 kilograms (60,900 pounds) of waste (CH2M HILL 2003b). The DR was estimated to be 0.5, meaning that only 50 percent of the container's contents would be damaged by the impact. The product of the ARF and RF from the impaction stress was estimated to be 9.8×10^{-6} (DOE Handbook 3010-94). The LPF was estimated to be 1.0. The resulting source term for material released to the environment was 0.135 kilograms (0.298 pounds) of waste. The frequency of the accident was assumed to be the same as that of the IHLW canister drop (SH91), 0.001 per year. The estimated impacts of this accident would be less than those of the IHLW glass canister drop (SH91) and were not analyzed further.

K.3.4.10.4 Cast Stone Storage Canister Drop (SH94)

A cast stone storage canister drop was postulated at the 200-East Area storage facility. The height of the drop was assumed to be 2 meters (6.6 feet). The MAR would be in 25,000 kilograms (55,100 pounds) of waste (CH2M HILL 2003c). The DR was estimated to be 0.5, meaning that only 50 percent of the container's contents would be damaged by the impact. The product of the ARF and RF from the impaction stress was estimated to be 9.8×10^{-6} (DOE Handbook 3010-94). The LPF was estimated to be 1.0. The resulting source term for material released to the environment was 0.123 kilograms

(0.27 pounds) of waste. The frequency of the accident was assumed to be the same as that of the IHLW canister drop (SH91), 0.001 per year. The estimated impacts of this accident would be less than those of the IHLW glass canister drop (SH91) and were not analyzed further.

K.3.5 Fast Flux Test Facility Accident Scenarios

This section describes the accident scenarios applicable to the FFTF Decommissioning alternatives. Four of the scenarios involve fires that consume radioactively contaminated sodium metal formerly used as FFTF coolant or reactor coolant system components containing radioactive materials. Two other fire scenarios involve inventories of sodium that was formerly used in other reactors, is now stored at Hanford, and would be converted to sodium hydroxide along with the FFTF sodium for use on site under FFTF Decommissioning Alternatives 2 and 3. The scenarios are attributed to a variety of initiating events, including aircraft crash, material defect, human error, and high winds. Each one might also be initiated by a seismic event of sufficient magnitude to cause severe damage to structures in which the sodium is stored. Applicability of scenarios to the FFTF Decommissioning alternatives is shown in Table K–66. All of the accident impacts were based on unmitigated releases, meaning that no credit is taken for HEPA filtration, structural confinement, or other engineered features that may limit the amount of radioactive material released to the environment. The alphanumeric code following the accident's title (e.g., SSF1) corresponds with the accident's description in the tables of this section and in Chapter 4, Section 4.2.11**;** it is provided to facilitate cross-referencing between tables and accident descriptions.

Table K–66. FFTF Decommissioning Alternatives – Radiological Accident Scenario Applicability

Accident Scenario[a]	Alternative 1	Alternatives 2 and 3			
		Disposition of RH-SCs		Disposition of Bulk Sodium	
		Hanford Option	Idaho Option	Hanford Reuse Option	Idaho Reuse Option
Sodium Storage Facility fire (SSF1)	Y	Y	Y	Y	Y
Hanford sodium storage tank failure (HSTF1)	Y	Y	Y	Y	Y
Remote-handled special component fire (RHSC1)	–	Y	Y	Y	Y
Hallam Reactor sodium fire (HSF1)	Y	Y	Y	Y	Y
Sodium Reactor Experiment sodium fire (SRE1)	Y	Y	Y	Y	Y
INL Sodium Processing Facility storage tank failure (INLSPF1)	–	–	–	–	Y

[a] The alphanumeric code following the accident's title (e.g., SSF1) corresponds with the code in the accident's description in Section K.3.5.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RH-SCs=remote-handled special components; Y=yes.

K.3.5.1 Accidents in the Hanford 400 Area

K.3.5.1.1 Sodium Storage Facility Fire (SSF1)

This accident scenario involves a postulated aircraft crash into the FFTF Sodium Storage Facility (SSF) that breaches all four sodium storage tanks and ignites the sodium metal within them. Although the SSF tanks would contain contaminated primary coolant mixed with relatively clean secondary coolant, it was conservatively assumed that the radionuclide inventory levels for the primary sodium represent the mix.

The MAR would be the entire 984,000-liter (260,000-gallon) inventory of sodium stored in the SSF (ANL-W and Fluor Hanford 2002). The surface of each tank was assumed to burn at the standard rate for an open pool of sodium on a steel liner, 10.8 grams per square meter per second (8 pounds per square foot per hour) (Himes 1996). The combined surface area for all four tanks is approximately 224 square meters (2,410 square feet) (WHC 1994). These factors would result in a burn rate of approximately 8,700 kilograms per hour (19,200 pounds per hour). Therefore, it would take approximately 105 hours for the entire contents of the tanks to burn. No credit was taken for any mitigation of the release by the building features; the LPF is therefore considered to be 1. Although Hanford safety analyses indicated that the probability of an accidental aircraft crash into a specific hazardous facility is less than 1×10^{-6} per year, the frequency of this scenario was conservatively assumed to be 1×10^{-6} per year (CH2M HILL 2003d).

K.3.5.1.2 Hanford Sodium Storage Tank Failure (HSTF1)

This accident was postulated to result from a large leak due to growth of a metal defect in one SSF storage tank. The contents of the tank would spill onto the steel floor of the secondary containment (an area of approximately 581 square meters [6,250 square feet]) and burn, releasing a sodium hydroxide aerosol plume (WHC 1994). Exposure to the burning pool of sodium was assumed to breach the other three tanks, causing the entire SSF inventory of 984,000 liters (260,000 gallons) of sodium to spill onto the floor and burn (ANL-W and Fluor Hanford 2002). Using the standard burn rate for an open pool of sodium on a steel liner, 10.8 grams per square meter per second (8 pounds per square foot per hour), the burn rate was estimated to be 22,600 kilograms per hour (49,800 pounds per hour), and the fire duration was estimated to be approximately 41 hours (Himes 1996). The estimated frequency of this scenario, based on the frequency of tank leaks, is 0.00001 per year (Bowman 1994).

K.3.5.1.3 Remote-Handled Special Component Fire (RHSC1)

This scenario represents the upper range of impacts from possible accidents involving removal and transport of the FFTF RH-SCs. A handling mishap was postulated to cause a breach of the largest, most radioactive component (the primary cold trap), resulting in exposure of the contained radioactive sodium to water and air. A portion (30 percent) of the sodium was assumed to burn, releasing the radionuclides in that amount of sodium as well as an equal percentage of the total cesium-137 and cobalt-60 inventory estimated to be in the cold trap. Ground-level release to the atmosphere was assumed. The sodium was assumed to have the radioactive characteristics of FFTF primary sodium (ANL-W and Fluor Hanford 2002). The amount of sodium burned would equal 750 kilograms (1,650 pounds). Additionally, 30 percent of the 470 curies of cesium-137 and 70 curies of cobalt-60 retained within the cold trap medium would be released (141 and 21 curies, respectively) (CEES 2006). For purposes of this analysis, this scenario was assumed to be initiated by human error and assigned a frequency of 0.01 per year (Fluor Hanford 2004a). This accident could also occur at the INL MFC under the Idaho Option for disposition of RH-SCs.

K.3.5.2 Accidents in the Hanford 200-West Area

K.3.5.2.1 Hallam Reactor Sodium Fire (HSF1)

Sodium formerly used as coolant in the Hallam Reactor is stored as a solid in five tanks in the 2727-W Building in the Hanford 200-West Area. Two tanks are full, one is half-full, and the remaining two contain only residual heels. In this scenario, the building would be damaged by high winds, causing a roof support beam to puncture a tank, releasing the cover gas. Rainwater would run down the beam and enter the tank, starting a fire from the exothermic reaction between sodium and water. The entire contents of the tank, 59,600 kilograms (131,000 pounds) of sodium, would burn and be released at ground level

over a period of 67 hours. The frequency of this accident was estimated to be 0.00002 per year (Himes 1996).

K.3.5.2.2 Sodium Reactor Experiment Sodium Fire (SRE1)

Sodium formerly used as coolant in the Sodium Reactor Experiment (SRE) is stored as a solid in drums in the South Alkali Metal Storage Modules near the 200-West Area Solid Waste Operations Complex (SWOC). In this scenario, a vehicle impacts a single storage module and come to rest inside of it. The module contains 20 drums, each of which holds 168 kilograms (370 pounds) of sodium (Fluor Hanford 2004b). The fuel from the vehicle was assumed to drain into the module reservoir and ignite, burning the total amount of sodium in the 20 drums (3,360 kilograms or 7,410 pounds) in approximately 15 hours. For purposes of this analysis, this scenario was assumed to be initiated by human error and was assigned a frequency of 0.01 per year (Fluor Hanford 2004a).

K.3.5.3 Accidents at Idaho National Laboratory

K.3.5.3.1 INL Sodium Processing Facility Storage Tank Failure (INLSPF1)

The accident associated with disposition of bulk sodium at the INL SPF with the largest expected impacts would be a failure of the secondary sodium drain tank located in the EBR-II secondary sodium boiler building with an accompanying fire. The structure and associated features were assumed to provide no mitigation of the release. Although this storage tank would contain a mixture of bulk sodium, it was conservatively assumed that the radionuclide inventory levels for the FFTF primary sodium represent the mixture. Failure of the tank would result in a spill of its working capacity of 56,800 liters (15,000 gallons) of molten sodium (ANL-W and Fluor Hanford 2002). The burn rate was estimated to be 2,250 kilograms per hour (5,000 pounds per hour) and the duration was estimated to be 24 hours. The estimated frequency of this accident, based on the frequency of tank leaks, is 0.00001 per year (Bowman 1994).

K.3.6 Waste Management Accident Scenarios

The documented safety analysis for solid waste operations (DSASW) (Fluor Hanford 2007) identifies and analyzes a range of potential accidents at the Hanford low-level radioactive waste burial grounds (LLBGs), CWC, T Plant complex, and WRAP. These four facilities compose SWOC, which performs the solid waste management function for Hanford. The accidents analyzed in the DSASW represent a range of severity (consequences) and frequency and provide the basis for SWOC operating controls and limits. The solid waste management operations covered by the DSASW would continue under each of the three Waste Management alternatives examined in this *TC & WM EIS*. Under Waste Management Alternatives 2 and 3, new facilities or expansions of existing facilities would be required and there would be limited shipments of low-level radioactive waste (LLW) and mixed low-level radioactive waste (MLLW) to Hanford from other DOE sites. Accordingly, each of the scenarios analyzed in the current DSASW or some updated and refined version of it would be applicable to each of the Waste Management alternatives. The frequency and human health risk from a particular type of accident may vary somewhat as a function of the volume of waste that is managed and/or the duration (years) of each specific waste management component under each Waste Management alternative. Under Waste Management Alternative 1 (No Action), construction of IDF-East would be discontinued in 2008. Therefore, accidents associated with the onsite disposal of ILAW are not applicable to Waste Management Alternative 1. Scenarios for accidents involving ILAW were taken from *Project 520, Immobilized Low-Activity Waste Disposal Facility, Preliminary Documented Safety Analysis* (Burbank 2002). Applicability of the accident scenarios to the Waste Management alternatives is shown in Table K–67.

Table K–67. Waste Management Alternatives – Accident Scenario Applicability

Accident Scenario[a]	Alternative		
	1	2	3
Single-drum deflagration (SWOC FIR-1)	Y	Y	Y
Medium fire inside facility (SWOC FIR-6)	Y	Y	Y
Glovebox or greenhouse fire (SWOC FIR-8)	Y	Y	Y
Large fire of waste containers outside facility (SWOC FIR-4)	Y	Y	Y
Handling spill of single waste container (SWOC SP-2)	Y	Y	Y
Large handling spill of boxes or multiple waste containers (SWOC SP-3A)	Y	Y	Y
Spill of single large-diameter container (SWOC SP-4)	Y	Y	Y
Design-basis seismic event (SWOC NPH-1)	Y	Y	Y
Beyond-design-basis accident (SWOC NPH-2)	Y	Y	Y
Range fire (SWOC EE-1)	Y	Y	Y
Aircraft crash (SWOC EE-2)	Y	Y	Y
Earthmover shears tops off six ILAW containers (ILAW1)	–	Y	Y
Crushing of ILAW containers by falling crane boom (ILAW2)	–	Y	Y

[a] The alphanumeric code following the accident's title (e.g., SWOC FIR-1) corresponds with the code in the accident's description in Section K.3.6.

Key: ILAW=immobilized low-activity waste; Y=yes.

Source: Burbank 2002; Fluor Hanford 2007.

K.3.6.1 Solid Waste Operations Complex Accidents

Appendix D identifies total inventories of waste. However, only a portion of those totals would be subject to the accidents hypothesized in the scenarios at any given time. Waste would be received and managed in accordance with waste acceptance criteria and operational controls established on the basis of the DSASW results. Therefore, the quantities of radioactive material in individual waste packages and the total amounts in specific locations would be controlled such that accident source terms for reasonably foreseeable scenarios would be no greater than those assumed in the DSASW and used in these EIS calculations.

The DSASW describes and analyzes a range of severities for several accident types. Because the potential for all of the scenarios would be present regardless of the Waste Management alternative selected, a detailed examination of each scenario does little to discriminate between the alternatives or inform the decision-making process. Accordingly, only selected representative DSASW scenarios with relatively higher human health impacts are described here for several event types (e.g., fires, spills, natural phenomena). The other DSASW scenarios of each type are summarized with respect to their salient features, frequencies, and consequences. Consistent with the DSASW accident descriptions, the SWOC accident source terms are specified as plutonium-239 dose-equivalent curies (Pu-239 DE-curies), the amount of plutonium-239 (in curies) that would deliver the same radiation dose to an exposed individual or population as the mixture of radionuclides that would actually be released if an accident occurred.

Plutonium-239 Dose-Equivalent Curies (Pu-239 DE-curies)

- Dose equivalence is a method of expressing amounts of radionuclide mixtures in terms of the amount of a single radionuclide that, if inhaled, would produce the same dose to an individual as the mixture.
- Transuranic (TRU) waste managed at the Hanford Site Solid Waste Operations Complex (SWOC) are contaminated with mixtures of several different radionuclides, including plutonium-238, -239, -240, and -241; americium-241; and others.
- SWOC safety documents use a value of 0.165 plutonium-239 dose-equivalent curies per gram of TRU isotopes to calculate doses to workers and the public from accidents involving TRU waste.

K.3.6.1.1 Fires and Deflagrations

K.3.6.1.1.1 Single-Drum Deflagration (SWOC FIR-1)

The single-container (i.e., drum) deflagration event would result from the ignition of accumulated flammable gases (e.g., hydrogen) or a chemical reaction between incompatible materials. This scenario could occur in any SWOC facility, indoors or outdoors, and during many activities. It was postulated to occur at the LLBGs because that location has the greatest number of containers susceptible to the scenario. Ignition of the flammable gases was postulated to result in lid loss and ejection of a fraction of the container's contents, followed by partial or total combustion of both the ejected portion of the waste and the waste remaining in the container. However, the resulting fire was not postulated to propagate to other waste containers. The highest inventory selected for a hypothetical single standard drum at SWOC was selected as 82.5 Pu-239 DE-curies of TRU waste material, of which 5 percent (4.13 Pu-239 DE-curies) was assumed to be ejected by the deflagration. ARF and RF values of 0.001 and 1.0, respectively, apply to the material that is ejected, yielding a source term contribution of 0.0041 Pu-239 DE-curies. Both the ejected material and the material remaining in the container (78.4 Pu-239 DE-curies) would be subject to burning, resulting in additional release of radioactive material (Fluor Hanford 2007).

A DR of 0.18 was assumed for the ejected material because it was calculated that the radiant energy from the deflagration would only be sufficient to ignite 18 percent of the material. The ARFs for ejected plastics (31 percent of ejected material) and nonplastic combustibles (34 percent of ejected material) were assumed to be 0.05 and 0.01, respectively. The RFs and LPFs were assumed to be 1.0 (Fluor Hanford 2007). The contribution to the source term from this material is 0.0145 Pu-239 DE-curies.

For the waste that remains in the container, the DR and LPF were assumed to be 1.0. The combustible portion (65 percent) was treated as packaged waste (ARF of 0.0005, RF of 1.0). The noncombustible portion (35 percent) was assumed to have an ARF of 0.006 and an RF of 0.01. The contribution to the source term from this material is 0.0267 Pu-239 DE-curies (Fluor Hanford 2007).

The cumulative source term would be 0.045 Pu-239 DE-curies. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.001 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.1.2 Medium Fire Inside Facility (SWOC FIR-6)

A medium fire is one in which several containers are subject to a fire. The postulated scenario involves failure of the WRAP Automated Stacker/Retrieval System (AS/RS), which would cause a pallet of four drums to fall, breaching the drums and spilling some of their contents. The falling pallet would also sever the AS/RS hydraulic lines, releasing up to 53 liters (14 gallons) of hydraulic fluid. The hydraulic fluid would ignite due to heating from nearby equipment or an electrical short circuit, engulfing the breached drums. An additional 48 drums in the storage rack would be heated by the fire and lose their lids, ejecting part of their contents. Both the ejected contents and the contents remaining in the drum would burn in the fire. The fire would not propagate through the facility.

The MAR for the scenario would be the sum of the 4 drums dropped and the 48 drums enveloped by the burning puddle of hydraulic fluid. The resulting source term would be 0.83 Pu-239 DE-curies. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.01 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency of this accident was estimated to be 0.01 per year.

K.3.6.1.1.3 Glovebox or Greenhouse Fire (SWOC FIR-8)

This scenario was postulated to occur in a WRAP glovebox line (either the TRU waste or TRU waste/LLW line) where a maximum of eight drums would be present. Only two of the drums were considered to represent uncontained waste. The other drums in the TRU waste glovebox would be considered packaged waste and would be represented by a closed, intact container on the transfer car. A variety of initiating events could cause the fire, such as the presence of flammable or combustible materials and ignition sources within the waste being repackaged or electrical or static ignition sources. This postulated fire was assumed to engulf all open waste being processed in the glovebox line. Staged drums outside the glovebox line would not become involved in the fire. The MAR would be the radioactive inventory of eight containers involved in the accident: four containers at 33 Pu-239 DE-curies each, two containers at 12.4 Pu-239 DE-curies each, and two containers at 2.3 Pu-239 DE-curies each. The MAR used to calculate the source term from the glovebox would be combined with the 2.3 Pu-239 DE-curies of MAR from the HEPA filter for a total of 164 Pu-239 DE-curies. The cumulative source term value would be 1.6 Pu-239 DE-curies derived from the burning of the waste material. The glovebox fire accident is one of a group of accidents hypothesized for SWOC. The impacts of such a fire would be larger than those of others such as a greenhouse fire. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.01 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.1.4 Large Fire of Waste Containers Outside Facility (SWOC FIR-4)

This scenario postulates that a transport vehicle crashes into an outside stored waste array, causing spills and vehicle damage that create a flammable fuel pool that ignites and burns the stored waste and the transported waste containers. This scenario is based on a fire at the T Plant, but it could occur at any SWOC facility. Waste containers are stored or staged outside in stacks when they need to be transferred to other facilities or when they are received from offsite generators during waste management operations. These waste container pick-up and drop-off activities are typically performed using tractor-trailers that carry up to 80 containers and travel close to the stored or staged waste. Operator error or mechanical failure of the vehicle could cause loss of control, causing the vehicle to travel at high speed into the stored or staged waste array. The high-energy impact was postulated to overturn or otherwise impact the trailer so that the drums on it are thrown violently from the vehicle, impacted, and breached. The 80 containers were assumed to land in a burning fuel pool, and 100 percent of the drum contents were conservatively assumed to burn as unconfined waste. The collision would also impact a stored waste array of 384 drums, breaching 12 containers by direct impact and spilling 100 percent of their contents, which would also burn unconfined. The other 372 drums would experience varying degrees of damage and lid loss, and different portions of their contents would burn as contained or uncontained waste. The total MAR involved in the fire would be 2,310 Pu-239 DE-curies, of which 14 Pu-239 DE-curies would be ultimately released to the atmosphere. The frequency of the initiating event (truck impact) was estimated to be greater than 0.01 per year, but a truck impact resulting in a large fire was estimated to have a frequency of less than 0.01 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.1.5 Other Solid Waste Operations Complex Fire/Deflagration Scenarios

The DSASW describes and analyzes an additional seven fire scenarios. Table K–68 shows how the source terms (and therefore, the consequences) of those scenarios compare with the four scenarios detailed above (shown in bold font). The scenarios are arranged by source term, in ascending order.

Table K–68. Fire and Deflagration Scenarios Analyzed in the DSASW

Source Term (Pu-239 DE-curies)	Description	DSASW Designator	Frequency
0.0052	Fire of large-diameter container in T Plant	FIR-10	U
0.0045	**Single-drum deflagration**	**FIR-1**	**A**
0.063	Vapor cloud explosions and boiling liquid expanding vapor explosions	FIR-9	EU
0.83	**Medium fire inside facility**	**FIR-6**	**A**
1.6	Small fire inside facility	FIR-5	A
1.6	Small fire of waste containers outside facility	FIR-2	A
2.0	Medium fire of waste containers outside facility	FIR-3	A
1.6	**Glovebox or greenhouse fire**	**FIR-8**	**A**
7.0	Large fire inside facility	FIR-7	U
7.4	Large fire inside facility with aisle spacing	FIR-7A	U
14	**Large fire of waste containers outside facility**	**FIR-4**	**U**

Note: Entries evaluated in this environmental impact statement are in **bold** text.
Key: A=anticipated (frequency $>10^{-2}$ per year); DSASW=documented safety analysis for solid waste operations; EU=extremely unlikely (10^{-4} per year > frequency > 10^{-6} per year); Pu-239 DE-curies=plutonium-239 dose-equivalent curies; U=unlikely (10^{-2} per year > frequency $>10^{-4}$ per year).

K.3.6.1.2 Spills and Sprays

K.3.6.1.2.1 Handling Spill of Single Waste Container (SWOC SP-2)

Waste containers can be impacted physically or lose confinement from various causes during storage and handling. Material-handling equipment (e.g., forklifts) or other vehicles can inadvertently impact waste containers—puncturing, crushing, or toppling them. Raised or suspended loads can drop onto waste containers as a result of lifting equipment failure or improper rigging. This scenario postulates that waste handling operations cause a single-container spill during retrieval of TRU waste drums from buried stacks of TRU waste. The MAR for this scenario would be 82.5 Pu-239 DE-curies of TRU waste. The DR would be 1.0 for mechanical release from the drop of a corroded drum. The ARF and RF values for external impact on packaged waste in drums would be 0.001 and 0.1, respectively. The resultant source term for the single-container spill would be 0.0083 Pu-239 DE-curies. The frequency of this accident was estimated to be 0.01 per year (Fluor Hanford 2007).

K.3.6.1.2.2 Large Handling Spill of Boxes or Multiple Waste Containers (SWOC SP-3A)

This multiple-container spill was postulated to occur as the result of a large, heavy waste box dropping onto TRU waste containers stored or staged in arrays. The large waste box was assumed to be concrete and large enough to impact several stacked waste containers. Based on the dimensions of the waste box, 48 drums would be directly impacted and two layers of drums directly beneath the impacted drums (48 drums each) would also be damaged, for a total of 144 drums plus the waste box. The MAR would be 82.5 Pu-239 DE-curies for the waste box and 818 Pu-239 DE-curies for the 144 impacted containers. The resultant source term would be 0.041 Pu-239 DE-curies. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.01 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.2.3 Spill of Single Large-Diameter Container (SWOC SP-4)

A large-diameter container (LDC) spill was postulated to occur in the 221-T Canyon Building because it is the only location where an LDC is removed from its shipping cask or lifted over other LDCs or blanket fuel assemblies in a storage cell. The drop scenario assumes that the LDC contains dry, high-activity sludge. Based on the largest expected inventory for this sludge mix, the total content (MAR) would be 1,610 Pu-239 DE-curies in 3,800 kilograms (8,380 pounds) of sludge. Applying a conservative ARF and RF of 0.0025, the source term for this scenario would be 0.4 Pu-239 DE-curies. No credit was taken for confinement provided by the T Plant structure or systems. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.01 per year (Fluor Hanford 2007). For purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.2.4 Other Solid Waste Operations Complex Spill/Spray Scenarios

The DSASW describes and analyzes an additional five spill/spray scenarios. Table K–69 shows how the source terms (and therefore, the consequences) of these scenarios compare with the scenarios detailed above (shown in bold font). The scenarios are arranged by source term, in ascending order.

Table K–69. Spill and Spray Scenarios Analyzed in the DSASW

Source Term (Pu-239 DE-curies)	Description	DSASW Designator	Frequency
0.0021	Spray release event	SP-7	A
0.0083	**Handling spill of single waste container**	**SP-2**	**A**
0.012	Waste container spill due to vehicle collision	SP-1	A
0.014	Handling spill of multiple waste containers	SP-3	A
0.017	Glovebox spill due to loss of confinement	SP-6	A
0.024	Spill of multiple large-diameter containers	SP-5	A
0.041	**Large handling spill of boxes or multiple waste containers**	**SP-3A**	**A**
0.4	**Spill of single large-diameter container**	**SP-4**	**A**

Note: Entries evaluated in this environmental impact statement are in **bold** text.
Key: A=anticipated (frequency $>10^{-2}$ per year); DSASW=documented safety analysis for solid waste operations; Pu-239 DE-curies=plutonium-239 dose-equivalent curies.
Source: Fluor Hanford 2007.

K.3.6.1.3 Natural Phenomena

K.3.6.1.3.1 Design-Basis Seismic Event (SWOC NPH-1)

A design-basis seismic event was postulated to impact the four SWOC facilities and result in the release of radioactive materials. All exposed waste containers stored outside would topple. Unstacked waste containers and the bottom tiers of stacked waste containers would not fail because they were assumed to be robust and able to survive a fall of less than 1.2 meters (4 feet). It was conservatively assumed that all stacked waste containers above the first tier would topple and spill. Most waste containers stored inside structures qualified to seismic performance category (PC)-2 parameters (DOE Standard 1021-93) would topple. Waste containers would topple and spill, except for fuel assemblies stored in the pool cell of the 221-T Canyon Building, sludge stored in LDCs in storage arrays in cells in the 221-T Canyon Building, unstacked containers, and the bottom tiers of stacked containers. The event would cause structures not qualified to PC-2 parameters to fail and buildings to collapse, causing waste containers stored inside to spill. Waste containers stored inside would be impacted and breached by falling objects (e.g., lights, fire suppression sprinkler lines) and other overhead equipment not seismically rated in structures that are qualified to PC-2 parameters. The total source term would be the sum of 0.027 Pu-239 DE-curies (LLBGs), 0.35 Pu-239 DE-curies (CWC), 0.005 Pu-239 DE-curies (T Plant), and

0.0038 Pu-239 DE-curies (WRAP), for a total of 0.39 Pu-239 DE-curies. Impacts from this event are larger than those for all other design-basis natural phenomena impacts (lightning, high wind/tornado, flood, volcano, snow loading). The frequency of this accident was estimated to be 0.001 per year (Fluor Hanford 2007).

K.3.6.1.3.2 Beyond-Design-Basis Accident (SWOC NPH-2)

A beyond-design-basis earthquake was postulated to impact the four SWOC facilities and result in the release of radioactive materials. All exposed waste containers stored outside would topple. Unstacked waste containers and the bottom tiers of stacked waste containers would not spill because they were assumed to be robust and able to survive a fall of less than 1.2 meters (4 feet). It was conservatively assumed that all stacked waste containers above the first tier would topple and spill. All structures would collapse, impacting waste containers stored inside and causing them to spill. Waste containers stored inside would be impacted and breached by falling objects (e.g., lights, fire suppression sprinkler lines, structural members) and other overhead equipment. The total source term would be the sum of 0.027 Pu-239 DE-curies (LLBGs), 0.35 Pu-239 DE-curies (CWC), 0.50 Pu-239 DE-curies (T Plant), and 0.57 Pu-239 DE-curies (WRAP), for a total of 1.5 Pu-239 DE-curies. Because this earthquake would be stronger than the design-basis seismic event, the frequency would be lower (less than 0.001). However, a quantitative estimate of the frequency of this event was not made. Therefore, for analysis purposes, the frequency was assumed to be 0.001 for purposes of this analysis (Fluor Hanford 2007).

K.3.6.1.4 External Events

K.3.6.1.4.1 Range Fire (SWOC EE-1)

The postulated range fire would encroach on SWOC facility structures, vehicles, and stacked waste, burning waste containers and releasing radioactive materials. Range fires can impact all SWOC facilities. The CWC was selected to represent the most conservative analysis of impacts of a range fire event because it is the westernmost facility, closest to a large amount of natural vegetation. It also has the largest inventory (17,500 waste containers located in the 2403-WD Waste Storage Building). The 2403-WD Waste Storage Building also was considered more vulnerable than buildings constructed of less combustible materials (i.e., the 221-T Canyon Building, WRAP structure). Because of the lack of combustibles inside the building, not all containers would be affected. The fire was postulated to affect 1,019 drums. The resultant source term would be 7.0 Pu-239 DE-curies. Without credit for any controls, the frequency of this accident was estimated to be greater than 0.01 per year (Fluor Hanford 2007). For the purposes of this analysis, the frequency was assumed to be 0.01 per year.

K.3.6.1.4.2 Aircraft Crash (SWOC EE-2)

An aircraft crash into SWOC facilities was postulated to forcefully impact the CWC 2403-WD Waste Storage Building, penetrate the building, and impact waste containers stacked three tiers high. The impact would breach containers and puncture the aircraft fuel tank, causing a pool fire. The exposed MAR would burn, and the pool fire would cause additional damage and release of MAR through lid loss and partial ejection of contents, lid loss and contained burning, and lid seal failure with pyrolysis (chemical change brought about by the action of heat). The SWOC facilities considered for selection as the crash location with the largest impact were the structures at the LLBGs, CWC, WRAP, and T Plant that contain a relatively high amount of MAR. The CWC 2403-WD Waste Storage Building was selected as the accident location because (1) it contains the largest vulnerable "footprint," (2) it is expected to provide little protection to the MAR, and (3) with 17,500 stacked waste containers, it contains the greatest amount of vulnerable MAR of all SWOC facilities. The aircraft crash impacts would be larger than those for accident scenarios involving other SWOC structures and areas. The total source term is 16 Pu-239 DE-curies. The frequency of this accident was estimated to be 0.00003 per year (Fluor Hanford 2007).

K.3.6.1.5 Criticality

The DSASW analyzes two criticality events: a liquid criticality at the T Plant (CR-1) and a solid waste criticality (CR-2). The DSASW shows that radiation doses to workers in the immediate vicinity might be in the range where severe radiation injury or death could result (337 rem from CR-1 and 467 rem from CR-2 to a worker 100 meters [110 yards] from the accident). The dose to the maximum offsite individual would be 0.12 rem from CR-1 and 0.2 rem from CR-2. Both criticalities were determined to be "beyond extremely unlikely" (because the frequency is less than one in a million per year, they are not considered "reasonably foreseeable" events for the purposes of this *TC & WM EIS*) (Fluor Hanford 2007).

K.3.6.2 ILAW Disposal Accidents

K.3.6.2.1 Earthmover Shears Tops Off Six ILAW Containers (ILAW1)

An earthmover was assumed to be pushing fill dirt over the tops of rows of ILAW containers when the blade shears the tops off of six containers. The blade force exerted by the earthmover was assumed to be entirely expended in shattering and grinding vitrified waste, producing a total release of 94 cubic centimeters (5.7 cubic inches) of ILAW glass particles in the respirable size range. More than 99 percent of the potential dose from the aerosol would be due to releases of strontium-90 (0.00666 curies), plutonium-238 (3.52×10^{-7} curies), plutonium-239 (0.0000115 curies), plutonium-240 (1.96×10^{-6} curies), and americium-241 (0.000122 curies). The estimated frequency of this accident is between 0.01 and 1 per year (Burbank 2002). For purposes of this analysis, it was assigned a frequency value of 0.1.

K.3.6.2.2 Crushing of ILAW Containers by Falling Crane Boom (ILAW2)

A crane is used to lift ILAW containers from the transporter and place them in the burial trench. It was assumed that the crane boom falls into the trench and strikes part of the exposed container array. The impact energy of the falling boom was assumed to be entirely expended in shattering and grinding the vitrified waste, producing a total release of 846 cubic centimeters (52 cubic inches) of ILAW glass particles in the respirable size range. More than 99 percent of the potential dose from the aerosol would be due to releases of strontium-90 (0.0599 curies), plutonium-238 (3.17×10^{-6} curies), plutonium-239 (0.000104 curies), plutonium-240 (0.0000176 curies), and americium-241 (0.0011 curies). The estimated frequency of this accident is between 0.01 and 1 per year (Burbank 2002). For purposes of this analysis, the frequency was assumed to be 0.1 per year.

K.3.7 Radiological Impacts of Accidents

The consequences of a radiological accident to workers and the public can be expressed in a number of ways. Three ways are used in this *TC & WM EIS*. The first is individual dose expressed in terms of rem or millirem for a worker or member of the public and collective dose expressed in terms of person-rem for a population of workers or members of the public. The second is a postexposure effect that reflects the likelihood of an LCF for an exposed individual or the expected number of LCFs in a population of exposed individuals. Individual or public exposure to radiation occurs if there is an accident involving radioactive materials, which leads to the third measure, risk. Risk is the mathematical product of the

probability (or frequency) that the accident occurs and the LCF consequences. Risk is calculated as follows:

$$R_i = D_i \times F \times P$$

or

$$R_p = D_p \times F \times P$$

where:

R_i	=	risk of an LCF for an individual receiving a dose D_i
R_p	=	risk of a number of LCFs for a population receiving a collective dose D_p
D_i	=	dose to a worker or member of the public, rem or millirem
D_p	=	collective dose to a population of workers or members of the public, person-rem
F	=	dose-to-LCF conversion factor, which is 0.0006 LCFs per rem (for an individual) or person-rem (for a population)
P	=	probability or frequency of the accident, usually expressed on a per-year basis

Once the source term, the amount of radioactive material released to the environment for each accident scenario, is determined, the radiological consequences are calculated. The calculations and resulting impacts vary depending on how the release is dispersed, what material is involved, and which receptor is being considered.

For example, if the dose to the MEI or worker is 10 rem, the probability of an LCF for an individual is $10 \times 0.0006 = 0.006$, where 0.0006 is the dose-to-LCF conversion factor. If the MEI or worker receives a dose exceeding 20 rem, the dose-to-LCF conversion factor is doubled to 0.0012. Thus, if the MEI receives a dose of 30 rem, the probability of an LCF is $30 \times 0.0012 = 0.036$. For an individual, the calculated probability of an LCF would be in addition to the probability of cancer from all other causes.

For the population, the same dose-to-LCF conversion factor is used to estimate the number of LCFs. The calculated number of LCFs in the population is in addition to the number of cancer fatalities that would result from all other causes. The MACCS2 computer code is used to calculate the dose to an average individual living in a particular geographic area (sector) near the site. The individual dose is then multiplied by the number of people in that sector and the appropriate dose-to-LCF conversion factor to estimate the probability of an LCF within the entire sector's population. The probabilities for all sectors are then summed to produce an estimate of the total probability of an LCF (or total number of LCFs) in the population living within 80 kilometers (50 miles) of the site.

K.3.7.1 Radiological Impacts of Tank Closure Accidents

For the Tank Closure No Action Alternative, severe accidents involving waste tanks are represented by a seismically induced waste tank dome collapse. Table K–70 shows the consequences for this accident. Table K–71 shows the frequency and annual cancer risks for this accident.

Table K–70. Tank Closure Alternative – 1 Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on a population of 488,897 persons residing within 80 kilometers (50 miles) of the 200-West Area.

[c] The alphanumeric code following the accident's title (i.e., TK53) corresponds with the code in the accident's description in Section K.3.4.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF for an individual, assuming the accident occurs.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: LCF=latent cancer fatality.

Table K–71. Tank Closure Alternative – 1 Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of Latent Cancer Fatality		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}

[a] The alphanumeric code following the accident's title (i.e., TK53) corresponds with the code in the accident's description in Section K.3.4.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on a population of 488,897 persons residing within 80 kilometers (50 miles) of the 200-West Area.

Key: LCF=latent cancer fatality.

The following tables (Tables K–72 through K–91) provide the accident consequences for each Tank Closure action alternative. For each alternative, there are two tables showing the impacts. The first table presents the consequences (doses and LCFs) assuming the accident occurs—that is, not reflecting the frequency of accident occurrence. The second table shows accident risks that are obtained by multiplying the LCF values in the first table by the frequency of the corresponding accident.

Table K–72. Tank Closure Alternative – 2A Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.000014	9×10^{-9}	0.19	0 (0.0001)	0.043	0.00003
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	4.3	0.003	58,000	35	13,000	1
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–73. Tank Closure Alternative – 2A Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.0005	4×10^{-12}	0 (6×10^{-8})	1×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–74. Tank Closure Alternative – 2B Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.000043	3×10^{-8}	0.57	0 (0.0003)	0.13	0.00008
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	4.3	0.003	58,000	35	13,000	1
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–75. Tank Closure Alternative – 2B Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.0005	1×10^{-11}	0 (2×10^{-7})	4×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–76. Tank Closure Alternative – 3A Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	7×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	6×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.000014	9×10^{-9}	0.19	0 (0.0001)	0.043	0.00003
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	4.3	0.003	58,000	35	13,000	1
Bulk vitrification waste receipt tank failure – unmitigated (200-East Area) (BV61)	2.8×10^{-8}	2×10^{-11}	0.00038	0 (2×10^{-7})	0.000083	5×10^{-8}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	3.5×10^{-6}	2×10^{-9}	0.016	0 (1×10^{-5})	0.0032	2×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	2.2×10^{-6}	1×10^{-9}	0.0029	0 (0.00002)	0.0025	1×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	6.6×10^{-6}	4×10^{-9}	0.030	0 (0.00002)	0.0024	1×10^{-6}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–77. Tank Closure Alternative – 3A Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6×30 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6×30 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.0005	4×10^{-12}	0 (6×10^{-8})	1×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Bulk vitrification waste receipt tank failure – unmitigated (200-East Area) (BV61)	0.0005	8×10^{-15}	0 (1×10^{-10})	3×10^{-11}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	0.0005	1×10^{-12}	0 (5×10^{-9})	1×10^{-9}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	0.0005	6×10^{-13}	0 (9×10^{-9})	7×10^{-10}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	0.0005	2×10^{-12}	0 (9×10^{-9})	7×10^{-10}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–78. Tank Closure Alternative – 3B Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.000014	9×10^{-9}	0.19	0 (0.0001)	0.043	0.00003
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	4.3	0.003	58,000	35	13,000	1
Cast stone feed receipt tank failure – unmitigated (200-East Area) (CS71)	2.8×10^{-8}	2×10^{-11}	0.00038	0 (2×10^{-7})	0.000083	5×10^{-8}
Cast stone feed receipt tank failure – unmitigated (200-West Area) (CS71)	3.5×10^{-6}	2×10^{-9}	0.016	0 (1×10^{-5})	0.0032	2×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	2.2×10^{-6}	1×10^{-9}	0.029	0 (0.00002)	0.0025	1×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	6.6×10^{-6}	4×10^{-9}	0.030	0 (0.00002)	0.0024	1×10^{-6}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–79. Tank Closure Alternative – 3B Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT 23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.0005	4×10^{-12}	0 (6×10^{-8})	1×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Cast stone feed receipt tank failure – unmitigated (200-East Area) (CS71)	0.0005	8×10^{-15}	0 (1×10^{-10})	3×10^{-11}
Cast stone feed receipt tank failure – unmitigated (200-West Area) (CS71)	0.0005	1×10^{-12}	0 (5×10^{-9})	1×10^{-9}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	0.0005	6×10^{-13}	0 (9×10^{-9})	7×10^{-10}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	0.0005	2×10^{-12}	0 (9×10^{-9})	7×10^{-10}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–80. Tank Closure Alternative – 3C Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCFs[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.000014	9×10^{-9}	0.19	0 (0.0001)	0.043	0.00003
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	4.3	0.003	58,000	35	13,000	1
Steam reforming feed receipt tank failure – unmitigated (200-East Area) (SRF1)	2.8×10^{-8}	2×10^{-11}	0.00038	0 (2×10^{-7})	0.000083	5×10^{-8}
Steam reforming feed receipt tank failure – unmitigated (200-West Area) (SRF1)	3.5×10^{-6}	2×10^{-9}	0.016	0 (1×10^{-5})	0.0032	2×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	2.2×10^{-6}	1×10^{-9}	0.029	0 (0.00002)	0.0025	1×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	6.6×10^{-6}	4×10^{-9}	0.030	0 (0.00002)	0.0024	1×10^{-6}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–81. Tank Closure Alternative – 3C Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.0005	4×10^{-12}	0 (6×10^{-8})	1×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Steam reforming feed receipt tank failure – unmitigated (200-East Area) (SRF1)	0.0005	8×10^{-15}	0 (1×10^{-10})	3×10^{-11}
Steam reforming feed receipt tank failure – unmitigated (200-West Area) (SRF1)	0.0005	1×10^{-12}	0 (5×10^{-9})	1×10^{-9}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	0.0005	6×10^{-13}	0 (9×10^{-9})	7×10^{-10}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	0.0005	2×10^{-12}	0 (9×10^{-9})	7×10^{-10}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z ×Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–82. Tank Closure Alternative – 4 Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.000014	9×10^{-9}	0.19	0 (0.0001)	0.043	0.00003
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	4.3	0.003	58,000	35	13,000	1
Cast stone feed receipt tank failure – unmitigated (200-East Area) (CS71)	2.8×10^{-8}	2×10^{-11}	0.00038	0 (2×10^{-7})	0.000083	5.0×10^{-8}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	3.5×10^{-6}	2×10^{-9}	0.016	0 (1×10^{-5})	0.0032	2×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	2.2×10^{-6}	1×10^{-9}	0.029	0 (0.00002)	0.0025	1×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	6.6×10^{-6}	4×10^{-9}	0.030	0 (0.00002)	0.0024	1×10^{-6}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–83. Tank Closure Alternative – 4 Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT 23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (30 MTG/day)	0.0005	4×10^{-12}	0 (6×10^{-8})	1×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×30 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Cast stone feed receipt tank failure – unmitigated (200-East Area) (CS71)	0.0005	8×10^{-15}	0 (1×10^{-10})	3×10^{-11}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	0.0005	1×10^{-12}	0 (5×10^{-9})	1×10^{-9}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	0.0005	6×10^{-13}	0 (9×10^{-9})	7×10^{-10}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	0.0005	2×10^{-12}	0 (9×10^{-9})	7×10^{-10}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z ×Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–84. Tank Closure Alternative – 5 Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (45 MTG/day)	0.000021	1×10^{-8}	0.29	0 (0.0002)	0.065	0.00004
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×45 MTG/day)	4.3	0.003	58,000	35	13,000	1
Cast stone feed receipt tank failure – unmitigated (200-East Area) (SRF1)	2.8×10^{-8}	2×10^{-11}	0.00038	0 (2×10^{-7})	0.000083	5×10^{-8}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	3.5×10^{-6}	2×10^{-9}	0.016	0 (1×10^{-5})	0.0032	2×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	2.2×10^{-6}	1×10^{-9}	0.029	0 (0.00002)	0.0025	1×10^{-6}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	6.6×10^{-6}	4×10^{-9}	0.030	0 (0.00002)	0.0024	1×10^{-6}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–85. Tank Closure Alternative – 5 Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT 23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (45 MTG/day)	0.0005	6×10^{-12}	0 (9×10^{-8})	2×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×45 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Cast stone feed receipt tank failure – unmitigated (200-East Area) (CS71)	0.0005	8×10^{-15}	0 (1×10^{-10})	3×10^{-11}
Bulk vitrification waste receipt tank failure – unmitigated (200-West Area) (BV61)	0.0005	1×10^{-12}	0 (5×10^{-9})	1×10^{-9}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-East Area) (TR81)	0.0005	6×10^{-13}	0 (9×10^{-9})	7×10^{-10}
Mixed TRU waste/MLLW liquid sludge transfer line spray leak – unmitigated (200-West Area) (TR81)	0.0005	2×10^{-12}	0 (9×10^{-9})	7×10^{-10}
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z ×Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MLLW=mixed low-level radioactive waste; MTG/day=metric tons of glass per day; TRU=transuranic; WTP=Waste Treatment Plant.

Table K–86. Tank Closure Alternative – 6A Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (15 MTG/day)	0.029	0.00002	380	0 (0.2)	83	0.1
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (15 MTG/day)	0.046	0.00003	620	0 (0.4)	160	0.2
Seismically induced WTP collapse and failure – unmitigated (WT41) (15 MTG/day)	0.058	0.00004	780	0 (0.5)	180	0.2
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of LCF for an individual, assuming the accident occurs.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–87. Tank Closure Alternative – 6A Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (15 MTG/day)	0.0005	9×10^{-9}	0 (0.0001)	0.00005
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (15 MTG/day)	0.0005	1×10^{-8}	0 (0.0002)	0.00009
Seismically induced WTP collapse and failure – unmitigated (WT41) (15 MTG/day)	0.0005	2×10^{-8}	0 (0.0002)	0.0001
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z ×Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–88. Tank Closure Alternative – 6B Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.004)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.000043	3×10^{-8}	0.57	0 (0.0003)	0.13	0.00008
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	4.3	0.003	58,000	35	13,000	1
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–89. Tank Closure Alternative – 6B Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT 23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.0005	1×10^{-11}	0 (2×10^{-7})	4×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–90. Tank Closure Alternative – 6C Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.0013	8×10^{-7}	5.8	0 (0.003)	1.4	0.0008
Spray leak in transfer line during excavation – unmitigated (PT23)	0.007	4×10^{-6}	94	0 (0.06)	24	0.03
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.88	0.0005	12,000	7	2,900	1
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.011	7×10^{-6}	150	0 (0.09)	33	0.04
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.019	0.00001	250	0 (0.1)	63	0.08
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.000043	3×10^{-8}	0.57	0 (0.0003)	0.13	0.00008
Seismically inducted WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	4.3	0.003	58,000	35	13,000	1
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.00021	1×10^{-7}	0.96	0 (0.0006)	0.22	0.0001
IHLW glass canister drop – unmitigated (SH91)	0.00026	2×10^{-7}	3.5	0 (0.002)	0.91	0.0005

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF, assuming the accident occurs, except at high individual doses (hundreds of rem or more) where acute radiation injury may cause death within weeks. Value cannot exceed 1.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality ; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

Table K–91. Tank Closure Alternative – 6C Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Spray release from jumper pit during waste retrieval – unmitigated (TK51)	0.011	8×10^{-9}	0 (0.00004)	9×10^{-6}
Spray leak in transfer line during excavation – unmitigated (PT 23)	0.0001	4×10^{-10}	0 (6×10^{-6})	3×10^{-6}
Pretreatment Facility waste feed receipt vessel or piping leak – unmitigated (PT22)	0.0005	3×10^{-7}	0 (0.004)	0.002
Seismically induced failure of HLW melter feed preparation vessels – unmitigated (HL11) (6 MTG/day)	0.0005	3×10^{-9}	0 (0.00005)	0.00002
HLW molten glass spill caused by HLW melter failure – unmitigated (HL14) (6 MTG/day)	0.0005	6×10^{-9}	0 (7×10^{-5})	4×10^{-5}
Seismically induced LAW Vitrification Facility collapse and failure – unmitigated (LA31) (90 MTG/day)	0.0005	1×10^{-11}	0 (2×10^{-7})	4×10^{-8}
Seismically induced WTP collapse and failure – unmitigated (WT41) (6×90 MTG/day)	0.0005	1×10^{-6}	0 (0.02)	0.008
Seismically induced waste tank dome collapse – unmitigated (TK53)	0.0005	6×10^{-11}	0 (3×10^{-7})	7×10^{-8}
IHLW glass canister drop – unmitigated (SH91)	0.001	2×10^{-10}	0 (2×10^{-6})	5×10^{-7}

[a] The alphanumeric code following the accident's title (e.g., TK51) corresponds with the code in the accident's description in Section K.3.4. The term "Z × Y MTG/day," read as "Z by Y MTG/day," refers to a WTP design capacity of Z MTG/day of HLW and Y MTG/day of LAW; for example, 6 × 30, 6 × 45, 6 × 90, or 15 × 0 MTG/day.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; MTG/day=metric tons of glass per day; WTP=Waste Treatment Plant.

K.3.7.2 Radiological Impacts of FFTF Decommissioning Accidents

The accident scenarios involving the stored sodium inventories at Hanford in the 400 Area SSF and the 200-West Area are applicable under any of the FFTF Decommissioning alternatives. Table K–92 shows the consequences of these accidents. Table K–93 shows the annual probability and the cancer risks of the accidents. The Hallam Reactor sodium fire and SRE sodium fire could occur in either the 200-West Area where the sodium is stored, or in the 400 Area after the sodium is transferred there for processing. Tables K–92 and K–93 present the impacts of these accidents occurring in the 200-West Area; the Hanford sodium storage tank failure has the largest impacts of accidents occurring in the 400 Area.

Table K–92. FFTF Decommissioning Alternatives – Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Sodium Storage Facility fire (SSF1)	1.0×10^{-6}	6×10^{-10}	0.048	0 (0.00003)	3.4×10^{-7}	2×10^{-10}
Hanford sodium storage tank failure (HSTF1)	1.1×10^{-6}	6×10^{-10}	0.048	0 (0.00003)	8.7×10^{-7}	5×10^{-10}
Hallam Reactor sodium fire (HSF1)	4.6×10^{-10}	3×10^{-13}	5.9×10^{-6}	0 (4×10^{-9})	2.5×10^{-10}	2×10^{-13}
Sodium Reactor Experiment sodium fire (SRE1)	4.5×10^{-8}	3×10^{-11}	0.00058	0 (3×10^{-7})	1.1×10^{-7}	7×10^{-11}

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 488,897 persons residing within 80 kilometers (50 miles) of the 200-West Area (HSF1 and SRE1) and 357,391 persons residing within 80 kilometers (50 miles) of the 400 Area (SSF1 and HSTF1).

[c] The alphanumeric code following the accident's title (e.g., SSF1) corresponds with the code in the accident's description in Section K.3.5.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of LCF for an individual, assuming the accident occurs.

[f] The reported value of the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality.

Table K–93. FFTF Decommissioning Alternatives – Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Sodium Storage Facility fire (SSF1)	1×10^{-6}	6×10^{-16}	0 (3×10^{-11})	2×10^{-16}
Hanford sodium storage tank failure (HSTF1)	1×10^{-5}	6×10^{-15}	0 (3×10^{-10})	5×10^{-15}
Hallam Reactor sodium fire (HSF1)	2×10^{-5}	5×10^{-18}	0 (7×10^{-14})	3×10^{-18}
Sodium Reactor Experiment sodium fire (SRE1)	1×10^{-2}	3×10^{-13}	0 (3×10^{-9})	7×10^{-13}

[a] The alphanumeric code following the accident's title (e.g., SSF1) corresponds with the code in the accident's description in Section K.3.5.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 488,897 persons residing within 80 kilometers (50 miles) of the 200-West Area (HSF1 and SRE1) and 357,391 persons residing within 80 kilometers (50 miles) of the 400 Area (SSF1 and HSTF1).

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality.

The sodium storage fire accident scenarios represent a reasonable range of potential accidents for the FFTF Decommissioning No Action Alternative. For the two FFTF Decommissioning action alternatives, additional scenarios are considered for the options for dispositioning RH-SCs and bulk sodium at Hanford or INL. These accidents could occur under either FFTF Decommissioning Alternative 2 or 3.

Under FFTF Decommissioning Alternatives 2 and 3, RH-SCs would be removed from FFTF prior to final disposition of the structures. A fire could occur at the Hanford 400 Area during handling of the RH-SCs. Table K–94 presents the radiological consequences of fire under the Hanford Option for disposition of RH-SCs. The risks of such an accident, determined by multiplying the consequences by the estimated frequency of the accident, are presented in Table K–95. Under the Hanford Reuse Option for disposition of bulk sodium, the accidents listed in Tables K–92 and K–93 represent a reasonable range of accidents, and no additional scenarios need to be evaluated.

Table K–94. FFTF Decommissioning Alternatives 2 and 3, Hanford Option for Disposition of RH-SCs – Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Remote-handled special component fire (RHSC1) at Hanford	0.00011	7×10^{-8}	4.4	0 (0.003)	0.0009	5×10^{-7}

a The dose presented here results from an accident release of radioactive materials to the atmosphere and is from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

b Based on a population of 357,391 persons residing within 80 kilometers (50 miles) of the 400 Area.

c The alphanumeric code following the accident's title (i.e., RHSC1) corresponds with the code in the accident's description in Section K.3.5.

d The accident listed was analyzed because it had the highest consequences and/or risks in its category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

e Increased likelihood of LCF for an individual, assuming the accident occurs.

f The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality; RH-SCs=remote-handled special components.

Table K–95. FFTF Decommissioning Alternatives 2 and 3, Hanford Option for Disposition of RH-SCs – Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Remote-handled special component fire (RHSC1) at Hanford	0.01	7×10^{-10}	0 (0.00003)	5×10^{-9}

a The alphanumeric code following the accident's title (i.e., RHSC1) corresponds with the code in the accident's description in Section K.3.5.

b The accident listed was analyzed because it had the highest consequences and/or risks in its category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

c Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

d The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

e Based on a population of 357,391 persons residing within 80 kilometers (50 miles) of the 400 Area.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; LCF=latent cancer fatality; RH-SCs=remote-handled special components.

However, the Idaho Option for either of these activities would introduce new accident scenarios. Under the Idaho Option for disposition of RH-SCs, the RH-SC fire (RHSC1) could occur both at Hanford (during removal) and at INL (during processing). The consequences and risks of an RH-SC fire at Hanford are presented in Tables K–94 and K–95. The radiological consequences of an RH-SC fire at INL are presented in Table K–96. Table K–97 presents the annual risks from an RH-SC fire, taking into account the probability of the accident occurring. The Idaho Reuse Option for disposition of bulk sodium would introduce a new scenario involving failure of the SPF sodium storage tank (INLSPF1) at INL. The consequences if the accident were to occur and the annual risks associated with the accident are presented in Tables K–96 and K–97.

Table K–96. FFTF Decommissioning Alternatives 2 and 3, Idaho Option for Disposition of RH-SCs and Idaho Reuse Option for Disposition of Bulk Sodium – Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Remote-handled special component fire (RHSC1) at INL	0.0001	6×10^{-8}	0.25	0 (0.0002)	0.0036	2×10^{-6}
INL Sodium Processing Facility storage tank failure (INLSPF1)	5.5×10^{-8}	3×10^{-11}	0.0002	0 (1×10^{-7})	3.4×10^{-7}	2×10^{-10}

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on a population of 205,962 persons residing within 80 kilometers (50 miles) of the INL Materials and Fuels Complex.

[c] The alphanumeric code following the accident's title (e.g., RHSC1) corresponds with the code in the accident's description in Section K.3.5.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF for an individual, assuming the accident occurs.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; LCF=latent cancer fatality; RH-SCs=remote-handled special components.

Table K–97. FFTF Decommissioning Alternatives 2 and 3, Idaho Option for Disposition of RH-SCs and Idaho Reuse Option for Disposition of Bulk Sodium – Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Remote-handled special component fire (RHSC1) at INL	0.01	6×10^{-10}	0 (2×10^{-6})	2×10^{-8}
INL Sodium Processing Facility storage tank failure (INLSPF1)	0.00001	3×10^{-16}	0 (1×10^{-12})	2×10^{-15}

[a] The alphanumeric code following the accident's title (e.g., INLSPF1) corresponds with the code in the accident's description in Section K.3.5.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on a population of 205,962 persons residing within 80 kilometers (50 miles) of the INL Materials and Fuels Complex.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; LCF=latent cancer fatality; RH-SCs=remote-handled special components.

K.3.7.3 Radiological Impacts of Waste Management Accidents

Table K–98 shows the consequences of the accidents associated with the Waste Management No Action Alternative. For the No Action Alternative, the accident scenarios involving the disposal of ILAW in the IDF-East are not applicable. Table K–99 shows the frequency and annual cancer risks for the accidents.

Table K–98. Waste Management Alternative – 1 Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Single-drum deflagration (SWOC FIR-1)	0.00079	5×10^{-7}	3.6	0 (0.002)	0.84	0.0005
Medium fire inside facility (SWOC FIR-6)	0.015	9×10^{-6}	66	0 (0.04)	16	0.009
Glovebox or greenhouse fire (SWOC FIR-8)	0.028	0.00002	130	0 (0.08)	30	0.04
Large fire of waste containers outside facility (SWOC FIR-4)	0.25	0.0002	1,100	1 (0.7)	260	0.3
Handling spill of single waste container (SWOC SP-2)	0.00015	9×10^{-8}	0.66	0 (0.0004)	0.16	0.00009
Large handling spill of boxes or multiple waste containers (SWOC SP-3A)	0.00072	4×10^{-7}	3.3	0 (0.002)	0.77	0.0005
Spill of single large-diameter container (SWOC SP-4)	0.007	4×10^{-6}	32	0 (0.02)	7.5	0.004
Design-basis seismic event (SWOC NPH-1)	0.0068	4×10^{-6}	31	0 (0.02)	7.3	0.004
Beyond-design-basis accident (SWOC NPH-2)	0.026	0.00002	120	0 (0.07)	28	0.03
Range fire (SWOC EE-1)	0.12	0.00007	560	0 (0.3)	130	0.2
Aircraft crash (SWOC EE-2)	0.28	0.0002	1,300	1 (0.8)	300	0.4

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East Area and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., SWOC FIR-1) corresponds with the code in the accident's description in Section K.3.6.

[d] The reported value of the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Increased likelihood of an LCF for an individual, assuming the accident occurs.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: LCF=latent cancer fatality.

Table K–99. Waste Management Alternative – 1 Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Single-drum deflagration (SWOC FIR-1)	0.01	5×10^{-9}	0 (0.00002)	5×10^{-6}
Medium fire inside facility (SWOC FIR-6)	0.01	9×10^{-8}	0 (0.0004)	0.00009
Glovebox or greenhouse fire (SWOC FIR-8)	0.01	2×10^{-7}	0 (0.0008)	0.0004
Large fire of waste containers outside facility (SWOC FIR-4)	0.01	2×10^{-6}	0 (0.007)	0.003
Handling spill of single waste container (SWOC SP-2)	0.01	9×10^{-10}	0 (4×10^{-6})	9×10^{-7}
Large handling spill of boxes or multiple waste containers (SWOC SP-3A)	0.01	4×10^{-9}	0 (0.00002)	5×10^{-6}
Spill of single large-diameter container (SWOC SP-4)	0.01	4×10^{-8}	0 (0.0002)	0.00004
Design-basis seismic event (SWOC NPH-1)	0.001	4×10^{-9}	0 (0.00002)	4×10^{-6}
Beyond-design-basis accident (SWOC NPH-2)	0.001	2×10^{-8}	0 (0.00007)	0.00003
Range fire (SWOC EE-1)	0.01	7×10^{-7}	0 (0.003)	0.002
Aircraft crash (SWOC EE-2)	0.00003	5×10^{-9}	0 (0.00002)	0.00001

[a] The alphanumeric code following the accident's title (e.g., SWOC FIR-1) corresponds with the code in the accident's description in Section K.3.6.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: LCF=latent cancer fatality.

Tables K–100 and K–101 provide the accident consequences for Waste Management Alternatives 2 and 3. Table K–100 presents the consequences (doses and LCFs), assuming the accident occurs, that is, not reflecting the frequency of accident occurrence. Table K–101 shows accident risks obtained by multiplying the LCF values from Table K–100 by the frequency of the accident. Under Alternatives 2 and 3, new facilities or expansions of existing facilities would be required and there would be limited shipments of LLW and MLLW to Hanford from other DOE sites. As noted previously, each of the scenarios analyzed in the current DSASW or some variant of it would be applicable to each of the Waste Management alternatives, although the human health risk from a particular type of accident would depend on the volume of waste that is ultimately managed and the duration (years) of each operation.

Table K–100. Waste Management Alternatives 2 and 3 – Radiological Consequences of Accidents[a]

Accident[c, d]	Maximally Exposed Individual		Offsite Population[b]		Noninvolved Worker	
	Dose (rem)	LCF[e]	Dose (person-rem)	LCFs[f]	Dose (rem)	LCF[e]
Single-drum deflagration (SWOC FIR-1)	0.00079	5×10^{-7}	3.6	0 (0.002)	0.84	0.0005
Medium fire inside facility (SWOC FIR-6)	0.015	9×10^{-6}	66	0 (0.04)	16	0.009
Glovebox or greenhouse fire (SWOC FIR-8)	0.028	0.00002	130	0 (0.08)	30	0.04
Large fire of waste containers outside facility (SWOC FIR-4)	0.25	0.0002	1,100	1 (0.7)	260	0.3
Handling spill of single waste container (SWOC SP-2)	0.00015	9×10^{-8}	0.66	0 (0.0004)	0.16	0.00009
Large handling spill of boxes or multiple waste containers (SWOC SP-3A)	0.00072	4×10^{-7}	3.3	0 (0.002)	0.77	0.0005
Spill of single large-diameter container (SWOC SP-4)	0.007	4×10^{-6}	32	0 (0.02)	7.5	0.004
Design-basis seismic event (SWOC NPH-1)	0.0068	4×10^{-6}	31	0 (0.02)	7.3	0.004
Beyond-design-basis accident (SWOC NPH-2)	0.026	0.00002	120	0 (0.07)	28	0.03
Range fire (SWOC EE-1)	0.12	0.00007	560	0 (0.3)	130	0.2
Aircraft crash (SWOC EE-2)	0.28	0.0002	1,300	1 (0.8)	300	0.4
Earthmover shears tops off six ILAW containers (ILAW1)	3.4×10^{-6}	2×10^{-9}	0.016	0 (9×10^{-6})	0.0036	2×10^{-6}
Crushing of ILAW containers by falling crane boom (ILAW2)	0.000031	2×10^{-8}	0.14	0 (0.00008)	0.033	0.00002

[a] The doses presented here result from accident releases of radioactive materials to the atmosphere and are from direct exposure to the plume and inhalation only. Doses from other pathways, such as consumption of foodstuffs and exposure to radioactive material deposited on the ground, are small by comparison.

[b] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

[c] The alphanumeric code following the accident's title (e.g., SWOC FIR-1) corresponds with the code in the accident's description in Section K.3.6.

[d] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[e] Increased likelihood of an LCF for an individual, assuming the accident occurs.

[f] The reported value is the projected number of LCFs in the population, assuming the accident occurs, and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

Key: ILAW=immobilized low-activity waste; LCF=latent cancer fatality.

Table K–101. Waste Management Alternatives 2 and 3 – Annual Cancer Risks from Accidents

Accident[a, b]	Frequency	Risk of LCF		
		Maximally Exposed Individual[c]	Offsite Population[d, e]	Noninvolved Worker[c]
Single-drum deflagration (SWOC FIR-1)	0.01	5×10^{-9}	0 (0.00002)	5×10^{-6}
Medium fire inside facility (SWOC FIR-6)	0.01	9×10^{-8}	0 (0.0004)	0.00009
Glovebox or greenhouse fire (SWOC FIR-8)	0.01	2×10^{-7}	0 (0.0008)	0.0004
Large fire of waste containers outside facility (SWOC FIR-4)	0.01	2×10^{-6}	0 (0.007)	0.003
Handling spill of single waste container (SWOC SP-2)	0.01	9×10^{-10}	0 (4×10^{-6})	9×10^{-7}
Large handling spill of boxes or multiple waste containers (SWOC SP-3A)	0.01	4×10^{-9}	0 (0.00002)	5×10^{-6}
Spill of single large-diameter container (SWOC SP-4)	0.01	4×10^{-8}	0 (0.0002)	0.00004
Design-basis seismic event (SWOC NPH-1)	0.001	4×10^{-9}	0 (0.00002)	4×10^{-6}
Beyond-design-basis accident (SWOC NPH-2)	0.001	2×10^{-8}	0 (0.00007)	0.00003
Range fire (SWOC EE-1)	0.01	7×10^{-7}	0 (0.003)	0.002
Aircraft crash (SWOC EE-2)	0.00003	5×10^{-9}	0 (0.00002)	0.00001
Earthmover shears tops off six ILAW containers (ILAW1)	0.1	2×10^{-10}	0 (9×10^{-7})	2×10^{-7}
Crushing of ILAW containers by falling crane boom (ILAW2)	0.1	2×10^{-9}	0 (8×10^{-6})	2×10^{-6}

[a] The alphanumeric code following the accident's title (e.g., SWOC FIR-1) corresponds with the code in the accident's description in Section K.3.6.

[b] The accidents listed were analyzed because they had the highest consequences and/or risks in their category (e.g., leak, spill, mechanical impact, natural phenomena). In some instances, more than one accident is in a category to include similar accidents at different facilities. For some categories (e.g., criticality, flooding), no accidents are listed because either none are applicable or the risks of accidents in the categories are very low.

[c] Increased risk to the individual of an LCF, taking into account the probability (frequency) of the accident.

[d] The reported value is the projected number of LCFs in the population, based on the accident probability (frequency), and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor (0.0006 LCFs per person-rem) is shown in parentheses.

[e] Based on populations of 451,556 and 488,897 persons residing within 80 kilometers (50 miles) of the 200-East and 200-West Areas, respectively.

Key: ILAW=immobilized low-activity waste; LCF=latent cancer fatality.

K.3.8 Secondary Impacts of Accidents

As previously described in this appendix, technological emergencies or terrorist attacks involving release of radionuclides could produce airborne plumes and cause inhalation impacts on workers and the public. Secondary impacts on human health and other resource areas (e.g., land use, ecology) could also result from the deposition of radioactive material on the ground. The magnitude of any secondary impacts depends on the characteristics of the release, the meteorological conditions at the time of the event, and the type of land area affected. In general, the concentration of radioactive material deposited on the ground will decrease with increasing distance from the point of release. Low windspeeds will usually result in more deposition near the release point and less deposition at greater distances, whereas higher windspeeds may increase the distance at which ground concentration exceeds levels of concern. The

occurrence of rain or snow at the time of the release may accelerate deposition and cause higher concentrations in areas where precipitation has fallen. The radiation dose and associated human health impacts on workers and the public resulting from resuspension (inhalation exposure), ingestion, or ground shine (direct exposure) would not significantly add to the impacts from exposure to the passing plume. However, deposition of radionuclides may also have impacts on land use, socioeconomics, environmental justice, ecology, and other environmental resource areas.

After the initial phase of response to an emergency, EPA may lead efforts to protect human health and the environment from adverse impacts. Working with various stakeholders, EPA may provide technical advice and response support to state, tribal, and local governments; the site or facility owner/operator; and Federal agencies. EPA also has the authority to order private-party cleanup and to oversee and monitor emergency response by others (EPA 2000b). EPA has concluded that soil concentration levels (i.e., deposition) on the order of 0.1 to 1 microcuries per square meter "represent a proper level for concern and initiation of protective actions and temporary access restrictions. A realistic assessment would be expected to lead to less restrictive conclusions" (Burley 1990). Actions and restrictions may take the form of interdiction of agricultural products and limitations on commercial and residential activities, which could in turn affect employment. Cleanup of contaminated areas or property use restrictions may involve substantial monetary cost and loss of beneficial use of property for commercial, residential, agricultural, recreational, institutional, or other purposes. Impacts on water, biological, ecological, and cultural resources are also possible in areas with contamination in excess of the EPA level of 0.1 microcuries per square meter.

A full quantitative assessment of secondary impacts would involve characterizing the amount and current use of onsite and offsite land affected by each accident, as well as the cost of any use restrictions, mitigation efforts, and cleanup. The magnitude of secondary impacts would, in general, be proportional to the amount of radioactive material released and to the direct human health impacts reported in detail in this appendix. A full quantitative analysis of secondary impacts therefore was not performed for this *TC & WM EIS*. Instead, the distances at which the EPA contamination limits would be exceeded are reported as a semi-quantitative expression of the secondary impacts of representative tank closure, FFTF decommissioning, and waste management accidents.

K.3.8.1 Secondary Impacts of Tank Closure Accidents

Severe accidents, such as the seismically induced WTP collapse and failure (WT41), could produce large secondary impacts because of the large release. However, the frequency of this accident is low (1 chance in 2,000 years); therefore, the risk of secondary impacts would be low. In addition, a seismic event could cause simultaneous releases from other Hanford facilities and additional injuries and fatalities that are not associated with exposure to radioactivity. For these reasons, severe accidents are not good examples for estimating secondary impacts.

An accident associated with operations is the spray release from a jumper pit during waste retrieval (TK51). This accident has a higher frequency of occurrence (about 1 chance in 100 years) than a severe accident and serves as a good example for estimating secondary impacts. The analysis of this accident indicates that the 0.1-microcurie-per-square-meter limit would be exceeded out to a distance of 12.9 kilometers (8 miles), while the 1.0-microcurie-per-square-meter limit would be exceeded out to a distance of 3.2 kilometers (2 miles) from the release location. The specific area affected would depend upon the wind direction at the time, duration of the release, and deposition velocity. For this analysis, a 1-hour release and a 0.01-meter-per-second deposition velocity were assumed for all relevant radionuclides. Longer release durations and/or slower deposition velocities would produce larger affected areas. At Hanford, the prevailing wind direction is from the northwest to the southeast. If this accident were to occur at a time of the prevailing wind direction, the secondary impacts and post-accident cleanup would occur in areas within the site boundary. In the event that the wind direction at the time of the

accident were from the east to the west, it would be possible for the 0.1-microcurie-per-square-meter limit to be exceeded a short distance off site, depending on wind and deposition velocities.

Based on information in safety documentation for the WTP, postulated accidents with a higher frequency of occurrence would have smaller releases; therefore, their secondary impacts would likely be within the Hanford boundary. In the event of a lower-frequency/higher-consequence accident, the limits could be exceeded off site, but the risk of secondary impacts would be low.

K.3.8.2 Secondary Impacts of Fast Flux Test Facility Accidents

An RH-SC fire (RHSC1) has an estimated frequency of occurring about once in 100 years and would produce the largest release of radioactive material of all the analyzed FFTF accident scenarios. The analysis of this accident indicates that the 0.1-microcurie-per-square-meter limit would be exceeded out to a distance of 38.2 kilometers (23.7 miles), while the 1.0-microcurie-per-square-meter limit would be exceeded out to a distance of 0.35 kilometers (0.22 miles) from the release location. The specific area affected would depend upon the wind direction at the time, duration of the release, and deposition velocity. For this analysis, an 8-hour release and a 0.01-meter-per-second deposition velocity were assumed for all relevant radionuclides. Longer release durations and/or slower deposition velocities would produce larger affected areas. Regardless of the wind direction at the time of this accident, the secondary impacts and post-accident cleanup would likely extend to areas outside the Hanford boundary. However, the most heavily impacted areas (with deposition greater than the 1.0-microcurie-per-square-meter limit) would be entirely within the site boundary. The SSF fire (SSF1) would result in the 0.1-microcurie-per-square-meter limit being exceeded out to a distance of 22.2 kilometers (13.8 miles), while the 1.0-microcurie-per-square-meter limit would be exceeded out to a distance of 1.75 kilometers (1.1 miles) from the release location. However, the estimated frequency of SSF1 is much lower than that of RHSC1 (about 1 in 1 million years for SSF1 versus 1 in 100 years for RHSC1).

K.3.8.3 Secondary Impacts of Waste Management Accidents

A large fire of waste containers outside a facility (SWOC FIR-4) at the 200-West Area SWOC has an estimated frequency of occurring about once in 100 years; this fire would cause the 0.1-microcurie-per-square-meter limit to be exceeded out to a distance of 12 kilometers (7.5 miles) from the point of release, while the 1.0-microcurie-per-square-meter limit would be exceeded out to a distance of 0.1 kilometers (0.06 miles) from the release location. The specific area affected would depend upon the wind direction at the time, duration of the release, and deposition velocity. For this analysis, a 1-hour release and a 0.01-meter-per-second deposition velocity were assumed for all relevant radionuclides. Longer release durations and/or slower deposition velocities would produce larger affected areas. Depending on the wind direction at the time of this accident, the secondary impacts and post-accident cleanup might extend a few kilometers beyond the Hanford boundary. However, the most heavily impacted areas (with deposition greater than the 1.0-microcurie-per-square-meter limit) would be entirely within the site boundary. The aircraft crash at SWOC with ensuing fire (SWOC EE-2) would result in the 0.1-microcurie-per-square-meter limit being exceeded at a distance of 14.5 kilometers (9.0 miles). However, the estimated frequency of SWOC EE-2 is much lower than that of SWOC FIR-4 (about 3 in 100,000 years for SWOC EE-2 versus 1 in 100 years for SWOC FIR-4).

K.3.9 Chemical Impacts of Accidents

The evaluation of chemical impacts of potential accidents at Hanford considers the accidental release of two kinds of chemicals or toxic materials: (1) those chemicals used in the treatment process or supporting operations and (2) potentially toxic materials that are constituents of the treated waste.

K.3.9.1 Chemical Impacts of Tank Closure Accidents

A project report issued in September 2002, *Determination of Extremely Hazardous Substances* (Lindquist 2006b), documents the process by which chemicals used in the WTP were evaluated to determine which would be treated as "extremely hazardous substances." This identification plays a part in the regulatory process that will be applied to the WTP management of chemical safety.

Chemicals stored in substantial quantities and used for the vitrification process or supporting operations were addressed in determining which WTP chemicals might be considered extremely hazardous substances, whereas quantities of chemicals contained within the process streams or chemicals created as byproducts of the process were not considered. The evaluation resulted in two chemicals (anhydrous ammonia and 12.2 molar nitric acid) being declared "extremely hazardous substances" (Lindquist 2006b). Table K–102 presents a summary of chemicals that would be used at the WTP and their approximate quantities and locations.

Table K–102. Summary of Chemicals at the Waste Treatment Plant Complex

Chemical Name	Formula	Concentration	Quantity[a, b]			
			Pretreatment Facility	Balance of Facilities at WTP Complex	LAW Vitrification Facility	HLW Vitrification Facility
Alkyl epoxy carboxylate	Proprietary	N/A[c]	–	550 gal	–	–
Aluminum silicate	$A1_2SiO_5$	100%	–	2,175 ft^3	–	–
Ammonia, anhydrous	NH_3	100%	–	12,000 gal	–	–
Antifoam 1520	(Emulsion)	N/A[c]	1,500 gal		–	–
Argon	Ar	100%	–	–	120 ft^3	5,372 ft^3 at 2,400 psig
Borax	$Na_2B_4O_7 \cdot 10H_2O$	100%	–	2,150 ft^3	–	–
Boric acid	H_3BO_3	100%	–	3,000 ft^3	–	–
Calcium silicate	$CaSiO_3$	100%	–	3,000 ft^3	–	–
Carbon (activated)	C	70 wt%	–	–	446 ft^3	1,320 ft^3
Carbon dioxide	CO_2	100%	–	–	28 tons	–
Cerium nitrate	$Ce(NO_3)_3 \cdot H_2O$	0.5 M	–	–	–	550 gal
Ferric oxide	Fe_2O_3	100%	–	1,000 ft^3	–	–
Hydrogen peroxide	H_2O_2	30%	–	–	–	5 gal
Ion exchange resins	SuperLig®[644]	100%	1,200 gal	–	–	–
Lithium carbonate	Li_2CO_3	100%	–	2,500 ft^3	–	–
Magnesium silicate	$MgSiO_3$	100%	–	1,000 ft^3	–	–
Nitric acid	HNO_3	12.2 M	–	21,000 gal	–	–
Nitric acid	HNO_3	5 M	–	1,800 gal	–	–
Nitric acid	HNO_3	2 M	–	2,900 gal	–	1,300 gal
Nitric acid	HNO_3	0.5 M	14,000 gal	–	–	1,500 gal
Nitrogen	N_2	100%	2,688 ft^3 at 2,100 psig	–	–	–
Silica	SiO_2	100%	–	8,500 ft^3	–	–
Silver mordenite	AgZ	18 wt%	–	–	–	414 ft^3
Sodium bromide	NaBr	40%	–	400 gal	–	–
Sodium carbonate	Na_2CO_3	100%	–	1,500 ft^3	–	–
Sodium hydroxide	NaOH	19 M	–	21,000 gal	–	–
Sodium hydroxide	NaOH	5 M	–	3,900 gal	5,100 gal	1,400 gal
Sodium hydroxide	NaOH	2 M	–	2,700 gal	–	–

Table–102. Summary of Chemicals at the Waste Treatment Plant Complex *(continued)*

Chemical Name	Formula	Concentration	Quantity[a, b]			
			Pretreatment Facility	Balance of Facilities at WTP Complex	LAW Vitrification Facility	HLW Vitrification Facility
Sodium hydroxide	NaOH	0.25 M	–	1,200 gal	–	–
Sodium hydroxide	NaOH	0.1 M	3,042 gal	–	–	–
Sodium hypochlorite	NaOCl	12%	–	1,100 gal	–	–
Sodium permanganate	$NaMnO_4$	40 wt%	–	2,000 gal	–	–
Strontium nitrate	$Sr(NO_3)_2$	40 wt%	–	4,000 gal	–	–
Sucrose	$C_{12}H_{22}O_{11}$	100%	–	1,800 ft^3	–	–
Titanium dioxide	TiO_2	100%	–	1,000 ft^3	–	–
Zinc oxide	ZnO	100%	–	2,500 ft^3	–	–
Zirconium silicate	$ZrSiO_4$	100%	–	1,000 ft^3	–	–

[a] Quantities are approximate and based on current design estimates. A dash (–) indicates that significant quantities of the chemical would not be present in the indicated portion of the WTP (Lindquist 2006b).
[b] Mixtures of glass formers exist in LAW and HLW, but are not listed.
[c] The named product is a proprietary compound or mixture.
Note: To convert gallons to liters, multiply by 3.7854; cubic feet to cubic meters, by 0.028317.
Key: %=percent; ft^3=cubic feet; gal=gallon; HLW=high-level radioactive waste; LAW=low-activity waste; M=molar (moles per liter); N/A=not applicable; psig=pounds per square inch gauge; wt%=weight-percent; WTP=Waste Treatment Plant.
Source: Lindquist 2006b.

K.3.9.1.1 Ammonia

Anhydrous ammonia is a gas stored as a liquid under pressure; its normal boiling point at 1 standard atmosphere unit of pressure is –33 °C (–28 °F). Therefore, under most conditions, it rapidly returns to its gaseous state upon release to the environment. Inhalation may cause irritation (possibly severe), lack of sense of smell, nausea, vomiting, chest pain, difficulty breathing, headache, and lung damage; inhalation may be fatal. Skin contact may cause irritation (possibly severe), blisters, and frostbite. Eye contact may cause irritation (possibly severe), frostbite, tearing, blindness, and glaucoma. Ingestion may cause irritation (possibly severe), difficulty breathing, and kidney damage.

Ammonia is a negligible fire hazard and a moderate explosion hazard. Containers could rupture or explode if exposed to heat.

It is incompatible with acids, combustible materials, metals, oxidizing materials, metal salts, halo carbons, amines, reducing agents, cyanides, and bases. When used at the HLW Vitrification Facility within the WTP, it may react with boric acid, cerium nitrate, hydrogen peroxide, lithium carbonate, nitric acid, or sucrose to produce heat. The reaction with hydrogen peroxide may also liberate toxic gas, and the reaction with cerium nitrate may liberate flammable gas. However, because anhydrous ammonia is a gas stored as a liquid under pressure, it returns to the gaseous state upon release at ambient pressure. All of the HLW chemicals that might cause a reaction are in the form of either solids as powders or liquids. As a result, there is very limited potential for these materials to mix and produce a reaction, and potential reactions would be limited by the surface area available for contact.

A catastrophic failure of the 45,400-liter (12,000-gallon) storage tank (with an operating capacity of approximately 43,500 liters [11,500 gallons]) containing anhydrous ammonia could rapidly release its entire contents as ammonia gas (Lindquist 2006b). The gas was assumed to be released directly to the atmosphere over a period of 30 minutes. This assumption does not credit the mitigative effects of the control equipment or the building that houses the storage tanks, which would limit the amount of ammonia released to the atmosphere.

K.3.9.1.2 Nitric Acid

In its concentrated form, nitric acid is an acute inhalation hazard. It is not combustible, but it is a strong oxidizer, and the heat produced by its reaction with reducing agents or combustibles may cause irritation. It can react with metals to release nitrogen oxides and flammable hydrogen gas. It may react explosively with combustible organic or readily oxidizable materials.

Nitric acid is present in various concentrations in the Pretreatment Facility, Wet Chemical Storage Facility, and HLW Vitrification Facility. At the Wet Chemical Storage Facility, nitric acid in any concentration could react with any concentration of sodium hydroxide to produce heat. The reaction between the highest concentrations of nitric acid and highest concentrations of sodium hydroxide could generate extreme heat, resulting in fire. In the HLW Vitrification Facility, nitric acid could react with ammonia, boric acid, cerium nitrate, hydrogen peroxide, lithium carbonate, sodium hydroxide, or sucrose to generate heat. Reactions between concentrated nitric acid and lithium carbonate or sucrose could generate heat and flammable gas, igniting byproducts of the reaction and causing a fire. During pretreatment, weak concentrations of nitric acid (0.5 molar) and sodium hydroxide (0.1 molar) could react to create heat. The reaction between ion exchange resins and weak nitric acid is part of the process to remove captured cesium; however, reaction of the resin with concentrated nitric acid (greater than 10 molar) is vigorous and exothermic and releases large quantities of carbon monoxide gas.

The consequences of a spill release involving 12.2 molar nitric acid from the storage tank at the balance of facilities at the WTP complex has been investigated (Graves 2003) and is considered representative of a severe accident involving this material. The consequences of chemical spills in the balance of facilities would be less than those of a spill of the entire contents of the 79,500-liter (21,000-gallon) 12.2 molar nitric acid storage vessel (with an operating capacity of approximately 64,400 liters [~17,000 gallons]). This vessel is surrounded by a berm that is designed to contain at least 100 percent of the largest volume of the largest tank within it. A number of different mechanisms that could result in the total or partial loss of contents of this storage vessel have been identified. As the storage area is covered but open on all sides, the vapor would be released directly to the atmosphere. Parameters used in developing inputs for the dispersion code are shown in Table K–103.

Table K–103. Balance-of-Facilities Nitric Acid Spill Dispersion Modeling Parameters

Item	Value
Operating volume	64,400 liters (17,000 gallons)
Maximum capacity	79,500 liters (21,000 gallons)
Area of berm	160 square meters (23 feet × 75 feet = 1,725 square feet)
Nitric acid storage temperature	20 °C (68 °F)
Diameter of storage tank	3.7 meters (12 feet)
Molecular weight of nitric acid	63.01 grams per mole
Density of 12.2 molar nitric acid at 20 °C (68 °F)	1,350.5 grams per liter (84 pounds per cubic foot) (Perry and Green 1984)
Concentration (weight-percent) of 12.2 molar nitric acid	57 percent
Vapor pressure at 35 °C (95 °F)	1.69 millimeters (0.07 inches) of mercury (Perry and Green 1984)

Key: °C=degrees Celsius; °F=degrees Fahrenheit.

The temperature of the spilled pool was assumed to be 35 °C (95 °F). This temperature corresponds to a hot summer day and yields a conservative value for vapor pressure. The surface area of the spill is equal to the area of the berm minus the area of the storage tank:

$$A_{spill} = 1{,}725 \text{ square feet} - [(12 \text{ feet}/2)^2 (3.14)] = 1{,}610 \text{ square feet (150 square meters).}$$

K.3.9.1.3 Direct Human Health Impacts

Two chemicals, nitric acid and ammonia, were selected to represent all chemicals and would have the largest expected impacts due to accident releases. The selection of these two chemicals was based on the large quantities that are potentially available for release and their chemical properties and health effects. For both chemicals, an accident scenario was postulated in which a break in a tank or piping occurs, allowing the chemical to be released over a short period. The cause of the break could be mechanical failure, corrosion, mechanical impact, or natural phenomena. The frequency of the accident is in the range of 0.001 to 0.01 per year. Nitric acid would form a pool within a berm surrounding the tank and, by evaporation, be released as a plume that disperses into the environment. Ammonia would be released from its storage tank in a gaseous form. The chemical plume would move away from its point of release in a prevailing wind direction and could potentially impact workers and the public.

Table K–104 shows the estimated concentrations of each chemical at specified distances for comparison with the 60-minute AEGL-2 and -3 (EPA 2009). The levels of concern for ammonia are 160 ppm for AEGL-2 and 1,100 ppm for AEGL-3. The levels of concern for nitric acid are 24 ppm for AEGL-2 and 92 ppm for AEGL-3. The results indicate that AEGL-2 and AEGL-3 thresholds would not be exceeded beyond the nearest site boundary. For the noninvolved worker 100 meters (110 yards) from the accident, both the AEGL-2 and AEGL-3 thresholds would be exceeded for the ammonia release, but not for the nitric acid release.

Table K–104. Tank Closure Accidents – Chemical Impacts

Chemical	Quantity Released (gallons)	AEGL-2[a]		AEGL-3[b]		Concentration (ppm)	
		Limit (ppm)	Distance to Limit (meters)	Limit (ppm)	Distance to Limit (meters)	Noninvolved Worker at 100 meters	Nearest Site Boundary at 8,600 meters
Ammonia	11,500	160	2,450	1,100	730	41,000	27.0
Nitric acid	17,000	24	<30	92	<30	4.7	0.004

[a] AEGL-2 (60-minute) is the airborne concentration (expressed as ppm or milligrams per cubic meter) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape (EPA 2009).

[b] AEGL-3 (60-minute) is the airborne concentration (expressed as ppm or milligrams per cubic meter) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death (EPA 2009).

Note: To convert gallons to liters, multiply by 3.7854; meters to yards, by 1.0936.
Key: AEGL=Acute Exposure Guideline Levels; ppm=parts per million.

K.3.9.1.4 Secondary Impacts

Ammonia releases are fairly common events. Each year, about 40 releases resulting in injuries or evacuation occur in the state of Washington alone (WSDOH 2008). Ammonia is a gas at normal ambient temperatures that disperses into the atmosphere following its release. If a large release occurs, the gas may burn the leaves of nearby downwind vegetation but will not affect the roots, so damaged plants may fully recover. If ammonia were directly spilled into surface water or if water used by a fire department to suppress an ammonia vapor cloud were allowed to reach surface water, aquatic life could be harmed. After a release of ammonia, the vapors react with moisture in the air to form ammonium, which eventually returns to Earth in rainfall. Deposition of ammonium may be heavy near the location of release if it rains during or shortly after the release, before the plume has dispersed. Ammonium rarely accumulates in soil because whatever is not taken up by plant roots is rapidly converted by bacteria into nitrates. Nitrates in the soil are taken up by plants or leach vertically through the root zone (MDOA 2008).

The only secondary impacts expected from a large ammonia release at Hanford would be possible temporary damage to green vegetation in the plume path, followed by enhanced growth of all plants in the same area as a result of the infusion of nitrates into the typically nitrogen-poor desert soils. Because essentially all of the annual precipitation that falls on the site is taken up by plant roots or evaporates directly from the soil, leaching of nitrates through the vadose zone to the water table is not expected to present a discernable environmental impact.

Nitric acid released to the atmosphere as a gas is removed by deposition processes. The estimated half-life for dry deposition of nitric acid is 1.5 to 2 days, and it is efficiently scrubbed from the atmosphere by precipitation. Nitric acid reacts with gaseous ammonia in the atmosphere to form particulate or aerosol nitrate, which in turn is removed by wet and dry deposition of the particles. The average half-life and lifetime for particles in the atmosphere is about 3.5 to 10 days (DEWHA 2005). During the timeframe suggested by these removal rates, a nitric acid plume from the analyzed WTP release is expected to disperse widely over the region rather than be concentrated on or near the release site. The effect of nitrates produced and subsequently deposited on the soil would be the same as described previously for those derived from an ammonia release.

Concentrated acidic rainfall during or shortly after a nitric acid release (before the plume disperses) might harm vegetation and crops in areas near the site. However, effects lasting more than a single growing season are not expected because the surface soils of the Columbia Basin typically range from neutral to quite alkaline (with pH values of 7 or higher) and contain significant amounts of carbonates. They therefore have the capacity to neutralize acids without significant changes in soil pH. In fact, farmers and gardeners in the region frequently apply elemental sulfur and fertilizers containing iron sulfate, ammonium sulfate, or aluminum sulfate specifically to reduce soil pH to a more-favorable range for crops (WSU 2004).

K.3.9.2 Chemical Impacts of Fast Flux Test Facility Accidents

During FFTF decommissioning activities, the only chemical capable of creating a significant airborne hazard resulting from an accidental release is the sodium formerly used as a reactor coolant. Three inventories of bulk sodium are addressed under the FFTF Decommissioning alternatives covered by this EIS. These inventories include the FFTF bulk sodium stored in the SSF, the Hallam Reactor sodium stored in the 2727-W Building, and the SRE sodium stored in the South Alkali Metal Storage Modules in the 200-West Area. Under the FFTF Decommissioning alternatives proposed and analyzed in this EIS, these inventories would be either stored for the foreseeable future or processed at INL or Hanford into a 50 weight-percent solution of sodium hydroxide for use at Hanford.

Bulk sodium in its solid or molten form does not represent a significant airborne hazard. However, metallic sodium reacts violently with a broad range of materials, including water. On contact with water, it will ignite and produce hydrogen. Metallic sodium is highly flammable and may ignite spontaneously on exposure to moisture in the air. If sodium is burned in air, the resulting combustion byproducts are mostly sodium oxide, with a small percentage of sodium carbonate and a very small percentage of sodium hydroxide. Because of the ability of sodium oxide to react with water in the air (or in the human respiratory tract) to form sodium hydroxide, all of the sodium released from a fire was assumed to come off as sodium hydroxide; 1 gram (0.35 ounces) of sodium would produce 1.74 grams (0.61 ounces) of sodium hydroxide (Himes 1996).

An accidental spill and evaporative release of the 50 weight-percent sodium hydroxide produced under the Hanford and Idaho Reuse Options of FFTF Decommissioning Alternatives 2 and 3 would not represent an airborne hazard. As evaporation occurred, the water in solution would escape, leaving an even more-concentrated solution of sodium hydroxide behind. Eventually, the sodium hydroxide would dry out to the point that it formed crystalline sodium hydroxide. Sodium hydroxide would also be

produced during component cleaning and residual sodium residuals treatment. This waste material would be pumped from the point of generation to collection, storage, or treatment tanks for processing. A spray release could occur during pumping operations, which would create an airborne release. However, the pumping operation would have to occur at pressures of 100 pounds per square inch or more to generate aerosols that are an inhalation concern. It is not anticipated that pressures of 100 pounds per square inch or more will be used in any of the operations planned under any of the FFTF Decommissioning alternatives.

Because the sodium metal is contaminated with radioactive material, any airborne release caused by a fire would cause radiological as well as chemical impacts. For each sodium fire scenario analyzed as part of the radiological impacts of facility accidents, there is also a chemical impact. Therefore, the accident scenarios analyzed in this section of this appendix are the same as those analyzed in Section K.3.5.

As with the analysis of radiological impacts due to accidents, analysis of chemical impacts due to accidents was based on unmitigated releases, meaning that no credit was taken for HEPA filtration, structural confinement, or other engineered features that may limit the amount of the chemical released to the environment. Although a fire normally implies some degree of thermal lofting, which would reduce ground-level air concentrations, the intensity of the fire, and therefore the degree of the lofting, cannot be predicted. For this reason, fire scenarios were conservatively assumed to be ground-level sources for purposes of estimating direct receptor exposures. Results of sodium fire studies indicate that rapid agglomeration and fallout of the combustion particles occur in the first 50 to 100 meters (55 to 110 yards) of transport (Himes 1996). This process would greatly reduce the downwind air concentrations; however, because of the difficulty in quantifying this effect, it was not included as a factor in the release model. Because of the conservative assumptions discussed above, air concentration results near the source may exceed 100 milligrams per cubic meter, commonly thought to be the highest particulate concentration that can be supported in the air at a point away from the source (Himes 1996).

The alphanumeric code following the accident's title (e.g., SSF1) corresponds with the code in the accident's description in the tables of this section and in Chapter 4, Section 4.2.11; it is provided to facilitate cross-referencing between tables and accident descriptions.

K.3.9.2.1 Accidents in the Hanford 400 Area

K.3.9.2.1.1 Sodium Storage Facility Fire (SSF1)

This accident scenario involves a postulated aircraft crash into the FFTF SSF, breaching all four sodium storage tanks and igniting the sodium metal within them. This accident would result in a release rate of approximately 8,730 kilograms per hour (19,200 pounds per hour). Assuming an ARF of 0.35 and a yield of 1.74 grams of sodium hydroxide per gram of sodium burned (Himes 1996), the resulting production rate of airborne sodium hydroxide particulate would be 8,700 kilograms per hour (19,200 pounds per hour) × 0.35 × 1.74 = 5,320 kilograms per hour (11,700 pounds per hour).

A complete description of this scenario can be found in Section K.3.5.1.1.

K.3.9.2.1.2 Hanford Sodium Storage Tank Failure (HSTF1)

This accident was postulated to result from a large leak due to growth of a metal defect in one SSF storage tank. The tank was assumed to be initially filled with molten sodium and the entire inventory of the tank was assumed to discharge onto the steel floor of the secondary containment and burn. Exposure to the burning pool of sodium was assumed to breach the other three tanks, causing the sodium to leak into the burning pool. The resulting burn rate was estimated to be 22,600 kilograms per hour (49,800 pounds per hour), and the fire duration was estimated to be approximately 42 hours. Using an ARF of 0.35 and a yield of 1.74 grams of sodium hydroxide per gram of sodium burned (Himes 1996),

the resulting production rate of airborne sodium hydroxide particulate would be 22,600 kilograms per hour (49,800 pounds per hour) × 0.35 × 1.74 = 13,700 kilograms per hour (30,000 pounds per hour).

A complete description of this scenario can be found in Section K.3.5.1.2.

K.3.9.2.1.3 Remote-Handled Special Component Fire (RHSC1)

This scenario represents possible accidents involving removal and transport of the FFTF RH-SCs that would have the largest impacts. A handling mishap was postulated to cause a breach of the largest component (the primary cold trap) and exposure of the contained sodium to water and air. As a result, a portion (30 percent) of the sodium, 750 kilograms (1,650 pounds), would burn. Assuming that the diameter of the primary cold trap is approximately 1.53 meters (5 feet), the surface area of the burning sodium would be approximately 1.84 square meters (19.64 square feet). Using the standard burn rate for an open pool of sodium on a steel liner, 10.8 grams per square meter per second (8 pounds per square foot per hour) (Himes 1996), the burn rate was estimated to be 71.5 kilograms per hour (157 pounds per hour), and the fire duration was estimated to be approximately 36 hours. Using the sodium burn release parameters previously listed, the resulting production rate of airborne sodium hydroxide particulate would be 71.5 kilograms per hour (157 pounds per hour) × 0.35 × 1.74 = 43.5 kilograms per hour (96 pounds per hour). The release rate for this event is less than 1 percent of that for the Hanford sodium storage tank failure. Because the consequences of a chemical release are directly proportional to the release rate, the consequences of this release would be a very small fraction of those from either the Hanford sodium storage tank failure or the SSF fire discussed above. As impacts of this event would be less than those of the preceding events, it was not analyzed further.

A complete description of this scenario can be found in Section K.3.5.1.3.

K.3.9.2.2 Accidents in the Hanford 200-West Area

K.3.9.2.2.1 Hallam Reactor Sodium Fire (HSF1)

Sodium formerly used as coolant in the Hallam Reactor is stored as a solid in five tanks in the 2727-W Building in the Hanford 200-West Area. Two tanks are full, one is half-full, and the remaining two contain only residual heels. In this scenario, the building and a tank would be breached, allowing water to enter a tank, causing a fire to start. The entire contents of the full tank, 59,600 kilograms (131,000 pounds) of sodium, would burn and be released at ground level over a period of 67 hours. The postulated maximum release rate corresponds to a sodium pool fire with a size equal to the area of the internal tank dimensions, i.e., a 3.66 meter-diameter by 6.10-meter effective length (12-foot diameter by 20-foot length), equivalent to 22.3 square meters (240 square feet). Using the sodium burn release parameters previously listed (Himes 1996), the resulting production rate of airborne sodium hydroxide particulate would be 22.3 square meters × 38.88 kilograms per square meter per hour (240 square feet × 8 pounds per square foot per hour) × 0.35 × 1.74 = 531 kilograms per hour (1,170 pounds per hour).

A complete description of this scenario can be found in Section K.3.5.2.1.

K.3.9.2.2.2 Sodium Reactor Experiment Sodium Fire (SRE1)

Sodium formerly used as coolant in the SRE is stored as a solid in drums in the South Alkali Metal Storage Modules near the 200-West Area CWC. In this scenario, a vehicle would impact a single storage module, causing a fire, which would involve 20 drums consisting of a total of 3,360 kilograms (7,410 pounds) of sodium. The burning area was estimated to be equivalent to the 5.9-square-meter (63-square-foot) footprint of the single storage module. Using the sodium burn release parameters previously listed (Himes 1996), the resulting production rate of airborne sodium hydroxide particulate

would be 5.9 square meters × 38.88 kilograms per square meter per hour (63.5 square feet × 8 pounds per square foot per hour) × 0.35 × 1.75 = 141 kilograms per hour (311 pounds per hour).

A complete description of this scenario can be found in Section K.3.5.2.2.

K.3.9.2.3 Accidents at Idaho National Laboratory

K.3.9.2.3.1 INL Sodium Processing Facility Storage Tank Failure (INLSPF1)

The accident with the largest impacts from disposition of bulk sodium at the INL SPF would be a failure of the secondary sodium drain tank located in the EBR-II secondary sodium boiler building with an accompanying fire. Failure of the tank would result in a spill of its working capacity of molten sodium. The burn rate of the resulting fire was estimated to be 2,250 kilograms per hour (5,000 pounds per hour). Using the sodium burn release parameters previously listed (Himes 1996), the resulting production rate of airborne sodium hydroxide particulate would be 2,250 kilograms per hour (5,000 pounds per hour) × 0.35 × 1.75 = 1,380 kilograms per hour (3,020 pounds per hour).

A complete description of this scenario can be found in Section K.3.5.3.1.

K.3.9.2.4 Direct Human Health Impacts

A sodium fire produces a heavy, opaque, white plume. Contact with the plume in high concentrations near the source of release is immediately irritating and can cause burns to the upper respiratory tract, exposed skin, and surface of the eyes. The recognizable and characteristic heavy white plume, coupled with the immediate and severe health effects, create a self-evacuation effect for personnel in close proximity to a release.

Table K–105 shows the estimated concentrations of particulate sodium hydroxide for each accident scenario analyzed. As AEGL values have not been developed for sodium hydroxide, the American Industrial Hygiene Association ERPG levels 2 and 3 were compared to the concentrations at specific distances as an indicator of human health impacts. The guideline levels for sodium hydroxide are 5 milligrams per cubic meter for ERPG-2 and 50 milligrams per cubic meter for ERPG-3 (DOE 2008). The results indicate that, for the Hanford sodium storage tank failure scenario, the ERPG-2 value is slightly exceeded beyond the site boundary. For the remaining scenarios, the ERPG-2 and ERPG-3 thresholds would not be exceeded beyond the nearest site boundary. For the noninvolved worker 100 meters (110 yards) from an accident, both the ERPG-2 and ERPG-3 thresholds would be exceeded for all scenarios analyzed.

Table K–105. Fast Flux Test Facility Accidents – Chemical Impacts

Scenario	Distance to Site Boundary (meters)	Release Rate (kg/hr)	ERPG-2[a]		ERPG-3[b]		Concentration (mg/m^3)	
			Limit (mg/m^3)	Distance to Limit (meters)	Limit (mg/m^3)	Distance to Limit (meters)	Noninvolved Worker at 100 Meters	Site Boundary
Sodium Storage Facility fire (SSF1)	6,800	5,320	5	3,700	50	850	2,400	2.2
Hanford sodium storage tank failure (HSTF1)	6,800	13,800	5	7,350	50	1,520	6,200	5.6
Hallam Reactor sodium fire (HSF1)	4,300	531	5	855	50	233	240	0.41
Sodium Reactor Experiment sodium fire (SRE1)	3,500	141	5	395	50	113	63	0.14
INL Sodium Processing Facility storage tank failure (INLSPF1)	5,500	1,380	5	1,530	50	390	620	0.75

[a] ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

[b] ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Note: To convert meters to yards, multiply by 1.0936; kilograms to pounds, by 2.2046.

Key: ERPG=Emergency Response Planning Guideline; Hanford=Hanford Site; INL=Idaho National Laboratory; kg/hr=kilograms per hour; mg/m^3=milligrams per cubic meter.

K.3.9.2.5 Secondary Impacts

Section K.3.8.2 presents the secondary radiological impacts of FFTF accidents. The SSF fire (SSF1) was estimated to produce ground deposition of radionuclides exceeding 1.0 microcurie per square meter to a distance of 1.75 kilometers (1.1 miles) and 0.1 microcuries per square meter to a distance of 22.2 kilometers (13.8 miles) from the release location. These ground contamination levels were calculated using the sum of all radionuclide concentrations in FFTF primary sodium (i.e., the sum 5.6×10^{-9} curies per gram of sodium-22, 4.8×10^{-11} curies per gram of cesium-137, and 5.2×10^{-8} curies per gram of tritium). Dividing the calculated ground contamination level by the total sodium activity concentration (5.8×10^{-8} curies per gram) indicates that the 0.1-microcurie-per-square-meter contamination level corresponds to deposition of 1.72 grams of sodium per square meter (3.0 grams of sodium hydroxide per square meter). The sodium hydroxide deposition corresponding to 1.0 microcurie per square meter is 10 times greater (30 grams per square meter).

In areas where high levels of dry deposition have occurred, airborne (resuspended) particles of sodium hydroxide could cause skin, eye, and respiratory system irritation and other acute toxic effects associated with inhalation of sodium hydroxide aerosol. These effects might necessitate evacuation or relocation of people from heavily contaminated areas. Sodium hydroxide is very soluble in water. Once dissolved, it would be transported into the soil, where it would be rapidly neutralized by organic chemicals (Salocks and Kaley 2003). Therefore, evacuation or relocation would likely be necessary only until a significant precipitation event occurs. Significant precipitation events on or near Hanford are infrequent during the typically dry period between late spring and mid-autumn, and the duration of an evacuation or relocation might be weeks or even months if the release were to occur during those seasons.

Heavy precipitation events that could produce strongly alkaline runoff into streams and rivers are infrequent in the vicinity of Hanford. However, a strongly alkaline solution that could be formed by the dissolution of sodium hydroxide in rain or irrigation water could harm the foliage or tender shoots of growing plants. Sodium hydroxide does not accumulate in the food chain (ATSDR 2002).

Significant long-term effects on soil fertility or productivity could occur in those areas where the deposition is heavy enough to cause a pronounced increase in soil pH. Most surface soils on and near Hanford are slightly to moderately alkaline (WSU 2008), and a large addition of sodium hydroxide might increase the pH to a level that causes essential minerals and nutrients to become less available to plants or the growth of beneficial microorganisms to be inhibited (SUNY ESF 2008). Soil texture and the ability of water and plant roots to penetrate it can also be negatively affected by excessive sodium. However, these effects can be remediated by addition of various fertilizers and soil amendments (Warrence, Bauder, and Pearson 2002).

K.3.9.3 Chemical Impacts of Waste Management Accidents

Hazardous waste at the SWOC exists in the contents of TRU waste containers and suspect TRU waste[2] containers and in sodium in storage modules at the CWC. The future disposition of the bulk sodium stored at the CWC is addressed in the FFTF Decommissioning alternatives. The consequences of accidents involving this inventory of hazardous material are addressed in Section K.3.9.2, "Chemical Impacts of Fast Flux Test Facility Accidents."

To estimate the potential impacts of an accidental release of the hazardous chemicals at SWOC, SWOC waste containers were evaluated using the methodologies of both the DOE safety analysis and emergency management programs to identify which hazardous chemicals should be subjected to quantitative analyses.

K.3.9.3.1 Safety Analysis Evaluation of Chemical Hazards

The DSASW (Fluor Hanford 2007) identifies a list of known hazardous chemical constituents that may be present in retrieved TRU waste and suspect TRU waste containers. The list was generated in 1992 by performing a survey of the *Solid Waste Information and Tracking System (SWITS)* database. The query identified nearly 400 chemicals known to exist in the containers present at SWOC through 1991. Because of the relative constancy of waste streams since the list was generated, it was assumed that the types and quantities of hazardous materials currently present in the SWOC containers are consistent with the types and quantities on the list (Fluor Hanford 2007). Using a set of criteria intended to identify hazardous materials that could potentially result in significant impacts on workers and the public, the list of 400 was condensed to a list of 24 hazardous materials. This condensed list is presented in Table K–106. The inventories of the materials on the condensed list were updated with the most current information and served as the starting point for the identification of materials requiring additional analysis in the DSASW. The DSASW notes that the material list and associated inventories are not intended to be inclusive of all hazardous chemicals that might be present in solid waste containers at SWOC, but the list is representative of the wide assortment of materials anticipated to be retrieved, handled, stored, and processed and results in a conservative estimate of impacts (Fluor Hanford 2007).

[2] Suspect TRU waste is radioactive waste that is thought to be TRU waste, but for which adequate characterization data are not yet available to confirm the classification.

Table K–106. Potential Hazardous Materials in Waste Feed Streams

Hazardous Material (CASRN)	Number of Containers with Amount Listed[a]	Maximum Amount in a Single Container (kilograms)	Median (kilograms)	Maximum Amount in a Single Location (kilograms)
Ammonia (7664-41-7)	5	2.61	0.45	2.94
Ammonium nitrate (6484-52-2)	3	32.5	7.4	32.5
Beryllium (7440-41-7)	118	7	1.814	7
Cadmium (7440-43-9)	157	93.54	0.0003	195.2
Cyclohexane (110-82-7)	4	18.1	2.22	18.1
Dioxane (123-91-1)	1	25.22	25.22	25.22
Hydrogen peroxide (7722-84-1)	4	0.50	0.10	1.85
Manganese (7439-96-5)	2	0.06	0.04	0.06
Mercury (7439-97-6)	184	31.8	0.041	661.5
Naphthylamine (91-59-8)	1	102.1	102.1	102.1
Nitric acid (7697-37-2)	149	130	0.02	411.6
Phosphoric acid (7664-38-2)	44	76.26	3.0	1,884.12
Propane (74-98-6)	1	3.35	0.90	5.9
Sodium (7440-23-5)	2	23.16	1.28	392.1
Sodium hydroxide (1310-73-2)	3,011	105.25	0.0004	3,247.3
Sodium hypochlorite (7681-52-9)	1	0.36	0.0075	0.36
Sodium oxide (12401-86-4)	16	48.26	48.26	724.4
Styrene (100-42-5)	6	15.46	0.556	15.46
Tetrahydrofuran (109-99-9)	6	2.98	0.0007	2.98
Uranium oxide (1344-57-6)	342	351.6	1.325	1,391.3
Uranyl nitrate hexahydrate (13520-83-7)	7	6.1	0.7	6.1
Vinyl chloride/ resins (75-01-4)	11	254	0.4536	1,135.5
Vinyl ester/acetate resins (9003-22-9)	4	2.75	0.95	2.75
Zirconium (7440-67-7)	187	13.8	11.64	1,168.4

[a] The number of individual containers for which the amount of the constituent was listed in the *Solid Waste Information and Tracking System (SWITS)* database. In some cases, records indicate contents only as a total for a group of containers.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: CASRN=Chemical Abstracts Service Registry Number.

Source: Fluor Hanford 2007:Table 3D-1.

The methodology used in the DSASW to evaluate danger associated with hazardous materials in retrieved TRU waste and suspect TRU waste involved comparison of the values of maximum inventories at a single location from Table K–106 with the reportable quantities, threshold quantities (TQs), and threshold planning quantities (TPQs) provided in applicable Federal regulations; see Table K–107 for a summary comparison. The goal of this process was to identify the hazardous waste material inventories that represent significant potential risks and select them for more-detailed analysis within the DSASW and comparison with the risk guidelines.

The first step of the screening process used in the DSASW included a comparison of values of maximum hazardous material inventories at a single location (see Table K–107) with the reportable quantity values presented in Table 302.4 of Title 40 of the CFR, Part 302, "Designation, Reportable Quantities, and Notification." The Hanford safety analysis methodology requires that a qualitative assessment of the

adequacy of controls be performed for chemical waste constituents that exceed reportable quantity values. As shown in Table K–107, this screening process concluded that the following chemical inventories at a single location exceed their respective reportable quantity values: beryllium, cadmium, mercury, naphthylamine (conservatively assumed to be beta, but alpha is also exceeded), sodium, sodium hydroxide, and vinyl chloride/resins. The results of the qualitative assessment of control adequacy determined that existing safety management programs would provide adequate protection for all receptors. The significant safety management programs are those designated for hazardous material protection (training, communication program), radioactive and hazardous waste management, operational safety (conduct of operations, fire protection), emergency preparedness (protective actions), and institutional safety (industrial safety). As a result, no quantitative accident analysis was performed in the DSASW for these chemicals (Fluor Hanford 2007).

Table K–107. Reportable Quantities

Hazardous Material (CASRN)	Maximum Amount in a Single Location (kilograms)	Reportable Quantity[a]	Threshold Quantity[b]	Threshold Planning Quantity[c]	Threshold Quantity for Accidental Release Prevention[d]
Ammonia (7664-41-7)	2.94	45.4 kilograms (100 pounds)	4,540 kilograms (10,000 pounds)	227 kilograms (500 pounds)	9,074 kilograms (20,000 pounds)
Ammonium nitrate (6484-52-2)	32.5	NR	NR	NR	NR
Beryllium (7440-41-7)	7	4.54 kilograms (10 pounds)	NR	NR	NR
Cadmium (7440-43-9)	195.2	4.54 kilograms (10 pounds)	NR	NR	NR
Cyclohexane (110-82-7)	18.1	454 kilograms (1,000 pounds)	NR	NR	NR
Dioxane (123-91-1)	25.22	45.4 kilograms (100 pounds)	NR	NR	NR
Hydrogen peroxide (7722-84-1)	1.85	NR	3,400 kilograms (7,500 pounds)	454 kilograms (1,000 pounds)	NR
Manganese (7439-96-5)	0.06	0.45 kilograms (1 pound)	NR	NR	NR
Mercury (7439-97-6)	661.5	0.45 kilograms (1 pound)	NR	NR	NR
Naphthylamine (91-59-8)	102.1	4.54 kilograms (10 pounds)	NR	NR	NR
Nitric acid (7697-37-2)	411.6	454 kilograms (1,000 pounds)	227 kilograms[e] (500 pounds)	NR	6,805 kilograms[f] (15,000 pounds)
Phosphoric acid (7664-38-2)	1,884.12	2,270 kilograms (5,000 pounds)	NR	NR	NR
Propane (74-98-6)	5.9	454 kilograms (1,000 pounds)	NR	NR	
Sodium (7440-23-5)	392.1	4.54 kilograms (10 pounds)	NR	NR	NR
Sodium hydroxide (1310-73-2)	3,247.3	454 kilograms (1,000 pounds)	NR	NR	NR
Sodium hypochlorite (7681-52-9)	0.36	45.4 kilograms (100 pounds)	NR	NR	NR
Sodium oxide (12401-86-4)	724.4	NR	NR	NR	NR
Styrene (100-42-5)	15.46	454 kilograms (1,000 pounds)	NR	NR	NR
Tetrahydrofuran (109-99-9)	2.98	454 kilograms (1,000 pounds)	NR	NR	NR

Table K–107. Reportable Quantities *(continued)*

Hazardous Material (CASRN)	Maximum Amount in a Single Location (kilograms)	Reportable Quantity[a]	Threshold Quantity[b]	Threshold Planning Quantity[c]	Threshold Quantity for Accidental Release Prevention[d]
Uranium oxide (1344-57-6)	1,391.3	NR	NR	NR	NR
Uranyl nitrate hexahydrate (13520-83-7)	6.1	45.4 kilograms (100 pounds)	NR	NR	NR
Vinyl chloride/ resins (75-01-4)	1,135.5	0.45 kilograms (1 pound)	NR	NR	4,540 kilograms (10,000 pounds)
Vinyl ester/acetate resins (9003-22-9)	2.75	2,270 kilograms (5,000 pounds)	NR	454 kilograms (1,000 pounds)	6,805 kilograms (15,000 pounds)
Zirconium (7440-67-7)	1,168.4	NR	NR	NR	NR

[a] Reportable quantity values taken from Table 302.4 of Title 40 of the *Code of Federal Regulations* (CFR), Section 302.4.
[b] Threshold quantity values taken from Appendix A of 29 CFR 1910.119.
[c] Threshold planning quantity values taken from Appendix A of 40 CFR 355.40.
[d] Threshold quantity values for accidental release prevention taken from Tables 1 and 3 of 40 CFR 68.130.
[e] A threshold quantity of 500 pounds (227 kilograms) is provided for 94.5 percent nitric acid (white fuming) in 29 CFR 1910.119. The Solid Waste Operations Complex waste stream does not include significant inventories of nitric acid at this concentration.
[f] The threshold quantity from 40 CFR 68, is for 80 percent nitric acid.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: CASRN=Chemical Abstracts Service Registry Number; NR=not reported—no reportable quantity, threshold quantity, or threshold planning quantity value was listed for these chemicals.

Source: Fluor Hanford 2007:Table 3D-2.

The next step of the DSASW screening process included a comparison of the maximum hazardous material inventories at single location (see Table K–107) with the TQ values presented in 29 CFR 1910.119 Appendix A, "Process Safety Management of Highly Hazardous Chemicals." Appendix A of 29 CFR 1910.119 provides a list of highly hazardous chemicals, toxics, and reactives with the potential to cause a catastrophic event when present at or above the TQ value. As shown in Table K–107, the maximum hazardous material inventories at a single location are below the respective TQ values for those chemicals that have a TQ listed in the appendix. Therefore, a process hazard analysis pursuant to 29 CFR 1910.119 was not required.

The maximum hazardous material inventories at a single location were then compared with the TPQ values presented in 40 CFR 355 Appendix A, "Emergency Planning and Notification," and the TQ values in of 40 CFR 68 Table 1, "Chemical Accident Prevention Provisions." Hazardous constituents of waste containers that did not exceed a TPQ or TQ value from the CFR sections listed above or that did not have a TPQ or TQ value listed were screened from further analysis based on the conclusion that these materials are not deemed to be highly hazardous materials by OSHA or EPA; thus, no further hazards assessments are required by the CFR.

The Hanford safety analysis methodology for assessing hazards associated with chemical waste constituents specifies that a quantitative analysis to compare potential exposures with evaluation guidelines be considered if a TQ (29 CFR 1910.119) or TPQ value (40 CFR 355) is exceeded. The methodology does not explicitly require a comparison with the 40 CFR 68 TQ values or direct actions if these values are exceeded. None of the maximum hazardous material inventories at a single location exceeded the TQ value from 29 CFR or 40 CFR or the TPQ value from 40 CFR. Consequently, it was not necessary to perform a quantitative analysis in the DSASW for any of the hazardous materials listed in Table K–107.

K.3.9.3.2 Emergency Management Evaluation of Chemical Hazards

In addition to evaluating chemical hazards found in the SWOC waste according to the safety analysis methodology, chemical hazards were evaluated using the methodology provided for the DOE Comprehensive Emergency Management Program, as required in DOE Order 151.1C, *Comprehensive Emergency Management System*. This methodology is intended to identify specific hazardous materials that, if released, could (1) cause impacts that would immediately threaten or endanger personnel and emergency responders in close proximity to the event, (2) potentially disperse beyond the immediate vicinity in quantities that threaten the health and safety of onsite personnel or the public, and (3) potentially disperse at a rate sufficient to require a time-urgent response to implement protective actions for workers and the public. Identified materials are quantitatively analyzed in an Emergency Preparedness Hazards Assessment to determine if they will be included as part of the technical planning basis for the DOE facility or activity.

The screening process prescribed by DOE Order 151.1C examines potential chemical hazards and eliminates materials from further consideration if they (1) are commonly used by the public, (2) are not readily dispersed in the atmosphere, (3) are not hazardous (toxic) to humans, or (4) exist in limited quantities. Because of the nature of the hazardous material within the waste found at SWOC, the "public use" exclusion does not apply.

The degree to which a substance represents an acute airborne hazard to humans is somewhat dependent on whether the material is in a form that can be readily dispersed. Solids that cannot be reduced to small particles by some mechanism are generally excluded from quantitative analysis. Liquids with a low vapor pressure (less than about 1 millimeter of mercury) are also excluded from quantitative analysis. However, waste packaging requirements generally prohibit free liquids from being disposed of in waste containers. Therefore, significant quantities of liquids that would create an airborne hazard due to evaporation are not likely to exist within SWOC waste containers. Most materials found in SWOC waste containers are powders consisting of a small percentage of particles of respirable size (less than about 10 microns in diameter) that are small enough to be transported a significant distance in air before they are removed due to gravitational settling. Also, most powders found in waste are contained in secondary containers (e.g., bags, cans, boxes). Therefore, mechanical impact or container spills are not expected to result in a significant airborne release of powders. The methodology used in the DSASW to produce the condensed list of chemicals shown in Table K–106 eliminated waste configurations that were not in a dispersible form, such as stabilized waste, grouted monoliths, waste containers in concrete high-integrity containers, waste containers in concrete culverts with lids in place, EBR-II casks in concrete storage vaults with lids in place, and alpha and mixed fission product caissons. As the waste forms that were obviously nondispersible have already been eliminated and little specific information was provided about the physical form of the materials listed, it was assumed that all materials listed were dispersible; thus, none were eliminated based on this criterion.

The DOE Hazardous Materials Emergency Management Program is primarily concerned with materials that cause significant adverse human health impacts as a result of acute exposures. In the chemical screening process, the National Fire Protection Association (NFPA) health hazard rating assigned to a chemical is used to indicate whether the possibility of adverse health effects is significant enough to warrant quantitative evaluation (DOE Order 151.1C). Chemicals with an NFPA health hazard rating of 0, 1, or 2 were presumed not to represent significant acute toxic health hazards to humans and were generally excluded from further analysis.

The DOE emergency management screening methodology specifies that hazardous materials should be eliminated as candidates for analysis if the materials are stored and used only in small quantities. A small quantity is considered a quantity that can be "easily and safely manipulated by one person" (DOE Order 151.1C). DOE guidance that accompanies the DOE emergency management order suggests

that the following values are consistent with the intent of the order: approximately 19 liters (5 gallons) for liquids, 18 kilograms (40 pounds) for solids, or 4.5 kilograms (10 pounds) for compressed gases (DOE Guide 151.1-2).

The results of applying the screening process discussed above are shown in Table K–108; the following chemicals would have been retained for further analysis based on emergency screening: cadmium, mercury, naphthylamine, nitric acid, phosphoric acid, sodium, sodium hydroxide, sodium oxide and uranium oxide. In the following discussion, these materials are subjected to the same analysis considerations used in an Emergency Preparedness Hazards Assessment to determine whether a material poses a significant hazard such that a quantitative analysis of the potential human health impacts would be included in a technical planning basis for a facility or activity.

Table K–108. Results of Emergency Management Screening

Hazardous Material (CASRN)	Maximum Amount in a Single Location (kilograms)	NFPA Health Hazard Rating[a]	Screening Results
Ammonia (7664-41-7)	2.94	3	Q
Ammonium nitrate (6484-52-2)	32.5	1	H
Beryllium (7440-41-7)	7	3	Q
Cadmium (7440-43-9)	195.2	4	R
Cyclohexane (110-82-7)	18.1	1	H
Dioxane (123-91-1)	25.22	2	H
Hydrogen peroxide (7722-84-1)	1.85	3	Q
Manganese (7439-96-5)	0.06	1	Q/H
Mercury (7439-97-6)	661.5	3	R
Naphthylamine (91-59-8)	102.1	NF	R
Nitric acid (7697-37-2)	411.6	3	R
Phosphoric acid (7664-38-2)	1,884.12	3	R
Propane (74-98-6)	5.9	1	Q/H
Sodium (7440-23-5)	392.1	3	R
Sodium hydroxide (1310-73-2)	3,247.3	3	R
Sodium hypochlorite (7681-52-9)	0.36	3	Q
Sodium oxide (1313-59-3)	724.4	3	R
Styrene (100-42-5)	15.46	2	Q/H
Tetrahydrofuran (109-99-9)	2.98	2	Q/H
Uranium oxide (1344-57-6)	1,391.3	3	R
Uranyl nitrate hexahydrate (13520-83-7)	6.1	1	Q/H
Vinyl chloride/resins (75-01-4)	1,135.5	2	H
Vinyl ester/acetate resins (9003-22-9)	2.75	2	Q/H
Zirconium (7440-67-7)	1,168.4	2	H

[a] NFPA health hazard ratings were obtained from the Savannah River Site database of hazard ratings (WSRC 2005).

Key: CASRN=Chemical Abstracts Service Registry Number; H=eliminated from further analysis based on health hazard rating criteria; NF=value not found; NFPA=National Fire Protection Association; Q=eliminated from further analysis based on quantity criteria; R=retained for further consideration.

K.3.9.3.2.1 Cadmium

Cadmium, a metal, was most likely used at Hanford in the form of sheets, foil, or wire. In these forms the material is nondispersible and could be screened from further consideration. However, it can also be found in granular or powder form; under accident conditions it was assumed to respond to dispersion like

a noncombustible contaminated solid. Table K–106 shows that the maximum amount in a single location is 195.2 kilograms (430.3 pounds) and the maximum amount in a single container is 93.54 kilograms (206.2 pounds). Therefore, the maximum quantity of cadmium at a single location is found in multiple containers. The accident event most likely to cause the maximum release from multiple containers is a fire event. Using the source term methodology employed in the DSASW for radiological releases, the ARF for a noncombustible contaminated solid (i.e., powders of nonreactive compounds) is 0.006, the RF is 0.01, and the DR for fire is 1.0 (Fluor Hanford 2007). Assuming the entire inventory at the location was involved in a fire, the resulting airborne release would be 0.006 × 0.01 × 1.0 × 195.2 kilograms (430.3 pounds) = 0.00117 kilograms (0.026 pounds). Under average meteorological dispersal conditions (i.e., 5 meters [16.4 feet] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 0.021 milligrams per cubic meter. TEELs 1, 2, and 3 for cadmium are 0.03, 1.25, and 9 milligrams per cubic meter (DOE 2008). Because the consequences of an airborne release from an accident would not exceed 10 percent of the TEEL-2 value at 100 meters (110 yards), the results of a quantitative accident analysis would not be included in the emergency management technical planning basis for the facility according to the Hanford criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.2 Mercury

Mercury is a silver-white, odorless, heavy transition metal; it is one of five elements that are liquid at or near room temperature and pressure. Long-term exposure to mercury vapors presents a severe health hazard. Short-term overexposure to high concentrations of mercury vapors can lead to breathing difficulty, coughing, acute chemical pneumonia, and pulmonary edema (fluid accumulation in the lungs/swelling). Mercury has a vapor pressure of 0.002 millimeters of mercury at 25 °C (77 °F); because it has a low vapor pressure, it evaporates extremely slowly. As a result, it would not be considered a significant acute airborne release hazard during a container spill, failure, or mechanical damage. Therefore, a fire event involving waste containers would be the most likely to cause an airborne release. Mercury is not flammable, but if heated to high temperatures will decompose into toxic vapors of mercury and mercury oxide. Using the same source term methodology employed previously, the ARF for packaged waste is 0.0005, the RF is 1.0, and the DR for fire is 1.0 (Fluor Hanford 2007). Assuming the entire inventory at a single location was involved in a fire, the resulting airborne release would be 0.0005 × 1.0 × 1.0 × 661.5 kilograms (1,460 pounds) = 0.331 kilograms (0.73 pounds). Under average meteorological dispersal conditions (e.g., 5 meters [16.4 feet] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 0.6 milligrams per cubic meter. The ERPG-1, -2, and -3 values for mercury vapor are 0.3, 2.05, and 4.1 milligrams per cubic meter, and the TEEL-1, -2, and -3 values for mercury oxide are 0.15, 1.08, and 10.8 milligrams per cubic meter (DOE 2008). As the consequences of an airborne release from an accident would not exceed either the ERPG-2 value for mercury vapor or the TEEL-2 value for mercury oxide at 100 meters (110 yards), emergency planning for response to the release would be needed only within the local area (i.e., within SWOC) according to the Hanford criteria to implement in the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.3 Naphthylamine

2-Naphthylamine is a white to red, shiny, flake-like solid that darkens on exposure to light. This substance is a known human carcinogen; chronic exposure has been shown to cause bladder cancer. The following acute health effects may occur immediately or shortly after exposure: contact can irritate the skin and eyes and high levels can interfere with the ability of blood to carry oxygen, causing headaches, fatigue, dizziness, and blue coloring of the skin and lips (NJDHSS 2004). The TEEL-1, -2, and -3 values for this substance are 5, 35, and 300 milligrams per cubic meter, respectively (DOE 2008); these values are relatively high because temporary exposure causes generally mild acute effects that are not life threatening. Although no NFPA health hazard rating was found for this chemical, relevant data indicated

that it is a health hazard because chronic exposure can cause cancer. The DOE emergency management program is primarily concerned with protecting workers and the public from acute health effects; thus, this material would be excluded from consideration in a facility technical planning basis because its primary health hazard (cancer) results from chronic exposure.

K.3.9.3.2.4 Nitric Acid

Nitric acid is extremely hazardous; it is corrosive, reactive, an oxidizer, and a poison. It is corrosive to the respiratory track if inhaled and can cause breathing difficulties and lead to pneumonia and pulmonary edema, which may be fatal. Nitric acid was used in a number of processing operations across Hanford in concentrations ranging from approximately 50 percent to 70 percent. The 60-minute AEGL-1, -2, and -3 values for nitric acid are 1.37, 61.8, and 237 milligrams per cubic meter, respectively (EPA 2009). These values were developed for white fuming nitric acid, which is a much more highly concentrated (with a higher percentage) nitric acid. It is most commonly found in liquid form; however, because free-standing liquids are prohibited in waste containers, it is most likely carried in absorbent materials within the waste. Nitric acid is not flammable but will decompose into toxic oxides of nitrogen when exposed to high temperatures. However, many of the materials found in waste containers (e.g., cellulose, plastics, rubber) also decompose to toxic oxides of nitrogen when exposed to high temperatures; many of these materials generate larger volumes of the toxic gases than nitric acid. The most severe dispersal condition would be a liquid spill. For purposes of estimating consequences of a severe release, it was assumed that all of the nitric acid listed in Table K–106 is in liquid form at an approximate percentage of 70 percent. At 25 °C (77 °F), 70 percent nitric acid has a partial pressure of 4.1 millimeters of mercury (Perry and Green 1984), and, assuming a spill depth of 1 centimeter (0.39 inches), would result in a pool surface area of approximately 27.4 square meters (295 square feet). Using this information and the EPIcode to model a liquid spill release results in a concentration of 6.7 milligrams per cubic meter at a distance of 100 meters (110 yards) from an accident. As the consequences of an artificially severe airborne release from an accident would not exceed the AEGL-2 value at 100 meters (110 yards), emergency planning for response to the release would be needed only within the local area (i.e., within SWOC) according to the Hanford criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.5 Phosphoric Acid

Phosphoric acid is a clear, colorless, syrupy liquid. Inhalation is not an expected hazard unless the material is released as an aerosol spray or heated to a high temperature. Mist or vapor inhalation can cause irritation to the nose, throat, and upper respiratory tract. Severe exposures can lead to chemical pneumonitis (inflammation of lung tissue). The vapor pressure is very low, 0.03 millimeters of mercury at 20 degrees Celsius (68 degrees Fahrenheit); therefore, it is not an airborne dispersal hazard due to its extremely slow evaporation (Mallinckrodt 2006). It is most commonly found in liquid form; however, because free-standing liquids are prohibited in waste containers, it is most likely carried in absorbent materials within the waste. The most likely means for phosphoric acid to be released to the air would be during a fire involving waste containers. The same source term methodology employed above is used to obtain an estimate of the consequences 100 meters (110 yards) from a fire. The ARF for packaged waste is 0.0005, the RF is 1.0, and the DR is 1.0 (Fluor Hanford 2007). Assuming the entire inventory at a single location was involved in a fire, the resulting airborne release would be $0.0005 \times 1.0 \times 1.0 \times 1{,}884.12$ kilograms (4,160 pounds) = 0.942 kilograms (2.08 pounds). Under average meteorological dispersal conditions (e.g., 5 meters [5.5 yards] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 0.17 milligrams per cubic meter. The TEEL-1, -2, and -3 values for phosphoric acid are 3, 500, and 500 milligrams per cubic meter, respectively (DOE 2008). As the consequences of an airborne release do not exceed 10 percent of the TEEL-2 value at 100 meters (110 yards) from an accident, the results of a quantitative accident analysis would not be included in the emergency management technical planning basis for the facility according to the Hanford

criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.6 Sodium Metal

As previously stated, the future disposition of the bulk sodium stored at the CWC is addressed in the discussion of the FFTF Decommissioning alternatives. The consequences of accidents involving this inventory of hazardous material are addressed in Section K.3.9.2, "Chemical Impacts of Fast Flux Test Facility Accidents."

K.3.9.3.2.7 Sodium Hydroxide

Sodium hydroxide is an odorless white solid usually found in the form of pellets or flakes. It was often used at Hanford in the form of a water-based solution. It is a severe irritant; effects from inhalation of sodium hydroxide dust or mist vary from mild irritation to serious damage of the upper respiratory tract, depending on severity of exposure. Symptoms may include sneezing, sore throat, and runny nose. Pneumonitis may occur following a severe acute exposure. Either in a water-based solution or as a solid, sodium hydroxide has a negligible vapor pressure; therefore, it is not a potential airborne hazard due to extremely slow evaporation. It is not flammable and is not considered a fire or explosion hazard. However, small particles of the solid could be suspended in the air during a fire if the material were absorbed in, packaged in, or in close contact with burning waste materials. Using the methodology referenced above for packaged waste and assuming that the entire maximum inventory at a single location is involved in a fire, the amount of material released to the atmosphere would be $0.0005 \times 1.0 \times 1.0 \times 3{,}247.3$ kilograms (7,170 pounds) = 1.62 kilograms (3.58 pounds). Under average meteorological dispersal conditions (e.g., 5 meters [5.5 yards] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 0.29 milligrams per cubic meter. The ERPG-1, -2, and -3 values for sodium hydroxide are 0.5, 5, and 50 milligrams per cubic meter, respectively (DOE 2008). As the consequences of an airborne release from an accident would not exceed 10 percent of the ERPG-2 value at 100 meters (110 yards), the results of a quantitative accident analysis would not be included in the emergency management technical planning basis for the facility according to the Hanford criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.8 Sodium Oxide

Sodium oxide is a white granular material; it reacts with water to produce sodium hydroxide and heat. When sodium oxide fumes or dust are inhaled, it comes into contact with the water in the respiratory tract and may result in severe burns, injury, or death. It is a noncombustible material, but it may decompose upon heating to produce corrosive and/or toxic fumes. However, many of the materials found in waste containers (e.g., cellulose, plastics, rubber) also decompose to toxic fumes when exposed to high temperatures; many of these materials would generate larger volumes of the toxic gases than sodium oxide when heated. The most likely means for sodium oxide to be released to the air would be a fire involving waste containers. The same source term methodology employed above was used to obtain an estimate of the consequences 100 meters (110 yards) from a fire resulting in the release of sodium oxide. The ARF for packaged waste is 0.0005, the RF is 1.0, and the DR for fire is 1.0 (Fluor Hanford 2007). Assuming the entire inventory at a single location was involved in a fire, the resulting airborne release would be $0.0005 \times 1.0 \times 1.0 \times 724.4$ kilograms (1,600 pounds) = 0.362 kilograms (0.80 pounds). Under average meteorological dispersal conditions (i.e., 5 meters [5.5 yards] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 0.65 milligrams per cubic meter. The TEEL-1, -2, and -3 values for sodium oxide are 0.25, 2.5, and 25 milligrams per cubic meter, respectively (DOE 2008). As the consequences of an airborne release from an accident would not exceed the TEEL-2 value at 100 meters (110 yards), emergency planning for response to the release would be needed only

within the local area (i.e., within SWOC) according to the Hanford criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.2.9 Uranium Oxide

Uranium oxide (uranium black oxide) is a black, radioactive, crystalline powder. It occurs naturally in the mineral uraninite and, if produced from enriched uranium, it is used in nuclear fuel rods in nuclear reactors. Prior to 1960, it was used as yellow and black color in ceramic glazes and glass. Depleted uranium oxide can be used as a material for radiation shielding. The form found primarily in the mixed waste containers is depleted. Using the methodology referenced above for packaged waste and assuming that the maximum inventory at a single location is involved in a fire, the amount of material released to the atmosphere would be $0.0005 \times 1.0 \times 1.0 \times 1{,}391.3$ kilograms (3,072 pounds) = 0.7 kilograms (1.55 pounds). Under average meteorological dispersal conditions (i.e., 5 meters [5.5 yards] per second and D stability), the airborne concentration 100 meters (110 yards) from a fire would be 1.3 milligrams per cubic meter. The ERPG-1, -2, and -3 values for uranium oxide (uranium black oxide) are 0.681, 10, and 30 milligrams per cubic meter, respectively (DOE 2008). As the consequences of an airborne release from an accident would not exceed the ERPG-2 value at 100 meters (110 yards), emergency planning for response to the release would be needed only within the local area (i.e., within SWOC) according to the Hanford criteria used to implement the DOE Comprehensive Emergency Management Program (DOE Order 151.1C).

K.3.9.3.3 Impacts

The chemicals listed as known chemical hazardous constituents that may be present in retrieved TRU waste and suspect TRU waste containers (see Table K–106 above) were examined using the methodologies for identifying hazardous chemicals that should be subjected to quantitative analyses in both the DOE safety analysis and emergency management programs. With the exception of sodium metal, which is addressed in Section K.3.8.2, none of the chemicals listed would require analysis or inclusion in a documented facility safety analysis or Emergency Preparedness Hazards Assessment because their forms, quantities, and associated health hazards do not warrant such analysis.

The chemical hazards in the waste management containers are generally mixed together with the radiological hazards. Radiological accident scenarios analyzed in Section K.3.6, "Waste Management Accident Scenarios," would be expected to release both radioactive and chemical materials. Based on the discussions above, the scenario most likely to release a significant quantity of hazardous chemicals is a fire event involving multiple waste containers. Of the radiological scenarios analyzed in Section K.3.6, the large fire of waste containers outside a facility (SWOC FIR-4) most closely resembles the maximum foreseeable scenario postulated for the release of a chemical hazard. The dose consequence to the noninvolved worker 100 meters (110 yards) from this event would be 260 rem, and doses from the other fire scenarios analyzed would range from approximately 1 rem to a maximum of 300 rem (see Tables K–98 and K–100).

The evaluation of chemical exposures shows that exposures to the noninvolved worker do not exceed the AEGLs (i.e., 60-minute AEGL-2 value) established by EPA and implemented by DOE as the trigger points for planning protective measures for the public in the event of a large release of hazardous chemicals. The equivalent radiological dose threshold established by EPA for planning protective measures in the event of a large release of radioactive material is 1 rem. From the results of the radiological analysis and the chemical evaluations, it is clear that the potential health impacts of the radioactive components of the waste far outweigh those of the chemical components. Therefore, further quantitative analysis to determine potential human health impacts due to an accidental release of hazardous chemicals from within the mixed waste is not necessary.

K.3.10 Impacts on Workers

In the event of an accident involving the release of radioactive material or toxic chemicals, onsite workers would be at risk of exposure and potentially harmful health effects. For the purposes of this EIS, the onsite worker population varies from approximately 2,000 to about 20,000, depending on the alternative.

The harmful impacts of an accidental release of radiological or chemical materials were assessed in terms of the probability (or frequency) of an accident's occurrence and consequences if the accident were to occur. For radiological accidents, the consequences are expressed in terms of radiation dose and the resulting risk of an LCF. For chemical accidents, the consequences are expressed in terms of the chemical concentrations in the air (ppm or milligrams per cubic meter) to which a worker might be exposed compared to the applicable concentration threshold (limit) at which certain health effects are expected. Depending on the severity of an accident, the consequences may also include prompt fatalities, particularly for involved workers close to the accident.

For this EIS, the impacts on an individual noninvolved worker located 100 meters (110 yards) from an accident were analyzed for a range of accidents. However, the impacts on the populations of involved and noninvolved workers were not analyzed for two reasons. First, the impacts on the populations of involved and noninvolved workers would depend on the distribution of the population, including the distance of each group from the accident location and whether each individual is indoors or outdoors. This information is too dynamic to properly model. Second, because Hanford tank closure facilities where involved workers would be located have not yet been constructed, no useful estimates of involved worker locations and protective features are available. That information is needed to accurately estimate accident impacts.

Alternatives with the least number of involved workers would generally have the lowest worker population impacts in the event of an accident. Workers nearest the accident would be the most vulnerable to harmful health effects and fatalities. Prior to initiation of operations, analyses would be conducted and documented in safety analysis reports and hazard assessment documents to ensure worker protection and safety during operations. Furthermore, technical safety requirements would be defined in conjunction with safety analysis reports for all facilities to minimize the risk to workers from potential accidents.

K.3.11 Assessment of Intentional Destructive Acts

Recent world events draw attention to the possibility of acts of sabotage and terrorism against U.S. interests, domestic and abroad. To protect against such actions, safeguards and security measures are employed at all DOE facilities. Because of the significance of its nuclear and chemical facilities as potential targets of such actions and for the purposes of this EIS, DOE has assessed the potential impacts of a deliberate airplane or vehicular crash into Hanford facilities.

K.3.11.1 Safeguards and Security

DOE has acted strongly and proactively to understand and to preclude or mitigate the threats posed by intentional destructive acts. In accordance with DOE Orders 470.4A and 470.3B, DOE conducts vulnerability assessments and risk analyses of facilities and equipment under its jurisdiction to evaluate the physical protection elements, technologies, and administrative controls needed to protect DOE assets. DOE Order 470.4A establishes the roles and responsibilities for the conduct of DOE's Safeguards and Security Program. DOE Order 470.3B (a) specifies those national security assets that require protection; (b) outlines threat considerations for safeguards and security programs to provide a basis for planning, design, and construction of new facilities or modifications to existing facilities; and (c) provides an adversary threat basis for evaluating the performance of safeguards and security systems. DOE also

protects against espionage, sabotage, and theft of radiological, chemical, or biological materials; classified information and matter; nonnuclear weapon components; and critical technologies.

No environmental impacts are expected because of compliance with DOE safeguard and security provisions based on the adequacy of the existing Hanford security provisions. Before startup of any new or substantially modified operations, DOE would conduct an indepth, site-specific safeguards and security inspection to ensure that existing safeguards and security programs satisfy DOE requirements. Any inadequacies would be resolved before the startup of the operations. Although it is not anticipated, if the safeguards and security review determined that additional security provisions were required, DOE would perform the appropriate NEPA review.

K.3.11.2 Assessment of Potential Impacts

The tank closure accident with the highest consequences and risks for all Tank Closure action alternatives is the unmitigated, seismically induced WTP collapse and failure (WT41). For the Tank Closure No Action Alternative, the unmitigated, seismically induced waste tank dome collapse (TK53) has the highest consequences and risks. The FFTF accident with the highest consequences and risks for all FFTF Decommissioning action alternatives is the RH-SC fire (RHSC1). For the FFTF Decommissioning No Action Alternative, the Hanford sodium storage tank failure (HSTF1) has the highest consequences and risks. The waste management accident with the highest consequences and risks for both the Waste Management No Action Alternative and the two action alternatives is the aircraft crash (SWOC EE-2). The accident scenarios are described in Sections K.3.4 through K.3.6.

A number of release scenarios that might be initiated by acts of terror or sabotage were considered with regard to how or whether they might aid in the comparison of EIS alternatives. The potential for and consequences of some intentional destructive act (IDA) scenarios are essentially the same under each of the alternatives. Because analysis of such acts would do little to aid or inform the decisionmaking process, scenarios were selected based primarily on whether the likelihood or consequences of the event would be substantially different under some EIS alternatives than under others. Primary considerations for selecting scenarios to be analyzed included the following:

- Quantities of radioactive or toxic material associated with each alternative
- Location(s) where the hazardous material is used or stored
- Degree of inherent physical protection against destructive acts that is associated with each alternative (for example, material that is kept in an underground vault under one alternative, but is stored above ground at some time under another)
- Properties of the material that affect its toxicity and/or dispersibility
- Proximity of a postulated release event to the MEI and/or general population (and hence, the health consequences of any given release to the environment)

Five scenarios caused by IDAs were selected for analysis: IDA-1 through IDA-5.

Explosive Device in Underground Waste Tank (IDA-1). It was postulated that explosions occur that displace a large portion of the soil overburden, breach the tank dome, and disperse a portion of the tank waste into the atmosphere. To maximize the radiological impact, all the tank waste was assumed to be solid (salt cake, sludge). In accordance with the recommendation of DOE Handbook 3010-94, the respirable release would be less than the TNT-equivalent weight of the explosive charge. The release was modeled as a ground-level release without mitigation (LPF of 1).

The assumptions and parameter values used to analyze the seismically induced waste tank dome collapse scenario (TK53) and explosive device in underground waste tank scenario (IDA-1) are summarized and compared in Table K–109. The results indicate that the impacts of an explosive device in an underground waste tank would be about four times greater than those of the seismically induced waste tank dome collapse.

Table K–109. Comparison of Seismically Induced Waste Tank Dome Collapse (TK53) and Explosive Device in Underground Waste Tank (IDA-1)

Scenario Assumption or Parameter	Seismically Induced Waste Tank Dome Collapse (TK53)	Intentional Destructive Act: Explosive Device in Underground Waste Tank (IDA-1)
Affected structures/buildings	One single-shell tank	One single-shell tank
Degree of structural damage	Collapse of dome with overburden falling into tank	Explosion that clears overburden followed by in-tank explosion that breaches tank dome and disperses waste
Material at risk	Contents of a typical single-shell tank	Contents of a typical single-shell tank
Damage ratio	1.0	1.0
Release mechanisms considered	Expulsion of headspace vapor and aerosols, splash of liquid, resuspension (entrainment) from exposed waste	Expulsion of headspace vapor and aerosols, explosive dispersal of solid waste
Release fraction (ARF × RF)	Headspace aerosols: 100 milligrams per cubic meter × 1,000 cubic meters Splash: 0.002 Entrainment – public (24 hour): 9.6×10^{-6} Entrainment – worker (8 hour): 3.2×10^{-6}	Headspace aerosols: 100 milligrams per cubic meter × 1,000 cubic meters (insignificant contributor to dose) Explosive dispersal: Respirable aerosols equal to TNT-equivalent weight of explosive
Release height	Ground level	Ground level
Mitigation	None (LPF=1)	None (LPF=1)
Consequences Population dose/risk MEI dose/risk Noninvolved worker dose/risk	 0.96 person-rem/0 (0.0006) LCFs 0.00021 rem/1×10^{-7} LCFs 0.22 rem/0.0001 LCFs	 3.8 person-rem/0 (0.0023) LCFs 0.00083 rem/5×10^{-7} LCFs 0.88 rem/0.0005 LCFs

Note: To convert kilograms to pounds, multiply by 2.2046; cubic meters to cubic feet, by 35.315.
Key: ARF=airborne release fraction; IDA=Intentional Destructive Act; LCF=latent cancer fatality; LPF=leak path factor; MEI=maximally exposed individual; RF=respirable fraction; TNT=trinitrotoluene.

Aircraft or Ground Vehicle Impact on WTP (IDA-2). A vehicle or aircraft crash and/or explosions initiated by an insider were postulated. It was assumed that these acts are sufficiently energetic to breach a portion of the exterior wall of the HLW Vitrification Facility. The HLW melter feed preparation vessels in the HLW vitrification process cell are protected by reinforced concrete radiation shielding walls 0.91 to 1.52 meters (3 to 5 feet) thick. For purposes of this analysis, it was postulated that the shield wall was penetrated and the two vessels were breached, causing the contents of 58,300 liters (15,400 gallons) of HLW melter feed to be spilled into the cell (BNI 2005). At the same time, aircraft or vehicle fuel was assumed to enter the cell and burn. The spilled radioactive waste slurry was assumed to heat to the boiling point. A boiling ARF × RF value of 0.001 (DOE Handbook 3010-94) was assumed, as well as the release of radioactive material to the environment through holes in the building walls (LPF of 1.0).

The assumptions and parameter values used to analyze the WTP collapse and IDA scenarios are summarized and compared in Table K–110. The results indicate that the impacts of a deliberate airplane or ground transport vehicle crash into the WTP would be about one order of magnitude lower than those for WT41, the seismically induced collapse and failure of the entire WTP.

Table K–110. Comparison of Seismically Induced WTP Collapse and Failure (WT41) and Aircraft or Ground Vehicle Impact on WTP (IDA-2)

Scenario Assumption or Parameter	Seismically Induced WTP Collapse and Failure (WT41 – 6×30)	Intentional Destructive Act: Aircraft or Ground Vehicle Impact on WTP (IDA-2)
Affected WTP structures/buildings	Pretreatment, LAW Vitrification, and HLW Vitrification Facilities	HLW Vitrification Facility
Degree of structural damage	Total structural failure, breach of external walls and cell walls	Penetration of external wall and cell wall
Material at risk	Contents of all tanks and vessels in all three buildings	Contents of HLW melter feed preparation vessels only
Damage ratio	1.0	1.0
Release mechanisms considered	Spill and resuspension (entrainment) from pool	Spill and boiling from burning 2,000 gallons of diesel or jet fuel in cell[a]
Release fraction (ARF × RF)	Spill: 0.00005 Entrainment – public (24 hour): 9.6×10^{-6} Entrainment – worker (8 hour): 3.2×10^{-6}	Spill: 0.00004 Boiling: 0.001
Release height	Ground level	Ground level
Mitigation	None (LPF=1)	None (LPF=1)
Consequences Population dose/risk MEI dose/risk Noninvolved worker dose/risk[b]	 58,000 person-rem/35 LCFs 4.3 rem/0.0026 LCFs 13,000 rem/1 LCF	 3,400 person-rem/2 LCFs 0.25 rem/0.00015 LCFs 860 rem/1 LCF

[a] Heavy construction equipment (crawlers, earthmovers, etc.) typically have fuel tanks with a capacity of a few hundred gallons or less. The Boeing 737, a common commercial aircraft of a size that a skilled pilot might be able to fly into a preexisting breach in the external wall of the HLW Vitrification Facility, has a fuel capacity of about 6,800 gallons. Of that, about 45 percent is carried within the wings, which would likely be sheared off on impact and not penetrate intact into the cell. Depending on the takeoff fuel load and distance flown, the center tank might contain somewhat less than 4,000 gallons, half of which was assumed to enter the cell before being ignited

[b] Increased likelihood of an LCF for an individual, assuming the event occurs; value cannot exceed 1.

Note: To convert gallons to liters, multiply by 3.7854.

Key: ARF=airborne release fraction; HLW=high-level radioactive waste; LAW=low-activity waste; LCF=latent cancer fatality; LPF=leak path factor; MEI=maximally exposed individual; RF=respirable fraction; WTP=Waste Treatment Plant.

Intentional Breach of WTP Ammonia Tank (IDA-3). Under all Tank Closure alternatives except the No Action Alternative, the WTP would be completed and a 45,000-liter (12,000-gallon) (nominal capacity) tank of anhydrous ammonia would be part of the WTP (Lindquist 2006a). Section K.3.9.1.1 analyzes a tank failure that releases the tank's entire contents (43,500 liters, or 11,500 gallons) over a period of 30 minutes, approximating the leak rate from a 2.5-centimeter-diameter (1-inch-diameter) hole in the tank. An event that causes a near-instantaneous release of the entire tank's contents would produce the highest release rate and the greatest potential health impact. An IDA was postulated whereby an explosion caused massive damage to the WTP ammonia tank. The entire 43,500 liters (11,500 gallons) of liquid ammonia was assumed to be vaporized over a period of 1 minute. Typical (average) atmospheric dispersion conditions were assumed. The results of the 30-minute accident release and the explosion are summarized and compared in Table K–111.

Table K–111. Comparison of Ammonia Tank Failure Accident with Intentional Destructive Act (IDA-3)

Scenario	Quantity Released (liters)	AEGL-2[a]		AEGL-3[b]		Concentration (ppm)	
		Limit (ppm)	Distance to Limit (meters)	Limit (ppm)	Distance to Limit (meters)	Noninvolved Worker at 100 Meters	Nearest Site Boundary at 8,600 Meters
Tank failure (30-minute release)	43,500	160	2,450	1,100	780	41,000	27.0
Explosion (1-minute release)	43,500	160	22,000	1,100	8,000	>500,000	950

a **AEGL-2** (60-minute) is the airborne concentration (expressed as ppm or milligrams per cubic meter) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape (EPA 2009).

b **AEGL-3** (60-minute) is the airborne concentration (expressed as ppm or milligrams per cubic meter) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death (EPA 2009).

Note: To convert liters to gallons, multiply by 0.26417; meters to yards, by 1.0936.

Key: AEGL=Acute Exposure Guideline Levels; ppm=parts per million.

Explosion in FFTF Primary Cold Trap (IDA-4). The doses associated with an accident that releases the primary cold trap radionuclide inventory have been shown to be about 100 times greater than the impacts from burning the entire Hanford bulk sodium inventory. Furthermore, a deliberate high-energy dispersal of the cold trap inventory might release substantially more of the material than the 30 percent assumed to be released under accident conditions (scenario RHSC1). The potential for an IDA to occur in the 400 Area or at one of two other destinations (Hanford 200 Area or INL) provides an opportunity for comparing the FFTF Decommissioning No Action Alternative with both the Hanford and Idaho Reuse Options for disposition of bulk sodium. Accordingly, an IDA was postulated whereby the FFTF primary cold trap, containing 2,700 liters (710 gallons) of sodium, 470 curies of cesium-137, and 70 curies of cobalt-60 (ANL-W and Fluor Hanford 2002), was destroyed by an explosive/incendiary device during removal or handling. All the radioactive material was assumed to aerosolize and be released to the atmosphere. The results of the accident scenario (RHSC1) and the deliberate act scenario (IDA-4) are summarized and compared in Table K–112.

Large Aircraft Crash at SWOC Storage Building (IDA-5). The potential for IDAs that disperse radioactive or toxic materials to the environment would be eliminated only when the waste is finally disposed of (buried on site or transported off site). Varying amounts of radioactive material would remain vulnerable to dispersal as long as wastes are being generated by tank closure and other onsite operations or are being received from offsite sources for disposal at Hanford. Waste Management alternatives are not distinguished from each other by quantitative analysis of hypothetical IDAs that could occur under any of them. However, the scale of potential impacts from an IDA directed at waste management operations can be understood by a simple extrapolation from the most severe accident analyzed, the aircraft crash (EE-2) (Fluor Hanford 2007). That scenario involves damage to 960 out of 17,500 waste containers in a SWOC storage building. The estimated mean population dose from that release would be 1,300 person-rem, and 1 LCF would be expected as a result. The dose to the MEI was estimated to be 0.28 rem, and the dose to the noninvolved worker was estimated to be 300 rem. The most pessimistic extrapolation from that scenario would involve a larger airplane, more fuel, and a comparable degree of damage to all 17,500 containers. About 18 times as much radioactive material would thereby be released, and the consequences would be proportionately greater (24,000 person-rem to the population, 5.1 rem to the MEI, and 5,400 rem to the noninvolved worker). However, as pointed out in the DSASW, a larger fire would tend to produce a more-buoyant plume, resulting in greater dispersion in the atmosphere and a lower dose to the MEI for each unit of radioactive material released.

Table K–112. Comparison of Fire in FFTF Primary Cold Trap Breach due to Accident Scenario (RHSC1) and Deliberate Explosion Scenario (IDA-4)

Scenario Assumption or Parameter	Breach of Primary Cold Trap with Remote-Handled Special Component Fire (RHSC1)	Intentional Destructive Act: Explosion in FFTF Primary Cold Trap (IDA-4)
Cold trap contents	2,700 liters sodium 470 curies cesium-137 70 curies cobalt-60	2,700 liters sodium 470 curies cesium-137 70 curies cobalt-60
Damage mode, degree of damage	Handling mishap with breach of cold trap shell	Total disassembly of cold trap by explosive/incendiary device
Damage ratio	1.0	1.0
Release fraction (ARF × RF)	0.3	1.0
Release height	Ground level	Ground level
Mitigation	None (LPF=1)	None (LPF=1)
Consequences Population dose/risk MEI dose/risk Noninvolved worker dose/risk	 4.4 person-rem/0 (0.003) LCFs 0.00011 rem/7×10^{-8} LCFs 0.0009 rem/5×10^{-7} LCF	 12 person-rem/0 (0.007) LCFs 0.00029 rem/2×10^{-7} LCFs 0.0096 rem/6×10^{-6} LCFs

Note: To convert liters to gallons, multiply by 0.26417.

Key: ARF=airborne release fraction; FFTF=Fast Flux Test Facility; LCF=latent cancer fatality; LPF=leak path factor; MEI=maximally exposed individual; RF=respirable fraction.

K.3.12 Analysis Conservatism, Uncertainty, and Design Changes

The analysis of accidents was based on calculations relevant to hypothetical sequences of events and models of the effects of these events. The models make use of a variety of information and assumptions, including estimates of event frequencies and source terms, assumed pathways for environmental transport and exposure, and risk factors relating exposure to effects on human health and the environment. Within the scope of the analysis, the inputs are as realistic as possible. However, uncertainties associated with each selected input value and model assumption contribute to overall uncertainty in the results. The uncertainty associated with the result of each individual analysis was not estimated, but from one alternative to the next, the overall uncertainties associated with the analyses were estimated to be about the same.

In many cases, the scarcity of experience with the postulated accidents leads to uncertainty in the calculation of the consequences and frequencies. This fact has promoted the use of models or input values that yield conservative estimates of consequences and frequency. Due to the layers of conservatism built into the accident analysis for the spectrum of postulated accidents, the estimated consequences and risks to the public and workforce represent the upper limit for the individual classes of accidents. The uncertainties associated with the accident frequency estimates are enveloped by the conservatism of the analysis.

Of particular interest are the uncertainties in the estimates of cancer fatalities from exposure to radioactive materials. As discussed in Section K.1, the numerical values of the health risk estimators used in this *TC & WM EIS* were obtained by linear extrapolation from the nominal risk estimate for lifetime total cancer mortality resulting from exposures of 10 rad. Because the health risk estimators were multiplied by conservatively calculated radiological doses to predict fatal cancer risks, the fatal cancer values presented in this EIS are overestimates.

For the purposes of this EIS, the impacts calculated from the linear model were treated as an upper-limit, consistent with the widely used methodologies for quantifying radiogenic health impacts. This does not imply that health effects are expected. Moreover, in cases where the upper-limit estimators predicted more than 1 LCF, this does not imply that the LCF risk can be determined for a specific individual.

Following the Record of Decision and selection of alternatives, actions could be taken during implementation of the alternatives that would change the basis for the analyses and results presented in the final EIS. Under DOE NEPA requirements, any such changes are subject to NEPA review to determine whether additional NEPA analyses or evaluations are necessary. Additionally, in accordance with DOE safety requirements, facility designs, modifications, and changes in operations are subject to a safety review process to safeguard the health and safety of workers and the public during operations. The process includes hazards assessments, safety analyses, and operational safety requirements that define conditions and requirements for a safe operating envelope and an authorization basis. Following construction and startup of operations, any change in facility design and operations would be reviewed for compliance with the authorization basis for operations. If deemed necessary, further safety studies would be conducted, which could influence planned design changes, identify mitigation measures, and revise the operational safety requirements for continued safeguarding of public health and safety.

K.4 INDUSTRIAL SAFETY

This section provides supporting information for estimating the industrial safety impacts presented in Chapter 4 of this *TC & WM EIS*. Tables in Appendix I list the work phases, activities specific to each phase, total labor hours for each activity, and the total number of years a work activity would be conducted. Using the historical accident and fatality incident rates and total labor hours, the potential impacts on worker safety were evaluated.

Two categories of industrial safety impacts, total recordable cases (TRCs) and fatalities, are represented in Chapter 4 of this EIS. TRCs include work-related death or illness or injury that results in loss of consciousness, restriction of work or motion, transfer to another job, or requires medical treatment beyond first aid. A fatal occurrence is a work-related injury or illness that causes the death of the employee.

DOE and contractor TRC and fatality incident rates were obtained from the CAIRS database (DOE 2007b, 2007c). The CAIRS database is used to collect and analyze DOE and DOE contractor reports of injuries, illnesses, and other accidents that occur during DOE operations. General industry data were obtained from information maintained by the U.S. Bureau of Labor Statistics (BLS 2008, 2009).

A review of the data from 2001 through 2006 indicates that occupational injuries and illnesses incurred at Hanford have decreased. The ORP incidence of TRCs has decreased from 2.02 to 2.0 per 200,000 labor hours over this period. This rate includes all labor categories (e.g., construction, operations, engineering, etc.) associated with tank farm management and operations. During the same period, ORP has not experienced a fatality.

A number of occupational incidence rates were available for use in estimating the industrial safety impacts of the alternatives considered in this *TC & WM EIS*. The rates vary between 1.3 and 6.7 incidents per 200,000 labor hours, as shown in Table K–113. This table provides the four most relevant sources of data for this EIS: ORP data, Idaho Operations Office data, DOE and contractor data, and private industry data maintained by the U.S. Bureau of Labor Statistics.

Table K–113. Total Recordable Cases and Fatality Incident Rates

Labor Category	Total Recordable Case Rate[a]	Fatality Rate[b]
DOE and contractor	1.88	0.26
Construction (DOE and contractor)	2.4	0.0
Operations/production (DOE and contractor)	1.3	0.0
DOE Office of River Protection	2.0	0.0
Idaho Operations Office	1.5	0.0
Private industry (BLS)	5.0	4.0
Construction (private industry) (BLS)	6.7	11.8

[a] Average illness and injury cases per 200,000 labor hours from 2001–2006.

[b] Average fatality rate per 100,000 employee years from 2001–2006.

Key: BLS=U.S. Bureau of Labor Statistics; DOE=U.S. Department of Energy.

Sources: BLS 2008, 2009; DOE 2007b, 2007c.

The ORP TRC rate of 2.0 per 200,000 labor hours was selected as representative of the types of work associated with the alternatives under consideration. It includes contributions from all labor categories (e.g., construction, operations, engineering, etc.) and is slightly higher than the 1.88 rate experienced by the DOE-wide facilities. The incident rate for private industry was deemed not representative of typical DOE project experience. One set of alternatives identifies activities taking place at INL. A different TRC rate specifically for Idaho operations was used in these calculations.

As ORP has not experienced a fatality during recent history, the DOE and contractor rate (for all labor categories) of 0.26 per 100,000 employee years was adopted as representative of fatal occurrences. The impacts of illness and injury can be calculated using the total project labor hours and the selected rate shown in Table K–113. The total labor hours were calculated from the scaled data sets (SAIC 2007a, 2007b, 2007c, 2008) and are listed in the Appendix I tables for each of the alternatives. The subtotal for each type of activity (i.e., construction, operations, deactivation, and closure) is also provided.

Using the incident rates selected above and the projected labor hours provided in Appendix I**,** the occupational safety impacts associated with each of the alternatives were calculated. These impacts were calculated by multiplying the total labor hours by the TRC rate and dividing by 200,000 (i.e., incidence per 200,000 labor hours).

The number of fatalities per year for an activity can be calculated by multiplying the projected number of employees involved in that activity by the selected fatality rate shown in Table K–113 and dividing by 100,000. When the estimated number of fatalities per year is less than 1, no fatalities would be expected. For example, the number of labor hours for WTP operations under Tank Closure Alternative 3B is 77.6 million and the WTP is expected to operate for 22 years (see Appendix I, Table I–18). Dividing 77.6 million hours (total hours) by 22 years (years of operation) equals 3.53 million hours per year. Dividing hours per year of operation by labor hours per year (2,000) equals a WTP workforce of 1,764 FTE workers for each year of operation. Finally, multiplying workers per year by the fatality rate of 0.26 and dividing the product by 100,000 equals 0.0046, the number of fatalities projected per year of WTP operation. Chapter 4, Tables 4–98, 4–127, and 4–150 provide the projected number of TRCs and fatalities for Tank Closure, FFTF Decommissioning, and Waste Management alternatives, respectively.

K.5 REFERENCES

ACGIH (American Conference of Governmental Industrial Hygienists), 2002, *2002 Chemical Substances TLVs and BEIs*, Cincinnati, Ohio.

ANL-W (Argonne National Laboratory-West), 2004, *Idaho National Laboratory, Conceptual Design Report for the Remote Treatment Project, Annex to the Hot Fuel Examination Facility*, W7000-0134-ES, Rev. 4, Idaho Falls, Idaho, December.

ANL-W and Fluor Hanford (Argonne National Laboratory-West, Idaho Falls, Idaho, and Fluor Hanford, Inc., Richland, Washington), 2002, *Hanford Site Sodium Disposition Trade-Off Study*, April.

Aromi, E.S., 2004, CH2M HILL Hanford Group, Inc., Richland, Washington, personal communication (memorandum) to all CH2M HILL Hanford Group, Inc., employees and subcontractors, "Changes in Respiratory Protection Measures," March 27.

ATSDR (Agency for Toxic Substances and Disease Registry), 2002, *ToxFAQs for Sodium Hydroxide*, accessed through http://www.atsdr.cdc.gov/tfacts178.html, April.

Beyeler, W.E., W.A. Hareland, F.A. Durán, T.J. Brown, E. Kalinina, D.P. Gallegos, and P.A. Davis, 1999, *Residual Radioactive Contamination from Decommissioning, Parameter Analysis, Draft Report for Comment*, NUREG/CR-5512, Vol. 3, U.S. Nuclear Regulatory Commission, Washington, D.C., October.

BLS (U.S. Bureau of Labor Statistics), 2008, *Industry Injury and Illness Data, Charts 2001 Through 2006*, Injuries, Illnesses, and Fatalities Program, accessed through http://www.bls.gov/iif/oshsum.htm, October 23.

BLS (U.S. Bureau of Labor Statistics), 2009, *Census of Fatal Occupational Injuries (CFOI) – Current and Revised Data*, "Rate of Fatal Work Injuries per 100,000 Workers, 1992–2006," "Number and Rate of Fatal Occupational Injuries, by Industry Sector, 2003–2006," "Numbers and Rates of Fatal Occupational Injuries per Industry Division, 2001–2002," Injuries, Illnesses, and Fatalities Program, accessed through http://www.bls.gov/iif/oshcfoi1.htm, March 11.

BNI (Bechtel National, Inc.), 2002, *Revised Severity Level Calculations for the LAW Facility*, 24590-LAW-Z0C-W14T-00003, Rev. B, Bechtel National, Inc., Richland, Washington, January 26.

BNI (Bechtel National Inc.), 2004, *Design Basis Event: High Level Waste Molten Glass Spills*, 24590-HLW-Z0C-HMP-00001, Rev. E, Richland, Washington, December 14.

BNI (Bechtel National, Inc.), 2005, *Revised Severity Level Calculations for the HLW Facility*, 24590-HLW-Z0C-W14T-00013, Rev. C, Richland, Washington, October 20.

Bowman, B., 1994, *Preliminary Safety Evaluation for the Sodium Storage Facility*, WHC-SD-FF-PSE-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington, September 30.

Burbank, D.A., 2002, *Project 520, Immobilized Low-Activity Waste Disposal Facility, Preliminary Documented Safety Analysis*, RPP-13201, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Burk, K.W., 2007, Battelle, Pacific Northwest National Laboratory, Richland, Washington, personal communication (email) to K.W. Owens, Science Applications International Corporation, Germantown, Maryland, "JFDs," May 15.

Burley, G., 1990, *Transuranium Elements*, Vol. 2, *Technical Basis for Remedial Actions*, EPA 520/1-90-016, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C., June.

Cash, R.J., 2004, Babcock Services, Richland, Washington, personal communication (email) to D.L. Parker, CH2M HILL Hanford Group, Inc., Richland, Washington, "Vapor Exposure Events," July 9.

CEES (Columbia Energy & Environmental Services, Inc.), 2006, *FFTF Remote-Handled Special Components Inventory*, 6734-FFTF-Inventory-001, Rev. 0, Richland, Washington, May 24.

Census (U.S. Census Bureau), 2007a, *Summary File 1, 2000 Census of Population and Housing: Technical Documentation*, SF1/14 (RV), Washington, D.C., July.

Census (U.S. Census Bureau), 2007b, *Summary File 1 (SF 1) – 100 Percent Data*, Census 2000 Data Releases, accessed through http://www.census.gov.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2003a, *Improved Worker Protection from Chemical Vapors: Integrated Safety Management (ISM)*, CHG0310-07, Richland, Washington, October.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2003b, *Production Bulk Vitrification System Pre-Conceptual Engineering Report*, RPP-16215, Rev. 1, Richland, Washington, July 31.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2003c. This reference is for Official Use Only.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2003d, *Assessment of Aircraft Crash Frequency for the Hanford Site 200 Area Tank Farms*, RPP-11736, Rev. 0, Richland, Washington, March 22.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2004a, *Tank Farm Abnormal Operating Procedure: Response to Reported Odors or Vapor Exposures*, TF-AOP-015, Rev. B-1, Richland, Washington, April 30.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2004b, *Integrated Safety Management Update: Taking Action to Enhance Worker Protection from Chemical Vapors*, CHG0401-06, Richland, Washington, February.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2004c, *Integrated Safety Management Update: Taking Action to Enhance Worker Protection from Chemical Vapors*, RPP-21487, Richland, Washington, June.

Chanin, D.I., and M.L. Young, 1997, *Code Manual for MACCS2*, Vol. 1, *User's Guide*, SAND 97-0594, Sandia National Laboratories, Accident Analysis/Consequence Assessment Department, Albuquerque, New Mexico, March.

CIRRPC (Committee on Interagency Radiation Research and Policy Coordination), 1992, *Use of BEIR V and UNSCEAR 1988 in Radiation Risk Assessment: Lifetime Total Cancer Mortality Risk Estimates at Low Doses and Low Dose Rates for Low-LET Radiation*, ORAU92/F-64, Science Panel Report No. 9, Office of Science and Technology Policy, Executive Office of the President, Washington, D.C., December.

DEWHA (Australian Government Department of the Environment, Water, Heritage and the Arts), 2005, *Nitric Acid – Substance Fact Sheet*, accessed through http://www.npi.gov.au/database/substance-info/profiles/65.html, August 15.

DOE (U.S. Department of Energy), 1992, *Environmental Assessment, Hanford Environmental Compliance Project, Hanford Site, Richland Washington*, DOE/EA-0383, Washington, D.C., March.

DOE (U.S. Department of Energy), 1995, *Hanford Site Risk Assessment Methodology*, DOE/RL-91-45, Rev. 3, Richland Operations Office, Richland, Washington, May.

DOE (U.S. Department of Energy), 2002, *Recommendations for Analyzing Accidents Under the National Environmental Policy Act*, Office of Environment, Safety and Health, Office of NEPA Policy and Compliance, Washington, D.C., July.

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

DOE (U.S. Department of Energy), 2004a, *Investigation of Worker Vapor Exposure and Occupational Medicine Program Allegations at the Hanford Site*, Office of Security and Safety Performance Assurance, Office of Independent Oversight and Performance Assurance, April.

DOE (U.S. Department of Energy), 2004b, *EPIcode Computer Code Application Guidance for Documented Safety Analysis, Final Report*, DOE-EH-4.2.1.3-EPIcode Code Guidance, Office of Environment, Safety and Health, Washington, D.C., June.

DOE (U.S. Department of Energy), 2004c, *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements*, 2nd ed., Office of Environment, Safety and Health, Office of NEPA Policy and Compliance, Washington, D.C., December.

DOE (U.S. Department of Energy), 2006, *Environmental Assessment, Sodium Residuals Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility (FFTF) Project, Hanford Site, Richland, Washington*, DOE/EA-1547F, Richland Operations Office, Richland, Washington, March.

DOE (U.S. Department of Energy), 2007a, *Type A Accident Investigation Report: The July 27, 2007, Tank 241-S-102 Tank Spill at Hanford Tank Farms*, Vol. 1, Office of Health, Safety and Security, Office of Corporate Safety Programs, Washington, D.C., September.

DOE (U.S. Department of Energy), 2007b, *Computerized Accident Incident Reporting and Recordkeeping System (CAIRS)*, "DOE and Contractor Fatality Incidence Rates," Office of Health, Safety and Security, accessed through http://www.hss.energy.gov/CSA/Analysis/cairs/cairs/summary/oipds064/fatrate.gif, January 5.

DOE (U.S. Department of Energy), 2007c, *Computerized Accident Incident Reporting and Recordkeeping System (CAIRS)*, "DOE and Contractor Injury and Illness Experience by Year by Quarter, 2001 Through 2006, 4th Quarter," Office of Health, Safety and Security, accessed through http://www.hss.energy.gov/CSA/Analysis/cairs/cairs/, January 31.

DOE (U.S. Department of Energy), 2008, *Protective Action Criteria (PAC) with AEGLs, ERPGs, and TEELs: Rev. 24 for Chemicals of Concern (09/2008)*, Office of Health, Safety and Security, accessed through http://www.hss.energy.gov/HealthSafety/WSHP/chem_safety.teel.html, September.

DOE and Ecology (U.S. Department of Energy, Richland Operations Office, Richland, Washington, and Washington State Department of Ecology, Olympia, Washington), 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, DOE/EIS-0189, August.

Eckerman, K.F., A.B. Wolburst, and A.C.B. Richardson, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal

Guidance Report No. 11, EPA 520/1-88-020, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C, September.

Eckerman, K.F., R.W. Leggett, C.B. Nelson, J.S. Puskin, and A.C.B. Richardson, 1999, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13, EPA 402-R-99-001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C., September.

EPA (U.S. Environmental Protection Agency), 1989, *Risk Assessment Guidance for Superfund*, Vol. 1, *Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C., December.

EPA (U.S. Environmental Protection Agency), 2000a, *Soil Screening Guidance for Radionuclides: User's Guide*, EPA/540-R-00-007, Office of Radiation and Indoor Air, Office of Solid Waste and Emergency Response, Washington, D.C., October.

EPA (U.S. Environmental Protection Agency), 2000b, *Radiological Emergency Response Plan*, Office of Radiation and Indoor Air, Washington, D.C., January 10.

EPA (U.S. Environmental Protection Agency), 2008, *Integrated Risk Information System*, accessed through http://www.epa.gov/iris, March 5.

EPA (U.S. Environmental Protection Agency), 2009, *Acute Exposure Guideline Levels (AEGLs)*, "AEGL Chemicals: Ammonia Results, Nitric Acid Results," accessed through http://www.epa.gov/opptintr/aegl/pubs/chemlist.htm, February 25.

Fluor Hanford (Fluor Hanford, Inc.), 2004a, *Hanford Safety Analysis and Risk Assessment Handbook*, HNF-8739, Rev. 1, Richland, Washington, August.

Fluor Hanford (Fluor Hanford, Inc.), 2004b, *Analysis of Sodium Hazards for the Solid Waste Operations Complex*, HNF-17444, Rev. 1, Richland, Washington, April.

Fluor Hanford (Fluor Hanford, Inc.), 2007. This reference is for Official Use Only.

Friedman, G.H., 2004, U.S. Department of Energy, Office of the Inspector General, Washington, D.C., personal communication (memorandum) to the Secretary of Energy, U.S. Department of Energy, Washington, D.C., "Investigation of Allegations Involving Occupational Medical Services and Tank Farm Vapor Exposures at the Hanford Site (OIG Case No. I04RL003)," June 1.

GAP (Government Accountability Project), 2003, *Knowing Endangerment: Worker Exposure to Toxic Vapors at the Hanford Tank Farms*, Nuclear Oversight Campaign, September.

Graves, R., 2003, *Design Basis Event: Balance of Facilities 12.2 M HNO_3 Vessel*, 24590-BOF-Z0C-30-00001, Rev. D, Bechtel National, Inc., Richland, Washington, May 19.

Himes, D.A., 1996, *Consequence Analysis of a Postulated NaOH Release from the 2727-W Sodium Storage Facility*, WHC-SD-WM-CN-045, Rev. 1, Westinghouse Hanford Company, Richland, Washington, September 27.

Homann, S., 2003, *Introduction to EPIcode*, Version 7.0, Homann Associates, Inc., September.

Lindquist, C., 2006a, *Consequence Analysis Methods for WTP Accident Analyses,* 24590-WTP-GPG-SANA-004, Rev. 3, Bechtel National, Inc., Richland, Washington, December 8.

Lindquist, C., 2006b, *Determination of Extremely Hazardous Substances*, 24590-WTP-RPT-ESH-01-001, Rev. 2, Bechtel National, Inc., Richland, Washington, March 23.

Mallinckrodt (Mallinckrodt Baker, Inc.), 2006, *Material Safety Data Sheet: Phosphoric Acid*, Phillipsburg, New Jersey, January 3.

MDOA (Minnesota Department of Agriculture), 2008, *Ecological Effects of Ammonia*, accessed through http://www.mda.state.mn.us/chemicals/ spills/ammoniaspills/ecoeffects.htm, December 9.

Medsker, M., 2007, *Safety Envelope Document; LAW Facility Specific Information*, 24590-WTP-SED-ENS-03-002-03, Rev. 1n, Bechtel National, Inc., Richland, Washington, October 11.

Napier, B.A., R.A. Peloquin, D.L. Strenge, and J.V. Ramsdell, 1988, *GENII – The Hanford Environmental Radiation Dosimetry Software System*, PNL-6584, Pacific Northwest Laboratory, Richland, Washington, December.

National Research Council, 1990, *Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V*, Committee on the Biological Effects of Ionizing Radiations, Board of Radiation Effects Research, Commission on Life Sciences, National Academy Press, Washington, D.C.

National Research Council, 2006, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*, Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, Board on Radiation Effects Research, Division on Earth and Life Sciences, National Academies Press, Washington, D.C.

NCRP (National Council on Radiation Protection and Measurements), 1987, *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 93, Bethesda, Maryland, September 1.

NJDHSS (New Jersey Department of Health and Senior Services), 2004, *Hazardous Substance Fact Sheet; 2-Naphthylamine*, Trenton, New Jersey, August.

NRC (U.S. Nuclear Regulatory Commission), 1990, *MELCOR Accident Consequences Code System (MACCS)*, NUREG/CR-4691, Washington, D.C., February.

Osborne, J.W., and J.L. Huckaby, 1994, *Program Plan for the Resolution of Tank Vapor Issues*, WHC-EP-0562, Rev. 1, Westinghouse Hanford Company, Richland, Washington, May.

Osborne, J.W., J.L. Huckaby, E.R. Hewitt, C.M. Anderson, D.D. Mahlum, B.A. Pulsipher, and J.Y. Young, 1995, *Data Quality Objectives for Generic In-tank Health and Safety Vapor Issue Resolution*, WHC-SD-WM-DQO-002, Rev. 1, Westinghouse Hanford Company, Richland, Washington, April.

Perry, R.H., and D.W. Green, 1984, *Perry's Chemical Engineers' Handbook*, 6th ed., McGraw Hill Book Company, New York, New York.

Rokkan, D.J., N.A. Homan, K. Rhoads, S.F. Snyder, and L.H. Staven, 2007, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2006*, DOE/RL-2007-01, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington, June.

SAIC (Science Applications International Corporation), 2007a, *Tank Closure Alternatives, Scaled Data Sets to Support the "Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,"* Germantown, Maryland, July 12.

SAIC (Science Applications International Corporation), 2007b, *Fast Flux Test Facility Alternatives, Scaled Data Sets to Support the "Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,"* Germantown, Maryland, July 12.

SAIC (Science Applications International Corporation), 2007c, *Waste Management Alternatives, Scaled Data Sets to Support the "Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,"* Germantown, Maryland, July 12.

SAIC (Science Applications International Corporation), 2008, *Revised Scaled Data Sets to Support the "Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington,"* Germantown, Maryland, October 9.

Salocks, C., and K.B. Kaley, 2003, *Technical Support Document: Toxicology, Clandestine Drug Labs: Methamphetamine*, Vol. 1, No. 7, *Sodium Hydroxide*, California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, September 24.

Schepens, R.J., 2005, U.S. Department of Energy, Office of River Protection, Richland, Washington, personal communication (letter) to E.S. Aromi, CH2M HILL Hanford Group, Inc., Richland, Washington, "Contract No. DE-AC27-99RL14047 – Assessment Report A-05-ESQ-TANKFARM-007, Industrial Hygiene (IH) Program," May 27.

Schofield, J.S., 2004, *Results of Nitrous Oxide Monitoring Equipment Tests and Badge Monitoring Non-personnel Area Tests Within Hanford Single Shell Tank Farms*, RPP-21448, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington, June.

Shire, P.R., W.L. Cowley, B.H. Gilbert, D.A. Smith, and G.L. Smith, 1995, *Potential Accidents with Radiological and Toxicological Source Terms for Hanford Tank Waste Remediation System Environmental Impact Statement*, WHC-SD-WM-ANAL-041, Rev. 0, Westinghouse Hanford Company, Richland, Washington, June.

Stock, L.M., and J.L Huckaby, 2000, *A Survey of Vapors in the Headspaces of Single-Shell Waste Tanks*, PNNL-13366, Pacific Northwest National Laboratory, Richland, Washington, October.

SUNY ESF (State University of New York College of Environmental Science and Forestry E-Center), 2008, *Soil pH: What it Means*, accessed through http://www.esf.edu/ pubprog/brochure/soilph/soilph.htm, December 9.

Valentin, J., ed., 2007, *Annals of the ICRP: The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103, International Commission on Radiological Protection, Elsevier, Amsterdam, The Netherlands, December.

Warrence, N.J., J.W. Bauder, and K.E. Pearson, 2002, *The Basics of Salinity and Sodicity Effects on Soil Physical Properties*, Montana State University, Land Resources and Environmental Sciences Department, accessed through http://waterquality.montana.edu/docs/methane/basics_highlight.shtml.

WHC (Westinghouse Hanford Company), 1994, *Conceptual Design Report - Sodium Storage Facility - Fast Flux Test Facility - Project F-031*, WHC-SD-FF-CDR-006, Rev. 0, Richland, Washington, October.

WHC (Westinghouse Hanford Company), 1996, *Assessment of the Potential for Ferrocyanide Propagating Reaction Accidents*, WHC-SD-WM-SARR-038, Rev. 1, Richland, Washington, July.

Woolfolk, S., 2007a, *Safety Envelope Document; HLW Facility Specific Information*, 24590-WTP-SED-ENS-03-002-04, Rev. 1q, Bechtel National, Inc., Richland, Washington, October 22.

Woolfolk, S., 2007b, *Safety Envelope Document; PT Facility Specific Information,* 24590-WTP-SED-ENS-03-002-02, Rev. 1o, Bechtel National, Inc., Richland, Washington, October 26.

WSDOH (Washington State Department of Health), 2008, *Ammonia Emergency Release Events in Washington State, 1993–2001*, Office of Environmental Health and Safety, Office of Environmental Health Assessments, Olympia, Washington.

WSRC (Westinghouse Savannah River Company), 2005, "Savannah River Site (SRS) Chemical Products Hazard Ratings," July.

WSU (Washington State University), 2004, *Soil pH*, Tree Fruit Research and Extension Center, accessed through http://soils.tfrec.wsu.edu/webnutritiongood/soilprops/soilpH.htm, November 22.

WSU (Washington State University), 2008, *Soils of Washington: Sagemoor Series, Hezel Series, Burbank Series*, accessed through http://remotesens.css.wsu.edu/washingtonsoil/, October 20.

Code of Federal Regulations

10 CFR 20, U.S. Nuclear Regulatory Commission, "Standards for Protection Against Radiation."

10 CFR 835, U.S. Department of Energy, "Occupational Radiation Protection."

10 CFR 835.1002, U.S. Department of Energy, "Occupational Radiation Protection: Facility Design and Modifications."

29 CFR 1910, Occupational Safety and Health Administration, U.S. Department of Labor, "Occupational Safety and Health Standards."

29 CFR 1910.106, Occupational Safety and Health Administration, U.S. Department of Labor, "Occupational Safety and Health Standards: Flammable and Combustible Liquids."

29 CFR 1910.119, Occupational Safety and Health Administration, U.S. Department of Labor, "Occupational Safety and Health Standards: Process Safety Management of Highly Hazardous Chemicals."

40 CFR 61.90–61.97, U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants," Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities."

40 CFR 68, U.S. Environmental Protection Agency, "Chemical Accident Prevention Provisions."

40 CFR 68.130, U.S. Environmental Protection Agency, "Chemical Accident Prevention Provisions: List of Substances."

40 CFR 141, U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations."

40 CFR 302, U.S. Environmental Protection Agency, "Designation, Reportable Quantities, and Notification."

40 CFR 302.4, U.S. Environmental Protection Agency, "Designation, Reportable Quantities, and Notification: Designation of Hazardous Substances."

40 CFR 355, U.S. Environmental Protection Agency, "Emergency Planning and Notification."

40 CFR 355.40, U.S. Environmental Protection Agency, "Emergency Planning and Notification: Emergency Release Notification."

U.S. Department of Energy Guides, Handbooks, Orders, and Standards

DOE Guide 151.1-2, *Technical Planning Basis – Emergency Management Guide*, July 11, 2007.

DOE Handbook 3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Vol. 1, *Analysis of Experimental Data*, December 1994.

DOE Order 151.1C, *Comprehensive Emergency Management System*, November 2, 2005.

DOE Order 470.1, *Safeguards and Security Program*, September 28, 1995.

DOE Order 470.3B, August 12, 2008. This reference is Classified.

DOE Order 470.4A, May 25, 2007. This reference is for Official Use Only.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, Change 2, January 7, 1993.

DOE Standard 1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components*, April 2002.

DOE Standard 1098-99, *Radiological Control*, July 1999.

APPENDIX L
GROUNDWATER FLOW FIELD DEVELOPMENT

This appendix describes the development of a regional-scale groundwater flow field for the Hanford Site. A groundwater flow field is a time-dependent, spatially varying representation of the direction and magnitude of groundwater flow. The Hanford groundwater flow field was critical to the evaluation and comparison of the potential long-term impacts of *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* alternatives, and evaluation of the long-term cumulative impacts, on resources related to groundwater.

L.1 INTRODUCTION

This *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* is being prepared in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 et seq.); U.S. Department of Energy (DOE) implementing procedures for NEPA (10 CFR 1021); and Council on Environmental Quality (CEQ) regulations for implementing the procedural provisions of NEPA (40 CFR 1500–1508). These regulations require that an environmental impact statement evaluate short- and long-term environmental impacts of the alternatives and their cumulative impacts. This *TC & WM EIS* evaluates the impacts of Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives on land resources, infrastructure, noise, air quality, geology and soils, water resources, ecological resources, cultural resources, socioeconomics (e.g., employment, regional demographics, housing and community services), public and occupational health and safety, environmental justice, and waste management activities. Contaminants in groundwater at the Hanford Site (Hanford) could potentially impact water resources, ecological resources, cultural resources, public health and safety, and environmental justice over the long term. In particular, the Columbia River and its associated ecological resources are highly valued resources that could be impacted by contaminants transported from Hanford through groundwater.

This *TC & WM EIS* quantifies impacts on the human and natural environment to the extent practicable, consistent with DOE's sliding-scale approach, taking into account available project information and design data. This approach to NEPA analysis implements CEQ's instruction to "focus on significant environmental issues and alternatives" (40 CFR 1502.1) and discuss impacts "in proportion to their significance" (40 CFR 1502.2[b]). This *TC & WM EIS* acknowledges uncertainty and incompleteness in the data and, where the uncertainty is significant or a major factor in understanding the impacts, explains how the uncertainty affects the analysis. Reasonably varied analyses are used to identify the range of potential flow fields consistent with the available data (see Section L.2). Thus, this *TC & WM EIS* balances the dual goals of accuracy and comparability against the available information and the need for timely decision-making.

L.1.1 Purpose

The purpose of this appendix is to describe the development of the model that simulates the groundwater flow field for Hanford. The groundwater pathway is one of the major pathways affecting the evaluation of the impacts of alternative and cumulative impacts at Hanford. The importance of the groundwater pathway is the connectivity between the waste disposal areas at the ground surface, the aquifer beneath Hanford, and the receptors exposed to that aquifer. The groundwater flow field is a calculation of the direction and rate of water movement in the aquifer. The groundwater flow field provides the connection between the source locations evaluated in the *TC & WM EIS* alternative and cumulative impact sources and the lines of analysis at which impacts are reported.

The groundwater flow field was calculated prior to simulation of contaminant transport in the vadose zone and unconfined aquifer. The groundwater flow field provides the numerical representation of water table

elevations and velocities that provided inputs to the vadose zone transport model STOMP [Subsurface Transport Over Multiple Phases] (see Appendix N) and the saturated zone transport model (see Appendix O). A well-calibrated groundwater flow field provides connection and consistency between the vadose zone and saturated zone transport models that are used to evaluate alternative and cumulative impacts.

Distinct flow fields resulting from different encoded data or assumptions, called design variants, were developed to span the range of expected conditions at Hanford. These reasonably varied design variants are used to assess the uncertainty of key flow field parameters, the sensitivity of simulated long-term impacts of *TC & WM EIS* alternatives to flow field parameters, and the effect reasonably foreseeable future scenarios would have on the flow field (see Section L.2).

Three key criteria were considered in the development of the *TC & WM EIS* groundwater flow field design variants based on NEPA requirements:

- The flow field must provide a basis for an unbiased evaluation of the impacts of the *TC & WM EIS* alternatives for the 10,000-year period of analysis (1940–11,940).
- The flow field must provide a basis for understanding the *TC & WM EIS* alternatives in the context of cumulative impacts.
- An evaluation and discussion of the effects of uncertainties and gaps in input data (e.g., spatial distribution of well borings across the study area), modeling assumptions (e.g., conceptualizing the top of basalt as a no-flow boundary), and numerical error (e.g., head and water balance residuals) must be provided.

This appendix describes how the *TC & WM EIS* groundwater flow field was developed to meet these requirements.

L.1.2 Scope

In describing the development of the *TC & WM EIS* groundwater flow field for Hanford, this appendix presents the following:

- The fundamental features of the regional-scale flow field model specific to Hanford
- Two design variants to evaluate the long-term impacts of TC & WM EIS alternatives
- The data sources, data, and representation (encoding) of the data in the flow field model
- Model parameters and settings
- Algorithms selected for the model
- Multiple phases of calibration to existing water-level data and the results of the preliminary and automated calibration processes

The model simulating the flow field was built incrementally as validated data became available; preliminary assumptions were tested, rejected, or finalized; and the interactions between release, vadose zone, and groundwater transport models were defined. This development history is not presented unless it informs the justification for the final model configuration. Similarly, numerous calculations were performed to evaluate the sensitivity of the simulated flow field to uncertainties in input parameters. This appendix describes the results where the calculations suggested that the groundwater flow field was

sensitive to changes in input parameters; other calculations are included in separate project documentation.

L.1.3 Technical Guidance

The *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose one and Groundwater Revised Analyses (Technical Guidance Document)* (DOE 2005) provides technical assumptions, model input parameters, and methodologies for proceeding with *TC & WM EIS* vadose zone (area of unsaturated soil and rock between ground surface and water table) and groundwater analyses. The technical bases supporting many of the assumptions result from various multiyear field- and science-based activities consistent with the Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement (Ecology, EPA, and DOE 1989); the Record of Decision for the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement (TWRS EIS)* (62 FR 8693); and the National Research Council's review of the *Draft TWRS EIS* (National Research Council 1996). This appendix indicates where design features or input data used in the development of the flow field are specified by the *Technical Guidance Document*.

The *Technical Guidance Document* specifies five key requirements for development of the *TC & WM EIS* groundwater flow field, as follows:

1. The flow field should be transient (i.e., change with time).

2. The factor driving the transient behavior should be operational recharge to the aquifer rather than time-changing boundary conditions.

3. The sitewide natural recharge rate should be 3.5 millimeters (0.14 inches) per year.

4. Both a Base Case and a Sensitivity (Alternate) Case should be investigated; the difference between the two cases should take into account the uncertainty in the top of basalt (TOB) elevation in the Gable Mountain–Gable Butte Gap (Gable Gap). The intent of the *TC & WM EIS* is to illustrate any potential differential effects this uncertainty might have on simulated alternative impacts. This approach was preferred (as opposed to presentation of results for all alternatives for each flow field) for brevity and clarity of presentation.

5. Flow field development should be consistent with the frameworks for vadose zone and contaminant transport modeling.

The *TC & WM EIS* groundwater flow model and simulated flow field meet these specifications.

L.2 DESIGN VARIANTS TO ADDRESS UNCERTAINTY AND SENSITIVITY

Groundwater at Hanford is found in a zone of permeable gravels, sands, silts, and clays that lie on top of multiple basalt flows and in interbed sediments (i.e., zones between basalt flows). The upper, fluvial (river–deposited) and lacustrine (lake–deposited) sediments on top of the basalt are referred to as suprabasalt sediments which are conductive and contain the upper, unconfined aquifer. The contact of the water-saturated suprabasalt materials with the relatively impermeable basalt is of particular importance at Hanford. For example, in the Gable Gap area near Gable Mountain and Gable Butte, the elevation of the basalt/suprabasalt sediment interface is uncertain. The difference between the top of basalt elevation and the water table elevation is an important factor governing groundwater flux through Gable Gap and consequently, the predominant direction of flow from the central plateau to the Columbia River. To address this uncertainty, two different flow fields were simulated.

The two flow fields, the Base and Alternate Cases, span the range of expected conditions at Hanford (see Sections L.2.1 and L.2.2). These cases result from different representations of the TOB elevation in the Gable Gap area. A third flow field was developed to evaluate the effect of a reasonably foreseeable future scenario—construction of the Black Rock Reservoir west of Hanford. Development of the Black Rock Reservoir case flow field and related analysis are described in Appendix V.

As discussed in Section L.1.3, the *Technical Guidance Document* (DOE 2005) specified development of two flow fields to take into account the uncertainty in the TOB surface in the Gable Gap area. The goal was to design two model variants that would perform the following actions:

- Simulate water table elevations during the operational period (1944–2006) equally well
- Exhibit different long-term (e.g., post-2006) flow directions and velocities in and around the Core Zone

For the purpose of this regional-scale model, the water balance in the unconfined aquifer beneath Hanford is assumed to have remained relatively constant since 1940, except for anthropogenic recharges resulting primarily from operations at Hanford. The basis for this modeling assumption is the *Technical Guidance Document* (see Section L.1.3). These operational recharges produced groundwater mounds beneath the 200-East and 200-West Areas on the Central Plateau of Hanford (see Section L.4.2.4). The dissipation of these mounds in terms of the long-term flow directions and velocities is strongly influenced by the TOB cutoff elevation in the Gable Gap area. If the TOB cutoff elevation in the Gable Gap area is high (relative to the water table), long-term flow from the Core Zone will be predominantly to the east. Conversely, lower TOB cutoff elevations in the Gable Gap area lead to long-term flow from the Core Zone that is predominantly to the north, through the Gable Gap.

The TOB surfaces in both the Base and Alternate Cases were produced by an analysis of approximately 850 point measurements of TOB elevations derived from boring logs and surface recordings. The analysis is discussed in detail in Section L.4.3.2.1 and is summarized here to develop the discussion of the Base and Alternate Cases. Each point measurement was assigned an uncertainty based on professional judgment of the quality of the record, the drilling method, the topography of the surface terrain, and the description of the contact between the suprabasalt sediments and basalt. The uncertainties in TOB elevation ranged from 1 to 30 meters (3.3 to 98.4 feet). All references to elevations in this appendix are relative to the North American Vertical Datum of 1988. From the best point estimates of TOB elevation and uncertainty, 100 sets (realizations) of point estimates were generated by adding a random variation (based on the uncertainty) to the best estimate of TOB elevation. A geostatistical analysis was used to create 100 TOB surfaces, one from each random realization. The TOB cutoff elevation in the Gable Gap area was identified for each realization.

L.2.1 Base Case

Because of the topology of the point estimates and their uncertainties, the TOB cutoff elevations in the Gable Gap area were not normally distributed. The distribution of cutoff elevations showed two reasonably strong tendencies: one approximately 118 meters (387 feet), and a second between 121 meters (397 feet) and 122 meters (400 feet) above mean sea level (amsl). A realization was chosen with a cutoff elevation of 121.5 meters (398.5 feet) amsl and encoded as the Base Case TOB surface. The Base Case represents the most likely TOB cutoff elevation in the Gable Gap area given the individual TOB measurements and their uncertainties.

L.2.2 Alternate Case

The Alternate Case was designed to have a lower TOB cutoff elevation in the Gable Gap area to increase the opportunity for long-term flow from the Core Zone to be predominantly northward, through the

Gable Gap. Ninety-five percent of the TOB surfaces had cutoff elevations greater than 118 meters (387 feet) amsl. The realization selected for the Alternate Case had a TOB cutoff elevation of 117.8 (387 feet) amsl. This model surface approaches the lower limit for the Gable Gap cutoff elevation that can be considered reasonably consistent with the measurements of TOB elevations.

L.3 MODEL DEVELOPMENT FRAMEWORK

The *TC & WM EIS* groundwater flow model simulates the time-varying spatial distribution of the rate and direction of water movement in the unconfined aquifer. Groundwater flow through the unconfined aquifer is simulated using the U.S. Geological Survey (USGS) MODFLOW [modular three-dimensional finite-difference groundwater flow model] 2000 Engine, Version 1.15.00 (USGS 2004). The commercial version used in this *TC & WM EIS* is Visual MODFLOW, Version 4.2 (WHI 2006). The resulting time-varying groundwater flow field is then used to simulate the transport of contaminants from their points of contact with the groundwater at various times in the history of the site to various receptor locations, including the Columbia River (see Appendix O).

The *TC & WM EIS* groundwater flow model was built using the best available information for Hanford. The development of the groundwater flow model was based, in part, on the Site-Wide Groundwater Model (e.g., Thorne et al. 2006), when features of the work were adequately documented, traceable, and independently verifiable. Previously compiled site data were used when they could be traced to a source and were judged to be adequate. When compiled site data were unavailable or inadequate for the development methodology used, historical primary data were obtained and processed for use or additional data were collected. Published conceptualizations informed some modeling decisions when neither compiled site data nor historical primary data were available for direct use or as input to associated models. When the above sources did not provide the necessary information, the required inputs were derived through engineering judgment or became model calibration parameters. MODFLOW groundwater flow model inputs derived both directly and indirectly from site data and knowledge are described in Section L.4. Model calibration data are described in Section L.6.1.

The MODFLOW groundwater flow model was developed in an incremental fashion, proceeding through a preliminary two-layer, steady state realization to the final transient, multilayered, calibrated, and parameterized model. This appendix presents the final version, describing the technical bases for model modifications, as well as the preliminary (see Section L.7), automated (see Section L.8), and Monte Carlo (see Section L.9) model calibration processes.

At key points during development of the MODFLOW groundwater flow model, technical reviews were performed to identify issues and concerns with important features of the model, provide suggestions for resolution of problem areas, and develop and understand alternative ways to conceptualize and encode model features. The technical review process had three major components:

- Review and comment by the Washington State Department of Ecology (Ecology), a cooperating agency on this *TC & WM EIS*
- Review and comment by a Local Users' Group (LUG), which consists of hydrogeologists and geologists from the Hanford community (modelers and field scientists)
- Review and comment by the MODFLOW Technical Review Group (MTRG), four experts with commercial, governmental, and academic experience in groundwater modeling and/or environmental engineering

During each review cycle, the *TC & WM EIS* groundwater modeling team presented status briefings to Ecology and LUG. Written comments from these two groups were solicited and provided to MTRG for their consideration and response, as they deemed appropriate. The *TC & WM EIS* groundwater modeling

team also presented the model development status briefing to MTRG. These presentations were open to the public. The *TC & WM EIS* groundwater modeling team and MTRG then spent several days discussing details of the model development effort and considering comments from Ecology and LUG. Finally, the MTRG provided their comments and suggestions in a closeout meeting, which was open to the public.

L.3.1 MODFLOW 2000

Per direction from the DOE Office of River Protection, the numeric engine selected for simulating groundwater flow was MODFLOW 2000, Version 1.15.00 (USGS 2004). A numeric engine performs the calculations to solve the equations describing water flow through the unconfined aquifer. MODFLOW 2000, a modular three-dimensional finite-difference groundwater flow model, describes the flow of groundwater into and out of every active finite model cell for each discrete time step and along all three dimensions: two horizontal and the vertical.

L.3.2 Visual MODFLOW 4.2

Per direction from the DOE Office of River Protection, the MODFLOW interface software selected for this *TC & WM EIS* was Visual MODFLOW, Version 4.2 (WHI 2006), a product that supports MODFLOW 2000 by providing tools for data input, model control, and presentation of model output. The MODFLOW 2000 numerical engine and its parameter settings in Visual MODFLOW, Version 4.2, are discussed further in Section L.5.3.

L.3.3 Parameter Estimation Module

The initial approach to model calibration included the use of Parameter Estimation Module (PEST) to determine the optimum set of hydraulic parameter values that would yield the best overall match of simulated head values to field-observed head values over the calibration period (1948–2006). This technical approach was implemented but resulted in unrealistically low uncertainty estimates for the range of optimum hydraulic parameter values. This result led the *TC & WM EIS* groundwater modeling team to believe that there may be multiple optimum sets of parameter values that are not related linearly. In other words, the objective function space is bumpy with several local minimums but not a single best minimum. The PEST process and results are discussed in more detail in Section L.8.

L.3.4 Monte Carlo Optimization

The PEST calibration process was useful in understanding the topography of objective function space but was not sufficient for determining an optimum set of hydraulic parameter values because this optimum set of values is non-unique. The *TC & WM EIS* groundwater modeling team then considered alternate methods to achieve the model calibration. They opted to perform a Monte Carlo optimization, selecting a random range of hydraulic parameter values around a specified mean value for each material type, then randomly combining these random sets of values together and completing a model run for that set. Thousands of model runs (6,660 cases for the Base Case model and 5,395 cases for the Alternate Case model) were completed with randomly selected hydraulic parameter values, and the root mean square (RMS) error (simulated heads compared to field-observed heads) for each model run was observed and tallied to determine which sets of random values produced the lowest RMS error. This approach to head calibration confirmed that there are many sets of reasonable hydraulic parameter values for the Base Case and Alternate Case models. This Monte Carlo optimization process is discussed in more detail in Section L.9.

L.4 MODEL INPUTS–CONCEPTUALIZATION, CHARACTERIZATION, AND ENCODING

This section describes the model inputs for defining the model grid design, cell properties, and flow boundary conditions. The encoding of these features of the *TC & WM EIS* groundwater flow model captures a conceptualization of the unconfined aquifer, its geomorphology, the hydrogeostratigraphic structure of the unconsolidated sediments, and its gross water budget based on underlying principles, data, and interpretation.

L.4.1 Discretization

"Discretization" of the groundwater flow model refers to the specification of the model domain (extent) and the compartmentalization (gridding) of the model domain in three dimensions: two horizontal and the vertical. Defining the model extent and the model grid is a matter of convenience informed by model purpose and computational considerations.

L.4.1.1 Extents

The *TC & WM EIS* groundwater flow model extents are determined by the Columbia and Yakima Rivers and by the top of the uppermost layer of basalt beneath the unconfined aquifer at Hanford.

The horizontal extents of the MODFLOW groundwater flow model are defined on the north, east, and south by the Columbia and Yakima Rivers. Review of hydrographs from wells along the river and comparison to river stage showed that the Columbia River is a reasonable hydrologic boundary. Coordinates for the Columbia and Yakima Rivers within the model domain were collected off shore within 25 meters (82 feet) of the nearshore bank using a global positioning system device in April 2006. The resulting river trace is shown in Figure L–1. The model extent on the west side is arbitrarily set at easting 557000, which is west of the Hanford boundary and the basalt ridge, Rattlesnake Mountain.

The minimum vertical extent is set at –90 meters (–295 feet) amsl, based on the lowest observed TOB elevation from boring logs for Hanford boreholes. The deepest estimated TOB elevation is –91 meters (–299 feet) amsl, which is rounded to –90 meters (–295 feet) in the model, given the uncertainties in elevation estimates. The maximum extent in the vertical direction is set at +165 meters (+541 feet) amsl, which is arbitrarily set above the maximum water table elevation (150 meters [492 feet]) for Hanford (Thorne et al. 2006:Figure 7.23).

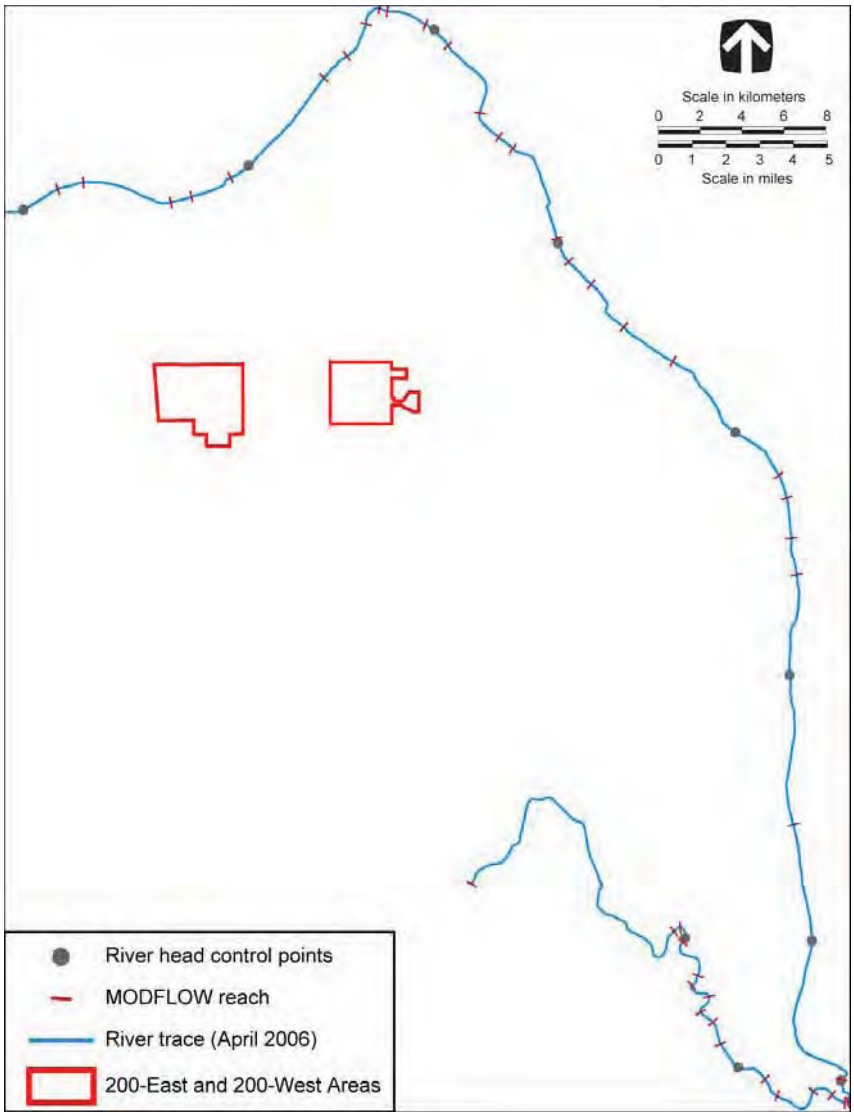
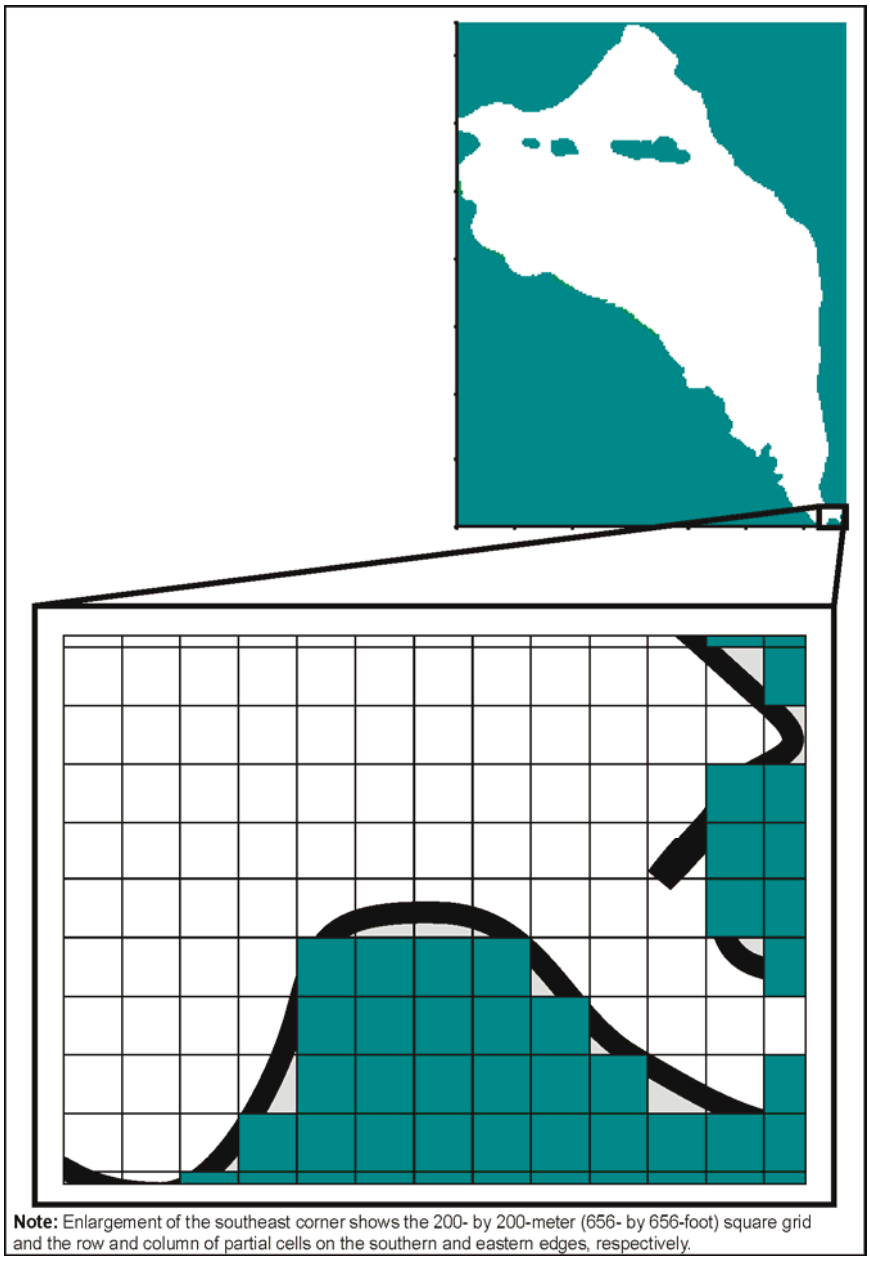


Figure L–1. MODFLOW Groundwater Flow Model Domain, Columbia and Yakima River Reaches, and River-Head Control Points

L.4.1.2 Gridding

The *TC & WM EIS* MODFLOW groundwater flow model divides Hanford within the model domain into three-dimensional blocks or cells. The model domain is divided into a 200- by 200-meter (656- by 656-foot) horizontal grid, with a "fringe" of partial cells on the northern, eastern, and southern sides. The sizes of the partial cells are defined by the distance between the last full-size row and column and the model extent. The horizontal grid and the fringe on the eastern and southern edges of the *TC & WM EIS* MODFLOW groundwater flow model are depicted in Figure L–2.



Note: Enlargement of the southeast corner shows the 200- by 200-meter (656- by 656-foot) square grid and the row and column of partial cells on the southern and eastern edges, respectively.

Figure L–2. Plan View of MODFLOW Horizontal Gridding

The interpolated elevation of the TOB surface in Gable Gap is not sensitive to the cell size of the horizontal grid. The lowest TOB elevation in Gable Gap (i.e., the "cutoff" elevation) determines the water level at which flow through the gap is possible. A comparison of 31 variants of the interpolated TOB surface for both a 200- by 200-meter (656- by 656-foot) grid and a 100- by 100-meter (328- by 328-foot) grid (see Section L.2.2) found that the elevation of the TOB surface in Gable Gap was not sensitive to grid size (see Table L–1). This finding justifies a uniform 200- by 200-meter (656- by 656-foot) grid across the entire model domain.

Table L–1. Top of Basalt "Cutoff"[a] Elevation in Gable Mountain–Gable Butte Gap by Grid Size and Aggregation Mean

Run	Description	Elevation (meters)	
		100- by 100-meter grid[b]	200- by 200-meter grid[c]
Default	Geostatistical Analyst (Johnston et al. 2001) default settings.	121	121
Variant 1	Reduce major range from default (22,580 m) to 22,354 m.	121	121
Variant 1a	Reduce major range from default (22,580 m) to 21,451 m.	121	121
Variant 2	Reduce minor range to 22,354 m; model direction = 0 degrees.	121	121
Variant 2a	Reduce minor range to 21,451 m. Major range = 22,580 m and model direction = 0 degrees.	120	120
Variant 3	Minor range = 22,354 m; model direction = 356 degrees.	121	121
Variant 3a	Reduce minor range to 21,451 m and change model direction to 352 degrees (or 172 degrees).	121	121
Variant 4	Reduce partial sill from default (12,519 m) to 12,394 m.	121	121
Variant 4a	Reduce partial sill from default (12,519 m) to 11,893 m.	121	121
Variant 5	Increase nugget from default (0 m) to 15 m.	121	121
Variant 5a	Increase nugget from default (0 m) to 150 m.	121	120
Variant 6	Partial sill = 12,394 m; increase nugget to 125 m; constant sill.	121	120
Variant 6a	Reduce partial sill from default (12,519 m) to 11,893 m and increase nugget to 626 m.	120	120
Variant 7	Increase neighbors to include per sector from default (5) to 6, "Include at Least" 2.	120	120
Variant 7a	Increase number of neighbors to include per sector from default (5, "Include at Least" 2) to 7, "Include at Least" 2.	120	120
Variant 8	Reduce lag size from default (4,859.2 m) to 4,810.7 m.	121	121
Variant 8a	Reduce lag size from default (4,859.2 m) to 4,616 m.	121	121
Variant 9	Increase number of lags to 13.	121	121
Variant 9a	Increase number of lags to 14.	121	121
Variant 10	Lag size 4,810.7 m; number of lags 13.	121	121
Variant 10a	Reduce lag size from default (4,859.2 m) to 4,616 m and increase number of lags to 14.	121	121

Table L–1. Top of Basalt "Cutoff"[a] Elevation in Gable Mountain–Gable Butte Gap by Grid Size and Aggregation Mean *(continued)*

Run	Description	Elevation (meters)	
		100- by 100-meter grid[b]	200- by 200-meter grid[c]
Random 1	Random Realization No. 1.	121	120
Random 2	Random Realization No. 2.	121	121
Random 3	Random Realization No. 3.	120	120
Random 4	Random Realization No. 4.	121	121
Random 5	Random Realization No. 5.	121	121
Random 6	Random Realization No. 6.	120	120
Random 7	Random Realization No. 7.	120	120
Random 8	Random Realization No. 8.	122	122
Random 9	Random Realization No. 9.	118	118
Random 10	Random Realization No. 10.	121	120

a Lowest maximum elevation along MODFLOW flow path through Gable Mountain–Gable Butte Gap.
b ESRI default mean.
c Harmonic mean.
Note: To convert meters to feet, multiply by 3.281.
Key: m=meters; MODFLOW=modular three-dimensional finite-difference groundwater flow model.

The *TC & WM EIS* MODFLOW groundwater flow model is divided into 31 layers in the vertical direction. Each layer is a uniform (constant) thickness across the entire model domain in the horizontal directions. The layers range in thickness from 1 meter (3.281 feet) to 40 meters (131 feet). The layering of the *TC & WM EIS* MODFLOW groundwater flow model is depicted in Figure L–3. The model has 1-meter (3.281-foot) thick layers at depths between 115 and 125 meters (377 and 410 feet) amsl, where the TOB surface is near the water table. These high-resolution layers span the TOB elevations simulated to occur in Gable Gap. Water levels fluctuate between these depths during the model simulation period. The thickest layers, which are greater than 15 meters (49.2 feet) thick, occur deep in the aquifer, where less resolution is required.

L.4.2 Boundary Conditions

The boundary conditions for the *TC & WM EIS* groundwater flow model are defined by the Yakima and Columbia Rivers, the subsurface influx of water into the unconfined aquifer along Rattlesnake Mountain, the basalt layer beneath the unconfined aquifer, and recharge (anthropogenic and natural) at the ground surface. The Columbia and Yakima Rivers and naturally occurring subsurface influxes of groundwater to the unconfined aquifer at three discrete locations along the western boundary are modeled as Generalized Head Boundaries (GHBs). With the exception of the discrete GHB-encoded areas along the western boundary where mountain-front recharge is thought to occur (see Section L.4.2.3), the basalt layer beneath the unconfined aquifer is assumed to be a no-flow boundary, i.e., no water enters the unconfined aquifer from the underlying basalt. For the *TC & WM EIS* groundwater flow model, the rivers, subsurface influx, basalt "basement," and natural recharges are taken as constant. The only time-varying fluxes of water across the model boundary are anthropogenic areal recharges. These boundary conditions are discussed below.

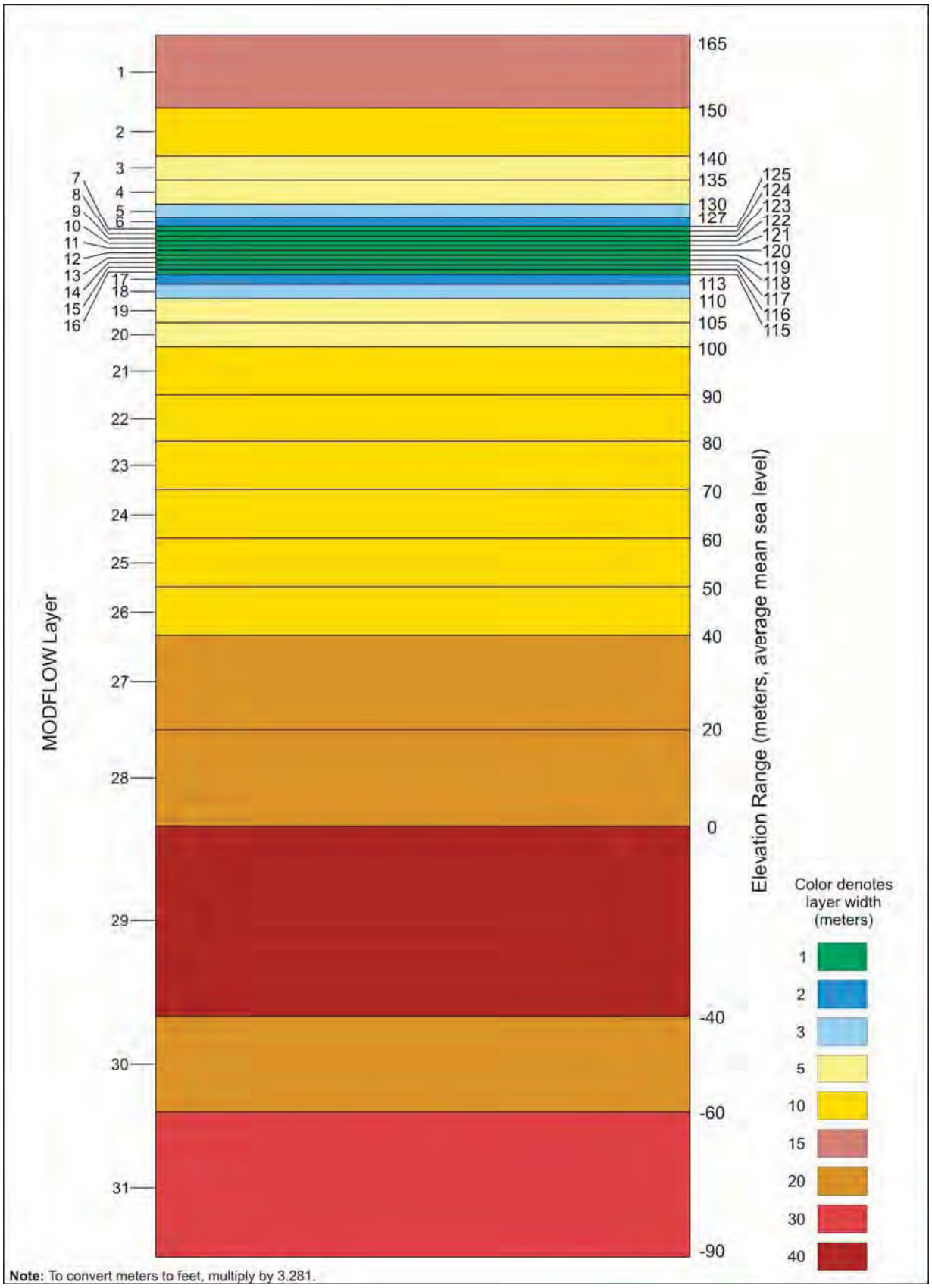


Figure L–3. Cross-Section View of MODFLOW Vertical Grid

L.4.2.1 Basalt Surface (No-Flow Boundary)

Massive basalts beneath the unconfined aquifer at Hanford define a no-flow boundary (aquiclude) in the *TC & WM EIS* groundwater flow model. A no-flow boundary represents a limit to flow within the unconfined aquifer. In this MODFLOW groundwater flow model, no water enters the unconfined aquifer from the underlying basalt. Except for a ridge of basalt in Gable Gap, the model cell in which the TOB surface (see Section L.2.2) is assigned and all lower cells are encoded in the model as "inactive." Inactive cells do not allow water to flow to neighboring cells and do not accept flow coming from neighboring cells. For the ridge of basalt in Gable Gap, only cells at 115 meters (377 feet) amsl and below are encoded as inactive; these elevations correspond to MODFLOW Layers 16 through 31. Cells above 115 meters (377 feet) amsl that are encoded as basalt are made active, with a hydraulic conductivity 500 times smaller than that of Hanford and Ringold muds (0.001 meters [0.00328 feet] per day). This active status prevents the MODFLOW cells from drying out during fluctuations of the water table which causes model instabilities (see Section L.5.1.1).

L.4.2.2 Columbia and Yakima Rivers (River Package)

The *TC & WM EIS* groundwater flow model uses the Visual MODFLOW river package to encode the Columbia and Yakima Rivers. This package encodes surface-water/groundwater interaction via a seepage layer (riverbed) separating the surface-water body from the groundwater aquifer. The portions of the Columbia and Yakima Rivers in the *TC & WM EIS* MODFLOW groundwater flow model domain (see Figure L–1) are encoded in the model as an unbroken sequence of cells sharing a face or vertex. Each 200- by 200-meter (656- by 656-foot) cell encoded as river is assigned to a reach, and each reach is assigned a conductance, which is an inverse measure of the resistance to flow between the streambed and the underlying aquifer. For the *TC & WM EIS* groundwater flow model, conductance is a calibration parameter.

In the MODFLOW river package, conductance is a function of the length and width of a reach and the thickness and conductivity of the streambed. The *TC & WM EIS* MODFLOW groundwater flow model sets streambed thickness at 2 meters (6.6 feet) and conductivity at 0.0004 meters (0.0013 feet) per second. Reach width is a uniform 200 meters (656 feet). Reaches of different lengths are defined on the basis of slope. Because the length and width of each reach are fixed, adjusting conductance during calibration implies an adjustment of the ratio of streambed conductivity to streambed thickness.

In the *TC & WM EIS* MODFLOW groundwater flow model domain, 27 reaches, each with a relatively constant slope, are defined on the Columbia River, and 14 reaches are defined on the Yakima River (see Figure L–1). Elevations were assigned to coordinates along the trace by interpolating from existing river elevation data developed by Pacific Northwest National Laboratory (PNNL) (Thorne et al. 2006). Elevations were assigned assuming constant slope between PNNL data points. The PNNL data set contains 700 data points for the Columbia River and 44 points for the Yakima River within the model extent. The entire Yakima River within the model domain is not modeled because the river upstream of Horn Rapids is assumed not in communication with the unconfined aquifer at Hanford.

The specified river stages, river bed thicknesses, and river bed conductances govern the interactions of the Columbia and Yakima Rivers with the unconfined aquifer. When the river stage is greater than the head in the aquifer immediately below, water flows from the river into the aquifer. The flow is reversed when the river stage is lower than the head in the aquifer immediately below. The former condition is described as a losing reach of the river, and the latter as a gaining reach. In general, the Columbia River gains throughout the modeled domain, and the Yakima River loses.

L.4.2.3 Mountain-Front Recharge (Generalized Head Boundary)

Groundwater is thought to enter the unconfined aquifer at Hanford from the underlying basalt layer in defined areas along the western boundary—Cold Creek Valley, Dry Creek Valley, and Rattlesnake Hills (Thorne et al. 2006). Well-documented springs occur in Cold Creek Valley and Dry Creek Valley. Runoff from the eastern face of Rattlesnake Hills is the third source of subsurface influx of groundwater along Hanford's "upstream" boundary.

These three examples of mountain-front recharge are encoded in the *TC & WM EIS* groundwater flow model using the Visual MODFLOW GHB package (see Figure L–4). With the GHB package, one defines groups of cells (zones) with specific values for head and parameters affecting conductance, the resistance to water flow into the cells of the zone. The head and conductance parameters for each of the three GHB zones in the *TC & WM EIS* MODFLOW groundwater flow model are varied to calibrate the model to observed water levels (see Section L.7).

L.4.2.4 Natural Areal Recharge (Recharge Boundary)

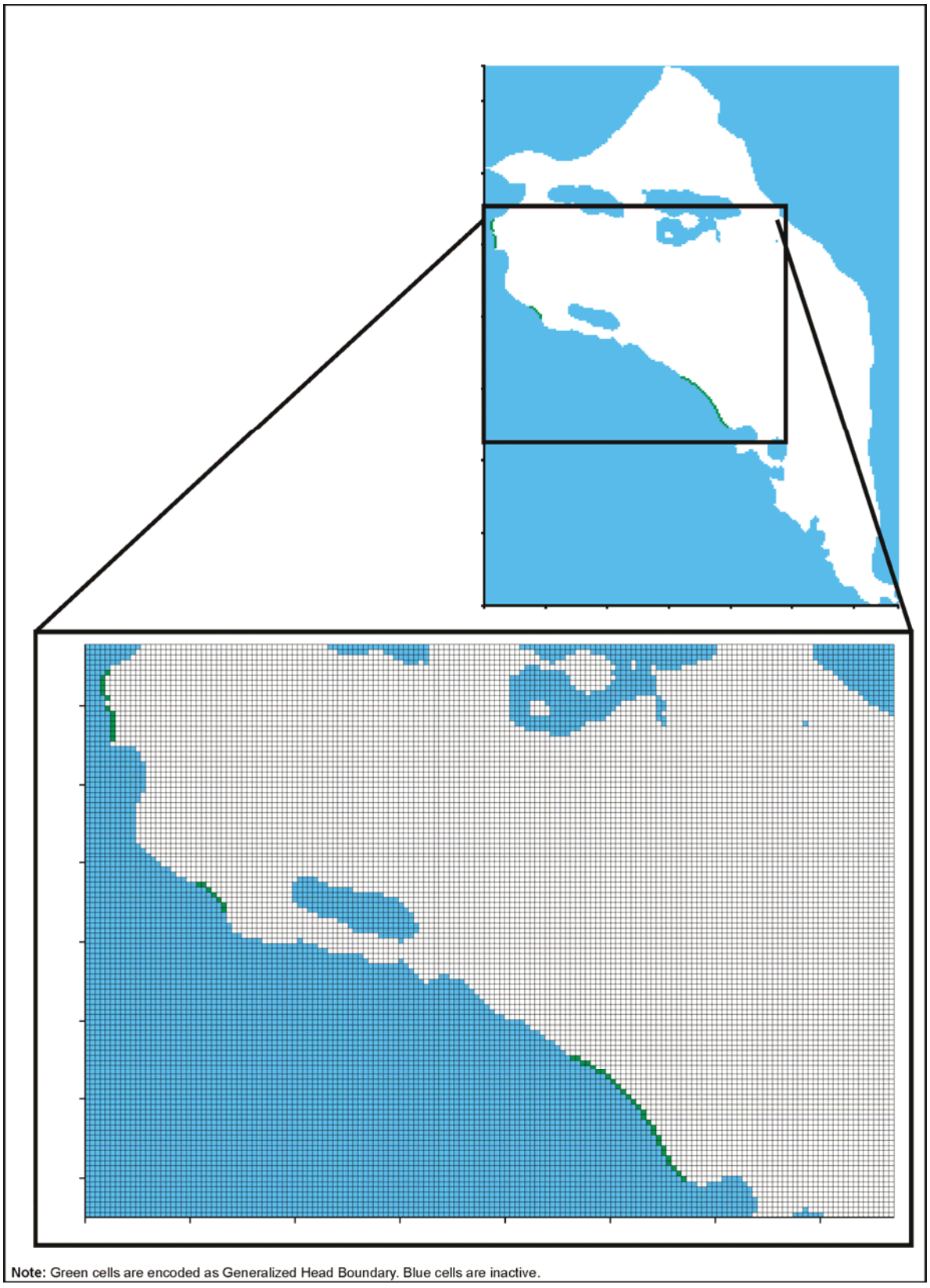
The *TC & WM EIS* groundwater flow model incorporates natural recharge at the rates specified in the *Technical Guidance Document* (DOE 2005). Cribs and trenches receive 50 millimeters (2 inches) per year, and tank farms receive 100 millimeters (4 inches) per year. Fifty millimeters per year is equivalent to 50 liters (13.2 gallons) per square meter per year. A fixed infiltration rate, 3.5 millimeters (0.14 inches) per year, representing precipitation on natural surfaces, is applied to the remaining areas not otherwise specified. Recharge in the city of Richland and surrounding agricultural land is a calibration parameter. These natural infiltration rates are also used in the STOMP vadose zone models (see Appendix N).

L.4.2.5 Artificial Recharge (Recharge Boundary)

Anthropogenic recharge associated with Hanford operations and, to a lesser extent, extraction (water withdrawal) and irrigation beyond the Hanford boundary represents the important time-varying fluxes of water into and out of the aquifer during the model period of analysis (1940–11,940). Water originally taken from the Columbia River was discharged onto the ground surface during operations. These anthropogenic recharge sources are the time-varying inputs that drive the transient behavior of the *TC & WM EIS* groundwater flow model.

Values for over 200 sources (or sinks) of water were taken from the Cumulative Impacts Inventory Database (SAIC 2006) and encoded into the model. These fluxes are encoded as constant flux boundary conditions in the MODFLOW cells that contain the sources and release sites. These recharge fluxes are also modeled using STOMP to simulate transport of contaminants through the vadose zone to the groundwater.

Of all the anthropogenic liquid sources identified in the Hanford inventory database, eight sites account for 88 percent of the total site recharge (see Table L–2). The volumes released at these sites range from 41 billion liters (10.8 billion gallons) at the 216-S-16 P Pond to 300 billion liters (79.3 billion gallons) at the 116-K-2 Trench. All eight sites combined released roughly 1.43 trillion liters (0.38 trillion gallons). Five of these sites are located in the 200 Areas, and they were major contributors to the mounds of water that built up beneath the 200-East and 200-West Areas during operations from 1945 through the mid-1990s.



Note: Green cells are encoded as Generalized Head Boundary. Blue cells are inactive.

Figure L–4. Mountain-Front Recharge Zones

Table L–2. Major Total Recharge Sources on the Hanford Site (1940–Present)

WIDS ID	Site Type	Source Type	Centroid Easting	Centroid Northing	Volume (liters)	Cumulative Fraction
116-K-2	Trench	Liquid	569801	147701	300,000,000,000	0.21
216-A-25	Pond	Liquid	574970	139650	293,899,037,982	0.42
216-B-3	Pond	Liquid	576898	136687	282,689,367,700	0.61
216-U-10	Pond	Liquid	566318	134602	159,859,250,966	0.73
116-N-1	Crib	Liquid	571534	149782	83,700,000,000	0.78
316-1	Pond	Liquid	594283	116106	51,116,602,319	0.82
216-T-4A	Pond	Liquid	566475	137133	42,826,720,640	0.85
216-S-16P	Pond	Liquid	565412	133192	40,723,265,275	0.88

Note: To convert liters to gallons, multiply by 0.26417.
Key: WIDS ID=Waste Information Data System Identification.

Anthropogenic areal recharge is encoded in the model in 1-year stress periods beginning in 1944. The model applies the estimated annual flux to the water table from each site in the appropriate 1-year stress periods, beginning the first year of operations at the site and ending in the final year of operations. The total recharge applied to the water table in a given stress period fluctuates from year to year as the number of contributing sites and their fluxes vary. For example, Figures L−5 and L−6 show the timing and magnitude of flux from the dominant anthropogenic recharge sources in the 200-East and 200-West Areas, respectively.

In addition to the liquid inventory sources, the model boundaries comprise three city of Richland water system well fields: North Richland, 1100B, and Wellsian Way. The pump houses at the North Richland and 1100B fields were constructed in 1978. Retention basins at these sites received Columbia River water, which was allowed to infiltrate to groundwater. Reference data for recharge from the

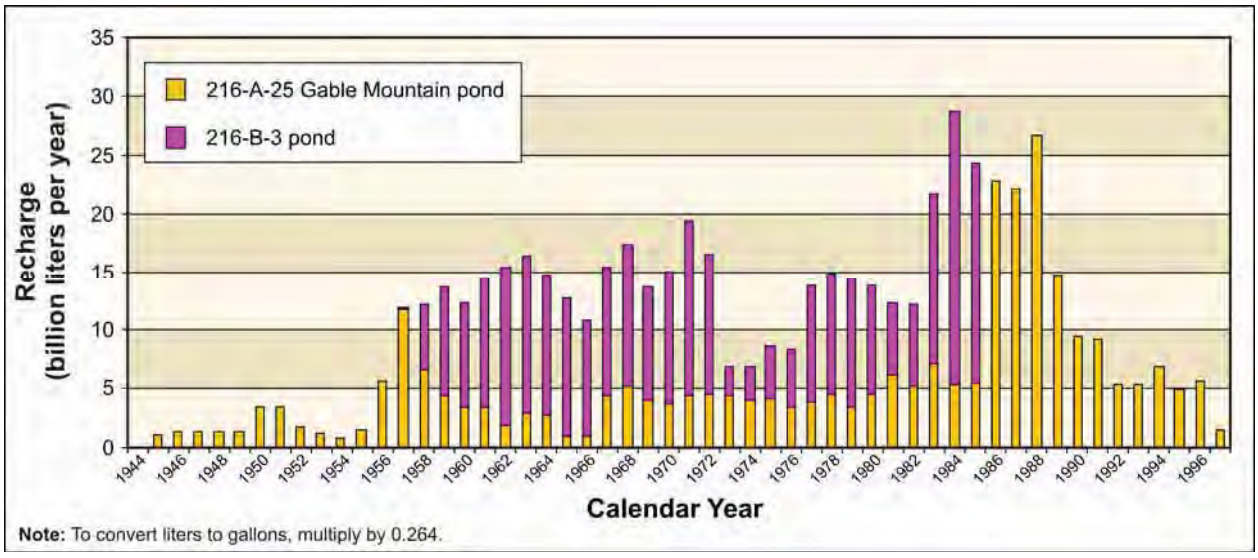


Figure L–5. Major Anthropogenic Recharge Sources in the 200-East Area

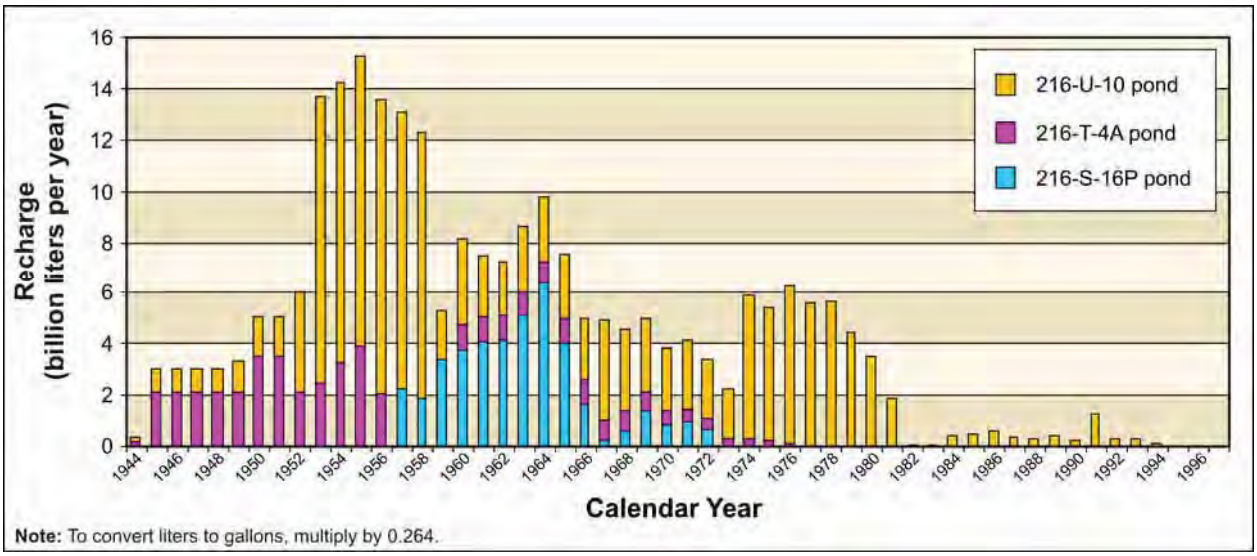


Figure L–6. Major Anthropogenic Recharge Sources in the 200-West Area

retention basins and production wells were obtained from city of Richland water system reports dating from 1981 to 2006 (see Table L–3). Based on information provided in the water system reports, a 95th percentile upper confidence limit on mean net recharge was calculated and used for the time period from 1978 to 1981. For the purposes of this analysis, future anthropogenic recharges were estimated based on past usage. The 95th percentile upper confidence limit on the mean was used for the years 2006 through 11,940 for all three city of Richland well field locations.

L.4.3 Lithology

Three major lithologic units that occur beneath Hanford are encoded in the *TC & WM EIS* groundwater flow model: Elephant Mountain basalt, Ringold Formation, and Hanford formation. The Elephant Mountain basalt represents the bottom of the unconfined aquifer (see Section L.4.3.2.1). The unconsolidated sediments of the Ringold and Hanford formations constitute the unconfined aquifer. The sediments of these two formations comprise the saturated zones through which groundwater flow is modeled.

L.4.3.1 Hydrogeologic Unit Definition

The *TC & WM EIS* groundwater flow model recognizes two major lithologic formations in the unconfined aquifer above the basalt, Hanford and Ringold, and two minor formations, Cold Creek and Plio-Pleistocene (PP) units. The Ringold Formation is the lower geologic unit of the unconfined aquifer, and, where it occurs, it sits on top of the underlying basalt. The Hanford formation is situated above the Ringold Formation where the latter occurs and directly above the basalt where the Ringold is missing. Between the Hanford and Ringold formations, the Cold Creek and PP units (formerly pre-Missoula/PP/early Palouse soil units) occur in some places at Hanford. Both the Hanford and the Ringold formations consist of fluvial and lacustrine sequences of mud, silt, sand, and gravel. The coarse-grained multifacies of the Cold Creek and PP units are thought to be more like Hanford formation gravel and sand than the harder, more-cemented Ringold Formation Gravel and Sand (Thorne et al. 2006).

Table L–3. City of Richland Water Supply Data – Annual Summary Report

Year	Extraction North Richland (Mgal)	Extraction 1100B (Mgal)	Positive Recharge (Mgal)[a]	Positive Recharge/ Extraction	Net Recharge (Mgal)	Net Recharge (gal)
1978	9.13×10^{2}	6.86×10^{1}	3.70×10^{3}[b]	3.77	2.72×10^{3}	2.72×10^{9}
1979	9.13×10^{2}	6.86×10^{1}	3.70×10^{3}[b]	3.77	2.72×10^{3}	2.72×10^{9}
1980	9.13×10^{2}	6.86×10^{1}	3.70×10^{3}[b]	3.77	2.72×10^{3}	2.72×10^{9}
1981	9.13×10^{2}	6.86×10^{1}	3.66×10^{3}	3.73	2.68×10^{3}	2.68×10^{9}
1982	9.13×10^{2}	6.86×10^{1}	2.36×10^{3}	2.40	1.38×10^{3}	1.38×10^{9}
1983	9.13×10^{2}	6.86×10^{1}	2.76×10^{3}	2.82	1.78×10^{3}	1.78×10^{9}
1984	5.31×10^{2}	0.00×10	3.61×10^{3}	6.79	3.07×10^{3}	3.07×10^{9}
1985	5.42×10^{2}	0.00×10	2.72×10^{3}	5.01	2.17×10^{3}	2.17×10^{9}
1986	3.99×10^{2}	1.08×10^{2}	2.35×10^{3}	4.63	1.84×10^{3}	1.84×10^{9}
1987	5.11×10^{2}	1.02×10^{2}	2.33×10^{3}	3.80	1.72×10^{3}	1.72×10^{9}
1988	5.39×10^{2}	1.08×10^{1}	1.94×10^{3}	3.53	1.39×10^{3}	1.39×10^{9}
1989	1.08×10^{3}	7.19×10	2.92×10^{3}	2.69	1.83×10^{3}	1.83×10^{9}
1990	1.45×10^{3}	4.07×10	2.70×10^{3}	1.86	1.25×10^{3}	1.25×10^{9}
1991	1.13×10^{3}	1.02×10^{1}	2.77×10^{3}	2.44	1.64×10^{3}	1.64×10^{9}
1992	8.39×10^{2}	4.35×10^{1}	1.71×10^{3}	1.93	8.23×10^{2}	8.23×10^{8}
1993	6.01×10^{2}	1.57×10^{1}	3.30×10^{3}	5.35	2.68×10^{3}	2.68×10^{9}
1994	1.34×10^{3}	6.17×10^{1}	2.64×10^{3}	1.89	1.24×10^{3}	1.24×10^{9}
1995	5.72×10^{2}	6.00×10^{1}	1.86×10^{3}	2.94	1.23×10^{3}	1.23×10^{9}
1996	5.03×10^{2}	5.84×10^{1}	2.34×10^{3}	4.16	1.77×10^{3}	1.77×10^{9}
1997	6.23×10^{2}	6.84×10^{1}	1.90×10^{3}	2.75	1.21×10^{3}	1.21×10^{9}
1998	1.33×10^{3}	1.47×10^{2}	1.86×10^{3}	1.26	3.85×10^{2}	3.85×10^{8}
1999	7.46×10^{2}	1.11×10^{2}	1.61×10^{3}	1.88	7.54×10^{2}	7.54×10^{8}
2000	7.65×10^{2}	3.64×10^{1}	1.83×10^{3}	2.29	1.03×10^{3}	1.03×10^{9}
2001	5.34×10^{2}	7.47×10^{1}	1.48×10^{3}	2.44	8.76×10^{2}	8.76×10^{8}
2002	1.19×10^{3}	6.85×10^{1}	3.05×10^{3}	2.43	1.80×10^{3}	1.80×10^{9}
2003	5.35×10^{2}	1.76×10^{1}	2.67×10^{3}	4.83	2.12×10^{3}	2.12×10^{9}
2004	4.10×10^{2}	5.79×10^{1}	1.69×10^{3}	3.61	1.22×10^{3}	1.22×10^{9}
2005	5.39×10	1.33×10^{2}	2.61×10^{3}	18.86	2.47×10^{3}	2.47×10^{9}
2006–11,940	9.13×10^{2}	6.86×10^{1}	3.70×10^{3}[b]	3.77	2.72×10^{3}	2.72×10^{9}
			Count	24.00		
			SD	1.35		
			Average	3.23		
			95% UCL	3.77		

[a] Positive recharge taken from city of Richland water system reports for years 1981–2005.

[b] Used the 95th percentile UCL ratio.

Note: To convert gallons to liters, multiply by 3.7854.

Key: %=percent; gal=gallon; Mgal=million gallons; SD=standard deviation; UCL=upper confidence limit.

L.4.3.2 Hydrogeologic Unit Encoding

The *TC & WM EIS* groundwater flow model has been encoded with hydrogeologic data for the entire model domain, developed from Hanford well borings completed as of September 2005. Approximately 5,000 boring logs were reviewed to determine if the geologic units and discrete hydrostratigraphic layers could be recognized from the geologic descriptions. When multiple logs existed for a borehole, higher credibility was given to those descriptions recorded by a professional geologist. Logs were reviewed for specific identification of the Elephant Mountain basalt, Hanford and Ringold formations, and Cold Creek

and PP units. The logs were further examined to discern textural types among the sedimentary units: mud, silt, sand, and gravel. Each of the resulting hydrogeologic units is encoded with unique properties (see Section L.4.4). The development of the hydrogeologic data for use in the *TC & WM EIS* groundwater flow model is described in the following sections.

L.4.3.2.1 Basalt Surface

The TOB surface encoded in the *TC & WM EIS* groundwater flow model was derived from boring logs, surface measurements, and geostatistical interpolation. Approximately 5,000 boring logs from Hanford and its surroundings were reviewed to determine if the geologic descriptions accompanying the boring logs indicated the depth of the uppermost basalt layer underlying the unconfined aquifer. When multiple logs existed for a borehole, higher credibility was given to those lithological descriptions recorded by a professional geologist. Only boreholes whose locations (coordinates) were known with some confidence were used. The TOB surface elevations at basalt outcroppings on or near Hanford were measured using a global positioning system device. Some TOB surface elevation values were taken from USGS topographic maps of Gable Mountain, Gable Butte, and Rattlesnake Mountain, which are massive outcroppings of the Elephant Mountain basalt, the formation underlying the unconfined aquifer at Hanford. Uncertainty estimates were assigned to each TOB elevation value.

The TOB surface encoded in the *TC & WM EIS* MODFLOW groundwater flow model is a geostatistical interpolation of the basalt-elevation data points from approximately 850 Hanford boring logs and 18 control points (see Figure L–7). Of the 18 control points, 12 are "structural," representing site knowledge about TOB surface elevation where there were limited or no data available and 6 are "visual," added to improve the depiction of the TOB surface. Nine of the 12 structural control points were added along the Columbia River where it enters Hanford to position the TOB surface beneath the river. The other 3 structural control points were added at borehole (well) locations where the boring did not extend completely to the basalt but only to the Ringold Formation Lower Mud Unit, which lies atop the basalt where it occurs. At these 3 locations, the TOB surface was estimated from other nearby borings that went deep enough to encounter the Ringold Formation Lower Mud Unit and the underlying basalt. Four of the 6 visual control points were added north of Gable Butte and Gable Mountain along the known position of the Gable Mountain Fault (see Figure L–7). The visual control points along the Gable Mountain Fault do not affect the simulated elevation of the TOB surface in Gable Gap (see Table L–4). The other 2 visual control points were added at Yakima Ridge. These 2 visual control points are not expected to affect the flow field in the operational areas of the site because of their distance from the operational areas (several kilometers to the south), and the predominant direction of groundwater flow (easterly).

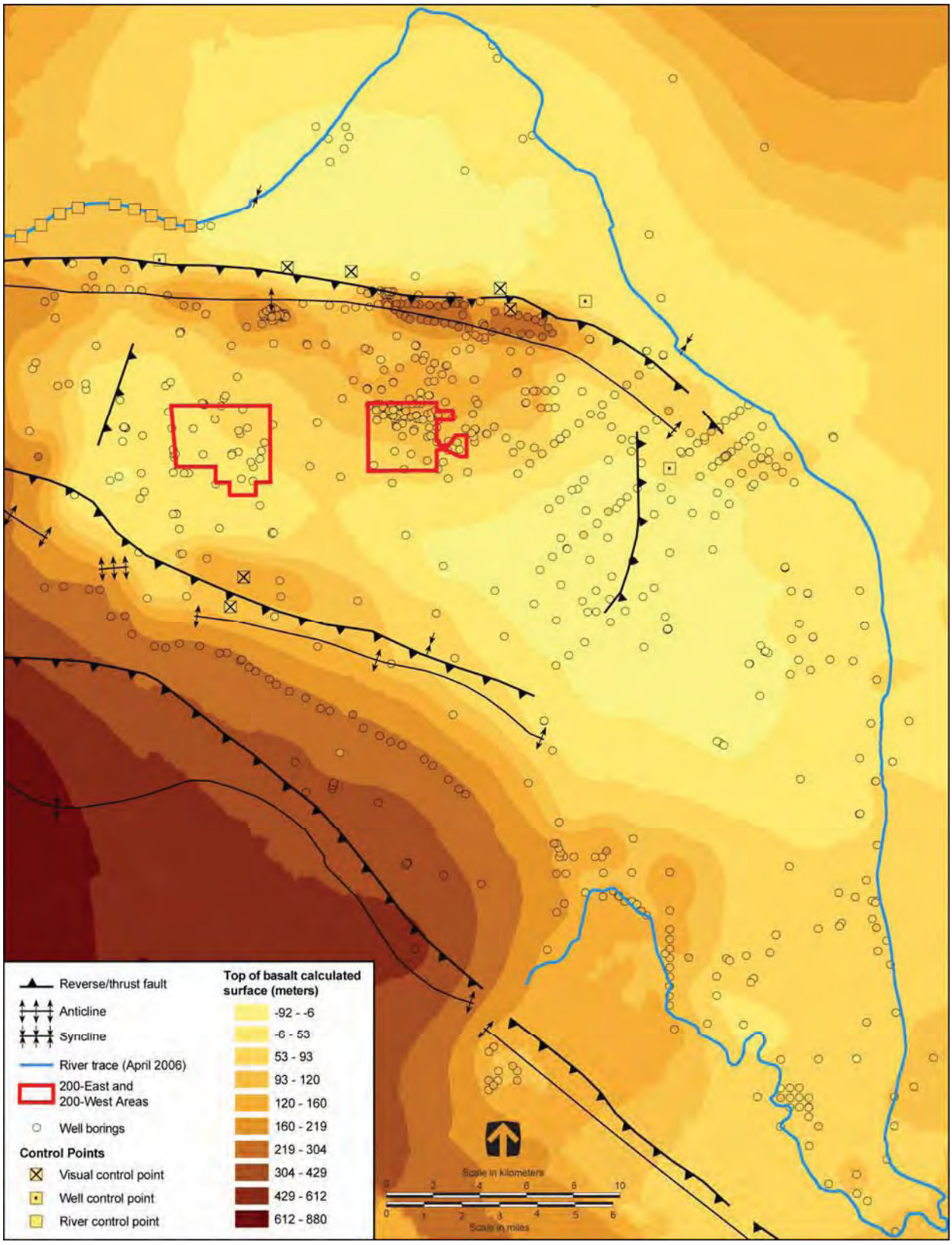


Figure L–7. Interpolated Top of Basalt Surface at the Hanford Site, Showing Faults, Anticlines, and Synclines

Table L–4. Effect of Visual Control Points on Top of Basalt "Cutoff"[a] Elevation in Gable Gap

Visual Control Points	Gable Gap Cutoff Elevation[a] (meters)	MODFLOW Layer (elevation in meters)	Notes
None	120.8407	11 (120–121)	–
5	120.8409	11 (120–121)	Includes new visual control points YRCP-1, YRCP-2, GMFCP-1, GMFCP-2, and GMFCP-3
6	120.8412	11 (120–121)	Includes five visual control points listed above and GMFCP-4 (closest to Gable Gap)

[a] Lowest maximum elevation along MODFLOW flow path through Gable Gap.

Note: To convert meters to feet, multiply by 3.281.

Key: Gable Gap=Gable Mountain–Gable Butte Gap; MODFLOW=modular three-dimensional finite-difference groundwater flow model.

The TOB surface encoded into the *TC & WM EIS* groundwater flow model was interpolated from the data and control points using ArcGIS Version 9.1, ArcInfo Level with Geostatistical Analyst Extension (Johnston et al. 2001). The interpolated TOB surface is not sensitive to the parameter settings assigned in ArcGIS. To make this determination, the TOB surface for the MODFLOW flow field model domain was interpolated by ordinary kriging using ArcGIS for the cases listed in Table L–5. The resulting TOB Gable Gap cutoff elevations, also shown in Table L–5, indicate that the interpolated TOB surface is insensitive to the parameter settings assigned in ArcGIS.

Table L–5. Top of Basalt "Cutoff"[a] Elevation in Gable Mountain–Gable Butte Gap Based on ArcGIS Parameter Settings

Run	Description	Top of Basalt Elevation (meters)[b]
Default	Geostatistical Analyst (Johnston et al. 2001) default settings.	121
Variant 1	Reduce major range from default (22,580 m) to 22,354 m.	121
Variant 1a	Reduce major range from default (22,580 m) to 21,451 m.	121
Variant 2	Reduce minor range to 22,354 m; model direction = 0 degrees.	121
Variant 2a	Reduce minor range to 21,451 m. Major range = 22,580 and model direction = 0.	121
Variant 3	Minor range 22,354 m; model direction = 356 degrees.	121
Variant 3a	Reduce minor range to 21,451 m and change model direction to 352 degrees (or 172 degrees).	121
Variant 4	Reduce partial sill from default (12,519 m) to 12,394 m.	121
Variant 4a	Reduce partial sill from default (12,519 m) to 11,893 m.	121
Variant 5	Increase nugget from default (0 m) to 15 m.	121
Variant 5a	Increase nugget from default (0 m) to 150 m.	121
Variant 6	Partial sill 12,394; increase nugget to 125 m; constant sill.	121
Variant 6a	Reduce partial sill from default (12,519 m) to 11,893 m and increase nugget to 626 m.	120
Variant 7	Increase neighbors to include per sector from default (5) to 6, "Include at Least" 2.	120
Variant 7a	Increase number of neighbors to include per sector from default (5, "Include at Least" 2) to 7, "Include at Least" 2.	120

Table L–5. Top of Basalt "Cutoff"[a] Elevation in Gable Mountain–Gable Butte Gap Based on ArcGIS Parameter Settings *(continued)*

Run	Description	Top of Basalt Elevation (meters)[b]
Variant 8	Reduce lag size from default (4,859.2 m) to 4,810.7 m.	121
Variant 8a	Reduce lag size from default (4,859.2) to 4,616 m.	121
Variant 9	Increase number of lags to 13.	121
Variant 9a	Increase number of lags to 14.	121
Variant 10	Lag size 4,810.7 m; number of lags 13.	121
Variant 10a	Reduce lag size from default (4,859.2 m) to 4,616 m and increase number of lags to 14.	121

a Lowest maximum elevation along MODFLOW (modular three-dimensional finite-difference groundwater flow model) flow path through Gable Mountain–Gable Butte Gap.

b Grid is 200-by-200 m (harmonic mean).

Note: To convert meters to feet, multiply by 3.281.

Key: m=meter; MODFLOW=modular three-dimensional finite-difference groundwater flow model.

The final TOB surface was interpolated using ordinary kriging with the default settings (see Figure L–8). The resulting TOB surface was output to a raster file containing the elevation of the center point of each cell of the 200- by 200-meter (656- by 656-foot) grid of the *TC & WM EIS* groundwater flow model. These values were used to encode the TOB surface at the proper vertical layer in the MODFLOW groundwater flow model. For each MODFLOW cell, the TOB surface was assigned to the layer containing the TOB elevation if the TOB elevation was greater than the midpoint of the layer; otherwise, the TOB surface was assigned to the next-lower layer. The cell to which the TOB surface was assigned and all lower cells were made inactive, i.e., assigned the "no-flow" condition.

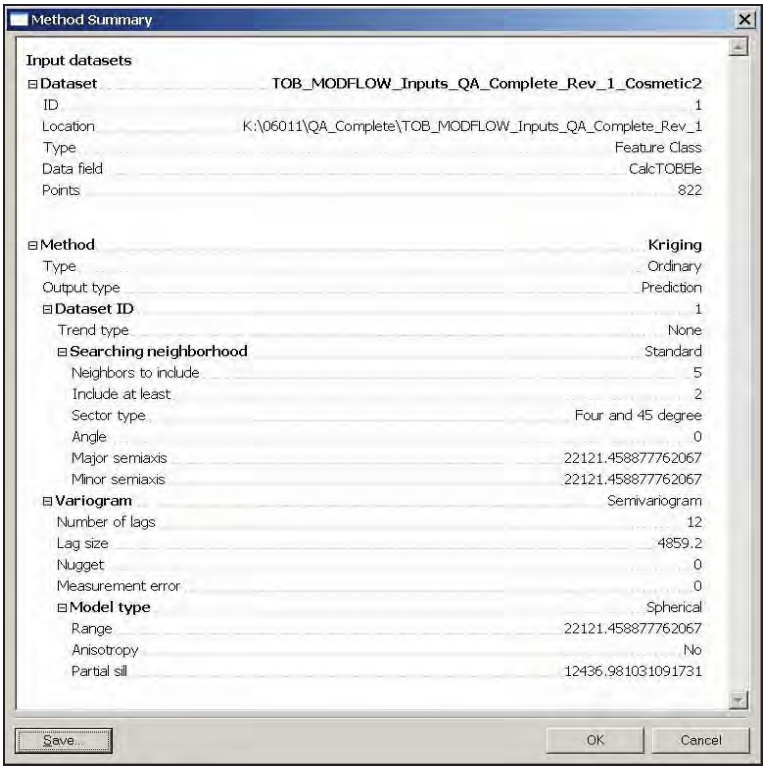


Figure L–8. Screen Print of Default Settings From Top of Basalt Surface Interpolation Using ArcGIS Geostatistical Analyst

The impact on the flow field of lower TOB elevations in Gable Gap is evaluated in this appendix (see Sections L.2.2 and L.10.2). The lowest TOB elevation in Gable Gap, i.e., the "cutoff" elevation, determines the water level at which flow to the north through the gap is possible. One hundred TOB surfaces were created by randomly selecting the TOB elevation for each of the 849 borings and 12 structural control points from a normal distribution, with the mean equal to the reported TOB elevation and the interval size equal to twice the elevation uncertainty estimate. The results indicated that there are multiple possible locations for the gap to occur, with different elevation values. The mean elevations of the three most frequent locations correspond to cutoffs encoded in the groundwater flow model at approximately 118 meters (387 feet), 121 meters (397 feet), and 122 meters (400 feet) amsl. Less than 5 percent of the realizations have a cutoff elevation lower than 118.5 meters (389 feet) amsl. The TOB surface encoded in Gable Gap for the *TC & WM EIS* groundwater flow model Alternate Case (see Section L.2.2) was interpolated from a random TOB elevation data set with a cutoff value of 117.8 meters (387 feet) amsl.

L.4.3.2.2 Suprabasalt Sedimentary Layers

Hanford boring logs were examined to discern textural layers of mud, silt, sand, and gravel within the Hanford and Ringold formations and Cold Creek and PP units. Individual layers are assigned to 1 of 13 material types (see Table L–6). The resulting lithological profiles—well name, well location, ground surface elevation, starting and ending depths of each layer, and each layer's assignment to the textural types—were imported into a database program that generates geologic cross sections.

Table L–6. Abundance of Textural Types in MODFLOW Groundwater Flow Model: Base Case

Textural Type (Model Material Type Zone)	Unweighted (Cells)	Unweighted Percent	Weighted (km^3)	Weighted Percent
Hanford mud (1)	245	0.05	0.05	0.04
Hanford silt (2)	2,238	0.43	0.30	0.28
Hanford sand (3)	33,237	6.38	8.71	8.06
Hanford gravel (4)	132,943	25.52	17.87	16.53
Ringold Sand (5)	27,333	5.25	10.27	9.51
Ringold Gravel (6)	168,246	32.29	37.39	34.60
Ringold Mud (7)	52,638	10.10	20.98	19.41
Ringold Silt (8)	1,757	0.34	0.47	0.43
Plio-Pleistocene sand (9)	115	0.02	0.06	0.05
Plio-Pleistocene silt (10)	186	0.04	0.09	0.09
Cold Creek sand (11)	3,444	0.66	0.40	0.37
Cold Creek gravel (12)	31,724	6.09	2.35	2.18
Highly conductive Hanford gravel(13)	65,933	12.65	9.10	8.42
Activated basalt (14)[a]	967	0.19	0.04	0.04

[a] Zone 14 (Activated basalt) was assigned to mitigate rewetting problems (see Section L.5.1.1) and was encoded over nine model layers.

Note: To convert cubic kilometers to cubic miles, multiply by 0.2399.

Key: km^3=cubic kilometers; MODFLOW=modular three-dimensional finite-difference groundwater flow model.

Hydrostratigraphic cross sections were constructed using HydroGeo Analyst, Version 3.0 (WHI 2005). Transects for these cross sections are located in the exact middle of a MODFLOW grid row (or column), and have a 100-meter (328-foot) buffer on either side. Thus, each cross section represents one row

(or column) of the *TC & WM EIS* groundwater flow model. Transect length varies, but generally cross sections do not span the entire model domain. Lithological profiles for boreholes located within the buffer area are projected onto the cross section for stratigraphic interpretation and interpolation. Elevations of contacts between the discrete geologic layers are determined by the resulting cross sections. Geologic layers within the cross section are encoded into the groundwater flow model based on elevation, from 165 meters (541 feet) amsl down to the TOB surface. If more than one geologic layer is contained within one MODFLOW cell, the cell is assigned the properties of the hydrostratigraphic type with the largest total thickness over the range of elevations represented by the MODFLOW layer. At elevations near the water table (115 to 125 meters [377 to 410 feet]), this approach allows encoding of features on the order of several meters in thickness. At elevations deeper in the aquifer, the vertical grid spacing increases, and the minimum thickness of features that can be represented in the model ranges from several to tens of meters (see Figure L–3). The overall thickness of the model domain is approximately 250 meters (820 feet). At a minimum, features with thicknesses of about 10 percent of the overall model domain (25 meters [82 feet]) are represented in the model, which is appropriate for a regional-scale representation.

The hydrostratigraphy encoded into the *TC & WM EIS* groundwater flow model on the basis of HydroGeo Analyst cross sections was fine-tuned to remove artifacts associated with the encoding of adjacent transects, to ensure consistency with the final TOB surface, to eliminate rewetting problems (see Section L.5.1.1), and to add zonation within textural types. Fine-tuning involved re-encoding the MODFLOW stratigraphy to achieve the following:

- Remove incongruities due to extrapolation from borehole out to edge of transect (seam).
- Remove incongruities due to truncation of lithology that should extend out to seam.
- Remove incongruities due to extrapolation of lowest layer of borehole down to TOB surface.
- Remove incongruities due to incorrect assignment to textural types.
- Remove inconsistent assignment to mud or silt from same formation.
- Eliminate disconnects due to lack of shared face at seam (edge contact only).
- Extend lithology laterally or vertically to TOB surface.
- Activate basalt in the Gable Gap area at elevations where water table fluctuates to mitigate rewetting problems. Refer to Section L.5.1.1 for more detailed information.
- Add zone of high hydraulic conductivity extending from north of Gable Gap, and through the Gable Gap, as well as south and southeast through the central area of the model domain. This change was a result of Local User Group input, MODFLOW Technical Review Group input, and testing which improved the match between model-simulated hydraulic heads and field-observed hydraulic heads across the model domain.

L.4.4 Material Properties

The different textural types in the Hanford, Ringold, and other sedimentary hydrostratigraphic units are characterized by different material properties. Material properties required for the groundwater flow model include hydraulic conductivity, specific storage, and specific yield. Hydraulic conductivity is a measure of how easily water moves through pore spaces. Specific storage of a saturated aquifer is the amount of water that a given volume of aquifer material will release under a unit change in hydraulic

head. Specific yield is the volumetric fraction of the bulk aquifer volume that an aquifer will yield when all the water is allowed to drain out of it under the forces of gravity.

Material properties for unconsolidated sediments below the water table are required for MODFLOW calculations. In MODFLOW, material of a given type can have only one value for a property, e.g., hydraulic conductivity. Each of the 14 material types encoded in the *TC & WM EIS* groundwater flow model (see Table L–6) has a unique combination of values for the several material properties. Material properties in this model are calibration parameters with the exception of Zone 14—activated basalt (refer to Section L.5.1.1 for more detailed information on activated basalt); the value for a given material type everywhere in the model is adjusted within some realistic range until simulated water levels are calibrated to observed water levels (see Sections L.7, L.8, and L.9).

L.5 MODEL INPUTS – ALGORITHM SELECTION, PARAMETERS, AND SETTINGS

Some model inputs are independent of site data. These inputs include initial conditions and settings specifying how to make the calculations and how to modify the model to eliminate numerical instabilities that may arise. Some of the inputs are required by the MODFLOW software, e.g., rewetting rules, while others are common to all groundwater simulation models, e.g., time-stepping settings and initial conditions. These data-independent model inputs are discussed in the following sections.

L.5.1 Rewetting Methods

MODFLOW allows for cells to become dry (inactive) if the simulated head falls below the elevation of the cell bottom. Conversely, if the simulated head rises above the cell bottom or the laterally adjacent cells are wet, a currently dry cell can become wet. This process is called rewetting. The rewetting rules and parameters used to develop the *TC & WM EIS* groundwater flow model were generally the default parameters of MODFLOW 2000 (USGS 2004). The settings selected in Visual MODFLOW for the *TC & WM EIS* groundwater flow model are given in Table L–7.

Table L–7. Visual MODFLOW Rewetting Settings

Option	Setting
Activate cell wetting	On
Wetting threshold	0.1
Wetting interval	1 (iteration)
Wetting method	From below
Wetting head	Calculated from neighboring cells
Head value in dry cells	-1×1030 (meters)
Minimum saturated thickness for bottom layer	0.01 (meters)

Note: To convert meters to feet, multiply by 3.281.
Key: MODFLOW=modular three-dimensional finite-difference groundwater flow model.

L.5.1.1 Mitigation of Rewetting Problems

Rewetting problems emerged during model development that required mitigating actions. The rewetting problems were encountered in areas within the model where the water table and the TOB (inactive model cells) were at or near the same elevation and resulted in dry model cells in areas that should have been wet, based on the elevation of the water table in surrounding active model cells. Based on the model's rewetting settings, once an active model cell becomes dry it can only be rewet from an active wet model cell below the active dry model cell. In our problem cases, the cell below the active dry model cell was an inactive cell that represented the TOB in that area within the model. This configuration would not allow the active dry model cell to rewet even though water table elevations in surrounding active wet

model cells would normally result in rewetting of the problem dry model cell. This problem was significant enough that mitigation was required in the area of the model that represents Gable Gap.

To mitigate the rewetting problem in the Gable Gap area within the model, inactive cells that represented the TOB were made active and assigned hydraulic conductivity values that are more than 500 times smaller than that of Hanford and Ringold Muds (0.001 meters [0.00328 feet] per day). Making the inactive cell active and using a low hydraulic conductivity value allowed the active water table cells above the TOB to rewet from below but also maintained the TOB as an impermeable boundary.

The TOB was activated in the Gable Gap area within the model between 124 meters (407 feet) amsl and 115 meters (377 feet) amsl.

L.5.2 Time-Stepping Settings

The *TC & WM EIS* groundwater flow model period of analysis is 10,000 years, from 1940—prior to the start of operations—to 11,940. The model is preconditioned by simulating the years 1940 through 1943 (pre-Hanford) in transient mode prior to the occurrence of any anthropogenic recharge influxes (see Section L.4.2.5). The model then continues running in transient mode to capture the time-varying anthropogenic recharge influxes and the resulting water table fluctuations. Anthropogenic inputs are applied in 1-year stress periods beginning in 1944. The final stress period begins in 2022 and ends in 11,940.

L.5.3 Numerical Engine Selection and Parameterization

The numeric engine selected for simulating groundwater flow was MODFLOW 2000, Version 1.15.00 (USGS 2004), which is public domain software supported by Visual MODFLOW, Version 4.2. The settings selected in Visual MODFLOW for the *TC & WM EIS* groundwater flow model are given in Table L–8.

Table L–8. Visual MODFLOW Numerical Solution Settings

Option	Setting
Simultaneous equation solver	Preconditioned conjugate-gradient (PCG2)
Preconditioning method	Modified incomplete Cholesky
Cholesky relaxation parameter	0.98
Maximum outer iterations	500
Maximum inner iterations	200
Head change criterion	0.01 (meter)
Residual criterion	5,000
Damping factor	1
Printout interval	10 (time steps)

Note: To convert meters to feet, multiply by 3.281.
Key: MODFLOW=modular three-dimensional finite-difference groundwater flow model.

The preconditioned conjugate-gradient package for solving simultaneous equations is described in USGS Water-Resources Investigations Report 90-4048 (Hill 1990). Modified incomplete Cholesky preconditioning of the hydrogeologic parameter matrix is efficient on scalar (non-vector) computers (WHI 2006). Outer iterations vary the preconditioned matrix of hydrogeologic parameters of the flow system, e.g., transmissivity, saturated thickness, in an approach toward the solution. Inner iterations continue until the user-defined maximum number of inner iterations has been executed or the final convergence criteria are met. Outer iterations continue until the final convergence criteria are met on the first inner iteration after an update. Both the head-change and residual criteria determine convergence of the solver. The head change criterion is used to judge the overall solver convergence; the residual

criterion is used to judge the convergence of the inner iterations of the solver. The damping factor allows the user to reduce the head change calculated during each successive outer iteration.

L.5.4 Initial Head Distribution

Pre-Hanford head observation data are not available. The *TC & WM EIS* groundwater flow model was assigned an initial arbitrarily high water table and run in transient mode for 500 years to simulate pre Hanford (1940–1943) conditions with only natural recharges applied per the *Technical Guidance Document* (DOE 2005). This initial 500-year model run approached long-term steady state conditions, which is assumed to represent pre-Hanford conditions.

L.6 CALIBRATION STRATEGY

The *TC & WM EIS* groundwater flow model is calibrated to heads observed beginning in 1948. Artificial recharges during Hanford operations, especially those from 1944 to the mid-1990s, produced mounding of groundwater underneath the 200-East and 200-West Areas on the Central Plateau of Hanford (see Section L.4.2.4). Groundwater mounding influenced the local direction of flow and transport and consequently needs to be accurately represented in the long-term groundwater flow model.

Model calibration to head is conducted in four process steps:

1. Prepare a calibration data set consisting of observed groundwater (head) levels across Hanford during the calibration period, 1948–2006, including the pre-conditioning period of 1940–1943.

2. Specify the model calibration criteria, that is, how similar model results need to be compared with the observations in the calibration data sets.

3. Conduct a preliminary model calibration to heads, during which the model parameters are adjusted manually to provide a reasonable starting point for the head calibration.

4. Conduct final model calibration using gradient-based and Monte Carlo optimization methods.

The technical approach to these tasks and the results are discussed below.

L.6.1 Calibration Data Set

The *TC & WM EIS* groundwater flow model is calibrated to head data collected between 1948 and 2006 for a large number of selected wells scattered across the site. The data came from the HydroDat database of measured water table elevations provided by PNNL and accepted by the *TC & WM EIS* team as quality-assurance complete (PNNL 2006). This database includes approximately 127,000 observations at approximately 1,800 discrete locations. Wells were excluded from use in the head observation data set under the following conditions:

- Closer than 600 meters (1,969 feet) to the Columbia River, to remove the periodic fluctuations in the river stage from the head observation data

- Outside the active model domain, because the model is not being calibrated in these areas

- Screened in basalt, because these observations measure head values within confined aquifers that are not part of this flow model calibration

- Obvious data recording or entry errors

Table L–9 details the number of well locations and head observations that were removed from the original head observation data set.

Table L–9. Number of Well Locations and Head Observations Removed from Original Head Observation Data Set

Change	Number of Observations Remaining	Number of Wells Remaining
Original head observation data set	127,063	1,805
Removes wells outside of the horizontal model domain	126,551	1,737
Remove observations with head values of greater than 165 meters (541 feet) or less than 100 meters (328 feet)	126,149	1,699
Remove wells screened in basalt	119,619	1,599
Remove wells located within 600 meters (1,968 feet) of the Columbia River	88,699	1,274
Average the observations for each well, screen, and year such that each well and/or screen has a single observation for each year	20,921	1,274
Retain the well and/or screen with the largest number of averaged observations	20,112	1,174
Edit well locations and observations per detailed hydrograph review	19,299	1,119

The data from the remaining wells were partitioned into four approximately equal sets for final calibration. The data assigned to each data set were selected at random, with the restriction that no more than one observation well could be assigned to any given MODFLOW cell. One data set (approximately 25 percent of the observation wells) was selected and set aside for validation. The remaining three data sets (approximately 75 percent of the observation wells) were used in independent calibrations to test the robustness of the calibration parameters. A common set of observation wells and their head observation data were assigned to all four calibration data sets to ensure representation across the model domain in each of the calibration data sets. The distribution of the number of wells and the number of observations assigned to each of the three calibration data sets and the validation data set are detailed in Table L–10.

Table L–10. Number of Well Locations and Head Observations Assigned to Calibration and Validation Data Sets

Head Observation Data Set	Number of Observations	Number of Wells
Calibration Data Set # 1	5,005	274
Calibration Data Set # 2	5,563	279
Calibration Data Set # 3	5,230	270
Validation Data Set # 4	4,482	264

L.6.2 Calibration Criteria

The calibration data sets are used to assess the ability of the model to accurately simulate water levels and flow direction in the past, which is an indication of its ability to accurately simulate water levels and flow direction in the future. The calibration criteria define acceptable model performance in terms of measures of similarity (difference) between observed and simulated values. The model calibration criteria are as follows:

- Residuals (differences between observed and modeled heads) should be reasonably distributed.
  - Residual distribution should be reasonably normal.

  - The mean residual should be approximately 0.
  - The number of positive residuals should approximate the number of negative residuals.
  - The correlation coefficient (calculated versus observed) should be greater than 0.9.
  - The RMS error (calculated versus observed) should be less than 5 meters (16.4 feet), approximately 10 percent of the gradient in the water table elevation.

- The residual distribution should meet the needs of this *TC & WM EIS*.
  - Residuals in the 200-East Area should be distributed similarly to those in the 200-West Area.
  - The residuals should be evenly distributed through time.
  - The residuals should be evenly distributed across the site.

- The calibrated parameters should compare reasonably well with field-measured values.

- Parameters should be reasonably uncorrelated. Correlation among the parameters is a symptom of a poorly posed problem with many non-unique solutions.

These criteria are used to assess the final head calibrations.

L.6.3 Development of Objective Function

The groundwater flow model is calibrated to observed hydraulic heads across Hanford during the calibration period (1948–2006). The objective of the head calibration was to minimize the difference between the model-simulated head values and the field-observed head values during the calibration period. All head observation wells used in the head calibration were weighted equally. No concentration calibration was performed as part of the flow model development. Concentration calibration of the groundwater transport model is discussed in Appendix O.

L.7 PRELIMINARY CALIBRATION

The goal of preliminary head calibration is to produce a reasonable starting point for the gradient-based head calibration and Monte Carlo optimization. The most important prerequisites for these are a working model and parameters that are reasonably close to the expected solution and reasonably stable in parameter space, with the important components of parameter variability defined and understood. In the transient *TC & WM EIS* MODFLOW simulation, the goal was to obtain an initial head distribution in the aquifer that reasonably represented the boundary conditions at the start of the simulation.

The head distribution in 1940 represents the starting point for the transient simulation. The model was first preconditioned by simulating the year 1940 (pre-Hanford) by running the model for 500 years in transient mode without any anthropogenic recharge influxes. This approach resulted in initial heads that are believed to reasonably represent the pre-Hanford water table. These initial heads were used as the starting point for the model simulation. The model was then run in transient mode through an additional preconditioning period (1940–1943), followed by the various stress periods (each of which is about 1 year during the Hanford operational period). Stress periods between 1944 and the mid-1990s represent changes in operational discharges to the aquifer, which caused mounding of the water table. Stress periods following the mid-1990s allowed the mound to dissipate as operational discharges ceased. Subsequently, the head distribution relaxed to a long-term steady state distribution that is consistent with the boundary conditions. This long-term steady state distribution closely matched the initial condition. The primary difference between the initial condition and the long-term steady state condition is the city of Richland long-term extractions and recharge.

The steps in the preliminary head-calibration process are:

1. Generate an initial list of parameters that are important to examine.

    a. Hydraulic conductivities of all of the hydrostratigraphic units
    b. Storage properties of all of the hydrostratigraphic units
    c. Conductance values of the riverbeds in each reach of the Columbia and Yakima Rivers
    d. Conductance values and heads of the GHBs representing mountain-front recharge

2. Generate an initial estimate for each parameter. The initial estimates for material properties (i.e., steps 1a and 1b above) come from site-specific studies. The initial estimates for conductance values of the riverbeds and GHBs are set to large values. The initial estimates for GHB heads are set to values consistent with observed heads near the GHB locations along the western edge of the active model domain.

3. Precondition the model to obtain the initial (1940) head distribution. This task is achieved with a 500 year preconditioning model run as described earlier in this section. Compare the head distribution to the 2006 water table elevation distribution—the best, albeit very rough, estimate of the long-term steady state head distribution. Iterate through this step, adjusting the parameters to provide reasonable agreement with the 2006 water table elevation distribution.

4. When the parameter settings are reasonably correct and the resulting initial head distribution is obtained, run the model in transient mode from 1940–2006, including the preconditioning period from 1940–1943. Compare the calculated and observed heads for the preliminary set of calibration parameters encoded in Visual MODFLOW. Iterate through this step, adjusting the material properties and conductance values to provide reasonable agreement between the observed and calculated heads.

Once preliminary head calibration met the calibration criteria for reasonable agreement between the observed and calculated heads (see Section L.6.2), the gradient-based head calibration and Monte Carlo optimization began.

The results of the preliminary calibration are discussed below.

L.7.1 Potential Calibration Parameters

Calibration parameters are adjustable model settings that allow the user to control model behavior during the model simulation. For the *TC & WM EIS* groundwater flow model, some calibration parameters were specified in the *Technical Guidance Document* (DOE 2005), some were provided by available data, some were not used, and the remaining parameters were adjusted to achieve the head calibration. Table L–11 lists the potential calibration parameters and how they were applied during calibration.

Table L–11. Potential Calibration Parameters

Potential Calibration Parameter	How Specified or Used
Initial heads	500-year model run to establish pre-Hanford heads
Natural recharge	Specified by the *Technical Guidance Document* (DOE 2005)
Anthropogenic recharge	Specified by data (SAIC 2006)
River head	Specified by data (Thorne et al. 2006)
River conductance	Adjustable calibration parameter
Mountain-front recharge head	Adjustable calibration parameter
Mountain-front recharge conductance	Adjustable calibration parameter
Flow storage properties of material types	Adjustable calibration parameter
Hydraulic conductivity properties of material types	Adjustable calibration parameter

Key: Hanford=Hanford Site; *Technical Guidance Document=Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose one and Groundwater Revised Analyses.*

These calibration parameters were encoded if specified by data or adjusted within reasonable ranges to achieve the groundwater flow model calibration. Details of the calibration are included in the following sections.

L.7.2 Sensitivity Analysis

During the preliminary calibration, model runs were made to determine the model's sensitivity to the adjustable calibration parameters. This sensitivity analysis is discussed in the following sections.

L.7.2.1 River Conductance

The Columbia and Yakima Rivers are modeled using the MODFLOW river package, which applies these boundaries as a GHB. River conductance values were initially set to arbitrarily high values, which resulted in the rivers behaving as constant head boundaries. This setting provided stability in the early stages of model development. Model runs were made, adjusting river conductance values over several orders of magnitude to determine the model's sensitivity to this parameter. The results of this analysis concluded that the head calibration was not highly sensitive to river conductance. The model's convergence behavior is sensitive to river conductance. In general, lower river conductance values resulted in greater model instability. The river conductance values derived during preliminary calibration ranged from 2.74×10^5 square meters (2.95×10^6 square feet) per year to 9.78×10^7 square meters (1.05×10^9 square feet) per year. Because the model is not sensitive to this parameter, these values were adopted for the Base and Alternate Case models.

L.7.2.2 Mountain-Front Recharge Head and Conductance

Natural recharges or influxes of water occur along the western boundary of the model domain. The locations and values of influx from these sources of model recharge have been studied extensively (Thorne et al. 2006). These recharge sources are modeled using the MODFLOW GHB package and are located in general locations as specified in prior work. The head and conductance values for these recharge sources were treated as calibration parameters, adjusted within reasonable ranges until the simulated head values reasonably matched the observed heads.

The *TC & WM EIS* groundwater flow model is sensitive to the GHB recharge head and conductance values. As expected, model-simulated head values increase across the model domain with increases in GHB recharge head values. The model-simulated head values were more sensitive to GHB recharge head values when conductance values were high.

The GHB head values derived during preliminary calibration for mountain-front recharge ranged from 128 meters (420 feet) amsl to 165 meters (541 feet) amsl. The GHB conductance values derived during preliminary calibration for mountain-front recharge ranged from 5.00×10^4 square meters (5.38×10^5 square feet) per year to 5.00×10^5 square meters (5.38×10^6 square feet) per year. Table L–12 details the GHB head and conductance ranges for each area of the model where the GHB boundary condition is encoded. Because model convergence and dry-cell behavior (particularly in the Gable Gap area) were extremely sensitive to the GHB parameters, these settings were adopted for the Base and Alternate Case models.

Table L–12. Summary of Encoded Generalized Head Boundary Head and Conductance Values

Model Domain Area	Minimum Head (meters)	Maximum Head (meters)	Minimum Conductance (square meters/year)	Maximum Conductance (square meters/year)
Rattlesnake Mountain Front	128	130	100,000	500,000
Dry Creek Area	165	165	50,000	100,000
Cold Creek Area	158	158	50,000	100,000

Note: To convert meters to feet, multiply by 3.281; square meters to square feet, by 10.7639.

L.7.2.3 Flow Storage Properties of Material Types

Specific yield is a flow storage parameter and is defined as the volume of water that an unconfined aquifer releases from storage per unit surface area per unit decline in the water table (WHI 2006). Specific yield values derived during preliminary calibration are listed in Table L–13. In general, preliminary calibration shows the groundwater flow model is not particularly sensitive to specific yield. The values listed in Table L–13 were not modified from their initial estimates. Later sensitivity analysis shows slightly better RMS error results can be achieved with a higher specific yield for Ringold Gravel. This result suggests that the specific yield of Ringold Gravel is higher than presented in Table L–13, a result more consistent with the specific yield of other gravels in the model.

Table L–13. Specific Yield Values Derived from the Preliminary Calibration

Material Type (Model Zone)	Specific Yield
Hanford mud (1)	0.2
Hanford silt (2)	0.18
Hanford sand (3)	0.26
Hanford gravel (4)	0.3
Ringold Sand (5)	0.26
Ringold Gravel (6)	0.15
Ringold Mud (7)	0.2
Ringold Silt (8)	0.18
Plio-Pleistocene sand (9)	0.26
Plio-Pleistocene silt (10)	0.18
Cold Creek sand (11)	0.26
Cold Creek gravel (12)	0.25
Highly conductive Hanford gravel (13)	Not encoded at preliminary calibration
Activated basalt (14)	Not encoded at preliminary calibration

L.7.2.4 Hydraulic Conductivity Properties of Material Types

The *TC & WM EIS* groundwater flow model is sensitive to hydraulic conductivity values for the various material types encoded in the model. The preliminary calibration found that the model is most sensitive to those material types occupying the largest volume of space within the model domain. As shown in Table L–6, the three material types that occupy the highest percentage of the model domain volume are Ringold Gravel (34.6 percent), Ringold Mud (19.4 percent), and Hanford gravel (16.5 percent). Hydraulic conductivity values derived during preliminary calibration are listed in Table L–14.

For comparison purposes, field and laboratory hydraulic conductivity from a limited data survey are summarized in Table L–15. Additional hydraulic conductivity data resulting from pump testing for the Hanford and Ringold Formations are included in Figure L–53.

Table L–14. Hydraulic Conductivity Values Derived from the Preliminary Calibration

Material Type (Model Zone)	Hydraulic Conductivity (K_x)[a]	Hydraulic Conductivity (K_y)[b]	Hydraulic Conductivity (K_z)[c]
Hanford mud (1)	0.5	0.5	0.05
Hanford silt (2)	15.0	15.0	1.5
Hanford sand (3)	175.0	175.0	17.5
Hanford gravel (4)	1,200.0	1,200.0	120.0
Ringold Sand (5)	15.0	15.0	1.5
Ringold Gravel (6)	25.0	25.0	2.5
Ringold Mud (7)	0.5	0.5	0.05
Ringold Silt (8)	1.1	1.1	0.11
Plio-Pleistocene sand (9)	75.0	75.0	7.5
Plio-Pleistocene silt (10)	10.0	10.0	1.0
Cold Creek sand (11)	125.0	125.0	12.5
Cold Creek gravel (12)	700	700	70
Highly conductive Hanford gravel (13)	Not encoded at preliminary calibration	Not encoded at preliminary calibration	Not encoded at preliminary calibration
Activated basalt (14)	Not encoded at preliminary calibration	Not encoded at preliminary calibration	Not encoded at preliminary calibration

[a] Hydraulic conductivity with respect to the *x* axis, meters per day.
[b] Hydraulic conductivity with respect to the *y* axis, meters per day.
[c] Hydraulic conductivity with respect to the *z* axis, meters per day.
Note: To convert meters to feet, multiply by 3.281.

L.7.3 Selection of Calibration Parameters, Initial Estimates, and Target Ranges

The process of preliminary calibration produced a groundwater flow model framework that had examined all of the potential calibration parameters (see Table L–11). Of these parameters, the initial heads, natural recharge, anthropogenic recharge, river heads, riverbed conductances, and mountain-front recharge heads and conductances were fixed by consideration of technical guidance, field data constraints, calculation, and/or model stability and sensitivity. The remaining adjustable parameters were the material properties, specifically storage parameters and hydraulic conductivities.

Initial estimates for the gradient-based calibration were chosen from a literature review of site-specific data. The data were largely based on field tests and laboratory-scale measurements of the properties of Hanford suprabasalt sediments. These initial estimates and target ranges are shown in Table L–15. The preliminary calibration suggested that the groundwater flow model was most sensitive to the hydraulic conductivities of the Ringold Gravel, Ringold Mud, and Hanford gravel model units.

Table L–15. Initial Estimates for Material Properties

Stratigraphic Unit/ Lithologic Unit	Low Laboratory Hydraulic Conductivity K_h,sat (m/day)	High Laboratory Hydraulic Conductivity K_h,sat (m/day)	Low Field Hydraulic Conductivity K_h,sat (m/day)	High Field Hydraulic Conductivity K_h,sat (m/day)	Range in Hydraulic Conductivity K_h,sat (m/day)[a]	MODFLOW Initial Estimate Hydraulic Conductivity K_h,sat (m/day)	Comment
Alluvium (Qal)	No Data	No Data	No Data	No Data	No Data	1×10^{2}	Assume Qal=Hs
Hanford gravel (Hg)	1.7×10^{-2}, b, c	2.3×10^{2}, b, c	1 d, e, f, g	3.35×10^{3}, e, f, g	1×10^{-3} to 3×10^{3}	1×10^{3}	
Hanford sand (Hs)	3.0×10^{-3}, b, c	5×10^{2}, b, c	1 d, e, f, g	2.41×10^{2}, d, g	1×10^{-3} to 5×10^{2}, d, g	1×10^{2}	
Hanford silt (Hss)	2.7×10^{-3}, b	1.49×10^{2}, b	No Data	No Data	1×10^{-3} to 1.5×10^{2}	10	
Hanford mud (Hm)	No Data	No Data	No Data	No Data	No Data	1×10^{-3}	Assume Hm=Rm
Cold Creek gravel (CCg)	No Data	No Data	No Data	No Data	No Data	1×10^{3}	Assume CCg=Hg
Cold Creek sand (CCs)	No Data	No Data	No Data	No Data	No Data	1×10^{2}	Assume CCs=Hs
Plio-Pleistocene gravel (Pplg)	No Data	No Data	No Data	No Data	No Data	1×10^{3}	Assume Pplg=Hg
Plio-Pleistocene sand (Ppls)	No Data	No Data	No Data	No Data	No Data	1×10^{2}	Assume Ppls=Hs
Plio-Pleistocene silt (Pplss)	2.3×10^{-3}, b, h	5.88×10^{2}, b, h	No Data	No Data	1×10^{-3} to 6×10^{2}	10	
Plio-Pleistocene cement (Pplc)	No Data	No Data	No Data	No Data	No Data	1	Assume Pplc=Ppls0.1
Ringold Gravel (RgE)	7.0×10^{-4}, c, i	6.7 c, i	5×10^{-2}, f, j-o	1.55×10^{3}, f, j-o	1×10^{-3} to 1.55×10^{3}	1×10^{2}	
Ringold Gravel (RgA)	2.2×10^{-3}, c, i	1.6 c, i	1.7 m	2 m	1×10^{-3} to 2	1	
Ringold Sand (Rs)	No Data	No Data	9 g	12 g	9 to 12	10	
Ringold Silt (Rss)	No Data	No Data	No Data	No Data	No Data	1	Assume Rss=Hs*0.1
Ringold Mud (Rm)	8.6×10^{-5}, c, d, i	5.62×10^{-2}, c, d, i	No Data	No Data	8.64×10^{-5} to 5.6×10^{-2}	1×10^{-3}	

a Textbook Ranges (Fetter 1988; Freeze and Cherry 1979) for these parameters in m/day are: gravel, mixed sand and gravel, 1 to 90000; sand, 0.1 to 900; silt, 0.01 to 90; and clay (mud), 0.0001 to 0.1.
b Khaleel and Freeman 1995.
c Connelly, Ford, and Borghese 1992.
d Schalla et al. 1988.
e Fruchter et al. 1996.
f Spane, Thorne, and Newcomer 2001a.
g DOE 1994.
h Rohay et al. 1993.
i Byrnes and Miller 2006.
j Rohay, Swett, and Last 1994.
k Williams et al. 2000.
l Spane and Thorne 2000.
m Spane, Thorne, and Newcomer 2001b.
n Spane, Thorne, and Newcomer 2002.
o Spane, Thorne and Newcomer 2003.

Note: To convert meters to feet, multiply by 3.281.

Key: K_h,sat=saturated hydraulic conductivity; m/day=meters per day; MODFLOW=modular three-dimensional finite-difference groundwater flow model.

L.8 GRADIENT-BASED CALIBRATION

The gradient-based calibration of the transient model used PEST in conjunction with MODFLOW. The goal of PEST is to adjust the variable parameters in the model in a way that minimizes the difference between observed values of head (historic field measurements) and corresponding model simulations. The development of the calibration data sets and the objective function were described in Section L.6.

The fundamental assumption underlying gradient-based calibration is that there is a single set of adjustable parameters that, when inserted in the flow model, yield a minimum value for the objective function. The further away the parameters are from the optimal set, the larger the objective function (i.e., discrepancy between field observation of head and model simulations). The gradient-based method starts with initial estimates for the set of parameters and calculates the steepest downhill gradient (i.e., the set of adjustments to the parameters that yields the maximum decrease in objective function). The parameters are all moved in the steepest downhill direction, and the calculation is repeated until two subsequent iterations are within a specified tolerance or the maximum number of iterations is achieved.

Initial calculations using this method confirmed that the flow model was more sensitive to hydraulic conductivity values than to storage parameters. In particular, the model was most sensitive to the hydraulic conductivities of the Hanford gravel, Ringold Sand, Ringold Gravel, Cold Creek gravel, and the Highly conductive Hanford gravel. A variety of different PEST settings and initial estimates were investigated. The final production results for the three calibration data sets are typical (Table L–16).

Table L–16. Base Case PEST-Optimized Conductivity Values with Confidence Limits – Selected Material Types (meters per day)

Horizontal Hydraulic Conductivity (K_h)				
Material Type (Model Zone)	Initial Value	PEST-Optimized Value	95th Percentile Confidence Limits	
			Lower Limit	Upper Limit
Head Calibration Data Set 1				
Hanford gravel (4)	600	229.698	216.106	244.144
Ringold Sand (5)	15	3.89152	3.00041	5.04728
Ringold Gravel (6)	25	12.8691	12.3253	13.437
Cold Creek gravel (12)	700	140	127.235	154.046
Highly conductive Hanford gravel (13)	3,000	5162.08	4637.68	5745.77
Head Calibration Data Set 2				
Hanford gravel (4)	600	246.565	232.431	261.558
Ringold Sand (5)	15	3.64608	3.1234	4.25624
Ringold Gravel (6)	25	13.7969	13.3136	14.2979
Cold Creek gravel (12)	700	214.445	187.926	244.707
Highly conductive Hanford gravel (13)	3,000	5219.59	4569.74	5961.85
Head Calibration Data Set 3				
Hanford gravel (4)	600	207.281	205.684	208.89
Ringold Sand (5)	15	3	2.62202	3.43246
Ringold Gravel (6)	25	14.2736	13.9357	14.6197
Cold Creek gravel (12)	700	140	130.501	150.191
Highly conductive Hanford gravel (13)	3,000	7124.82	6456.74	7862.03

Notes: K_z (vertical hydraulic conductivity) is equal to $K_h/10$. To convert meters to feet, multiply by 3.281.
Key: PEST=parameter estimation.

The final sets of parameters for the gradient-based calibrations appeared to have reasonable values and acceptable consistency among the three independent head calibration data sets. The confidence ranges

(i.e., difference between the upper and lower confidence limits) were considered unreasonably narrow for a primary purpose of this *TC & WM EIS*: to adequately describe the uncertainty of the groundwater flow model with respect to the parameters. The results suggested that the assumption of the gradient-based method that the objective function varied smoothly with the distance of the parameter set from their optimal values and that there was one unique set of optimal parameters may not be valid for this groundwater flow model.

To test this assumption, a number of MODFLOW calculations were performed in which all of the parameters were held at their optimal, PEST-derived values, except for one. The selected parameter was varied over a range greater than the PEST-derived confidence limit, and the objective function was calculated. This process was completed five times, each time varying only one of the hydraulic conductivity parameters. Figure L–9 shows one such result. The *x* axis shows the value of the hydraulic conductivity for Hanford gravel that was used in the specific calculation. All other hydraulic conductivities were kept at their optimal values. The *y* axis shows the resulting value of the objective function. If the gradient-based assumption was correct, this process should have resulted in a curve that was approximately parabolic in shape, with a single minimum. These calculations demonstrate that the objective function does not vary smoothly with parameter variations over a single range and suggest that the objective function contains many local minima. Although the gradient-based parameter values themselves are likely to be reasonable representations of the hydraulic conductivities for the flow model, the description of the uncertainties in these parameters did not meet the data quality objective for the calibration process.

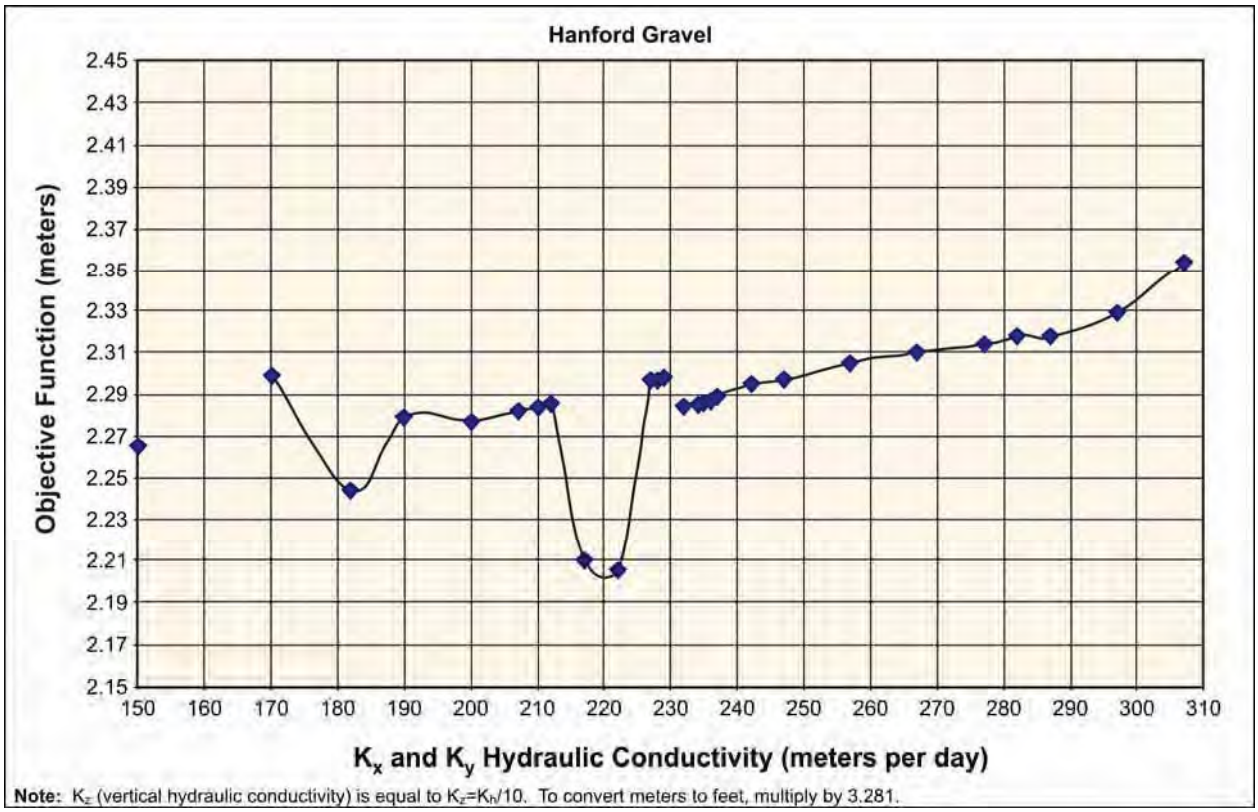


Figure L–9. Objective Function Variations as a Function of Hydraulic Conductivity Changes

L.9 MONTE CARLO OPTIMIZATION AND UNCERTAINTY ANALYSIS

The preliminary and gradient-based calibration processes demonstrated the following:

- The flow model is more sensitive to hydraulic conductivity variations than variations in storage parameters.
- The flow model requires a highly conductive zone of Hanford gravel across the center of the model through the Gable Gap area to satisfy the extremely flat water table conditions measured across this region over a large variation in operational recharge.
- Ringold Gravel, which is at the water table underneath the 200-West Area, is at least two orders of magnitude less conductive than the highly conductive zone of Hanford gravel, and at least 30 times less conductive than regular Hanford gravel.
- The flow model is sensitive to relatively small changes in hydraulic conductivities in the three primary units, with nonlinear responses in objective function.

At the end of these two processes, reasonable values for the hydraulic conductivities of the primary hydrostratigraphic units were obtained, but the uncertainty in these values was not well estimated. To further understand the behavior of the flow model to changes in the hydraulic conductivity parameters, a Monte Carlo optimization and uncertainty analysis was conducted on the groundwater flow model.

L.9.1 Design of the Analysis

The objective function (difference between field observations of water table elevation and model simulations) responds non-linearly to changes in the hydraulic conductivity parameters. Small changes in the sensitive parameters can lead to large changes in the quality of model agreement with historic water-level measurements. Further, an analysis of the topology of the objective function shows that there are many individual, discrete local minima. Because of this behavior, the problem of describing uncertainty with respect to the hydraulic conductivities changes from a description of the shape of a single nearly parabolic curve in parameter space (i.e., the conceptualization behind gradient-based methods) to a description of the locations of a collection of a large number of discrete local minima.

To solve this problem, three searches were conducted in the 13-dimensional hydraulic conductivity parameter space, one search for each calibration data set (see Section L.6). Each search was composed of a number of realizations: 6,660 Base Case realizations for Calibration Data Set 1, 6,400 Base Case realizations for Calibration Data Set 2, and 6,400 Base Case realizations for Calibration Data Set 3. Each realization was independent from all others. Each realization was created by randomly selecting hydraulic conductivity values for the 13 stratigraphic units with a linear probability distribution over a range of several orders of magnitude around the values listed in Table L–15. These randomly selected parameters were used to create a MODFLOW run over the calibration period of the model (1948–2006). The objective function was calculated for each run and tabulated. The process was repeated as computer resources permitted.

L.9.2 Base Case – Results of the Analysis

The cumulative density of the objective function for each of the three data sets are shown in Figures L–10 through L–12. The *x* axis of each plot is the RMS difference between the field-measured and modeled water table elevations for all wells in the calibration data set for all measurement times. The *y* axis shows the fraction of realizations that were lower than or equal to the corresponding RMS value. Note that the three curves have reasonably similar sigmoidally shaped cumulative distributions that vary over a similar RMS range.

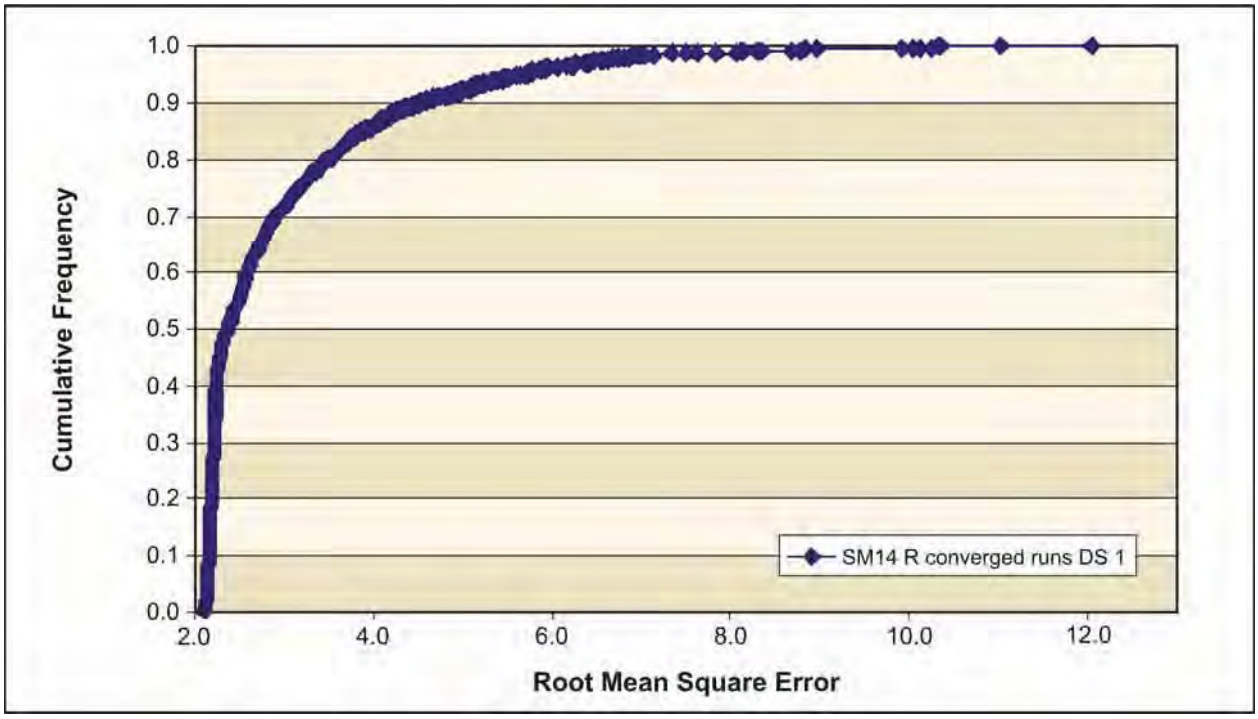


Figure L–10. Cumulative Density of the Objective Function – Base Case Model, Calibration Data Set 1

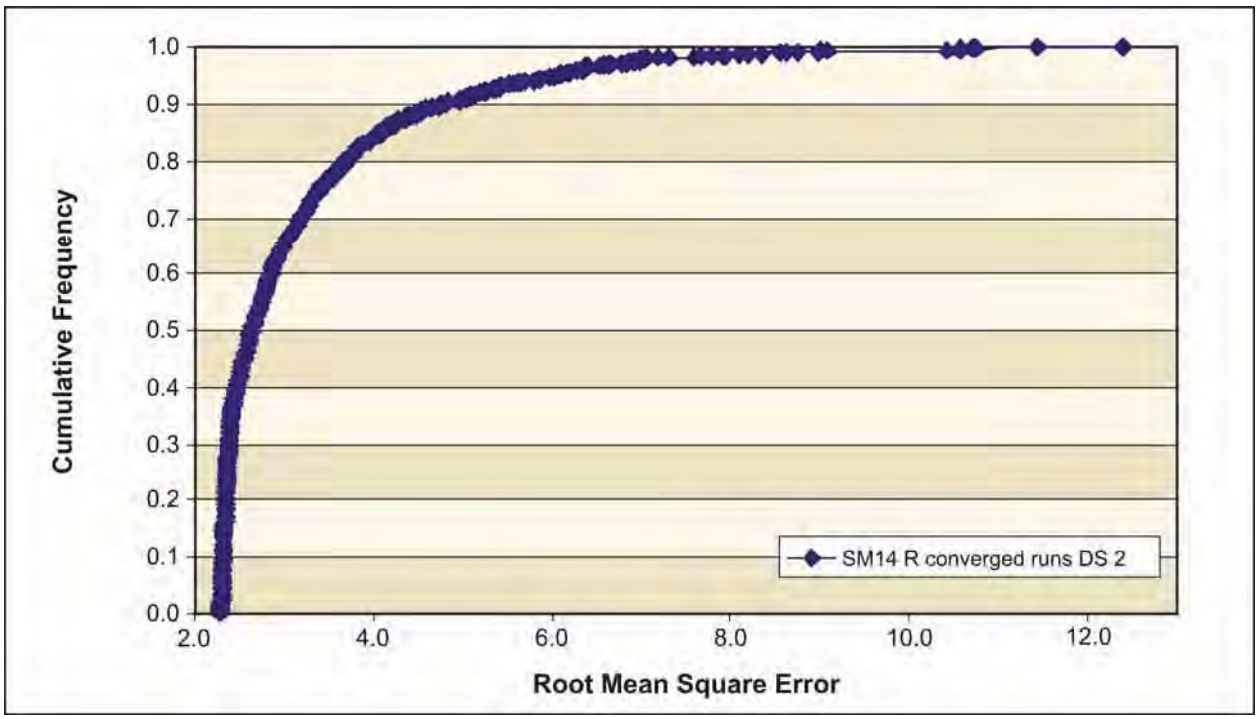


Figure L–11. Cumulative Density of the Objective Function – Base Case Model, Calibration Data Set 2

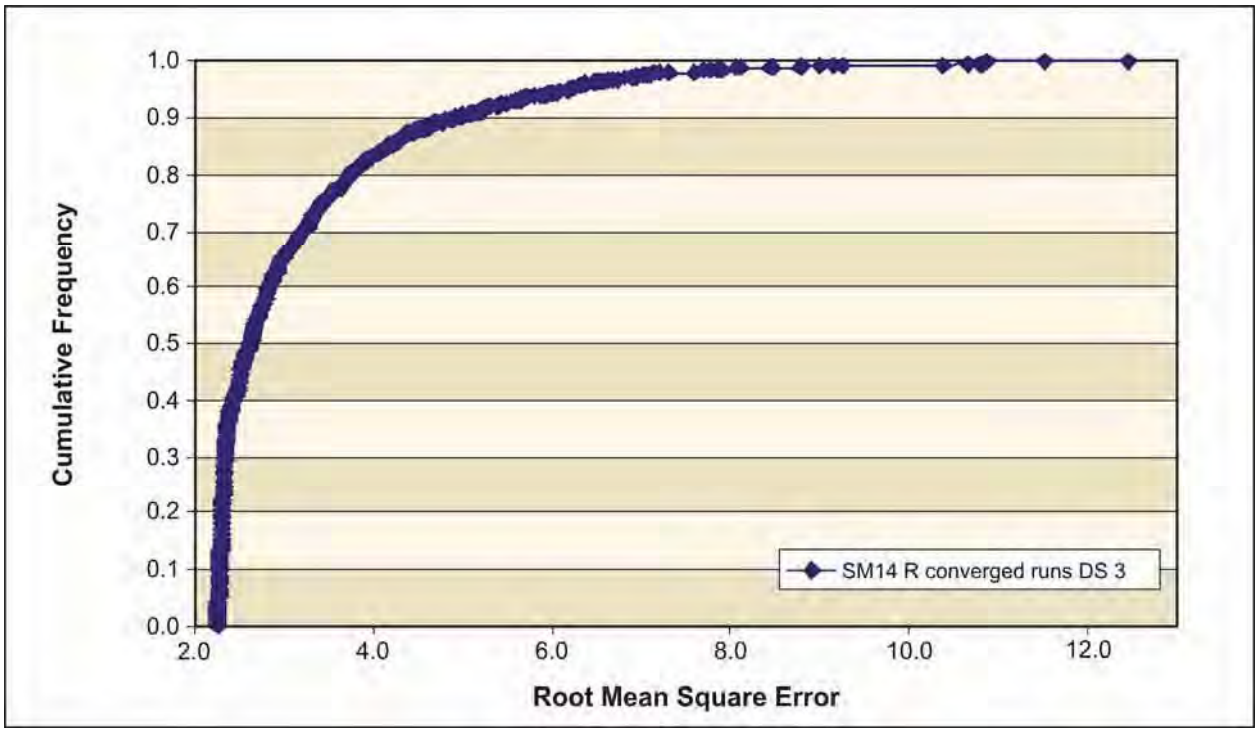


Figure L–12. Cumulative Density of the Objective Function – Base Case Model, Calibration Data Set 3

For each data set, the best realizations were chosen according to two criteria. The first criterion was that the RMS value for that realization was among the lowest (at least in the lowest 1 percent). The second criterion was that MODPATH (MODFLOW particle-tracking postprocessing package), particle tracks from sources in the 200-East Area showed reasonable qualitative agreement with the observed shape of the tritium plume originating near the Plutonium-Uranium Extraction (PUREX) Plant in the 200-East Area. In fact, as the RMS value decreased, the qualitative agreement of the MODPATH particle tracks with the PUREX Plant plume shape became increasing better. Section L.10.1.3.1 discusses the Base Case tritium plume delineations in more detail.

Finally, the distributions of the hydraulic conductivity values for the best realizations were compared to the distributions of the hydraulic conductivity values for all realizations. Figures L–13 through L–25 show these comparisons for the Base Case model, Calibration Data Set 1, for the 13 hydrostratigraphic units. (The comparisons for the other two calibration data sets are similar.) Each figure shows two cumulative densities. The *x* axis of each plot is the hydraulic conductivity (meters per day) for the hydrostratigraphic unit. The *y* axis shows the fraction of realizations that were lower than or equal to the corresponding hydraulic conductivity value. Two curves are plotted for each hydrostratigraphic unit. The curve plotted with the red symbols shows the cumulative distribution for all realizations. It is used to show the portion of parameter space that was searched. For example, for Hanford gravel (see Figure L–16) realizations were generated that covered the range of hydraulic conductivity from about 0.05 meters per day (0.16 feet per day) up to about 1,000,000 meters per day (3,281,000 feet per day), roughly a variation over eight orders of magnitude. The curve plotted with the green symbols shows the portion of parameter space that was covered by the best set of realizations. For example, the best realizations for Hanford gravel were restricted to a relatively narrow range – from about 110 meters per day (361 feet per day) to about 175 meters per day (574 feet per day). The steepness of the green curve relative to the red curve shows the degree of sensitivity the flow model shows to a particular hydraulic conductivity. When the green curve is steep, as it is for Hanford gravel (see Figure L–16), Ringold Gravel (see Figure L–18), and Highly conductive Hanford gravel(see Figure L–25), the flow model is

sensitive to those hydraulic conductivities and the best RMS values can only be obtained across a narrow range of values. For the units where the green curve is not as steep, and covers more of the range represented by the red curve, the flow model is less sensitive to those parameters, and good agreement between measured and modeled water table elevations can be obtained over a much broader range of hydraulic conductivities. Note that there is no particular ordering or correspondence in terms of RMS on either the green or red curves. Slight changes in hydraulic conductivity values can lead to higher or lower RMS error. The relationship between RMS and hydraulic conductivity is not linear. This analysis shows where (in hydraulic conductivity parameter space) the best realizations were found, but not that a particular hydraulic conductivity leads to a good result.

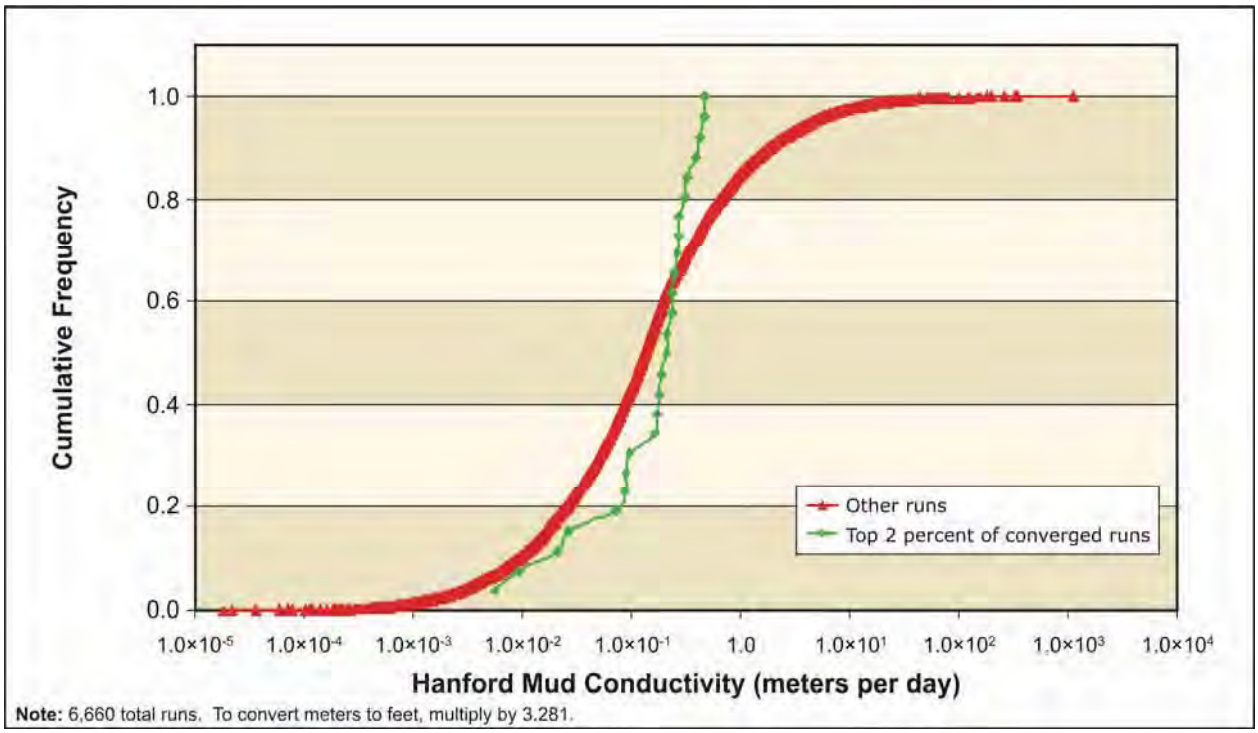


Figure L–13. Distribution of Hydraulic Conductivity Values – Hanford Mud

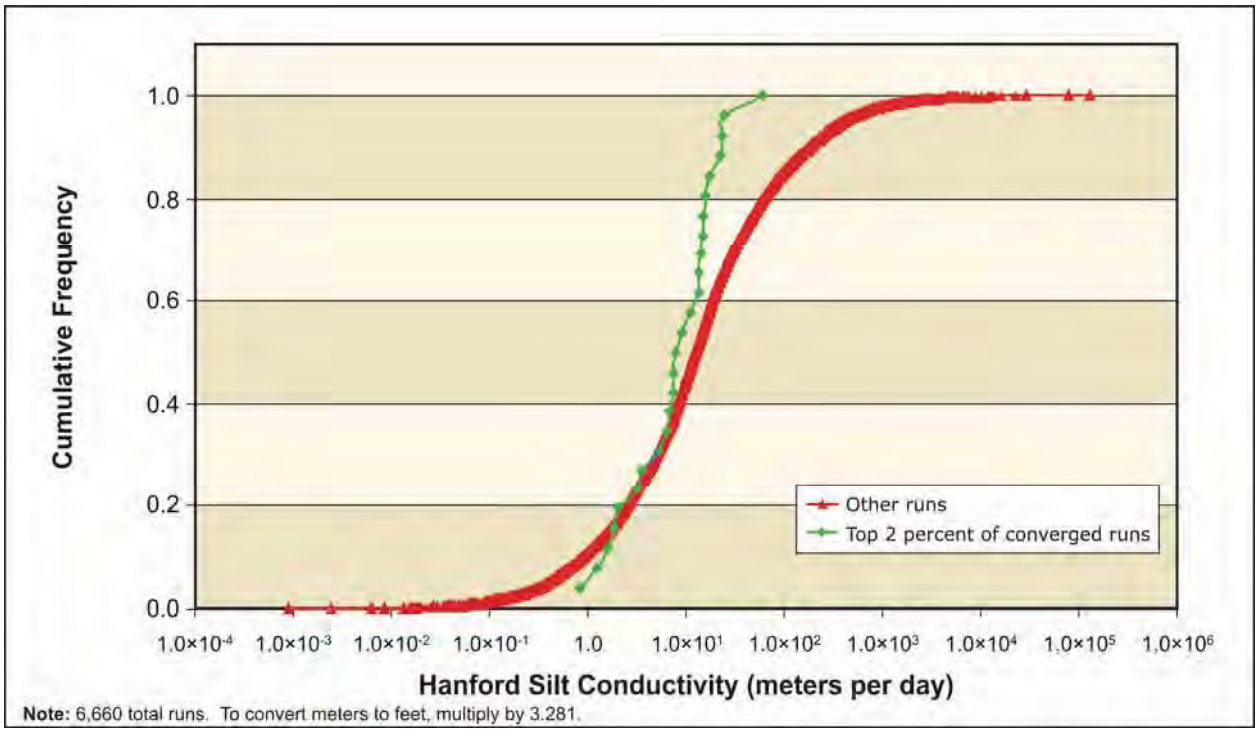


Figure L–14. Distribution of Hydraulic Conductivity Values – Hanford Silt

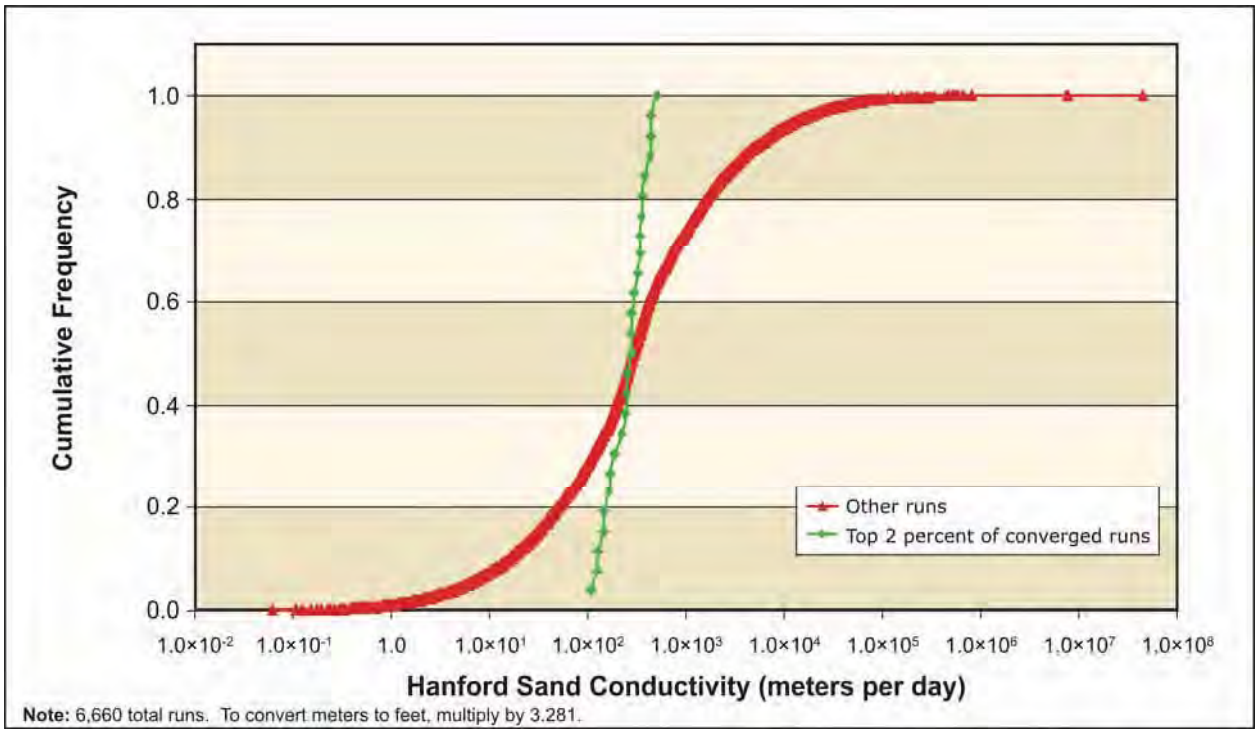


Figure L–15. Distribution of Hydraulic Conductivity Values – Hanford Sand

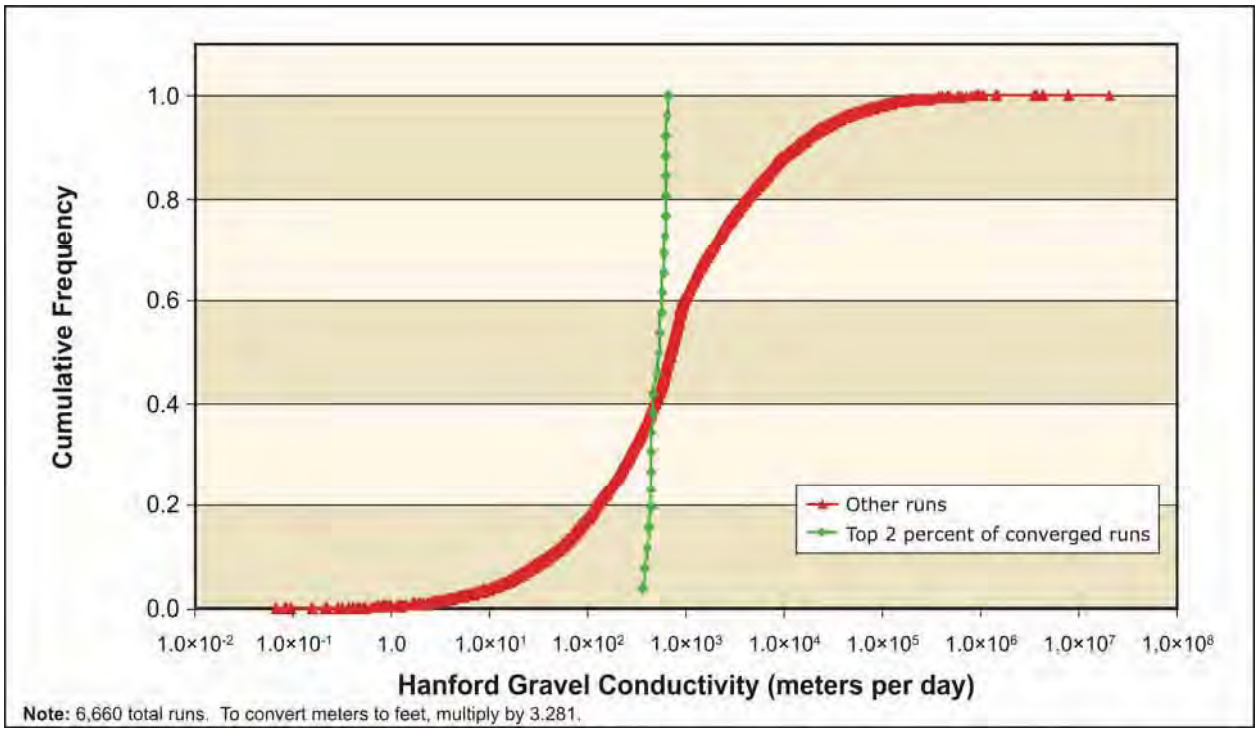


Figure L–16. Distribution of Hydraulic Conductivity Values – Hanford Gravel

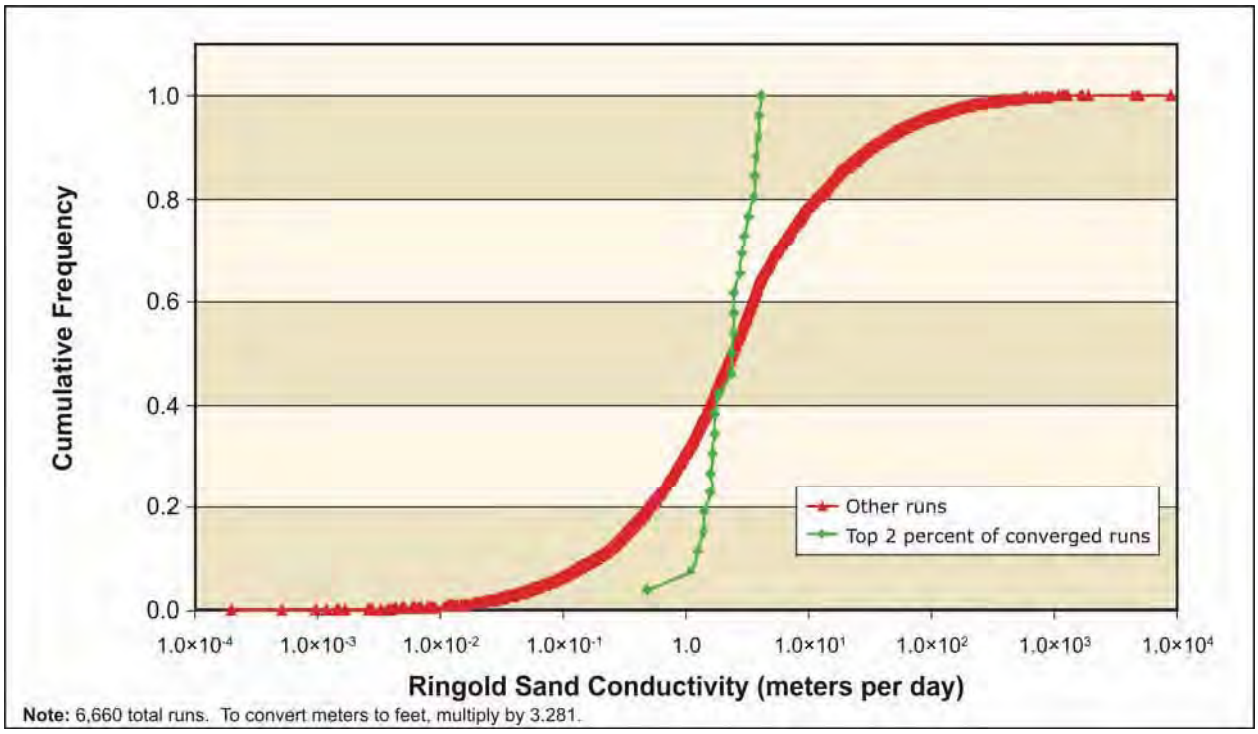


Figure L–17. Distribution of Hydraulic Conductivity Values – Ringold Sand

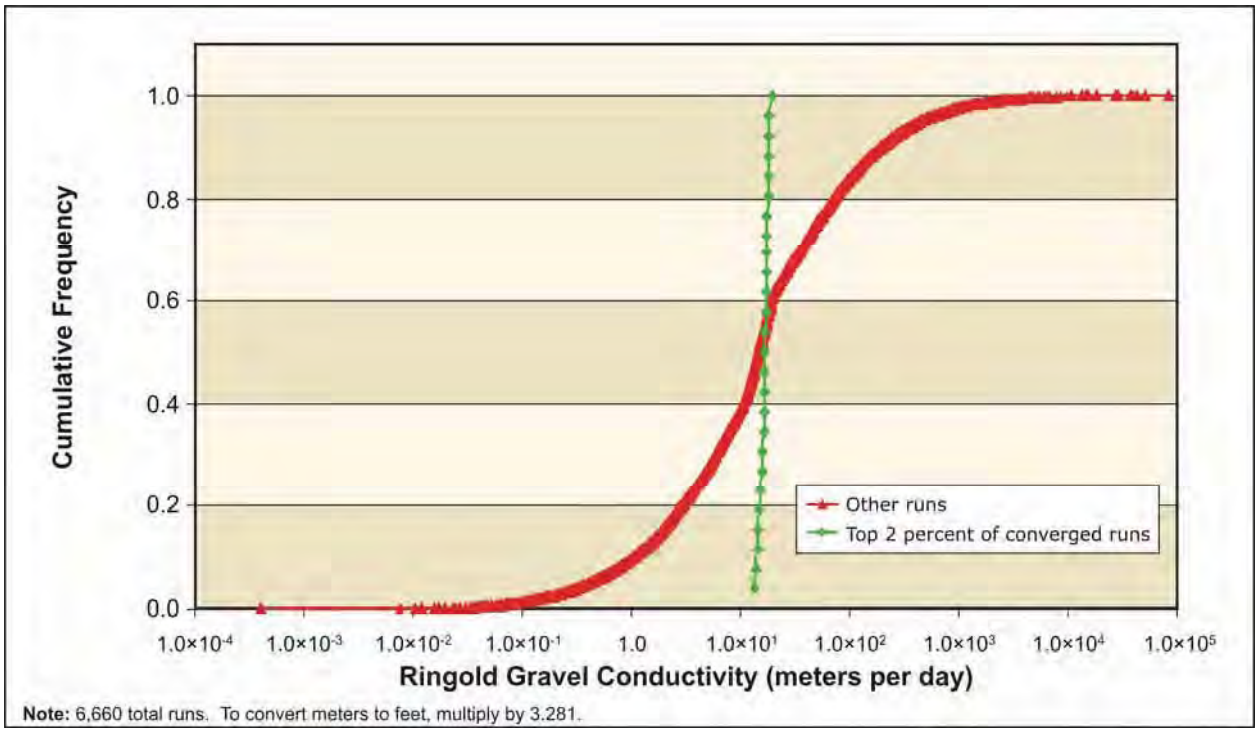


Figure L–18. Distribution of Hydraulic Conductivity Values – Ringold Gravel

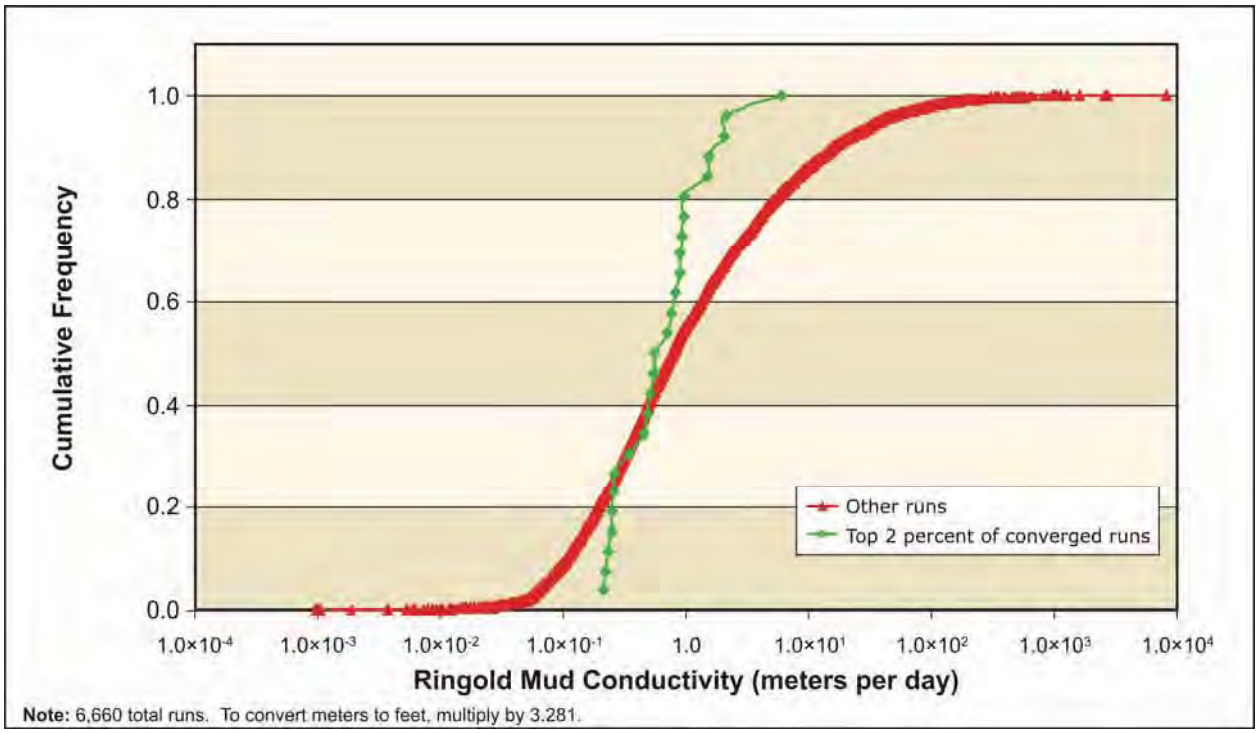


Figure L–19. Distribution of Hydraulic Conductivity Values – Ringold Mud

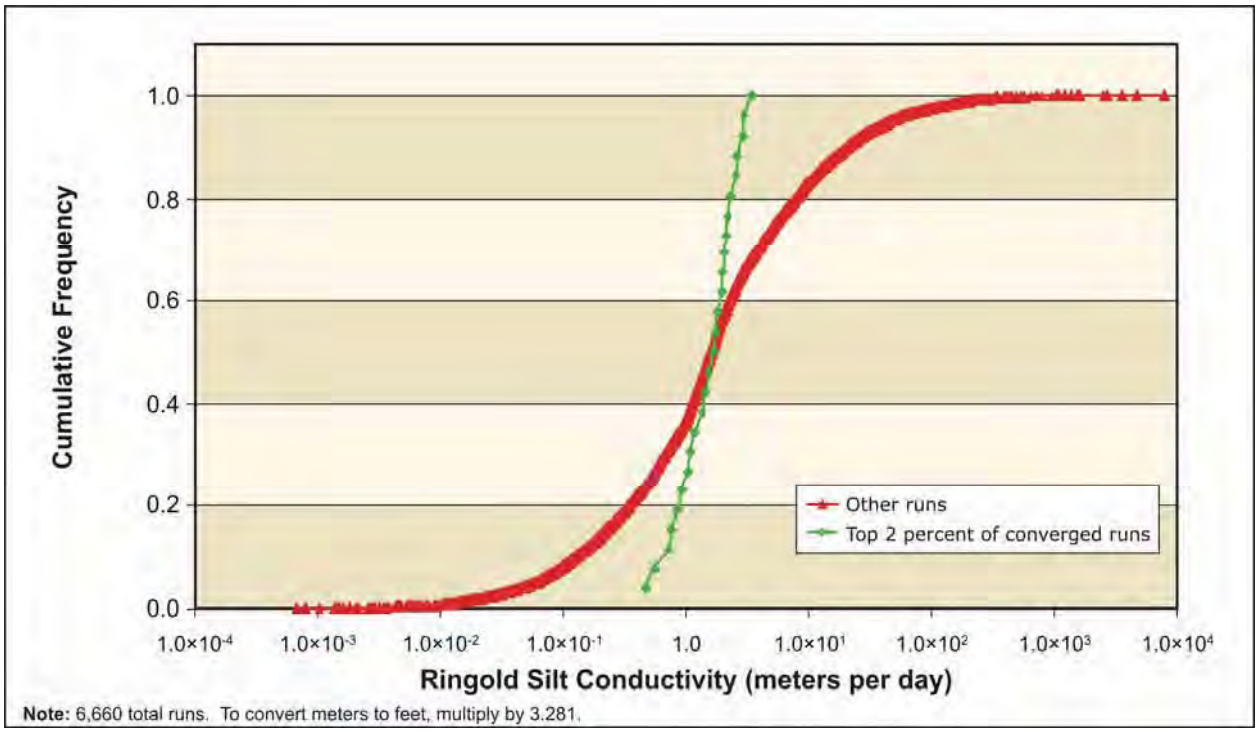


Figure L–20. Distribution of Hydraulic Conductivity Values – Ringold Silt

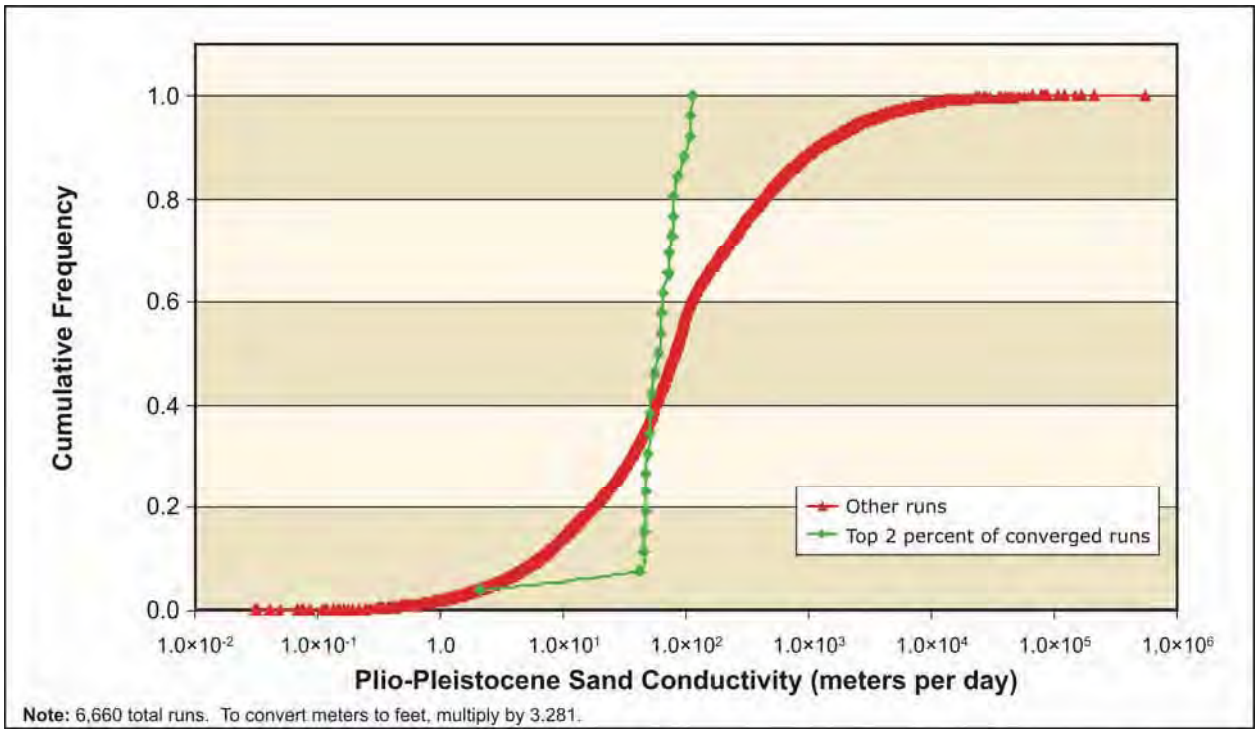


Figure L–21. Distribution of Hydraulic Conductivity Values – Plio-Pleistocene Sand

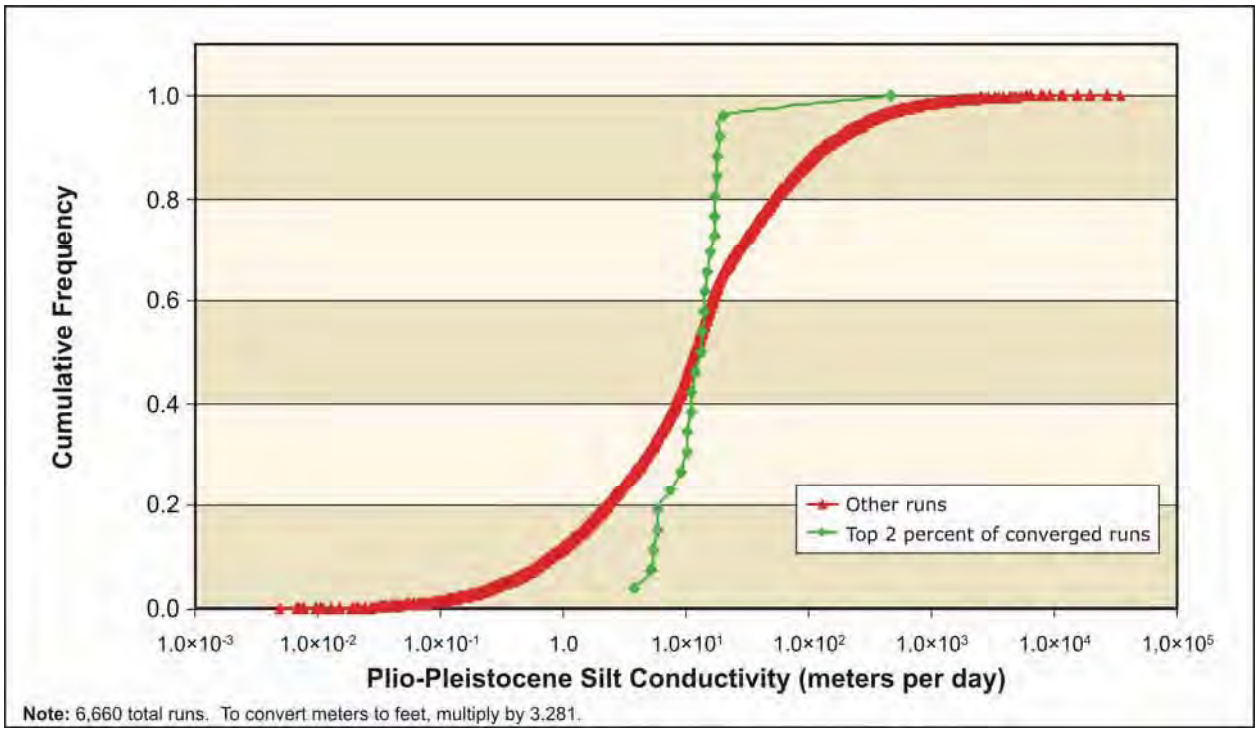


Figure L–22. Distribution of Hydraulic Conductivity Values – Plio-Pleistocene Silt

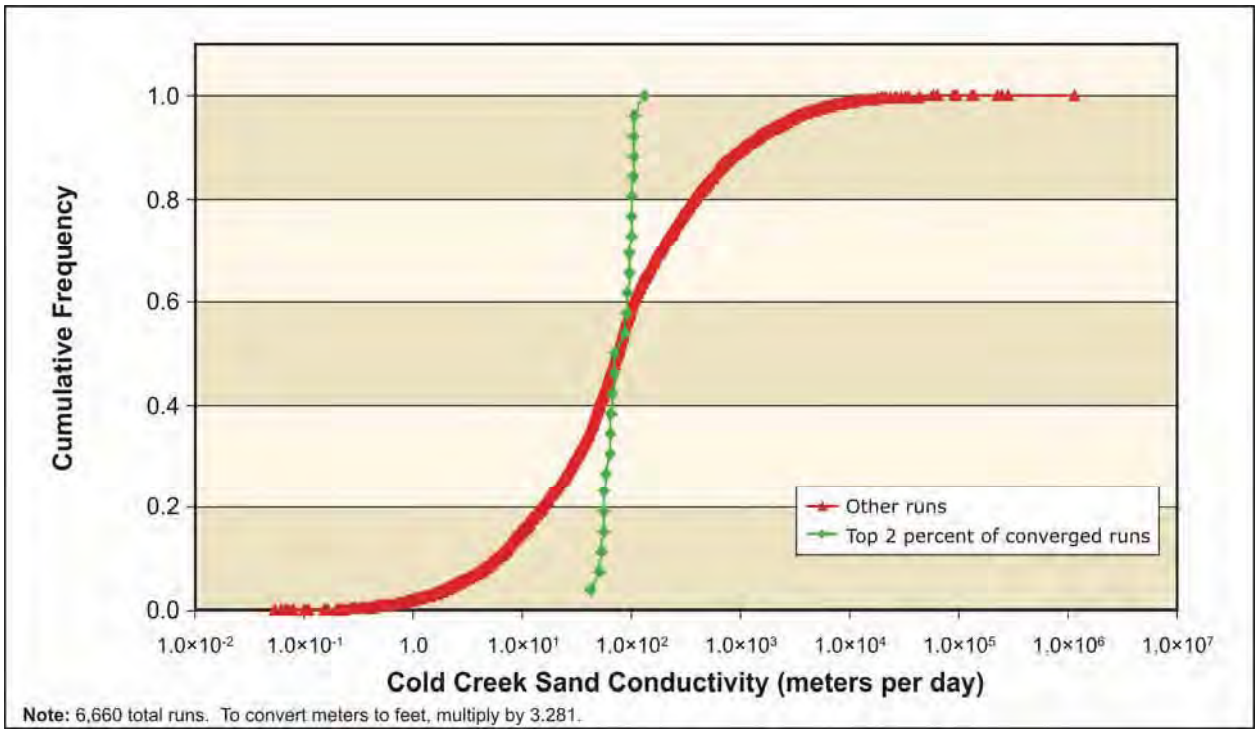


Figure L–23. Distribution of Hydraulic Conductivity Values – Cold Creek Sand

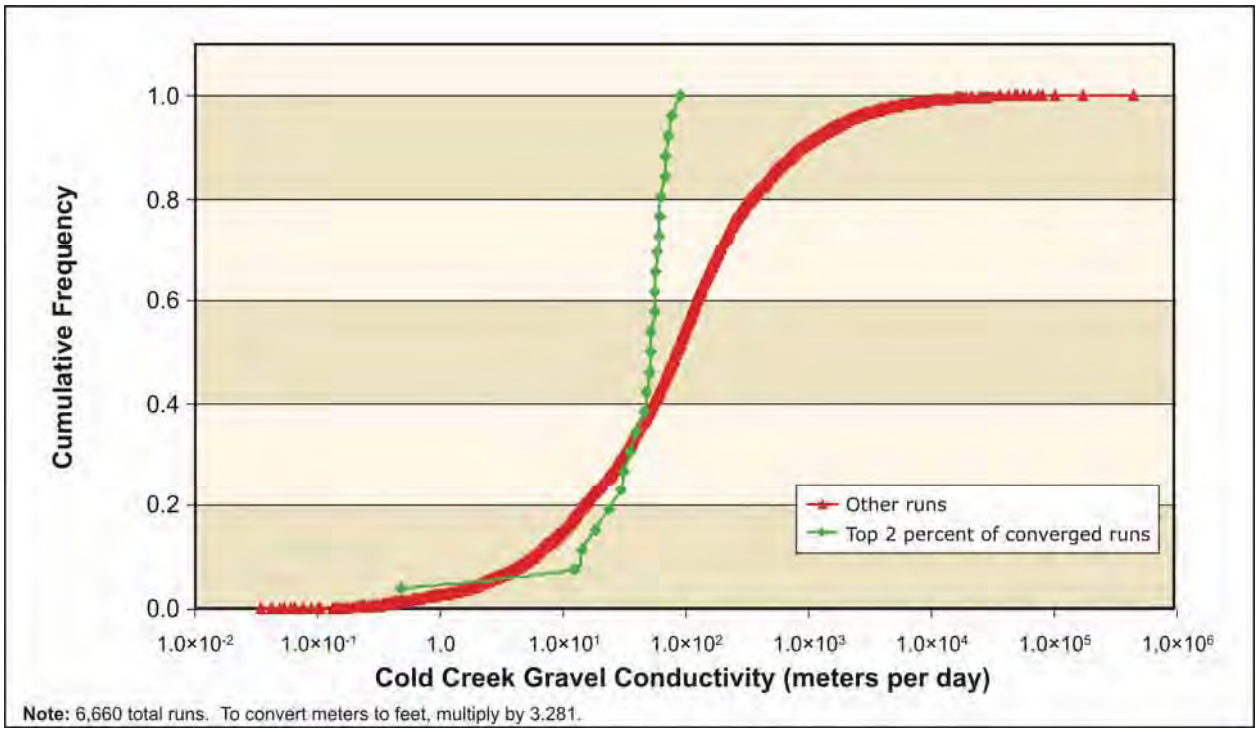


Figure L–24. Distribution of Hydraulic Conductivity Values – Cold Creek Gravel

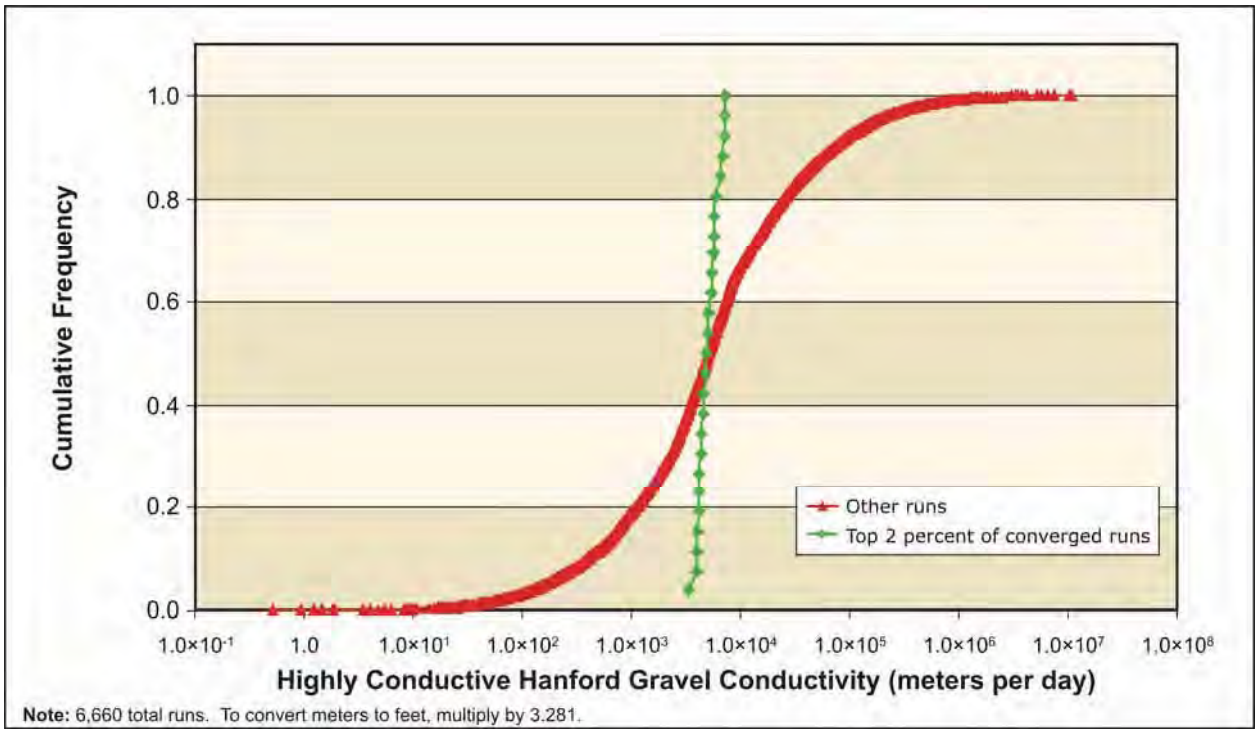


Figure L–25. Distribution of Hydraulic Conductivity Values – Highly Conductive Hanford Gravel

Table L–17 summarizes the results of the Base Case Monte Carlo Optimization and Uncertainty Analysis. For each of the three data sets, the thirteen hydrostratigraphic units are listed. For each unit, the range of hydraulic conductivity values found in the best realizations are listed. Note that the hydraulic conductivities found in the best realizations are similar to those found in the gradient-based search. However, the degree of sensitivity of the flow model to each parameter, and the range of acceptable values is much more reasonable from this analysis than from the gradient-based confidence intervals.

Table L–17. Summary of Base Case Monte Carlo Optimization and Uncertainty Analysis

Base Case Hydraulic Conductivity Distribution (meters per day)						
	Data Set 1		Data Set 2		Data Set 3	
Material Type	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Hanford mud	5.4×10^{-3}	4.7×10^{-1}	5.4×10^{-3}	4.7×10^{-1}	2.0×10^{-2}	5.0×10^{-1}
Hanford silt	8.0×10^{-1}	6.1×10^{1}	5.0×10^{-1}	6.1×10^{1}	2.3	1.8×10^{2}
Hanford sand	4.2×10^{1}	1.7×10^{2}	3.7×10^{1}	1.8×10^{2}	3.1×10^{1}	1.6×10^{2}
Hanford gravel	1.3×10^{2}	2.2×10^{2}	1.3×10^{2}	2.1×10^{2}	1.5×10^{2}	2.4×10^{2}
Ringold Sand	4.9×10^{-1}	4.2	2.7×10^{-1}	4.2	2.4×10^{-1}	4.1
Ringold Gravel	1.3×10^{1}	1.9×10^{1}	1.2×10^{1}	1.7×10^{1}	1.3×10^{1}	1.7×10^{1}
Ringold Mud	2.1×10^{-1}	6.0	2.9×10^{-1}	6.0	2.7×10^{-1}	2.1
Ringold Silt	4.6×10^{-1}	3.4	4.6×10^{-1}	3.3	5.1×10^{-1}	2.0×10^{1}
Plio-Pleistocene sand	2.1	1.1×10^{2}	2.1	1.2×10^{2}	2.6×10^{1}	1.2×10^{2}
Plio-Pleistocene silt	3.8	4.5×10^{2}	1.8×10^{-1}	4.5×10^{2}	1.0×10^{-2}	3.0×10^{1}
Cold Creek sand	4.2×10^{1}	1.3×10^{2}	3.0×10^{1}	1.3×10^{2}	3.0×10^{1}	1.0×10^{2}
Cold Creek gravel	5.0×10^{-1}	9.3×10^{1}	4.0	1.2×10^{2}	2.0×10^{1}	1.2×10^{2}
Highly conductive Hanford gravel	3.3×10^{3}	7.2×10^{3}	3.8×10^{3}	7.9×10^{3}	4.5×10^{3}	4.8×10^{3}

Note: To convert meters to feet, multiply by 3.281.

Approximately 400 model runs were completed, targeting head observation data set 4 (the validation data set), and RMS error values were calculated. Results concluded that the hydraulic conductivity values producing the lowest RMS error using validation data set 4 reasonably correlate to the hydraulic conductivity values that produced the lowest RMS error using calibration data sets 1, 2, and 3.

L.9.3 Alternate Case – Results of the Analysis

The cumulative density of the objective function for each of the three data sets are shown in Figures L–26 through L–28. The *x* axis of each plot is the RMS difference between the field-measured and modeled water table elevations for all wells in the calibration data set for all measurement times. The *y* axis shows the fraction of realizations that were lower than or equal to the corresponding RMS value. Note that the three curves have reasonably similar sigmoidally shaped cumulative distributions that vary over a similar RMS range.

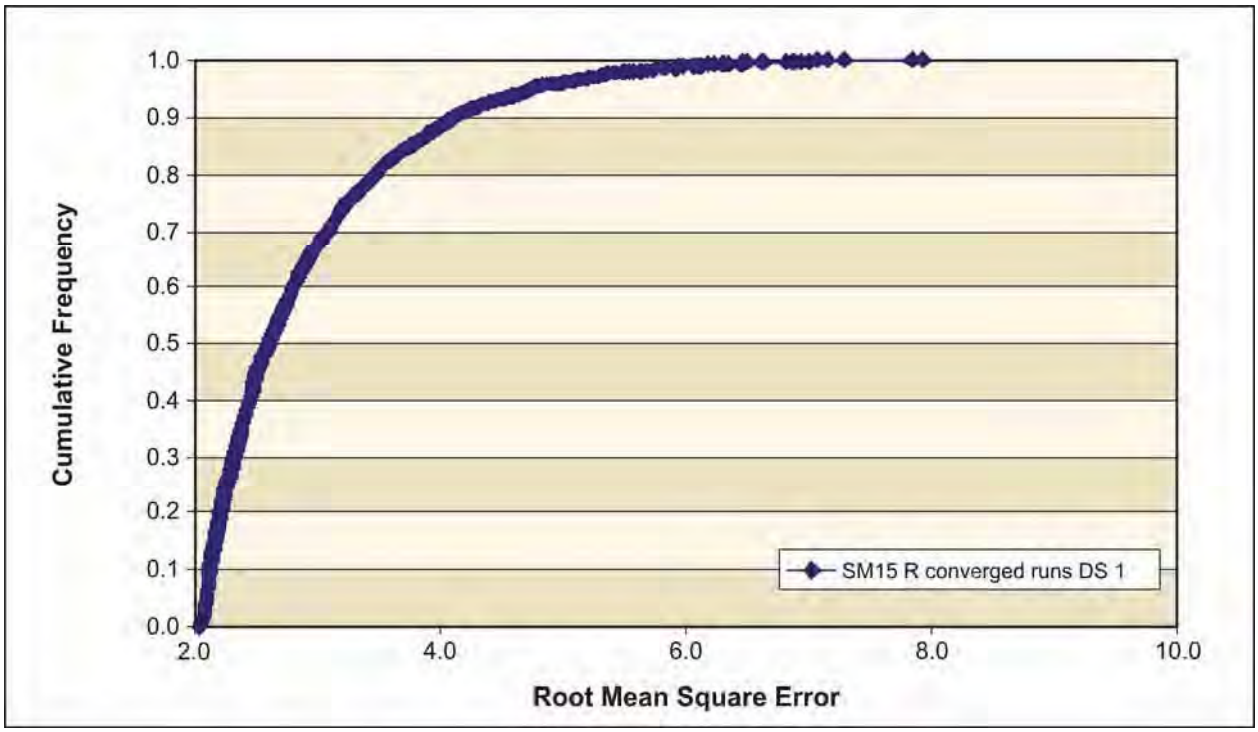


Figure L–26. Cumulative Density of the Objective Function – Alternate Case Model – Calibration Data Set 1

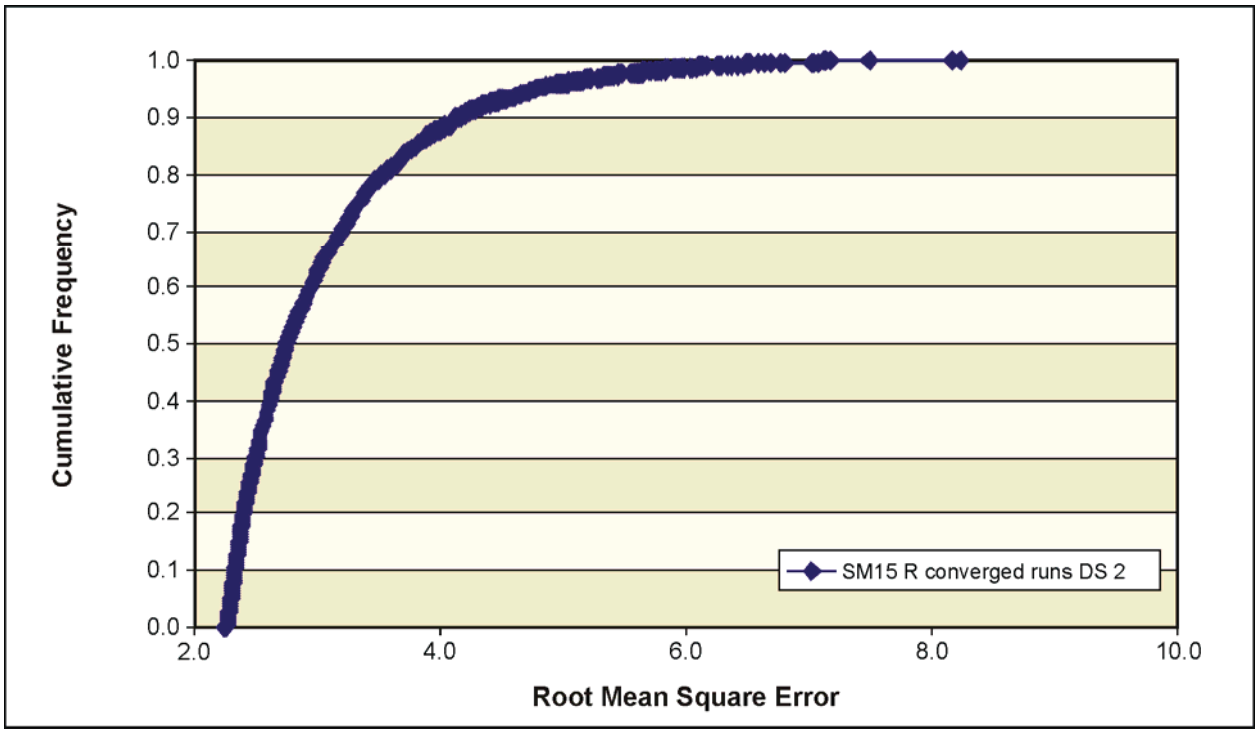


Figure L–27. Cumulative Density of the Objective Function – Alternate Case Model – Calibration Data Set 2

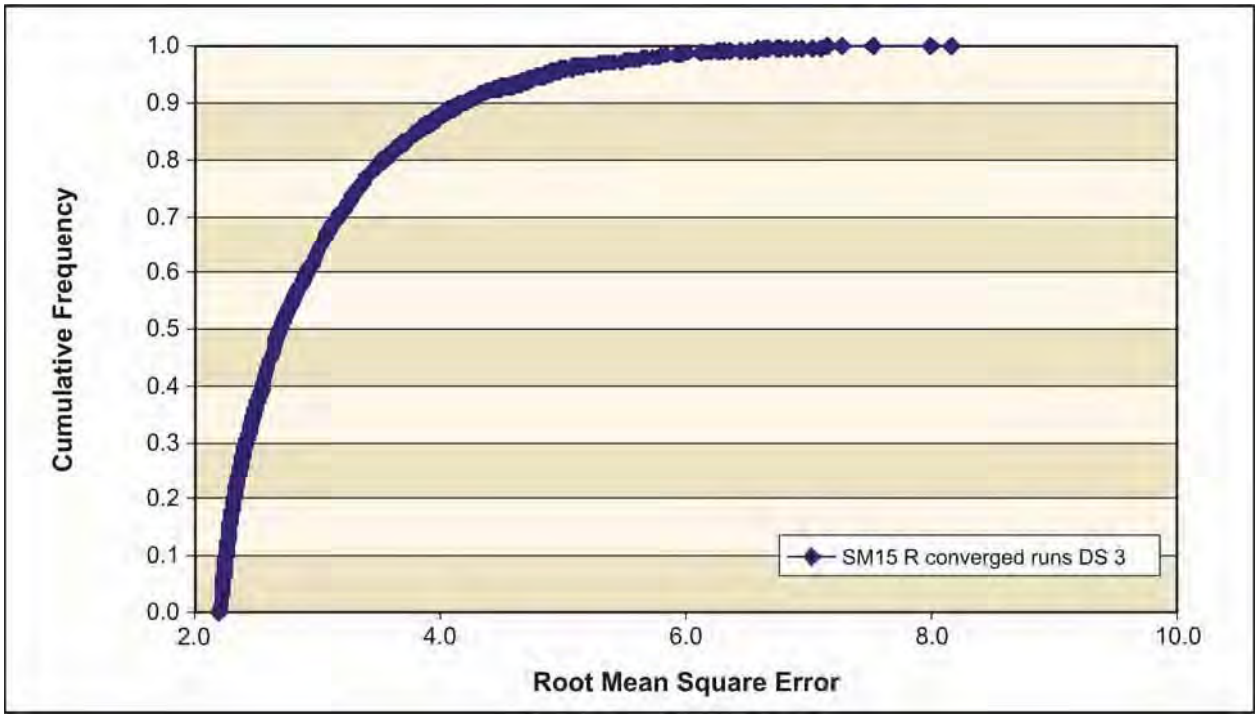


Figure L–28. Cumulative Density of the Objective Function – Alternate Case Model – Calibration Data Set 3

For each data set, the best realizations were chosen according to two criteria. The first criterion was that the RMS value for that realization was among the lowest (at least in the lowest 1 percent). The second criterion was that MODPATH particle tracks from sources in the 200-East Area showed reasonable qualitative agreement with the observed shape of the tritium plume originating near the PUREX plant in the 200-East Area. In fact, as the RMS value decreased, the qualitative agreement of the MODPATH particle tracks with the shape of the PUREX Plant plume became increasingly better. Section L.10.2.3.1 discusses the Alternate Case tritium plume delineations in more detail.

Finally, the distributions of the hydraulic conductivity values for the best realizations were compared to the distributions of the hydraulic conductivity values for all realizations. Figures L–29 through L–41 show these comparisons for the Alternate Case model, Calibration Data Set 1, for the 13 hydrostratigraphic units. (The comparisons for the other two calibration data sets are similar.) Each figure shows two cumulative densities. The *x* axis of each plot is the hydraulic conductivity (meters per day) for the hydrostratigraphic unit. The *y* axis shows the fraction of realizations that were lower than or equal to the corresponding hydraulic conductivity value. Two curves are plotted for each hydrostratigraphic unit. The curve plotted with the red symbols shows the cumulative distribution for all realizations. It is used to show the portion of parameter space that was searched. For example, for Hanford gravel (see Figure L–32), realizations were generated that covered the range of hydraulic conductivities from about 5 meters per day (16.4 feet per day) up to about 10,000 meters per day (32,810 feet per day), roughly a variation over three orders of magnitude. The curve plotted with the green symbols shows the portion of parameter space that was covered by the best set of realizations. For example, the best realizations for Hanford gravel were restricted to a relatively narrow range—from about 110 meters per day (361 feet per day) to about 175 meters per day (574 feet per day). The steepness of the green curve relative to the red curve shows the degree of sensitivity the groundwater flow model shows to a particular hydraulic conductivity. When the green curve is steep, as it is for Hanford gravel (see Figure L–32), Ringold Gravel (see Figure L–34), and Highly conductive Hanford gravel (see Figure L–41), the flow model is sensitive to those hydraulic conductivities, and the best RMS values can only be obtained across a narrow range of values. For the units where the green curve is not as steep

and covers more of the range represented by the red curve, the flow model is less sensitive to those parameters, and good agreement between measured and modeled water table elevations can be obtained over a much broader range of hydraulic conductivities. Note that there is no particular ordering or correspondence in terms of RMS on either the green or red curves. Realizations with low or high RMSs can (and are) plotted next to realizations with high or low RMSs. This analysis shows where (in hydraulic conductivity parameter space) the best realizations were found, but not that a particular hydraulic conductivity leads to a good result.

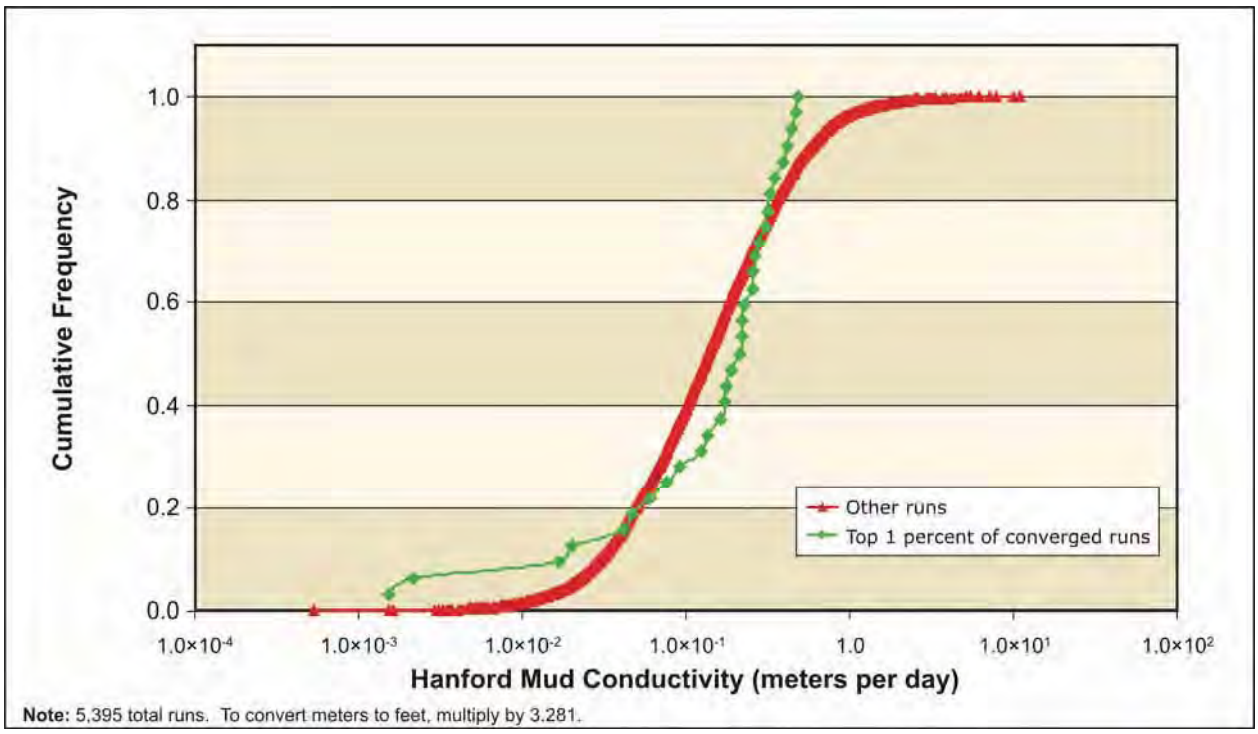


Figure L–29. Distribution of Hydraulic Conductivity Values – Hanford Mud

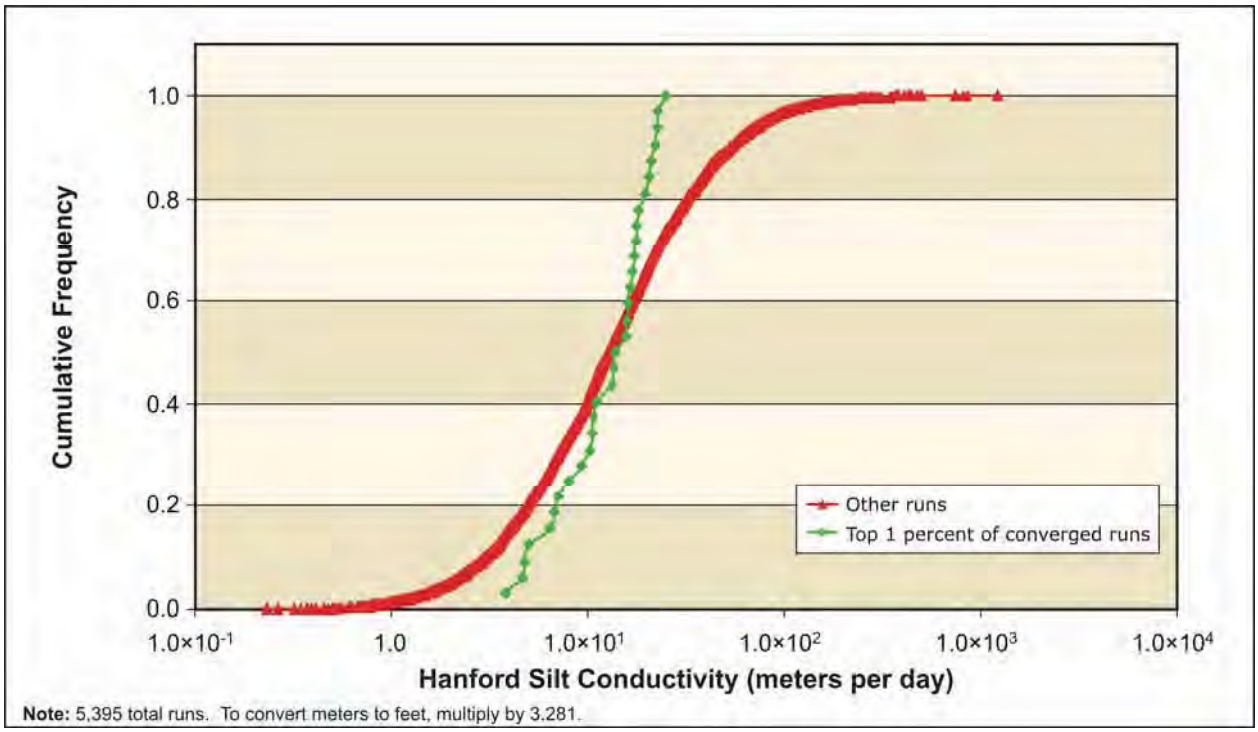


Figure L–30. Distribution of Hydraulic Conductivity Values – Hanford Silt

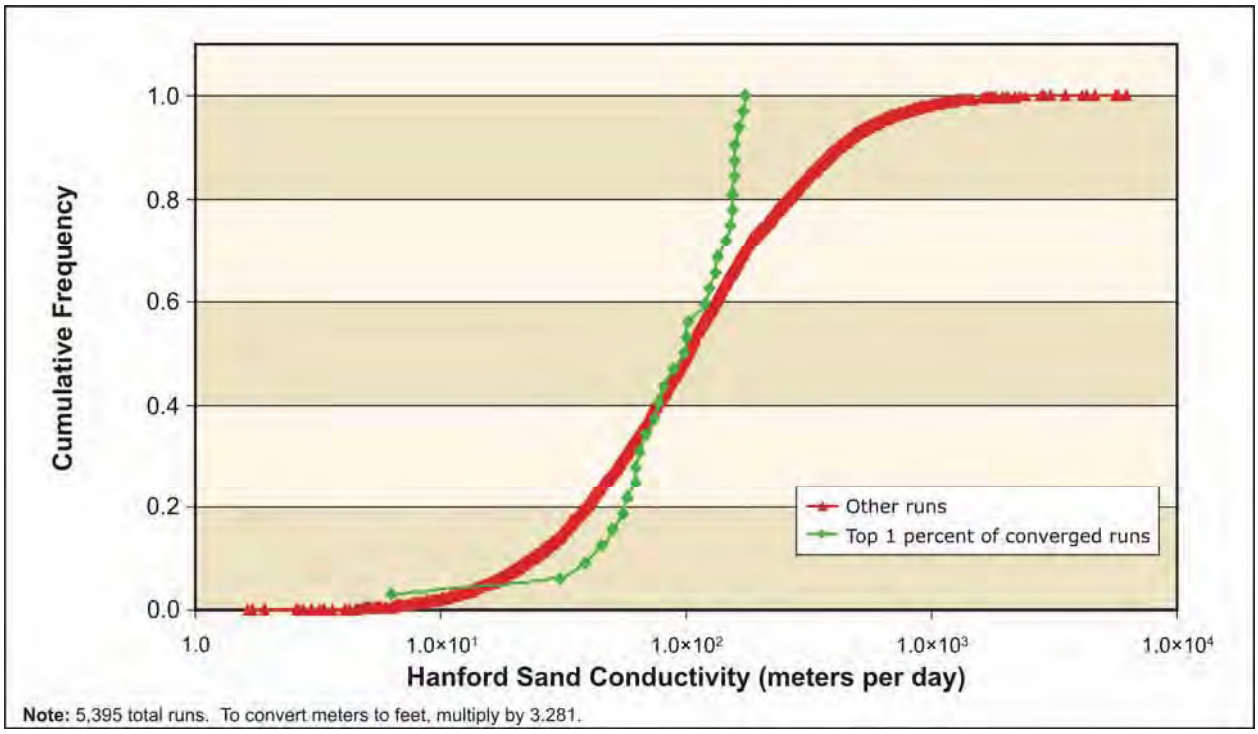


Figure L–31. Distribution of Hydraulic Conductivity Values – Hanford Sand

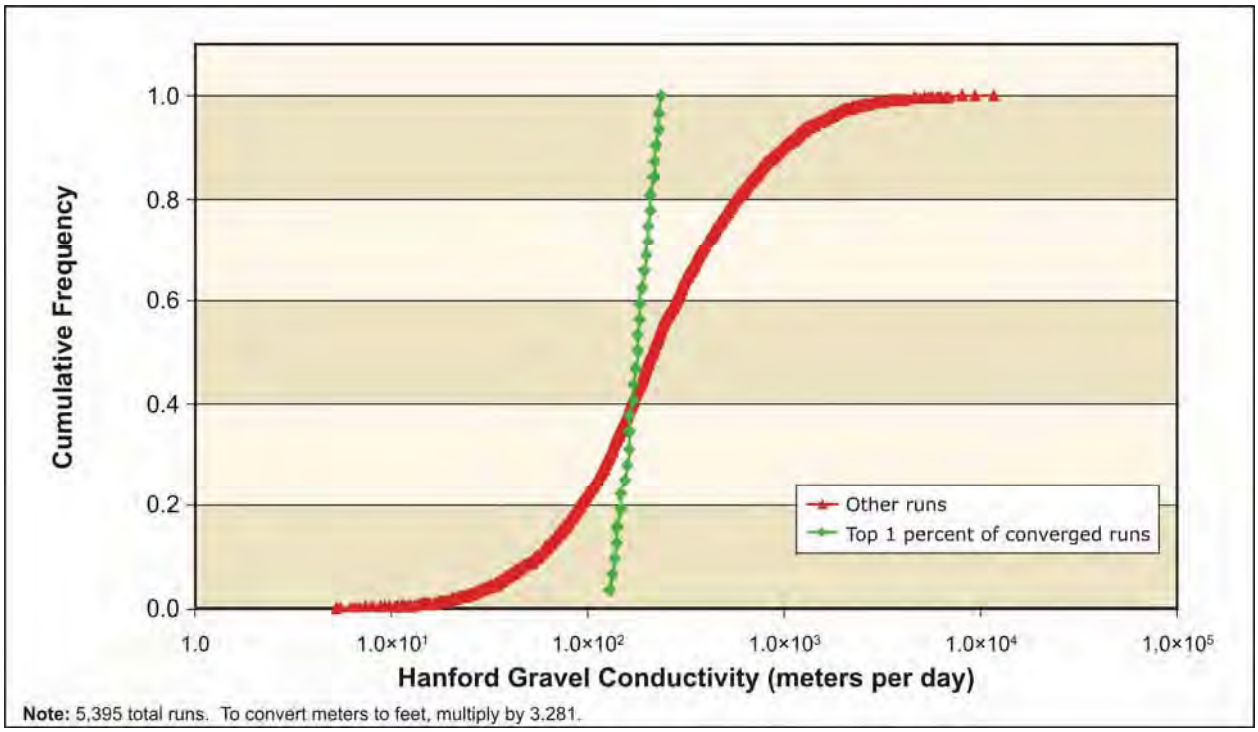


Figure L–32. Distribution of Hydraulic Conductivity Values – Hanford Gravel

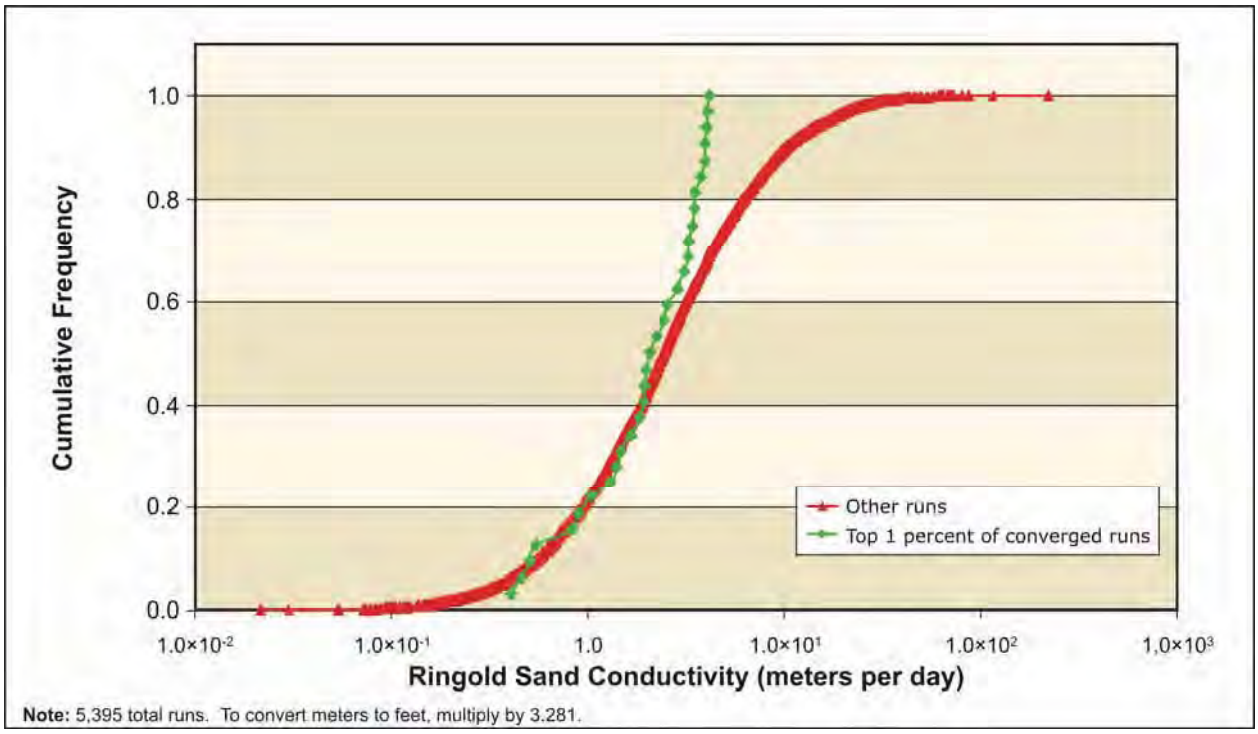


Figure L–33. Distribution of Hydraulic Conductivity Values – Ringold Sand

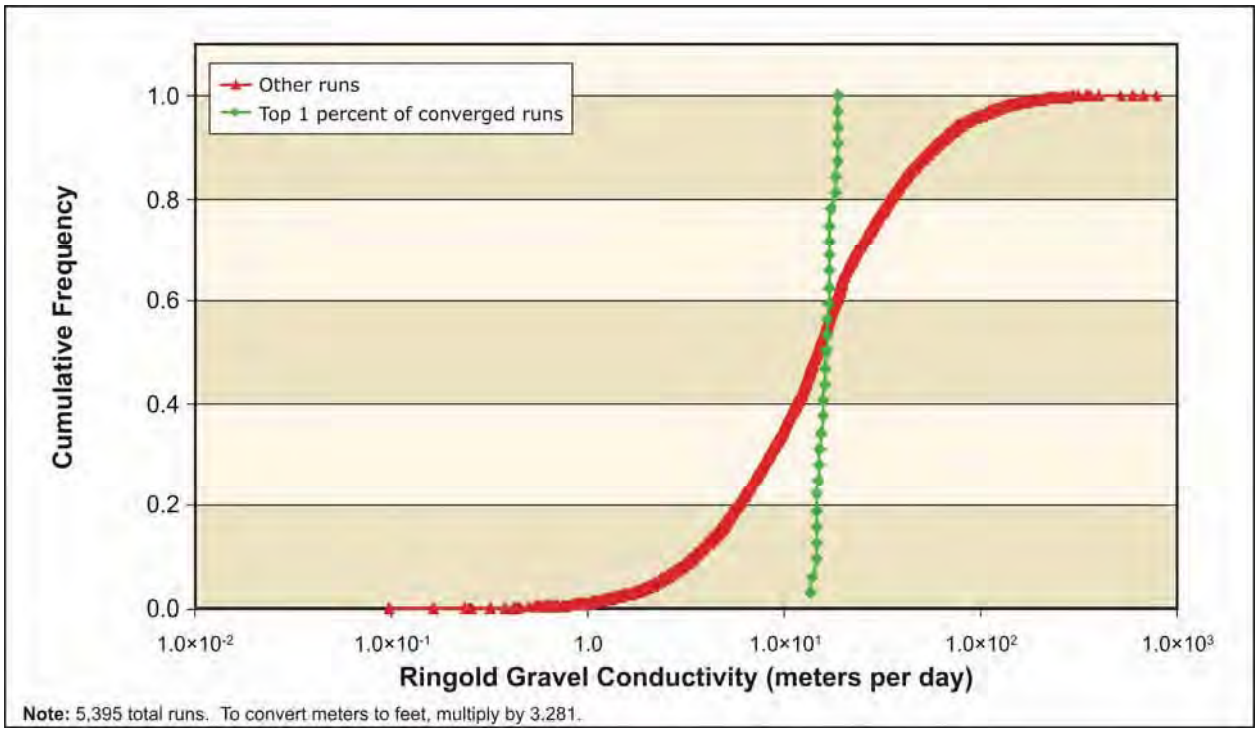


Figure L–34. Distribution of Hydraulic Conductivity Values – Ringold Gravel

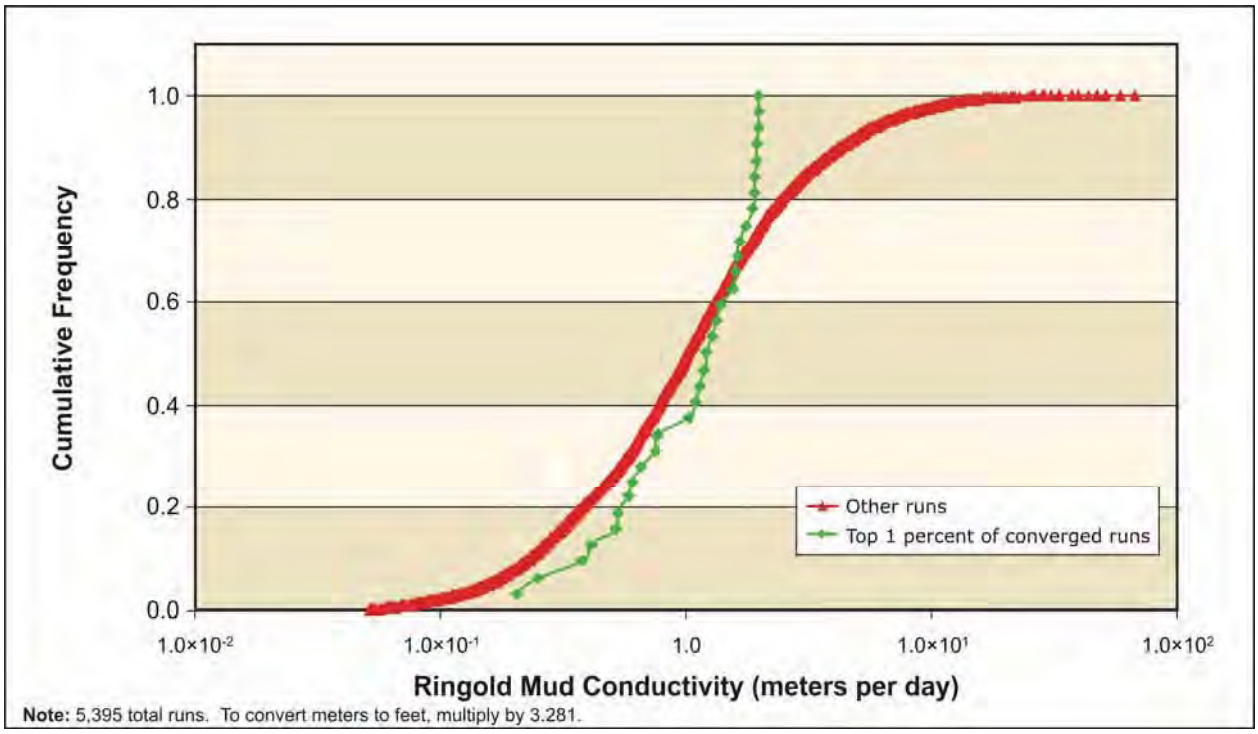


Figure L–35. Distribution of Hydraulic Conductivity Values – Ringold Mud

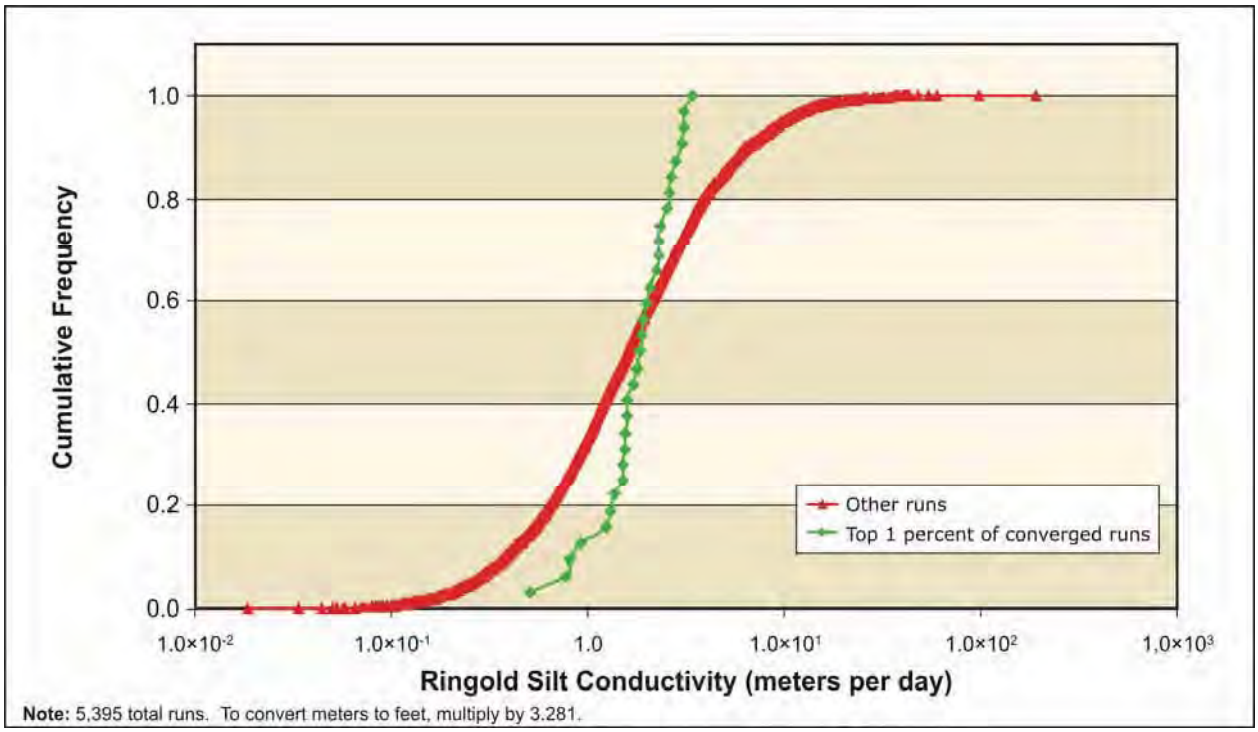


Figure L–36. Distribution of Hydraulic Conductivity Values – Ringold Silt

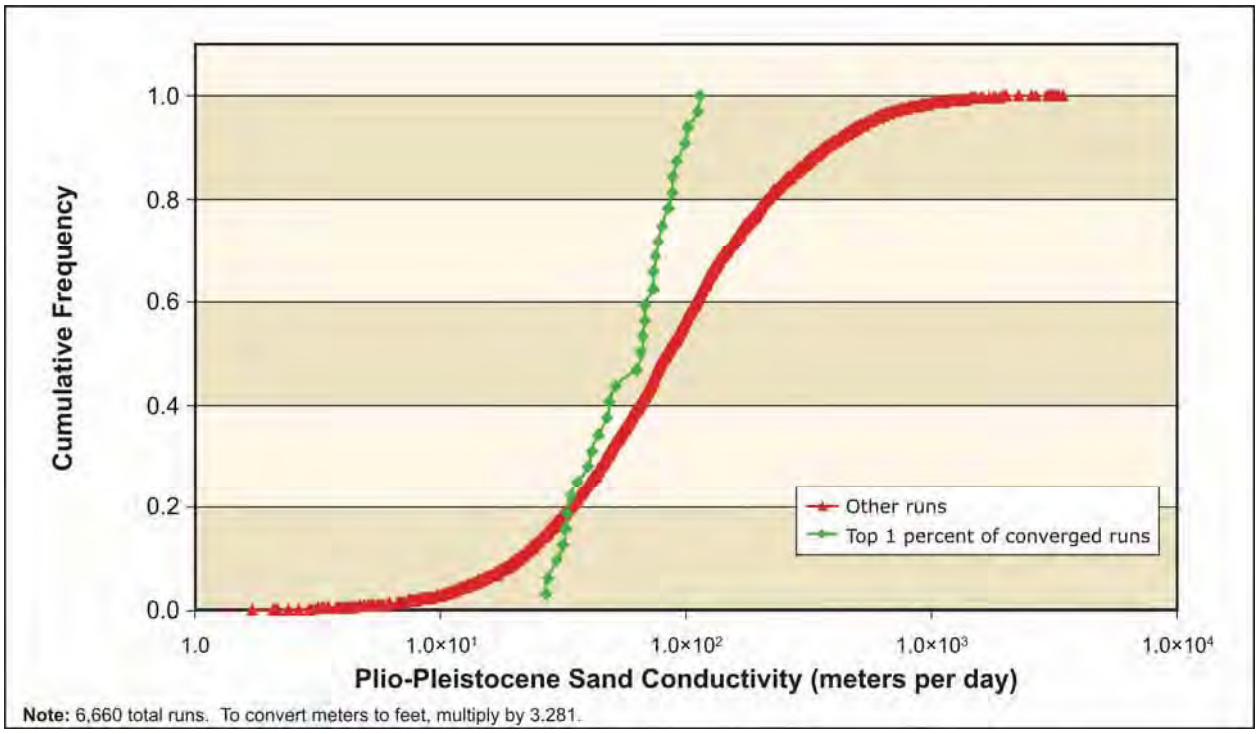


Figure L–37. Distribution of Hydraulic Conductivity Values – Plio-Pleistocene Sand

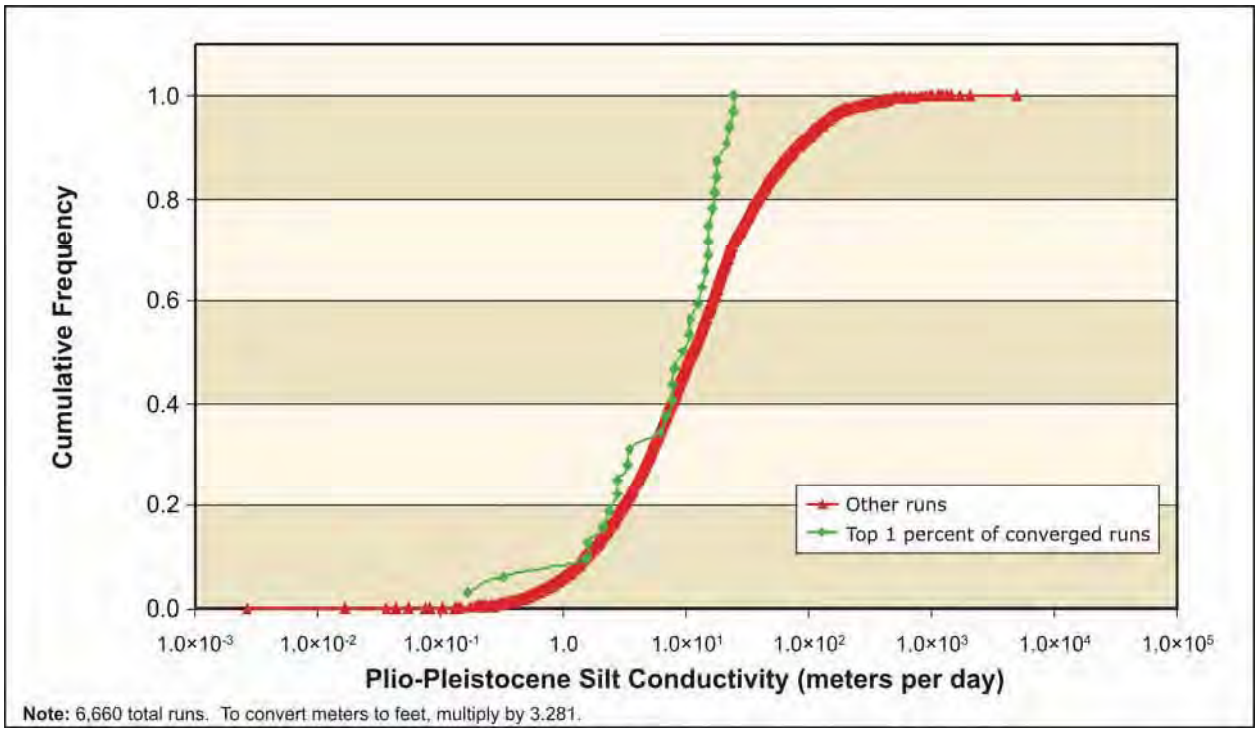


Figure L–38. Distribution of Hydraulic Conductivity Values – Plio-Pleistocene Silt

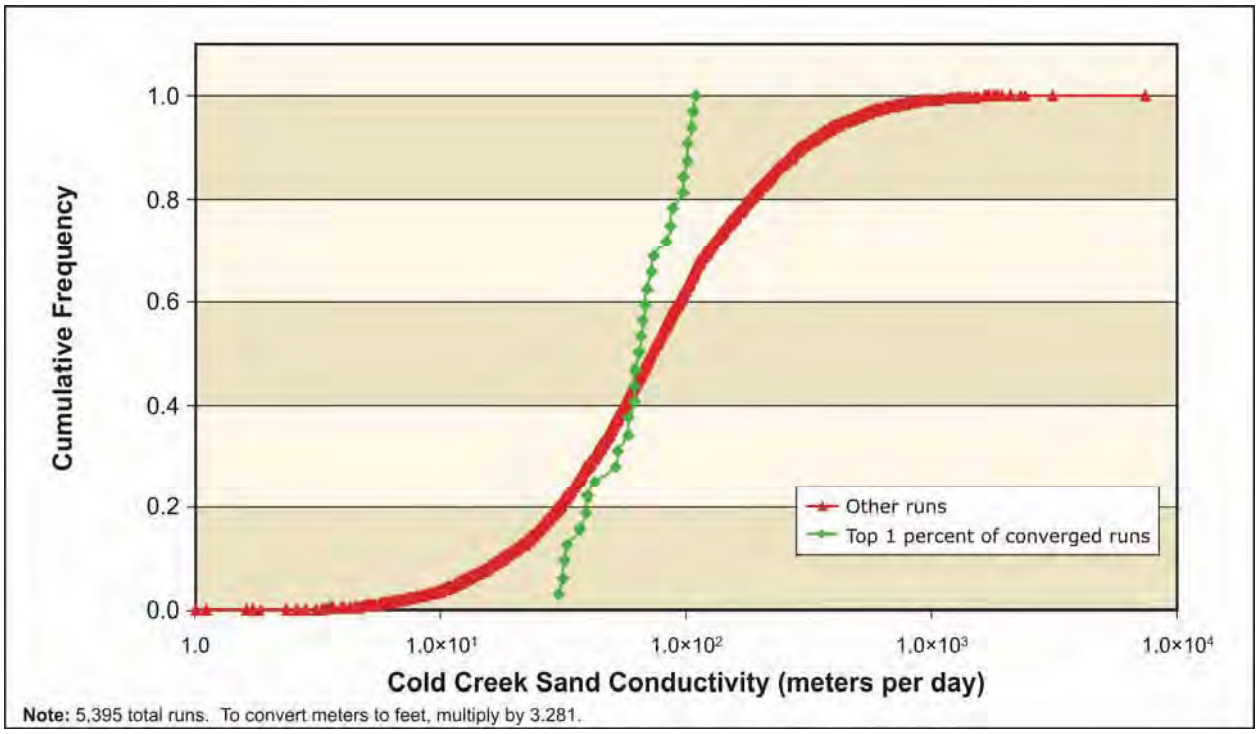


Figure L–39. Distribution of Hydraulic Conductivity Values – Cold Creek Sand

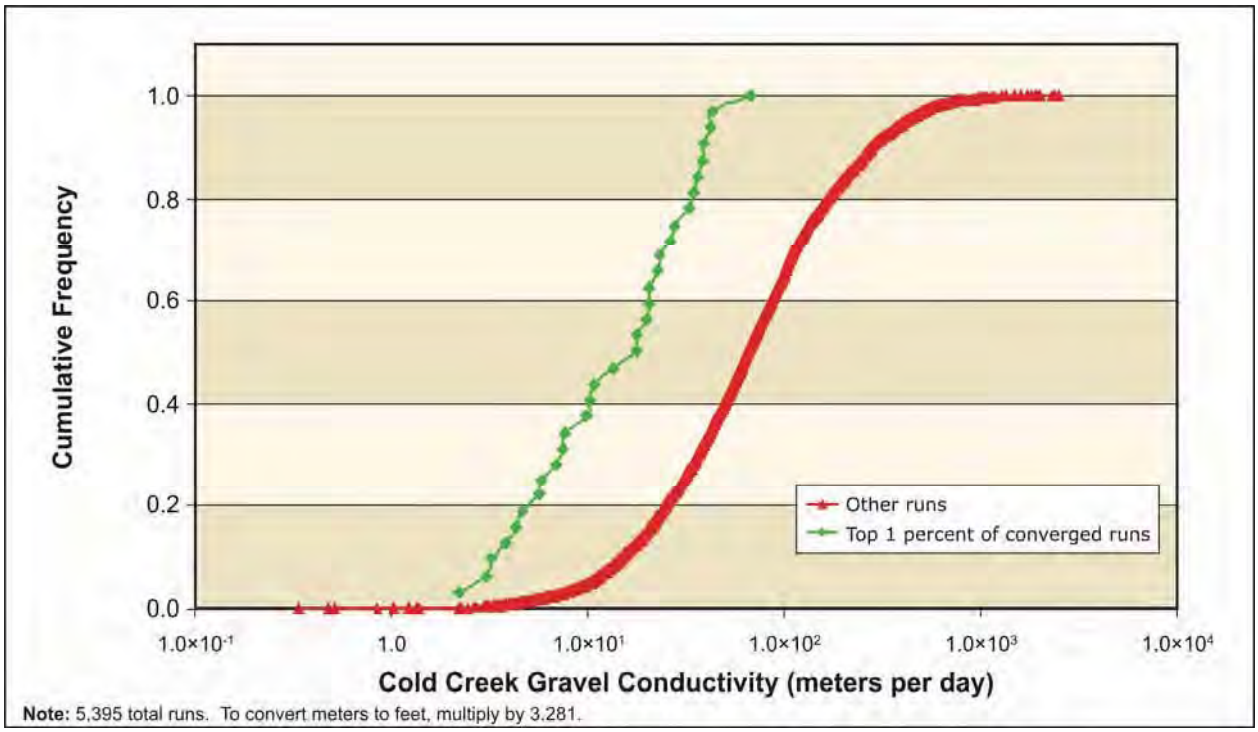


Figure L–40. Distribution of Hydraulic Conductivity Values – Cold Creek Gravel

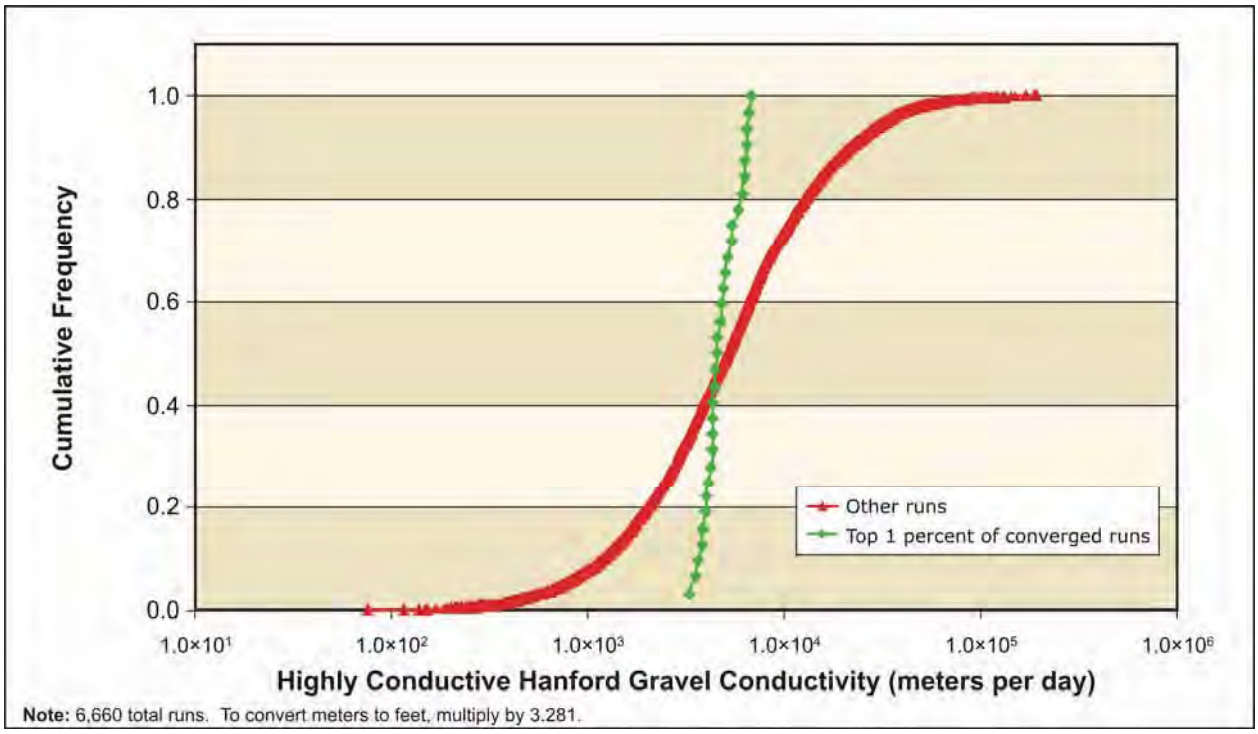


Figure L–41. Distribution of Hydraulic Conductivity Values – Highly Conductive Hanford Gravel

Table L–18 summarizes the results of the Alternate Case Monte Carlo optimization and uncertainty analysis. For each of the three data sets, the 13 hydrostratigraphic units is listed. For each unit, the range of hydraulic conductivity values found in the best realizations is listed. Note that the hydraulic conductivities found in the best realizations are not all that different than those found in the gradient-based search. However, this analysis yields a much more reasonable degree of sensitivity of the groundwater flow model to each parameter and range of acceptable values than the gradient-based confidence intervals.

Table L–18. Summary of Alternate Case Monte Carlo Optimization and Uncertainty Analysis

Alternate Case Hydraulic Conductivity Distribution (meters per day)						
	Data Set 1		Data Set 2		Data Set 3	
Material Type	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Hanford mud	2×10^{-3}	4.8×10^{-1}	8.4×10^{-3}	5×10^{-1}	1.4×10^{-2}	4.9×10^{-1}
Hanford silt	3.8	2.5×10^{1}	8.5×10^{-1}	3.5×10^{2}	8.0×10^{-1}	2.3×10^{1}
Hanford sand	6.2	1.7×10^{2}	3.7×10^{1}	2.1×10^{2}	3.1×10^{1}	1.6×10^{2}
Hanford gravel	1.3×10^{2}	2.3×10^{2}	1.4×10^{2}	2.3×10^{2}	1.5×10^{2}	2.4×10^{2}
Ringold Sand	4×10^{-1}	4.2	3.4×10^{-1}	1.1×10^{1}	2×10^{-1}	4.2
Ringold Gravel	1.3×10^{1}	1.9×10^{1}	9.7	1.7×10^{1}	1.3×10^{1}	1.6×10^{1}
Ringold Mud	2×10^{-1}	2	2.8×10^{-1}	9.5	3.9×10^{-1}	2.5
Ringold Silt	5×10^{-1}	3.4	2.9×10^{-1}	3.7	5.1×10^{-1}	3.3
Plio-Pleistocene sand	2.7×10^{1}	1.1×10^{2}	2.2×10^{1}	3.4×10^{2}	2.1×10^{1}	1.9×10^{2}
Plio-Pleistocene silt	4.6×10^{-1}	2×10^{1}	2.3×10^{-1}	1.1×10^{2}	3.1×10^{-1}	2×10^{1}
Cold Creek sand	3×10^{1}	1.1×10^{2}	4×10^{1}	5.6×10^{2}	3.8×10^{1}	5.6×10^{2}
Cold Creek gravel	2.2	6.7×10^{1}	5×10^{-1}	9.1×10^{1}	3×10^{-1}	1.1×10^{2}
Highly conductive Hanford gravel	3.3×10^{3}	6.7×10^{3}	3.7×10^{3}	7.4×10^{3}	4.1×10^{3}	7.9×10^{3}

Note: To convert meters to feet, multiply by 3.281.

Approximately 400 model runs were completed, targeting head observation data set 4 (the validation data set), and RMS error values were calculated. Results concluded that the hydraulic conductivity values producing the lowest RMS error using validation data set 4 reasonably correlate to the hydraulic conductivity values that produced the lowest RMS error using calibration data sets 1, 2, and 3.

L.10 RESULTS FOR DESIGN VARIANTS

L.10.1 Base Case

The Monte Carlo optimization described in Section L.9 focused on identifying sets of hydraulic conductivity values that result in model-simulated head values that reasonably match observed heads over time and across the model domain. For the Base Case flow model, the Monte Carlo optimization identified 26 model runs, each with different sets of hydraulic conductivity values, where model simulations of head values reasonably match observed heads. These 26 model runs were evaluated further to determine which one best met the following additional selection criteria:

- The majority of the particles released to the water table within the Core Zone Boundary (200 Area Central Plateau of Hanford) move to the east toward the Columbia River rather than to the north through Gable Gap.

- Particles released to the water table in the 200 Areas (representing a historical tritium release) result in particle pathlines that qualitatively match the observed 200-East and 200-West Area tritium plumes, without considering the effects of dispersion.

After this additional evaluation, the Base Case flow model was selected. The selected model must meet the calibration acceptance criteria described in Section L.6.2. Table L–19 summarizes the calibration acceptance criteria along with the Base Case flow model's performance for each criterion. Table L–20 lists calibrated hydraulic conductivity values for the Base Case flow model by material type. Table L–21 provides the hydraulic conductivity parameter correlation coefficient matrix for the Base Case flow model.

Table L–19. Summary of Base Case Flow Model Performance Compared to Calibration Acceptance Criteria

Flow Model Calibration Acceptance Criteria	Base Case Flow Model Performance
Residual distribution should be reasonably normal.	Residual distribution is reasonably normal (see Figure L–42).
The mean residual should be approximately 0.	Residual Mean = -0.164 meters (-0.538 feet).
The number of positive residuals should approximate the number of negative residuals.	Positive residuals approximately equal negative residuals (see Figure L–42).
The correlation coefficient (calculated versus observed) should be greater than 0.9.	Correlation coefficient = 0.979 (see Figure L–43).
The root mean square (RMS) error (calculated versus observed) should be less than 5 meters (16.4 feet), approximately 10 percent of the gradient in the water table elevation.	RMS error = 2.118 meters (6.948 feet) (see Figure L–43).
Residuals in the 200-East Area should be distributed similarly to those in the 200-West Area.	Residuals in the 200-East and 200-West Areas are distributed similarly (see Figures L−44 and L−45).
The residuals should be evenly distributed over time.	Residuals are approximately evenly distributed over time (see Figures L−46, L−47, L−48, and L−49).
The residuals should be evenly distributed across the site.	Residuals are approximately evenly distributed across the site (see Figures L−50, L−51, and L−52).
The calibrated parameters should compare reasonably well with field-measured values.	Calibrated hydraulic conductivity values are listed in Table L–20 and compare reasonably with field-measured values for material types to which the model is sensitive (i.e., Hanford formation and Ringold Formation material types). Figure L–53 provides field-measured values from aquifer pumping tests (Cole et al. 2001).
Parameters should be reasonably uncorrelated.	Hydraulic conductivity parameters are reasonably uncorrelated (see Table L–20 for the key to model material type zones and Table L–21 for the correlation coefficient matrix).

Table L–20. Base Case Flow Model Calibrated Hydraulic Conductivity Values

Material Type (Model Zone)	Hydraulic Conductivity (K_x)[a]	Hydraulic Conductivity (K_y)[b]	Hydraulic Conductivity (K_z)[c]
Hanford mud (1)	0.171	0.171	0.0171
Hanford silt (2)	6.8	6.8	0.68
Hanford sand (3)	123.6	123.6	12.36
Hanford gravel (4)	156.0	156.0	15.6
Ringold Sand (5)	3.57	3.57	0.357
Ringold Gravel (6)	19.2	19.2	1.92
Ringold Mud (7)	1.514	1.514	0.1514
Ringold Silt (8)	1.51	1.51	0.151
Plio-Pleistocene sand (9)	96.8	96.8	9.68
Plio-Pleistocene silt (10)	5.81	5.81	0.581
Cold Creek sand (11)	99.13	99.13	9.913
Cold Creek gravel (12)	62.7	62.7	6.27
Highly conductive Hanford gravel (13)	3982.0	3982.0	398.2
Activated basalt (14)	0.001	0.001	0.0001

[a] Hydraulic conductivity with respect to the *x* axis, meters per day.
[b] Hydraulic conductivity with respect to the *y* axis, meters per day.
[c] Hydraulic conductivity with respect to the *z* axis, meters per day.
Note: To convert meters to feet, multiply by 3.281.

Table L–21. Base Case Hydraulic Conductivity Parameter Correlation Coefficient Matrix

Model Zone	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.00	-0.14	0.00	0.01	-0.04	-0.09	0.12	-0.08	-0.07	0.00	0.13	-0.14	0.07
2	-0.14	1.00	-0.11	-0.20	0.12	-0.05	-0.18	0.04	0.88	-0.06	-0.10	-0.09	-0.12
3	0.00	-0.11	1.00	0.08	0.08	0.15	0.02	-0.09	-0.04	-0.03	0.04	-0.11	-0.02
4	0.01	-0.20	0.08	1.00	0.05	-0.39	0.11	0.04	-0.17	-0.12	0.04	-0.09	0.24
5	-0.04	0.12	0.08	0.05	1.00	-0.22	0.07	-0.07	0.09	-0.12	-0.28	-0.13	-0.12
6	-0.09	-0.05	0.15	-0.39	-0.22	1.00	-0.35	-0.15	0.03	0.06	0.14	-0.03	-0.15
7	0.12	-0.18	0.02	0.11	0.07	-0.35	1.00	0.03	-0.11	-0.10	-0.01	-0.02	0.01
8	-0.08	0.04	-0.09	0.04	-0.07	-0.15	0.03	1.00	-0.06	-0.04	0.46	-0.13	0.06
9	-0.07	0.88	-0.04	-0.17	0.09	0.03	-0.11	-0.06	1.00	0.00	-0.07	-0.08	-0.12
10	0.00	-0.06	-0.03	-0.12	-0.12	0.06	-0.10	-0.04	0.00	1.00	0.09	-0.04	0.13
11	0.13	-0.10	0.04	0.04	-0.28	0.14	-0.01	0.46	-0.07	0.09	1.00	-0.22	0.30
12	-0.14	-0.09	-0.11	-0.09	-0.13	-0.03	-0.02	-0.13	-0.08	-0.04	-0.22	1.00	-0.27
13	0.07	-0.12	-0.02	0.24	-0.12	-0.15	0.01	0.06	-0.12	0.13	0.30	-0.27	1.00

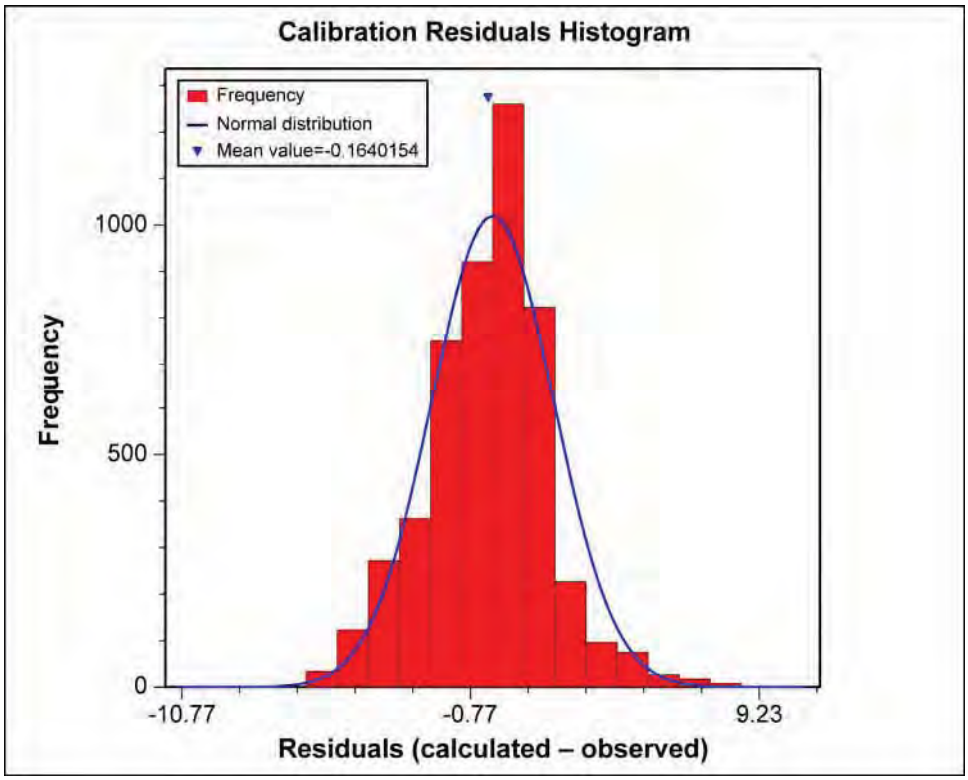


Figure L–42. Base Case Flow Model Residual Distribution

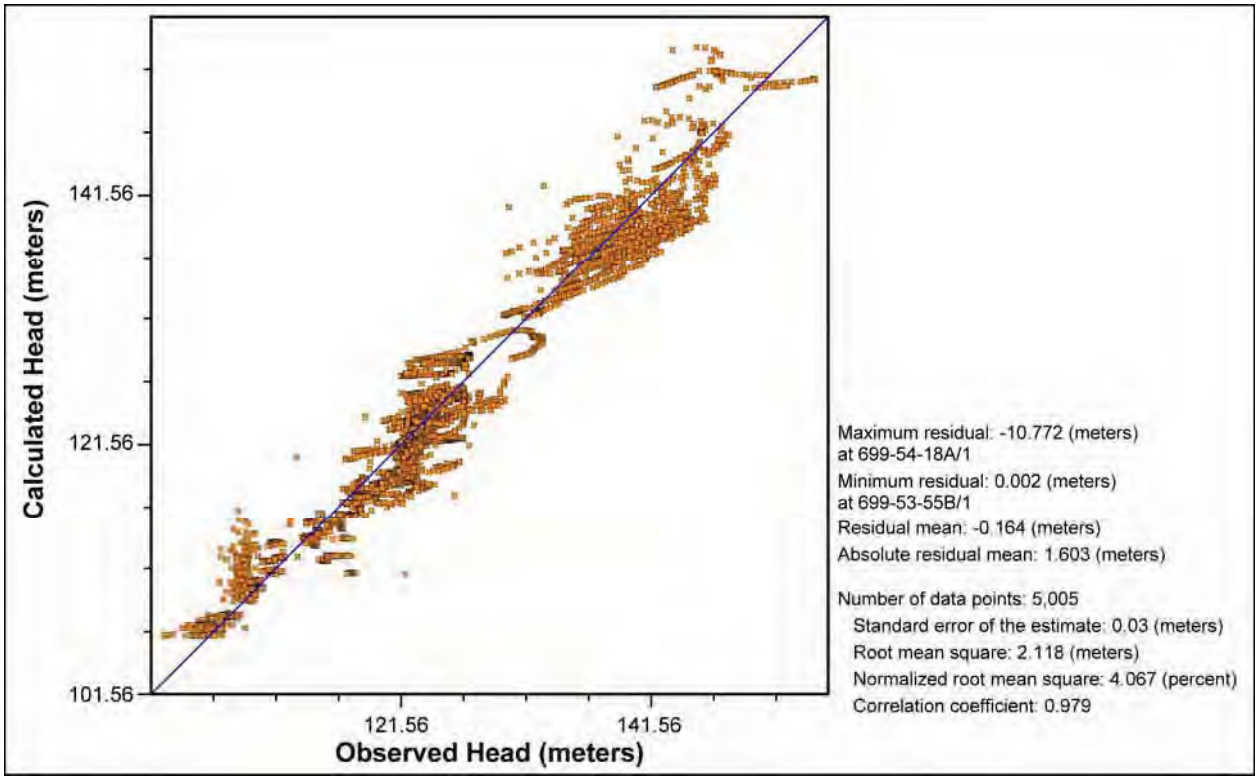


Figure L–43. Base Case Flow Model Calibration Graph and Statistics

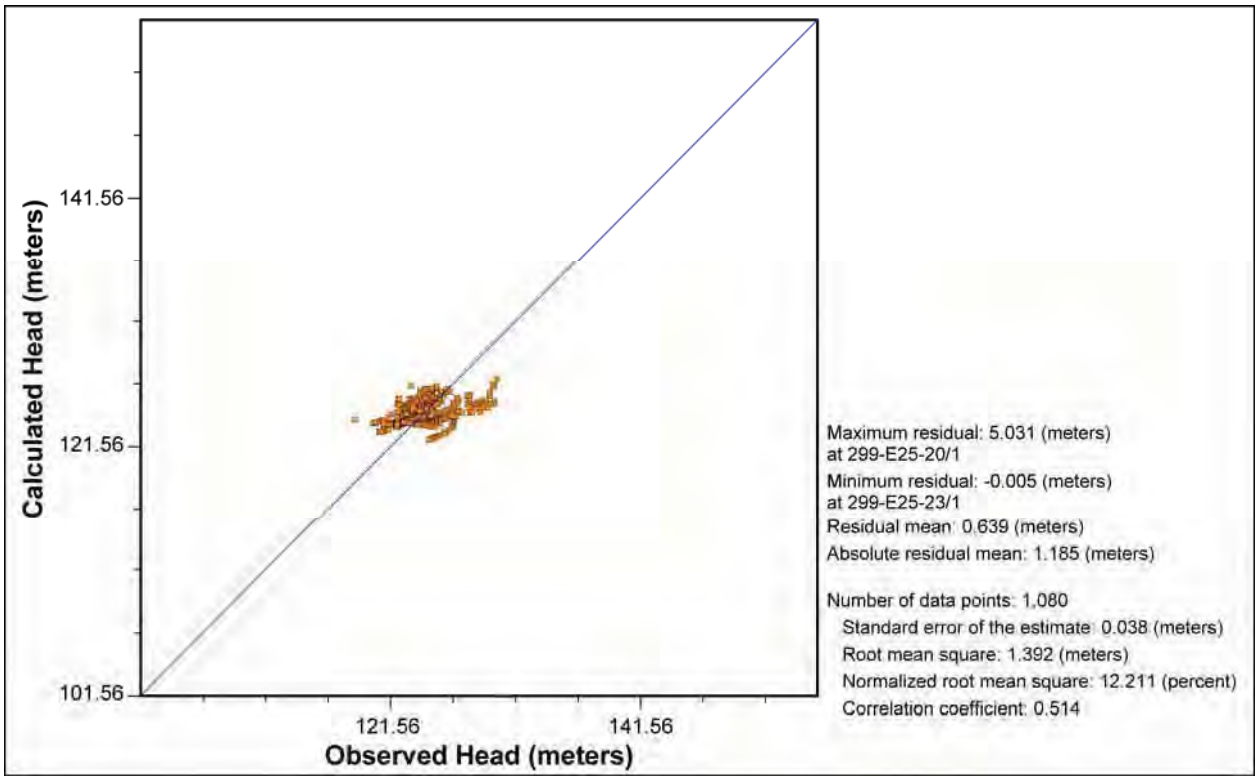


Figure L–44. Base Case Flow Model Residuals – 200-East Area

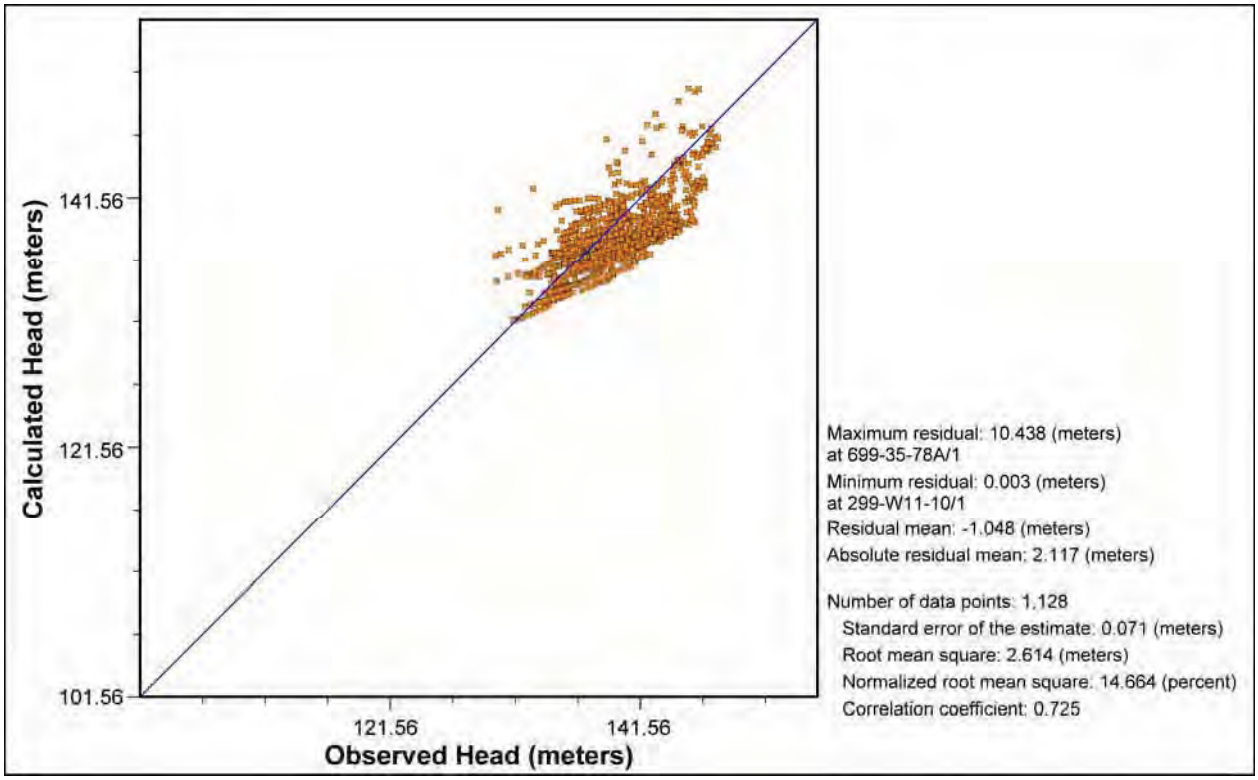


Figure L–45. Base Case Flow Model Residuals – 200-West Area

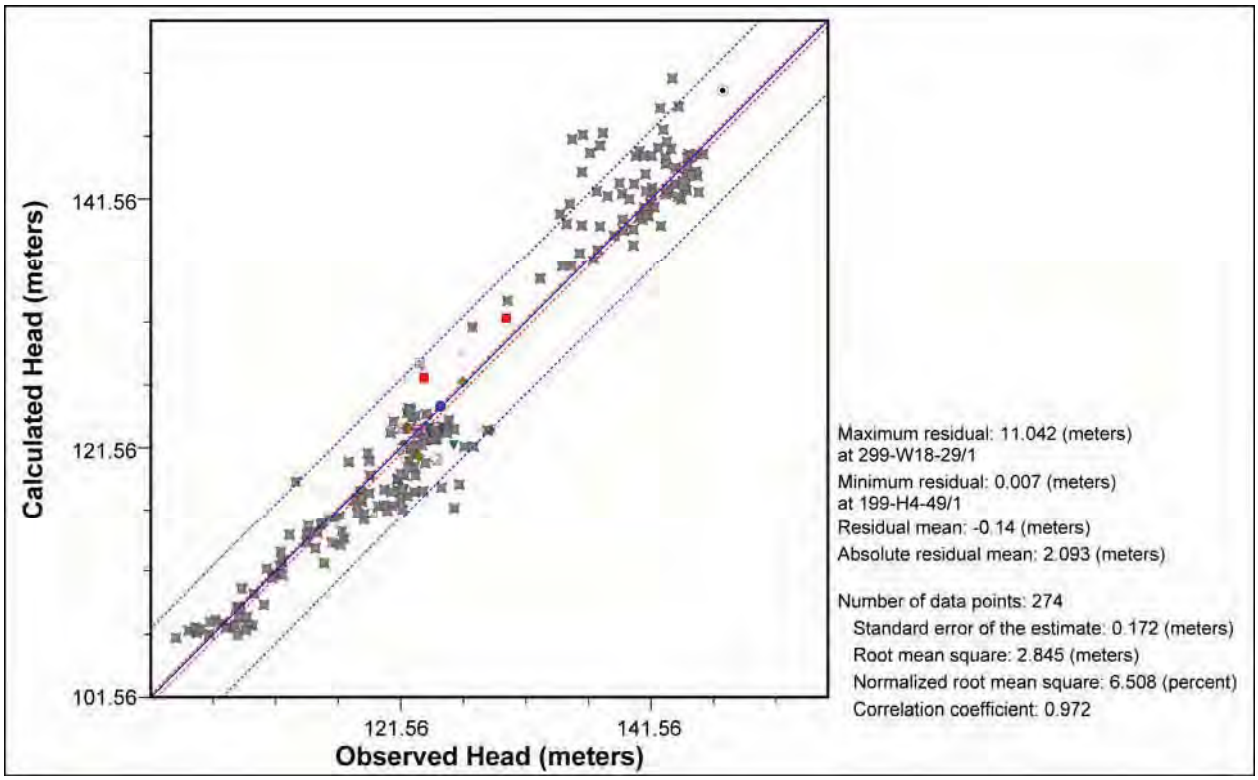


Figure L–46. Base Case Flow Model Residuals – Calendar Year 1955

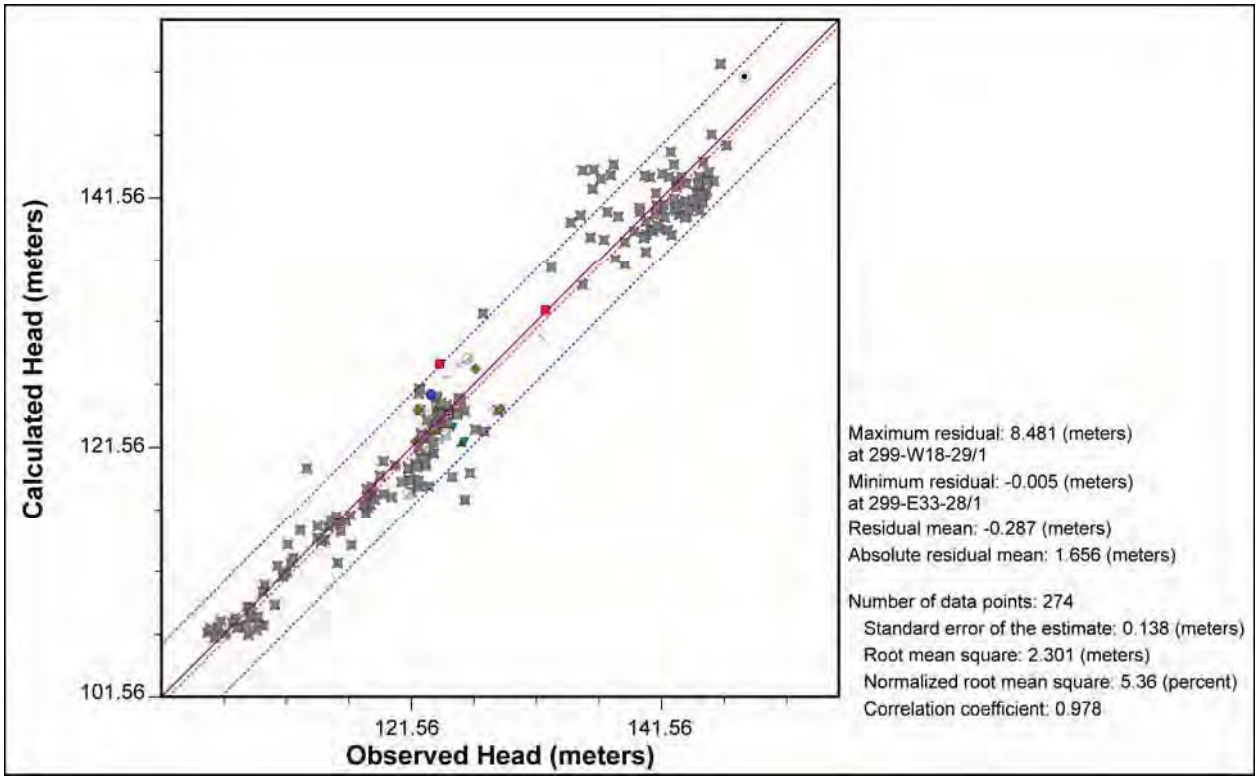


Figure L–47. Base Case Flow Model Residuals – Calendar Year 1975

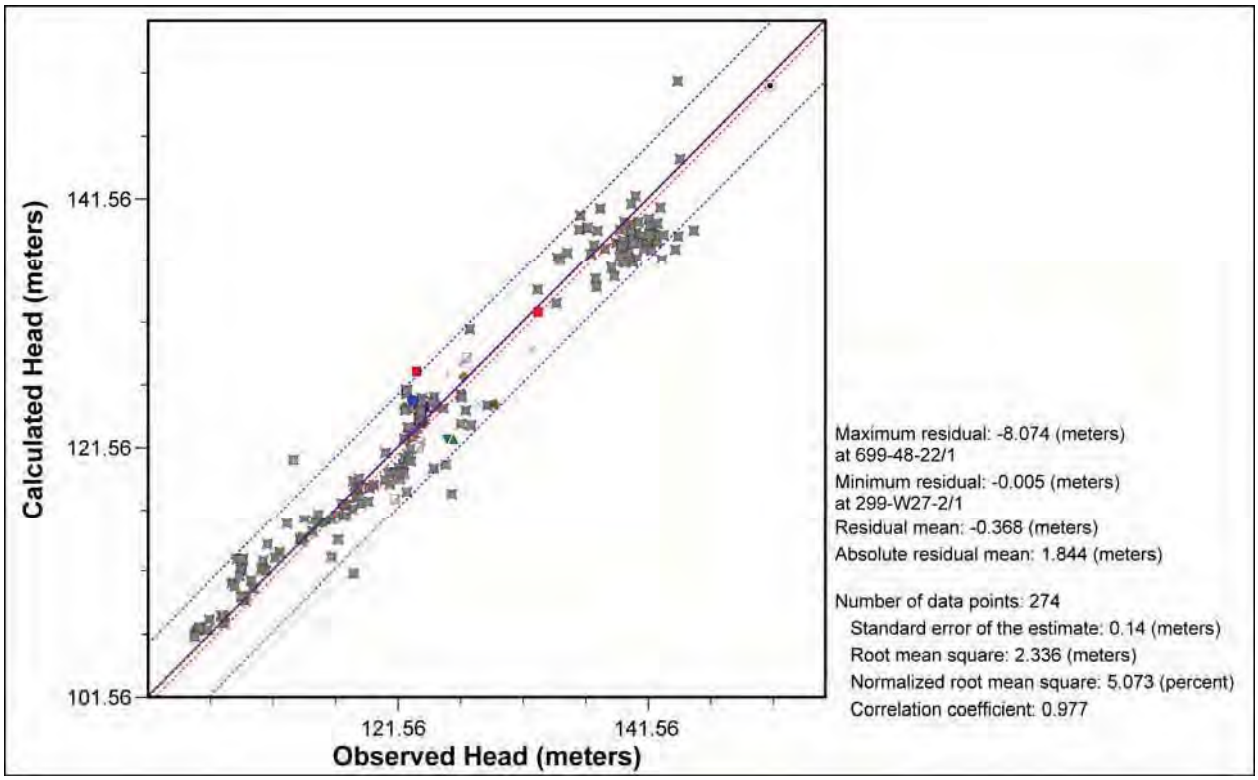


Figure L–48. Base Case Flow Model Residuals – Calendar Year 1995

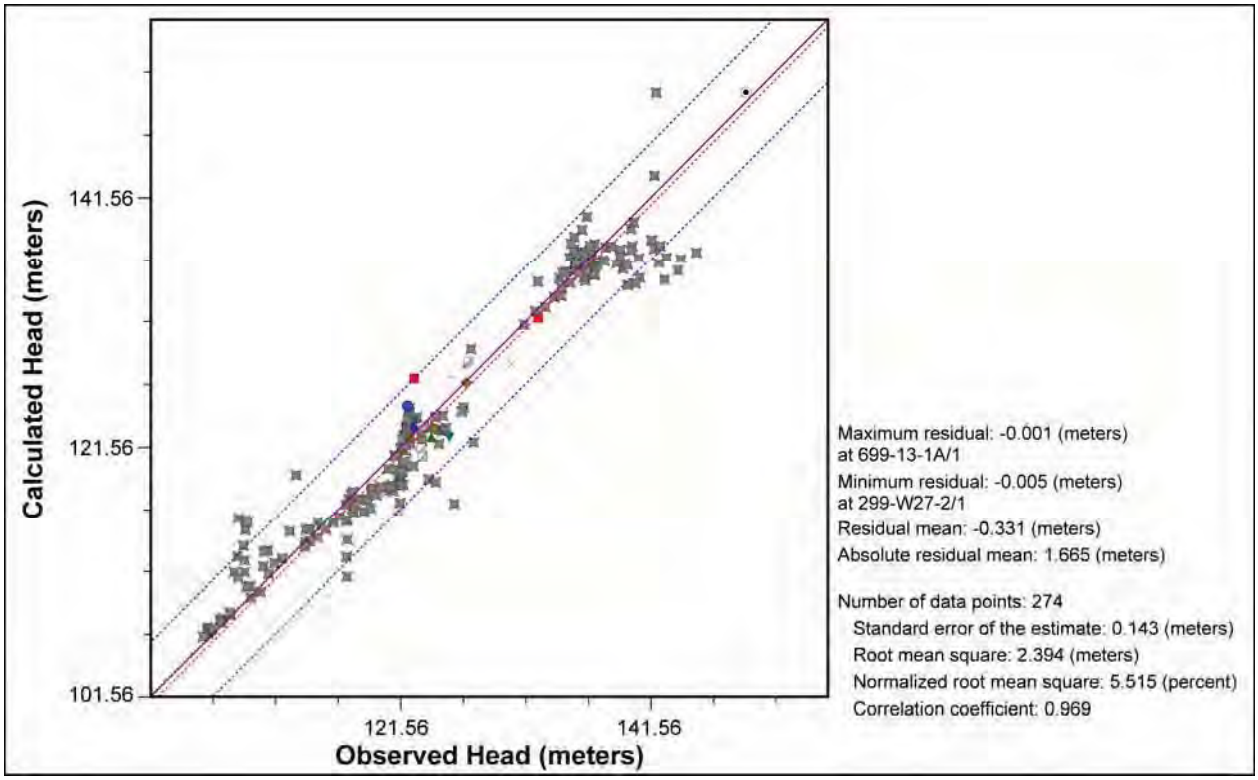


Figure L–49. Base Case Flow Model Residuals – Calendar Year 2015

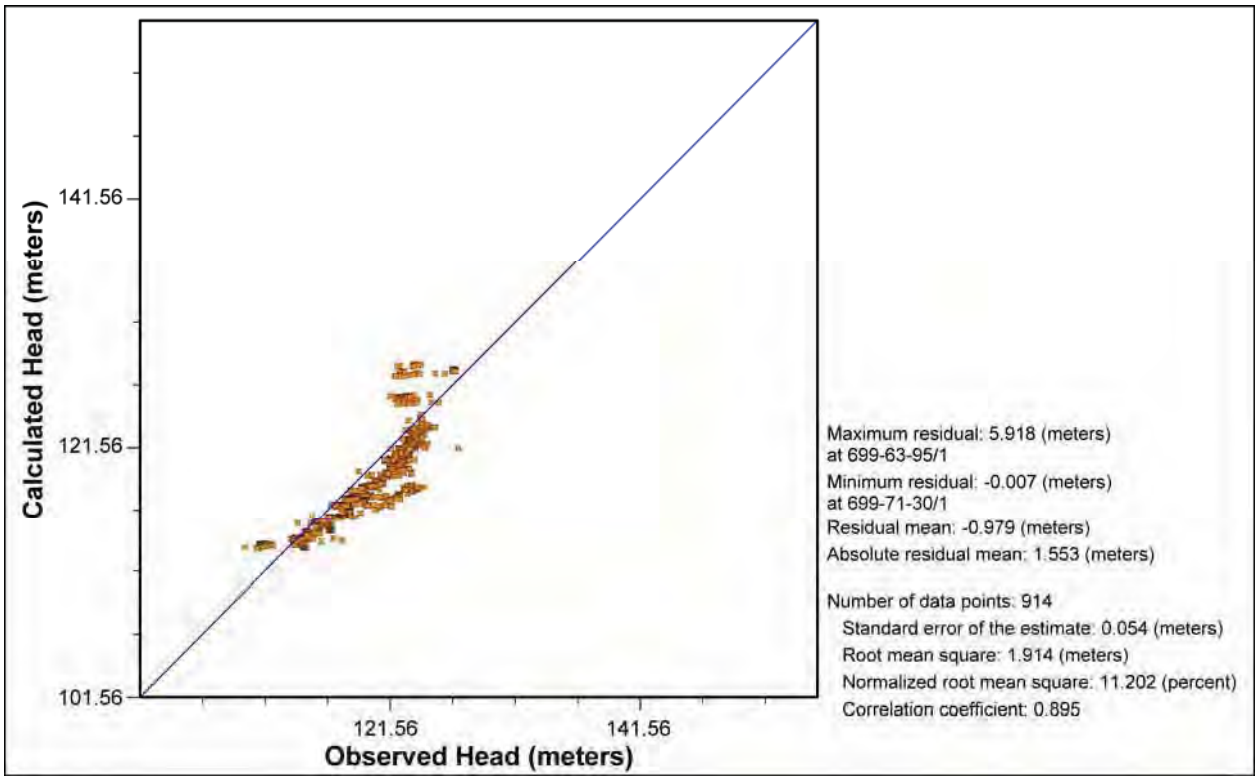


Figure L–50. Base Case Flow Model Residuals in Northern Region of Model

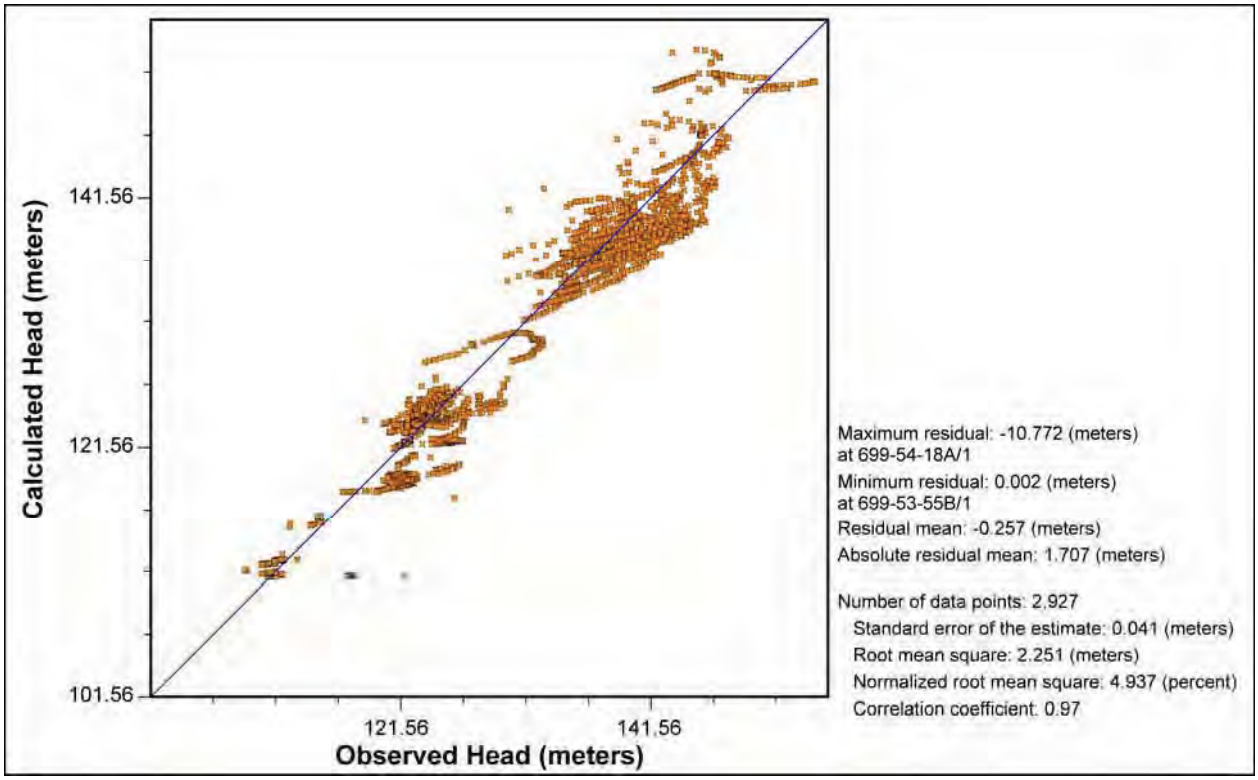


Figure L–51. Base Case Flow Model Residuals in Central Region of Model

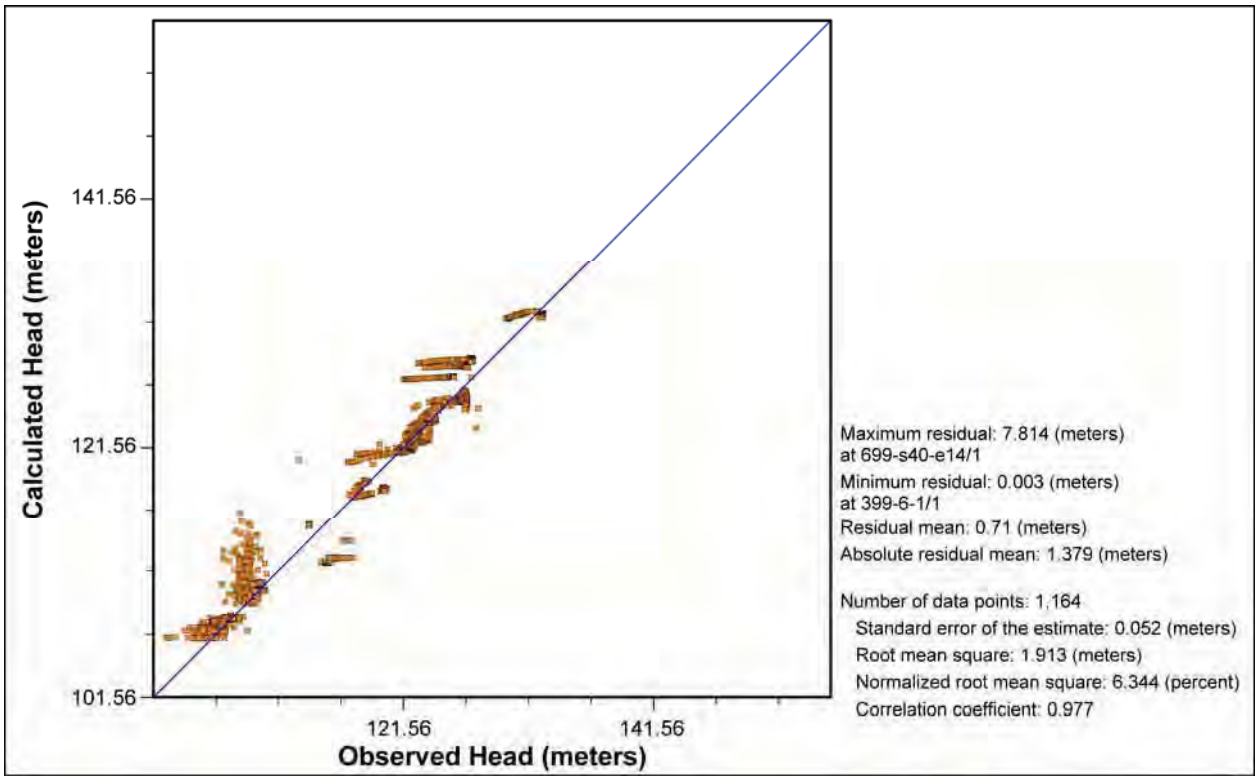


Figure L–52. Base Case Flow Model Residuals in Southern Region of Model

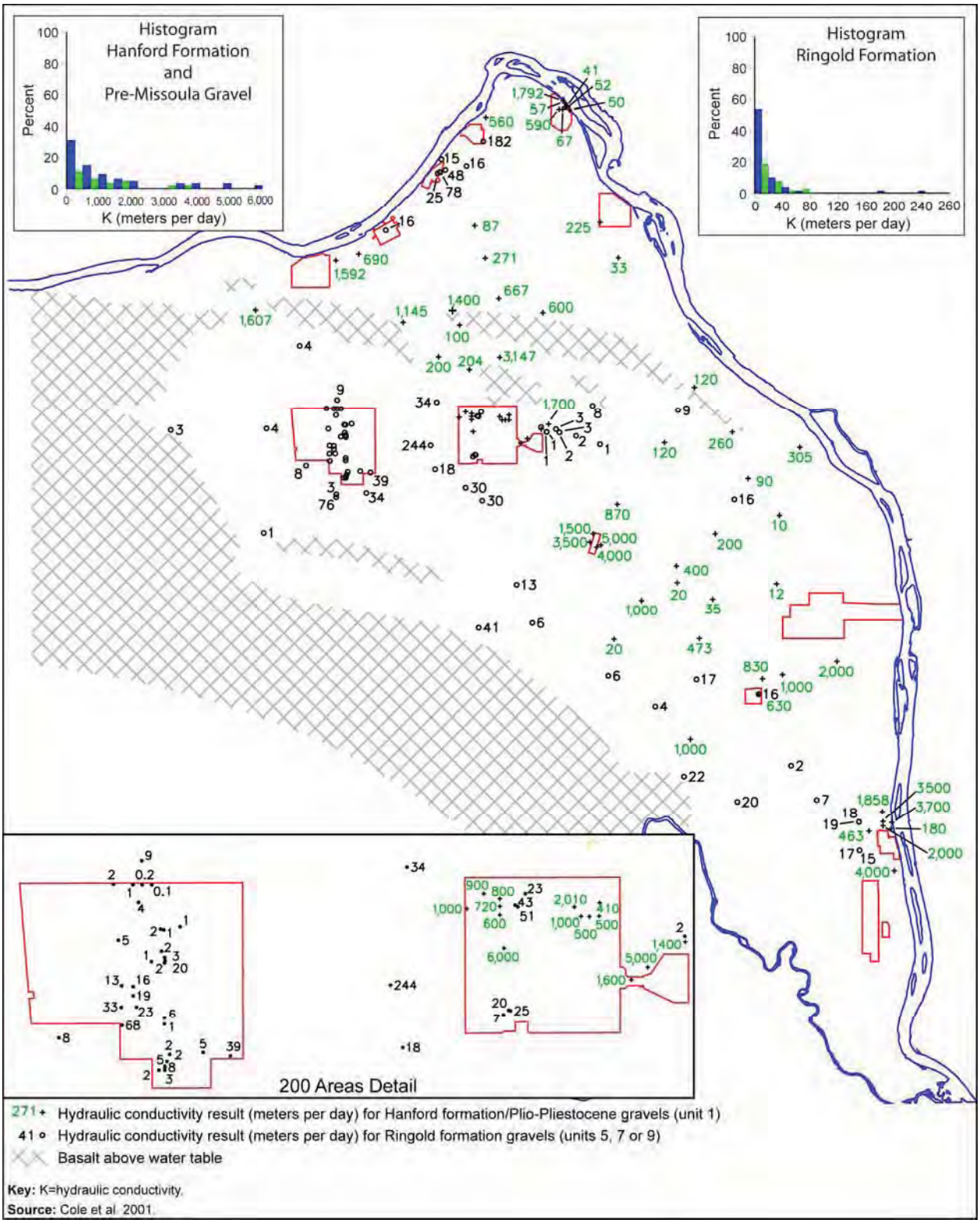


Figure L–53. Distribution of Wells with Hydraulic Conductivity Determined from Aquifer Pumping Tests

The Base Case flow model is most sensitive to the hydraulic conductivity values of the Ringold Gravel, the Hanford gravel, and the highly conductive Hanford gravel. The Base Case hydraulic conductivity of Ringold Gravel is about 20 meters per day (65.6 feet per day) (see Table L–20). The histogram of hydraulic conductivity distribution for the Ringold Formation as measured in aquifer pump tests is shown in the upper right-hand corner of Figure L–53. The majority of the field measured hydraulic conductivities are between 10 and 30 meters per day (between 32.8 and 98.4 feet per day), in reasonable agreement with the Base Case value. Base Case hydraulic conductivities for the Hanford gravel and the highly conductive Hanford gravel are about 125 meters per day (410 feet per day) and about 4,000 meters per day (13,124 feet per day), respectively (see Table L–20). The histogram of hydraulic conductivity for the Hanford Formation as measured in aquifer pump tests is shown in the upper left-hand corner of Figure L–53. Note that the range of measured hydraulic conductivities for the Hanford Formation is much broader than the Ringold Formation. Measured hydraulic conductivities for the Hanford Formation show a maximum of about 300 meters per day (984 feet per day), with a secondary occurrence between 3,000 and 5,000 meters per day (between 9,843 and 16,405 feet per day). This suggests that the inclusion of the highly conductive Hanford gravel in the conceptual model reflects an important component of the hydraulic conductivity distribution at the site.

In addition to the calibration acceptance criteria, water (or mass) balance and a long-term steady state condition must be achieved in the calibrated flow model. Cumulative mass water balance data are shown in Figure L–54, indicating a cumulative mass balance error of approximately –1.4 percent. Total water balance and storage data as a function of time are shown in Figure L–55. These data show storage values relative to the total water balance and indicate that storage-in is approximately equal to storage-out in model year 140 (calendar year 2080). This confirms that a long-term steady state condition is achieved. Note that, in Figure L–55, there is a spike in "Total Storage In" and "Total In" at model year 82. This spike is the result of a stress period change to the final long-term stress period. As a result, the model is moving from a relatively long time step at the end of the previous stress period to a relatively short time step at the beginning of the final stress period.

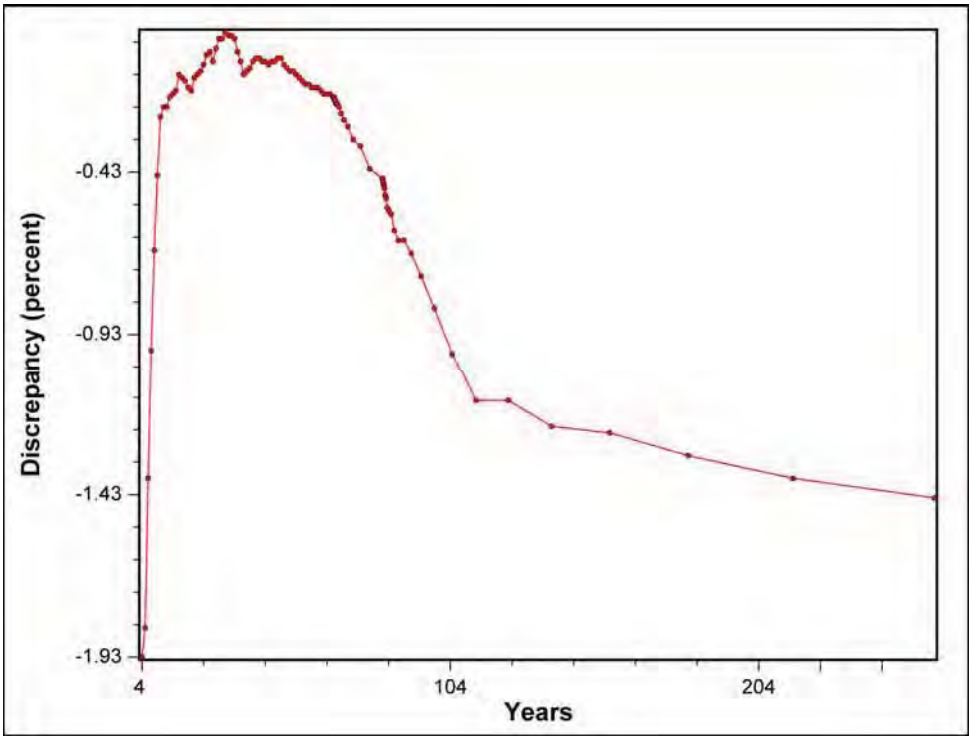


Figure L–54. Base Case Flow Model Cumulative Water Balance Discrepancy – Year 0 (Calendar Year 1940)

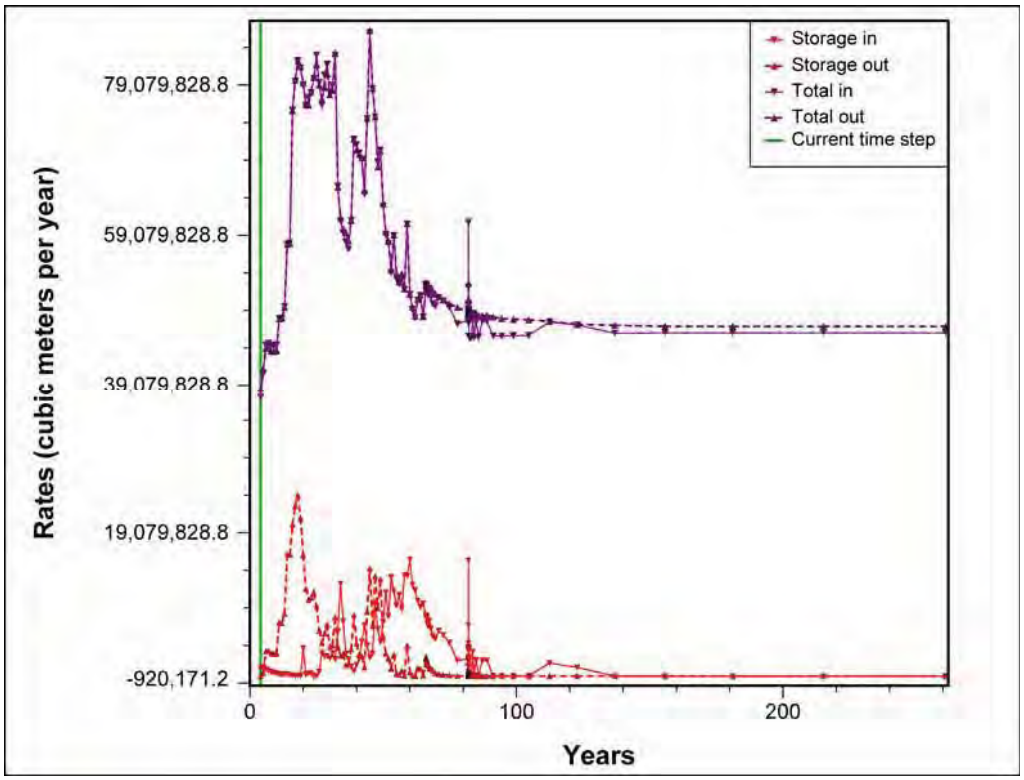


Figure L–55. Base Case Flow Model Total Water and Storage Rates Over Time – Year 0 (Calendar Year 1940)

L.10.1.1 Potentiometric Distribution

A goal for the Base Case flow model is to produce a potentiometric distribution of heads that shows a steep water table in the 200-West Area due to the low-conductivity material types in that area and a relatively flat water table in the 200-East Area where high-conductivity material types are present. The pre-Hanford potentiometric surface is assumed to be approximately the same as the post-Hanford long-term steady state condition, with water table mounding occurring below areas where and at times when Hanford operational discharges were released at the ground surface. Figures L–56, L–57, and L–58 are Base Case flow model simulations of the potentiometric surface in calendar years 1944 (pre-Hanford), 1975 (Hanford operations), and 2200 (post-Hanford), respectively.

Figure L–56. Base Case Flow Model Potentiometric Head Distribution – Calendar Year 1944

Figure L–57. Base Case Flow Model Potentiometric Head Distribution – Calendar Year 1975

Figure L–58. Base Case Flow Model Potentiometric Head Distribution – Calendar Year 2200

L.10.1.2 Velocity Field

The Base Case flow model velocity field is variable in both magnitude and direction over time and across the model domain. This variability at selected locations within the model is shown in Figures L−59 through L−64. As expected, the velocities simulated in 200-West Area are generally lower than those simulated in the 200-East Area. An additional observation is that the velocity directions are highly variable during the Hanford operational period, particularly at BY Cribs in the 200-East Area, where the velocity directions change by approximately 180 degrees due to water table mounding, coupled with this source's proximity to Gable Gap, where water table velocity and direction are sensitive to water table elevation.

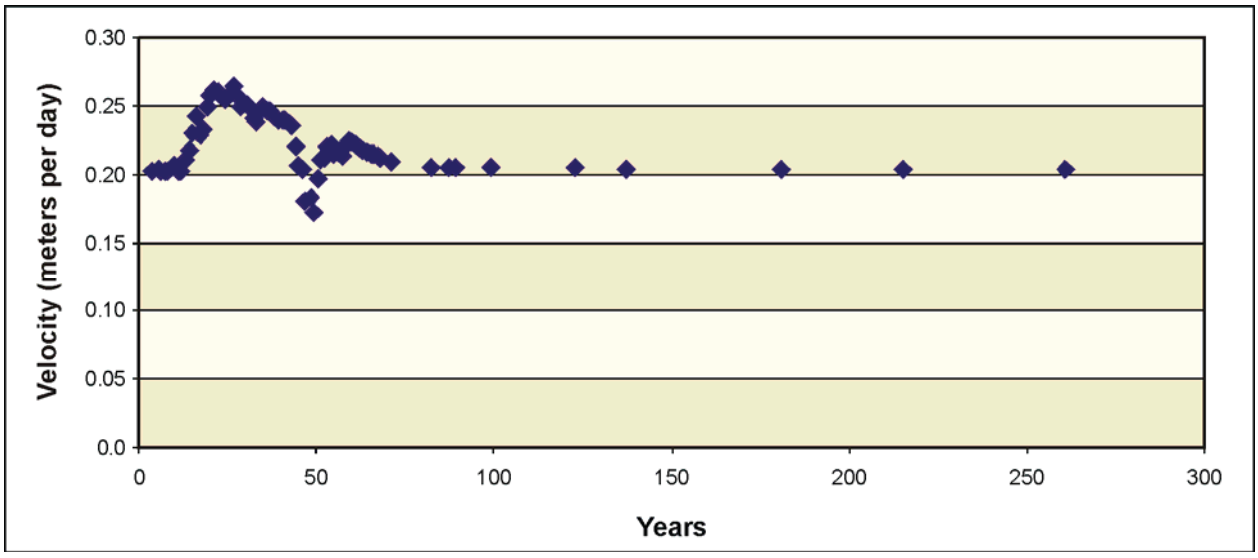


Figure L–59. Base Case Flow Model Velocity Magnitude at 216-B-26 (BC Cribs in 200-East Area) – Year 0 (Calendar Year 1940)

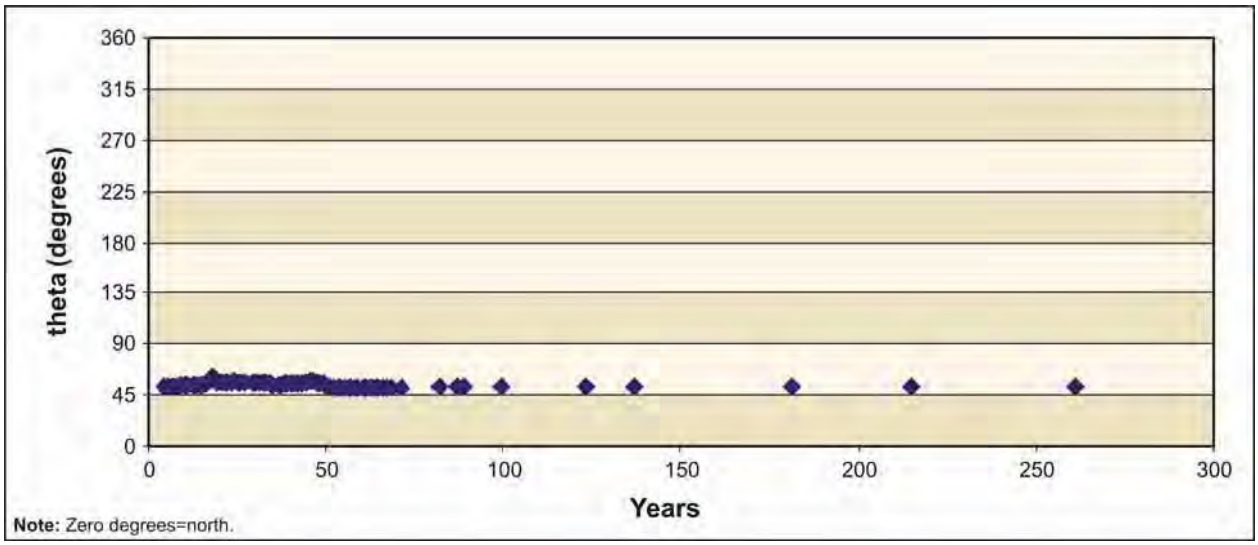


Figure L–60. Base Case Flow Model Velocity Direction at 216-B-26 (BC Cribs in 200-East Area) – Year 0 (Calendar Year 1940)

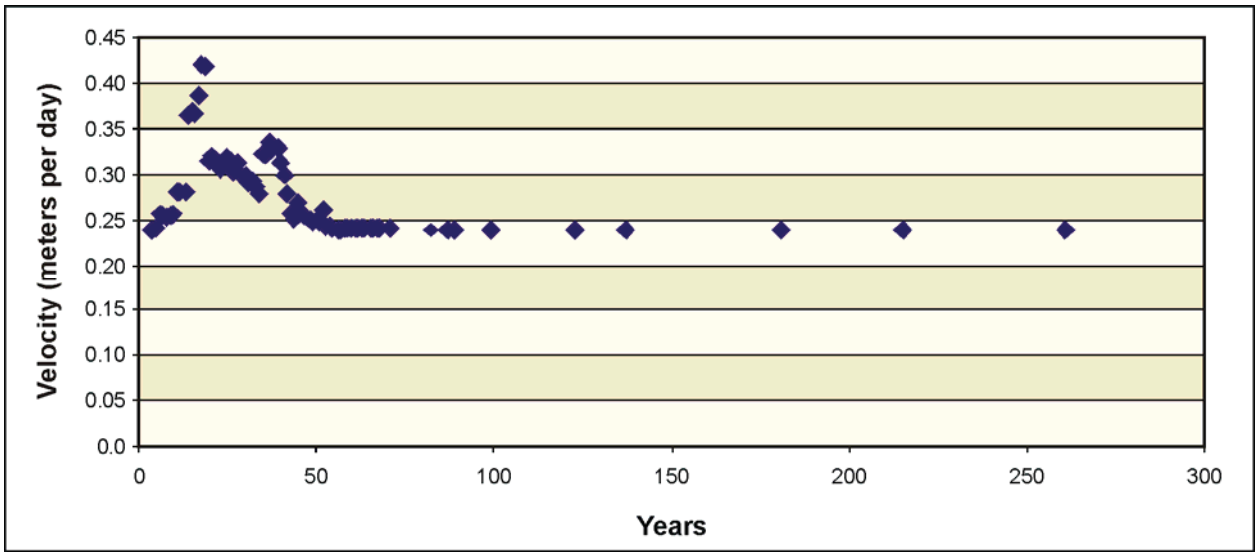


Figure L–61. Base Case Flow Model Velocity Magnitude at 216-T-28 Crib (200-West Area) –Year 0 (Calendar Year 1940)

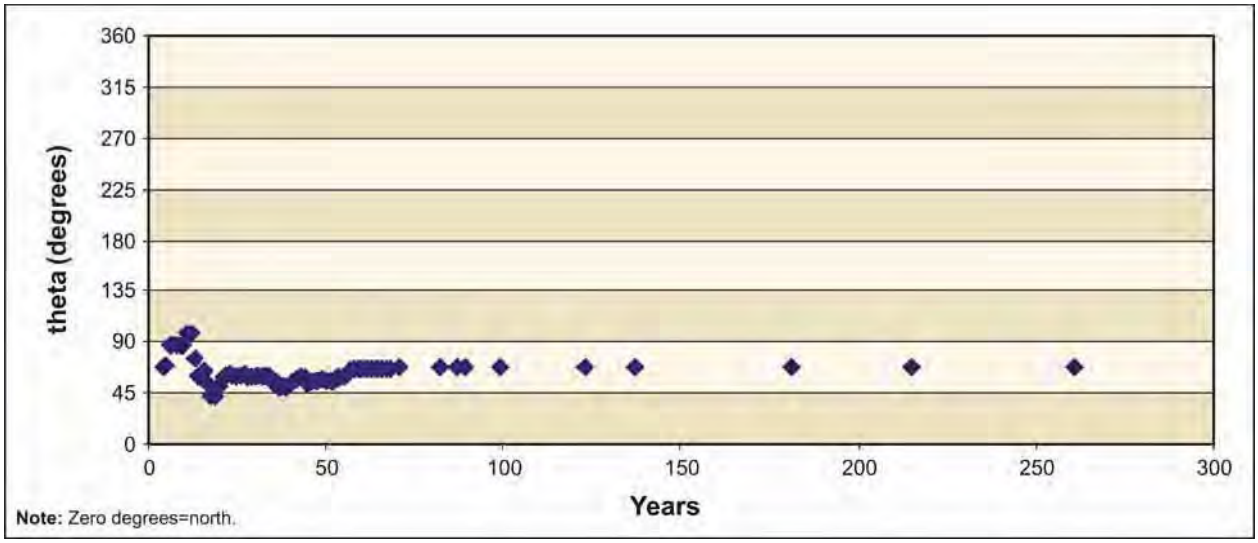


Figure L–62. Base Case Flow Model Velocity Direction at 216-T-28 Crib (200-West Area) –Year 0 (Calendar Year 1940)

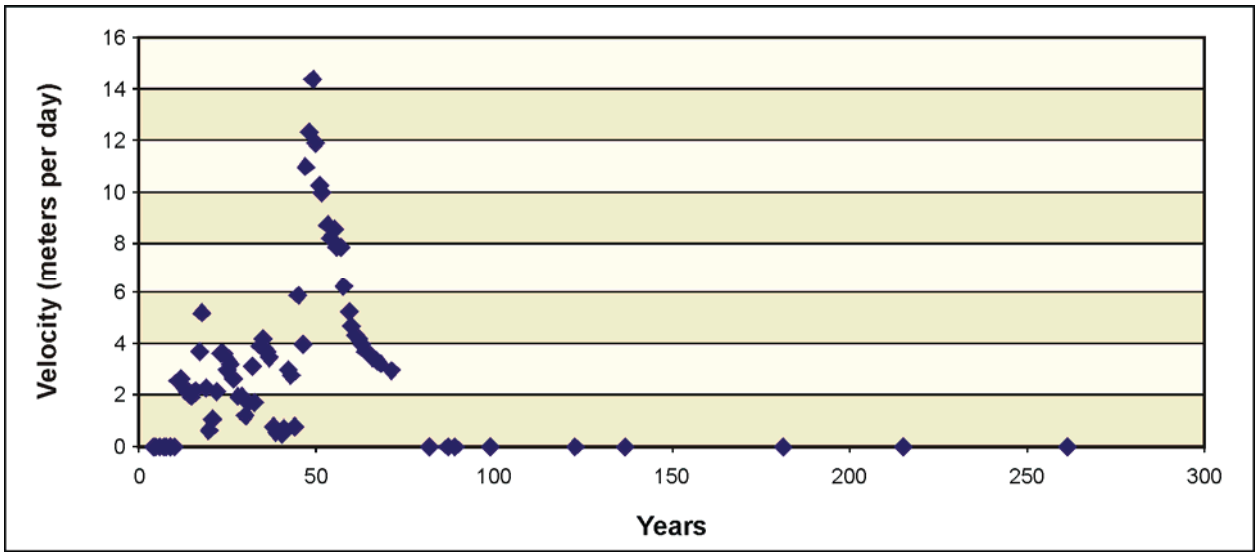


Figure L–63. Base Case Flow Model Velocity Magnitude at BY Cribs (200-East Area) – Year 0 (Calendar Year 1940)

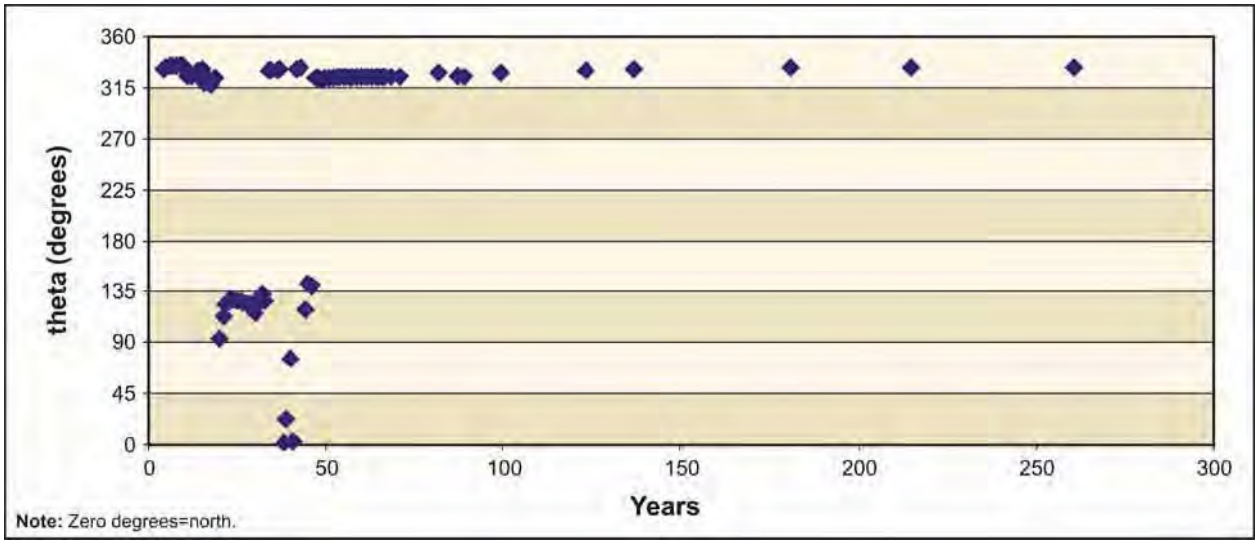


Figure L–64. Base Case Flow Model Velocity Direction at BY Cribs (200-East Area) – Year 0 (Calendar Year 1940)

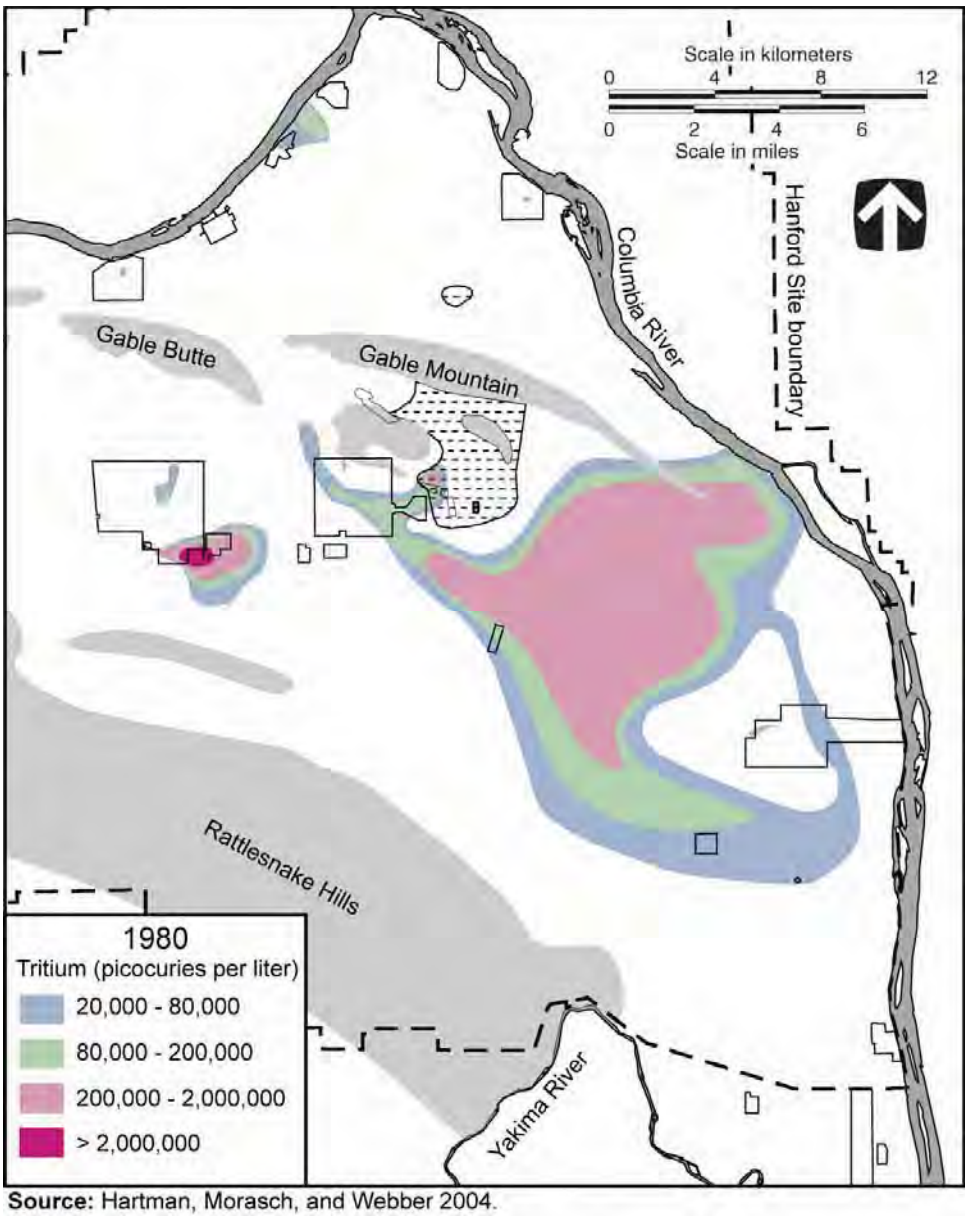
L.10.1.3 Pathline Analyses

Pathline analysis was performed on the top 26 model runs (see Section L.10.1) to narrow this field of models that performed well relative to the RMS error to a single Base Case flow model. Two pathline analyses, the tritium plume pathline analysis and the Central Plateau delineation pathline analysis, were performed on each of the top 26 models.

L.10.1.3.1 Hydrogen-3 (Tritium) Plume Pathline Analysis

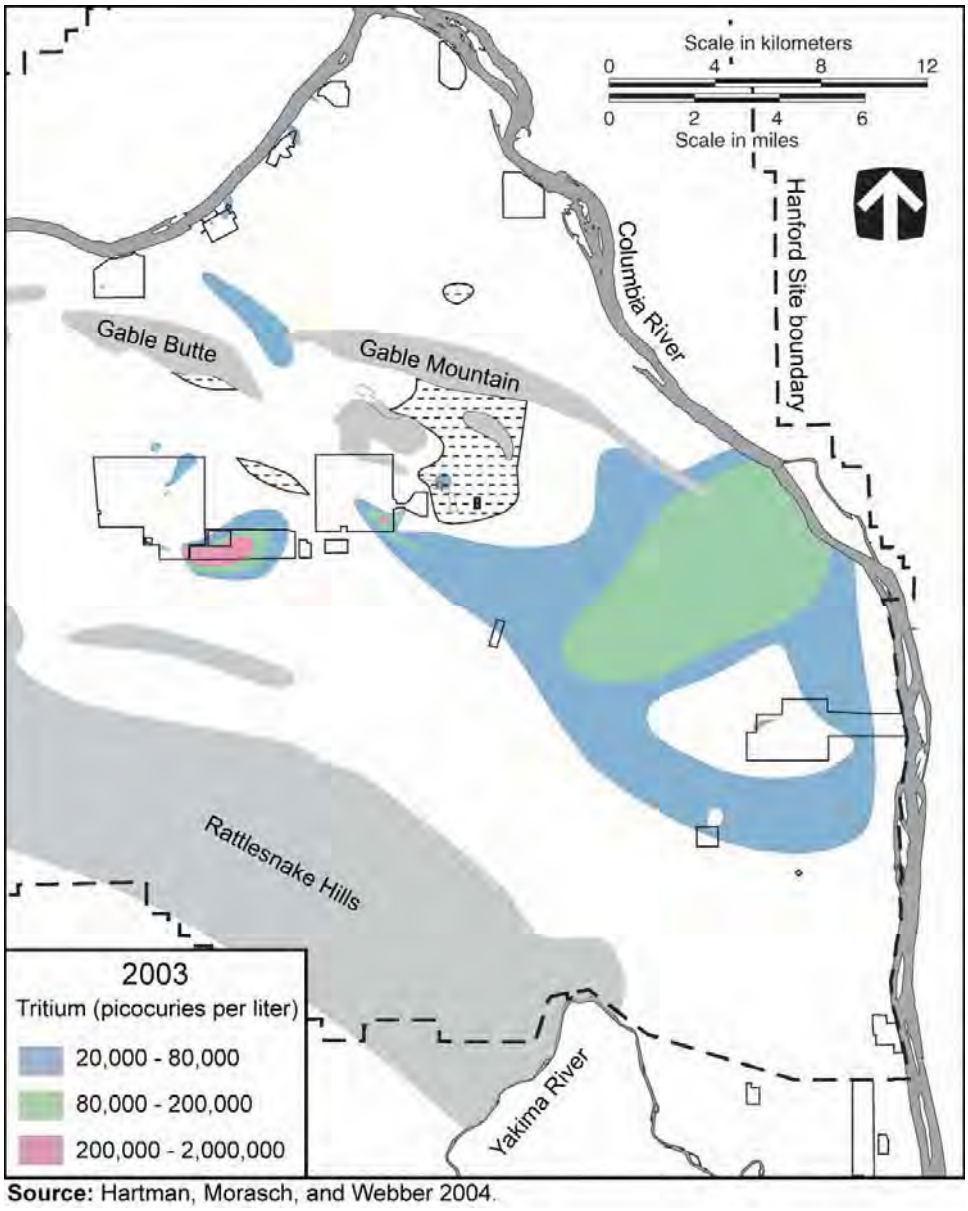
Tritium plume pathline analysis included a MODFLOW and MODPATH model run for each of the top 26 model cases, releasing particles in the 200-East and 200-West Areas representing an actual tritium release and comparing the particle pathlines to the general shape of the observed tritium plumes. This analysis is somewhat limited because no dispersion is applied to the particle pathlines so that spreading of the plume to its actual extents is constrained. This analysis does provide a qualitative means to compare

this final set of possible models to one another and aid in selecting the Base Case flow model. Figures L–65 and L–66 provide an interpretation of the field-observed tritium plume (Hartman, Morasch, and Webber 2004) to which the model-simulated pathlines were compared. Figures L−67 through L−70 provide the MODFLOW/MODPATH results of 4 of the 26 model runs, including the model run selected as the Base Case flow model. This analysis concluded that many of the top 26 model runs could be selected as the Base Case flow model if the selection were based only on the tritium plume pathline analysis.



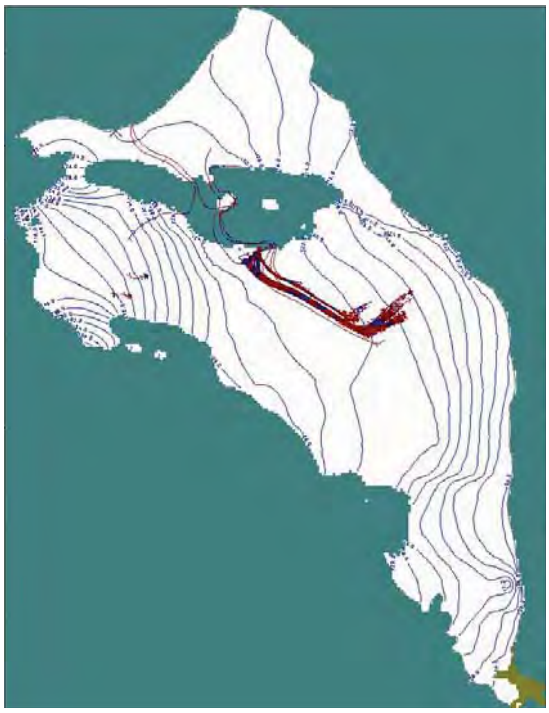
Source: Hartman, Morasch, and Webber 2004.

Figure L–65. Sitewide Hydrogen-3 (Tritium) Plumes – Calendar Year 1980



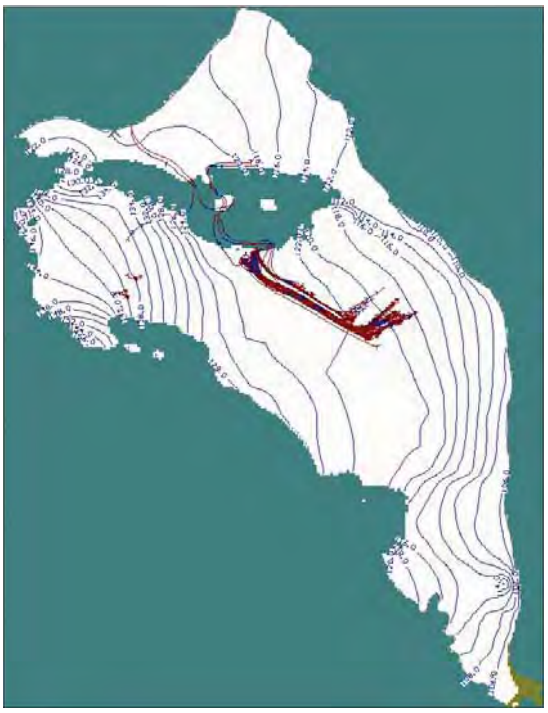
Source: Hartman, Morasch, and Webber 2004.

Figure L–66. Sitewide Hydrogen-3 (Tritium) Plumes – Calendar Year 2003



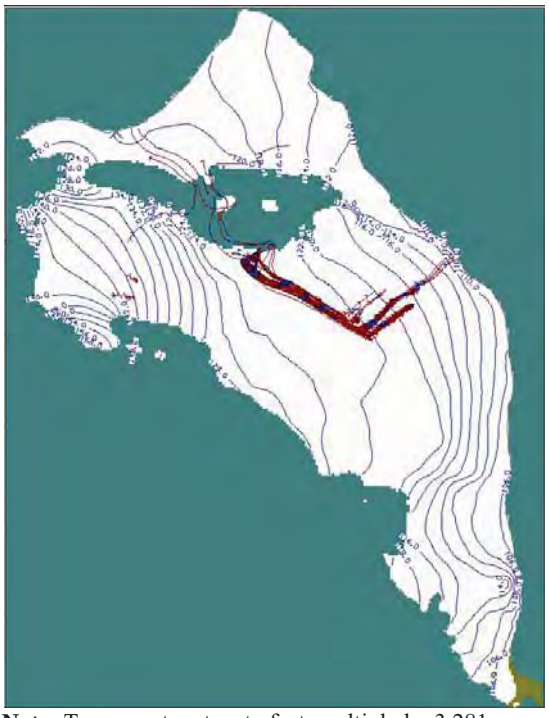
Note: To convert meters to feet, multiply by 3.281.

Figure L–67. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 483 (root mean square error = 2.122 meters)



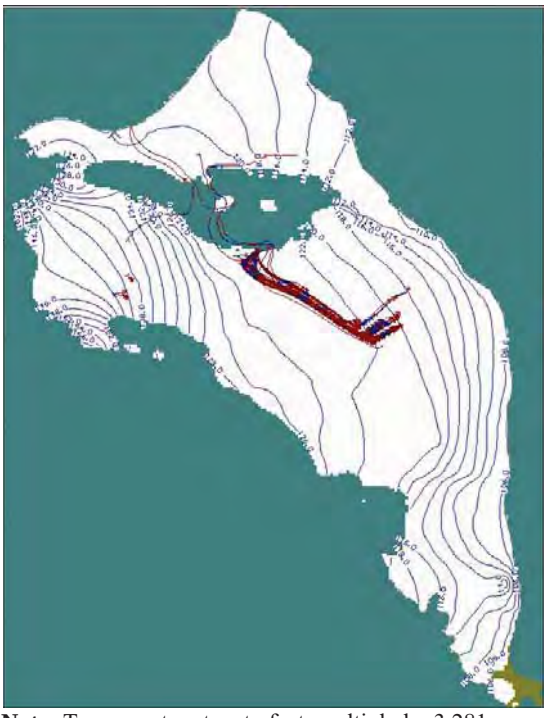
Note: To convert meters to feet, multiply by 3.281.

Figure L–68. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 710 (root mean square error = 2.116 meters) – Selected as Base Case Flow Model



Note: To convert meters to feet, multiply by 3.281.

Figure L–69. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 716 (root mean square error = 2.110 meters)



Note: To convert meters to feet, multiply by 3.281.

Figure L–70. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 723 (root mean square error = 2.090 meters)

L.10.1.3.2 Central Plateau Delineation Pathline Analysis

The *Technical Guidance Document* (DOE 2005) directed that the Base Case flow model would flow predominantly eastward from the 200 Areas of Hanford. The purpose of the central plateau delineation pathline analysis was to determine for each of the top 26 model runs the amount of particles released in the 200 Areas that would move to the north through Gable Gap and the amount of particles that would move to the east toward the Columbia River. This analysis included a MODFLOW and MODPATH model run for each of the top 26 model cases, releasing a uniformly distributed set of particles across the area across the central plateau. The central plateau is depicted as a rectangular-shaped boundary that includes all of the 200-East and 200-West Areas as well as other areas between and outside of the 200 Areas. This analysis provides a quantitative means to compare this final set of possible models to one another and aid in selecting a single Base Case flow model. Figures L−71 through L−74 provide the MODFLOW/MODPATH results of 4 of the 26 model runs, including the model run selected as the Base Case flow model (see Figure L–72).

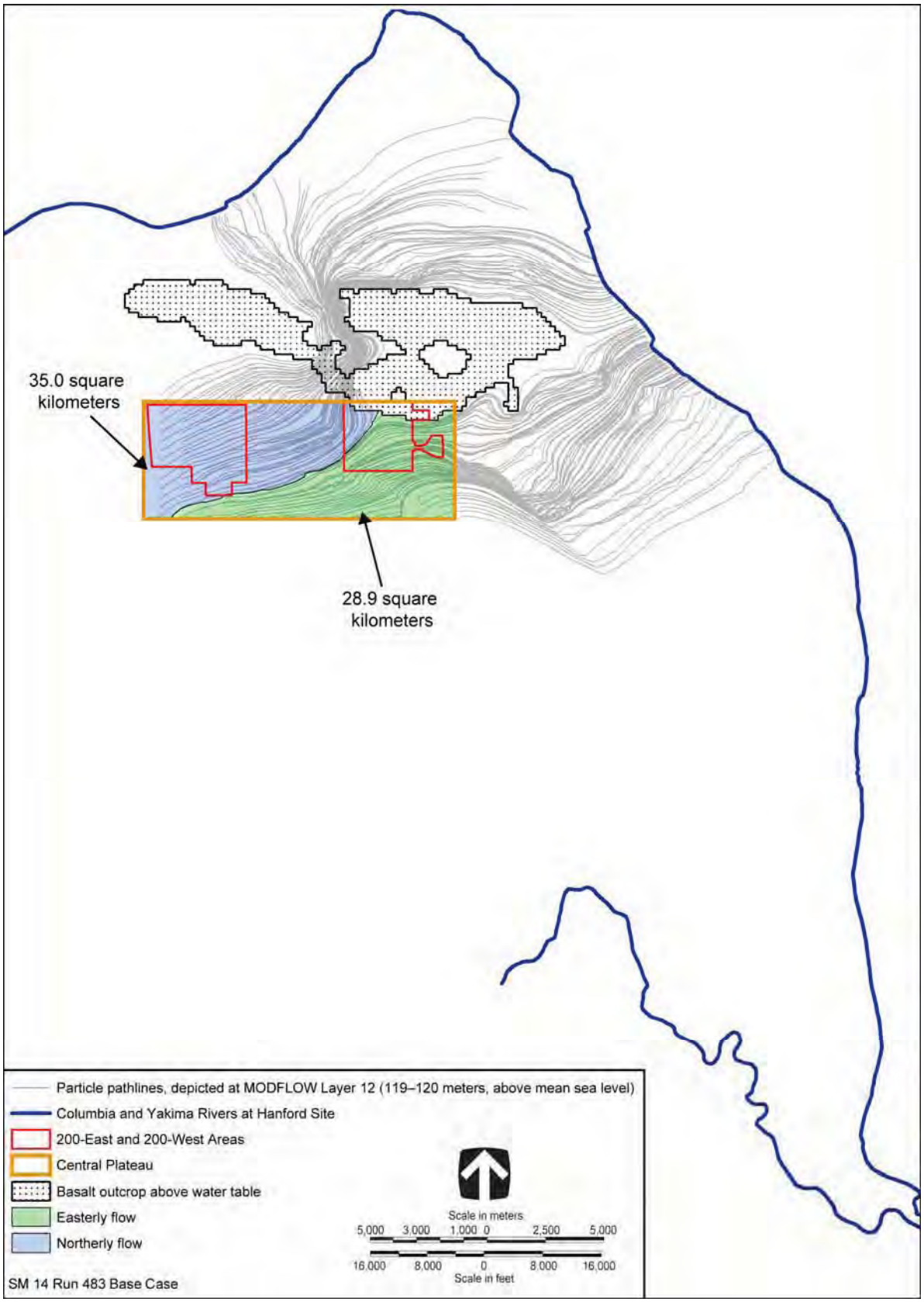


Figure L–71. Central Plateau Delineation Pathline Analysis Run 483 (root mean square error = 2.122 meters)

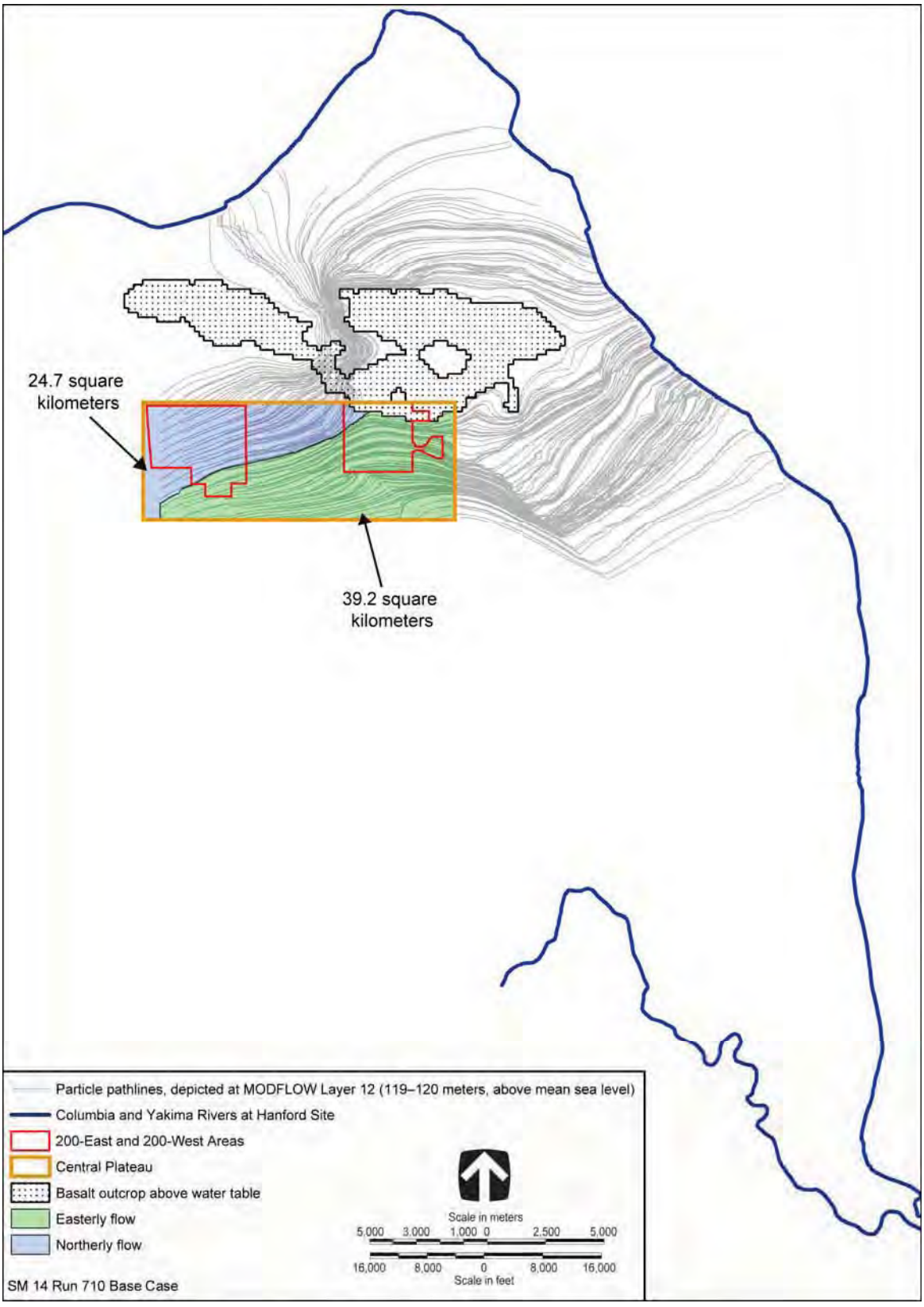


Figure L–72. Central Plateau Delineation Pathline Analysis Run 710 (root mean square error = 2.116 meters) – Selected as Base Case Flow Model

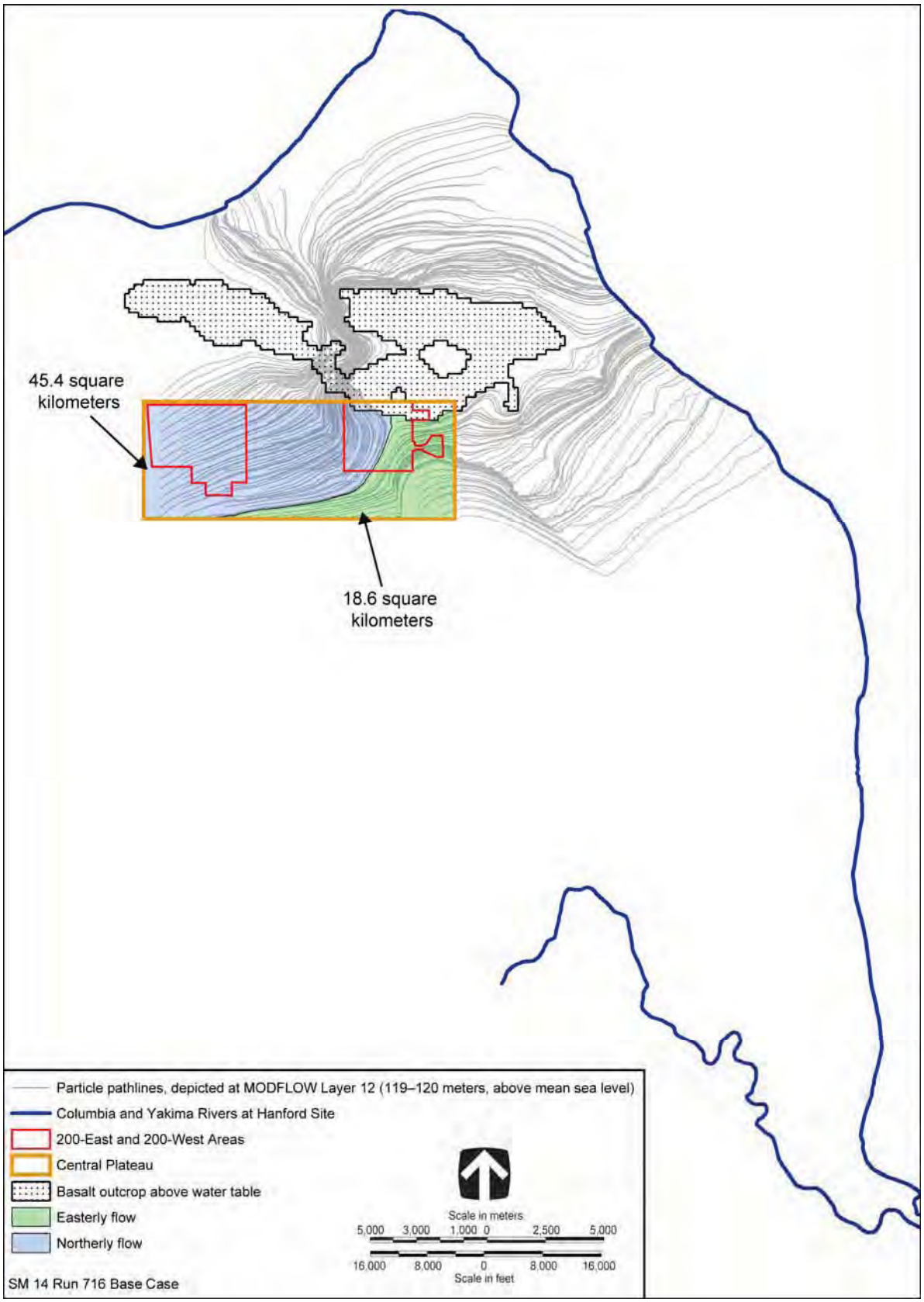


Figure L–73. Central Plateau Delineation Pathline Analysis Run 716 (root mean square error = 2.110 meters)

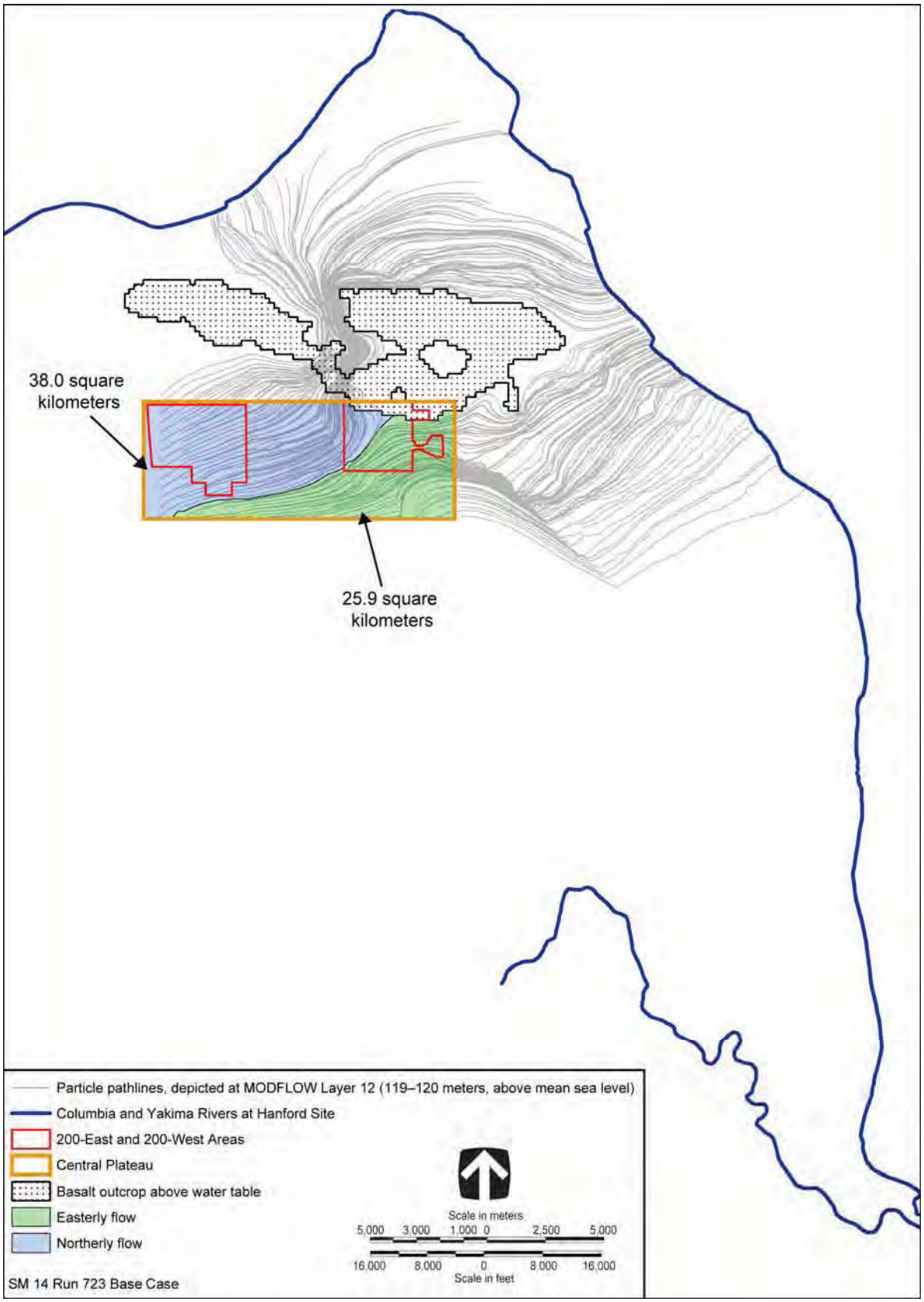


Figure L–74. Central Plateau Delineation Pathline Analysis Run 723 (root mean square error = 2.090 meters)

Table L–22 provides a summary of the percentages of particle pathlines flowing to the east and to the north for the top 26 Base Case model runs.

Table L–22. Summary of Top 26 Base Case Model Runs – Northerly Versus Easterly Flow

Run Number	Area of Northerly Flow (square kilometers)	Area of Easterly Flow (square kilometers)	Northerly Flow (percent)	Easterly Flow (percent)
710	24.7	39.2	39	61
690	26.8	37.1	42	58
712	27.0	37.0	42	58
734	29.1	34.9	45	55
376	32.4	31.5	51	49
449	32.5	31.4	51	49
306	33.2	30.8	52	48
G1543	33.6	30.3	53	47
483	35.0	28.9	55	45
422	36.3	27.6	57	43
612	36.9	27.0	58	42
682	37.3	26.7	58	42
637	37.4	26.5	59	41
671	37.9	26.0	59	41
723	38.0	25.9	59	41
023	39.5	24.5	62	38
725	41.5	22.4	65	35
709	43.3	20.7	68	32
645	43.6	20.3	68	32
716	45.4	18.6	71	29
455	45.6	18.4	71	29
631	45.8	18.1	72	28
680	49.7	14.3	78	22
340	53.1	10.9	83	17
698	54.3	9.7	85	15
659	56.2	7.7	88	12

Note: To convert square kilometers to square miles, multiply by 0.3861.

Based on the results of this analysis, run 710, which results in the largest area and highest percentage of easterly flow from particles released in the 200 Areas, was selected as the Base Case flow model.

L.10.2 Alternate Case

The Alternate Case flow model is encoded identically to the Base Case flow model with the following exceptions:

- The TOB cutoff elevation, which is the lowest elevation through which water can flow, is lowered by 3 meters (9.8 feet) in the Gable Gap Area in the Alternate Case flow model. See Section L.4.3.2.1 for a discussion of the basalt surface.

- The hydraulic conductivity values assigned in the Alternate Case model were calibrated independently, resulting in a set that is different from the hydraulic conductivity values assigned in the Base Case flow model.

The Monte Carlo optimization described in Section L.9 focused on identifying sets of hydraulic conductivity values that result in simulated head values over time and across the model domain that reasonably match observed heads over time and across the model domain. For the Alternate Case flow model, the Monte Carlo optimization identified 32 model runs, each with different sets of hydraulic conductivity values, where model simulations of head values reasonably match observed heads. These 32 model runs were evaluated further to determine which one best met the following additional selection criteria:

- The majority of the particles released to the water table within the Core Zone Boundary (200 Area Central Plateau of Hanford) move to the north through Gable Gap rather than to the east toward the Columbia River.
- Particles released to the water table in the 200 Areas (representing a historical tritium release) result in particle pathlines that qualitatively match the observed 200-East and 200-West Area tritium plumes, without considering the effects of dispersion.
- Performance of the tritium plume particle pathlines for the selected Alternate Case flow model should reasonably match performance of the tritium plume particle pathlines for the selected Base Case flow model (see Section L.10.1.3.1).

After this additional evaluation, the Alternate Case flow model was selected. The selected model must meet the calibration acceptance criteria described in Section L.6.2. Table L–23 summarizes the calibration acceptance criteria along with the Alternate Case flow model's performance for each criterion.

Table L–23. Summary of Alternate Case Flow Model Performance Compared to Calibration Acceptance Criteria

Flow Model Calibration Acceptance Criteria	Alternate Case Flow Model Performance
Residual distribution should be reasonably normal.	Residual distribution is reasonably normal (see Figure L–75).
The residual mean should be approximately 0.	Residual Mean = –0.078 meters (–0.255 feet).
The number of positive residuals should approximate the number of negative residuals.	Positive residuals approximately equal negative residuals (see Figure L–75).
The correlation coefficient (calculated versus observed) should be greater than 0.9.	Correlation coefficient = 0.98 (see Figure L–76)
The root mean square (RMS) error (calculated versus observed) should be less than 5 meters (16.4 feet), approximately 10 percent of the gradient in the water table elevation.	RMS error = 2.058 meters (see Figure L–76).
Residuals in the 200-East Area should be distributed similarly to those in the 200-West Area.	Residuals in the 200-East and 200-West Areas are distributed similarly (see Figures L−77 and L−78).
The residuals should be evenly distributed over time.	Residuals are approximately evenly distributed over time (see Figures L−79, L−80, L−81, and L–82).
The residuals should be evenly distributed across the site.	Residuals are approximately evenly distributed across the site (see Figures L−83, L−84, and L−85).
The calibrated parameters should compare reasonably well with field-measured values.	Calibrated hydraulic conductivity values are listed in Table L–24 and compare reasonably with field-measured values for material types to which the model is sensitive (i.e., Hanford formation and Ringold Formation material types). Figure L–53 provides field-measured values from aquifer pumping tests (Cole et al. 2001).
Parameters should be reasonably uncorrelated.	Hydraulic conductivity parameters are reasonably uncorrelated (see Table L–24 for the key to model material type zones and Table L–25 for the correlation coefficient matrix).

Note: To convert meters to feet, multiply by 3.281.

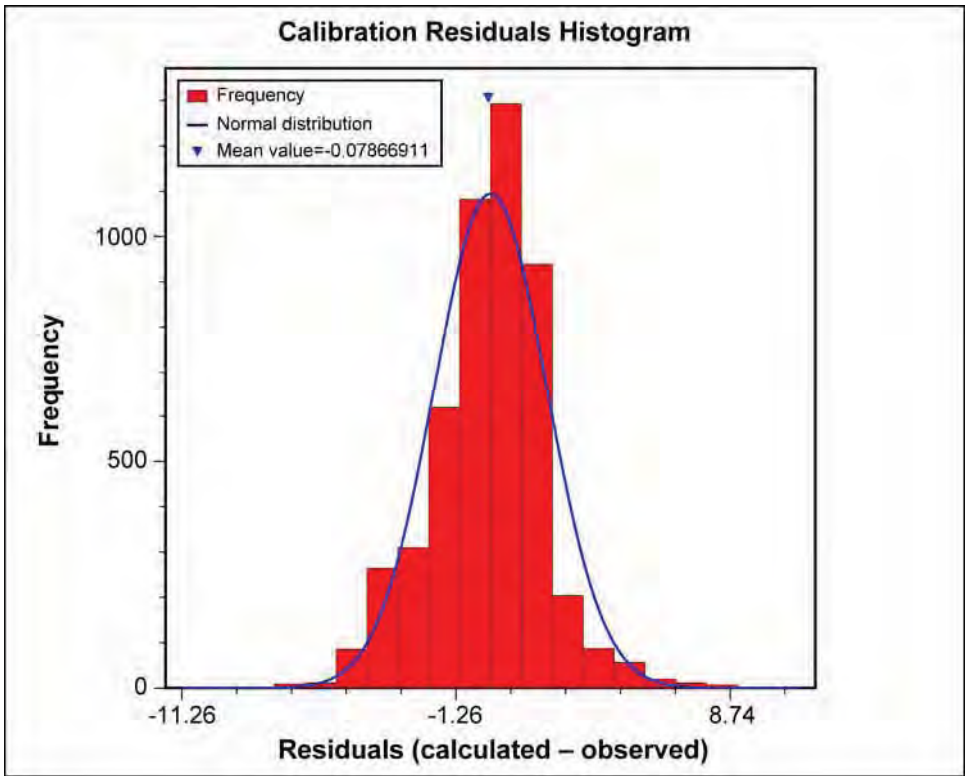


Figure L–75. Alternate Case Flow Model Residual Distribution

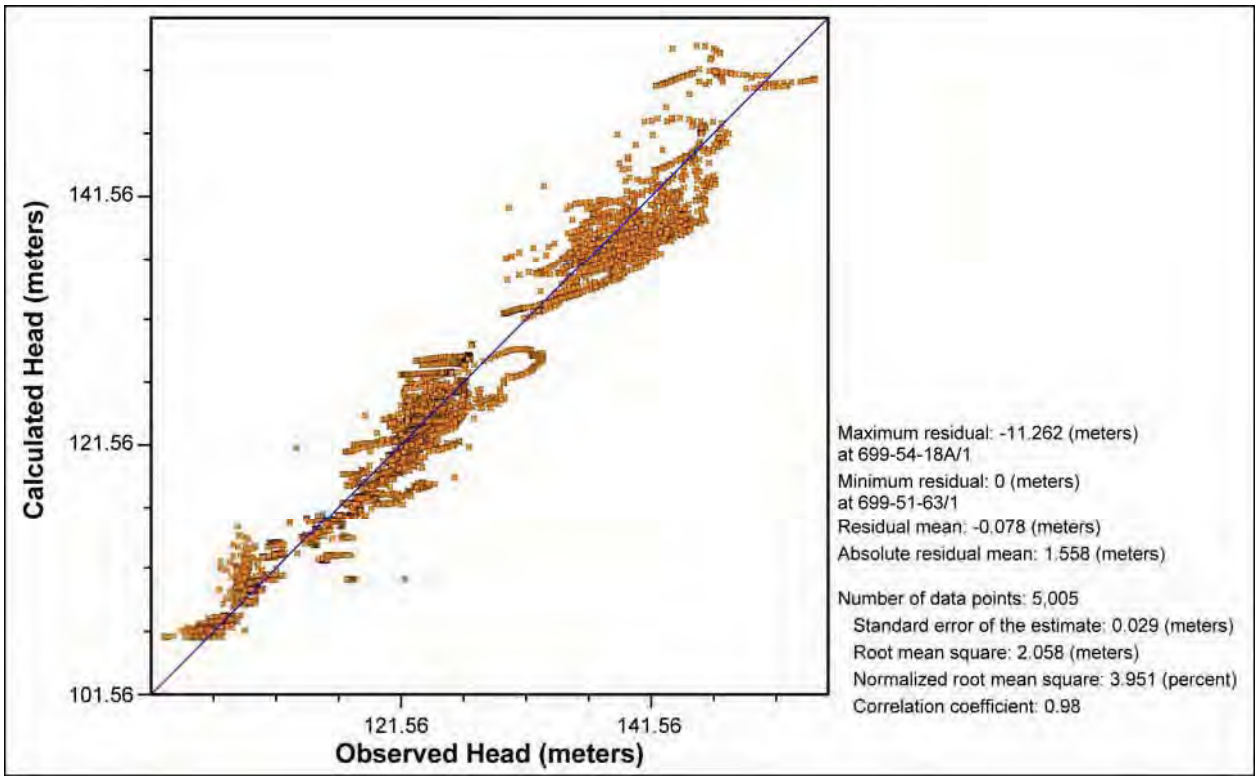


Figure L–76. Alternate Case Flow Model Calibration Graph and Statistics

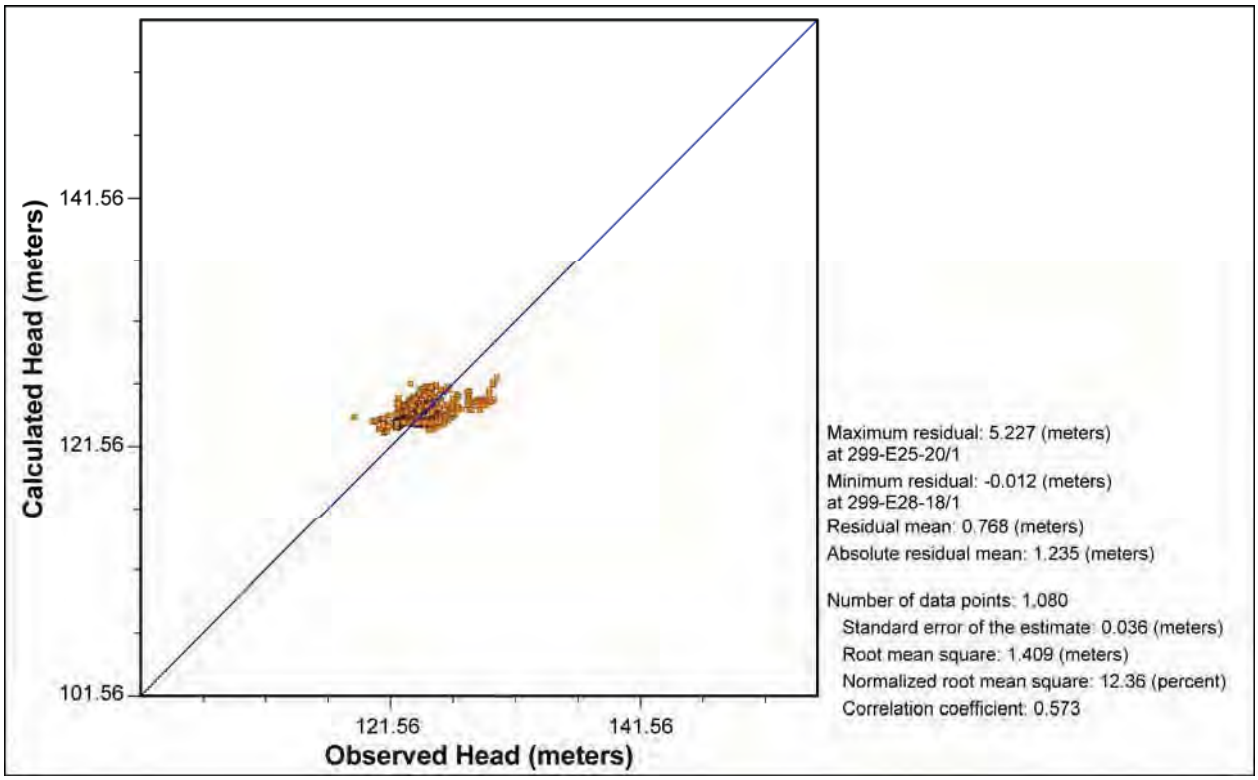


Figure L–77. Alternate Case Flow Model Residuals – 200-East Area

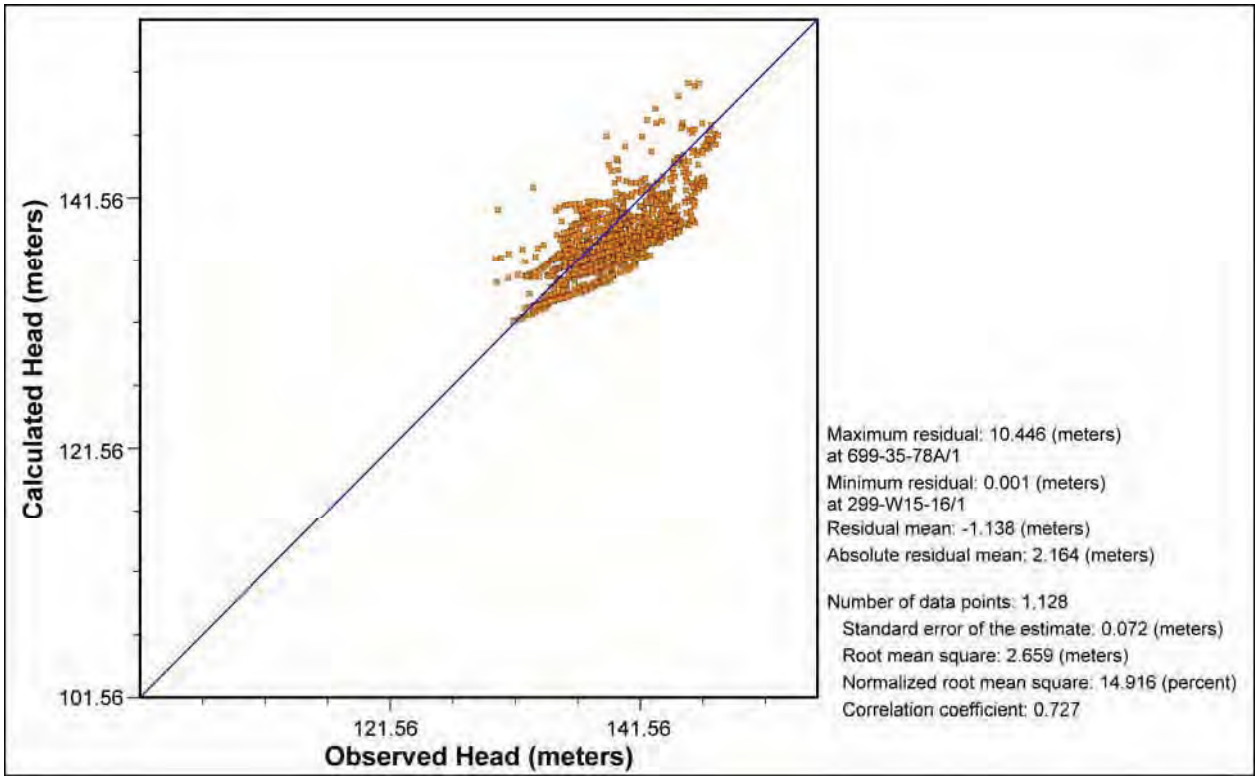


Figure L–78. Alternate Case Flow Model Residuals – 200-West Area

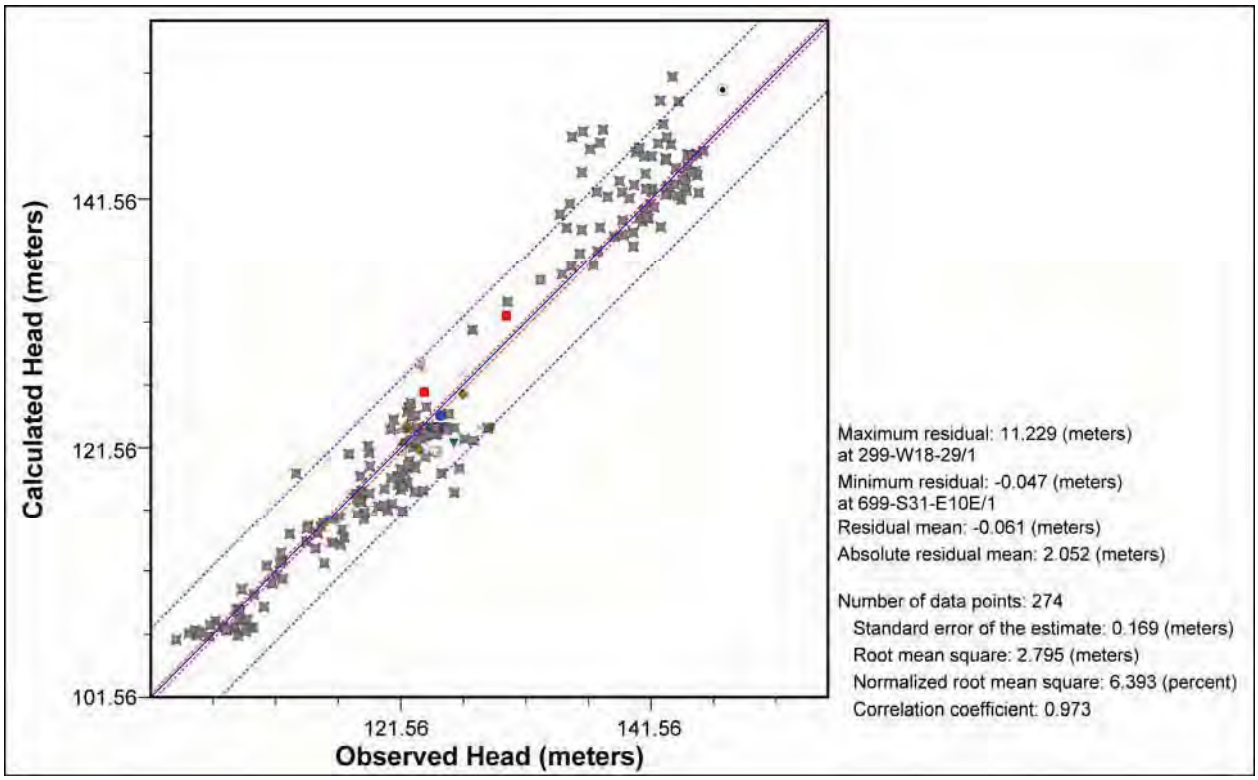


Figure L–79. Alternate Case Flow Model Residuals – Calendar Year 1955

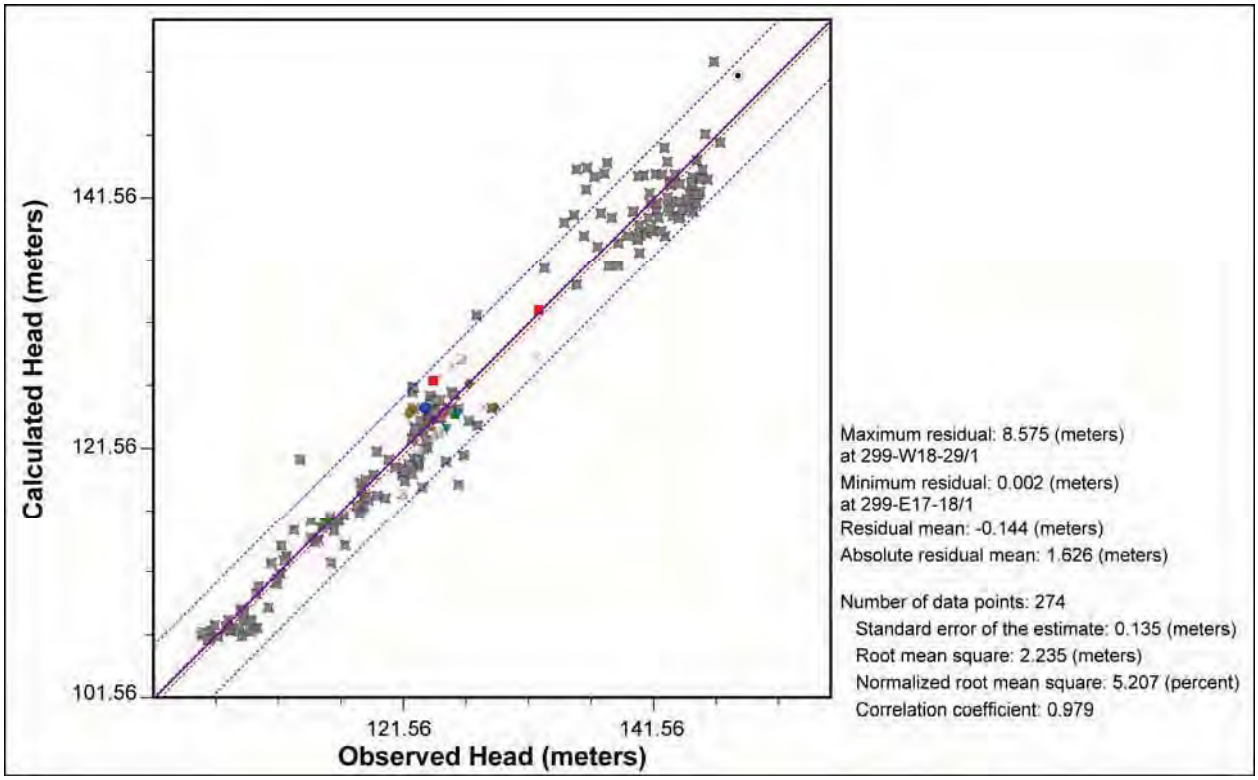


Figure L–80. Alternate Case Flow Model Residuals – Calendar Year 1975

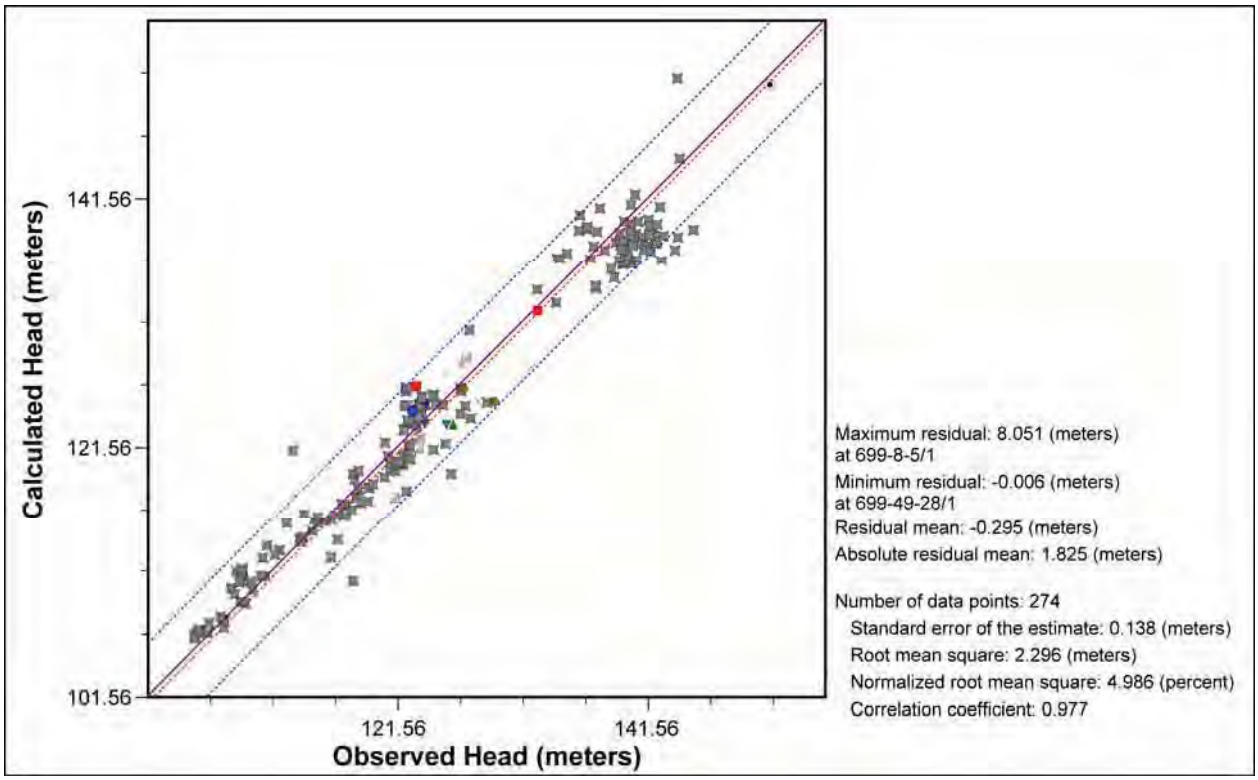


Figure L–81. Alternate Case Flow Model Residuals – Calendar Year 1995

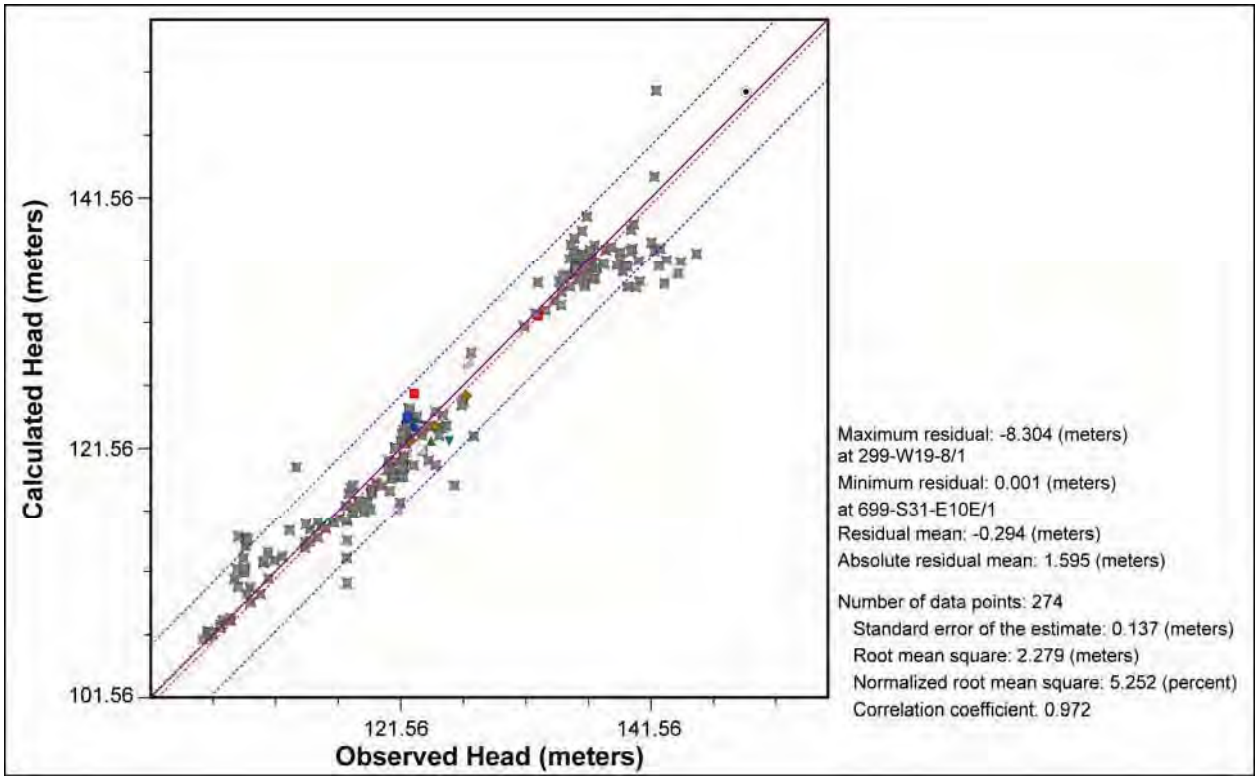


Figure L–82. Alternate Case Flow Model Residuals – Calendar Year 2015

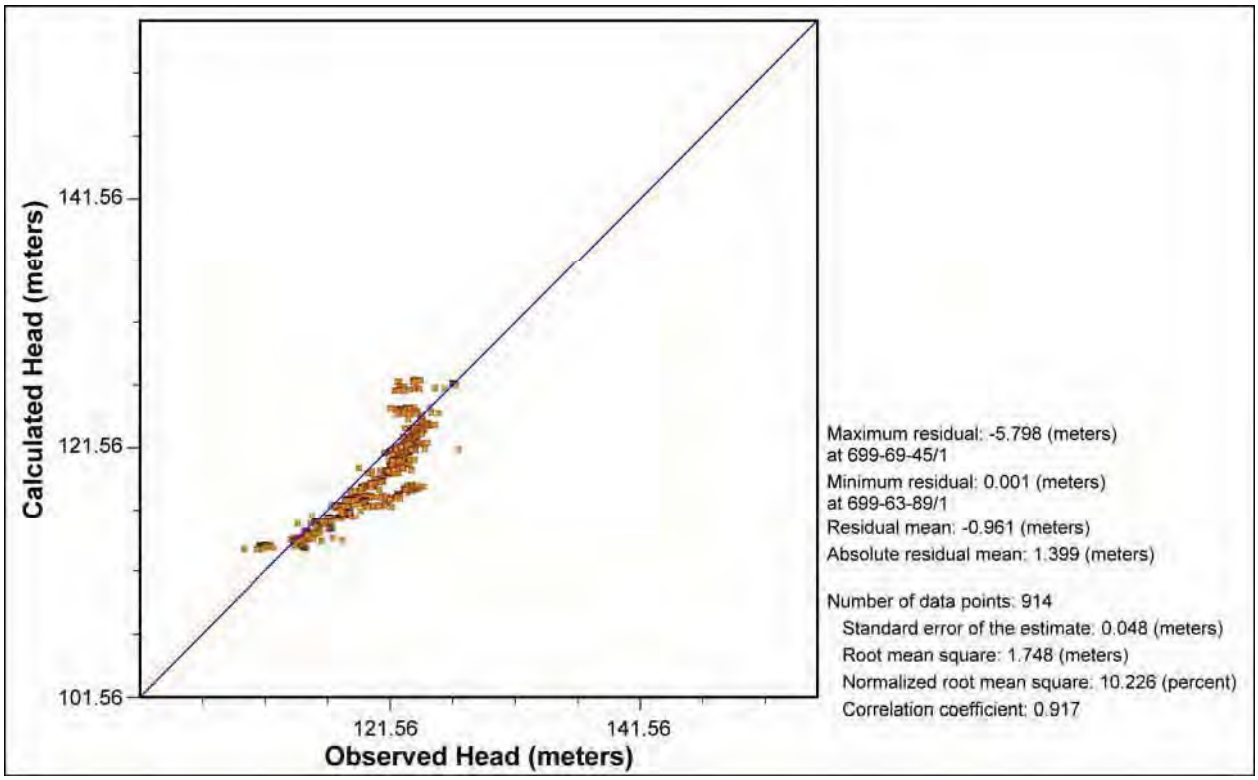


Figure L–83. Alternate Case Flow Model Residuals in Northern Region of Model

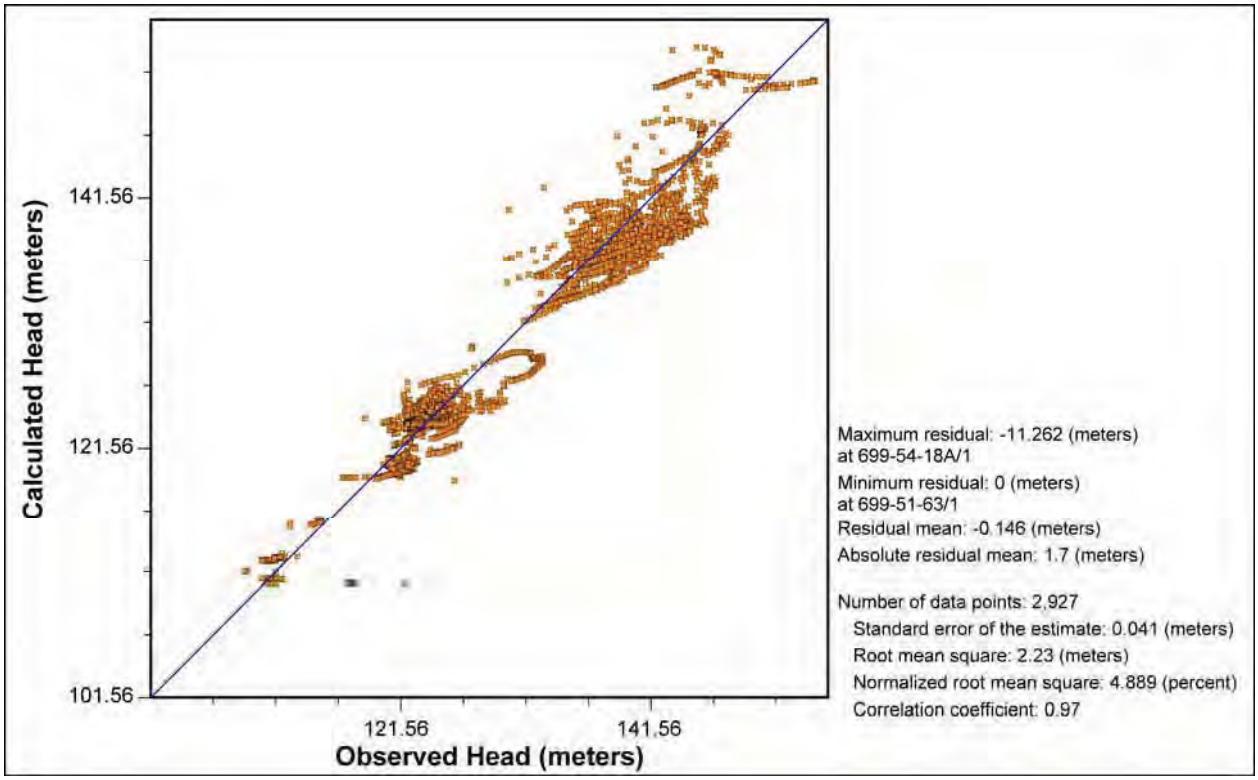


Figure L–84. Alternate Case Flow Model Residuals in Central Region of Model

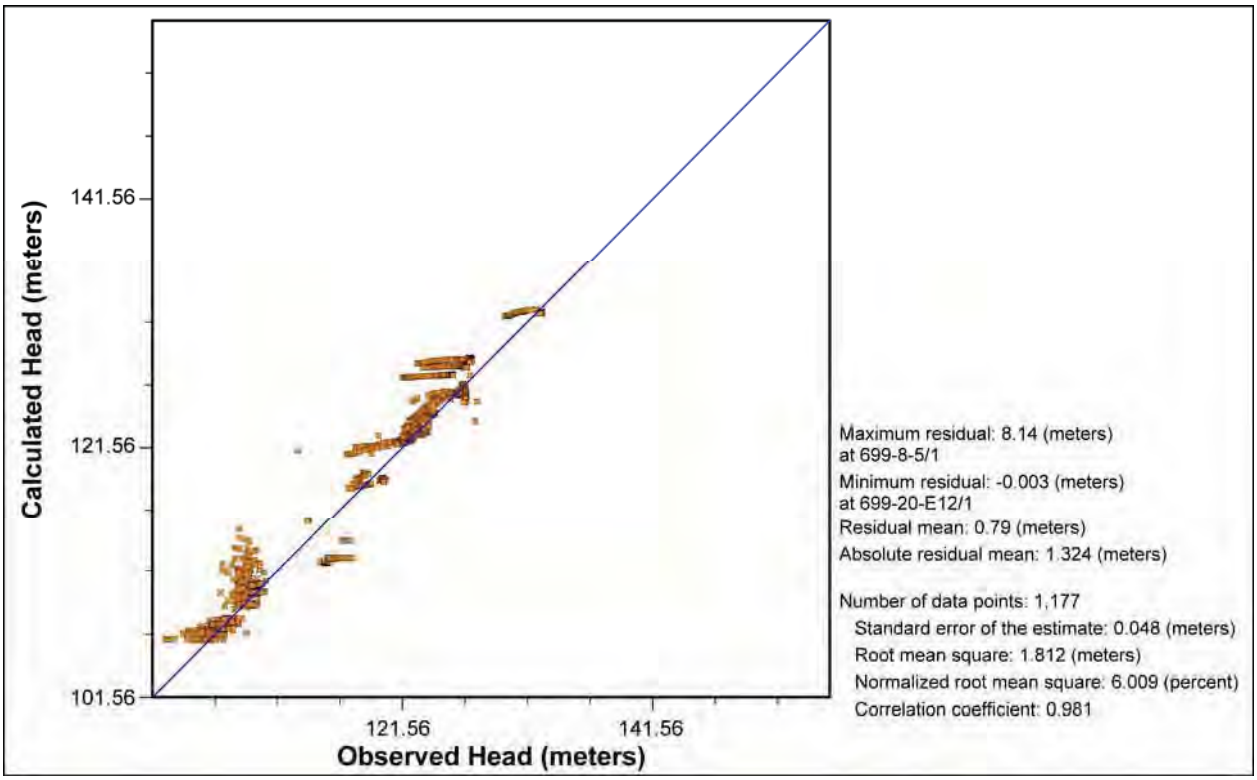


Figure L–85. Alternate Case Flow Model Residuals in Southern Region of Model

Table L–24. Alternate Case Flow Model Calibrated Hydraulic Conductivity Values

Material Type (Model Zone)	Hydraulic Conductivity (K_x)[a]	Hydraulic Conductivity (K_y)[b]	Hydraulic Conductivity (K_z)[c]
Hanford mud (1)	0.481	0.481	0.0481
Hanford silt (2)	21.8	21.8	2.18
Hanford sand (3)	30.4	30.4	3.04
Hanford gravel (4)	222.1	222.1	22.21
Ringold Sand (5)	0.83	0.83	0.083
Ringold Gravel (6)	18.7	18.7	1.87
Ringold Mud (7)	1.958	1.958	0.1958
Ringold Silt (8)	0.77	0.77	0.077
Plio-Pleistocene sand (9)	84.2	84.2	8.42
Plio-Pleistocene silt (10)	6.87	6.87	0.687
Cold Creek sand (11)	39.4	39.4	3.94
Cold Creek gravel (12)	5.6	5.6	0.56
Highly conductive Hanford gravel (13)	4331	4331	433.1
Activated basalt (14)	0.001	0.001	0.0001

[a] Hydraulic conductivity with respect to the *x* axis, meters per day.
[b] Hydraulic conductivity with respect to the *y* axis, meters per day.
[c] Hydraulic conductivity with respect to the *z* axis, meters per day.
Note: To convert meters to feet, multiply by 3.281.

Table L–25. Alternate Case Hydraulic Conductivity Parameter Correlation Coefficient Matrix

Model Zone	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.00	0.08	-0.01	0.14	-0.08	-0.20	0.33	0.11	0.29	-0.14	0.01	0.07	-0.03
2	0.08	1.00	0.00	-0.01	-0.05	-0.01	-0.05	0.01	0.02	-0.17	0.10	0.02	-0.11
3	-0.01	0.00	1.00	0.12	-0.06	-0.11	-0.12	-0.08	0.20	-0.11	0.19	-0.12	0.21
4	0.14	-0.01	0.12	1.00	-0.13	-0.31	-0.23	-0.23	-0.18	-0.11	0.06	-0.18	0.26
5	-0.08	-0.05	-0.06	-0.13	1.00	-0.54	-0.04	0.10	-0.07	0.18	-0.21	0.08	-0.23
6	-0.20	-0.01	-0.11	-0.31	-0.54	1.00	-0.23	-0.08	0.08	-0.09	0.03	0.03	-0.04
7	0.33	-0.05	-0.12	-0.23	-0.04	-0.23	1.00	0.13	0.16	-0.17	-0.09	0.08	-0.27
8	0.11	0.01	-0.08	-0.23	0.10	-0.08	0.13	1.00	-0.05	-0.06	-0.13	0.34	-0.22
9	0.29	0.02	0.20	-0.18	-0.07	0.08	0.16	-0.05	1.00	0.00	-0.01	0.04	-0.05
10	-0.14	-0.17	-0.11	-0.11	0.18	-0.09	-0.17	-0.06	0.00	1.00	-0.18	-0.12	0.12
11	0.01	0.10	0.19	0.06	-0.21	0.03	-0.09	-0.13	-0.01	-0.18	1.00	0.09	-0.07
12	0.07	0.02	-0.12	-0.18	0.08	0.03	0.08	0.34	0.04	-0.12	0.09	1.00	-0.42
13	-0.03	-0.11	0.21	0.26	-0.23	-0.04	-0.27	-0.22	-0.05	0.12	-0.07	-0.42	1.00

The Alternate Case flow model is most sensitive to the hydraulic conductivity values of the Ringold Gravel, the Hanford gravel, and the highly conductive Hanford gravel. The Alternate Case hydraulic conductivity of Ringold Gravel is about 20 meters per day (65.6 feet per day) (see Table L–24). The histogram of hydraulic conductivity distribution for the Ringold Formation as measured in aquifer pump tests is shown in the upper right-hand corner of Figure L–53. The majority of the field measured hydraulic conductivities are between 10 and 30 meters per day (between 32.8 and 98.4 feet per day), in reasonable agreement with the Base Case value. Alternate Case hydraulic conductivities for the Hanford gravel and the highly conductive Hanford gravel are about 220 meters per day (722 feet per day) and about 4,000 meters per day (13,124 feet per day), respectively (see Table L–24). The histogram of hydraulic conductivity for the Hanford Formation as measured in aquifer pump tests is shown in the upper left-hand corner of Figure L–53. Note that the range of measured hydraulic conductivities for the Hanford Formation is much broader than the Ringold Formation. Measured hydraulic conductivities for the Hanford Formation show a maximum of about 300 meters per day (984 feet per day), with a secondary occurrence between 3,000 and 5,000 meters per day (between 9,843 and 16,405 feet per day). This suggests that the inclusion of the highly conductive Hanford gravel in the conceptual model reflects an important component of the hydraulic conductivity distribution at the site.

In addition to the calibration acceptance criteria, water (or mass) balance and a long-term steady state condition must be achieved in the calibrated flow model. Cumulative mass water balance data are shown in Figure L–86, indicating a cumulative mass balance error of approximately –1.4 percent. Total water balance and storage data as a function of time are shown in Figure L–87. These data show storage values relative to the total water balance and indicate that storage-in is approximately equal to storage-out in model year 140 (calendar year 2080). This confirms that a long-term steady state condition is achieved. Note that, in Figure L–87, there is a spike in "Total Storage In" and "Total In" at about model year 82. This spike is the result of a stress period change to the final long-term stress period. As a result, the model is moving from a relatively long time step at the end of the previous stress period to a relatively short time step at the beginning of the final stress period.

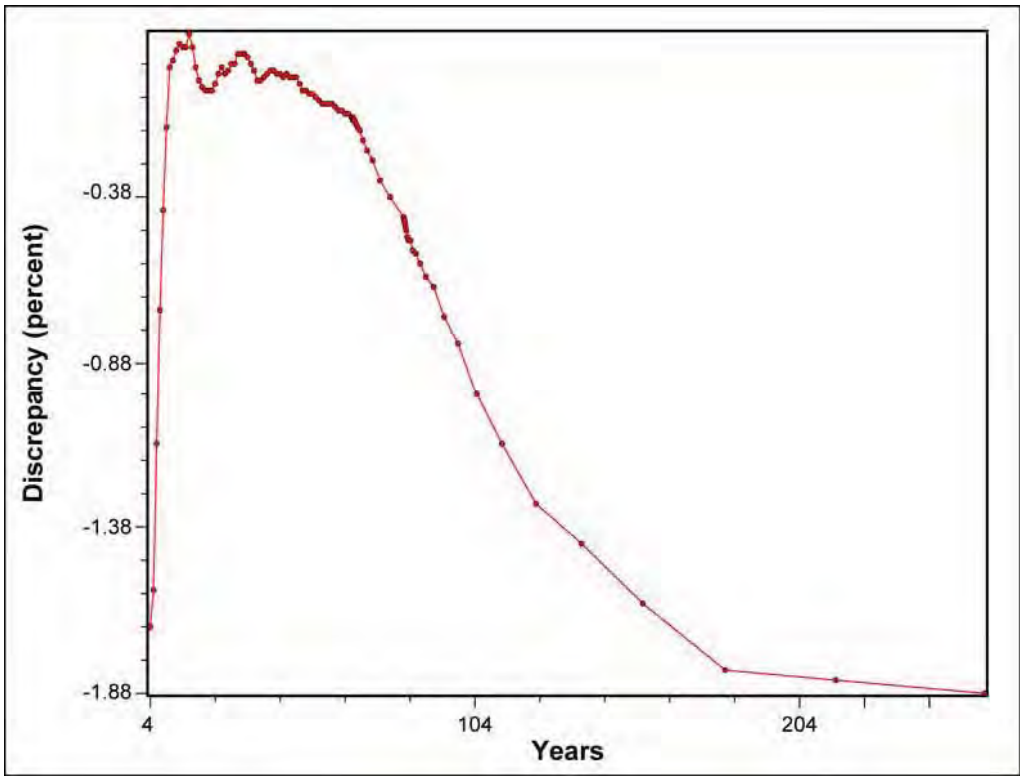


Figure L–86. Alternate Case Flow Model Cumulative Water Balance Discrepancy – Year 0 (Calendar Year 1940)

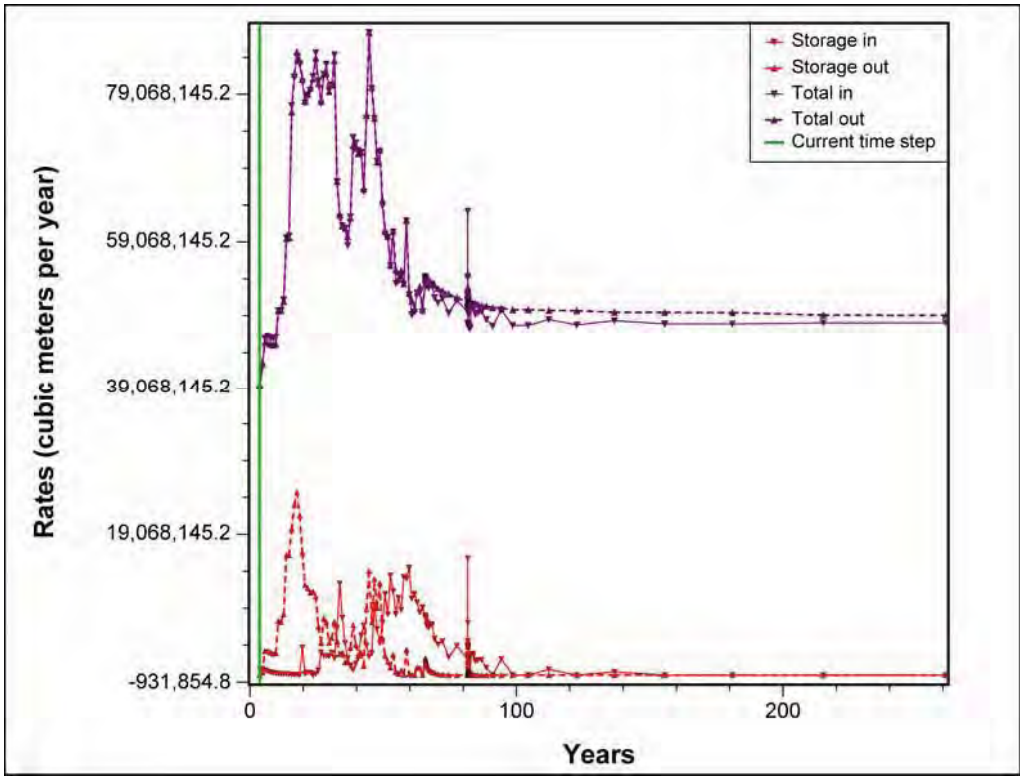


Figure L–87. Alternate Case Flow Model Total Water and Storage Rates Over Time – Year 0 (Calendar Year 1940)

L.10.2.1 Potentiometric Distribution

A goal for the Alternate Case flow model is to produce a potentiometric distribution of heads that shows a steep water table in the 200-West Area due to the low conductivity material types in that area and a relatively flat water table in the 200-East Area where high conductivity material types are present. The pre-Hanford potentiometric surface is assumed to be approximately the same as the post-Hanford long-term steady state condition, with water table mounding occurring below areas where and near times when Hanford operational discharges were released at the ground surface. Figures L−88 through L−90 are Alternate Case flow model simulations of the potentiometric surface in calendar years 1944 (pre-Hanford), 1975 (Hanford operations), and 2200 (post-Hanford), respectively.

Figure L–88. Alternate Case Flow Model Potentiometric Head Distribution – Calendar Year 1944

Figure L–89. Alternate Case Flow Model Potentiometric Head Distribution – Calendar Year 1975

Figure L–90. Alternate Case Flow Model Potentiometric Head Distribution – Calendar Year 2200

L.10.2.2 Velocity Field

The Alternate Case flow model is variable in both magnitude and direction over time and across the model domain. This magnitude and direction variability near the BY Cribs in the 200-East Area is shown in Figures L−91 and L−92. The BY Cribs are in close proximity to Gable Gap, which is the location within the model that has a lower TOB encoded for the Alternate Case flow model. This lower TOB in the Gable Gap area is the distinguishing feature between the Base Case flow model and the Alternate Case flow model. See Figures L−63 and L−64 for comparable Base Case flow model velocity data at the BY Cribs. Comparing the velocity data between the Base Case and Alternate Case flow models at the BY Cribs indicates that the velocity directions and magnitudes in the Gable Gap area are sensitive to the elevation of the TOB in this area.

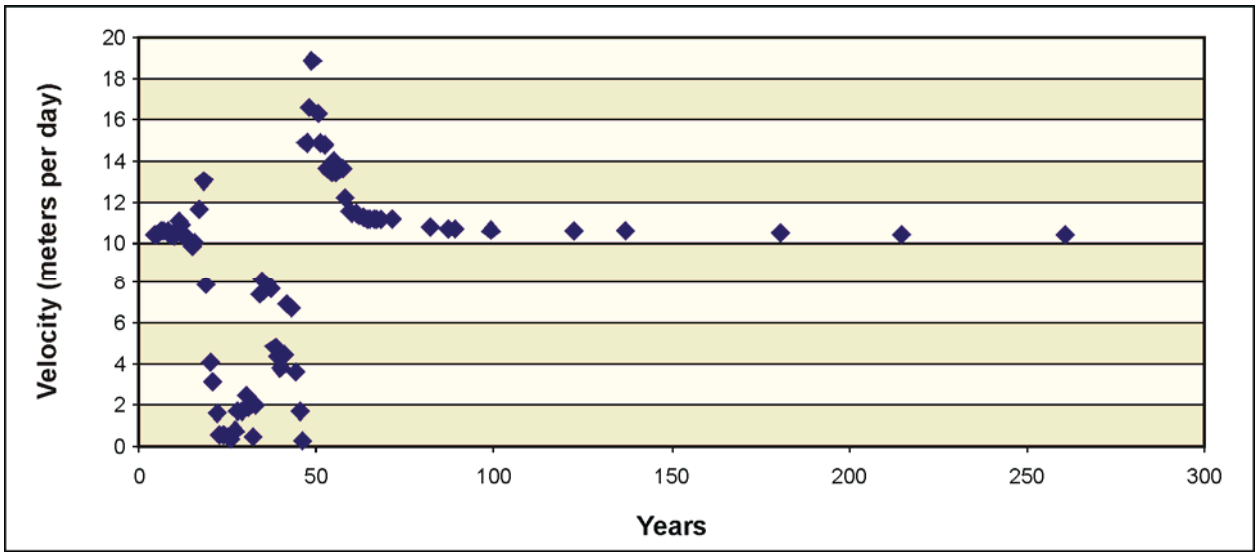


Figure L–91. Alternate Case Flow Model Velocity Magnitude at BY Cribs (200-East Area) – Year 0 (Calendar Year 1940)

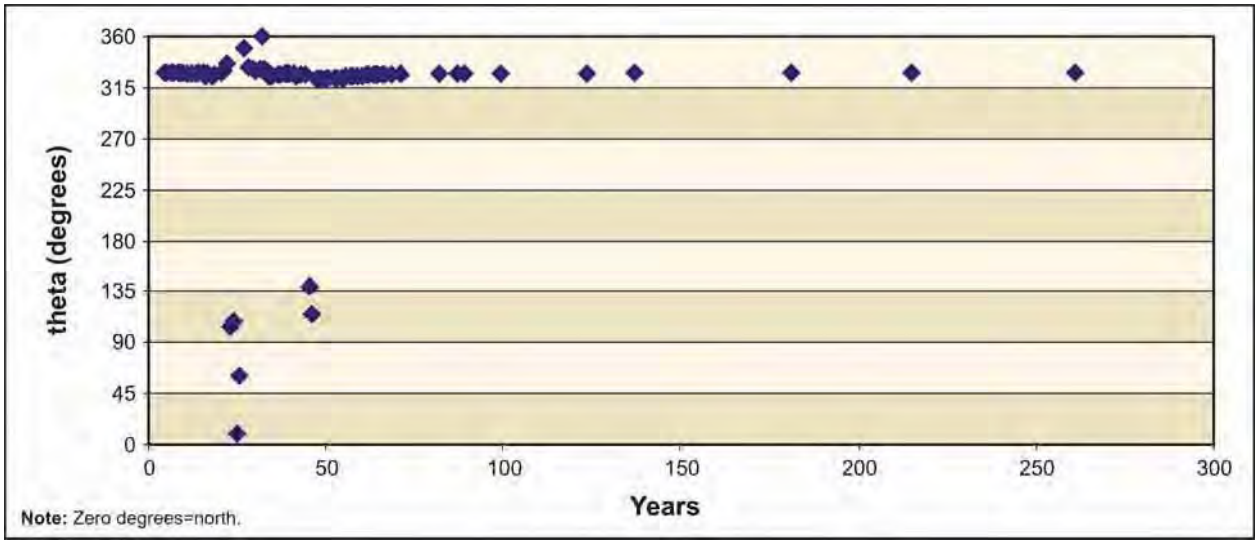


Figure L–92. Alternate Case Flow Model Velocity Direction at BY Cribs (200-East Area) – Year 0 (Calendar Year 1940)

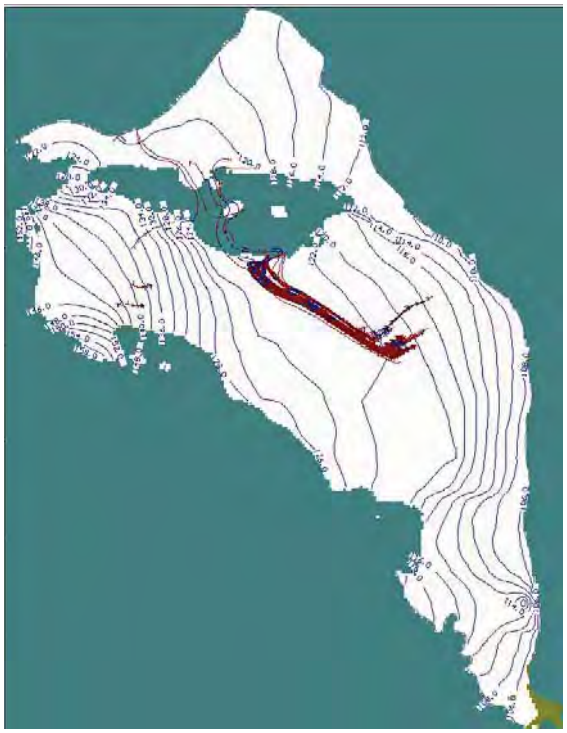
L.10.2.3 Pathline Analyses

Pathline analysis was performed on the top 32 model runs (see Section L.10.2) to narrow this field of models that performed well relative to RMS error to a single Alternate Case flow model. Two pathline analyses, the tritium plume pathline analysis and the Central Plateau delineation pathline analysis, were performed on each of the top 32 models.

L.10.2.3.1 Hydrogen-3 (Tritium) Plume Pathline Analysis

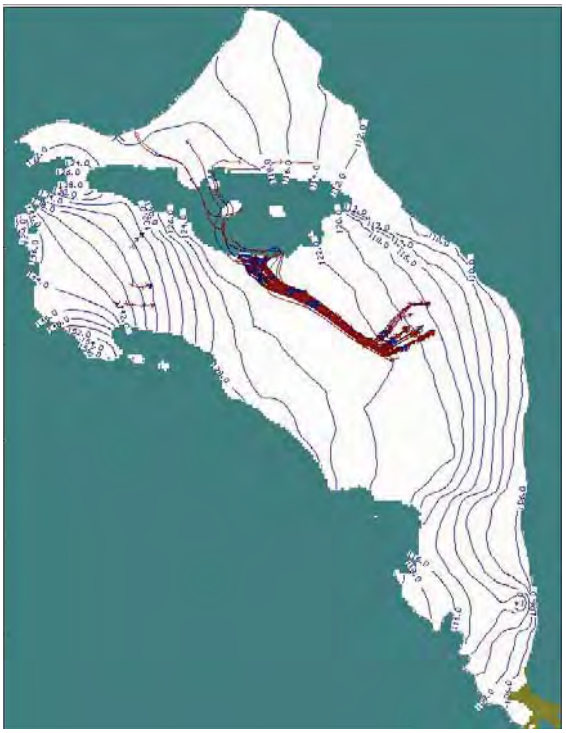
Tritium plume pathline analysis included a MODFLOW and MODPATH model run for each of the top 32 model cases, releasing particles in the 200-East and 200-West Areas representing an actual tritium release and comparing the particle pathlines to the general shape of the observed tritium plumes. This analysis is somewhat limited because no dispersion is applied to the particle pathlines so that spreading of the plume to its actual extents is constrained. This analysis does provide a qualitative means to compare

this final set of possible models to one another and aid in selecting the Alternate Case flow model. Figures L−65 and L–66 provide an interpretation of the field-observed tritium plume (Hartman, Morasch, and Webber 2004) to which the model-simulated pathlines were compared. Figures L−93 through L−96 provide the MODFLOW/MODPATH results of 4 of the top 32 model runs, including the model run selected as the Alternate Case flow model. Additionally, for the Alternate Case flow model, since the tritium plume pathline analysis covers the calibration period (1948–2006), it is important that the tritium plume result for the Alternate Case flow model qualitatively match the tritium plume result for the Base Case flow model. Figure L–68 shows the tritium plume pathline analysis results for the Base Case flow model. This analysis concluded that many of the top 32 model runs could be selected as the Alternate Case flow model if the selection were based only on the tritium plume pathline analysis.



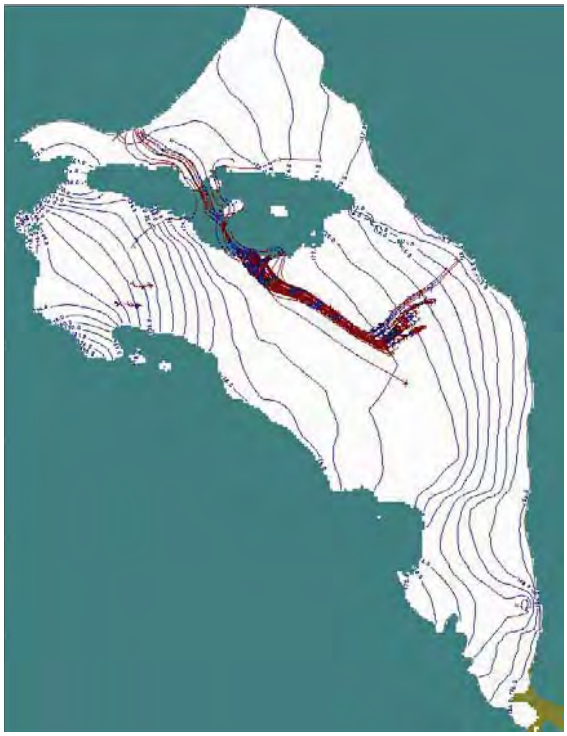
Note: To convert meters to feet, multiply by 3.281.

Figure L–93. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 407 (root mean square error = 2.065 meters)



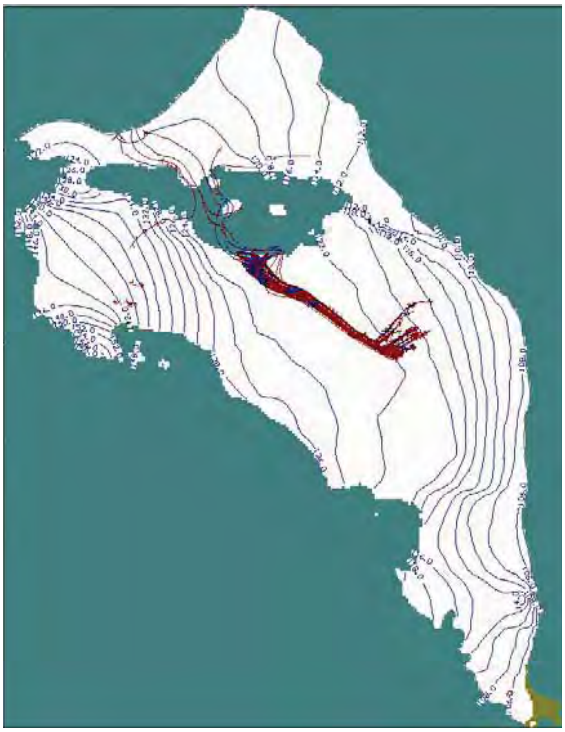
Note: To convert meters to feet, multiply by 3.281.

Figure L–94. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 195 (root mean square error = 2.056 meters) – Selected as Alternate Case Flow Model



Note: To convert meters to feet, multiply by 3.281.

Figure L–95. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 238 (root mean square error = 2.048 meters)



Note: To convert meters to feet, multiply by 3.281.

Figure L–96. Hydrogen-3 (Tritium) Plume Pathline Analysis Run 304 (root mean square error = 2.036 meters)

L.10.2.3.2 Central Plateau Delineation Pathline Analysis

The *Technical Guidance Document* (DOE 2005) directed that the Alternate Case flow model would flow predominantly northward from the 200 Areas of Hanford. The purpose of the central plateau delineation pathline analysis was to determine for each of the top 32 model runs the amount of particles released in the 200 Areas that would move to the north through Gable Gap and the amount of particles that would move to the east toward the Columbia River. This analysis included a MODFLOW and MODPATH model run for each of the top 32 model cases, releasing a uniformly distributed set of particles across the central plateau. The central plateau is depicted as a rectangular-shaped boundary that includes all of the 200-East and 200-West Areas as well as other areas between and outside of the 200 Areas. This analysis provides a quantitative means to compare this final set of possible models to one another and aid in selecting a single Alternate Case flow model. Figures L−97 through L−100 provide the MODFLOW/MODPATH results of 4 of the 32 model runs, including the model run selected as the Alternate Case flow model (see Figure L–98).

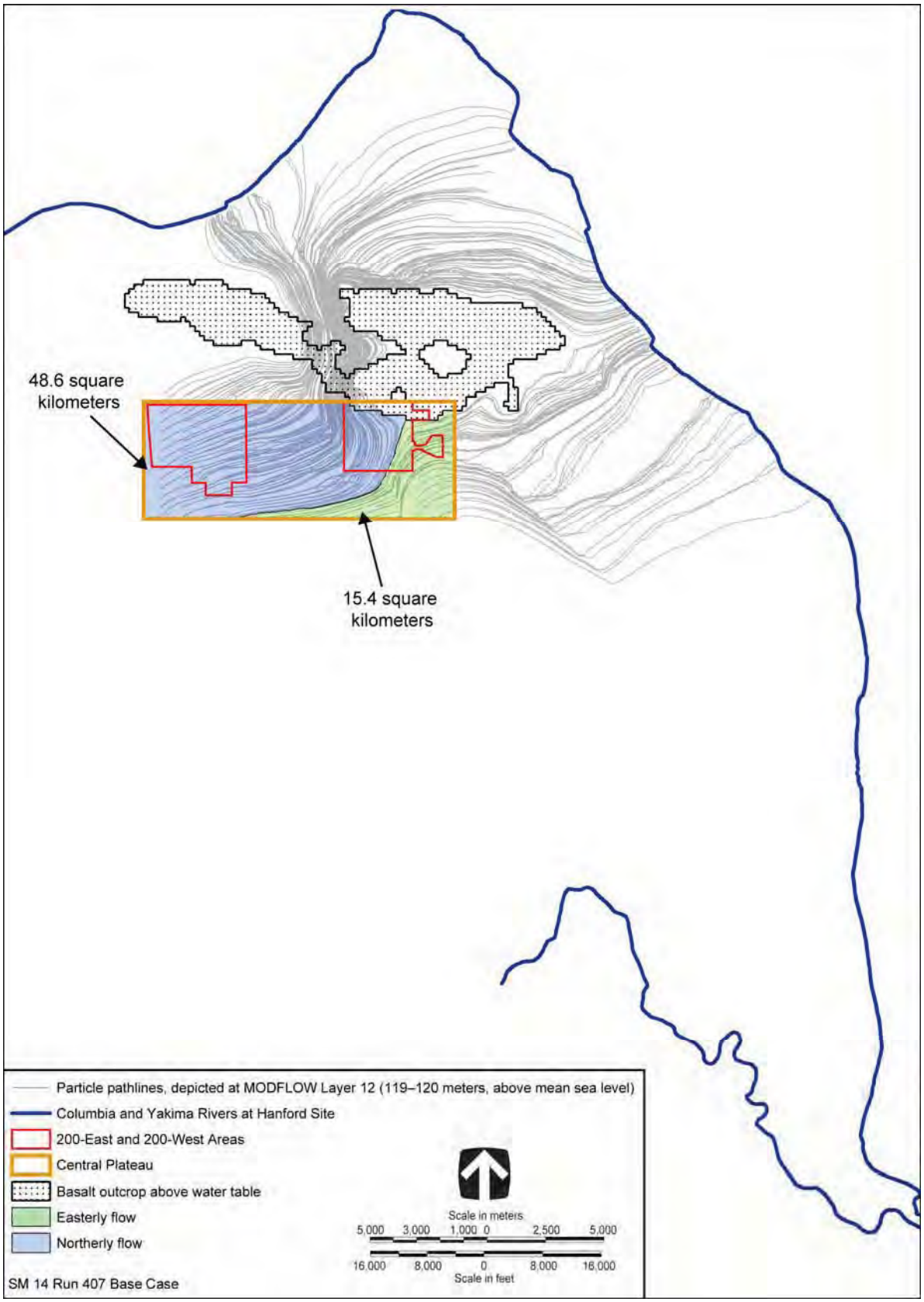


Figure L–97. Central Plateau Delineation Pathline Analysis Run 407 (root mean square error = 2.065 meters)

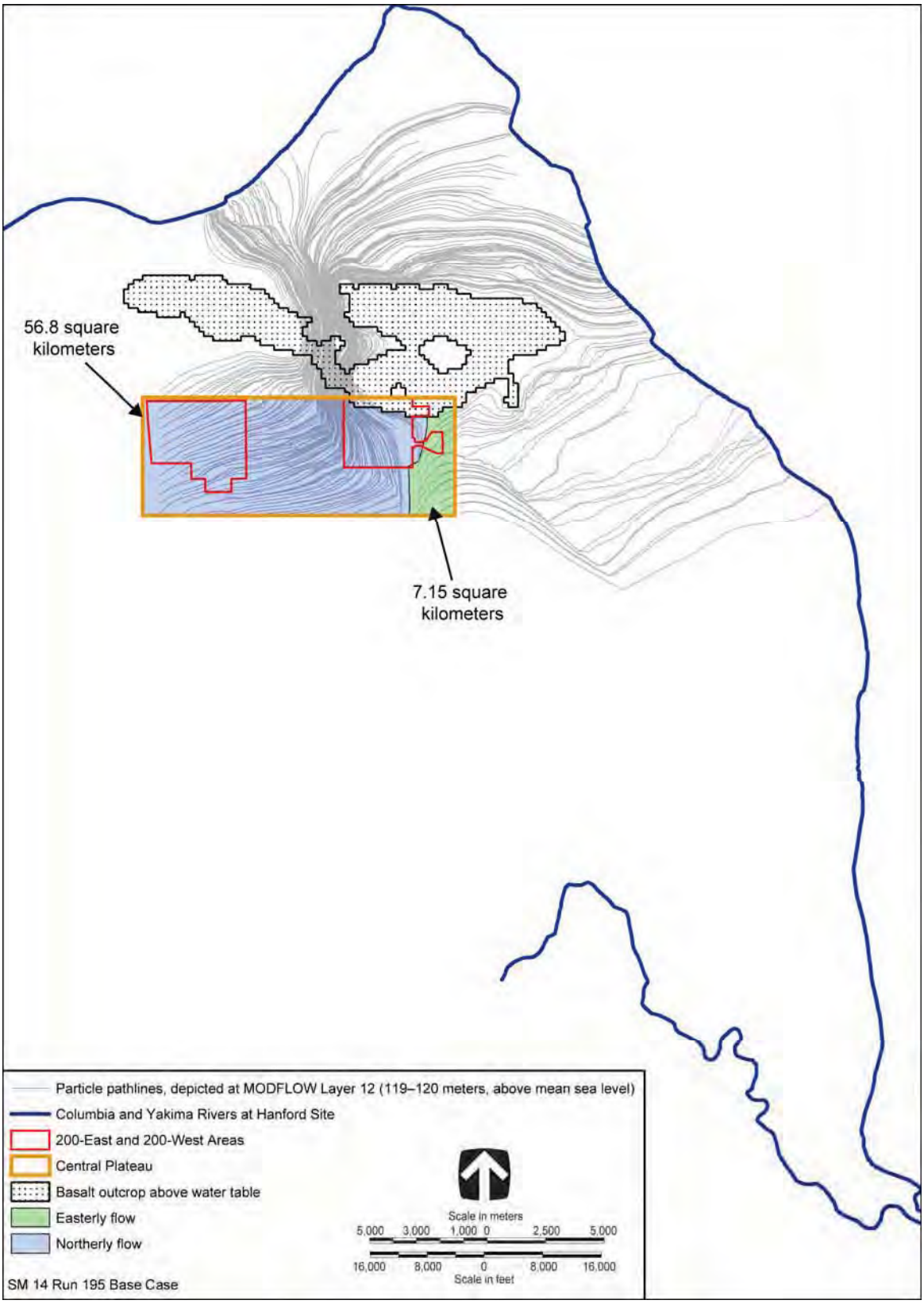


Figure L–98. Central Plateau Delineation Pathline Analysis Run 195 (root mean square error = 2.056 meters) – Selected as Alternate Case Flow Model

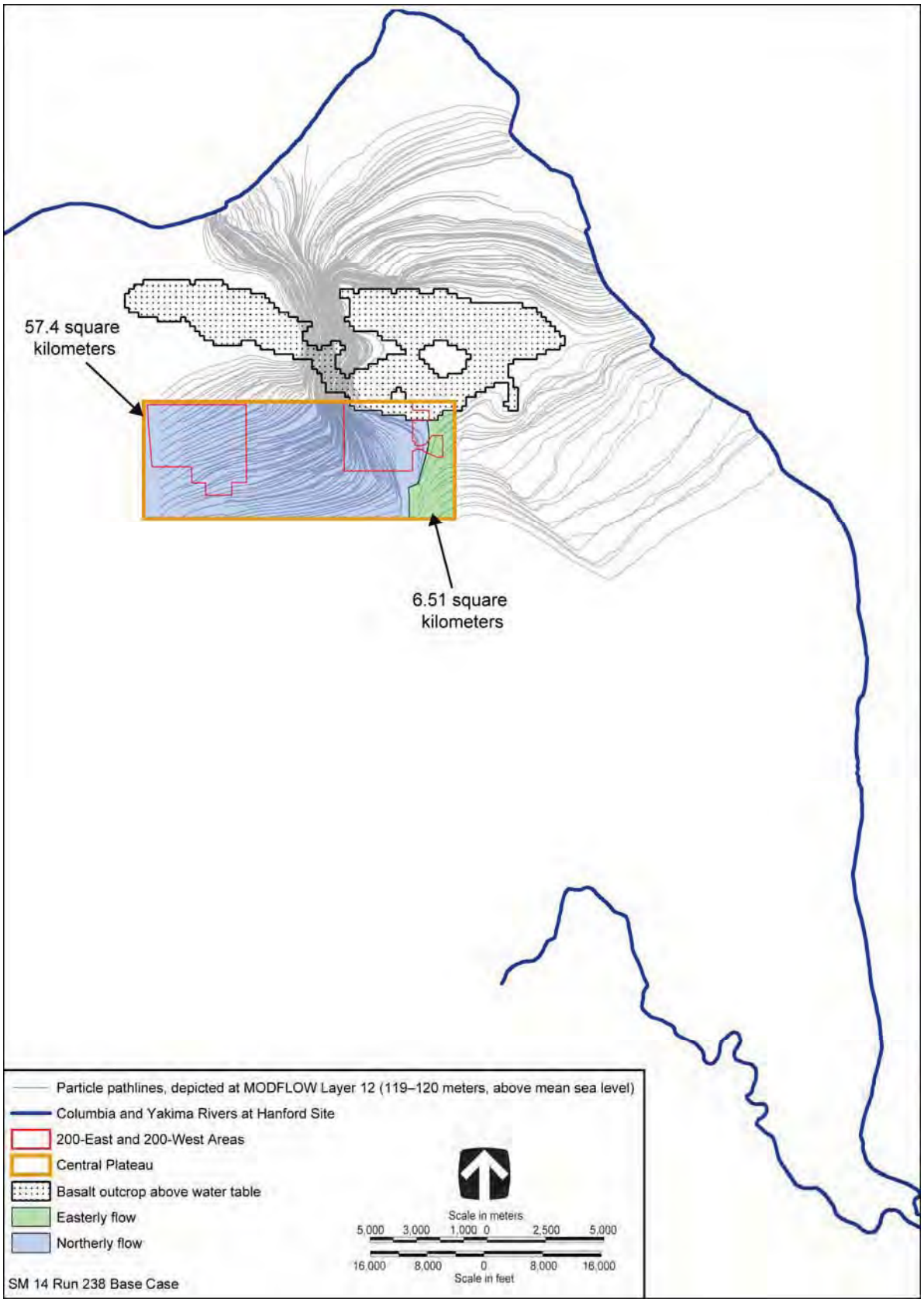


Figure L–99. Central Plateau Delineation Pathline Analysis Run 238 (root mean square error = 2.048 meters)

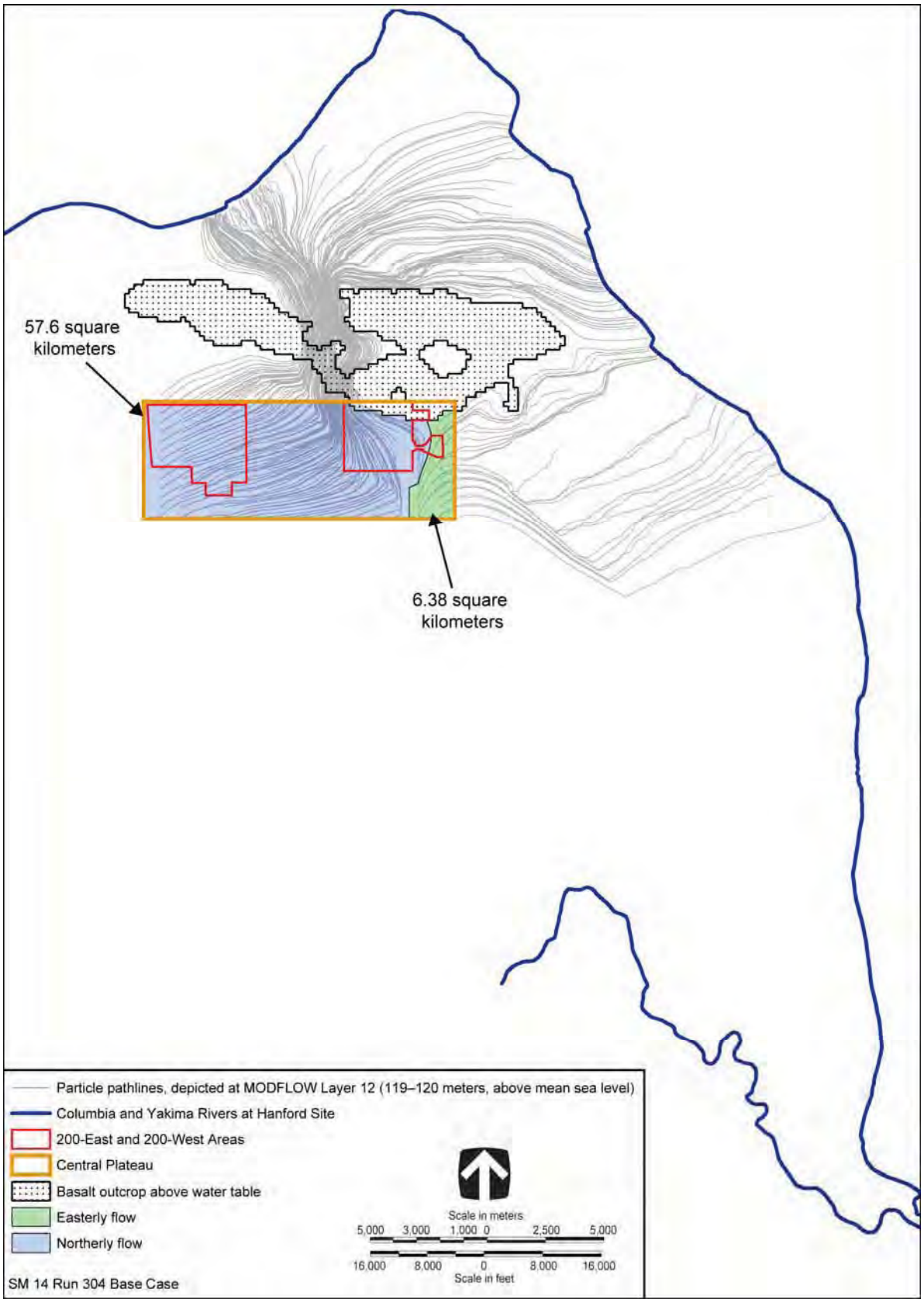


Figure L–100. Central Plateau Delineation Pathline Analysis Run 304 (root mean square error = 2.036 meters)

Table L–26 provides a summary of the percentage of particle pathlines flowing to the east and to the north for the top 32 Alternate Case model runs.

Table L–26. Summary of Top 32 Alternate Case Model Runs – Northerly Versus Easterly Flow

Run Number	Area of Northerly Flow (square kilometers)	Area of Easterly Flow (square kilometers)	Northerly Flow (percent)	Easterly Flow (percent)
075	61.5	2.4	96	4
210	61.0	3.0	95	5
321	60.8	3.1	95	5
120	60.6	3.3	95	5
148	59.0	5.0	92	8
290	58.4	5.6	91	9
043	58.2	5.8	91	9
118	57.7	6.2	90	10
304	57.6	6.4	90	10
215	57.4	6.5	90	10
238	57.4	6.5	90	10
286	57.1	6.8	89	11
020	57.1	6.8	89	11
214	57.0	7.0	89	11
109	56.9	7.1	89	11
195	56.8	7.2	89	11
133	56.7	7.2	89	11
060	56.6	7.3	89	11
039	56.6	7.4	88	12
185	56.6	7.4	88	12
126	56.5	7.5	88	12
369	56.4	7.5	88	12
380	56.4	7.6	88	12
198	56.2	7.8	88	12
390	54.4	9.5	85	15
353	54.0	10.0	84	16
033	53.8	10.1	84	16
212	49.4	14.6	77	23
407	48.6	15.4	76	24
066	48.6	15.4	76	24
059	44.2	19.7	69	31
068	43.5	20.4	68	32

Note: To convert square kilometers to square miles, multiply by 0.386.

Based on the results of this analysis, coupled with the qualitative matching of the Alternate Case flow model tritium plume pathline analysis with the Base Case flow model results, run 195 was selected as the Alternate Case flow model.

L.11 FLOW FIELD EXTRACTION

To support analysis of potential contaminant transport patterns in the saturated zone, the MODFLOW groundwater flow model developed for this *TC & WM EIS* is being used as the basis for particle-tracking simulations. The selected particle-tracking code does not directly read MODFLOW output files to calculate the velocities required as input to particle tracking; instead, the MODFLOW files must be independently processed to generate these velocities.

The Base Case and Alternate Case flow model data files were processed by extracting hydraulic heads and velocities at each active cell within the model domain at selected times. The times selected for extracting the head and velocity data files are included in Table L–27.

Table L–27. Selected Times for Extracting the Base Case and Alternate Case Head and Velocity Data Files

Stress Period	Time Step	Model Year	Calendar Year
1	5	4	1943
2	10	5	1944
3	10	6	1945
4	10	7	1946
5	10	8	1947
6	10	9	1948
7	10	10	1949
8	10	11	1950
9	10	12	1951
10	10	13	1952
11	10	14	1953
12	10	15	1954
13	10	16	1955
14	10	17	1956
15	10	18	1957
16	10	19	1958
17	10	20	1959
18	10	21	1960
19	10	22	1961
20	10	23	1962
21	10	24	1963
22	10	25	1964
23	10	26	1965
24	10	27	1966
25	10	28	1967
26	10	29	1968
27	10	30	1969
28	10	31	1970
29	10	32	1971
30	10	33	1972
31	10	34	1973
32	10	35	1974
33	10	36	1975
34	10	37	1976
35	10	38	1977

Table L–27. Selected Times for Extracting the Base Case and Alternate Case Head and Velocity Data Files *(continued)*

Stress Period	Time Step	Model Year	Calendar Year
36	10	39	1978
37	10	40	1979
38	10	41	1980
39	10	42	1981
40	10	43	1982
41	10	44	1983
42	10	45	1984
43	10	46	1985
44	10	47	1986
45	10	48	1987
46	10	49	1988
47	10	50	1989
48	10	51	1990
49	10	52	1991
50	10	53	1992
51	10	54	1993
52	10	55	1994
53	10	56	1995
54	10	57	1996
55	10	58	1997
56	10	59	1998
57	10	60	1999
58	10	61	2000
59	10	62	2001
60	10	63	2002
61	10	64	2003
62	10	65	2004
63	10	66	2005
64	70	67	2006
64	90	67.9	2006.9
64	100	68.6	2007.6
64	110	69.5	2008.5
64	120	70.8	2009.8
64	130	72.5	2011.5
64	140	74.8	2013.8
64	150	77.9	2016.9
64	160	82	2021
65	230	83.2	2022.2
65	250	84.1	2023.1
65	270	85.8	2024.8
65	280	87.2	2026.2
65	290	88.9	2027.9
65	300	91.3	2030.3

Table L–27. Selected Times for Extracting the Base Case and Alternate Case Head and Velocity Data Files *(continued)*

Stress Period	Time Step	Model Year	Calendar Year
65	310	94.5	2033.5
65	320	98.8	2037.8
65	330	104.6	2043.6
65	340	112.4	2051.4
65	350	122.8	2061.8
65	360	136.9	2075.9
65	370	155.7	2094.7
65	380	181.1	2120.1
65	390	215.2	2154.2
65	400	261	2200

The Base Case and Alternate Case flow models have achieved a long-term steady state condition as of model year 140 (calendar year 2080). Four additional time steps after model year 140 (through model year 261, calendar year 2200) were extracted for use in groundwater transport modeling. Appendix O contains simulations of groundwater plumes for both the operational and post-operational timeframes to illustrate the effects of the uncertainty in predominant flow field direction on contaminant transport simulations.

L.12 SUMMARY

A three-dimensional transient flow model was developed to support the *TC & WM EIS* analyses of alternatives and cumulative impacts. The flow model was developed using the MODFLOW 2000 engine within the Visual MODFLOW framework. The site conceptual model consists of an unconfined, heterogeneous aquifer bounded at the bottom by an impermeable basalt surface. Water enters the model from mountain-front recharge along Rattlesnake Mountain, from the Yakima River, from areal recharge, and from operational discharges, primarily at the Central Plateau of Hanford. Water leaves the model via the Columbia River and several pumping wells. The operational discharges and pumping well withdrawals vary with time, providing the transient drivers to the model.

Standard data gathering and encoding techniques were used to develop the model extents, gridding, TOB topography, location and elevation of the Columbia and Yakima Rivers, lithology, and artificial discharges and withdrawals. These elements of the model were encoded directly from site-specific data. The background areal recharge was encoded using the *Technical Guidance Document* (DOE 2005). Initial estimates for GHB heads and conductances, riverbed conductances, and material properties were encoded and refined through a flow calibration process.

Initial calibration suggested that the model was extremely sensitive to GHB heads and conductances. These items were calibrated manually using water-level data for a selected subset of wells near the GHB locations. Initial calibration also suggested that the model was relatively insensitive to the riverbed conductances, as long as these values were reasonably high. Gradient-based PEST calibration was initially used to estimate the material properties (the primary model sensitivity was to hydraulic conductivity). The results from the gradient-based calibration suggested that this method seriously overestimated the confidence in the calibration parameters and that the topology of the objective function was characterized by many local minima.

For the purposes of this *TC & WM EIS*, an accurate estimate of the uncertainty in the model is an important objective. Accordingly, an effort was made to better estimate the span of parameter space that

provided acceptable agreement with historic field measurements of water-level data using Monte Carlo optimization. The parameter space was searched at random, with over 5,000 realizations of hydraulic conductivity values tested. The results of the Monte Carlo optimization were that the model is primarily sensitive to the values of hydraulic conductivity for five of the material types and that acceptable ranges for these hydraulic conductivities could be established.

At the start of the model development effort, it was anticipated that the model could be extremely sensitive to the TOB elevation in the Gable Gap area. The *Technical Guidance Document* (DOE 2005) directed that an Alternate Case should be developed to investigate this sensitivity. A geostatistical analysis of the available elevations of the unconfined aquifer/TOB contact was performed. The mean surface was used in the Base Case model, and the 95th percentile lower confidence limit surface was used in the Alternate Case model. Results showed that both the Base Case and Alternate Case models could yield reasonable agreement with measured water-level data during the operational period (1944–2006) and that long-term post-Hanford flow directions from the sources in the Core Zone were primarily to the east for the Base Case and primarily to the north for the Alternate Case.

Flow fields were extracted from both the Base and Alternate Cases for use with contaminant transport modeling for the long-term groundwater impacts analyses (see Appendix O). These flow fields contain magnitude and direction of the pore water velocity field throughout the active model domain. Finally, the Base Case model was used in conjunction with modeling results from the Bureau of Reclamation to estimate the effects of leakage from the proposed Black Rock Reservoir (see Appendix V), a reasonably foreseeable future condition.

L.13 REFERENCES

Byrnes, M.E., and M.S. Miller, 2006, *Remedial Investigation Report for 200- P-1 Groundwater Operable Unit*, DOE/RL-2006-24, Draft A, U.S. Department of Energy, Richland, Washington, April.

Cole, C.R., M.P. Bergeron, C.J. Murray, P.D. Thorne, S.K. Wurstner, and P.M. Rogers, 2001, *Uncertainty Analysis Framework – Hanford Site-Wide Groundwater Flow and Transport Model*, PNNL-13641, Pacific Northwest National Laboratory, Richland, Washington, November.

Connelly, M.P, B.H. Ford, and J.V. Borghese, 1992, *Hydrogeologic Model for the 200 West Groundwater Aggregate Area*, WHC-SD-EN-TI-014, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

DOE (U.S. Department of Energy), 1994, *Limited Field Investigation Report for the 100-HR-3 Operable Unit*, DOE/RL-93-43, Rev. 0, Richland, Washington, September.

DOE (U.S. Department of Energy), 2005, *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose one and Groundwater Revised Analyses*, Final Rev. 0, Office of River Protection, Richland, Washington, March 25.

Ecology, EPA, and DOE (Washington State Department of Ecology, Olympia, Washington; U.S. Environmental Protection Agency, Washington, D.C.; and U.S. Department of Energy, Richland, Washington), 1989, Hanford Federal Facility Agreement and Consent Order, 89-10, as amended, accessed through http://www.hanford.gov/tpa/tpahome.htm, May 15.

Fetter, C.W., 1988, *Applied Hydrogeology*, 2nd ed., Merrill Publishing Company, Columbus, Ohio.

Freeze, R.A., and J.A. Cherry, 1979, *Groundwater*, Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Fruchter, J.S., J.E. Amonette, C.R. Cole, Y.A. Gorby, M.D. Humphrey, J.D. Isok, F.A. Spane et al., 1996, *In Situ Redox Manipulation Field Injection Test Report – Hanford 100-H Area*, PNNL-11372, Pacific Northwest National Laboratory, Richland, Washington, December.

Hartman, M.J., L.F. Morasch, and W.D. Webber, eds., 2004, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*, PNNL-14548, Pacific Northwest National Laboratory, Richland, Washington, March.

Hill, M.C., 1990, *Preconditioned Conjugate-Gradient 2 (PCG2), A Computer Program for Solving Ground-Water Flow Equations*, Water-Resources Investigations Report 90-4048, U.S. Geological Survey, Denver, Colorado.

Johnston, K., J.M. Ver Hoef, K. Krivoruchko, and N. Lucas, eds., 2001, *Using ArcGIS Geostatistical Analyst*, Environmental Systems Research Institute, Inc., Redlands, California.

Khaleel, R., and E.J. Freeman, 1995, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*, WHC-EP-0883, Rev. 0, Westinghouse Hanford Company, Richland, Washington, October.

National Research Council, 1996, *The Hanford Tanks: Environmental Impacts and Policy Choices*, Committee on Remediation of Buried and Tank Wastes, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources, National Academy Press, Washington, D.C.

PNNL (Pacific Northwest National Laboratory), 2006, HydroDat_DataReq239.xls, HydroDat_ DataReq239_WithOrigDate.xls, qry_DataRequest239.txt, September.

Rohay, V.J., K.J. Swett, and G.V. Last, 1994, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site*, WHC-SD-EN-TI-248, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rohay, V. J., K.J. Swett, V.M. Johnson, G.V. Last, D.C. Lanigan, and L.A. Doremus, 1993, *FY93 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site*, WHC-SD-EN-TI-202, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

SAIC (Science Applications International Corporation), 2006, *Cumulative Impacts Analysis, Inventory Development*, Rev. 4, Germantown, Maryland, October 2.

Schalla, R., R.W. Wallace, R.L. Aaberg, S.P. Airhart, D.J. Bates, J.V.M. Carlile, C.S. Cline et al., 1988, *Interim Characterization Report for the 300 Area Process Trenches*, PNL-6716, Pacific Northwest Laboratory, Richland, Washington, September.

Spane, F.A., Jr., and P.D. Thorne, 2000, *Analysis of the Hydrologic Response Associated with Shutdown and Restart of the 200- P-1 Pump-and-Treat System*, PNNL-13342, Pacific Northwest National Laboratory, Richland, Washington, September.

Spane, F.A., Jr., P.D. Thorne, and D.R. Newcomer, 2001a, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*, PNNL-13378, Pacific Northwest National Laboratory, Richland, Washington, January.

Spane, F.A., Jr., P.D. Thorne, and D.R. Newcomer, 2001b, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*, PNNL-13514, Pacific Northwest National Laboratory, Richland, Washington, May.

Spane, F.A., Jr., P.D. Thorne, and D.R. Newcomer, 2002, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*, PNNL-14113, Pacific Northwest National Laboratory, Richland, Washington, November.

Spane, F.A., Jr., D.R. Newcomer, and P.D. Thorne, 2003, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*, PNNL-14186, Pacific Northwest National Laboratory, Richland, Washington, February.

Thorne, P.D., M.P. Bergeron, M.D. Williams, and V.L. Freeman, 2006, *Groundwater Data Package for Hanford Assessments*, PNNL-14753, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington, January.

USGS (U.S. Geological Survey), 2004, *MODFLOW 2000 Engine, Version 1.15.00*, August 6.

WHI (Waterloo Hydrogeologic, Inc.), 2005, *HydroGeo Analyst v. 3.0 User's Manual – Database Utilities*, Borehole Logging/Reporting, 2D Mapping and Cross Sections, and 3D Visualization, Waterloo, Ontario, Canada.

WHI (Waterloo Hydrogeologic, Inc.), 2006, *Visual MODFLOW v. 4.2 User's Manual: For Professional Applications in Three-Dimensional Groundwater Flow and Contaminant Transport Modeling*, Waterloo, Ontario, Canada.

Williams, M.D., V.R. Vermeul, J.E. Szecsody, and J.S. Fruchter, 2000, *100-D Area In Situ Redox Treatability Test for Chromate-Contaminated Groundwater*, PNNL-13349, Pacific Northwest National Laboratory, Richland, Washington, September.

Code of Federal Regulations

10 CFR 1021, U.S. Department of Energy, "National Environmental Policy Act Implementing Procedures."

40 CFR 1500–1508, Council on Environmental Quality, Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act.

40 CFR 1502.1, Council on Environmental Quality, "Environmental Impact Statement: Purpose."

40 CFR 1502.2(b), Council on Environmental Quality, "Environmental Impact Statement: Implementation."

Federal Register

62 FR 8693, U.S. Department of Energy, 1997, "Record of Decision for the *Tank Waste Remediation System, Hanford Site, Richland, WA*," February 26.

United States Code

42 U.S.C. 4321 et seq., National Environmental Policy Act of 1969.

APPENDIX M
RELEASE TO VADOSE ZONE

This appendix describes methods used to estimate release rates to the vadose zone, summarizes values of parameters used in the release models, summarizes results of application of the models, and presents a sensitivity analysis for particular cases.

M.1 INTRODUCTION

The assessment of human health impacts is an important element of analysis for this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*. Activities associated with alternatives under consideration for tank closure and waste management include the placement of waste containing radiological and chemical constituents in the vadose zone at the Hanford Site (Hanford). In addition, past practices resulting in spills, leaks, planned discharge, and the disposal of waste also placed such materials in the vadose zone. Major steps in assessing human health impacts are estimation of release rates to the vadose zone, rate of transport through the vadose zone, rate of transport through the unconfined aquifer, and magnitude of health impact at the point of exposure. This appendix describes methods used to estimate release rates to the vadose zone, summarizes values of parameters used in the release models, summarizes results of application of the models, and presents a sensitivity analysis for particular cases. Although best available data and models are used to develop the analysis described in this appendix, uncertainty in results remains. The uncertainty derives from variability in natural and engineered materials, such as soil and grout and lack of knowledge, such as applicability of specific models to site-specific locations or type of climate experienced in the future. The release models described in this appendix are applicable for sources defined within the *TC & WM EIS* alternatives and for sources associated with the cumulative analysis. Further detail on sources associated with cumulative analysis is presented in Appendix S.

M.2 DESCRIPTION OF RELEASE MODELS

A variety of sources with related release mechanisms needed to be analyzed for this *TC & WM EIS*. To provide a consistent approach and to ensure quality results, the stepwise procedure summarized in Table M–1 was applied for release model development. Releases to the vadose zone may be characterized according to the physical phase of the source and by the rate controlling mechanism of the release. For this *TC & WM EIS*, releases to the vadose zone are characterized as occurring from the liquid or solid phase sources. For solid sources, release may be controlled by liquid-solid phase partitioning, solubility, or diffusion mechanisms. For each release model, the variation in time of infiltration rate is represented as a series of pulses. The increase or decrease in the infiltration rate reflects the change in conditions, including the removal or recovery of vegetation and the placement and weathering of an engineered barrier. The form of the time dependence of the infiltration rate is presented in Figure M–1. The balance of this section describes release models for this set of sources and mechanisms.

Table M–1. Steps in Release Model Development

Step Number	Content
1	Identify sources and characterize physical processes
2	Develop conceptual model of the release process
3	Develop mathematical description of the release
4	Develop algorithm for solution of mathematical model
5	Develop computer code implementing equations and solution algorithm
6	Verify computer code, including documentation of concepts, equations, and algorithms and execution of test cases
7	Apply release model

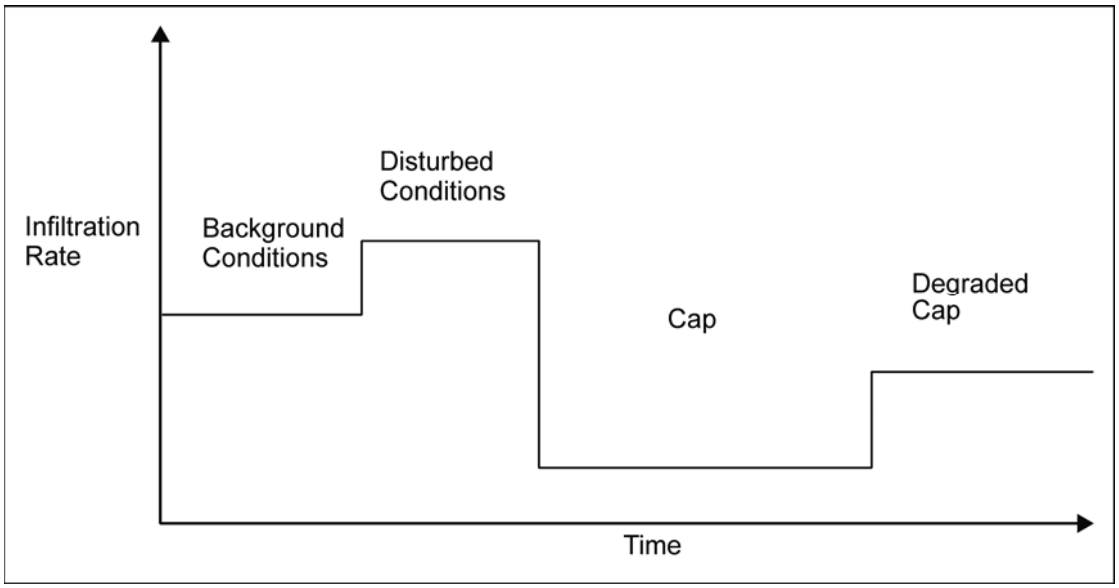


Figure M–1. Time Dependence of Infiltration Rate

M.2.1 Liquid Sources

The set of types of sources for liquid releases include planned discharges to near-surface facilities, unplanned releases to near-surface soil, past leaks from tanks, and retrieval leaks from tanks. For a given location, the release model is defined by the specification of the elevation, the area and aqueous volume of the source, the duration of the release, and inventories of constituents released during the specified time interval.

M.2.2 Solid Sources

Releases from solid sources are categorized according to the mechanism of release. Release mechanisms include partitioning from the solid to liquid phase with convective flow through the waste form, waste form dissolution with convective flow through or around the waste form, fractional release, partitioning from the solid to liquid phase with diffusive transport in the waste form, and constituent solubility limited release. The balance of this section describes details of release models for each mechanism.

M.2.2.1 Partitioning-Limited, Convective Flow Release Model

In the partitioning-limited, convective flow release model, the waste form of a given cross-sectional area with a constant thickness perpendicular to an infiltrating flow of water is located in the vadose zone. A schematic representation of the concept is presented in Figure M–2.

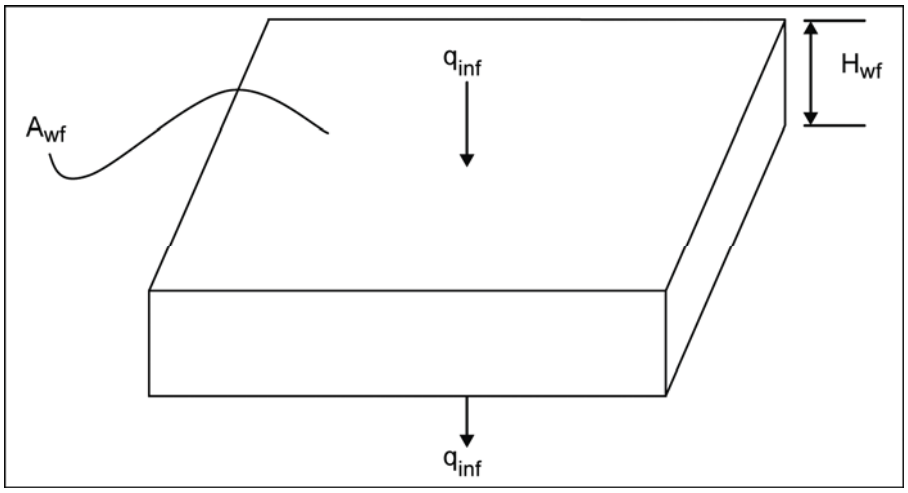


Figure M–2. Schematic of Release Concept for Partitioning-Limited, Convective Flow Release

A constituent bound to the solid is available for transfer to water moving through the waste form and the release rate is determined by the extent of partitioning between the solid and liquid phases within the waste form and the rate of movement of water through the waste form. Constituents are assumed free to move within the pore space of the waste form, producing a uniform concentration of the constituent throughout the waste form. A mass balance on a constituent within the waste form provides a relation between the liquid phase concentration and the initial mass of constituent and dimensions and properties of the waste form. The mass of the constituent within the waste form is contained within the liquid and solid phases:

$$AT = V_l C_l \quad V_s C_{s,v}$$

$$= \varepsilon V_t C_l \quad (1 - \varepsilon) V_t C_{s,v} \qquad \text{(M–1)}$$

where:

AT	=	total mass at a given time, grams
V_l	=	volume of liquid in the waste form, cubic meters
C_l	=	concentration of the constituent in the liquid phase, grams per cubic meter
V_s	=	volume of solid within the waste form, cubic meters
$C_{s,v}$	=	concentration of the constituent in the solid phase, grams per cubic meter
V_t	=	total volume of the waste form, cubic meters
ε	=	porosity of the waste form, unitless

The relationship between volumetric and mass concentration in the solid phase is:

$$C_{s,v} = \rho_s C_{s,m} \qquad \text{(M–2)}$$

where:

$C_{s,r}$	=	concentration of the constituent in the solid phase, grams per cubic meter
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
$C_{s,m}$	=	concentration of constituent in the solid phase, grams per gram

The relationship between concentration of the constituent in the liquid and solid phases is:

$$C_{s,m} = K_d\, C_l \qquad \text{(M–3)}$$

where:

- $C_{s,m}$ = concentration of the constituent in the solid phase, grams per gram
- K_d = distribution coefficient for the constituent in the waste form, milliliters per gram, and other variables as defined above
- C_l = concentration of the constituent in the liquid phase, grams per cubic meter

Substitution of the supporting relations into the mass relation allows calculation of liquid phase concentration for a given inventory:

$$C_l = AT / (\varepsilon\, V_t\, R_d) \qquad \text{(M–4)}$$

where:

- C_l = concentration of the constituent in the liquid phase, grams per cubic meter
- AT = total mass at a given time, grams
- ε = porosity of the waste form, unitless
- V_t = total volume of the waste form, cubic meters
- R_d = retardation factor for the constituent in the waste form, unitless

$$R_d = 1 \quad [(1 - \varepsilon)/\varepsilon]\, \rho_s\, K_d \qquad \text{(M–5)}$$

where:

- R_d = retardation factor for the constituent in the waste form, unitless
- ε = porosity of the waste form, unitless
- ρ_s = particle density of the solid in the waste form, grams per cubic centimeter
- K_d = distribution coefficient for the constituent in the waste form, milliliters per gram

A mass balance formed around the waste form during a time interval *j* reflects release by convection and decrease of mass within the waste form. The rate of flow of water through the waste form is equal to the rate of infiltration at the ground surface, which is represented as a series of pulses defined for a set of time intervals (see Figure M–1). The mass balance formed around the waste form is:

$$\partial\, AT/\partial t = -\, A_{wf}\, q_{\text{inf,j}}\, C_l$$

$$(1/AT)\, \partial\, AT/\partial t = -\, q_{\text{inf,j}} / (\varepsilon\, H_{wf}\, R_d)$$

$$= -\, f_j \qquad \text{(M–6)}$$

where:

- AT = total mass at a given time, grams
- A_{wf} = cross-sectional area of the waste form perpendicular to flow (square meters)
- $q_{\text{inf,j}}$ = rate of infiltration during time period *j* (meters per year)
- C_l = concentration of the constituent in the liquid phase, grams per cubic meter
- ε = porosity of the waste form, unitless
- H_{wf} = height of the waste form parallel to flow (meters)
- R_d = retardation factor for the constituent in the waste form, unitless

The total mass remaining in the waste form at any time in the time interval j, AT (grams), is:

$$AT = AT_{s,j} \exp [- f_j (t - t_{s,j})] \quad \text{(M–7)}$$

where:

$AT_{s,j}$ = mass in the waste form at the start of time interval j, grams
t = time, year
$t_{s,j}$ = time at the start of time interval j, years

The release rate of the constituent during time interval j, R_{wfj} (grams per year) is:

$$R_{wfj} = f_j AT_{s,j} \exp [- f_j (t - t_{s,j})] \quad \text{(M–8)}$$

where:

$AT_{s,j}$ = mass in the waste form at the start of time interval j, grams
t = time, years
$t_{s,j}$ = time at the start of time interval j, years

For small values of f_j or short intervals of time, the release rate can be calculated as the product of f_j and $AT_{s,j}$. The partitioning-limited, convective flow release model is applicable for contaminated soil sources and grout waste forms that have degraded over hundreds of years. Primary parameters of the model are rate of infiltration, dimensions of the waste form, and distribution coefficient of constituents.

M.2.2.2 Matrix Solubility Limited-Release Model

In the matrix solubility limited-release model, hazardous constituents are assumed to be uniformly distributed throughout a much larger mass of soluble material, such as salt cake. The matrix is porous and water flowing through the waste form dissolves the matrix and releases encapsulated constituents. The waste form is in the unsaturated zone with a downward flow as depicted in Figure M–2. The time variation of infiltration is represented as a series of step functions as shown in Figure M–1. A mass balance formed on the matrix is:

$$\partial M_{sc} / \partial t = - A_{wf} q_{inf,j} C_{s,sc} \quad \text{(M–9)}$$

where:

M_{sc} = mass of matrix, grams
t = time, years
A_{wf} = cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$ = rate of infiltration, meters per year
$C_{s,sc}$ = solubility of waste matrix, grams per cubic meter

The mass of waste matrix present at any time during a time period is:

$$M_{sc} = M_{sc,j} - [(A_{wf} q_{inf,j} C_{s,sc}) (t - t_{s,j})] \quad \text{(M–10)}$$

where:

M_{sc} = mass of waste matrix at time t, grams
$M_{sc,j}$ = mass of waste matrix at start of time period j, grams
A_{wf} = cross-sectional area of the waste matrix for flow, square meters
$q_{inf,j}$ = rate of infiltration, meters per year
$C_{s,sc}$ = solubility of waste matrix, grams per cubic meter
$t_{s,j}$ = time at start of time period j, years

During any interval, the rate of loss of waste matrix given by the second term on the right-hand side of Equation M–10 cannot exceed the amount of waste matrix present at the start of the time interval. When the waste matrix is completely removed by dissolution, the release is terminated. The release rate of hazardous constituent during time interval j equals the rate of dissolution of waste matrix multiplied by the concentration of the constituent in the matrix:

$$R_{wfj} = A_{wf}\, q_{\mathrm{inf},j}\, C_{s,sc} C_{i,m} \qquad \text{(M–11)}$$

where:

R_{wfj} = rate of release of constituent during time interval j, grams per year
A_{wf} = cross-sectional area of the waste matrix for flow, square meters
$q_{\mathrm{inf,j}}$ = rate of infiltration, meters per year
$C_{s,sc}$ = solubility of waste matrix, grams per cubic meter
$C_{i,m}$ = concentration of hazardous constituent i in the waste matrix, grams per gram

The primary application of the matrix solubility limited-release model is for releases from salt cake in high-level radioactive waste (HLW) tanks under Tank Closure Alternatives 1 and 2A and from steam reforming solids under Tank Closure Alternative 3C. Primary parameters of the model are rate of infiltration, mass of the waste matrix, solubility of the waste matrix, and concentration of hazardous constituents in the waste matrix.

M.2.2.3 Fractional Release Rate Model

In chemical reactions where reactants and products are present in excess or where complex chemical and physical processes produce a constant rate of degradation of the waste form, the release rate is linearly proportional to the amount of hazardous constituent remaining at the source. The physical configuration of the waste form is the same as that represented in Figure M–2. A mass balance on the hazardous constituent at the source is:

$$\partial M / \partial t = - f_{wf}\, M \qquad \text{(M–12)}$$

where:

M = mass of hazardous constituent at the source, grams
f_{wf} = fractional rate of degradation of the waste form, grams per gram per year
t = time, years

The amount of hazardous constituent present at the source at any time is:

$$M = M_j - [f_{wf}\, M_j\, (t - t_j)] \qquad \text{(M–13)}$$

where:

M = mass of hazardous constituent at the source, grams
M_j = mass of hazardous constituent present at the source at the beginning of the time period j, grams
f_{wf} = fractional rate of degradation of the waste form, grams per gram per year
t = time, years
t_j = time at start of time period j, years

The release rate of the constituent from the waste form at any time is:

$$R_{wf} = f_{wf} M_j (t - t_j) \quad \text{(M–14)}$$

where:

R_{wf} = rate of release of the constituent from the waste form, grams per year
f_{wf} = fractional rate of degradation of the waste form, grams per gram per year
M_j = mass of hazardous constituent present at the source at the beginning of the time period j, grams
t = time, years
t_j = time at start of time period j, years

The fractional release rate model is applicable for Waste Treatment Plant (WTP) immobilized low-activity waste (ILAW) glass, bulk vitrification glass, and glass in retired melters. Primary parameters of the model are the fractional release rate constant and the initial inventory of hazardous constituents.

M.2.2.4 Diffusion Limited-Release Models

If a waste form were to have a value of hydraulic conductivity much lower than that of the surrounding material, convective flow would be diverted around the waste form. In this case, diffusive transport of the hazardous constituent within the waste form constitutes the primary mechanism for constituent release to the environment. The boundary condition specified for the concentration of the constituent outside the waste form plays a role in determining the release rate. In a conservative approach to specification of this boundary condition, the convective flow outside the waste form is assumed to maintain the concentration of the constituent at a low value at the outside boundary of the form. This maximizes the release rate of the constituent diffusing out of the waste form. In a less conservative approach to specification of this boundary condition, the rate of convective flow may be used to establish the concentration of the constituent at the boundary of the waste form. Also, the waste form may degrade over time, allowing convective flow through the form and a transition from the release controlled by diffusion to the release controlled by convection. In each case, transport by diffusion or convection occurs only in the liquid-filled pore space of the waste form, and partitioning of constituents between the solid and liquid phases is included in the release model. The geometry of the waste form is a factor in determining transport distances and the area available for release. For this *TC & WM EIS*, diffusion-controlled release models have been developed for rectangular and cylindrical geometries. For both geometries, the rate of transport by diffusion is conservatively represented by a shrinking core model to simplify the mathematical form of the model.

A source with rectangular symmetry is shown in Figure M–3.

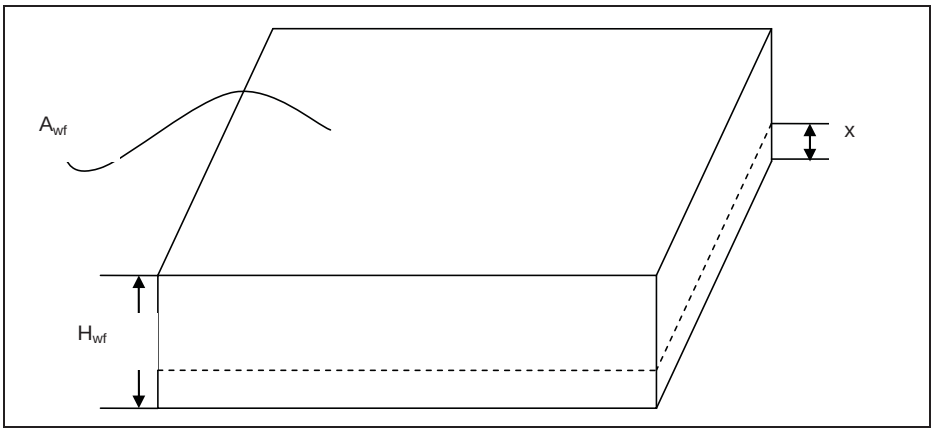


Figure M–3. Schematic of Rectangular Waste Form with Diffusion Release from Lower Surface

Resistance to mass transfer is assumed to reside in a layer, with thickness designated as x in Figure M–3, that exists between the shrinking core and the environment. The concentration of the constituent outside the waste form is assumed to be negligible. A mass balance on the diffusing constituent formed in the waste form is:

$$-\varepsilon A_{wf} T D_w (C_l / x) = A_{wf} R_d C_l \partial (H_{wf} - x) / \partial t \quad \text{(M–15)}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon] \rho_s K_d \quad \text{(M–16)}$$

where:

ε	=	porosity of the waste form, unitless
A_{wf}	=	diffusion release area of the waste form, square meters
T	=	tortuosity of the waste form, unitless
D_w	=	diffusivity of the constituent in water, square meters per year
C_l	=	concentration of the constituent in the liquid in the core portion of the waste form, grams per cubic meter
x	=	thickness of transport layer, meters
R_d	=	retardation factor for the constituent in the waste form, unitless
ρ_s	=	particle density of the solid in the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent in the waste form, unitless
H_{wf}	=	thickness of waste form, meters
t	=	time, years

Assuming that the concentration of the diffusing constituent is maintained at a low level outside of the waste form, the cumulative release of the constituent from the form, $R_{wf\text{cum}}$ (grams), calculated from the mass balance is:

$$R_{wf\text{cum}} = [AT_0/(H_{wf} - x_0)] \sqrt{\{ [(2 T D_w)/ R_d] t \quad x_0^2 \}} -$$

$$[AT_0/(H_{wf} - x_0)] (x_0) \quad \text{(M–17)}$$

where:

AT_o = initial inventory of the constituent, grams
H_{wf} = thickness of waste form, meters
x_0 = initial thickness of the waste form layer outside the core, meters
T = tortuosity of the waste form, unitless
D_w = diffusivity of the constituent in water, square meters per year
R_d = retardation factor for the constituent in the waste form, unitless
t = time, years

This rectangular geometry model assumes that the release occurs from only the lower surface of the waste form.

If the release occurs from both the upper and lower surfaces, the waste form is represented as shown in the volume of Figure M–4. Using the same approach as for a release from a single surface, the cumulative release of the constituent from both surfaces is calculated as:

$$R_{wf\text{cum}} = [2\ AT_0/(H_{wf}/2 - x_0)]\ \sqrt{\{\ [(2\ T\ D_w\ )/\ R_d\ ]\ t \quad x_0^{\,2}\ \}} - [2\ AT_0/(H_{wf}/2 - x_0)]\ (\ x_0\ ) \qquad \text{(M–18)}$$

where:

$R_{wf\text{cum}}$ = cumulative release of the constituent from the waste form, grams
AT_o = initial inventory of the constituent, grams
H_{wf} = thickness of waste form, meters
x_0 = initial thickness of the waste form layer outside the core, meters
T = tortuosity of the waste form, unitless
D_w = diffusivity of the constituent in water, square meters per year
R_d = retardation factor for the constituent in the waste form, unitless
t = time, years

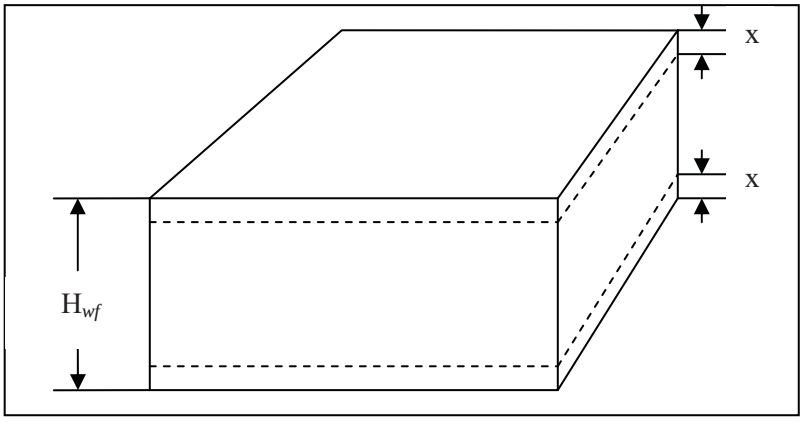


Figure M–4. Schematic of Rectangular Waste Form with Diffusion Release from Upper and Lower Surfaces

A source with cylindrical symmetry is shown in Figure M–5.

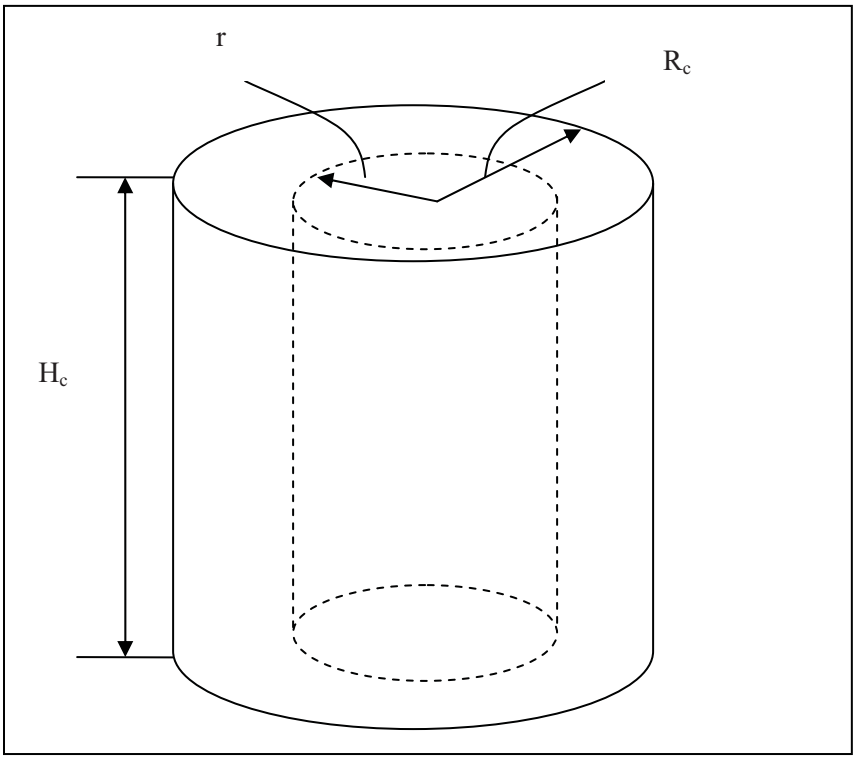


Figure M–5. Schematic of a Cylindrical Diffusion Release Model

Resistance to mass transfer is assumed to reside in an annular layer with thickness $R_c - r$ (see Figure M–5) that separates the core portion of the cylinder from the environment. Waste forms are assumed to be placed in a rectangular array, and infiltrating water flows downward through the space between waste packages. The constituent is released from the waste form by diffusion into the space between waste packages and then flows downward with the convective flow of infiltrating water. A mass balance formed on the diffusing constituent in the waste form is:

$$(\varepsilon \pi H_c) R_d C_l \partial r^2 / \partial t = -R_{wf} \quad \text{(M–19)}$$

$$R_{wf} = (\varepsilon 2 \pi r H_c) T D_w [(C_l - C_{vz})/(R_c - r)] \quad \text{(M–20)}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon] \rho_s K_d \quad \text{(M–21)}$$

where:

ε	=	porosity of the waste form, unitless
H_c	=	height of the cylindrical waste form, meters
R_d	=	retardation factor (see Equation M–5) for the constituent in the waste form, unitless
C_l	=	concentration of the constituent in the pore space of the waste form, grams per cubic meter
r	=	radius of the shrinking core, meters
t	=	time, years
R_{wf}	=	rate of release of the constituent from the waste form, grams per year
T	=	tortuosity of the waste form, unitless
D_w	=	diffusion coefficient of the constituent in water, square meters per year
C_{vz}	=	concentration of the constituent in the vadose zone between the waste packages, grams per cubic meter
R_c	=	radius of the cylinder, meters

ρ_s = particle density of the solid in the waste form, grams per cubic centimeter
K_d = distribution coefficient for the constituent and waste form, milliliters per gram

If the concentration of the diffusing constituent is maintained at a low level outside of the waste form ($C_{vz} = 0$), the cumulative release of the constituent from the form calculated using the mass balance is:

$$R_{wfcum} = (2\,[R_c / r_0^2]\,AT_0\,) \surd \{[(2\,T\,D_w\,)/\,R_d\,]\,t + (R_c - r_0)^2\,\} - [\,R_c - r_0\,]) - ([\,AT_0 / r_0^2\,]\,[(2\,T\,D_w\,)/\,R_d\,]\,t\,) \quad \text{(M–22)}$$

where:

R_{wfcum} = cumulative release of the constituent from the waste form, grams
R_c = radius of the cylinder, meters
r_0 = initial radius of the core of the waste form, meters
AT_0 = initial inventory of the constituent in the waste form, grams
T = tortuosity of the waste form, unitless
D_w = diffusion coefficient of the constituent in water, square meters per year
R_d = retardation factor (see Equation M–5) for the constituent in the waste form, unitless
t = time, years

If the concentration of the constituent in the vadose zone between waste forms is not maintained at a low level, the solution procedure is extended to include a mass balance formed on the constituent in the volume of soil and water in the space between waste packages. This additional mass balance is expressed as:

$$(A_f - A_{wf}\,)\,H_{wf}\,\theta_{vz}\,R_{d,vz}\,\partial\,C_{vz} / \partial t = R_{wf} - Rvz \quad \text{(M–23)}$$

$$Rvz = A_f\,q_{\text{inf,j}}\,C_{vz} \quad \text{(M–24)}$$

$$R_{d,vz} = 1 + [\,(1 - \varepsilon_{vz})/\,\theta_{vz}\,]\,\rho_s\,K_{d,vz} \quad \text{(M–25)}$$

where:

A_f = area in horizontal plane for infiltration of water, square meters
A_{wf} = area in horizontal plane intersected by stacks of waste packages, square meters
H_{wf} = height of a stack of waste packages, meters
θ_{vz} = moisture content of the vadose between the waste packages, unitless
$R_{d,vz}$ = retardation factor for the constituent in the vadose zone between waste packages, unitless
C_{vz} = concentration of the constituent in the water in the vadose zone between the waste packages, grams per cubic meter
t = time, years
R_{wf} = rate of release of the constituent from the waste form, grams per year
Rvz = rate of release of the constituent from the vadose zone between the waste packages to the vadose zone below the waste packages, grams per year
$q_{\text{inf,j}}$ = rate of infiltration during time interval j, meters per year
ε_{vz} = porosity of the vadose zone between the waste packages, unitless
ρ_s = particle density of the solid in the waste form, grams per cubic centimeter
$K_{d,vz}$ = distribution coefficient for the constituent in the vadose zone between the waste packages, milliliters per gram

Mass balances of Equations M–19 and M–23 are solved simultaneously for the concentration of the constituent in the vadose zone between waste packages (C_{vz}) and the release rates to the vadose zone below waste packages (*Rvz*).

For both the rectangular and cylindrical versions, transition to a convective flow, partition-limited release can be specified to occur after the specified design life of the waste form. Following this specified time, the release rate is calculated using Equation M–8.

Diffusion-controlled release models are applicable for grout or cement waste forms, such as grouted HLW tanks or cast stone. Primary parameters of the model are dimensions and tortuosity of the waste form, and the diffusion coefficient, distribution coefficient, and initial inventory for the constituent.

M.2.2.5 Constituent Solubility Limited-Release Model

In the constituent solubility limited-release model, a waste form of rectangular or cylindrical horizontal cross-section and uniform height is assumed to be in the vadose zone. A schematic representation is the same as that presented in Figure M–2. If the equilibrium solubility of the constituent is low, precipitation of the constituent within the waste form may occur. In addition, the constituent may partition between the liquid and solid phases of the waste form. Water moves through the waste form at the local rate of infiltration and may transport a liquid constituent in the waste form's pore space out of the form. The initial step is calculating the maximum concentration of the constituent in the pore space using the mass balance approach of Equation M–4:

$$C_l = AT_0 / (\varepsilon\, V_{wf}\, R_d) \tag{M–26}$$

$$R_d = 1 + [(1 - \varepsilon)/\varepsilon]\, \rho_s\, K_d \tag{M–27}$$

where:

C_l	=	maximum concentration of the constituent in the aqueous phase of the waste form, grams per cubic meter
AT_0	=	initial inventory of the constituent in the waste form, grams
ε	=	porosity of the waste form, unitless
V_{wf}	=	volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless
ρ_s	=	particle density of the waste form, grams per cubic centimeter
K_d	=	distribution coefficient for the constituent and waste form, milliliters per gram

If the concentration calculated using Equation M–26 is greater than the equilibrium solubility for the constituent, precipitation of the constituent is assumed to occur. The release rate of the constituent is estimated as:

$$R_{wf} = q_{\text{inf,j}}\, C_s \tag{M–28}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
$q_{\text{inf,j}}$	=	rate of infiltration during infiltration period *j*, meters per year
C_s	=	solubility of the constituent in groundwater, grams per cubic meter

When the mass of precipitate in the waste form is fully dissolved, the liquid phase concentration will decrease below the solubility limit. The release rate will be controlled by liquid-solid partitioning as described by Equations M–6 and M–8:

$$R_{wf} = (q_{\text{inf,j}} / [\varepsilon H_{wf} R_d)]) AT_j \quad \text{(M–29)}$$

where:

$$AT_j = (\varepsilon V_{wf} R_d) C_l \quad \text{(M–30)}$$

where:

R_{wf}	=	rate of release of the constituent from the waste form, grams per year
$q_{\text{inf,j}}$	=	rate of infiltration during infiltration period *j*, meters per year
ε	=	porosity of the waste form, unitless
V_{wf}	=	volume of the waste form, cubic meters
R_d	=	retardation factor for the constituent in the waste form, unitless
AT_j	=	mass of the constituent present at the termination of the solubility-controlled release, grams
C_l	=	maximum concentration of the constituent in the aqueous phase of the waste form, grams per cubic meter

The constituent limited solubility model could be applied for locations where large quantities of material with low solubility were discharged to the soil or to waste forms with local chemical environments favoring precipitation.

M.3 TECHNICAL BASIS AND VALUES OF RELEASE MODEL PARAMETERS

Factors affecting release rates of constituents to the vadose zone include environmental factors, such as rate of infiltration, and factors specific to the nature of the source and the disposal system. Values of rate of infiltration adopted for use in this *TC & WM EIS* are those recommended in the *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose one and Groundwater Revised Analyses (Technical Guidance Document)* (DOE 2005). *Technical Guidance Document* values recommended for base case analysis are summarized in Table M–2. Post–design life conditions in Table M–2 correspond to the period of time labeled as "Degraded Cap" in Figure M–1.

Values of parameters related to specific actions and types of sources are summarized in the following sections for the Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives. Tank Closure alternatives evaluate impacts occurring in the long-term period following stabilization or closure of the HLW tanks. Under Waste Management Alternative 2, waste disposal would occur in an Integrated Disposal Facility (IDF) in the 200-East Area, (IDF-East) and facilities in 200-East and 200-West Areas under Waste Management Alternative 3.

Table M–2. Rates of Infiltration for *TC & WM EIS* Base Case Analysis

Location	Rate of Infiltration (millimeters per year)
Pre-Hanford background	
IDF	0.9
Balance of site	3.5
Disturbed conditions	
Gravel (HLW tanks)	100
Sand (cribs and trenches [ditches])	50
IDF barrier	
Design life	0.5
Post–design life	0.9
Sitewide barrier	
Design life	0.5
Post–design life	3.5

Key: HLW=high-level radioactive waste; IDF=Integrated Disposal Facility; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

M.3.1 Tank Closure Alternatives

Types of sources considered for Tank Closure alternatives include past leaks, retrieval leaks, tank residuals, and ancillary equipment at 18 tank farms and planned discharges at six sets of cribs and trenches (ditches) associated with tank farm operations. These facilities are all in the 200-East and 200-West Areas.

M.3.1.1 Tank Farm Sources

Liquid and solid sources are considered for release analysis at the 18 HLW tank farms. Descriptions of the dimensions, configuration and closure systems for tank farms are presented in the *Tank System Closure and Facility D&D* [decontamination and decommissioning] *Data Package* (DOE 2003a).

Primary liquid sources are past leaks and retrieval leaks from 100- and 200-series tanks located at single-shell tank farms for all Tank Closure alternatives and ancillary equipment failure leaks at all tank farms and tank failure leaks at double-shell tank farms for Tank Closure Alternatives 1 and 2A for which tank closure does not occur.

For past leaks, 67 tanks are included in the analysis, and model parameters include volume of liquid, inventory of constituents, and time of occurrence of the leak. Volumes of liquid assumed for the purpose of analysis are those presented in the Hanlon waste tank summary report (Hanlon 2003). If a volume estimate is missing from the Hanlon report for a specific tank, an estimate of the smallest detectable leak volume of 30 cubic meters (8,000 gallons) is assumed for that tank. Inventory estimates for past leaks are developed from field investigation reports (FIRs) for tank farms B, BX, and BY (Knepp 2002); S and SX (CH2M HILL 2002); and T, TX, and TY (Myers 2005). Subsurface conditions reports are used for estimates of inventory for tank farms A, AX, and C (Wood et al. 2003) and U (Wood and Jones 2003). If an inventory estimate for a specific tank included in the Hanlon list is not presented in an FIR or subsurface conditions report, the inventory for that tank is estimated using the average concentration for leaks from that tank farm presented in the FIR or subsurface conditions report and the leak volume from the Hanlon report. Estimates of volume of leak and date of occurrence for the 67 tanks are presented in Table M–3. Estimates of date of occurrence are adopted from the FIRs, subsurface conditions reports,

and preliminary field studies (Jones et al. 2000, 2001). Estimates of quantities of constituents released with past leaks are presented in Appendix D of this environmental impact statement (EIS).

Table M–3. Summary of Estimates of Volumes and Dates for Past Leaks

Tank	Leak Volume (gallons)[a]	Date of Occurrence	Tank	Leak Volume (gallons)	Date of Occurrence
241-A-103	5,500	1956[b]	241-SX-104	6,000	1954[b]
241-A-104	2,500	1975[c]	241-SX-107	5,000	1964[f]
241-A-105	277,000	1963[c]	241-SX-108	35,000	1965[f]
241-AX-102	3,000	1965[b]	241-SX-109	10,000	1964[f]
241-AX-104	8,000	1965[b]	241-SX-110	5,500	1974[f]
241-B-101	8,000	1974[d]	241-SX-111	2,000	1973[f]
241-B-103	8,000	1945[b]	241-SX-112	30,000	1969[f]
241-B-105	8,000	1968[d]	241-SX-113	15,000	1962[f]
241-B-107	8,000	1966[d]	241-SX-114	8,000	1972[f]
241-B-110	10,000	1970[d]	241-SX-115	50,000	1964[f]
241-B-111	8,000	1945[b]	241-T-101	7,500	1969[g]
241-B-112	2,000	1945[b]	241-T-103	1,000	1973[g]
241-B-201	1,200	1966[c]	241-T-106	115,000	1973[g]
241-B-203	300	1966[c]	241-T-107	8,000	1944[b]
241-B-204	400	1966[c]	241-T-108	1,000	1944[b]
241-BX-101	8,000	1968[e]	241-T-109	1,000	1944[b]
241-BX-102	70,000	1951[e]	241-T-111	1,000	1944[b]
241-BX-108	2,500	1948[b]	241-TX-105	8,000	1949[b]
241-BX-110	8,000	1948[b]	241-TX-107	2,500	1977[g]
241-BX-111	8,000	1965[d]	241-TX-110	8,000	1949[b]
241-BY-103	5,000	1950[b]	241-TX-113	8,000	1949[b]
241-BY-105	8,000	1950[b]	241-TX-114	8,000	1949[b]
241-BY-106	8,000	1950[b]	241-TX-115	8,000	1949[b]
241-BY-107	15,100	1950[b]	241-TX-116	8,000	1949[b]
241-BY-108	5,000	1950[b]	241-TX-117	8,000	1949[b]
241-C-101	20,000	1946[b]	241-TY-101	1,000	1953[b]
241-C-110	2,000	1946[b]	241-TY-103	3,000	1971[g]
241-C-111	5,500	1946[b]	241-TY-104	1,400	1953[b]
241-C-201	550	1946[b]	241-TY-105	35,000	1960[g]
241-C-202	450	1946[b]	241-TY-106	20,000	1957[g]
241-C-203	400	1946[b]	241-U-101	30,000	1946[b]
241-C-204	350	1946[b]	241-U-104	55,000	1956[h]
241-S-104	24,000	1965[f]	241-U-110	8,100	1975[h]
			241-U-112	8,500	1946[b]

[a] Hanlon 2003.
[b] Anderson 1990.
[c] Wood et al. 2003.
[d] Jones et al. 2001.
[e] Knepp 2002.
[f] CH2M HILL 2002.
[g] Jones et al. 2000.
[h] Wood and Jones 2003.

U.S. Department of Energy (DOE) estimates that a volume of 15 cubic meters (4,000 gallons) would leak from each of the 149 single-shell tanks during waste retrieval (see Section E.1.2.2.5.2). For each tank farm, the retrieval leaks are assumed to occur simultaneously in calendar year 2018. Estimates of the inventory of constituents for retrieval leaks are developed by assuming that three volumes of sluicing liquid are required to entrain one volume of tank solids and that the solids have the composition of the

December 2002 estimate of the Best-Basis Inventory (BBI). The BBI is documented in the *Inventory and Source Term Data Package* (DOE 2003b). Estimates of quantities of constituents released in retrieval leaks are presented in Appendix D of this EIS.

Primary solid sources at tank farms are salt cake remaining in single-shell tanks under Tank Closure Alternatives 1 and 2A and grouted residuals in tanks and ancillary equipment under Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C.

For releases from salt cake, the release model proposed is the matrix solubility limited-release model described in Section M.2.2.2. The proposed value of solubility for the matrix is a literature estimate of the solubility of sodium nitrate: 920,000 grams per cubic meter (Weast and Selby 1967). The mass and volume of waste in each tank farm and inventory of constituents are those documented in the *Inventory and Source Term Data Package* (DOE 2003b). For Tank Closure Alternative 1, the residual inventory remaining in each tank at the time of failure (time of loss of administrative or institutional control) is the total inventory of the BBI. For Tank Closure Alternative 2A, the inventory remaining in each tank at the time of failure is 1 percent of the BBI. The magnitude and timing of infiltration for Tank Closure Alternatives 1 and 2A are summarized in Table M–4.

Table M–4. Tank Closure Alternatives 1 and 2A Infiltration Sequence Description

Location Conditions	Tank Closure Alternative 1	Tank Closure Alternative 2A	Infiltration Value (millimeters per year)
	Year at Start of Infiltration Value		
Pre-Hanford	1940	1940	3.5
Disturbed conditions	1948	1948	100
Post–barrier design life	2108	2194	3.5

For releases from grouted residuals in HLW tanks and ancillary equipment, the proposed release model is the partition-limited, convective flow release model described in Section M.2.2.1. The inventory is assumed to reside in the bottom meter of the tank with a short diffusion distance in the downward vertical direction and a large diffusion distance in the upward vertical direction. Dimensions of the tank are those described in the *Tank System Closure and Facility D&D Data Package* (DOE 2003a), and the constituent inventories are fractions of the BBI appropriate for each alternative with the BBI specified in the *Inventory and Source Term Data Package* (DOE 2003b).

Primary remaining parameters of the model are the rate of recharge and the retardation factor defined in conjunction with Equation M–5. The magnitude and timing of the sequence of infiltration for Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C are summarized in Table M–5. For Alternatives 2B, 3A, 3B, 3C, 4, and 6C, modified Resource Conservation and Recovery Act (RCRA) Subtitle C barriers with a design life of 500 years would be placed over the tank farms. Hanford barriers with a design life of 1,000 years would be placed over the tank farms for Tank Closure Alternative 5. Values of distribution coefficient used in the calculation of retardation factor are presented in Tables M–6 (radiological constituents) and M–7 (chemical constituents) and are those recommended for grout (DOE 2005) or reported in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990).

Table M–5. Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C Infiltration Sequence Description

Location Conditions	Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, and 6C	Tank Closure Alternative 5	Infiltration Value (millimeters per year)
	Year at Start of Infiltration Value		
Pre-Hanford	1940	1940	3.5
Disturbed conditions	1948	1948	100
Barrier design life	2050	2050	0.5
Post–barrier design life	2550	3050	3.5

Table M–6. Values of Distribution Coefficient for Radiological Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	5	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	15	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	1	DOE 2005
Iodine	50	DOE 2005
Cesium	280	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	35	DOE 2005
Neptunium	15	DOE 2005
Plutonium	550	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–7. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	4×10^{2}	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	8×10^{1}	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	8×10^{1}	DOE 2005
Manganese	5×10^{1}	Beyeler et al. 1999
Mercury	1×10^{1}	DOE 2005
Molybdenum	1×10^{1}	Beyeler et al. 1999
Nickel	4×10^{2}	Beyeler et al. 1999
Nitrate	0	DOE 2005
Silver	9×10^{1}	Beyeler et al. 1999
Strontium	1×10^{1}	Sheppard and Thibault 1990
Total uranium	6×10^{-1}	Sheppard and Thibault 1990
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenols	1.7×10^{5}	DOE 2005
2,4,6-Trichlorophenol	3.8×10^{-1}	DOE 2005

Table M–7. Values of Distribution Coefficient for Chemical Constituents in Hanford Grout *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.2 Tank Closure Waste Forms

Primary waste forms associated with tank farm closure are: ILAW glass, bulk vitrification glass, bulk vitrification castable refractory block, cast stone, steam reforming solids, Effluent Treatment Facility (ETF) secondary grout, sulfate grout, retired melters, and contaminated soil. A primary constituent of ETF secondary waste is iodine-129 recovered from offgases of thermal treatment processes (vitrification, bulk vitrification, and steam reforming).

For ILAW glass and glass in retired melters, the fractional release rate model is applied. The value of the fractional release rate is 2.8×10^{-8} (gram per gram) per year based on detailed analysis using the STORM [Subsurface Transport Over Reactive Multiphases] model (Mann et al. 2003). For bulk vitrification glass, the fractional release rate model is applied. The value of the fractional release rate is 1.0×10^{-8} (gram per gram) per year based on detailed analysis using the STORM model (Mann et al. 2003). During the bulk vitrification process, a portion of the feed technetium is volatilized and trapped in refractory above the glass surface. For this material, the partition-limited, convective flow release model with value of zero for distribution coefficient of technetium is applied. The refractory is porous ceramic material and research has demonstrated that technetium volatilized during bulk vitrification collects in this material (Mann et al. 2003). The fraction of technetium present in the original melt that resides in the castable refractory block has been measured and an upper limit of 6.5 percent has been established (peer review). For cast stone and ETF secondary and sulfate grout waste forms, the cylindrical geometry, diffusion limited-release model described in Section M.2.2.4 is applied. Values of aqueous diffusivity are based on ion conductivity data (Weast and Selby 1966:5-111) with values for key species iodate, pertechnetate, and nitrate of 1.1×10^{-5}, 1.5×10^{-5}, and 1.9×10^{-5} square centimeters per second, respectively. The porosity of grout is estimated as 0.43 based on a crystal density of 2.65 grams per cubic centimeter for natural silicates (Freeze and Cherry 1979:337; Mason and Berry 1968) and bulk density of grout of 1.5 grams per cubic centimeter (DOE 2003c:6-100). Because the value of effective porosity has not been established for site conditions, the value of total porosity is applied for effective porosity as a conservative limit of release rates. Site-specific tests of effective diffusivity of nitrate in grout are reported as 3×10^{-8} square centimeters per second (Lockrem 2005). Effective diffusivity is defined as the product of tortuosity and aqueous diffusivity divided by the retardation factor. Assuming that nitrate does not adsorb onto the grout, these data imply a site-specific value of tortuosity of 1.6×10^{-3}. Using the definition of effective diffusivity and *Technical Guidance Document*–recommended values of effective diffusivity (DOE 2005) implied values of the distribution coefficient for technetium and iodine in grout are 1 and 50 milliliters per gram, respectively. Values of aqueous diffusivity and effective diffusivity for grout consistent with the *Technical Guidance Document* (DOE 2005) are summarized in Tables M–8 and M–9 for radiological and chemical constituents, respectively. The experimental program for characterization of steam reforming solids has established operability of the solidification process (THOR Treatment Technologies 2002) and characterization of release mechanisms and rates (Lorier, Pareizs, and Jantzen 2005; McGrail et al. 2003a, 2003b) is under way but has not yielded a complete basis for long-term performance assessment. In addition, alternate forms of the final product are under investigation (Jantzen

2006). For the purpose of long-term performance assessment for this *TC & WM EIS*, steam reforming solids are assumed to have the form of a finely divided solid. In light of the above considerations, an upper limit on the rate of release of constituents from steam reforming solids was developed based on the limited availability of water and the stoichiometry of hydrolysis of steam reforming solids. Research has identified nepheline (Na_2AlSiO_4) as the primary component of steam reforming solids (McGrail et al. 2003a). For a hydrolysis reaction requiring two moles of water for each mole of nepheline and water infiltration rates of 0.5 and 0.9 millimeters per year for the cap design period of 500 years and post-design periods, complete dissolution of finely divided steam reforming solids would occur within 1890 years. This corresponds to an equivalent solubility of 3.95×10^6 grams per cubic meter for use on the waste matrix solubility limited release model. For contaminated soil disposed of at the River Protection Project Disposal Facility (RPPDF), the partition-limited, convective flow model is applied. Values of distribution factor for soil are those recommended in the *Technical Guidance Document* (DOE 2005) for Hanford vadose zone sediments or in nationwide surveys of soil (Beyeler et al. 1999; Sheppard and Thibault 1990). These values are summarized in Tables M–10 and M–11 for radiological and chemical constituents, respectively.

Table M–8. Values of Aqueous and Effective Diffusivity for Radiological Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Hydrogen	9.3×10^{-5}	1.5×10^{-7}
Carbon	9.2×10^{-6}	7.9×10^{-10}
Potassium	2.0×10^{-5}	5.8×10^{-10}
Strontium	7.9×10^{-6}	2.3×10^{-10}
Zirconium	2.0×10^{-5}	1.5×10^{-11}
Technetium	1.5×10^{-5}	5.2×10^{-9}
Iodine	1.1×10^{-5}	1.0×10^{-10}
Cesium	2.1×10^{-5}	3.3×10^{-11}
Gadolinium	6.0×10^{-6}	5.1×10^{-10}
Thorium	4.3×10^{-6}	6.0×10^{-13}
Uranium	4.3×10^{-6}	5.5×10^{-11}
Neptunium	4.3×10^{-6}	1.3×10^{-10}
Plutonium	4.3×10^{-6}	3.5×10^{-12}
Americium	4.3×10^{-6}	1.0×10^{-12}

Table M–9. Values of Aqueous and Effective Diffusivity for Chemical Constituents in Hanford Grout

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Arsenic	9.05×10^{-6}	1.03×10^{-11}
Boron	1.25×10^{-5}	2.00×10^{-8}
Cadmium	7.19×10^{-6}	4.08×10^{-11}
Chromium	1.13×10^{-5}	1.81×10^{-8}
Fluoride	1.48×10^{-5}	2.36×10^{-8}
Lead	9.45×10^{-6}	5.36×10^{-11}
Manganese	7.12×10^{-6}	6.45×10^{-11}
Mercury	8.47×10^{-6}	3.75×10^{-10}
Molybdenum	1.98×10^{-5}	8.79×10^{-10}
Nickel	6.66×10^{-7}	7.58×10^{-13}
Nitrate	1.90×10^{-5}	3.04×10^{-8}
Silver	1.65×10^{-5}	8.32×10^{-11}
Strontium	7.91×10^{-6}	3.50×10^{-10}
Total uranium	4.26×10^{-6}	2.19×10^{-9}

Table M–9. Values of Aqueous and Effective Diffusivity for Chemical Constituents in Hanford Grout *(continued)*

Constituent	Aqueous Diffusivity (square centimeters per second)	Effective Diffusivity (square centimeters per second)
Acetonitrile	8.77×10^{-7}	1.40×10^{-9}
Benzene	6.38×10^{-6}	2.26×10^{-9}
Butanol	6.26×10^{-6}	8.69×10^{-10}
Polychlorinated biphenols	3.71×10^{-6}	9.93×10^{-15}
2,4,6-Trichlorophenol	5.00×10^{-6}	3.43×10^{-9}
1,2-Dichloroethane	6.84×10^{-6}	1.09×10^{-8}
1,4-Dioxane	6.54×10^{-6}	1.05×10^{-8}
Carbon tetrachloride	6.06×10^{-6}	9.70×10^{-9}
Dichloromethane	7.75×10^{-6}	1.24×10^{-8}
Hydrazine	1.25×10^{-5}	1.99×10^{-8}
Vinyl chloride	7.48×10^{-6}	1.20×10^{-8}
Trichloroethylene	6.33×10^{-6}	1.01×10^{-8}

Table M–10. Values of Distribution Coefficient for Radiological Constituents for Contaminated Soil

Constituent	Distribution Coefficient (milliliters per gram)	Source
Hydrogen	0	DOE 2005
Carbon	4	DOE 2005
Potassium	15	Sheppard and Thibault 1990
Strontium	10	DOE 2005
Zirconium	600	Sheppard and Thibault 1990
Technetium	0	DOE 2005
Iodine	0	DOE 2005
Cesium	80	DOE 2005
Gadolinium	5	Sheppard and Thibault 1990
Thorium	3,200	Beyeler et al. 1999
Uranium	0.6	DOE 2005
Neptunium	2.5	DOE 2005
Plutonium	150	DOE 2005
Americium	1,900	Beyeler et al. 1999

Table M–11. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils

Constituent	Distribution Coefficient (milliliters per gram)	Source
Arsenic	4×10^{2}	Sheppard and Thibault 1990
Boron	0	Sheppard and Thibault 1990
Cadmium	8×10^{-1}	Sheppard and Thibault 1990
Chromium	0	DOE 2005
Fluoride	0	Sheppard and Thibault 1990
Lead	8×10^{1}	DOE 2005
Manganese	5×10^{1}	Beyeler et al. 1999
Mercury	1×10^{1}	DOE 2005
Molybdenum	1×10^{1}	Beyeler et al. 1999
Nickel	4×10^{2}	Beyeler et al. 1999
Nitrate	0	DOE 2005
Silver	9×10^{1}	Beyeler et al. 1999
Strontium	1×10^{1}	Sheppard and Thibault 1990
Total uranium	6×10^{-1}	Sheppard and Thibault 1990

Table M–11. Values of Distribution Coefficient for Chemical Constituents for Contaminated Soils *(continued)*

Constituent	Distribution Coefficient (milliliters per gram)	Source
Acetonitrile	0	DOE 2005
Benzene	1	DOE 2005
Butanol	3	DOE 2005
Polychlorinated biphenols	1.7×10^{5}	DOE 2005
2,4,6-Trichlorophenol	3.8×10^{-1}	Sheppard and Thibault 1990
1,2-Dichloroethane	0	Sheppard and Thibault 1990
1,4-Dioxane	0	Sheppard and Thibault 1990
Carbon tetrachloride	0	Sheppard and Thibault 1990
Dichloromethane	0	Sheppard and Thibault 1990
Hydrazine	0	Sheppard and Thibault 1990
Vinyl chloride	0	Sheppard and Thibault 1990
Trichloroethylene	0	Sheppard and Thibault 1990

M.3.1.3 Cribs and Trenches (Ditches)

Sources at cribs and trenches (ditches) are liquid sources modeled as pulse releases characterized by liquid volume, source area, and time of occurrence. Values for these model parameters are those reported in the Hanford Soil Inventory Model (SIM) database and are summarized in Appendix D of this EIS.

M.3.2 FFTF Decommissioning Alternatives

Under FFTF Decommissioning Alternative 1, the FFTF Reactor Containment Building (RCB, Building 405), and the other buildings within the 400 Area Property Protected Area, would be maintained under administrative controls for 100 years through 2107. After 2107, remaining waste would be available for release to the environment.

FFTF Decommissioning Alternative 2 calls for in-place closure of FFTF. The main RCB and the two immediately adjacent support facilities (Buildings 491E and 491W), all above-grade structures would be dismantled. Demolition waste would be consolidated in the below-grade spaces or disposed of at an IDF. Below-grade spaces would be filled with demolition waste and stabilized with fill material (grout) to immobilize hazardous materials and minimize future subsidence. A modified RCRA Subtitle C barrier would be constructed over the filled area with a design life of 500 years.

FFTF Decommissioning Alternative 3 describes removal and clean closure of FFTF. All above-grade structures around the main RCB and the immediately adjacent support facilities would be dismantled, and the contaminated demolition debris would be disposed of at an IDF. All other radioactively contaminated equipment and hazardous materials (including asbestos and lead shielding) would be removed for disposal at an IDF. Contaminated demolition debris would be removed to an IDF, and the vacated spaces backfilled, compacted, contoured, and revegetated. All radioactive and/or hazardous material, wood and large steel components would be removed. The surface would be contoured, and revegetated; no barrier would be required.

Consistent with this description of the three FFTF Decommissioning alternatives, the partition-limited, convective flow model is applied. The magnitude and timing of infiltration sequences for FFTF Decommissioning Alternatives 1, 2, and 3 are presented in Tables M–12, M–13, and M–14, respectively. The values of infiltration rate are based on chloride mass balance and lysimeter tests and are those recommended in the *Technical Guidance Document* (DOE 2005).

Table M–12. FFTF Decommissioning Alternative 1 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Key: Fast Flux Test Facility.

Table M–13. FFTF Alternative 2 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
Barrier design life	2022	0.5
Post–barrier design life	2522	3.5

Key: Fast Flux Test Facility.

Table M–14. FFTF Decommissioning Alternative 3 Infiltration Sequence Description

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1980	50
End of institutional controls	2107	3.5

Key: Fast Flux Test Facility.

M.3.3 Waste Management Alternatives

Primary facilities considered in Waste Management alternatives are one or two IDFs, the RPPDF, and trenches 31 and 34 at low-level radioactive waste burial ground (LLBG) 218-W-5.

M.3.3.1 Low-Level Radioactive Waste Burial Facilities

Sources at low-level radioactive waste (LLW) disposal facilities, including LLBG 218-W-5, are modeled as contaminated soil and debris. For contaminated soil sources, the partitioning limited, convective flow model is applied with soil type distribution coefficients presented in Tables M–10 and M–11. For stabilized waste, the cylindrical diffusion limited-release model is applied with effective diffusivities summarized in Tables M–8 and M–9.

Under Waste Management Alternative 1**,** LLW, mixed low-level radioactive waste (MLLW), and transuranic waste will be processed at the Central Waste Complex for disposal in LLBG 218-W-5 (lined) trenches 31 and 34. These trenches will operationally close in 2035. As discussed in Appendices D and S of this EIS, a barrier would not be placed over LLBG 218-W-5, including trenches 31 and 34, in 2035. The infiltration sequence used in modeling is described in Table M–15.

Table M–15. Waste Management Alternative 1 Infiltration Sequence Description for LLBG 218-W-5, Trenches 31 and 34

Location Conditions	Year at Start of Infiltration Value	Infiltration Value (millimeters per year)
Pre-Hanford	1940	3.5
Disturbed conditions	1986	50
Post–barrier design life	2086	3.5

Key: LLBG=low-level radioactive waste burial ground.

M.3.3.2 Integrated Disposal Facility Waste Forms

Characteristics of the primary and secondary tank closure waste forms proposed for disposal at an IDF are those described in Section M.3.1.2. The onsite non–Comprehensive Environmental Response, Compensation, and Liability Act (non-CERCLA) and waste management secondary wastes are modeled as grout waste forms with the characteristics described in Section M.3.1.2.

Waste Management Alternatives 2 and 3 include construction, operation, deactivation, closure, and postclosure care of IDF-East for tank, onsite-generated non-CERCLA, FFTF decommissioning, waste management, and offsite-generated LLW and MLLW. Under Waste Management Alternative 3, onsite-generated non-CERCLA, FFTF decommissioning, waste management, and offsite-generated LLW and MLLW would be disposed of in an IDF to be constructed in the 200-West Area (IDF-West), while tank LLW and MLLW would be disposed of in IDF-East. Three disposal groups were analyzed under these alternatives. Disposal Group 1 analyzes the operational completion date of 2050, with a barrier placed over IDF with a design life of 500 years. Disposal Group 2 analyzes the operational completion date of 2100, with a barrier placed over IDF with a design life of 500 years. Disposal Group 3 analyzes the operational completion date of 2165, with a barrier placed over IDF with a design life of 500 years. The magnitude and timing of the infiltration sequence for Waste Management Alternatives 2 and 3 are presented in Table M–16.

Table M–16. Waste Management Alternatives 2 and 3 Infiltration Sequence Description 200-East (West) Area Integrated Disposal Facility

Location Conditions	Disposal Group 1	Disposal Group 2	Disposal Group 3	IDF-East	IDF-West
	Year at Start of Infiltration Value			Infiltration Value (millimeters per year)	
Pre-Hanford	1940	1940	1940	0.9	3.5
Barrier design life	2050	2100	2165	0.5	0.5
Post–barrier design life	2550	2600	2665	0.9	3.5

Key: IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

M.4 RESULTS

M.4.1 Tank Closure Alternatives

M.4.1.1 Past Leaks from Cribs and Trenches (Ditches)

All Tank Closure alternatives are analyzed for the same constituent release to the vadose zone from past leaks from HLW tanks and discharges from cribs and trenches (ditches). Figures M–6 through M–11 demonstrate the total release of radiological and chemical constituents for the 10,000-year modeling period.

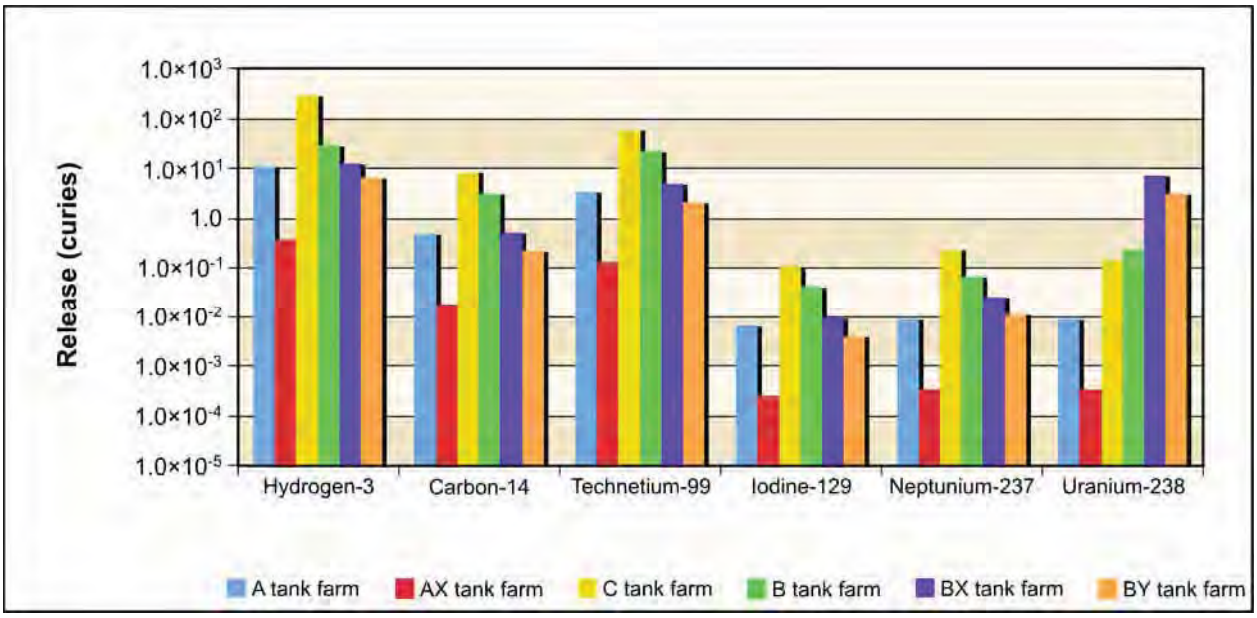


Figure M–6. Radiological Releases to Vadose Zone from 200-East Area Tank Farm Past Leaks

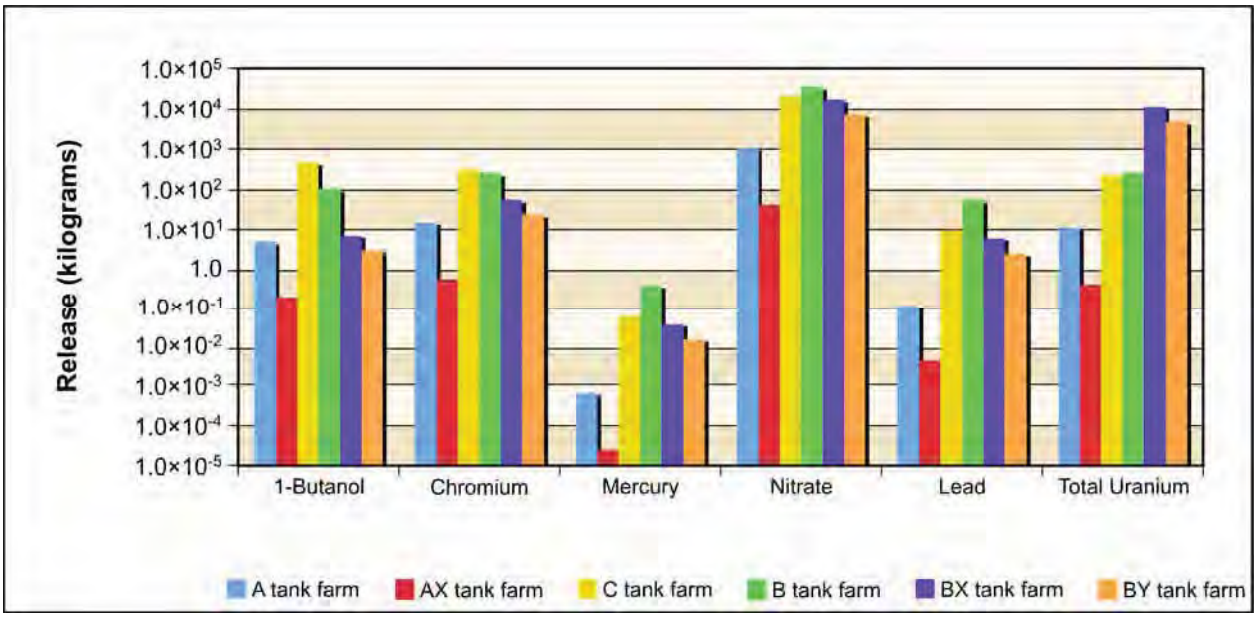


Figure M–7. Chemical Releases to Vadose Zone from 200-East Area Tank Farm Past Leaks

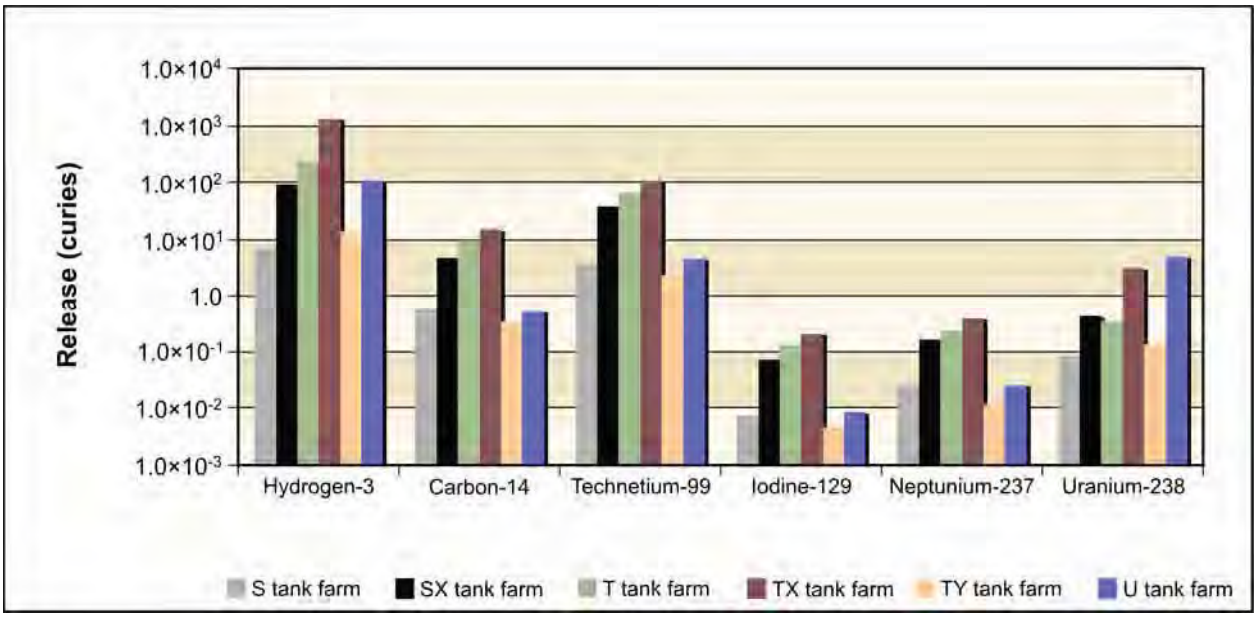


Figure M–8. Radiological Releases to Vadose Zone from 200-West Area Tank Farm Past Leaks

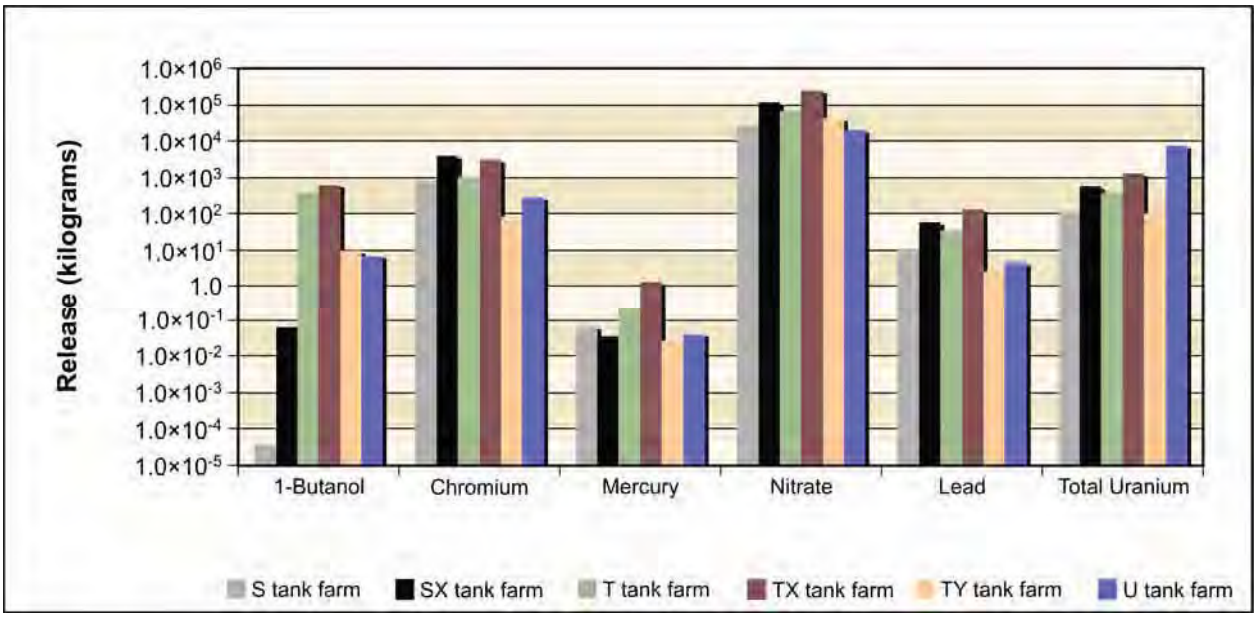


Figure M–9. Chemical Releases to Vadose Zone from 200-West Area Tank Farm Past Leaks

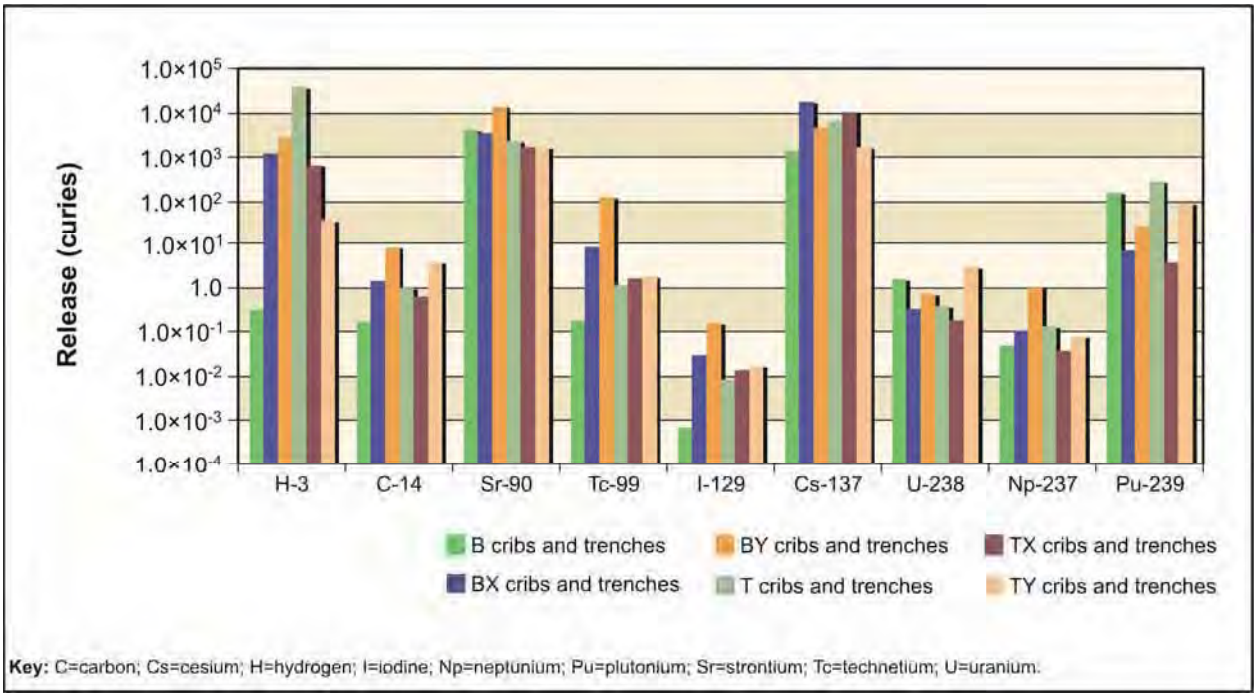


Figure M–10. Alternative Cribs and Trenches (Ditches) Radiological Releases to Vadose Zone

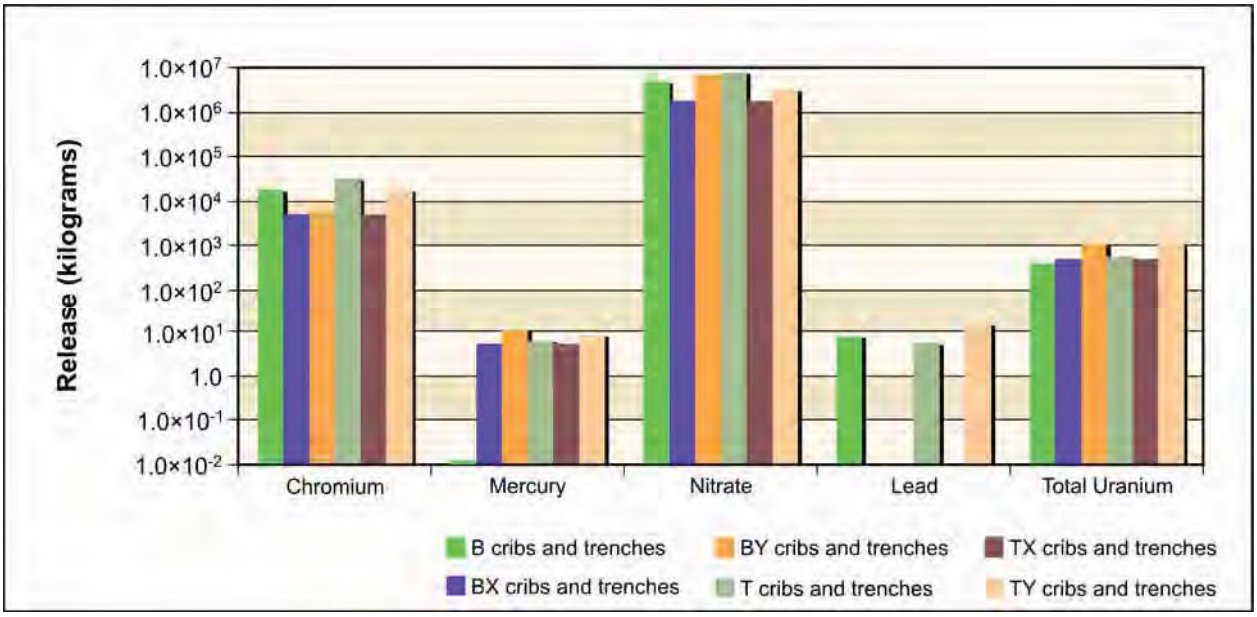


Figure M–11. Alternative Cribs and Trenches (Ditches) Chemical Releases to Vadose Zone

M.4.1.2 Releases from Other Sources in the Tank Farms

Releases from other sources related to the HLW tanks, including tank residuals, retrieval leaks, and ancillary equipment, were analyzed together. The amount of constituent released to the vadose zone is related to the activities under each Tank Closure alternative. Under Tank Closure Alternatives 6A and 6B, all tanks farms would be closed to a clean state by removing the tanks, ancillary equipment, and soil to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Therefore, releases from other sources related to the HLW tanks were not analyzed.

Under Tank Closure Alternative 1, tank farms would be maintained in the current condition indefinitely but, for the purpose of analysis, are assumed to fail after an institutional control period of 100 years. At this time, the salt cake in single-shell tanks is assumed available for leaching into the vadose zone, and the liquid contents of double-shell tanks are assumed to be discharged directly to the vadose zone. Figures M–12 through M–17 indicates the constituent release estimated under Tank Closure Alternative 1.

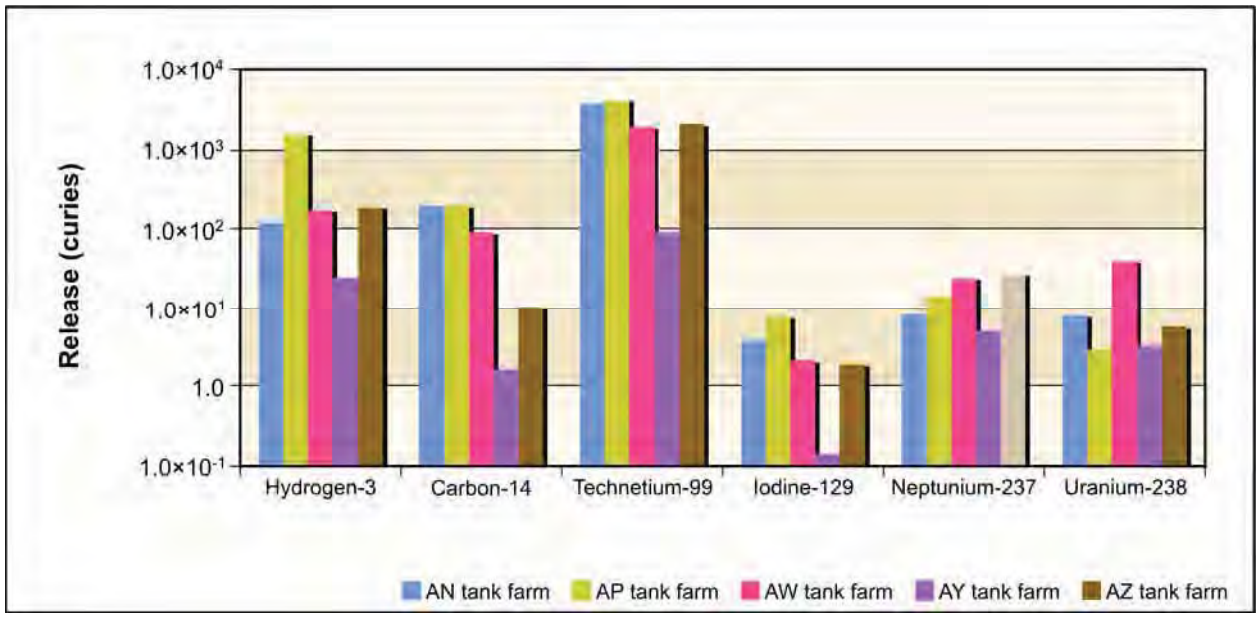


Figure M–12. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

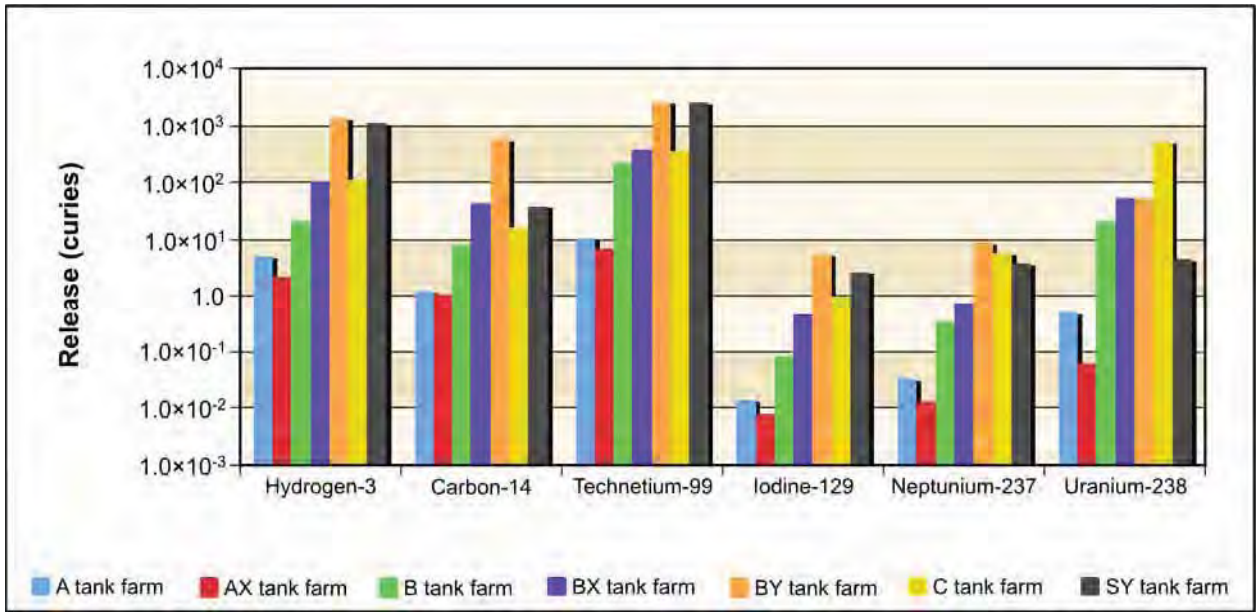


Figure M–13. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

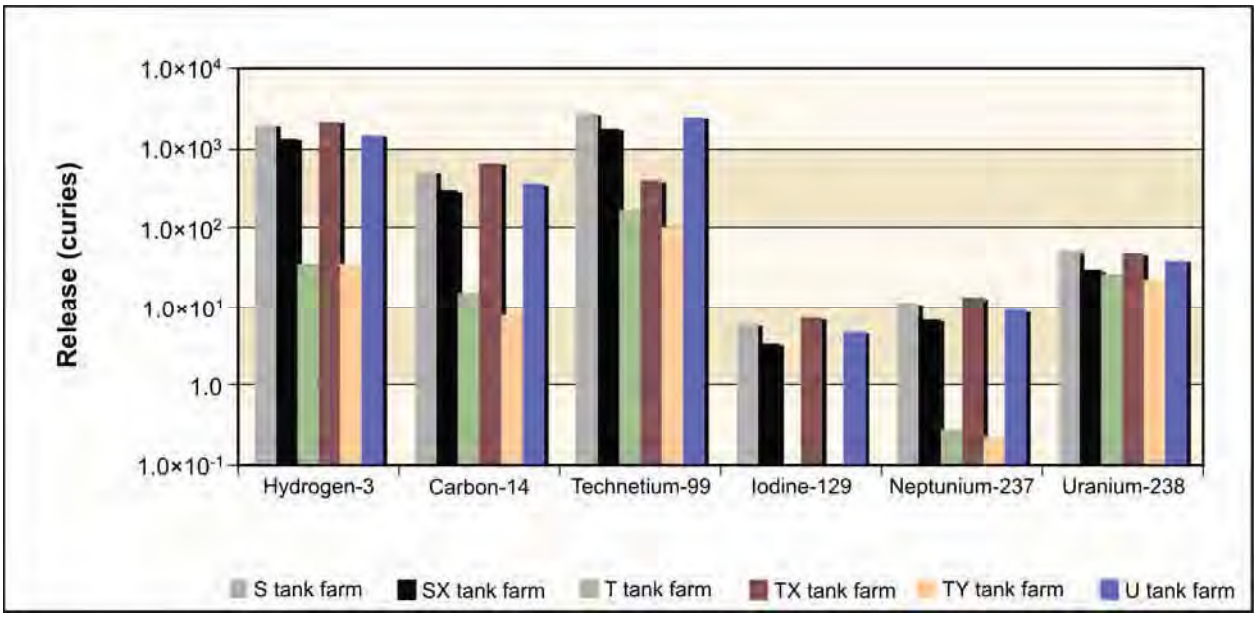


Figure M–14. Tank Closure Alternative 1 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

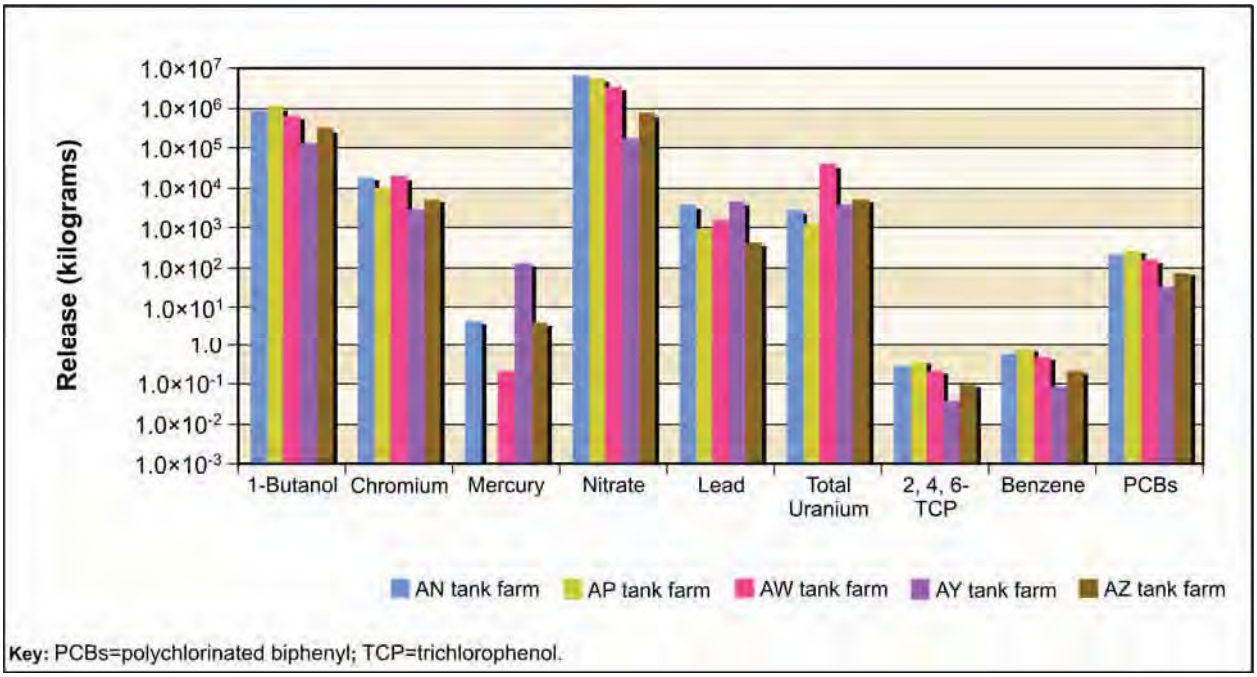


Figure M–15. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

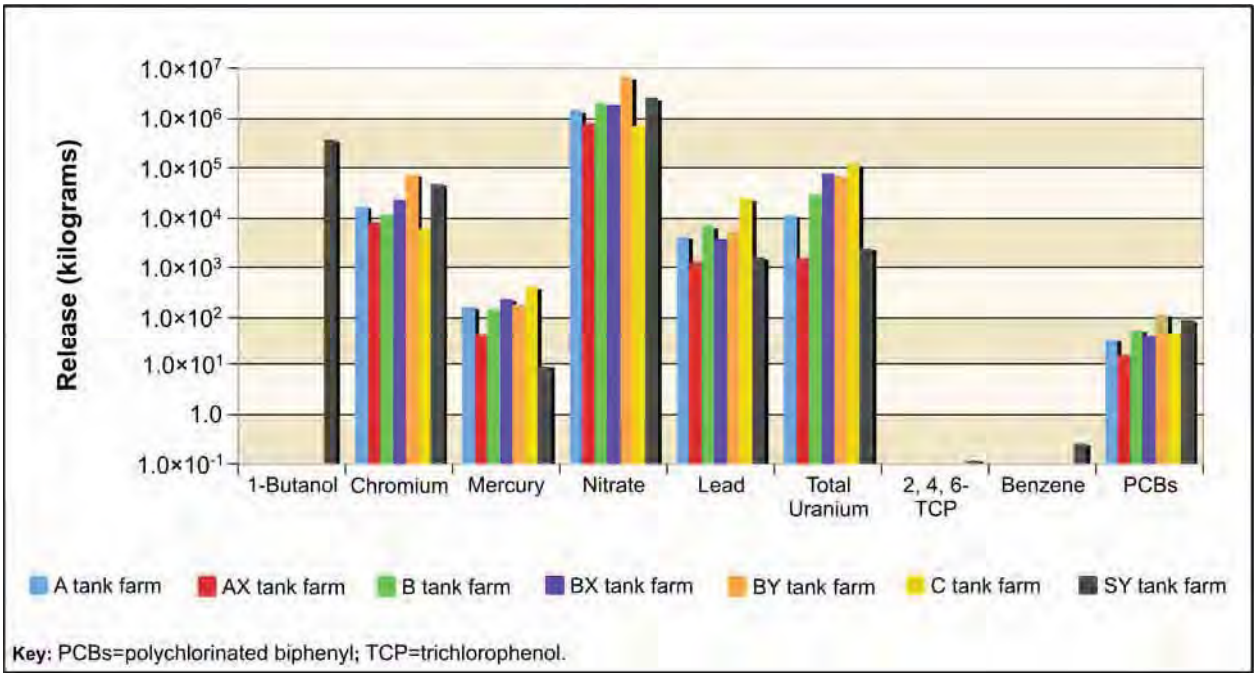


Figure M–16. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

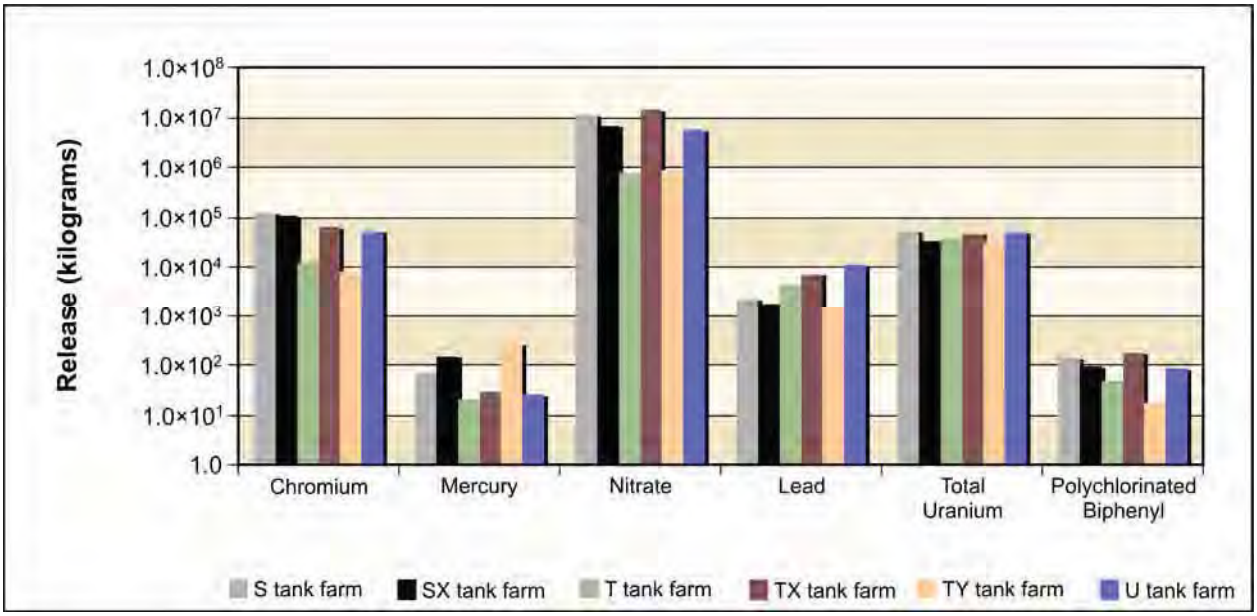


Figure M–17. Tank Closure Alternative 1 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but residual material in tanks would not be stabilized. After an institutional control period of 100 years, the salt cake in tanks is assumed available for dissolution in infiltrating water. Potential releases to the vadose zone under Tank Closure Alternative 2A are indicated in Figures M–18 through M–23.

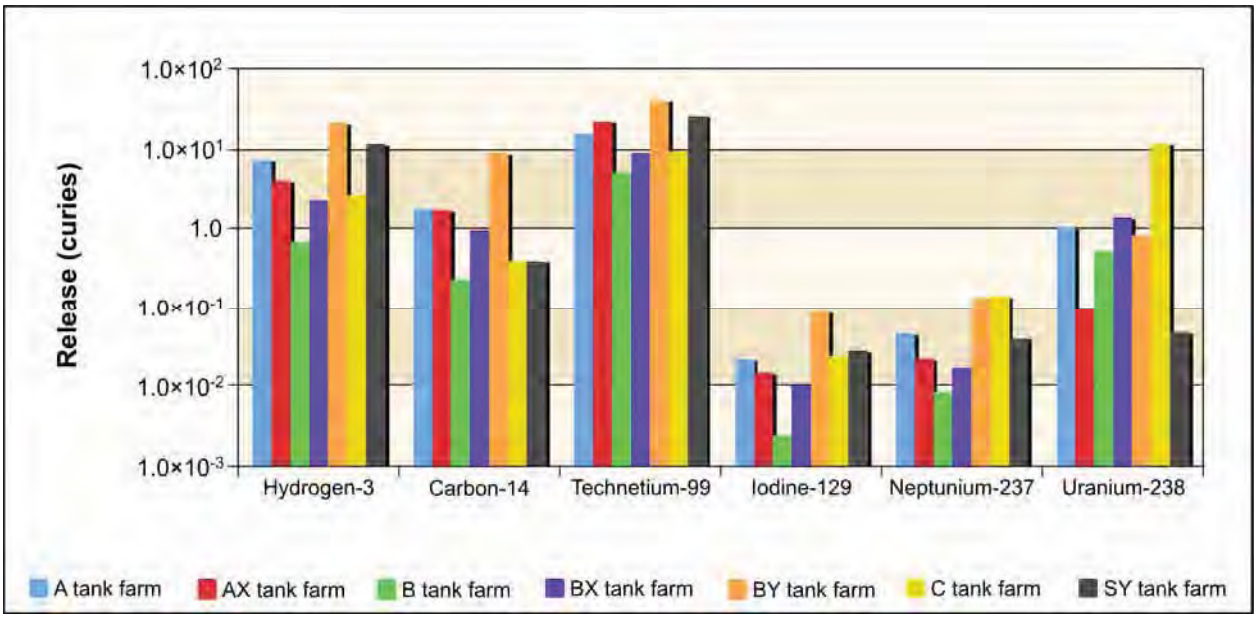


Figure M–18. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

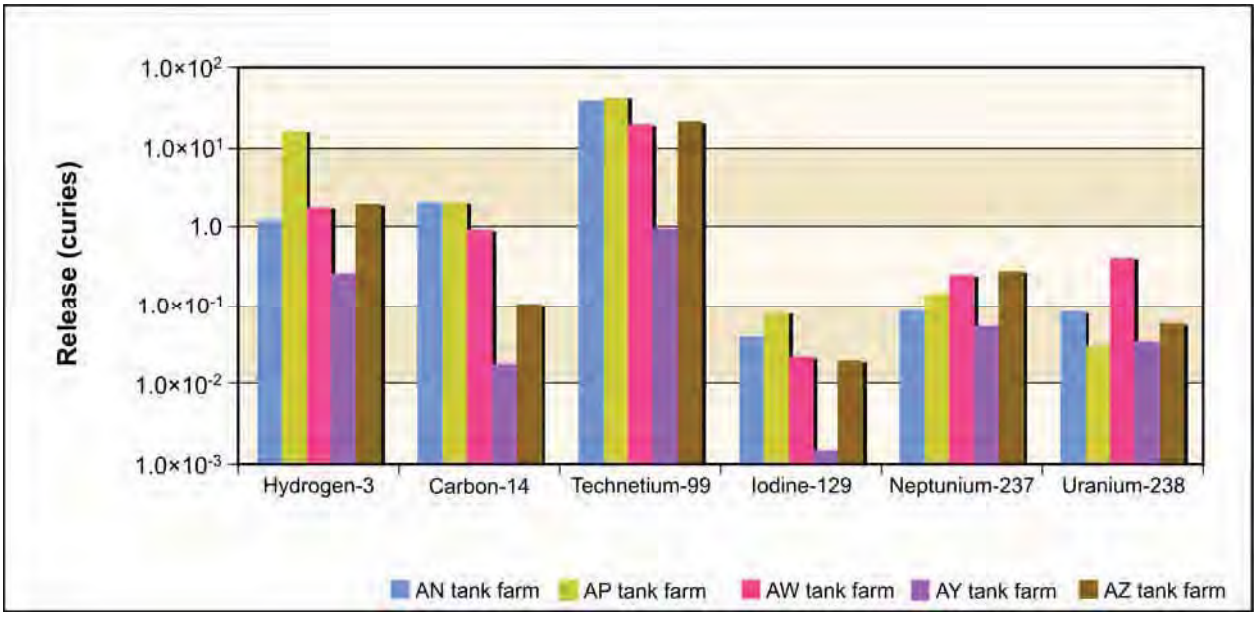


Figure M–19. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

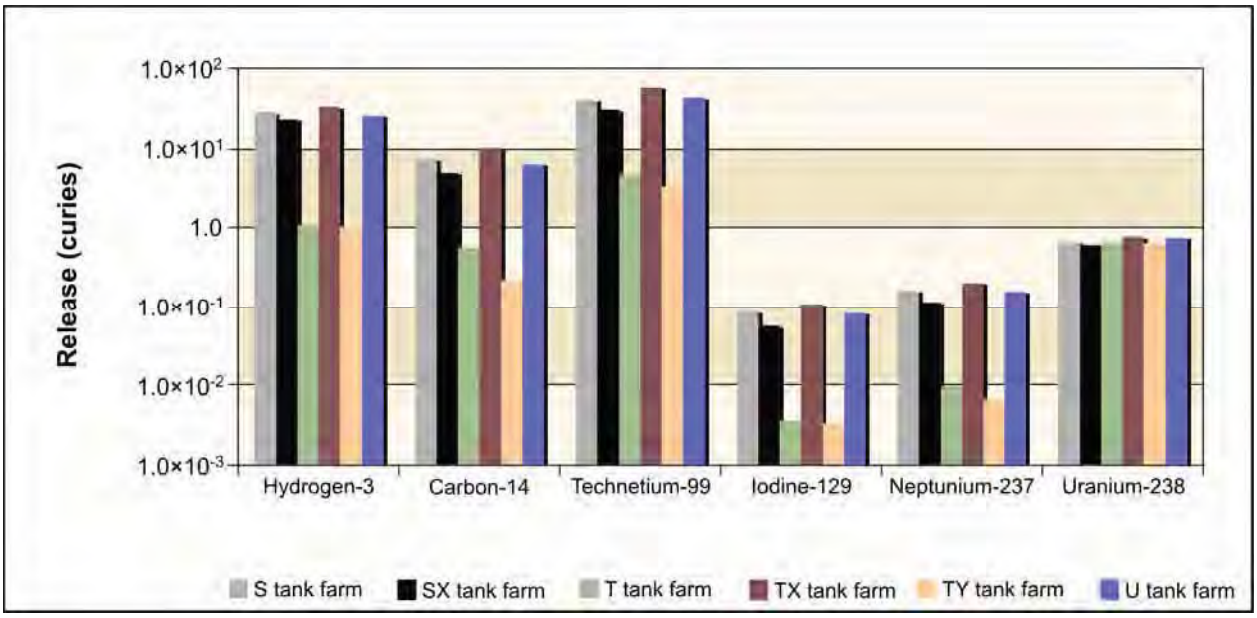


Figure M–20. Tank Closure Alternative 2A Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

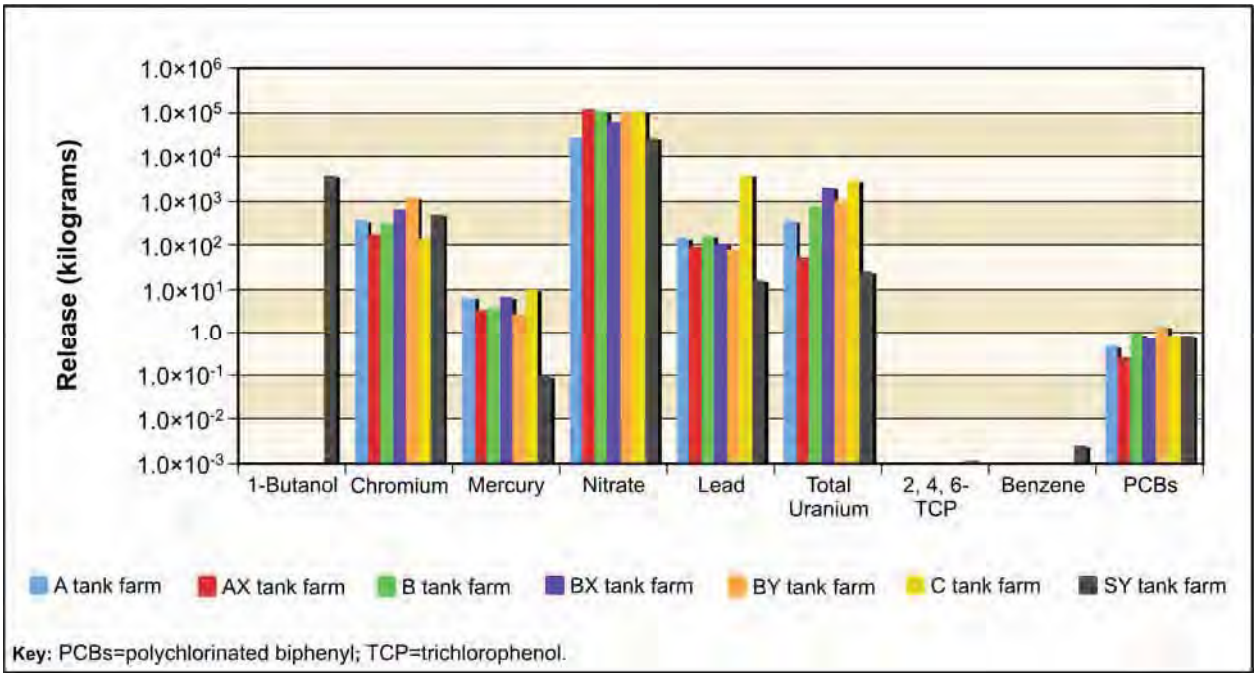


Figure M–21. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

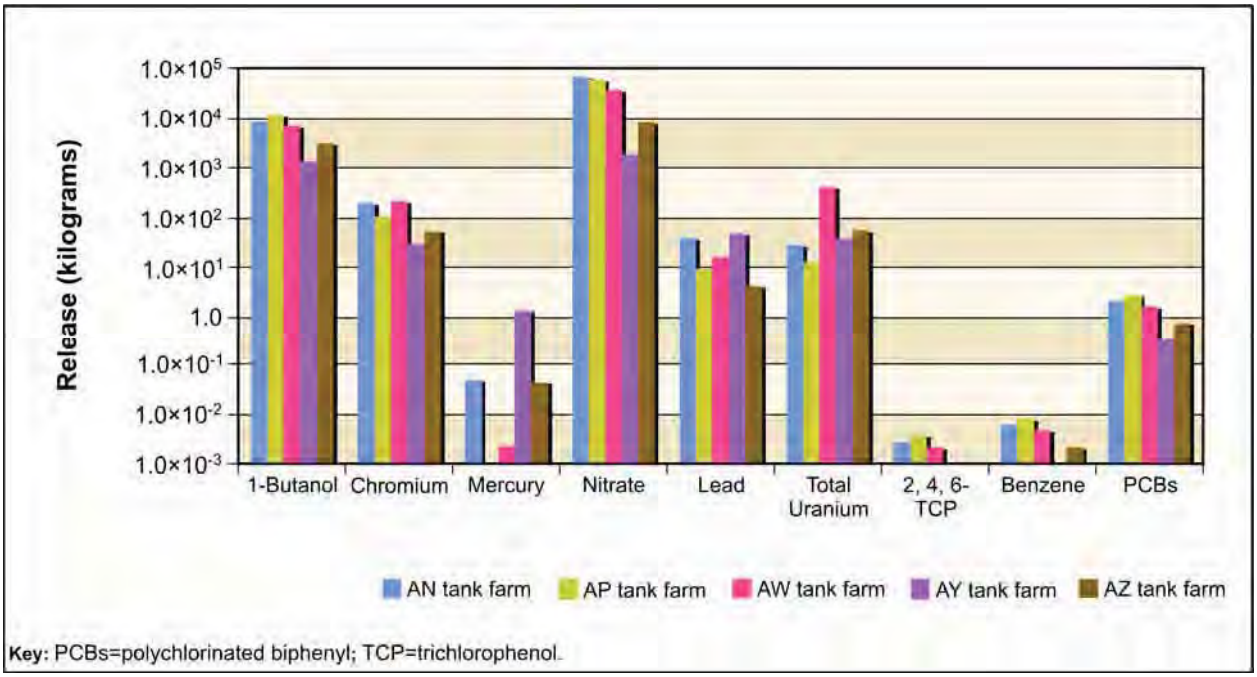


Figure M–22. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, and AZ

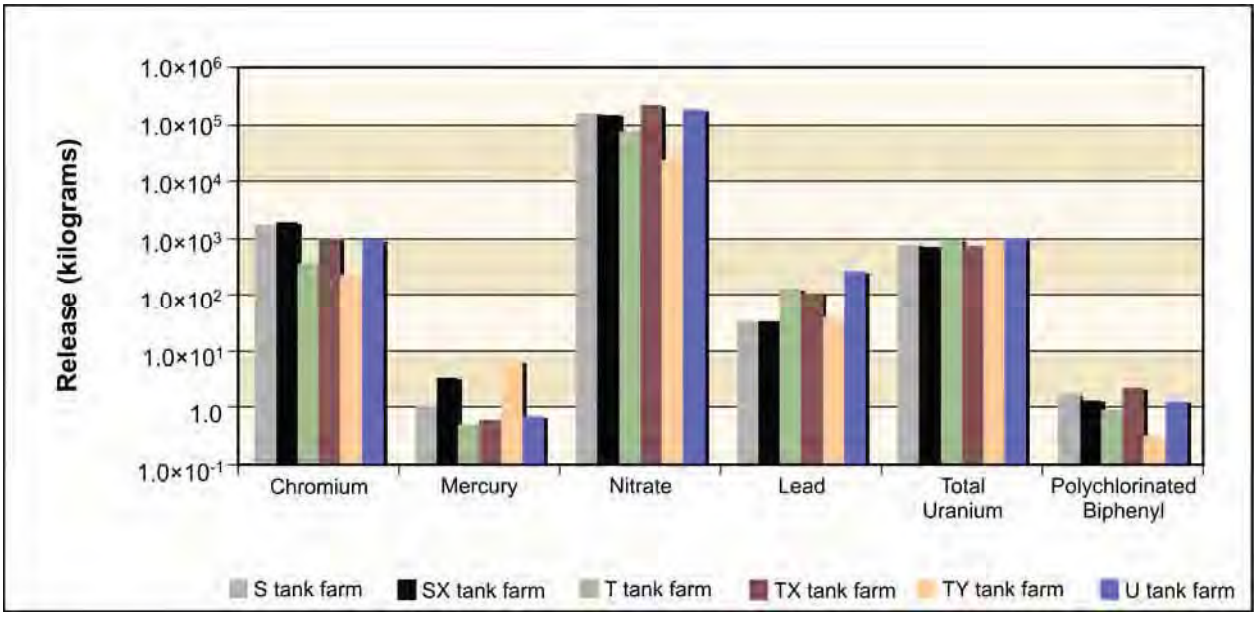


Figure M–23. Tank Closure Alternative 2A Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those of Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soil from onsite sources. Potential releases to the vadose zone under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C are indicated in Figures M–24 through M–29.

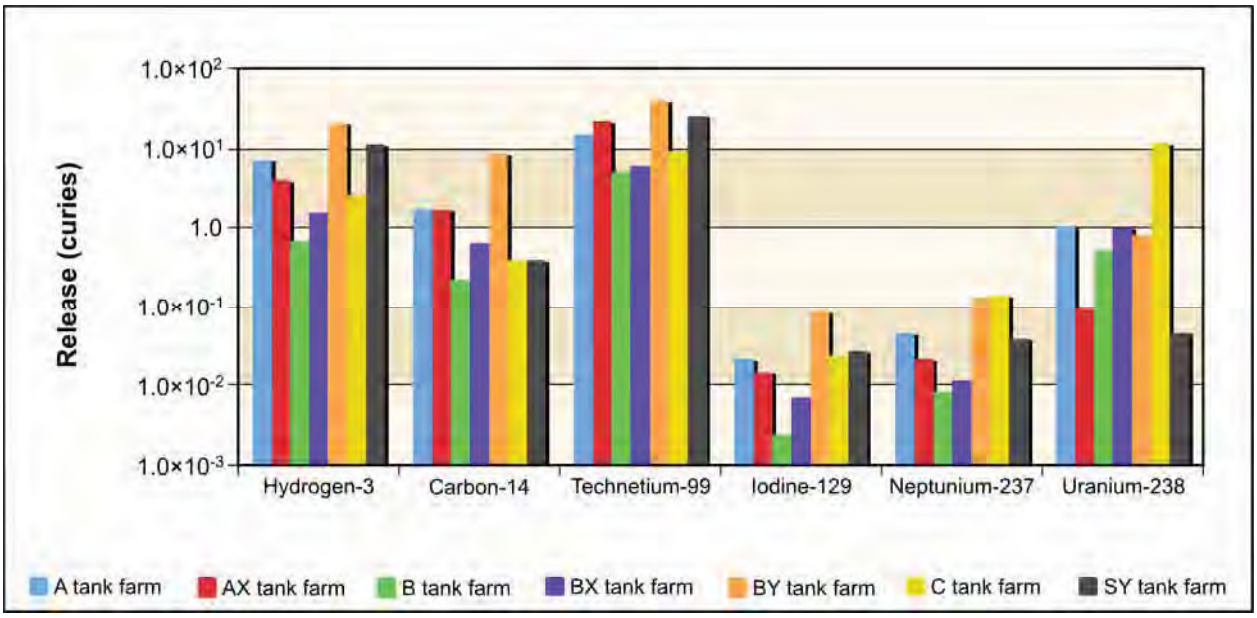


Figure M–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

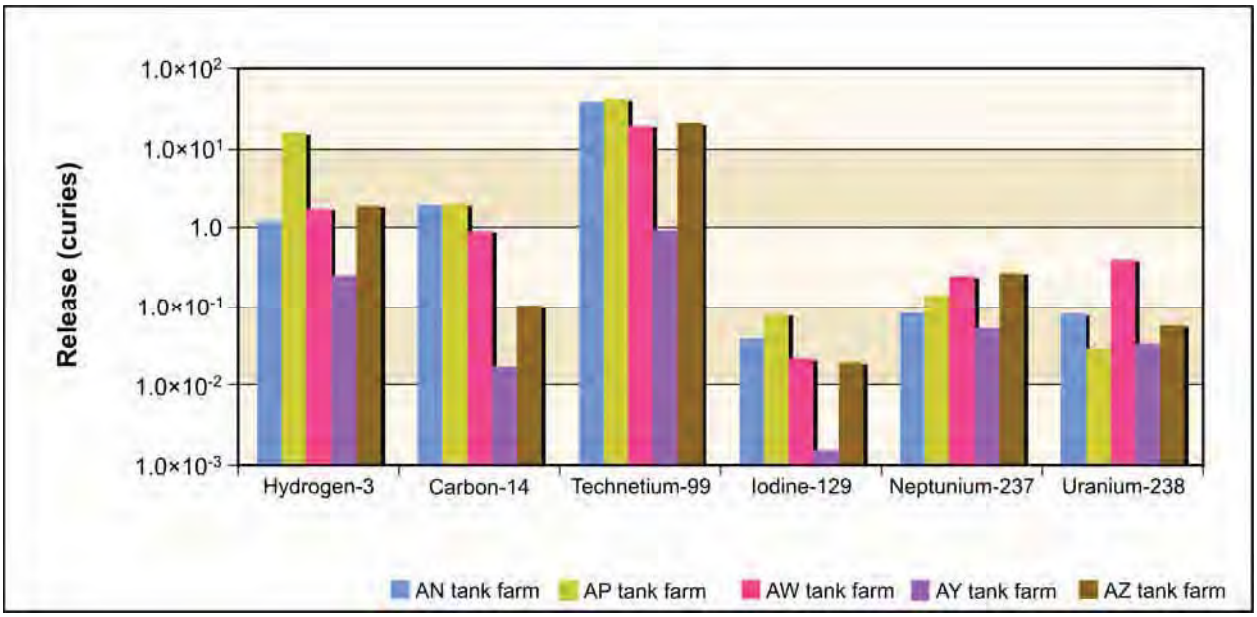


Figure M–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

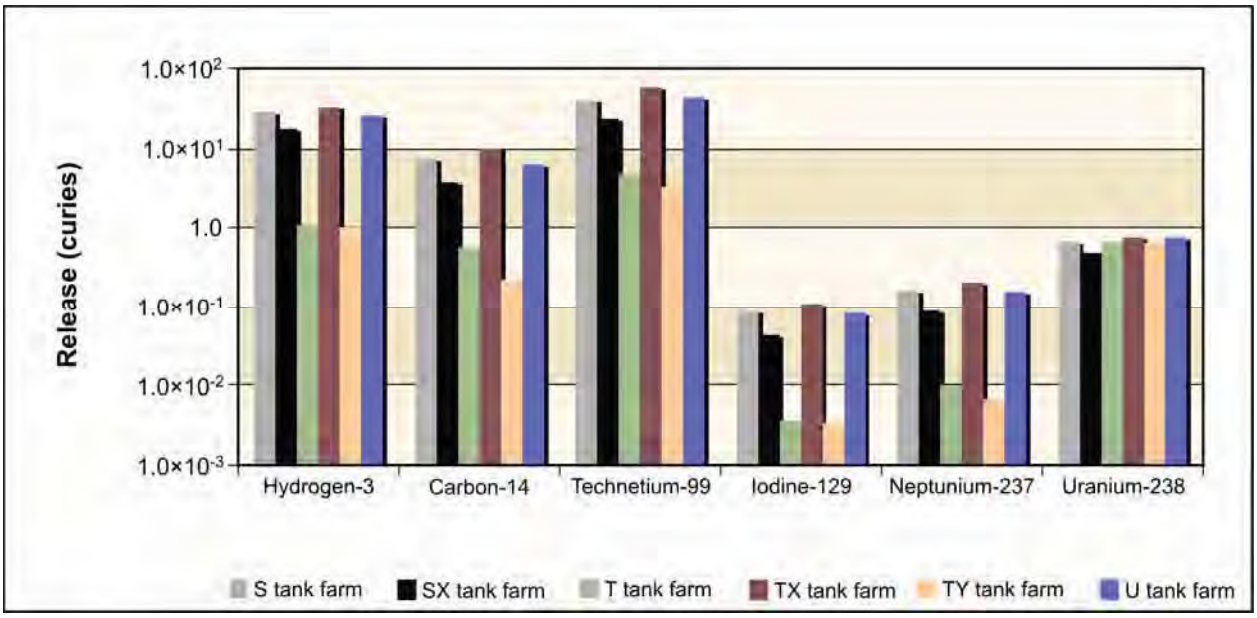


Figure M–26. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

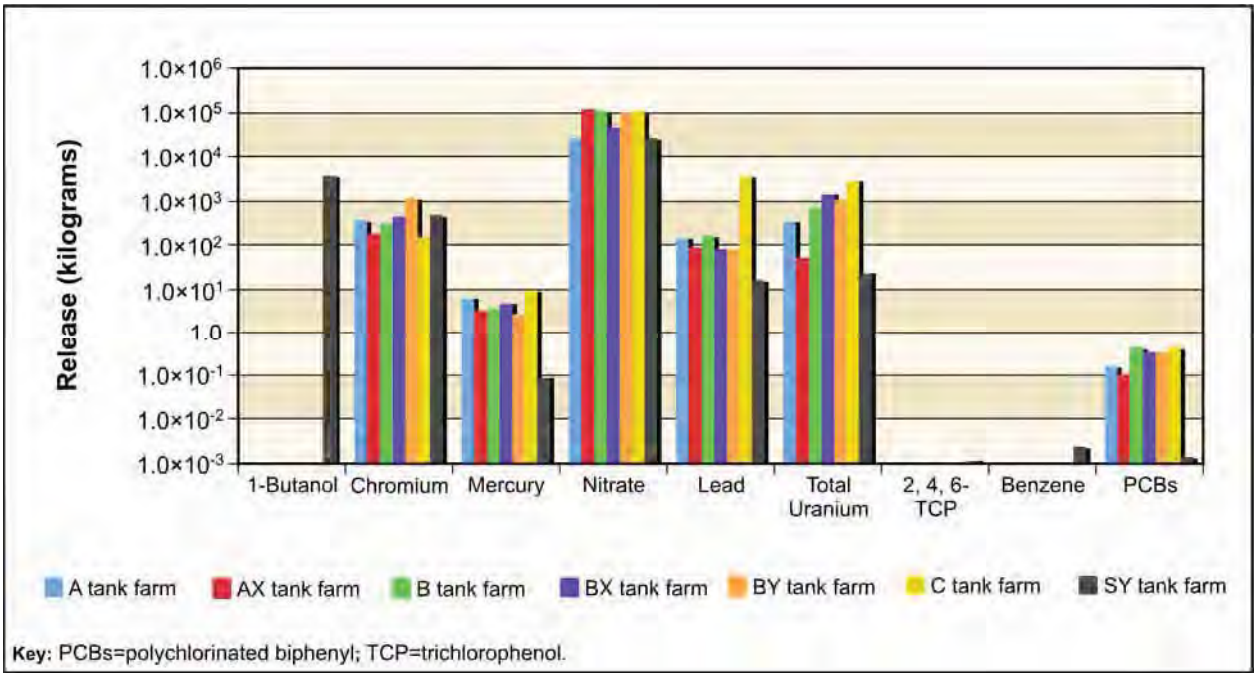


Figure M–27. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

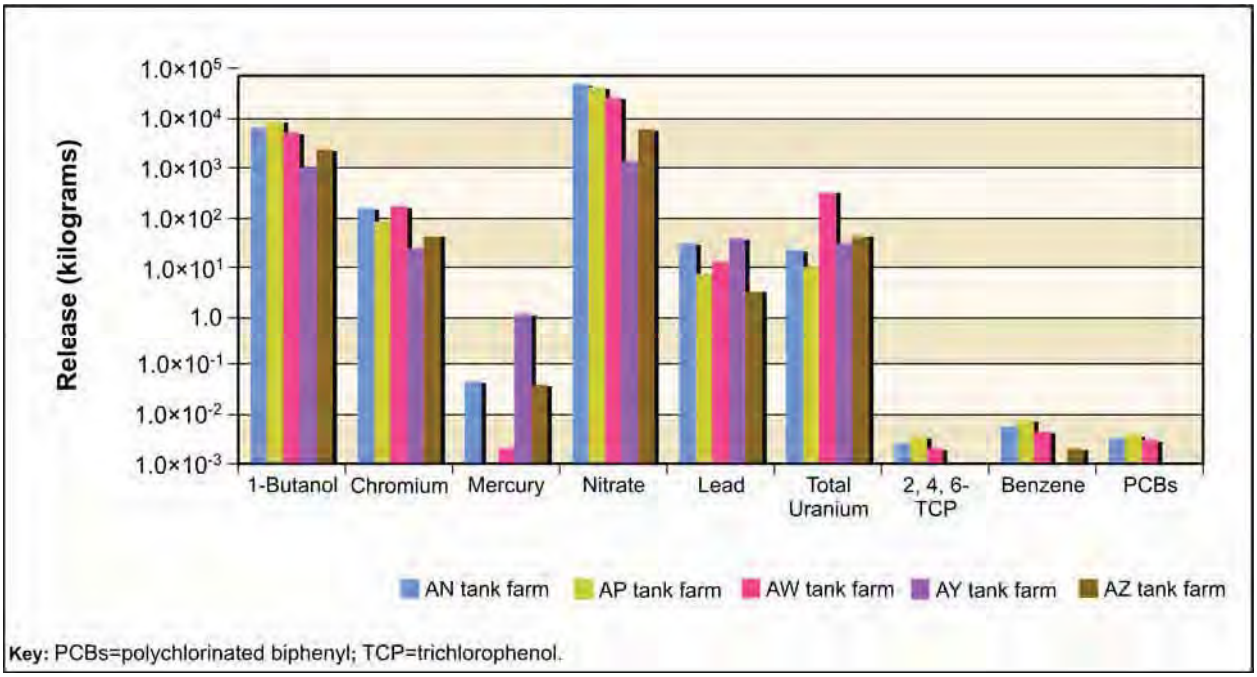


Figure M–28. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

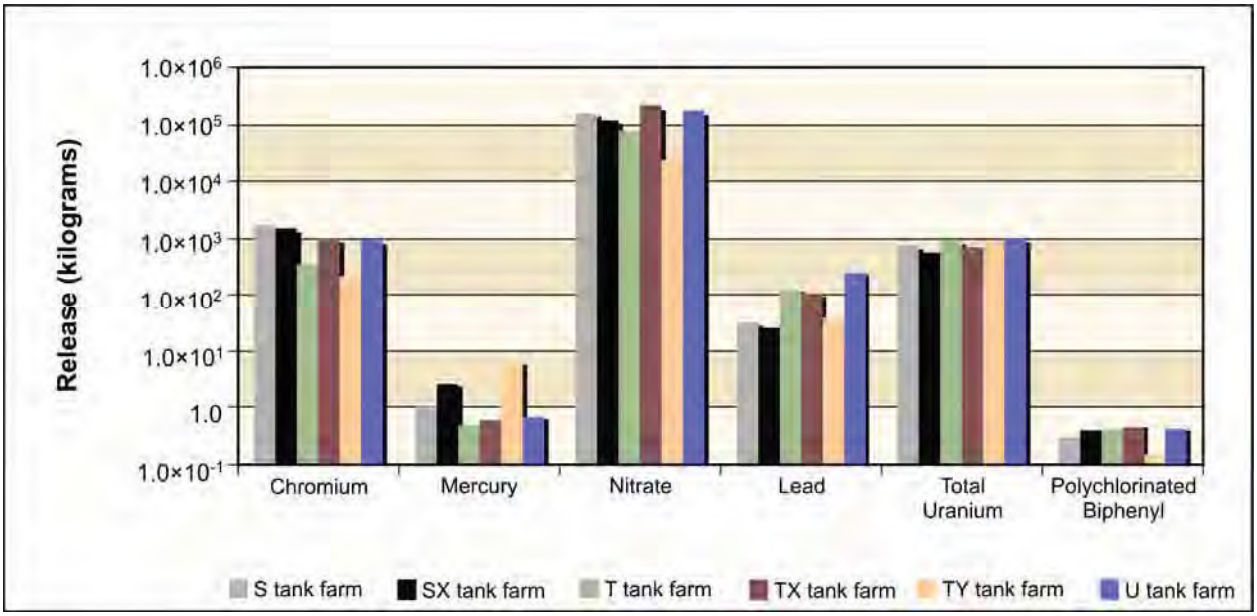


Figure M–29. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be closed to a clean state by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential releases to the vadose zone under Tank Closure Alternative 4 are indicated in Figures M–30 through M–35.

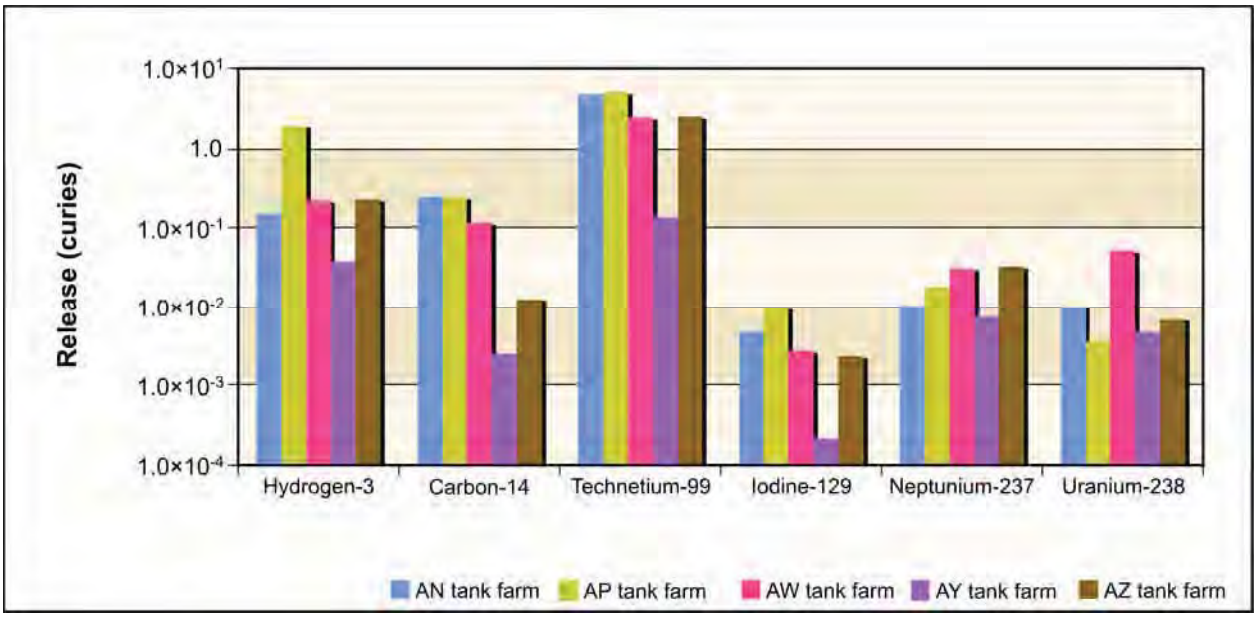


Figure M–30. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

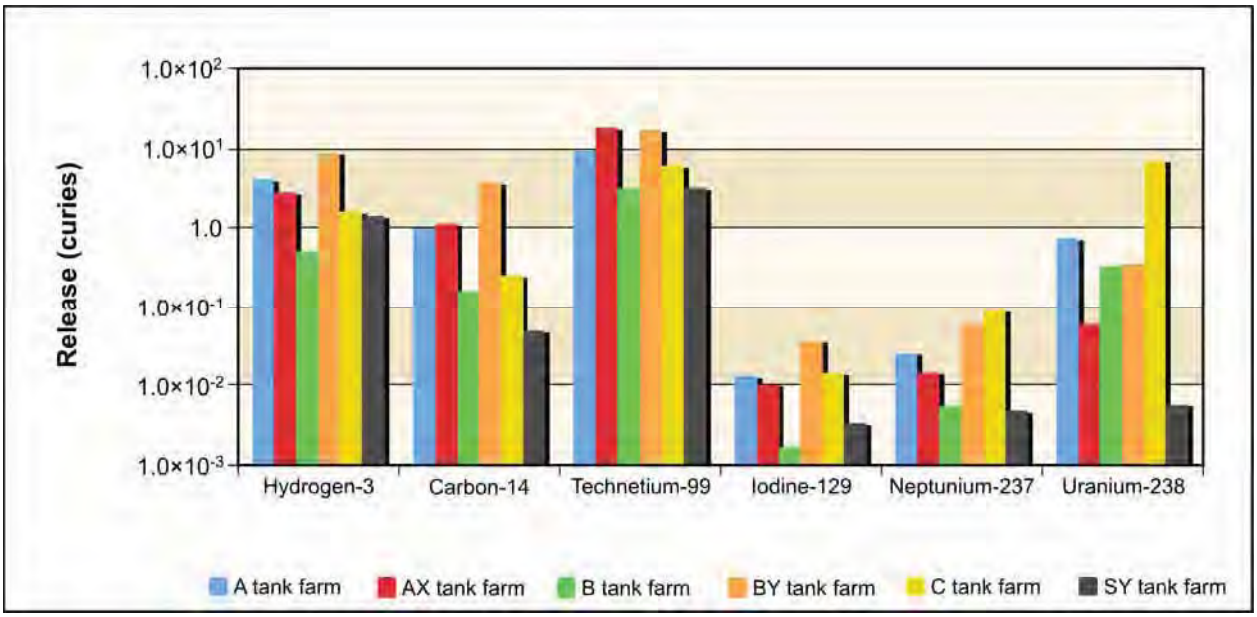


Figure M–31. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C and SY

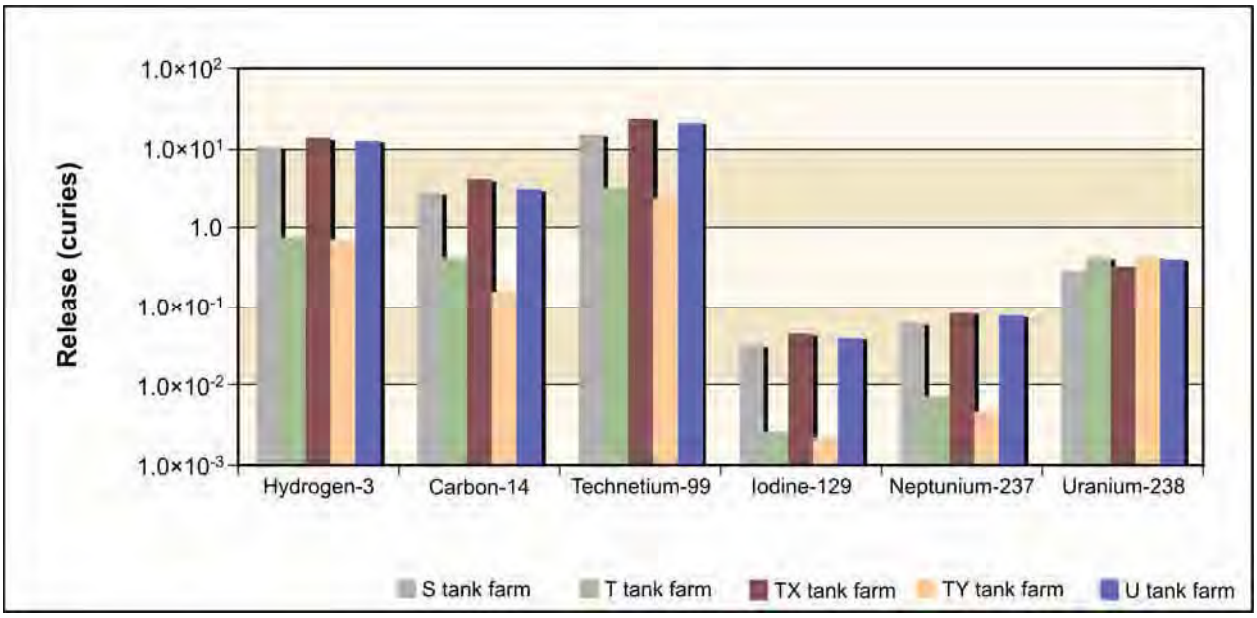


Figure M–32. Tank Closure Alternative 4 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

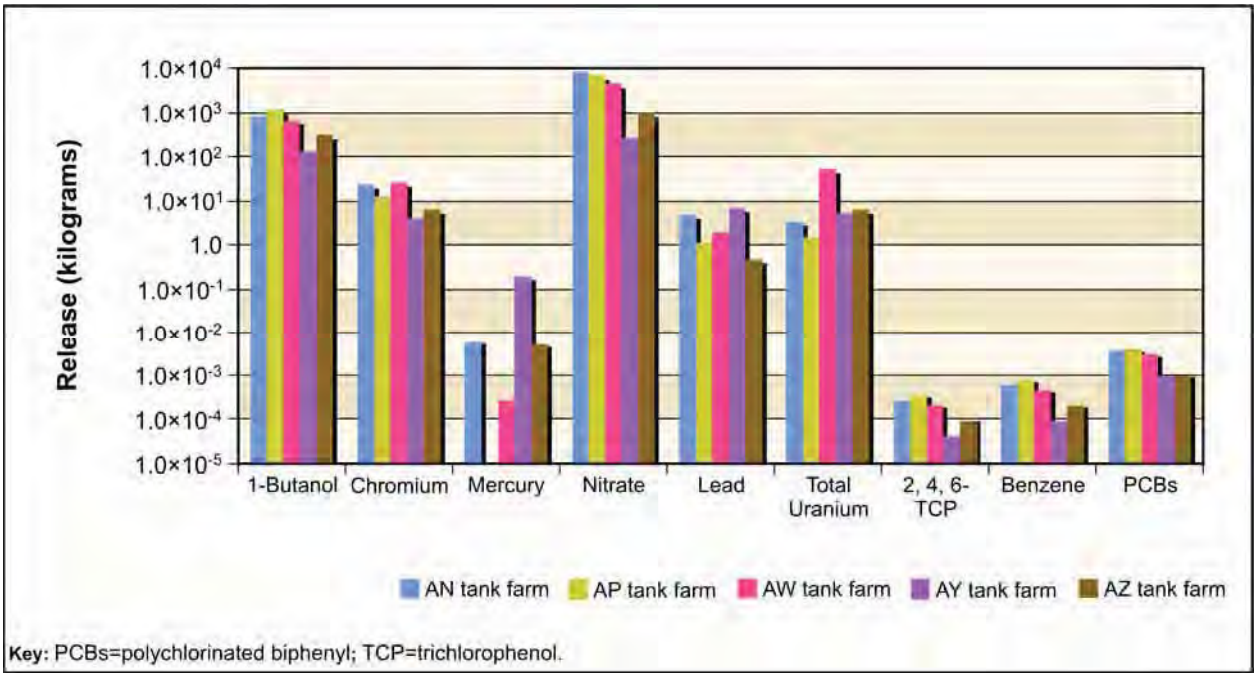


Figure M–33. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

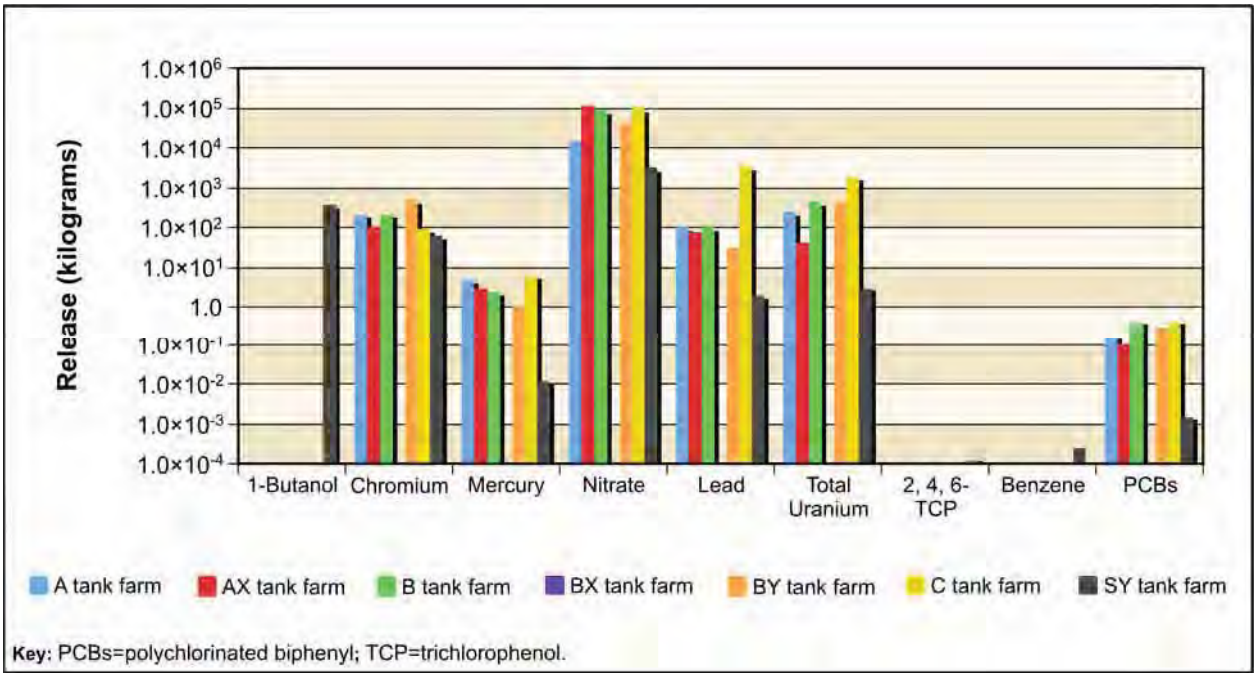


Figure M–34. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

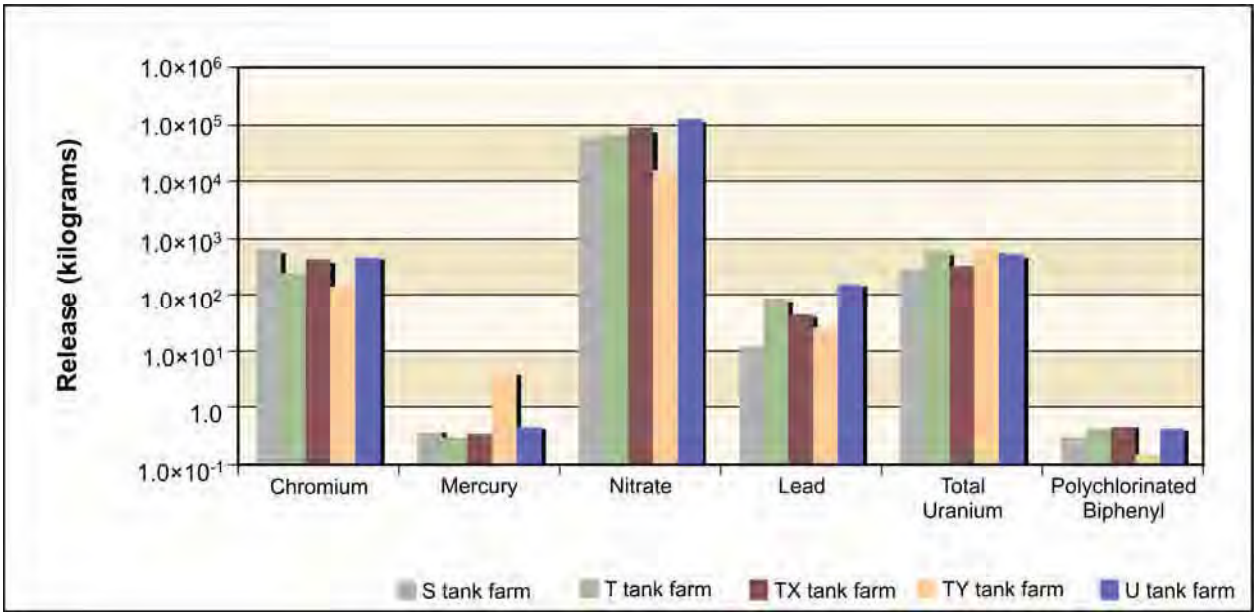


Figure M–35. Tank Closure Alternative 4 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, T, TX, TY, and U

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential releases to the vadose zone under Tank Closure Alternative 5 are indicated in Figures M–36 through M–41.

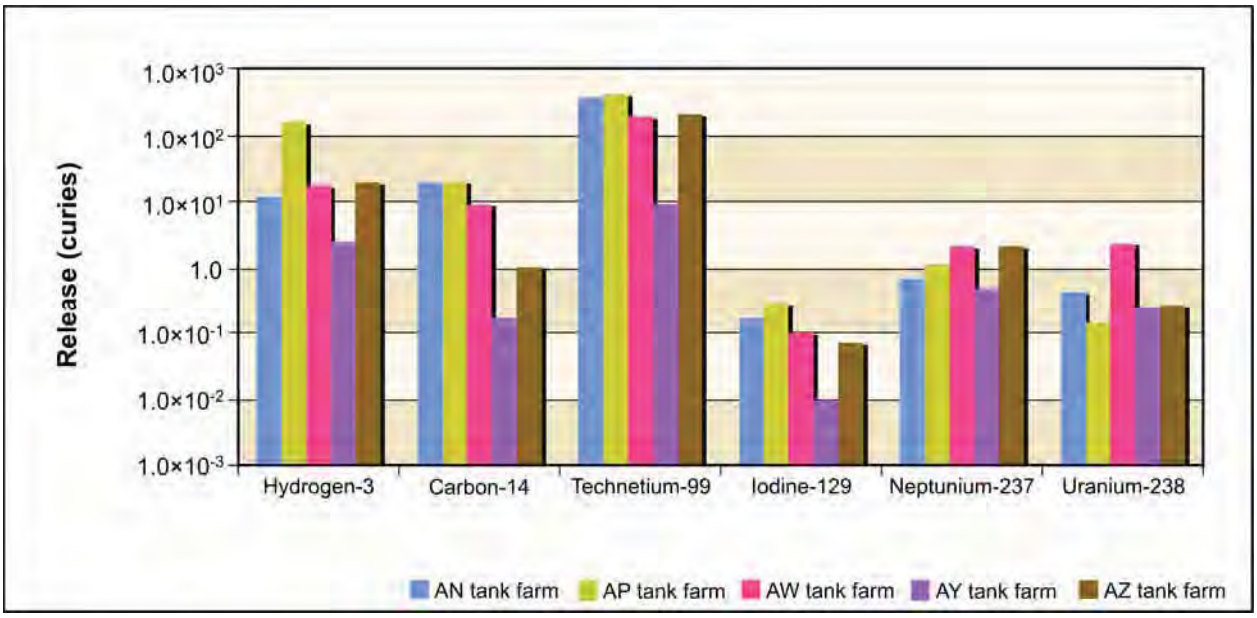


Figure M–36. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

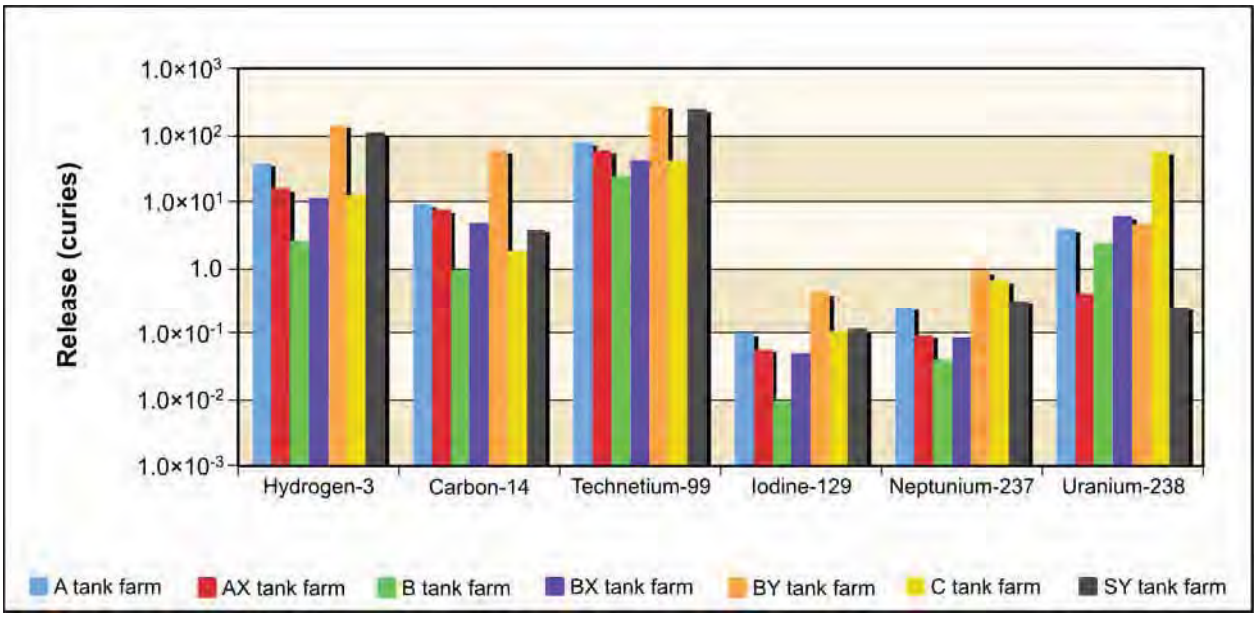


Figure M–37. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

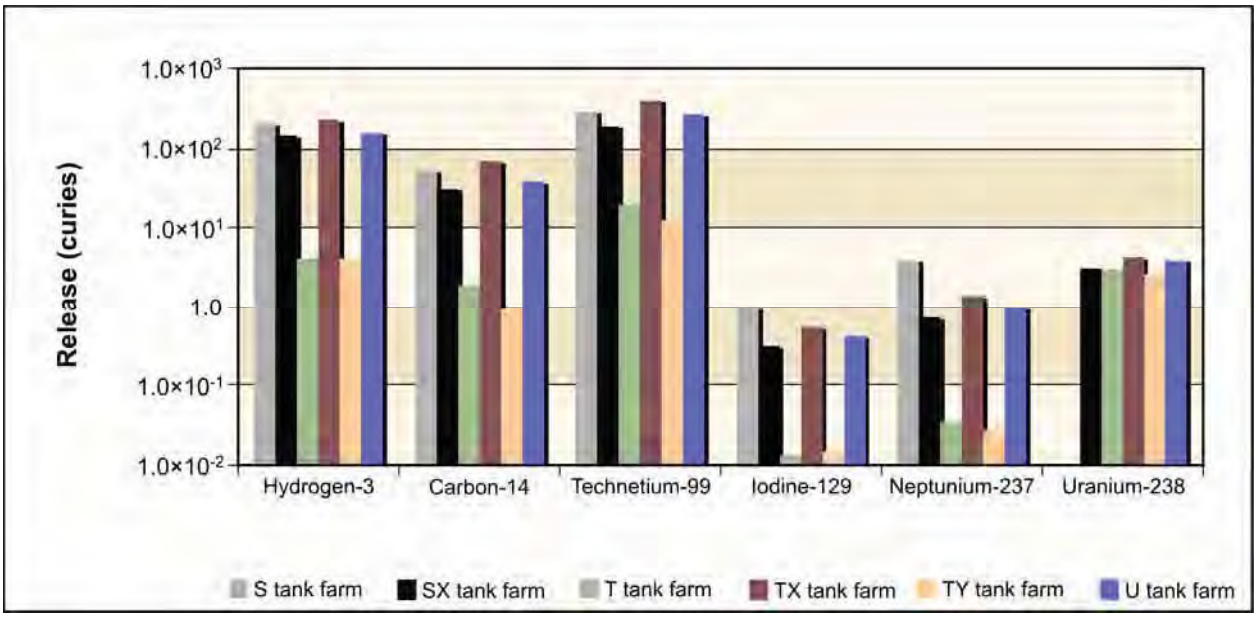


Figure M–38. Tank Closure Alternative 5 Radiological Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

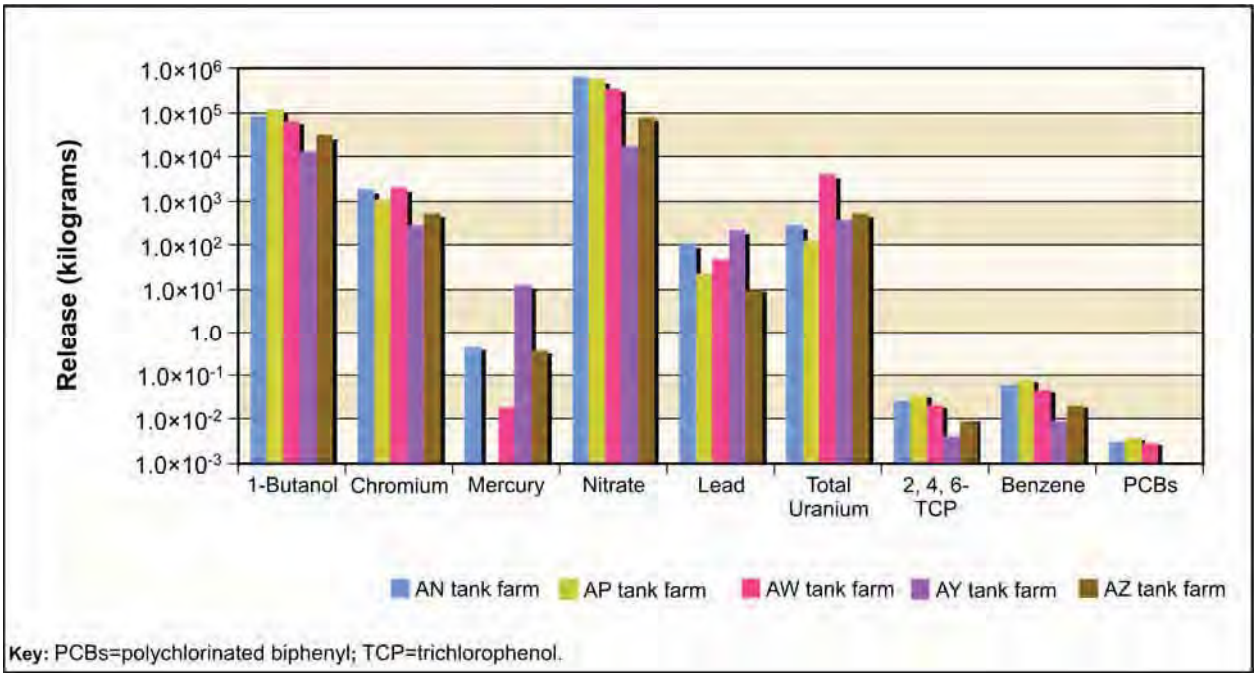


Figure M–39. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms AN, AP, AW, AY, and AZ

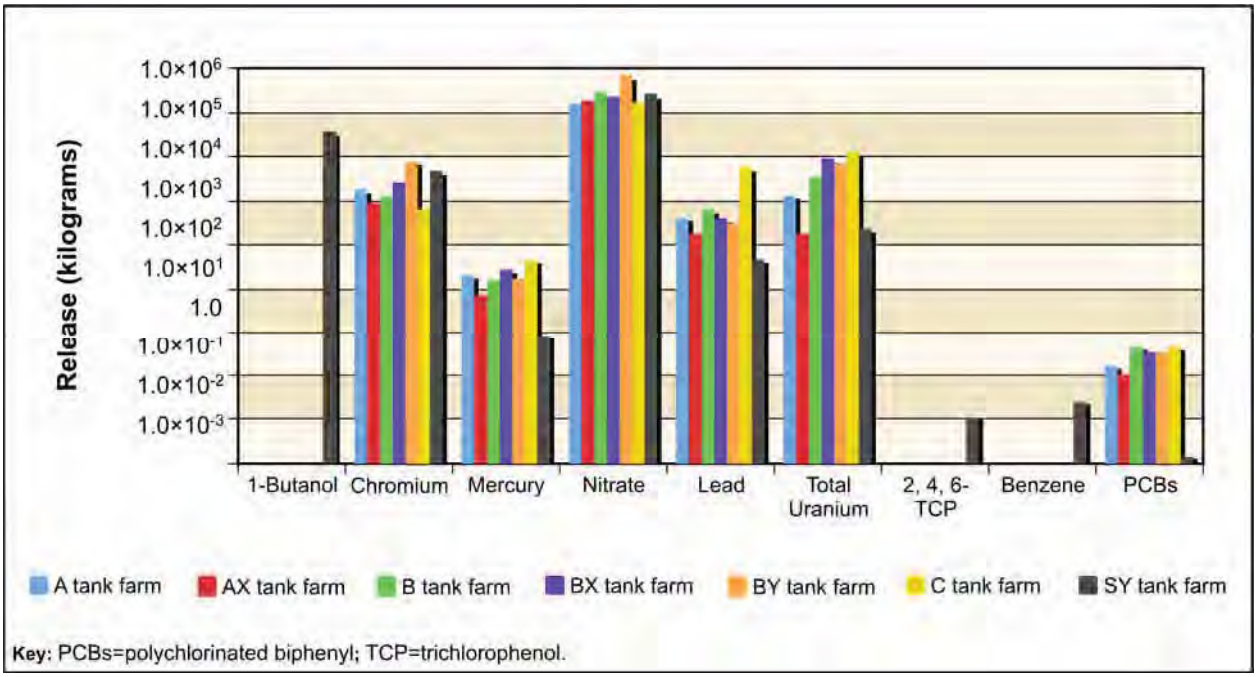


Figure M–40. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms A, AX, B, BX, BY, C, and SY

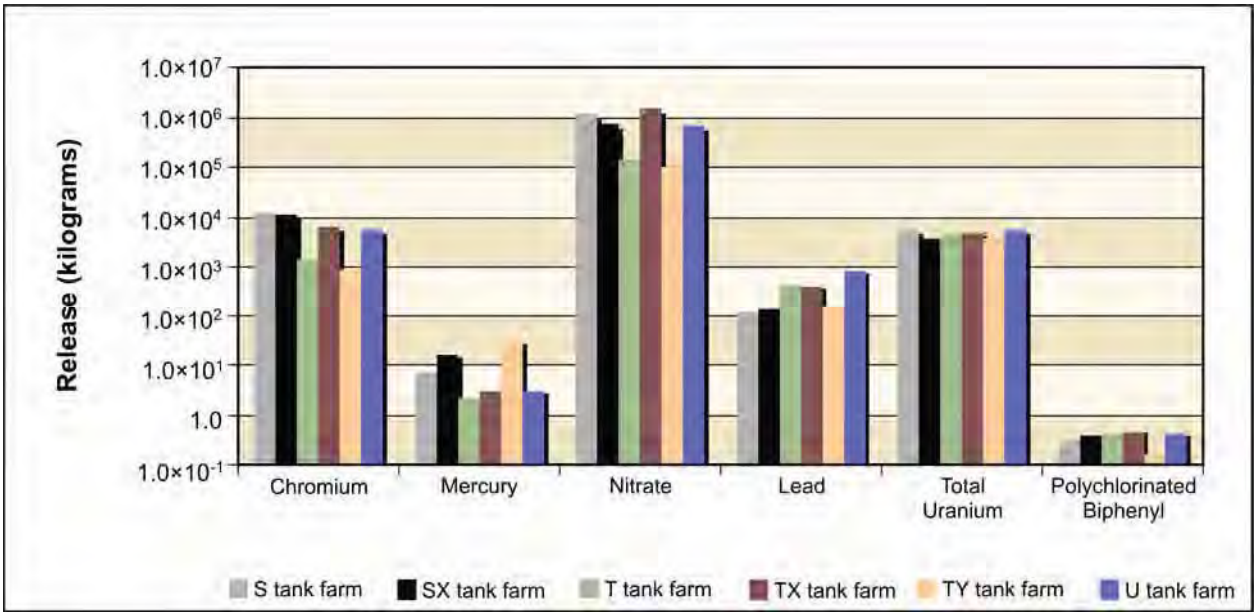


Figure M–41. Tank Closure Alternative 5 Chemical Releases to Vadose Zone from Other Sources in Tank Farms S, SX, T, TX, TY, and U

M.4.2 FFTF Decommissioning Alternatives

M.4.2.1 FFTF Decommissioning Alternative 1: No Action

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For purpose of analysis, the remaining waste would be available for release to the environment

after an institutional control period of 100 years. Potential releases to the vadose zone under FFTF Decommissioning Alternative 1 are indicated in Figures M–42 and M–43**.**

M.4.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the RCB and any other remaining below-grade structures (including the reactor vessel). Potential releases to the vadose zone under FFTF Decommissioning Alternative 2 are indicated in Figure M–44.

M.4.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures and contaminated below-grade structures, equipment, and materials would be removed. Potential releases to the vadose zone under FFTF Decommissioning Alternative 3 are indicated in Figure M–45.

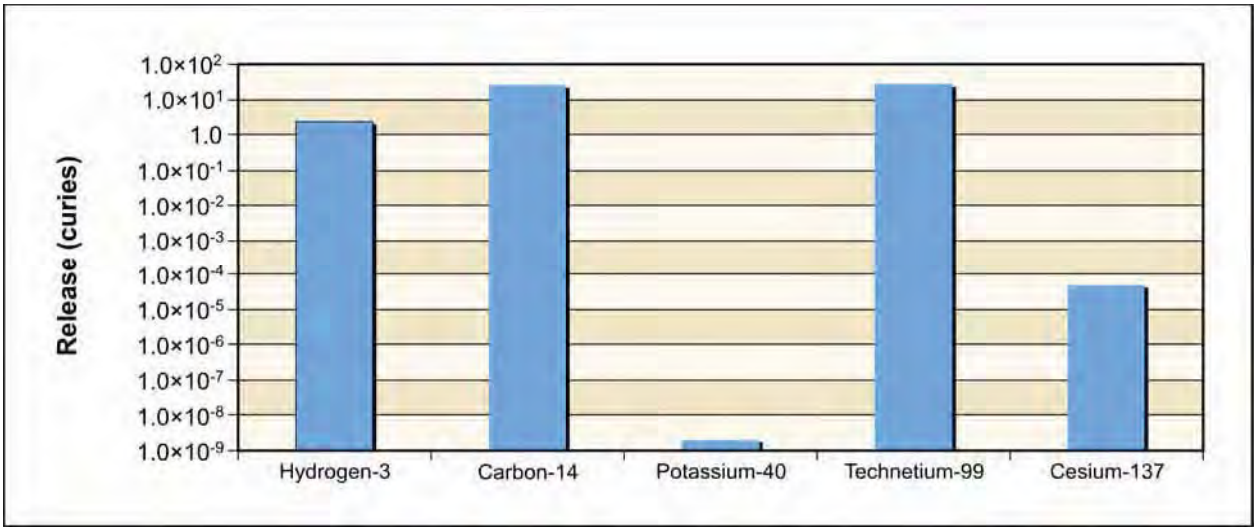


Figure M–42. FFTF Decommissioning Alternative 1 Radiological Releases to Vadose Zone

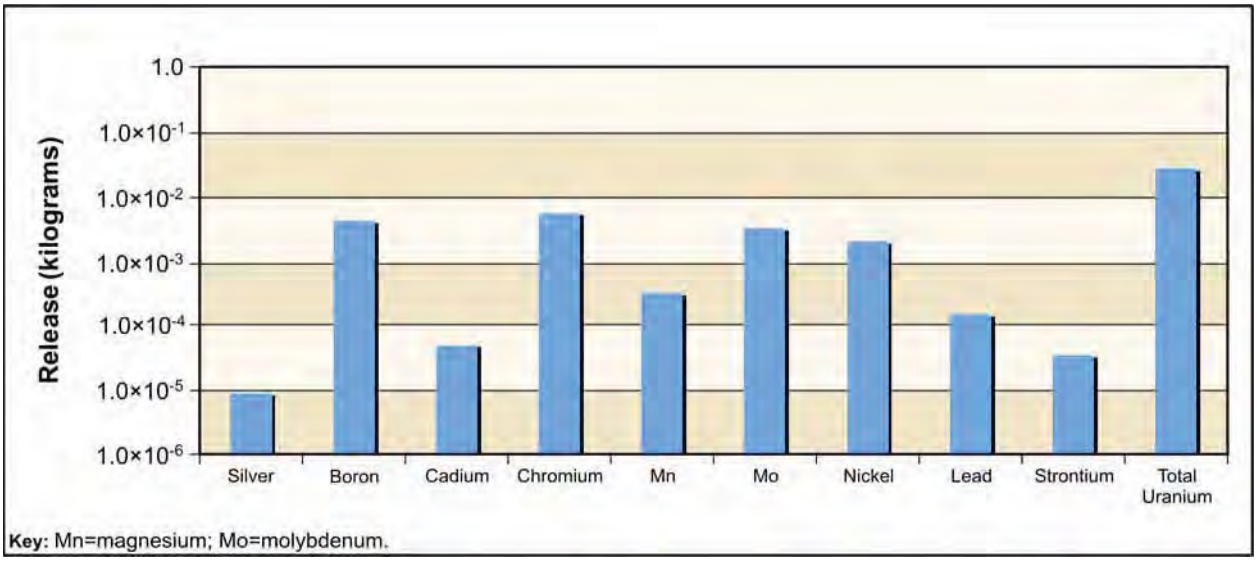


Figure M–43. FFTF Decommissioning Alternative 1 Chemical Releases to Vadose Zone

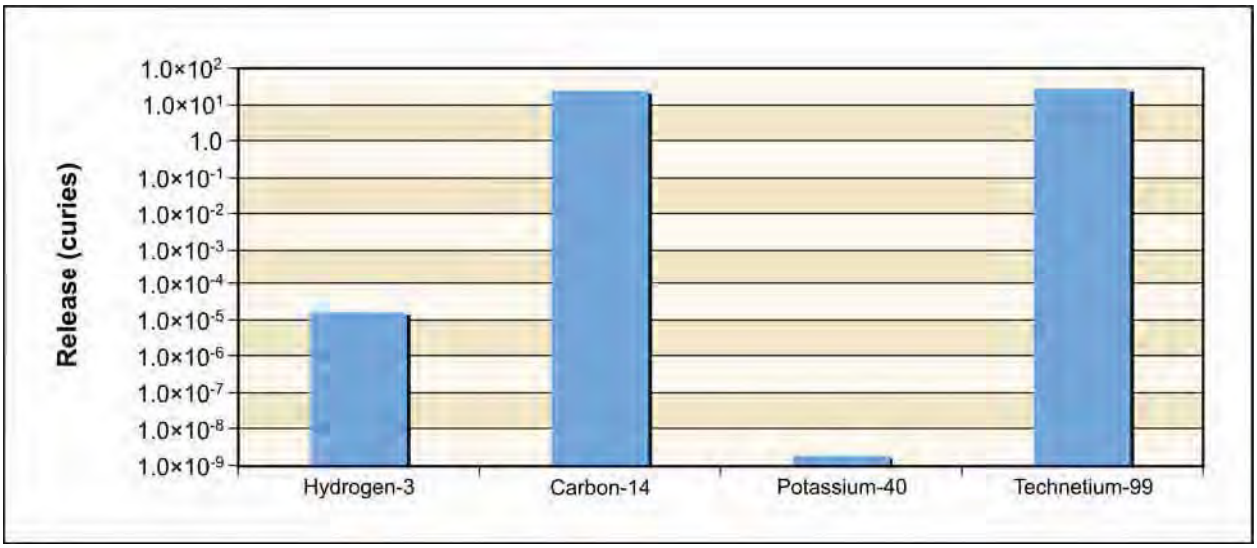


Figure M–44. FFTF Decommissioning Alternative 2 Radiological Releases to Vadose Zone

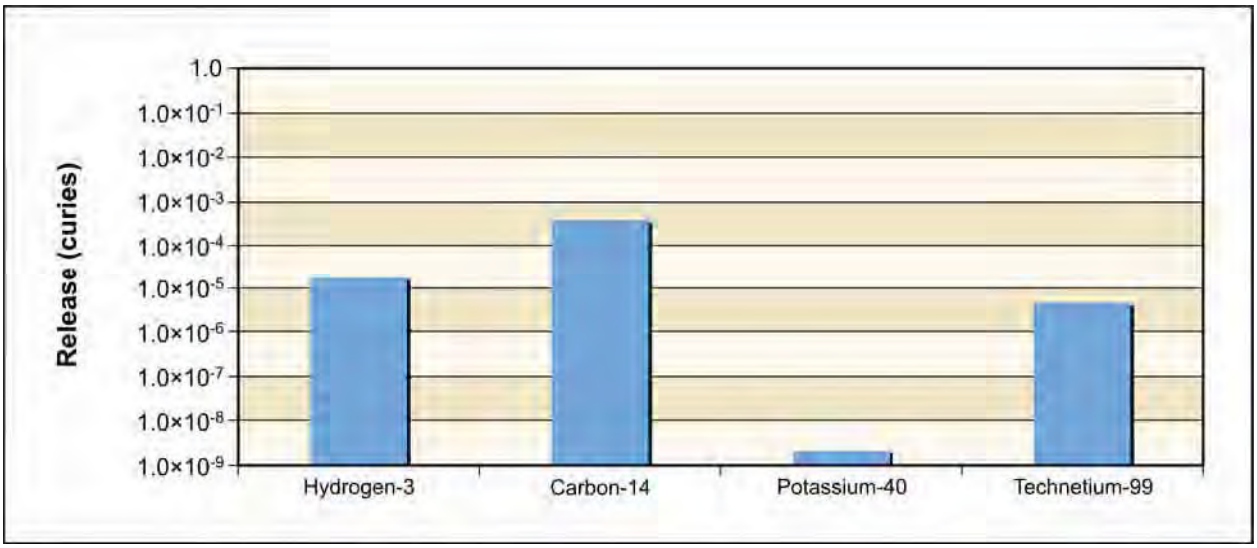


Figure M–45. FFTF Decommissioning Alternative 3 Radiological Releases to Vadose Zone

M.4.3 Waste Management Alternatives

M.4.3.1 Waste Management Alternative 1

Under Waste Management Alternative 1, only the waste currently generated onsite at Hanford from non-CERCLA actions would continue to be disposed of in the LLBG 218-W-5, trenches 31 and 34. Although short-term impacts do not address impacts associated with closure activities for this site, for purposes of analysis for long-term impacts it is assumed that these trenches would be closed using an RCRA-compliant barrier consistent with the closure plans for these burial grounds. As a result, the non-CERCLA waste disposed of in these trenches from 2008 to 2035 would become available for release to the environment. Potential releases to the vadose zone under Waste Management Alternative 1 are indicated in Figures M–46 and M–47.

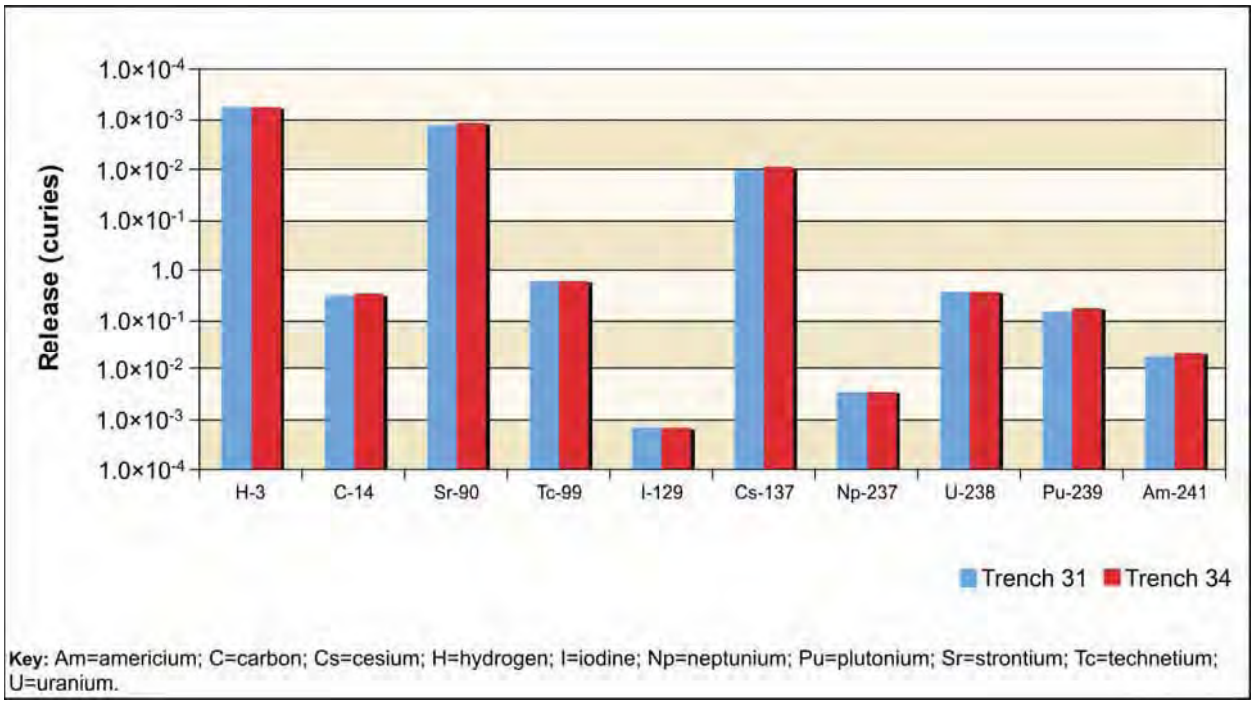


Figure M–46. Waste Management Alternative 1 Radiological Releases to Vadose Zone

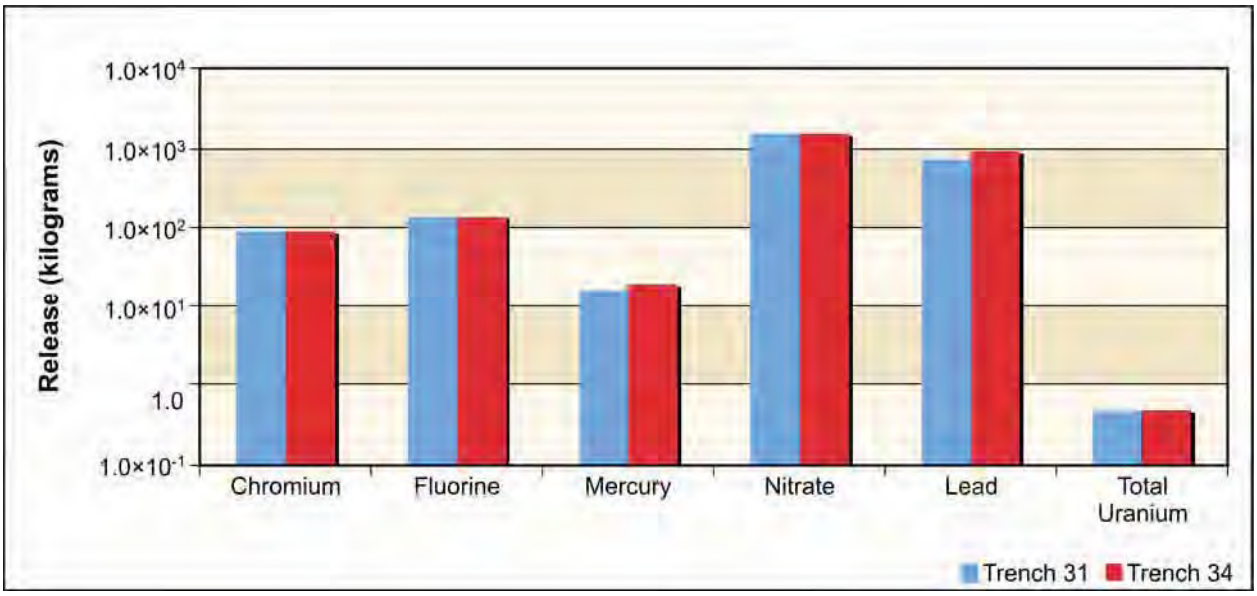


Figure M–47. Waste Management Alternative 1 Chemical Releases to Vadose Zone

M.4.3.2 Waste Management Alternative 2

Under Waste Management Alternative 2, waste from tank treatment operations, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-East. Waste from tank farm cleanup activities would be disposed of in the RPPDF. As a result, the waste disposed of in these two facilities would become available for release to the environment. Because different waste types would result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow for consideration of the different waste types resulting from the Tank Closure alternatives.

M.4.3.2.1 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, are indicated in Figures M–48 and M–49.

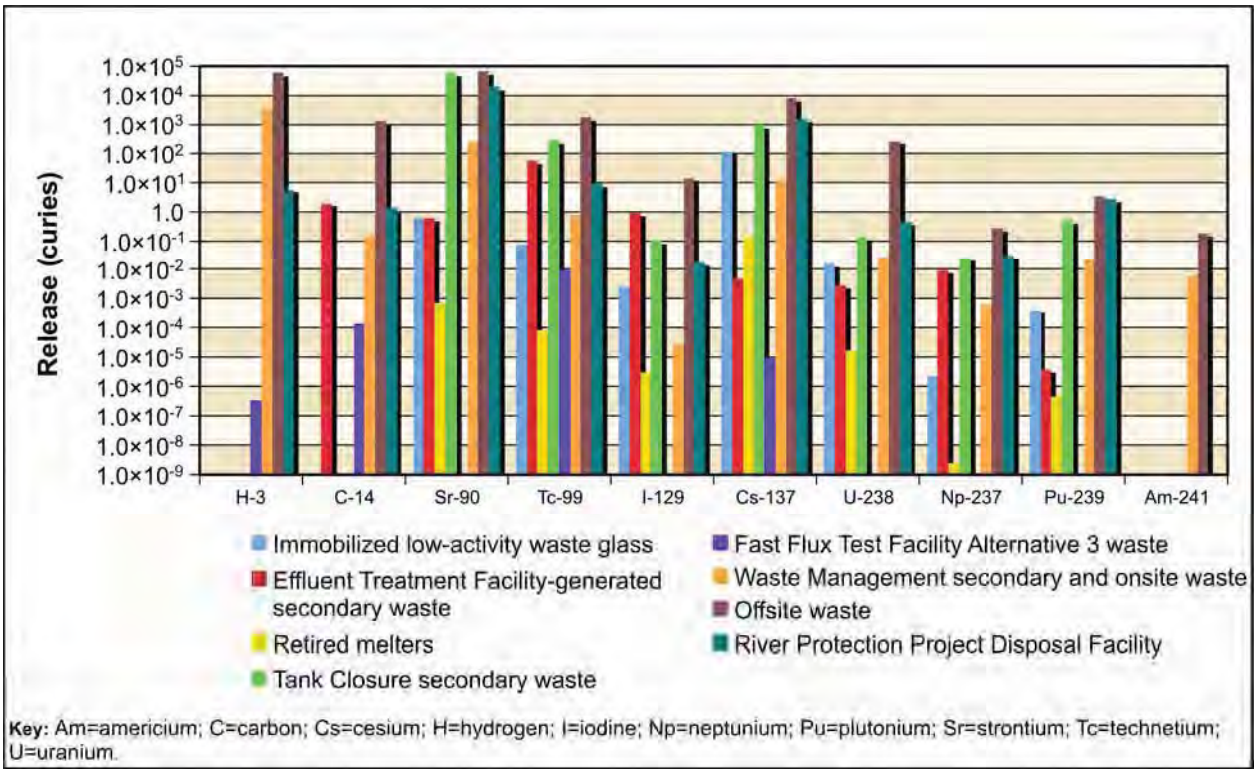


Figure M–48. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases to Vadose Zone

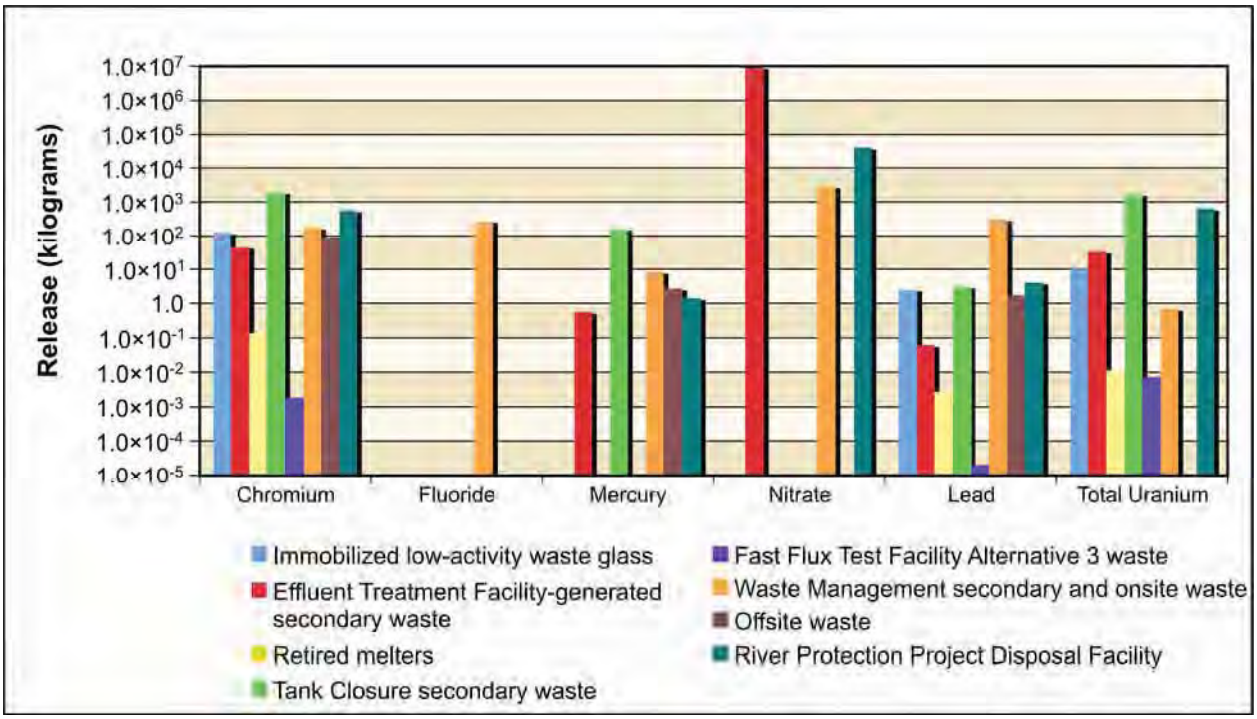


Figure M–49. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases to Vadose Zone

M.4.3.2.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, are indicated in Figures M–50 and M–51.

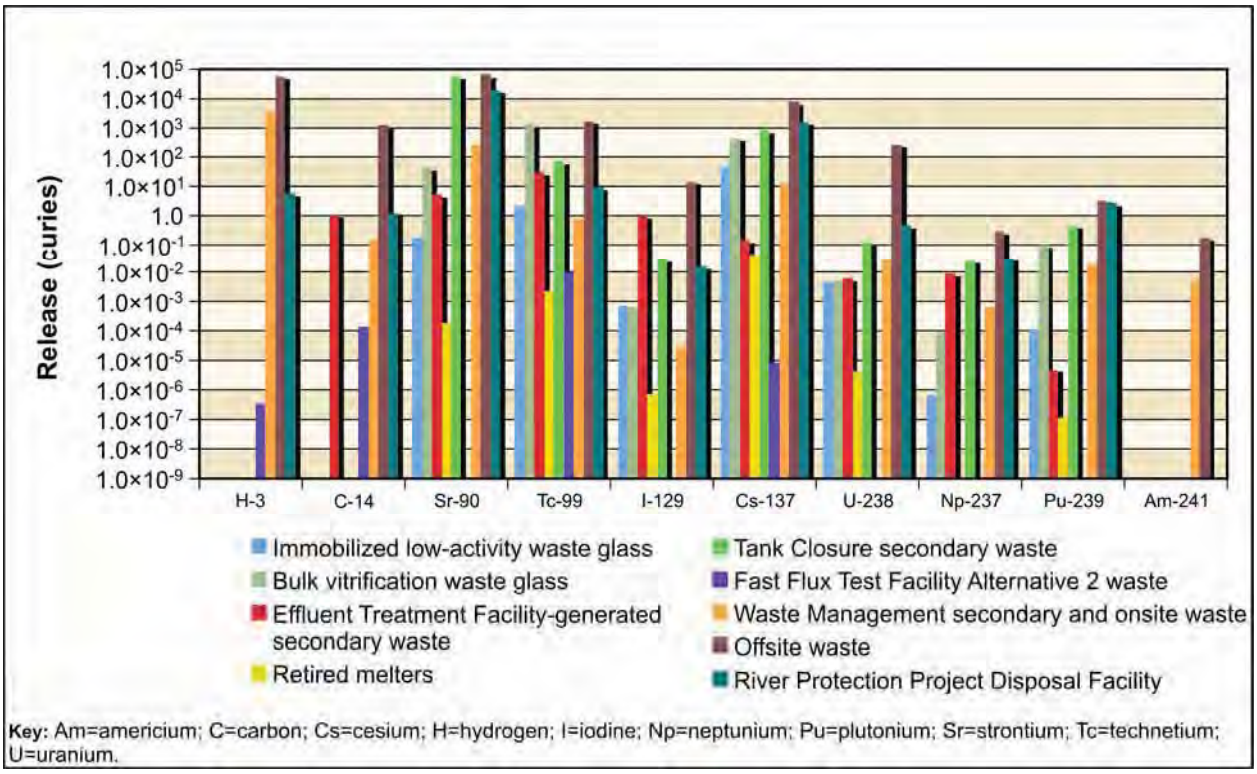


Figure M–50. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases to Vadose Zone

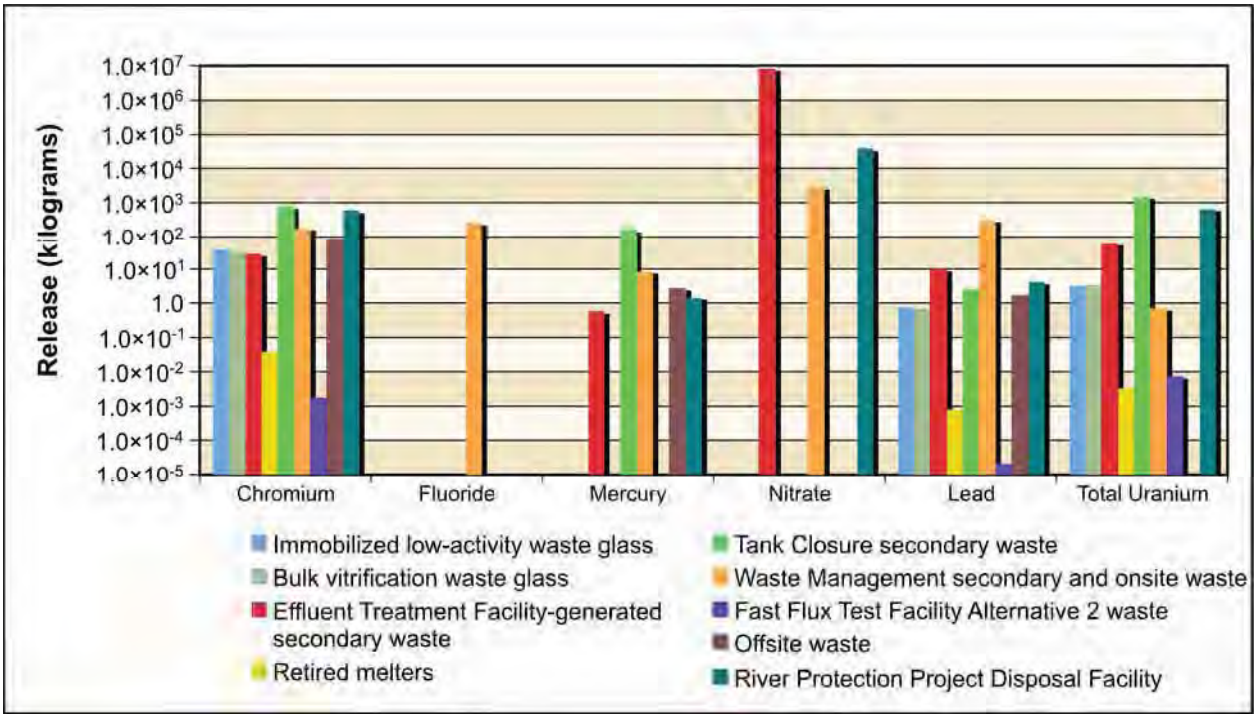


Figure M–51. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases to Vadose Zone

M.4.3.2.3 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, are indicated in Figures M–52 and M–53.

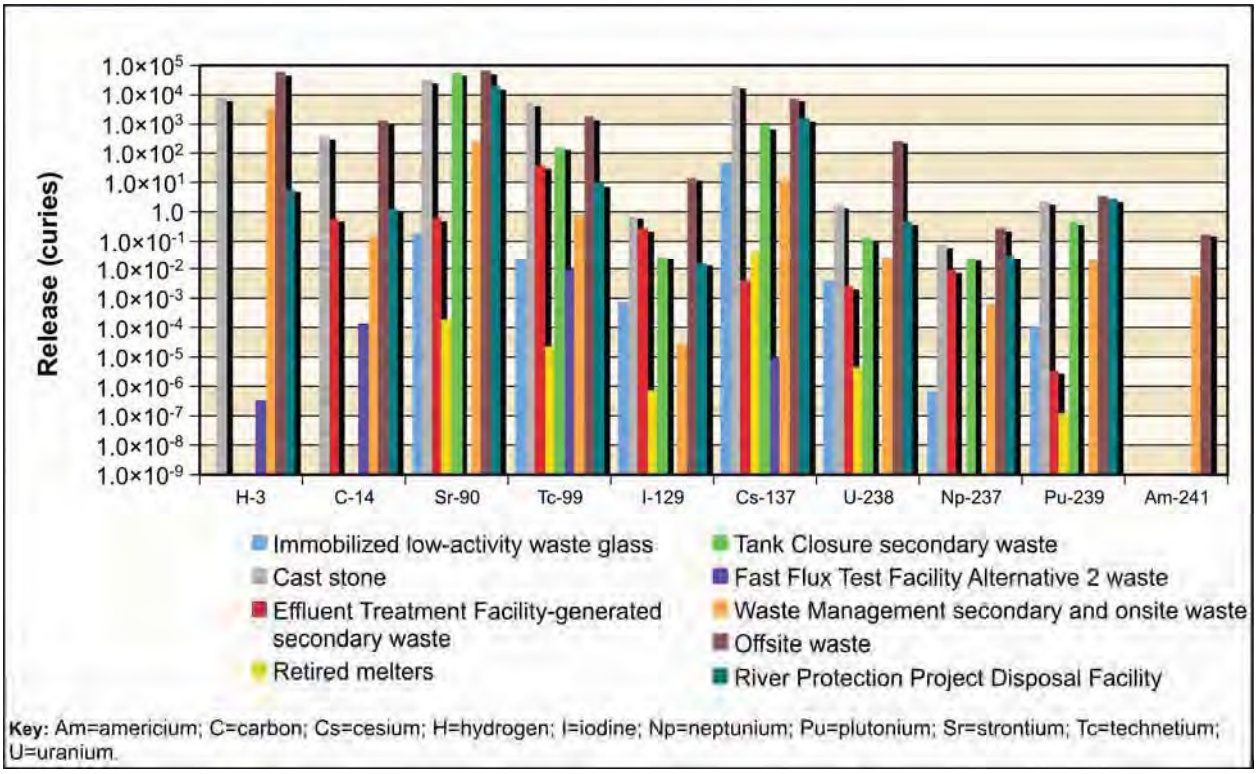


Figure M–52. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases to Vadose Zone

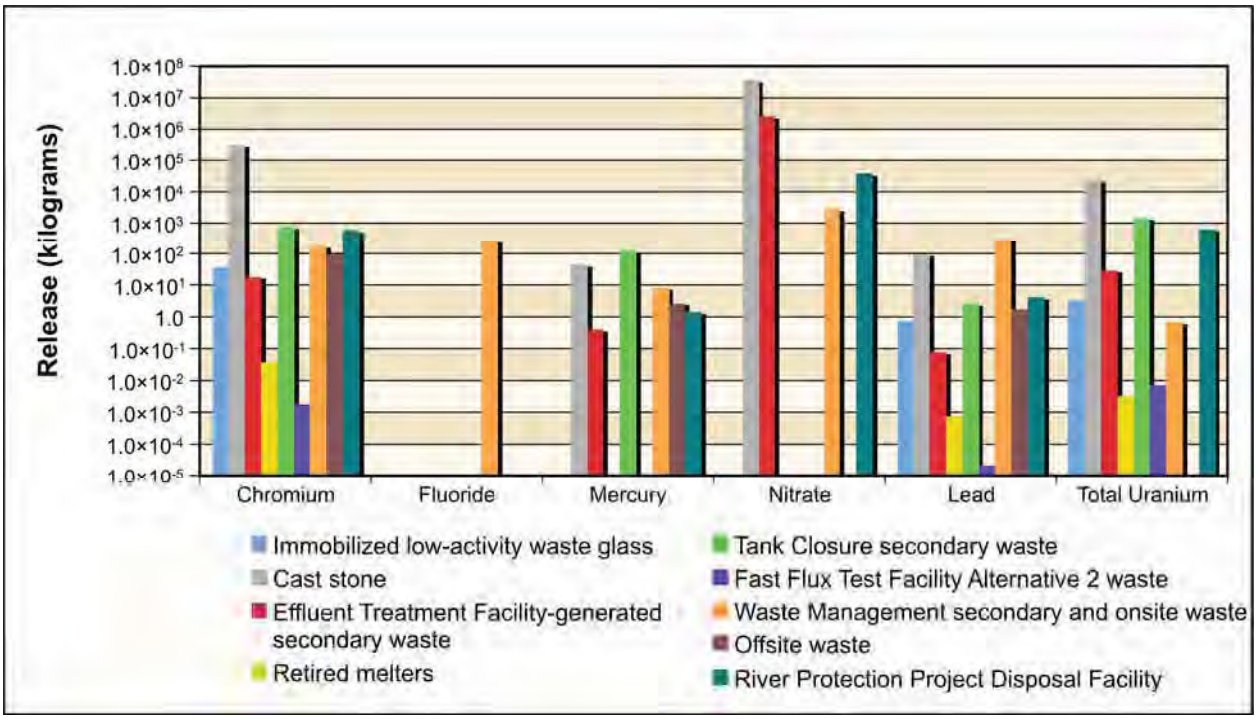


Figure M–53. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases to Vadose Zone

M.4.3.2.4 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, are indicated in Figures M–54 and M–55.

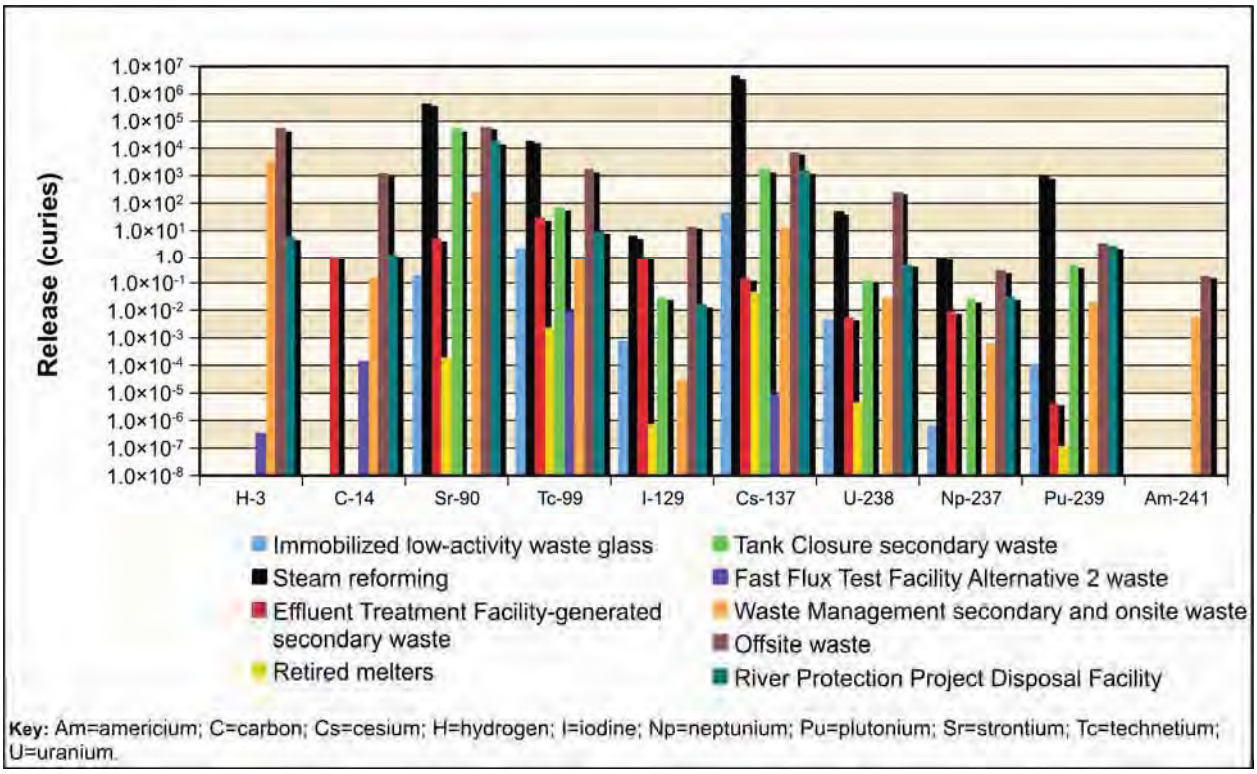


Figure M–54. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases to Vadose Zone

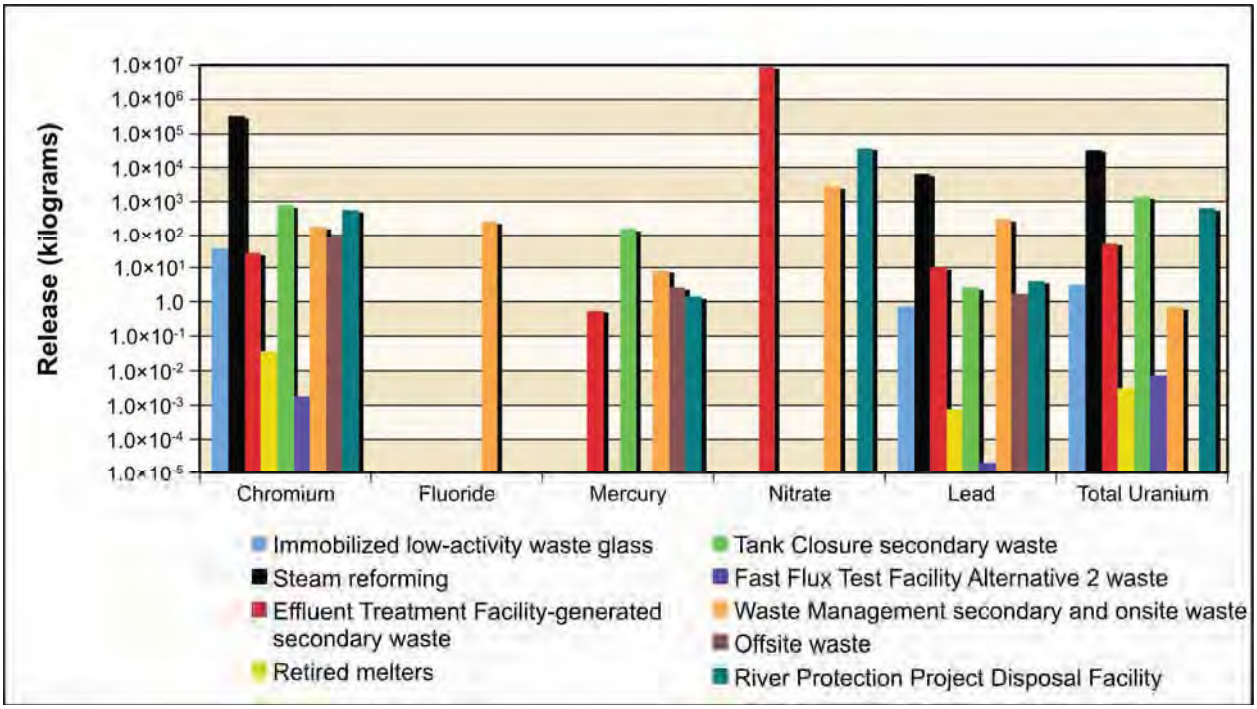


Figure M–55. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases to Vadose Zone

M.4.3.2.5 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 4. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, are indicated in Figures M–56 and M–57.

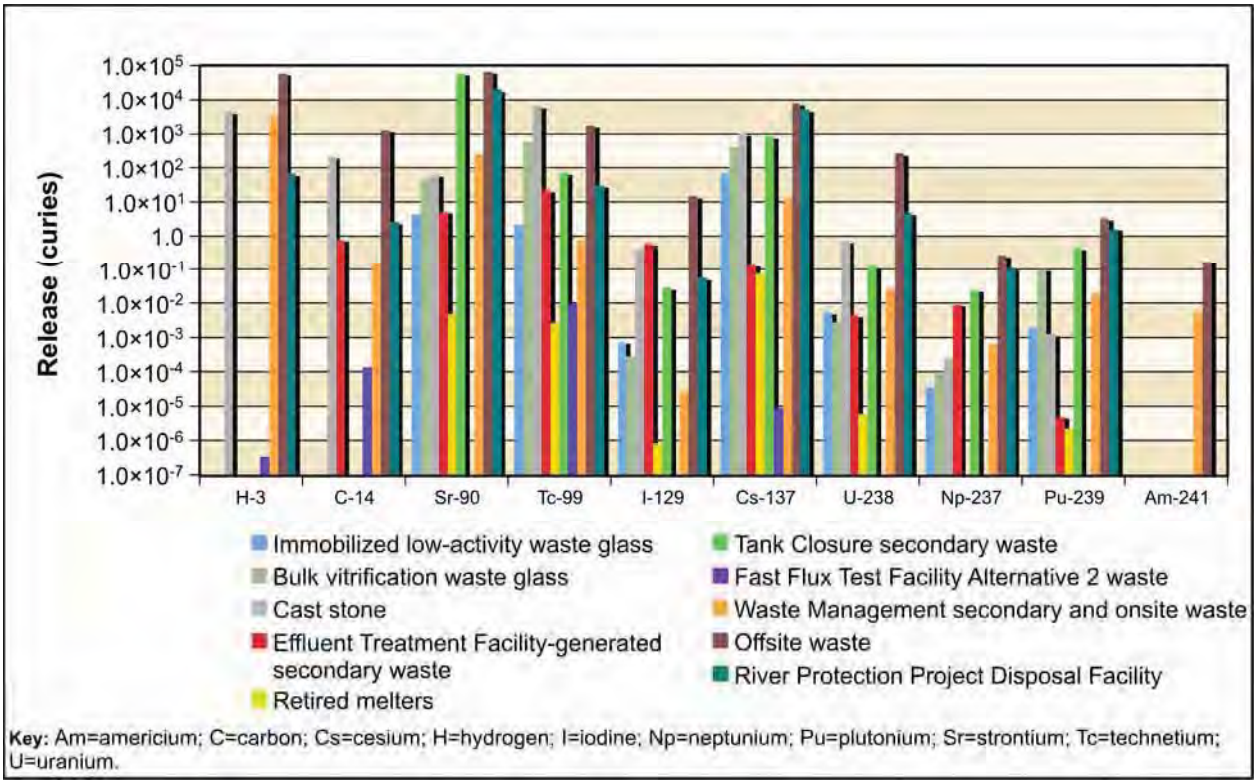


Figure M–56. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Releases to Vadose Zone

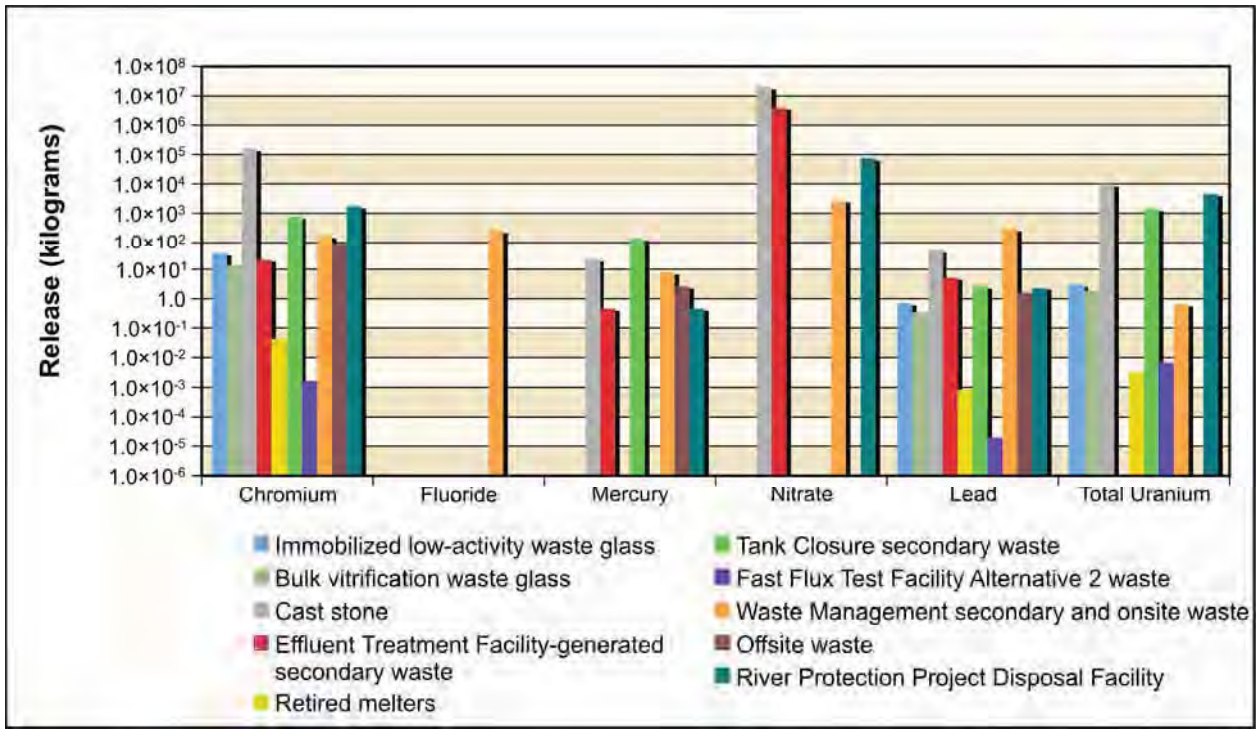


Figure M–57. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Releases to Vadose Zone

M.4.3.2.6 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, are indicated in Figures M–58 and M–59.

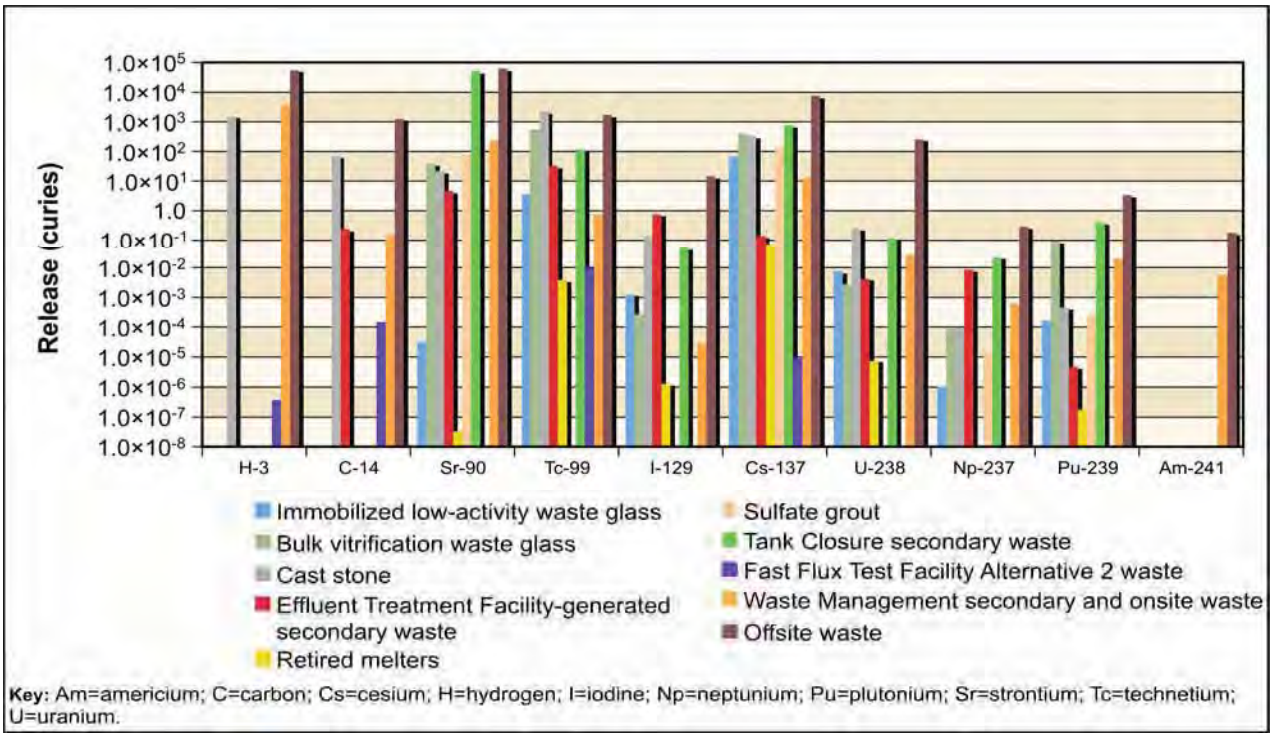


Figure M–58. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Releases to Vadose Zone

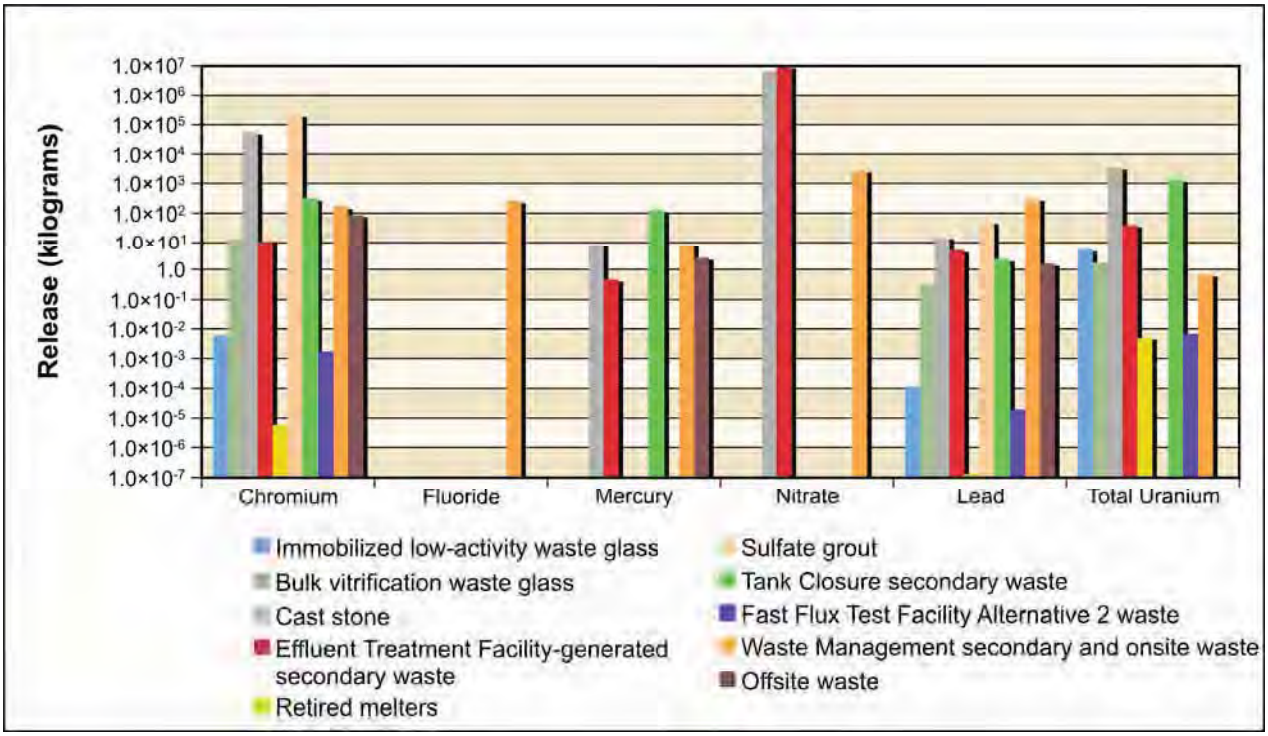


Figure M–59. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases to Vadose Zone

M.4.3.2.7 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, are indicated in Figures M–60 and M–61.

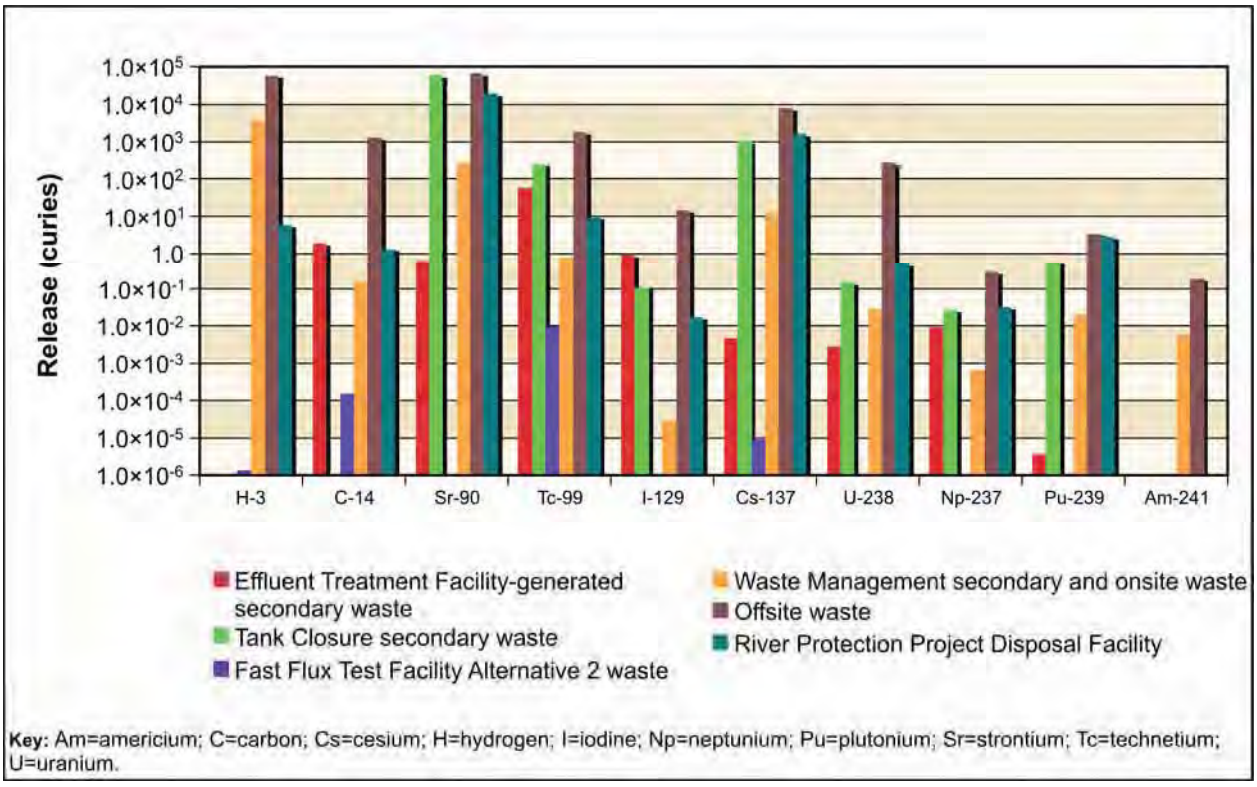


Figure M–60. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases to Vadose Zone

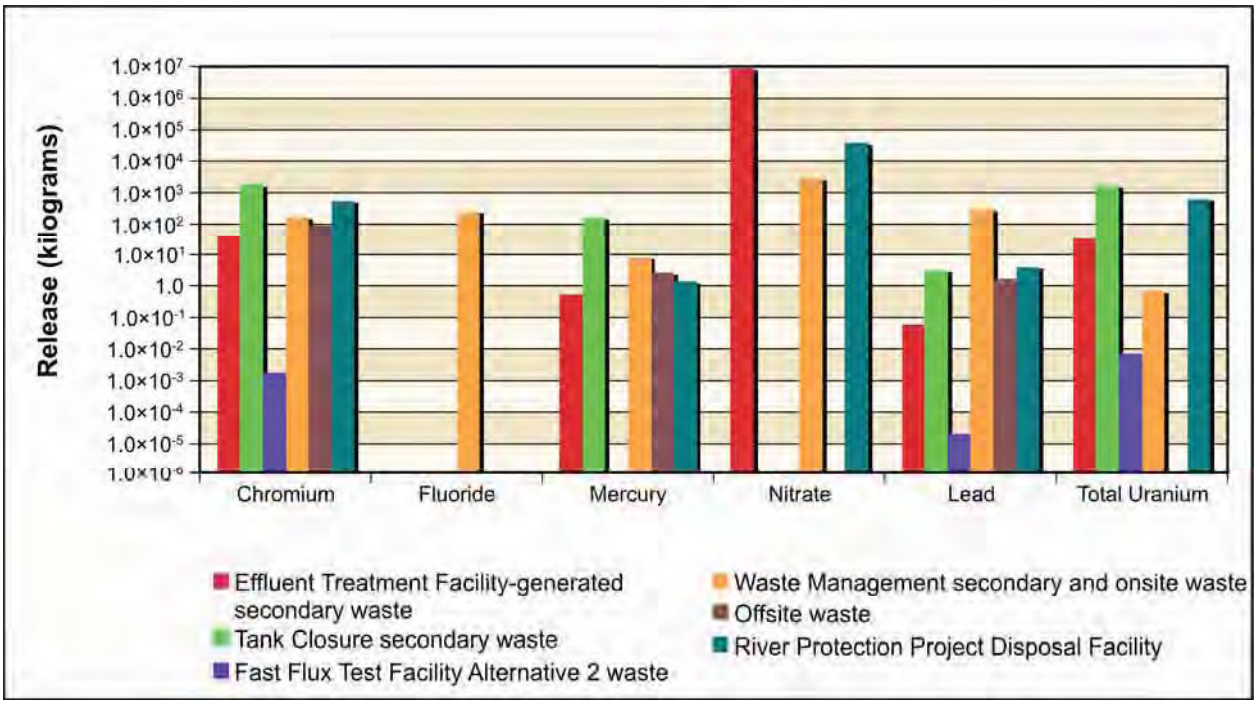


Figure M–61. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to Vadose Zone

M.4.3.2.8 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, are indicated in Figures M–62 and M–63.

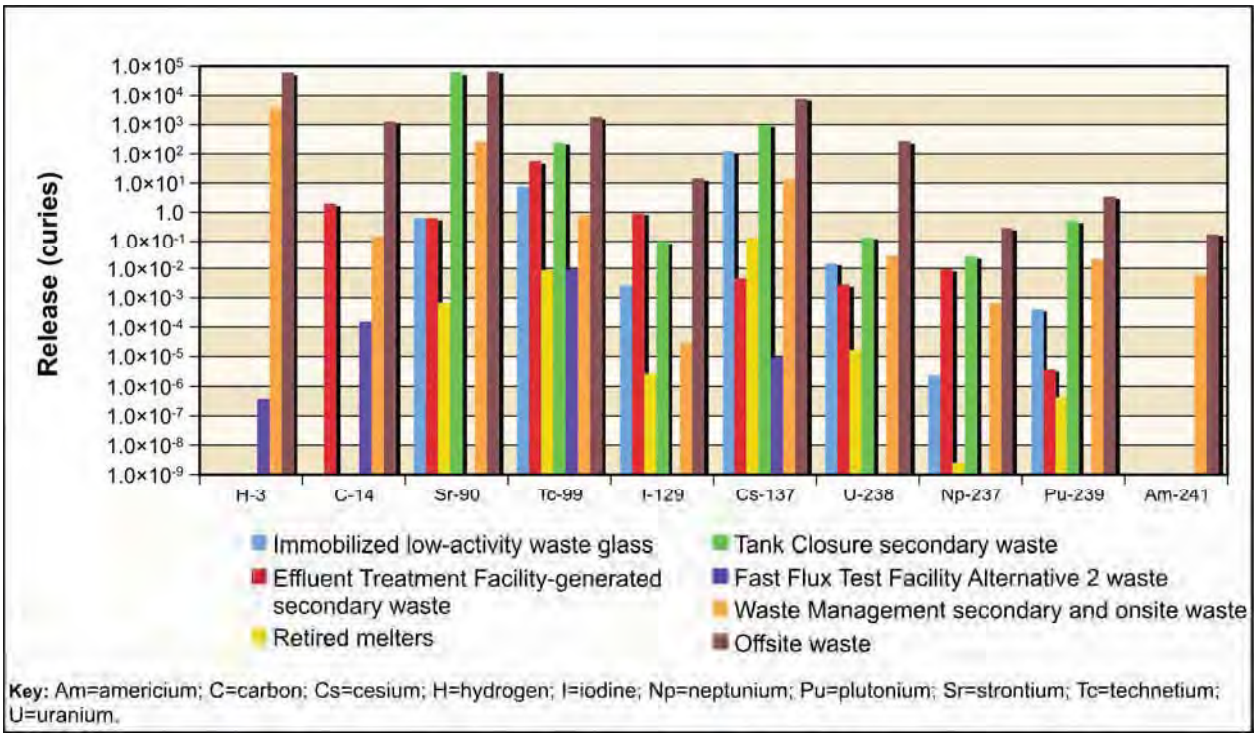


Figure M–62. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Releases to Vadose Zone

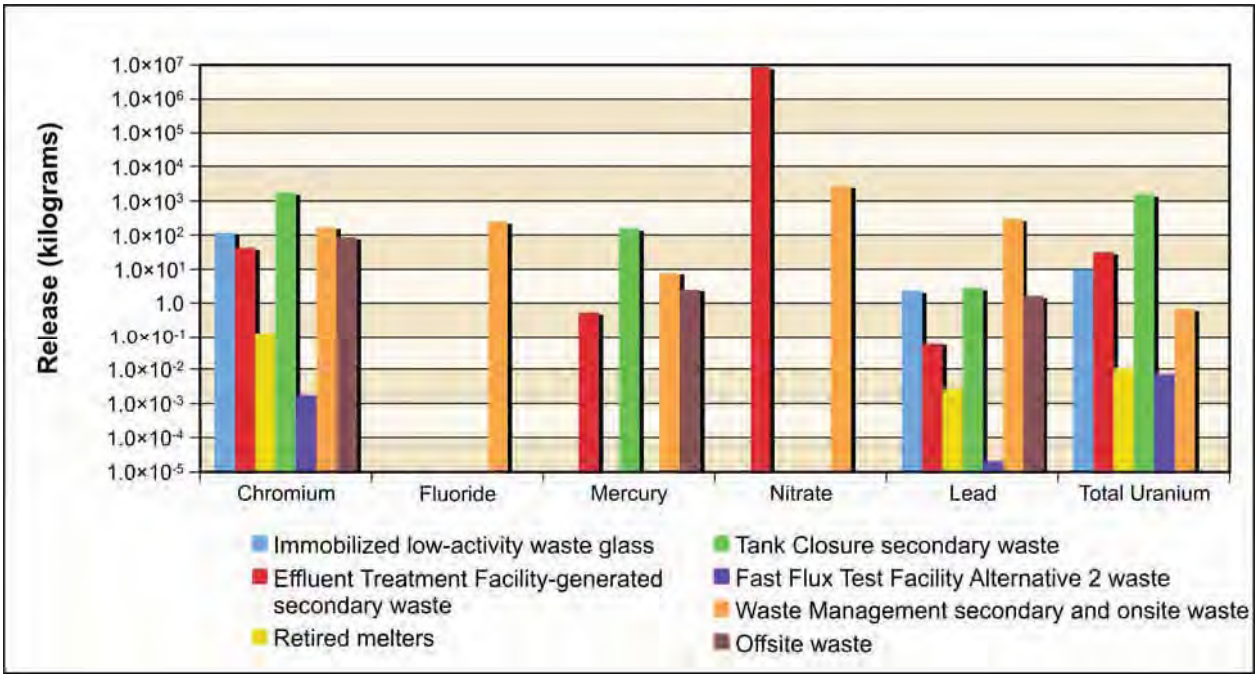


Figure M–63. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases to Vadose Zone

M.4.3.2.9 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- Preprocessing Facility (PPF) glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures M–64 through M–67.

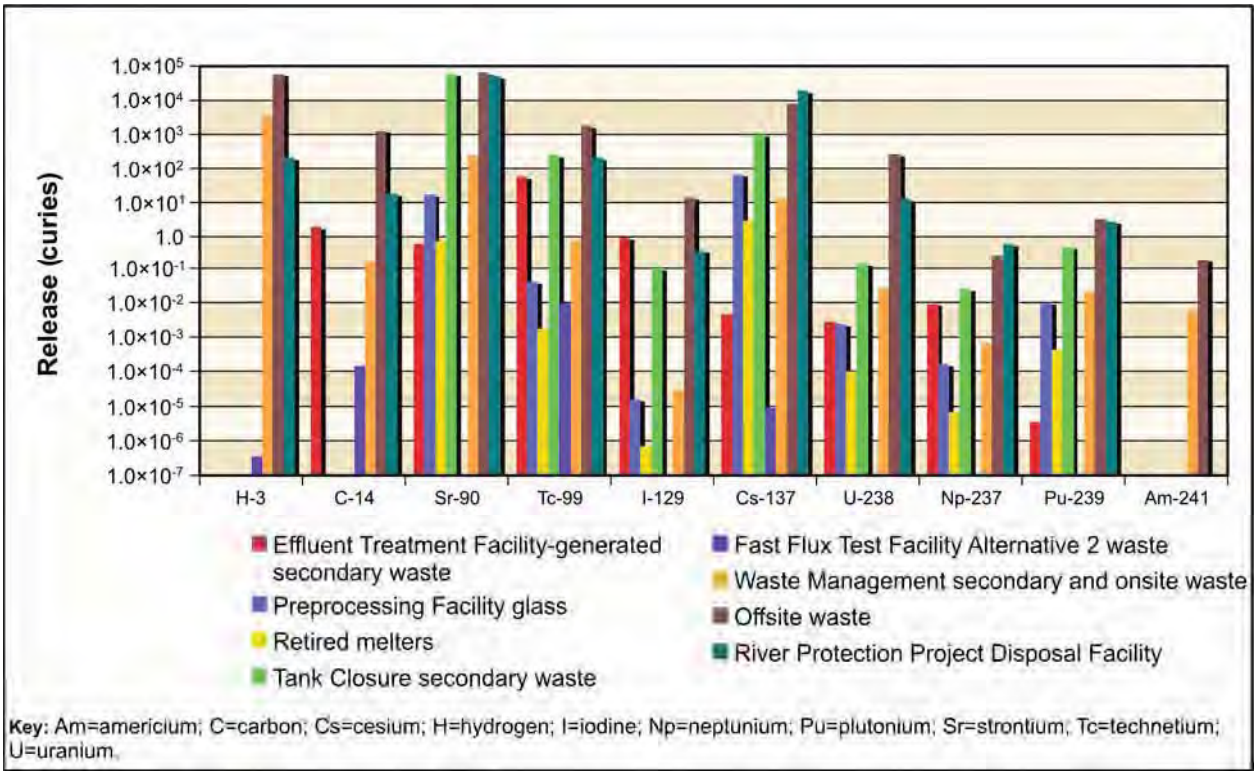


Figure M–64. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases to Vadose Zone

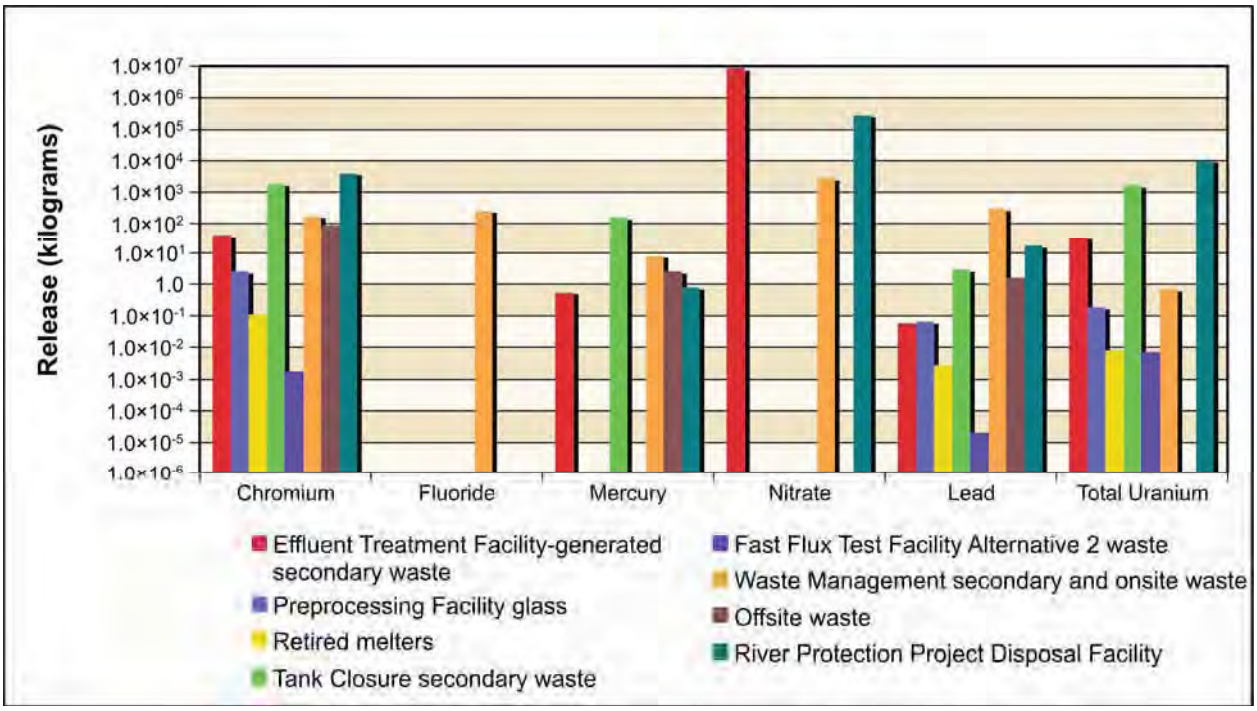


Figure M–65. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases to Vadose Zone

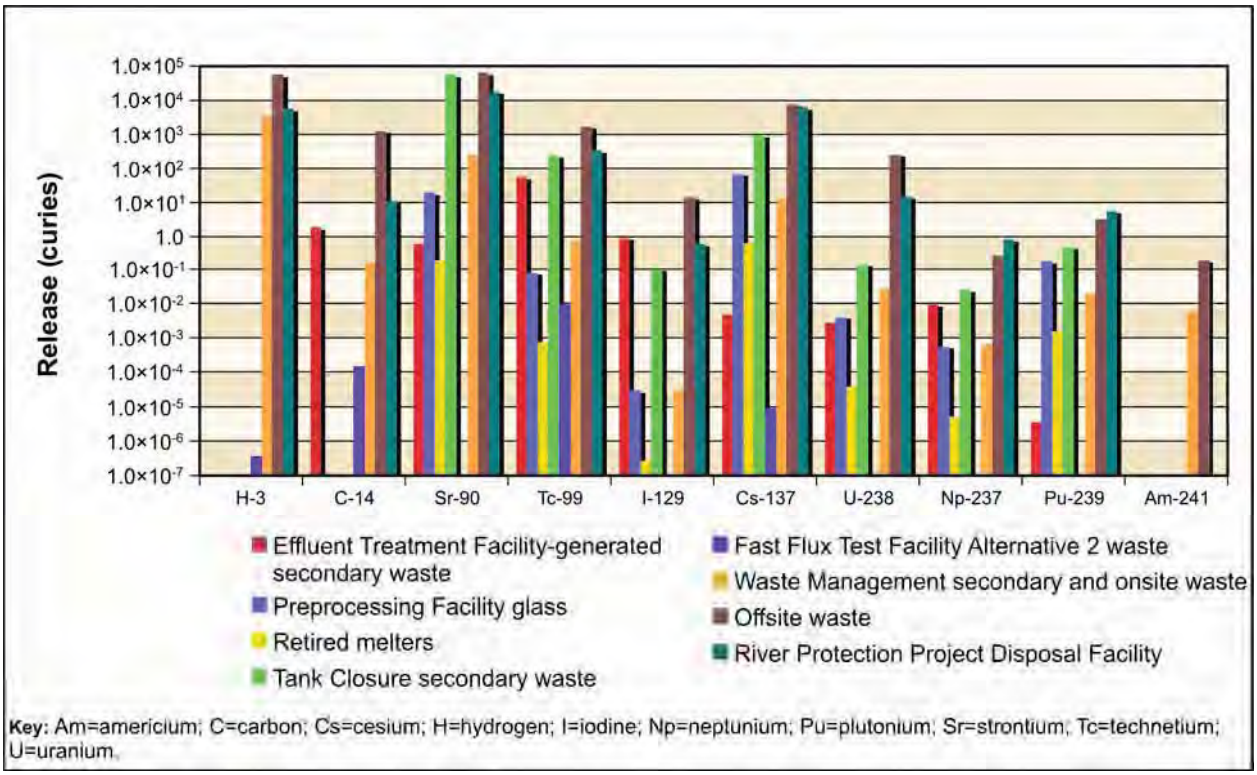


Figure M–66. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases to Vadose Zone

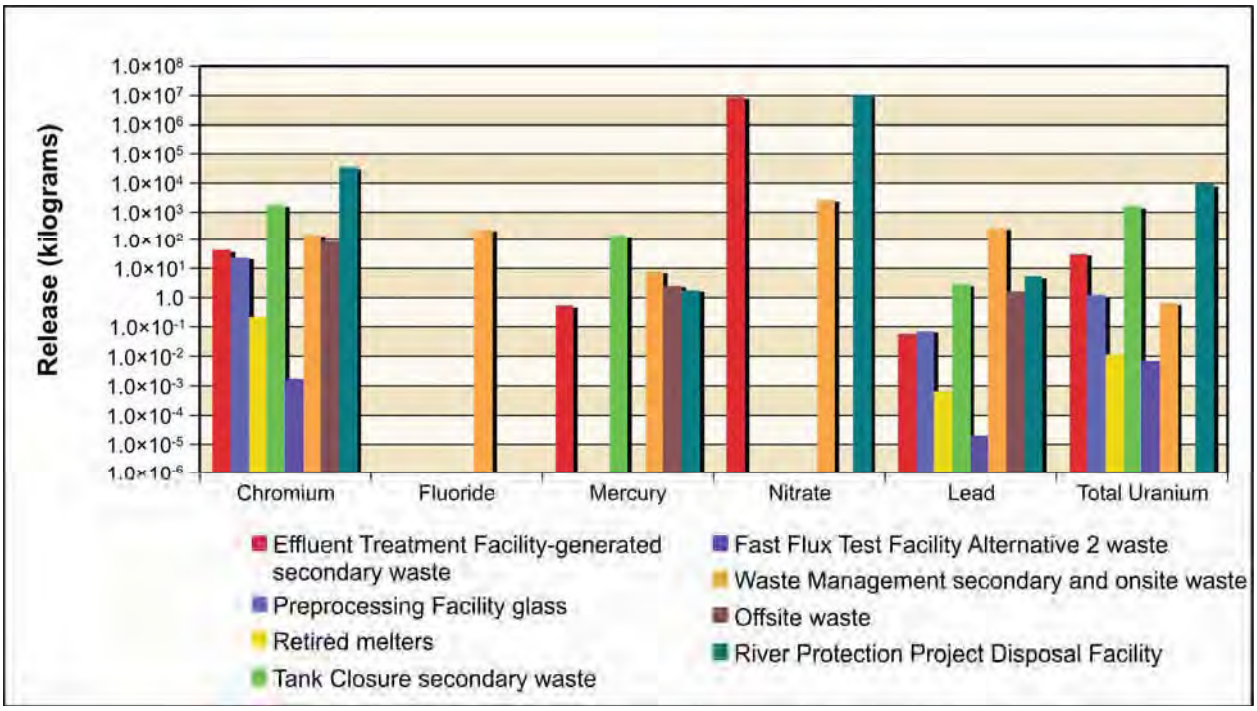


Figure M–67. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases to Vadose Zone

M.4.3.2.10 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 2, Disposal Group 3, Base and Option Cases, are indicated in Figures M–68 through M–71.

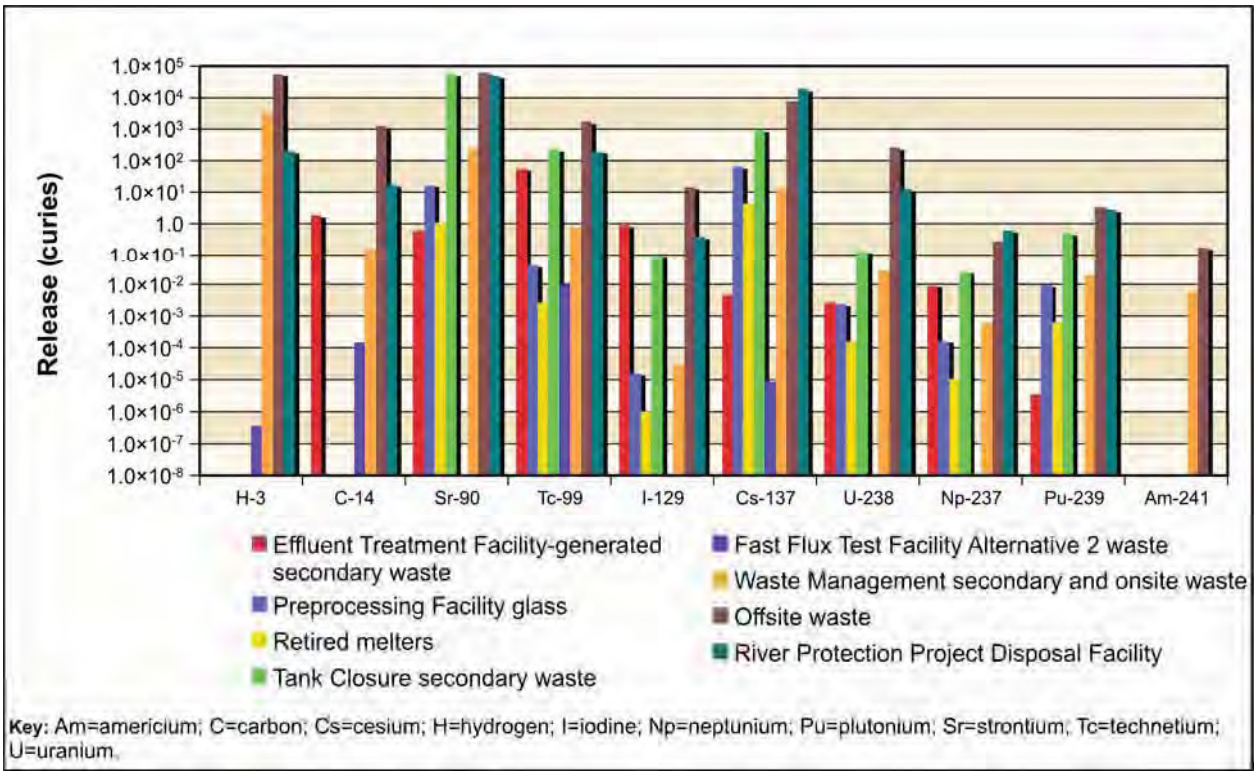


Figure M–68. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases to Vadose Zone

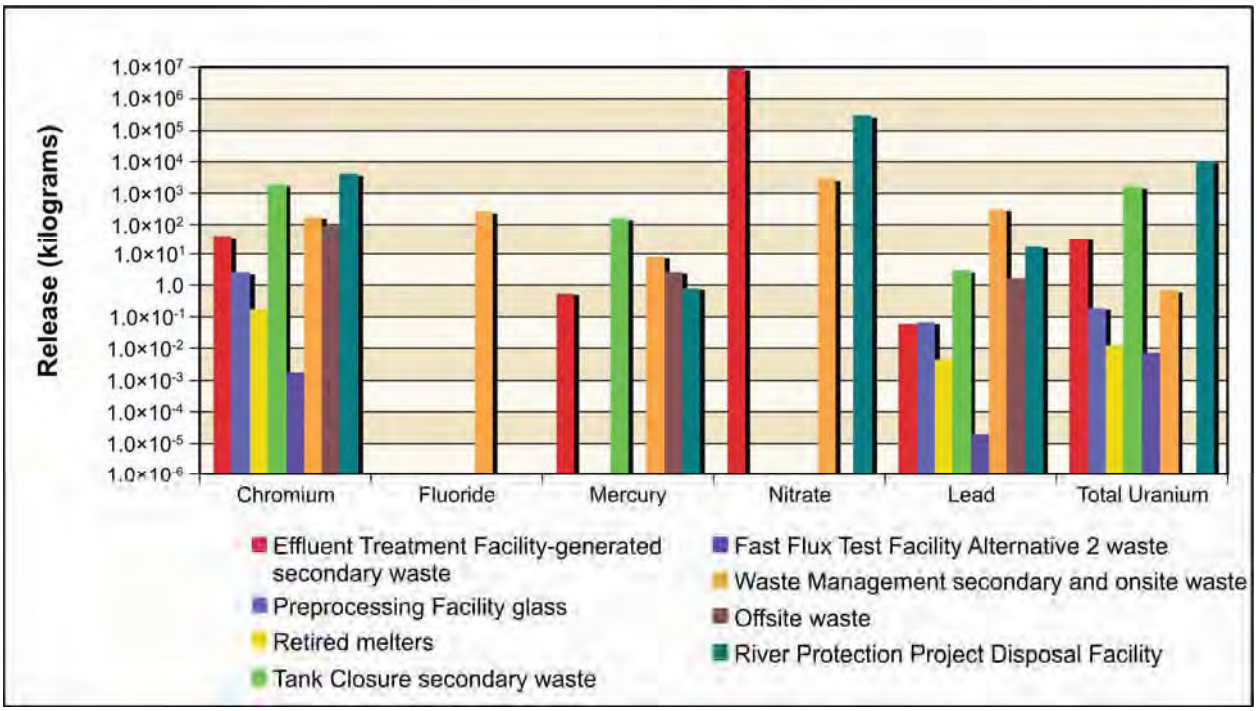


Figure M–69. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases to Vadose Zone

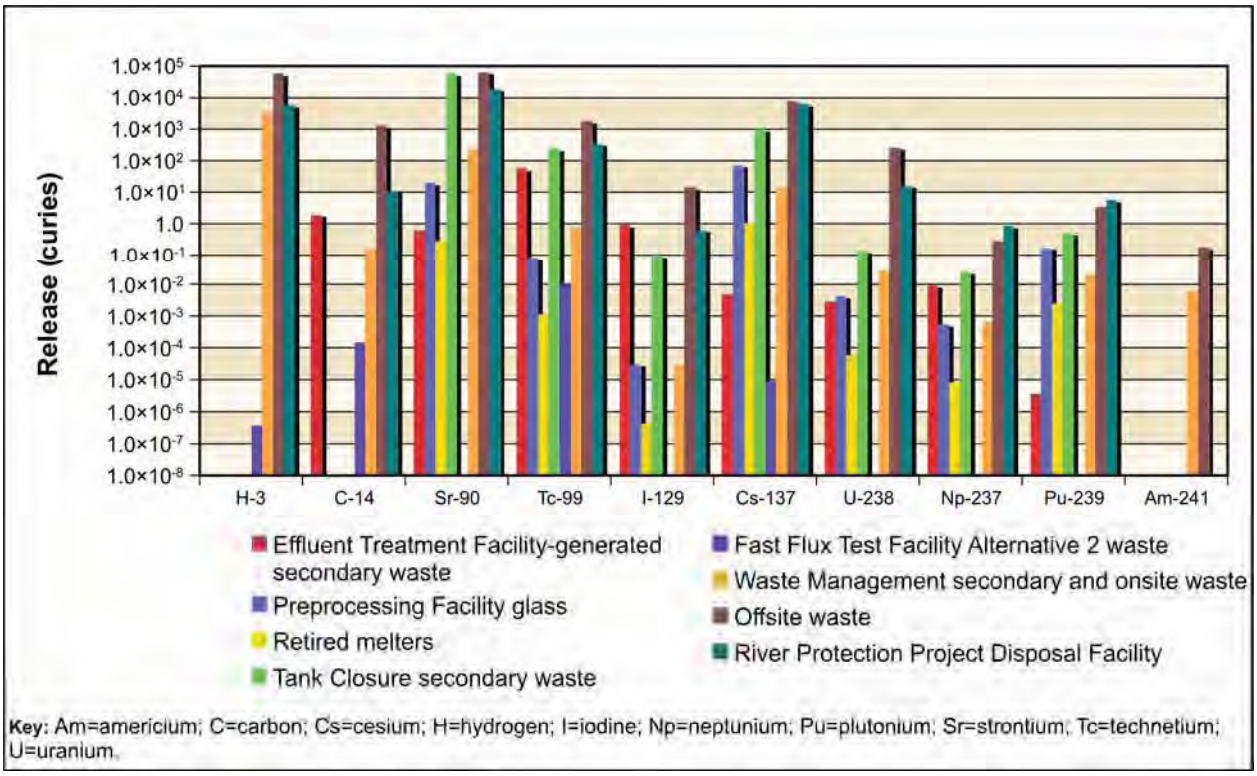


Figure M–70. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases to Vadose Zone

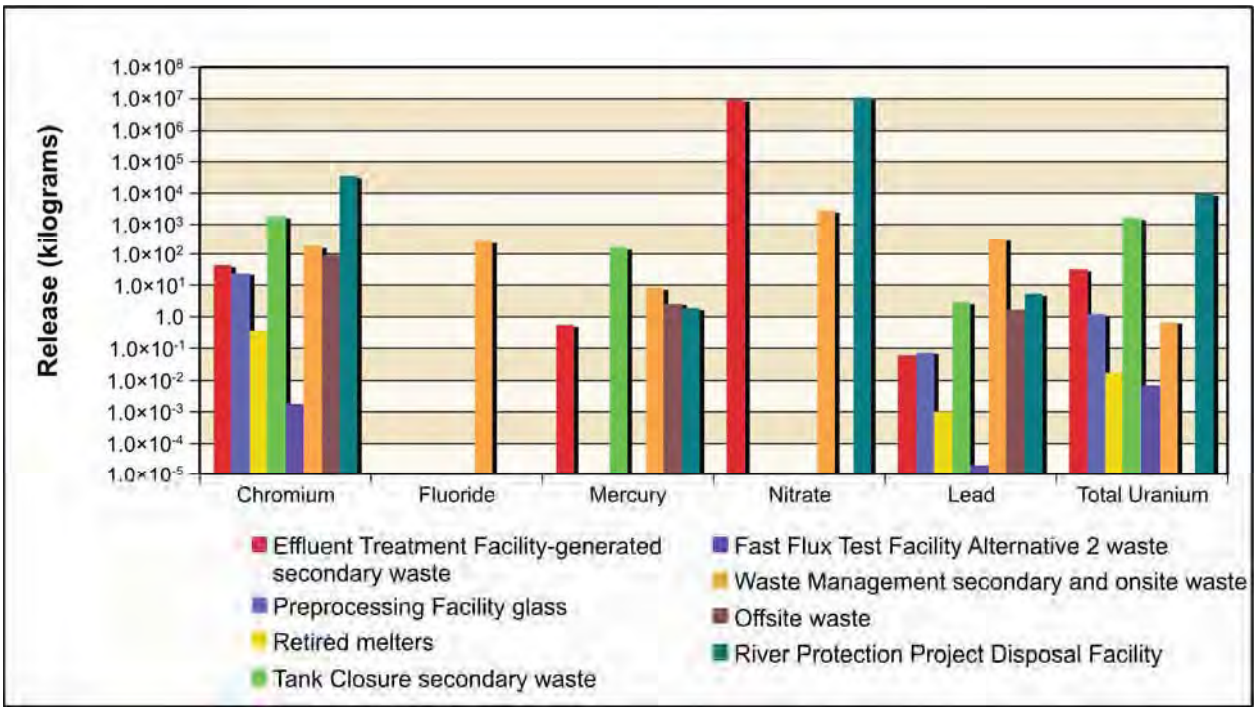


Figure M–71. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases to Vadose Zone

M.4.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas

Under Waste Management Alternative 3, the waste from tank treatment operations would be disposed of in IDF-East, and onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-West. Waste from tank farm cleanup operations would be disposed of in the RPPDF. As a result, the waste disposed of in these three facilities would become available for release to the environment. Because of the different waste types that result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives.

The amount of waste disposed of at IDF-West under each subgroup is identical. Potential releases to the vadose zone from IDF-West under Waste Management Alternative 3 are indicated in Figures M–72 and M–73, only presented once for all disposal groups for Waste Management Alternative 3.

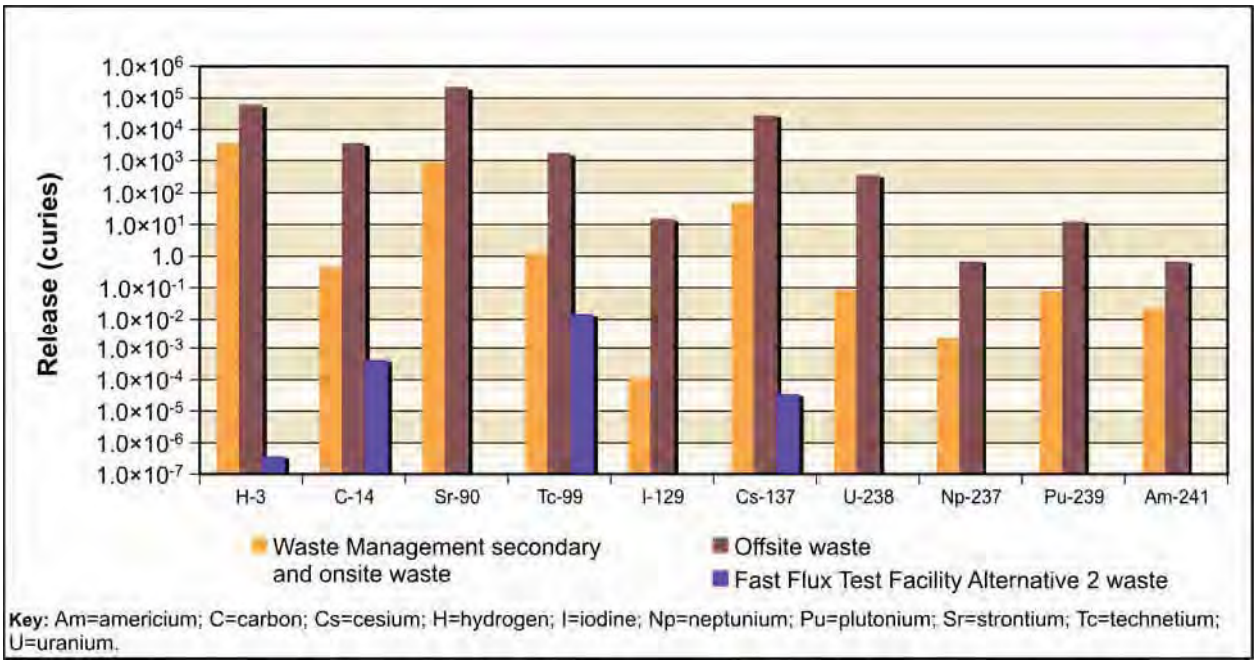


Figure M–72. Waste Management Alternative 3, All Disposal Groups, 200-West Area Integrated Disposal Facility Radiological Releases to Vadose Zone

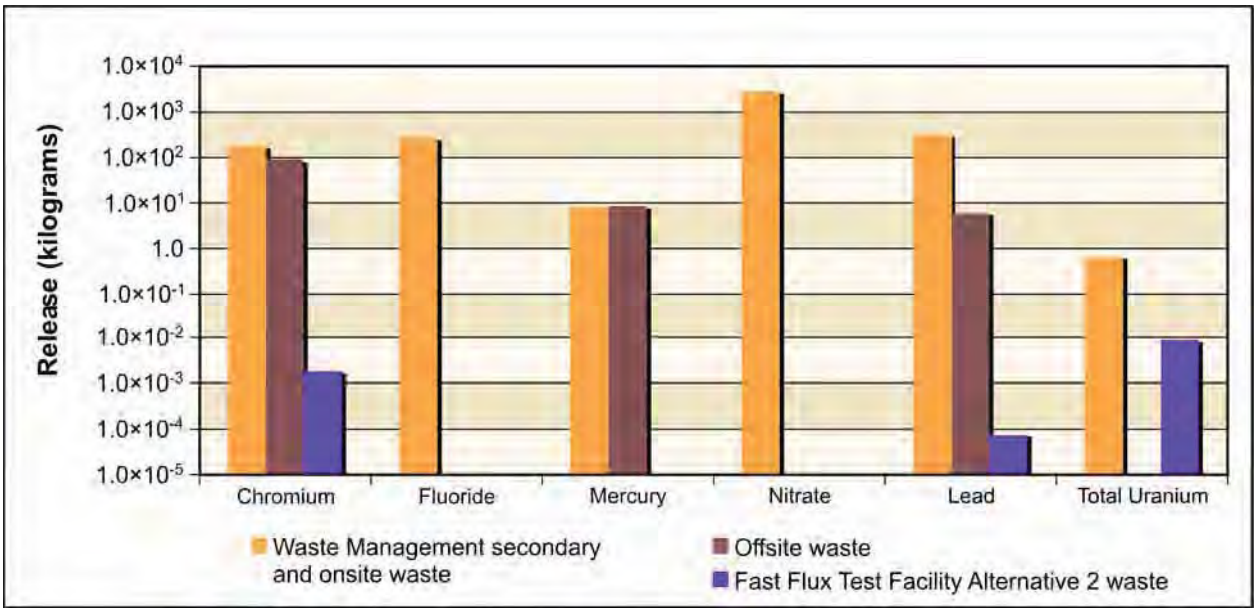


Figure M–73. Waste Management Alternative 3, All Disposal Groups, 200-West Area Integrated Disposal Facility Chemical Releases to Vadose Zone

Potential releases from IDF-East and RPPDF are discussed in the following sections.

M.4.3.3.1 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, are indicated in Figures M–74 and M–75.

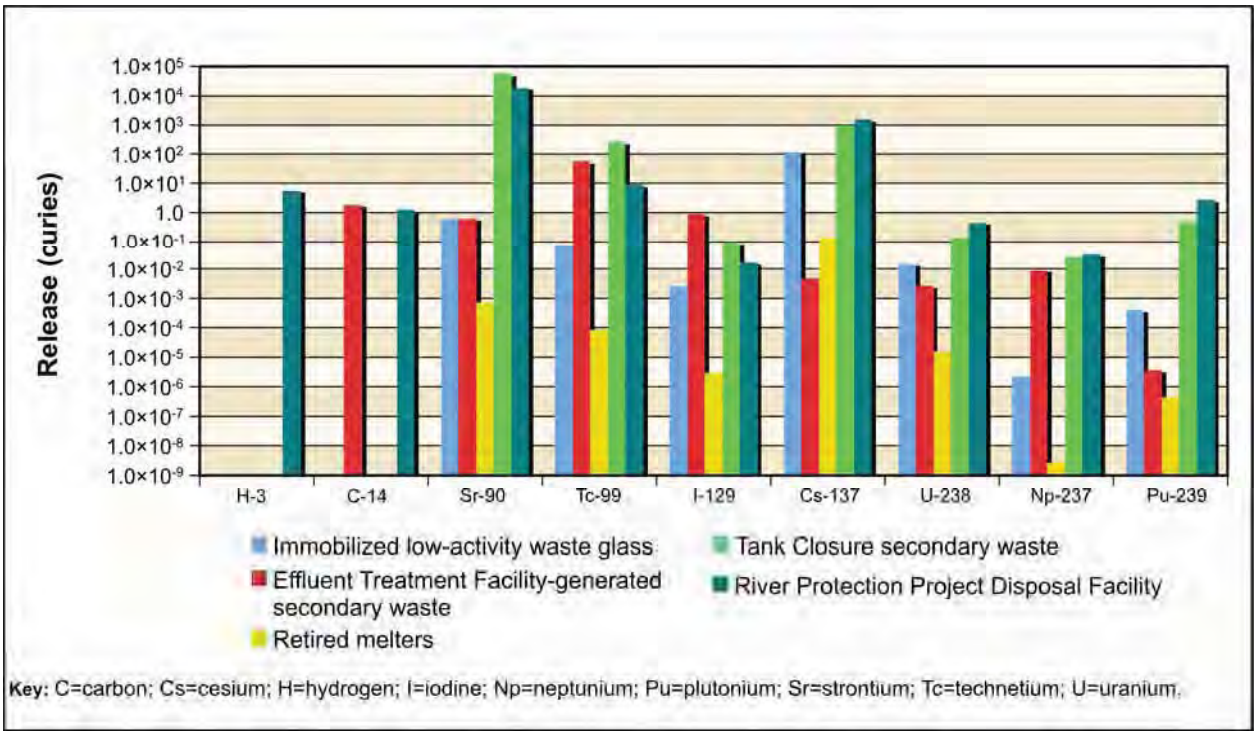


Figure M–74. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

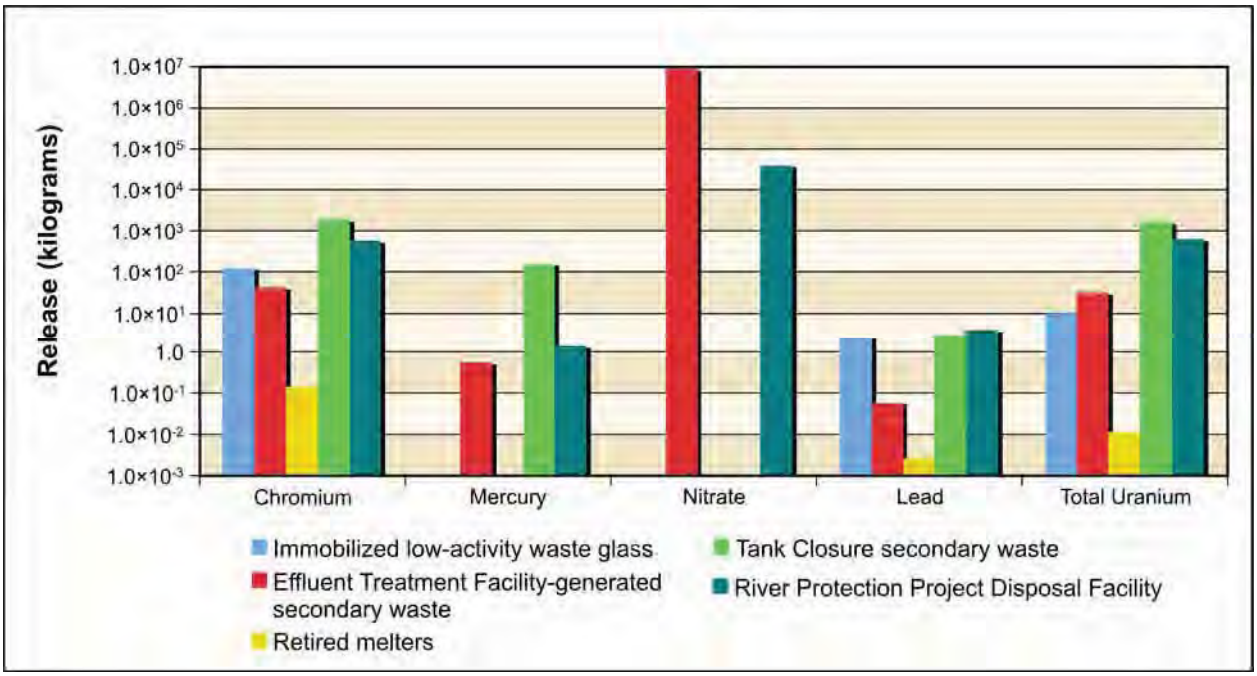


Figure M–75. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.2 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, are indicated in Figures M–76 and M–77.

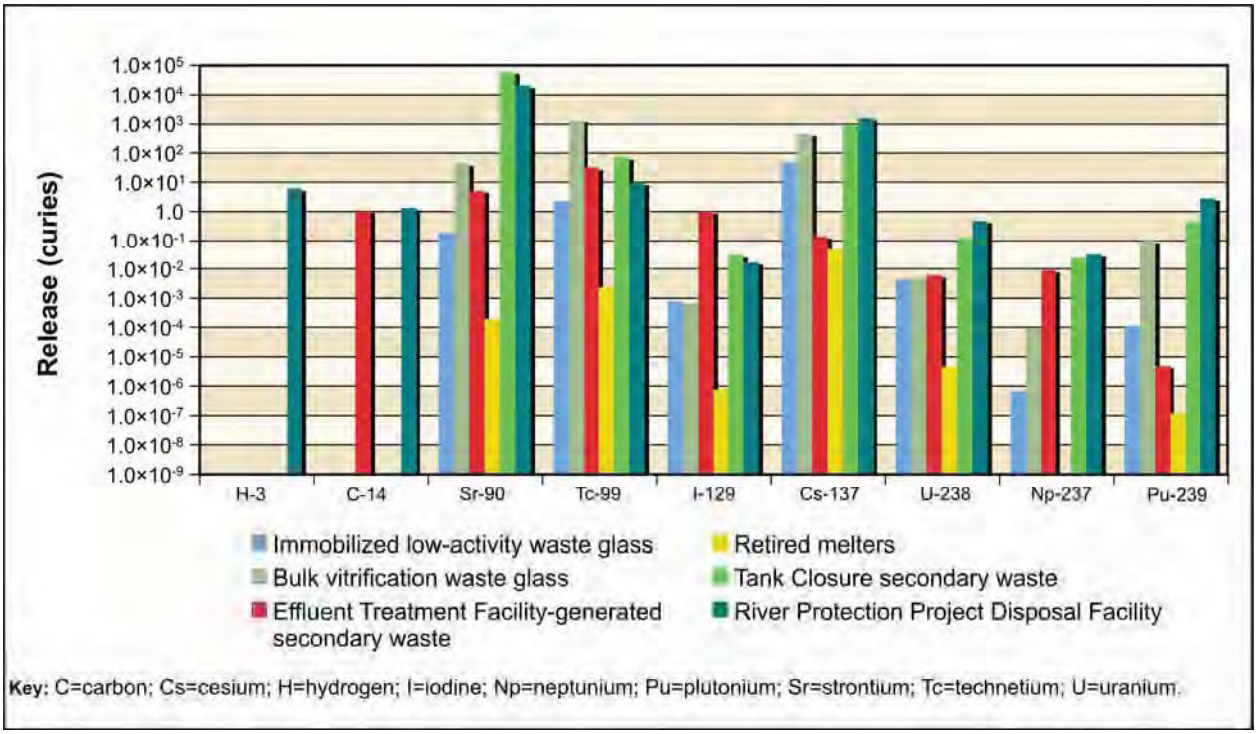


Figure M–76. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

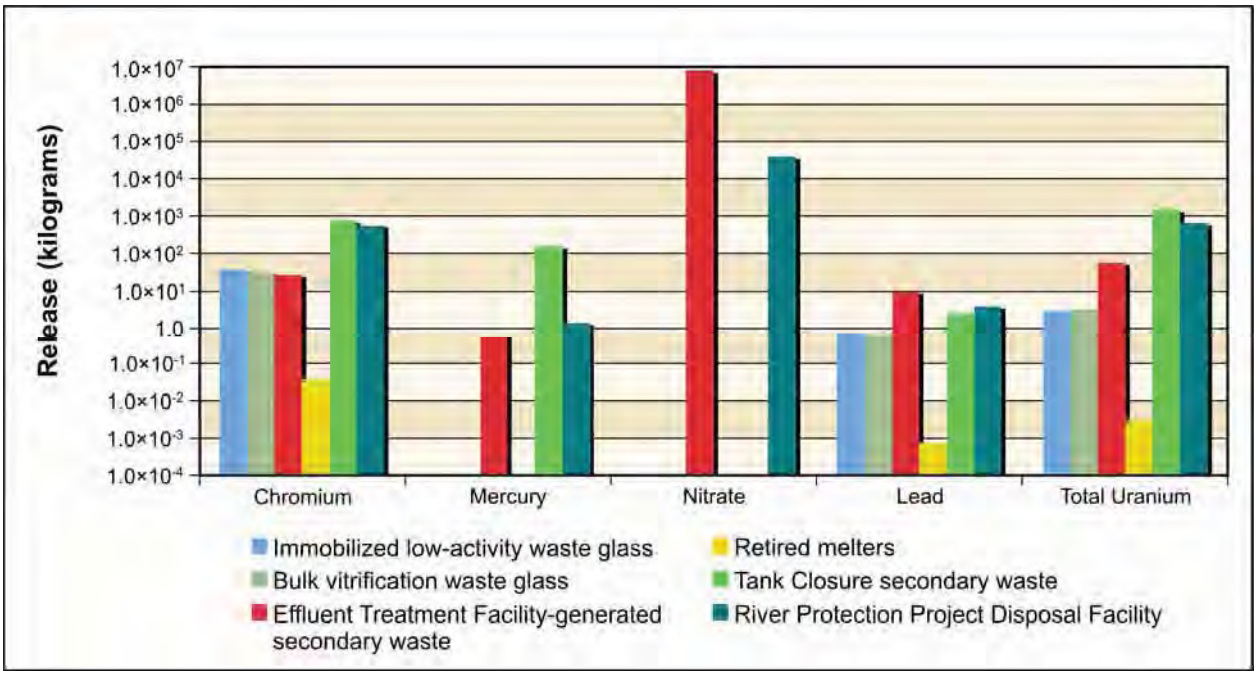


Figure M–77. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, are indicated in Figures M–78 and M–79.

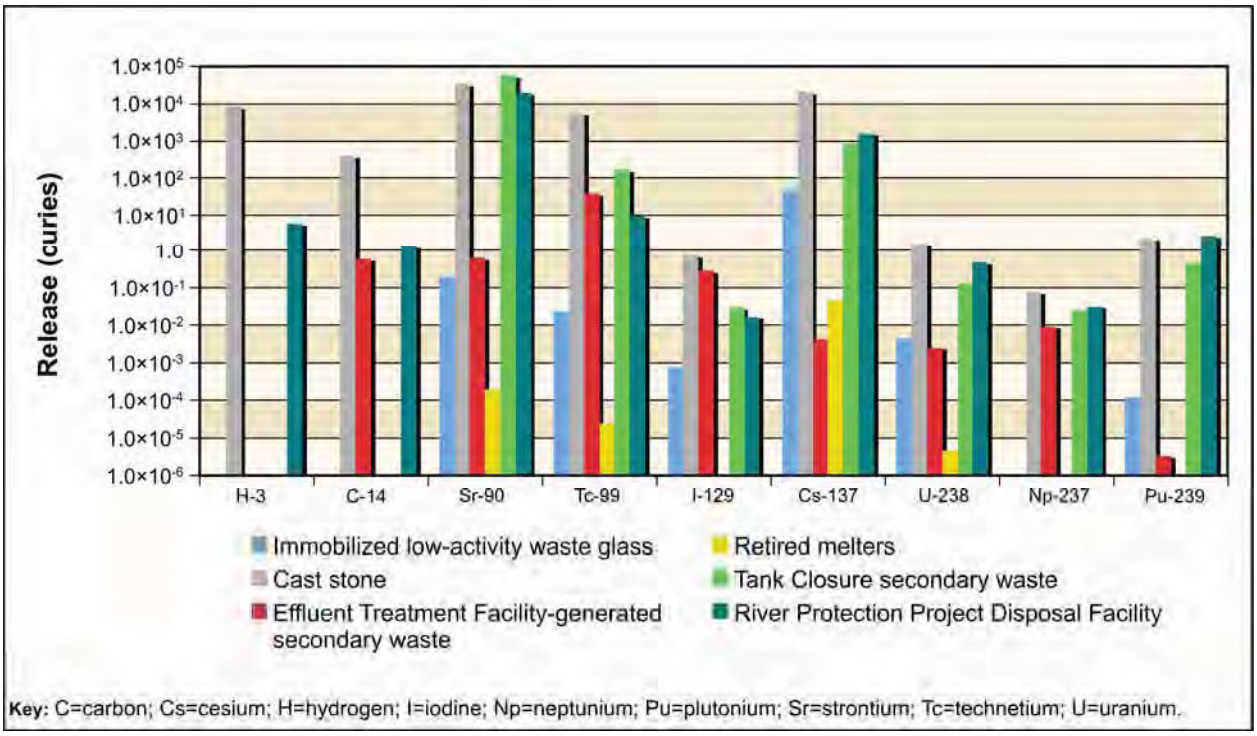


Figure M–78. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

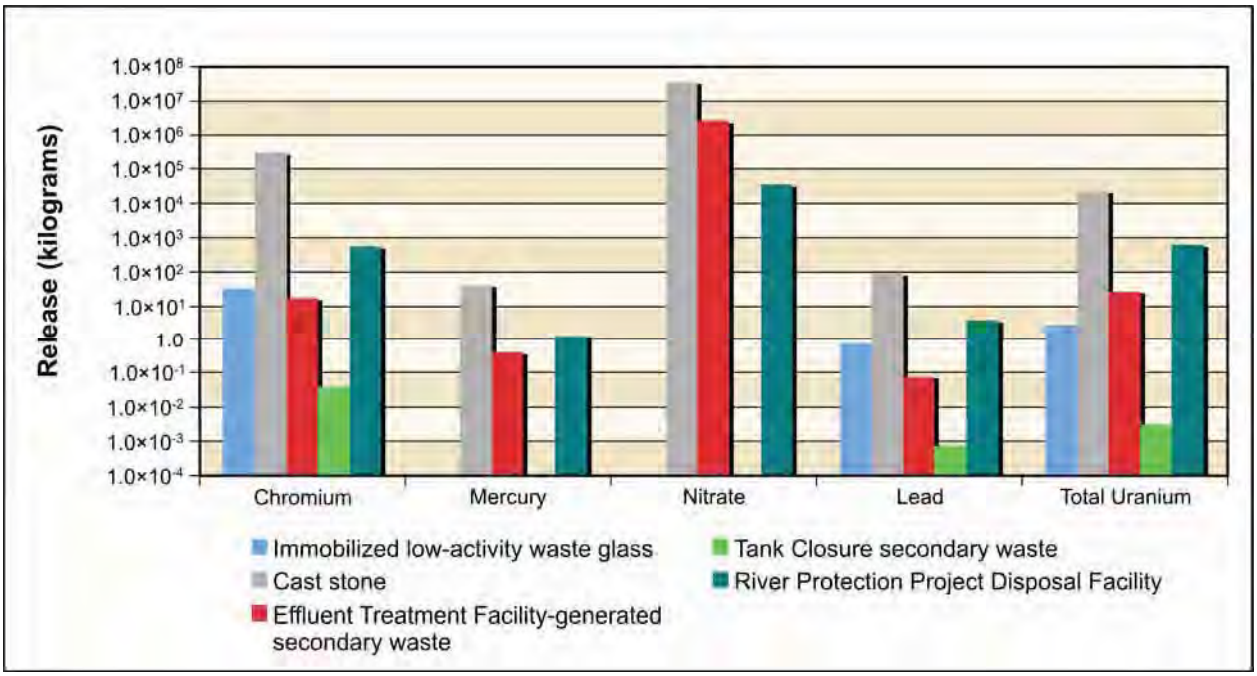


Figure M–79. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.4 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, are indicated in Figures M–80 and M–81.

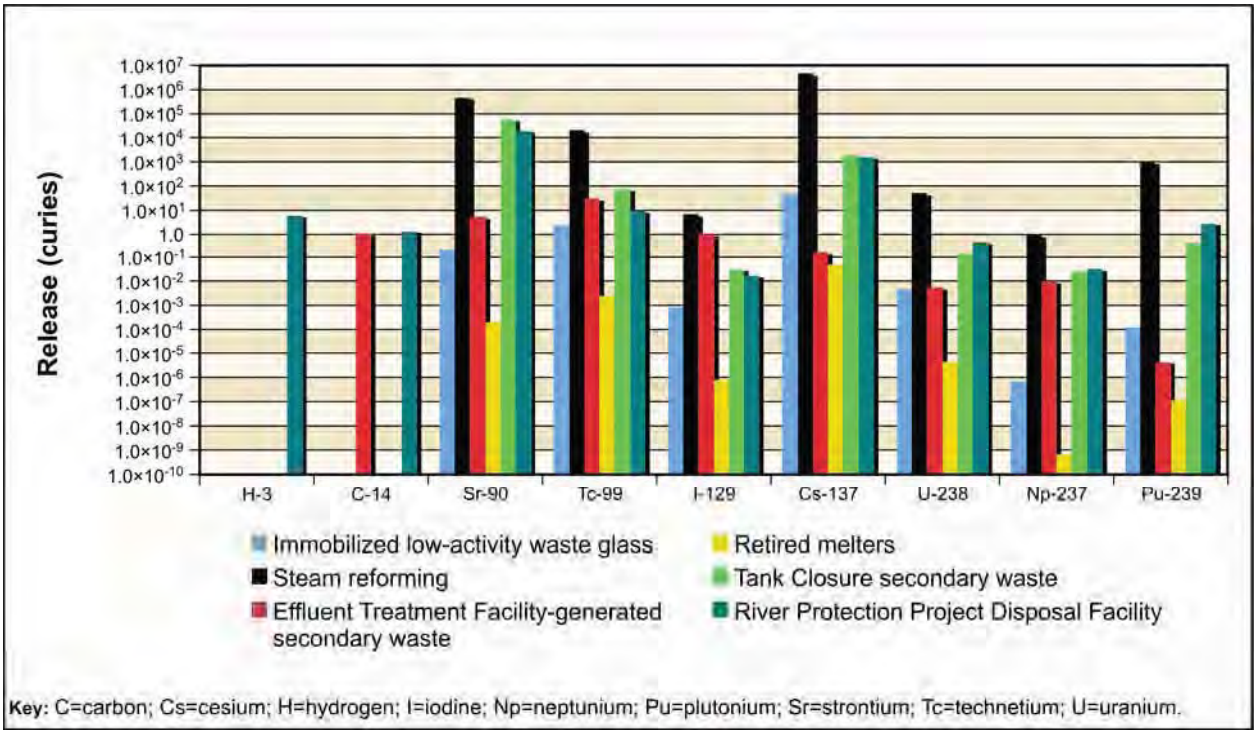


Figure M–80. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

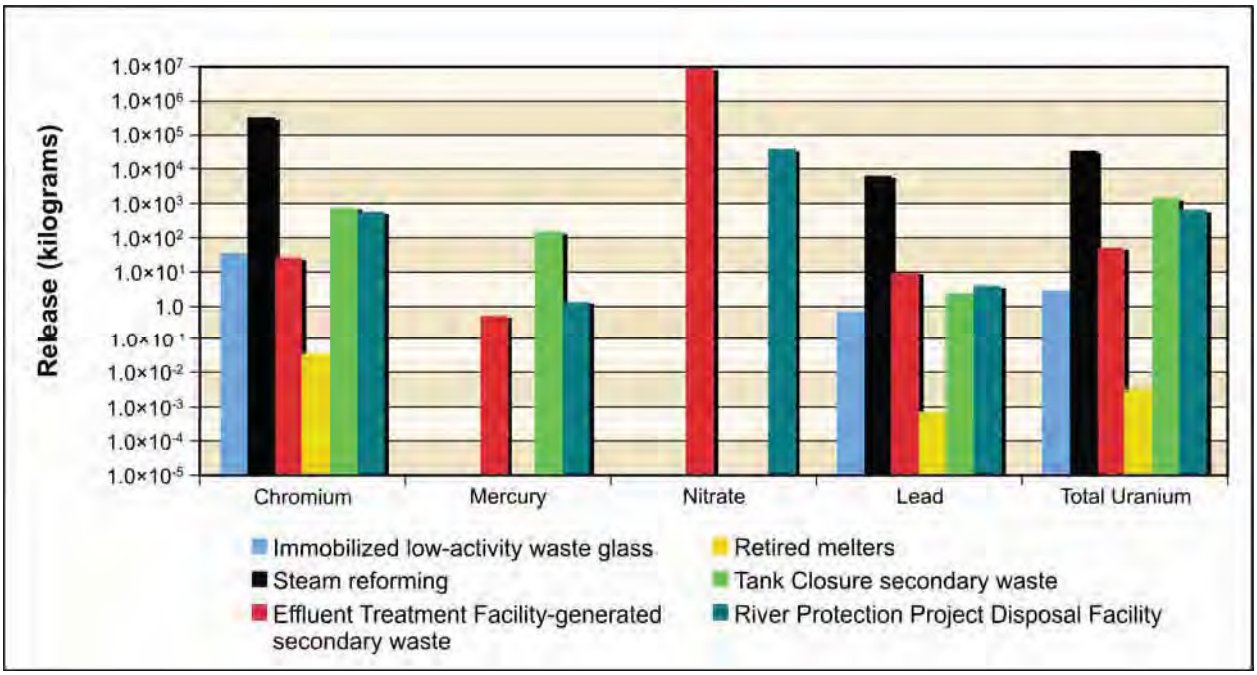


Figure M–81. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.5 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- ETF secondary solid waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 4 because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, are indicated in Figures M–82 and M–83.

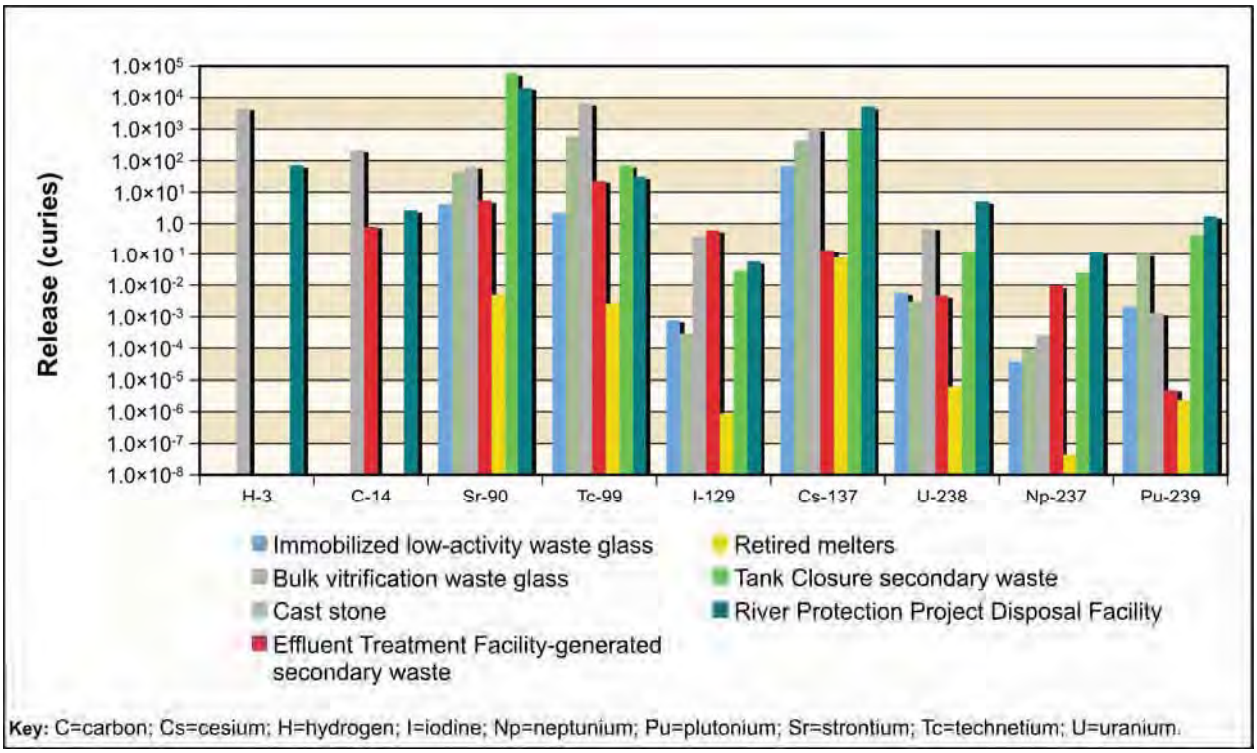


Figure M–82. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

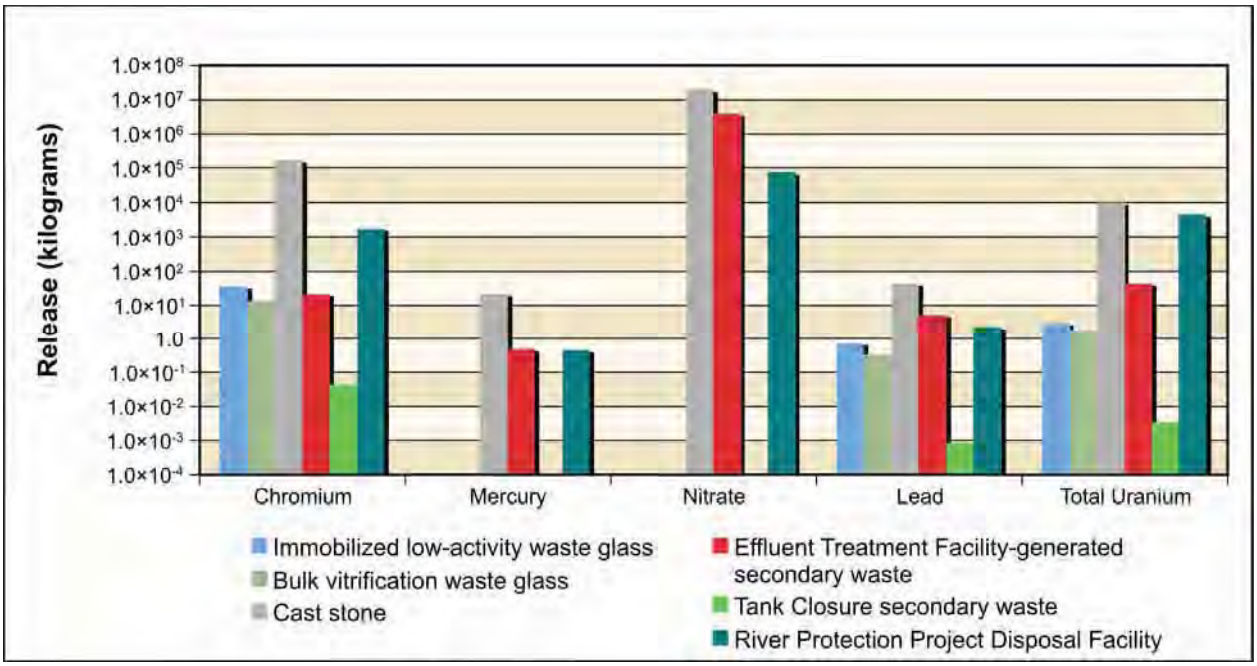


Figure M–83. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.6 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, are indicated in Figures M–84 and M–85.

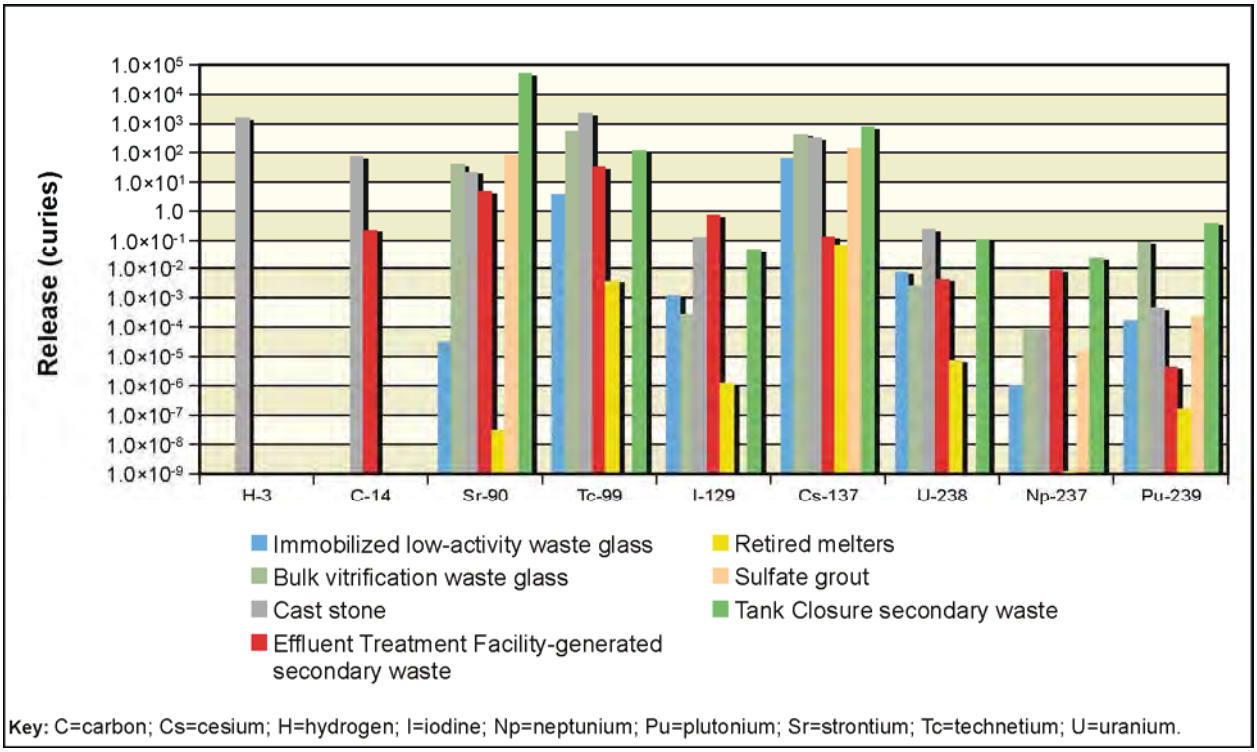


Figure M–84. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

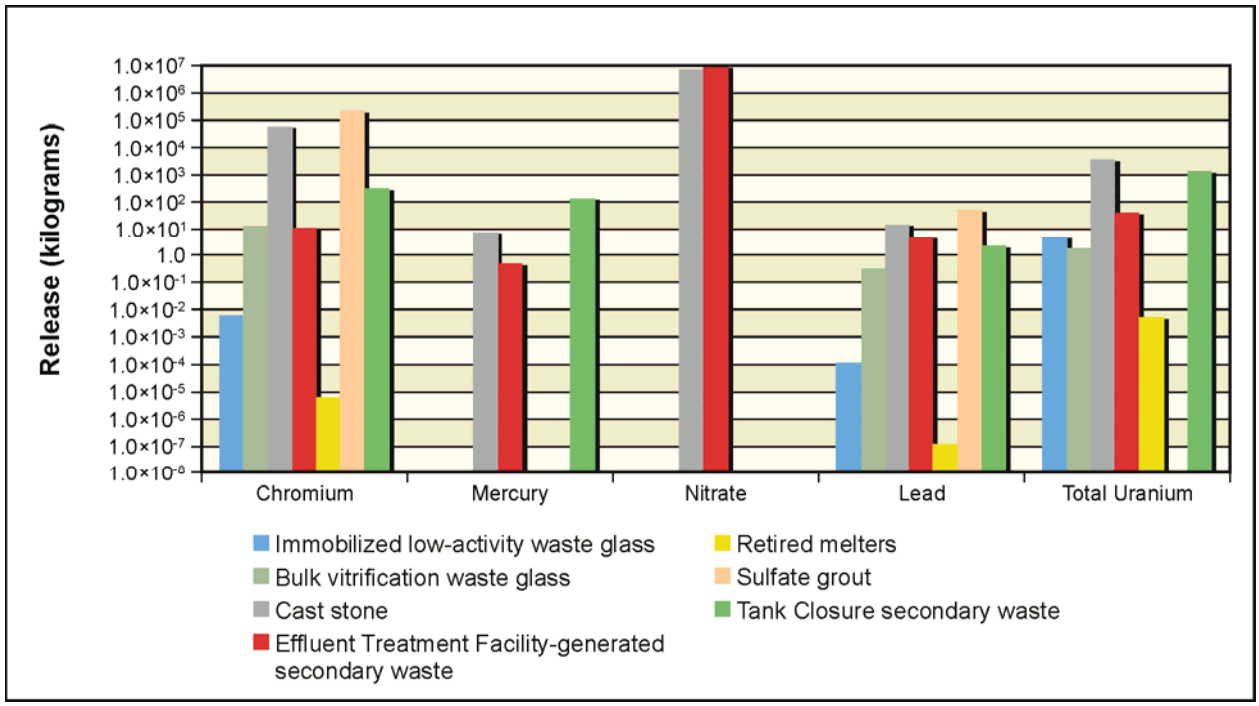


Figure M–85. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.7 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non–CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, are indicated in Figures M–86 and M–87.

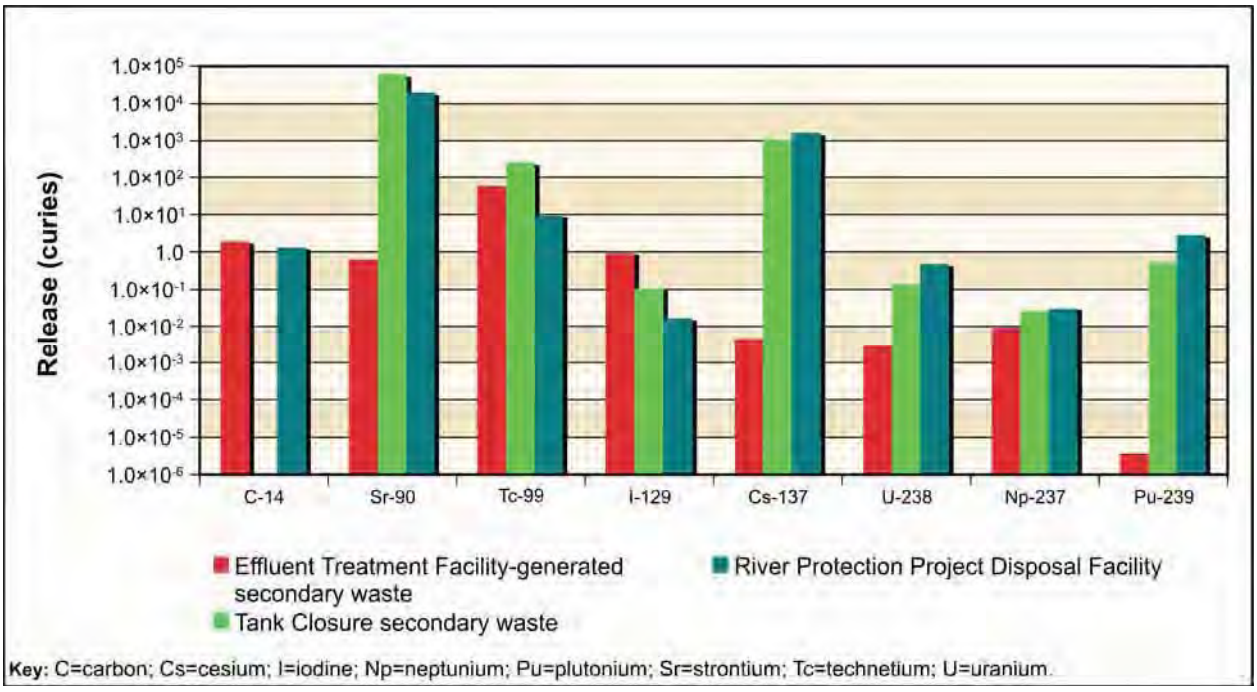


Figure M–86. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

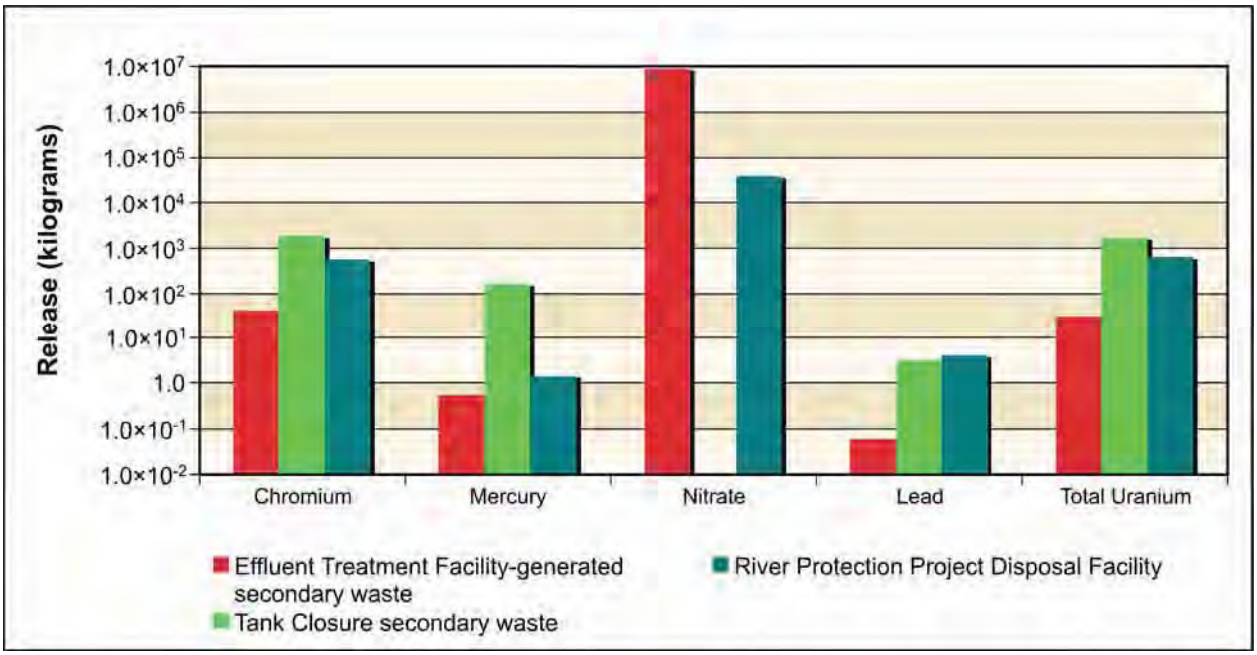


Figure M–87. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.8 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, are indicated in Figures M–88 and M–89.

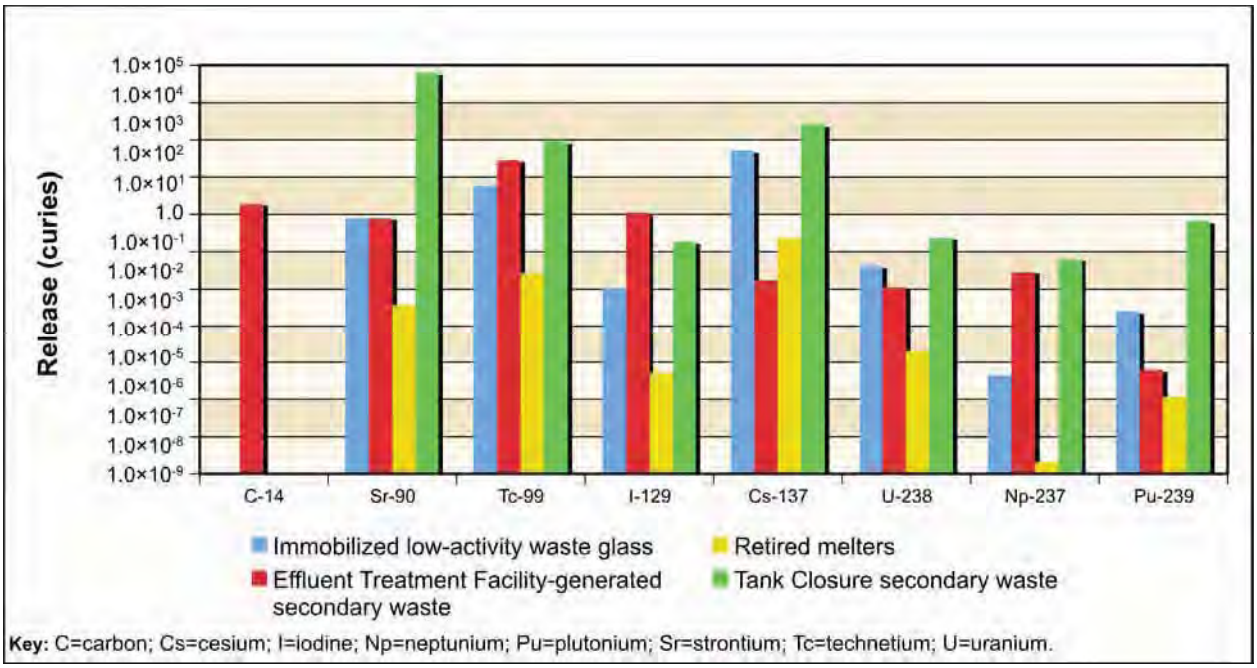


Figure M–88. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

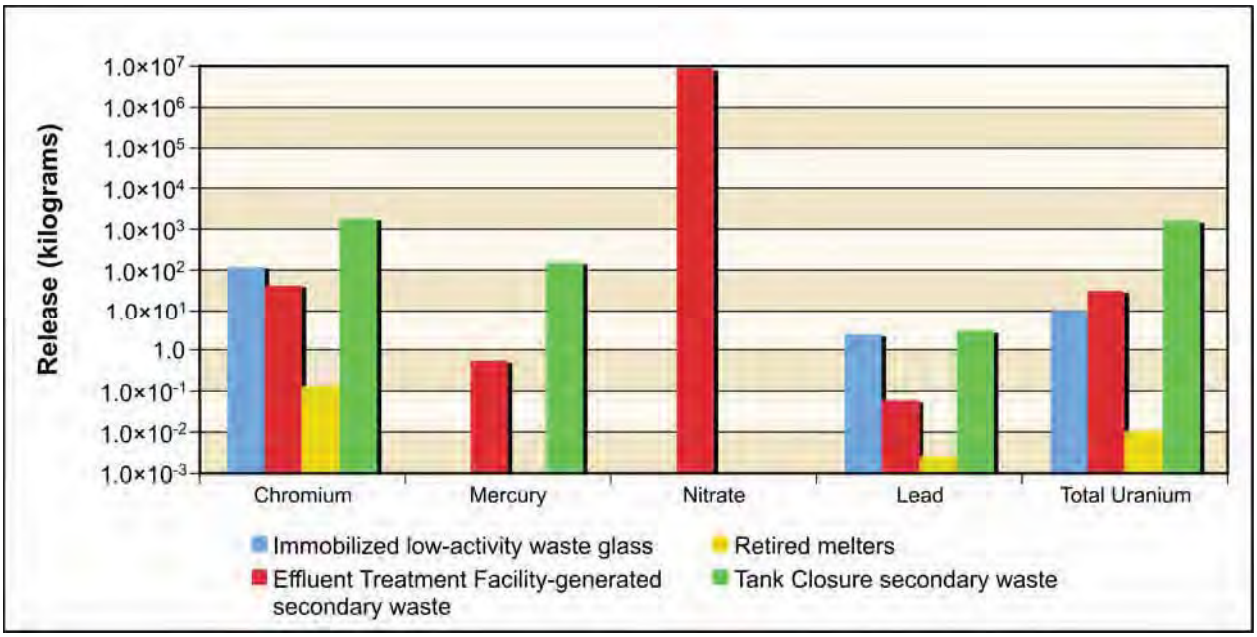


Figure M–89. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.9 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures M–90 through M–93.

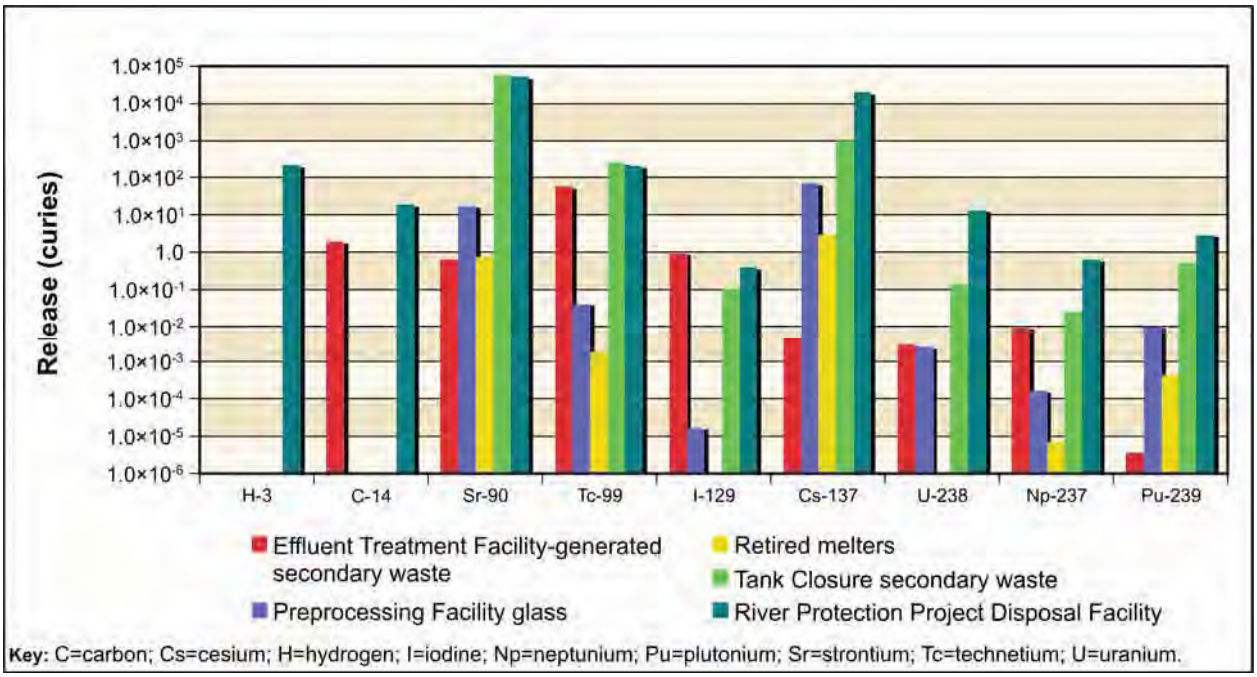


Figure M–90. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

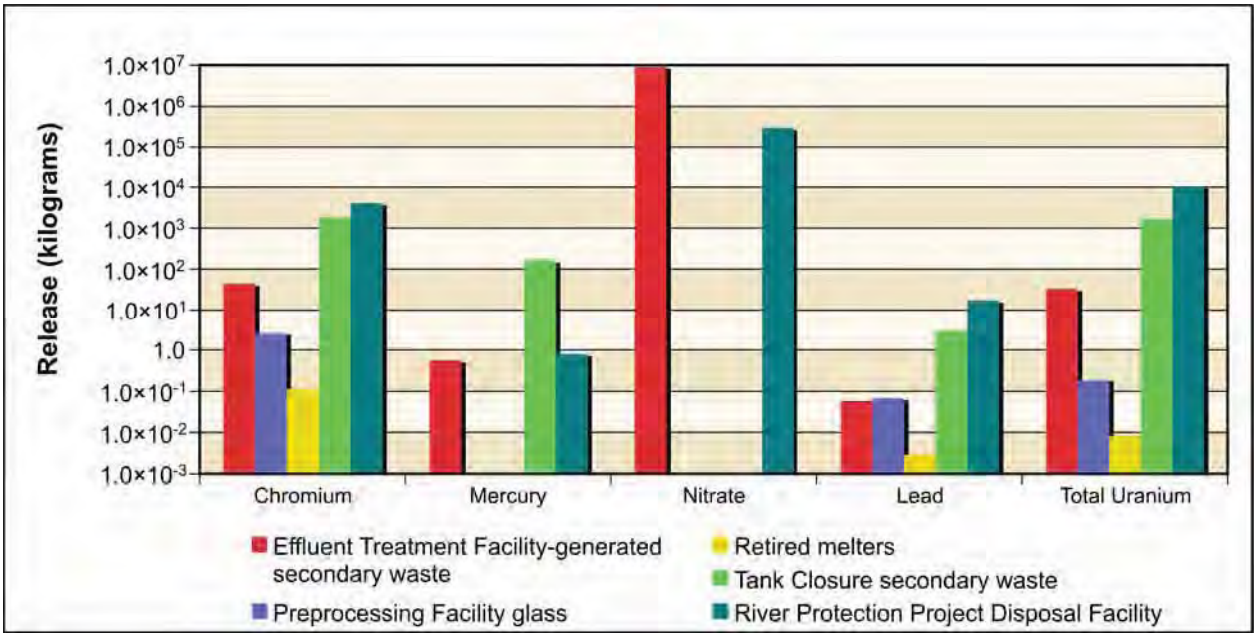


Figure M–91. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

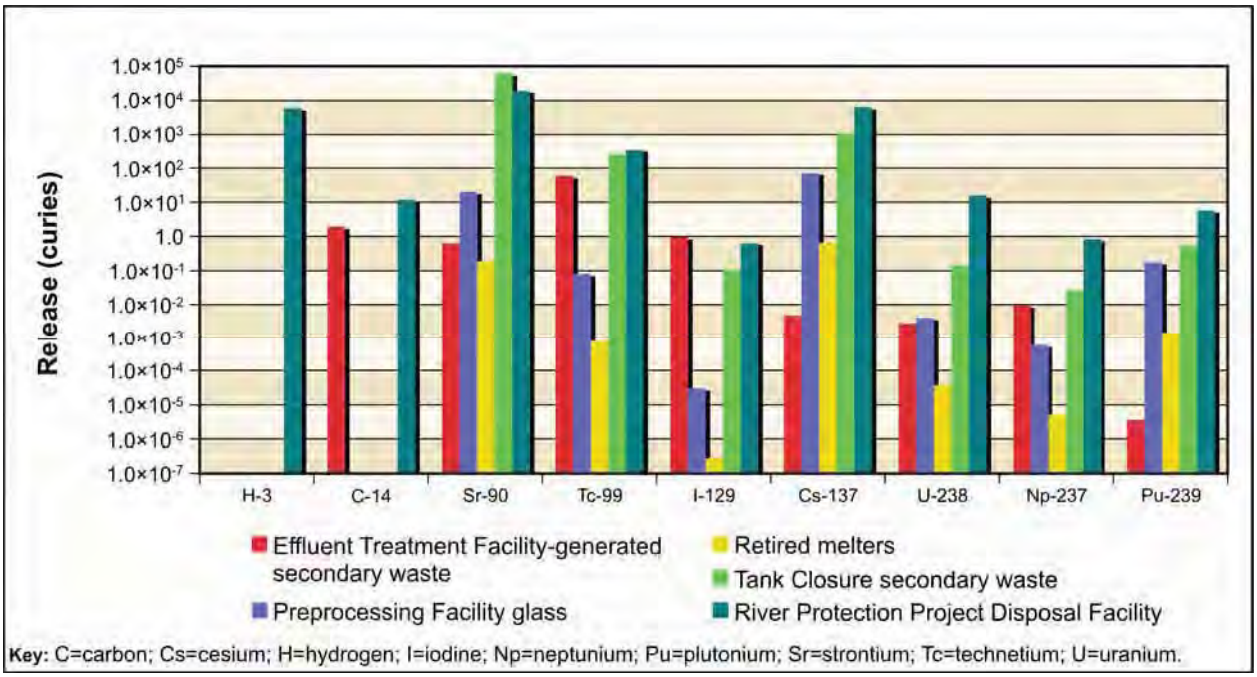


Figure M–92. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

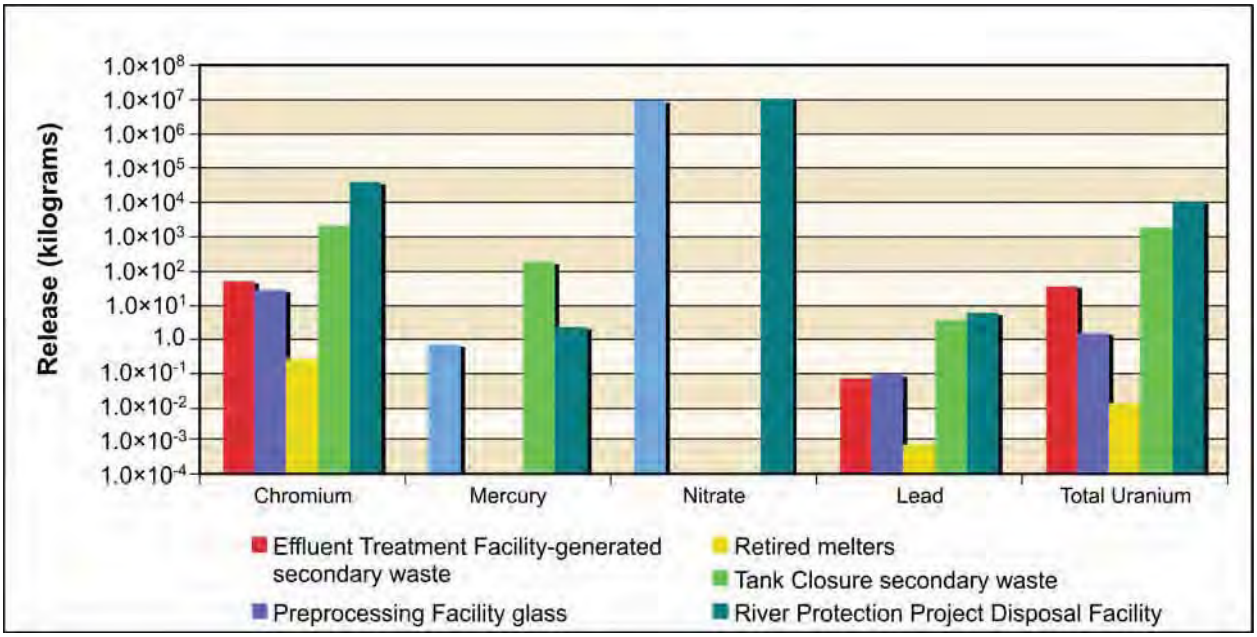


Figure M–93. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.4.3.3.10 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases; onsite non-CERCLA sources; FFTF decommissioning; waste management; and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the vadose zone under Waste Management Alternative 3, Disposal Group 3, Base and Option Cases, are indicated in Figures M–94 through M–97.

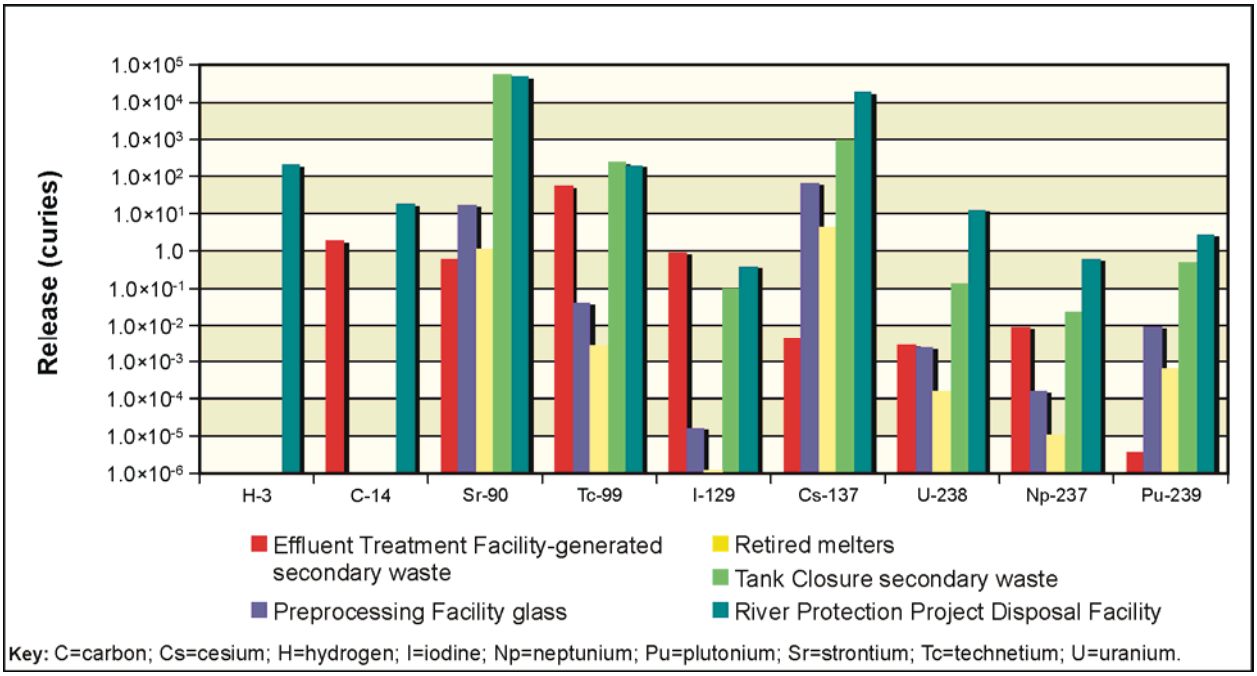


Figure M–94. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

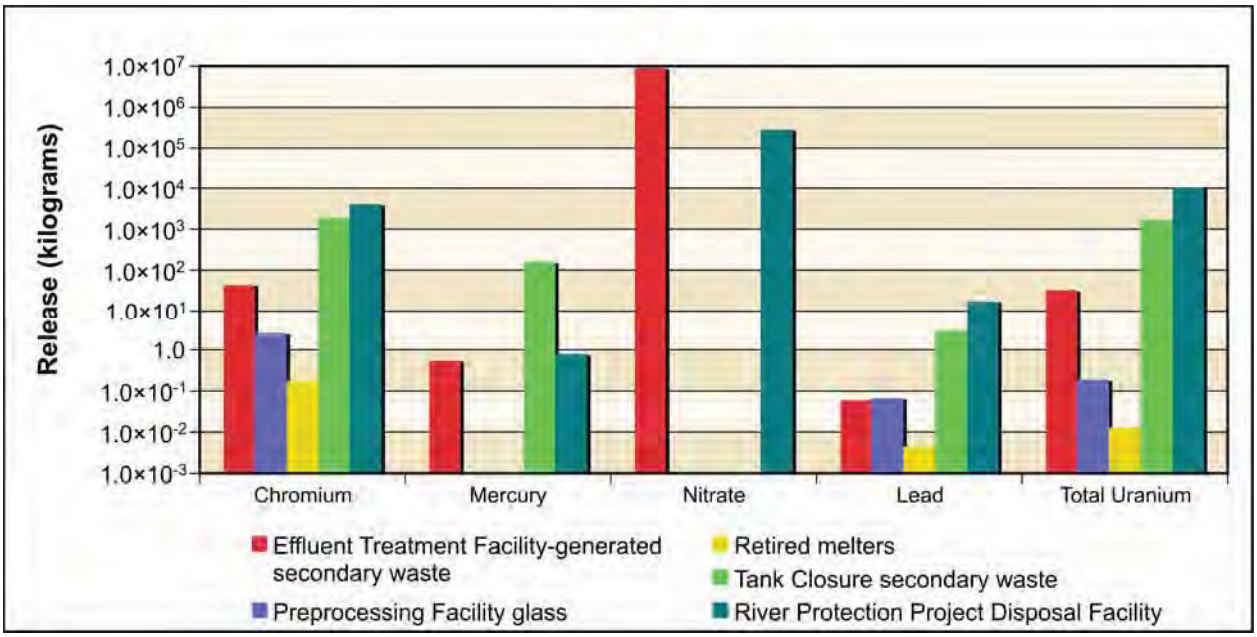


Figure M–95. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

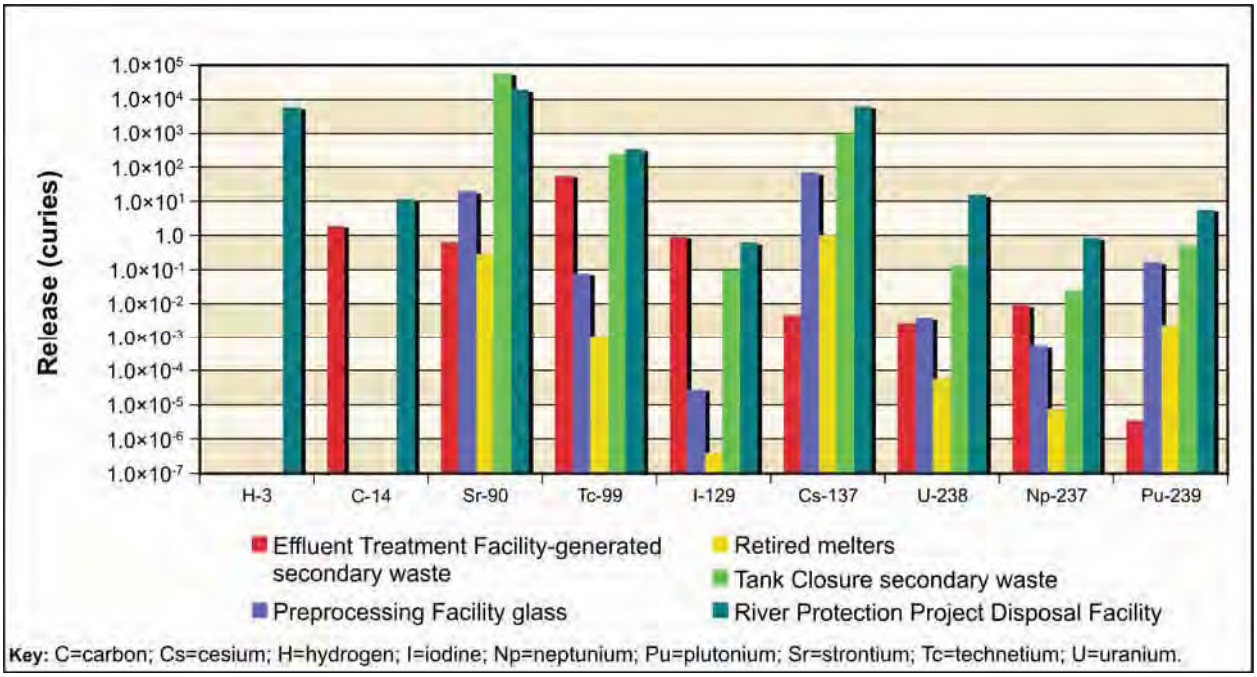


Figure M–96. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Radiological Releases to Vadose Zone

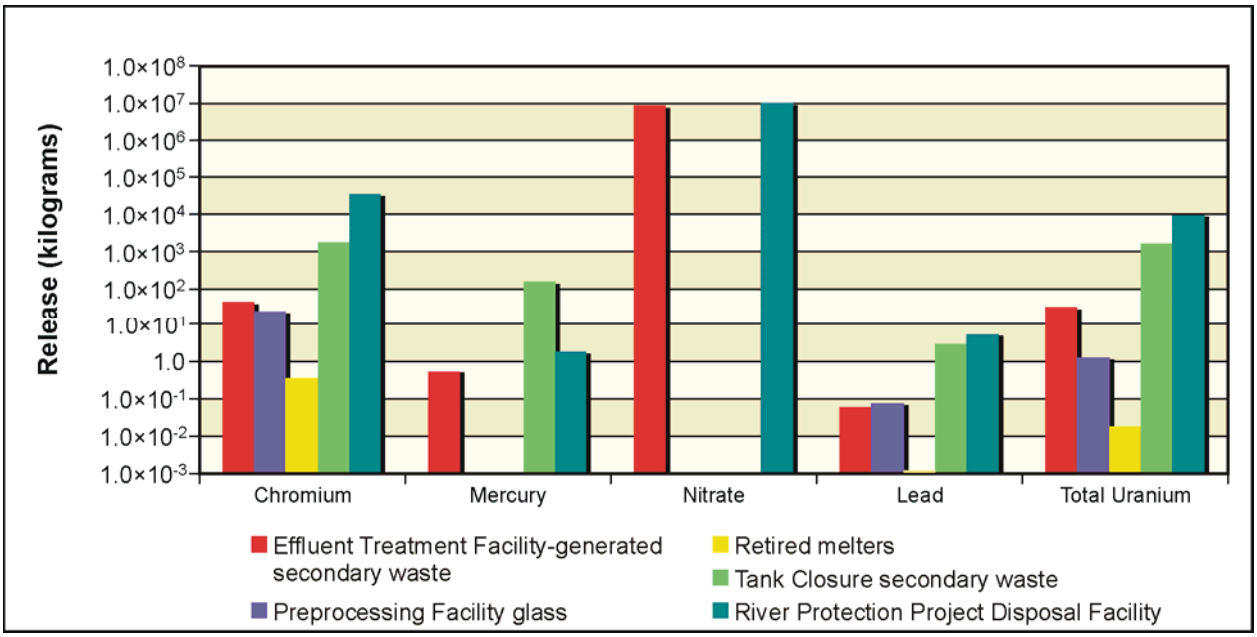


Figure M–97. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Chemical Releases to Vadose Zone

M.5 SENSITIVITY ANALYSIS

Because of the long-term nature of processes expected to occur at Hanford, mathematical models were developed to estimate the rate of release of constituents to the vadose zone. Estimates thus depend on the description of the release incorporated into the model and on values of parameters that quantify rates of physical and chemical processes comprising the model. The objective of this section is to investigate the sensitivity of the estimates of rate of release to the vadose zone to elements of the model concepts and to values of parameters used in the models. Three cases are considered: discharge of liquid and solute representing a past leak at a tank farm, leaching from supplemental waste forms in the 200-East Area, and diffusive release from a grout waste form. The three cases illustrate the range of sensitivities for liquid and solid sources.

M.5.1 Aqueous Volumetric Release

During tank farm operations, aqueous liquids and solutes were discharged to the vadose zone in uncontrolled leakage events. The magnitude, duration, and timing of the leaks and the spatial distribution of recharge at the tank farms are not well characterized. Studies have determined that the volume of leaks may be as large as 400 cubic meters (100,000 thousand gallons) (Hanlon 2003) and that recharge at the tank farms may be high relative to Hanford background conditions (DOE 2005). To investigate the sensitivity of potential impacts on conditions affecting an aqueous discharge at a tank farm, two cases were evaluated. In the first case, an isolated tank in the center of a tank farm was surrounded by an area of elevated recharge, and the release duration and timing were varied. In the second case, the area of an isolated tank was subject to excess recharge while the surrounding area experienced recharge at a normal background rate, and the leak duration and timing were varied. A plan view of the configuration is presented in Figure M–98. The inner area representing the tank is dimension 20 meters (66 feet) in both horizontal directions. In the first case, the dashed rectangle representing the tank farm area experienced recharge at 100 millimeters (4 inches) per year and the balance of the study area experienced recharge at 3.5 millimeters (0.012 inches) per year. In the second case, only the area of the source experienced recharge at 100 millimeters (4 inches) per year and the balance of the study area experienced recharge at 3.5 millimeters (0.012 inches) per year. The initial moisture profile was established as the steady state

condition at a recharge rate of 3.5 millimeters (0.012 inches) per year, and elevated recharge is assumed to begin at the start time of tank farm operations. In both cases, the site geology corresponded to 200-West Area conditions with Hanford Gravel, Hanford Sand, Plio-Pleistocene Silt, and Ringold Gravel layered from the ground surface downward to the water table at a depth of 70 meters (330 feet).

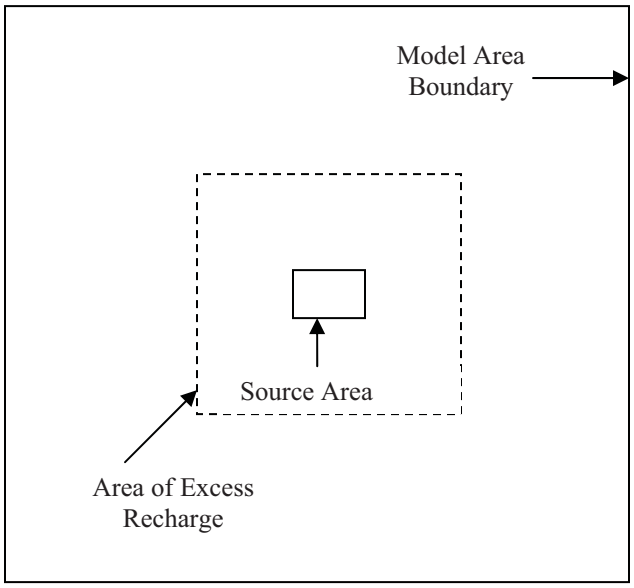


Figure M–98. Plan View of Aqueous Discharge Study Area

M.5.1.1 Extended Area of Elevated Recharge

In this first case, elevated recharge is assumed to occur over the area of a tank farm, approximately 10,000 square meters (110,000 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, a solute flux at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–99. Releases of relatively short duration are considered because these have the greatest potential to produce high flux of solute at the water table. Results show only a small dependence of solute flux at the water table on duration of release. For a 1-year release duration, solute flux at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–100. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 5 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose decreased by approximately 1 percent as time of release changed from start of operations to 30 years after start of operations.

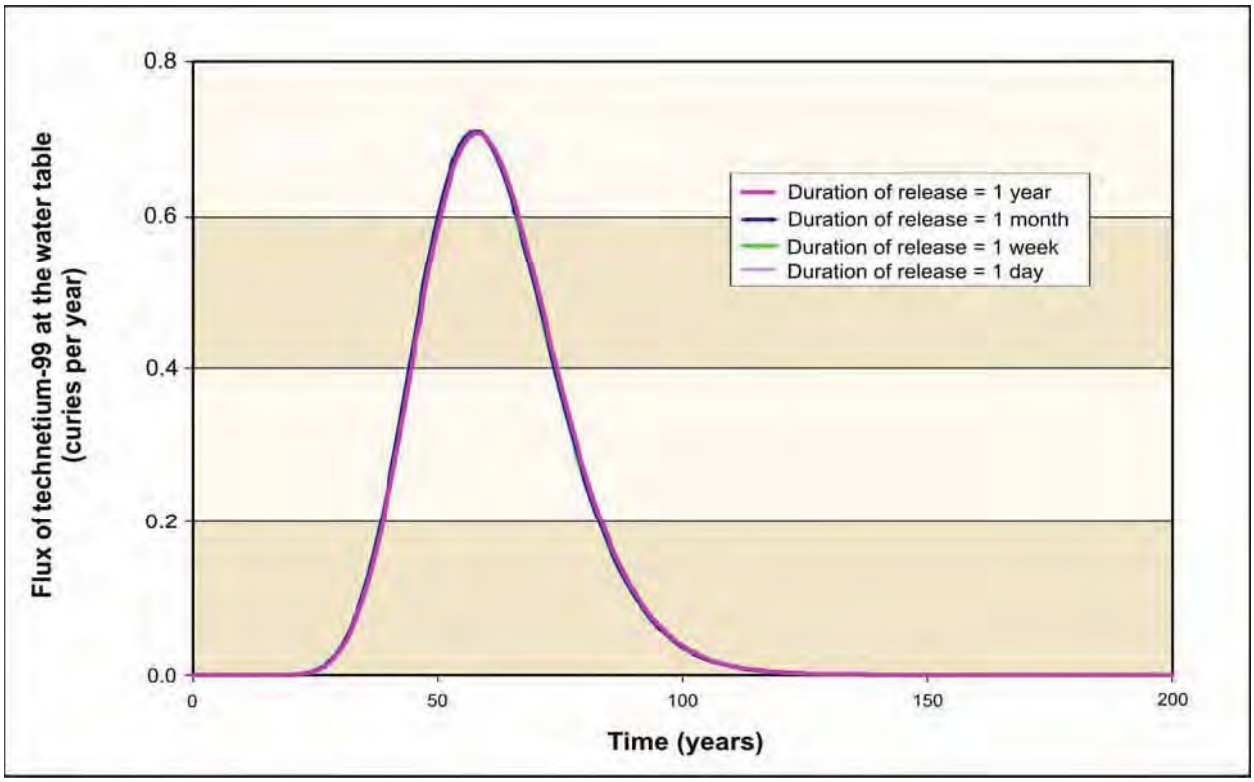


Figure M–99. Variation of Solute Flux at the Water Table with Release Duration for Extended Area of Elevated Recharge

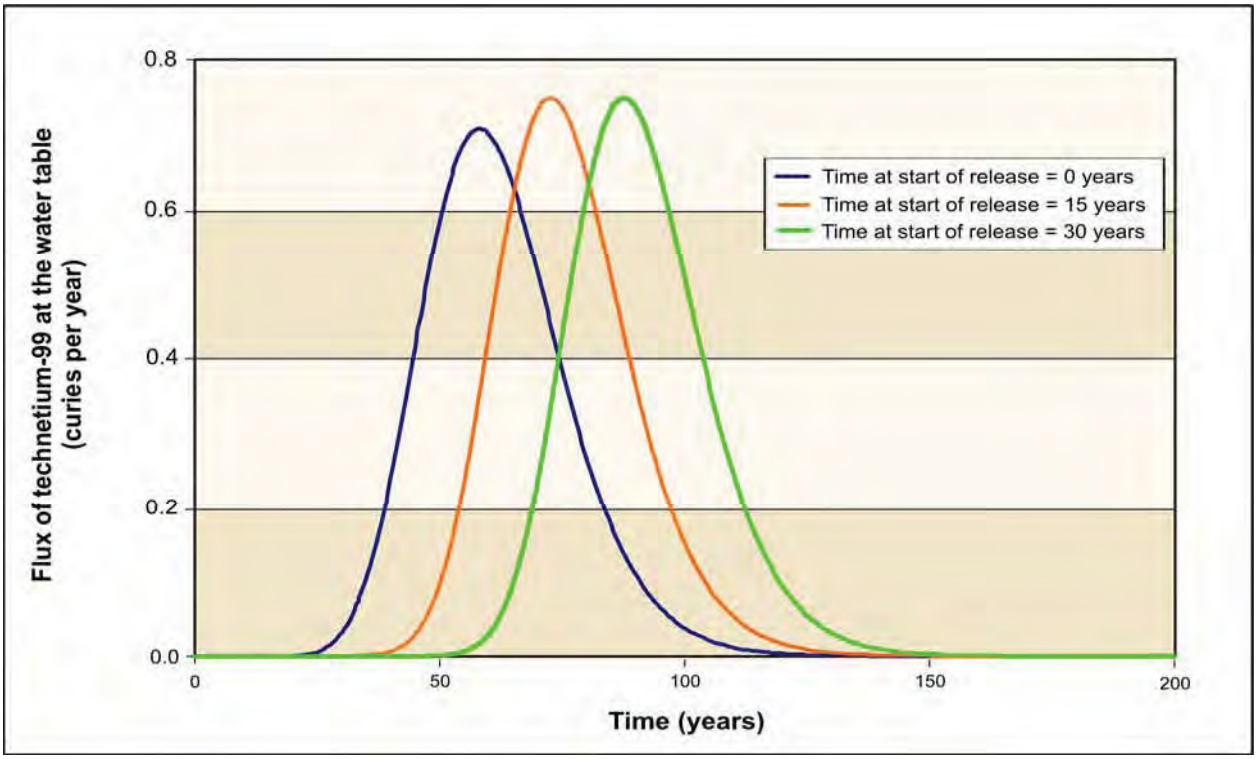


Figure M–100. Variation of Solute Flux at the Water Table with Release Timing for Extended Area of Elevated Recharge

M.5.1.2 Local Area of Elevated Recharge

In this second case, elevated recharge is assumed to occur only over the area of a tank, approximately 400 square meters (4300 square feet), and the leak duration and timing were varied. For a leak beginning at the start time of tank operations, solute flux at the water table for leaks of duration of 1 year, 1 month, 1 week, and 1 day are presented in Figure M–101. Results show only a small dependence of solute flux at the water table on duration of release. For a 1-year release duration, solute flux at the water table for releases beginning at the start of tank farm operations and at 15 and 30 years after start are presented in Figure M–102. Results indicate that the transition from background to elevated recharge moisture conditions did not have a significant effect on the time profile of solute flux. The magnitude of peak solute flux varied by approximately 2 percent as release timing changed from start of operations to 30 years after start of operations. Results reflect the delay in arrival due to the delay in beginning of release, but the interval of time from release to peak dose remained approximately constant as time of release changed from start of operations to 30 years after start of operations.

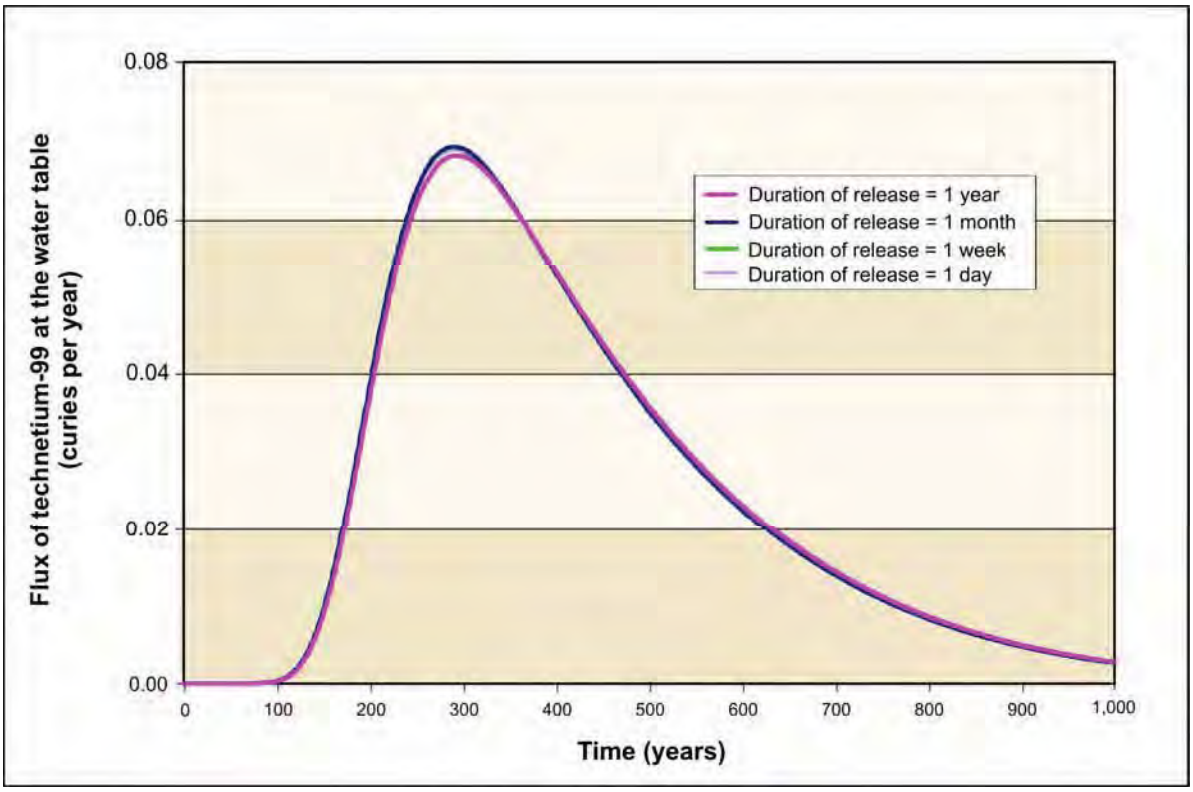


Figure M–101. Variation of Solute Flux at the Water Table with Release Duration for Local Area of Elevated Recharge

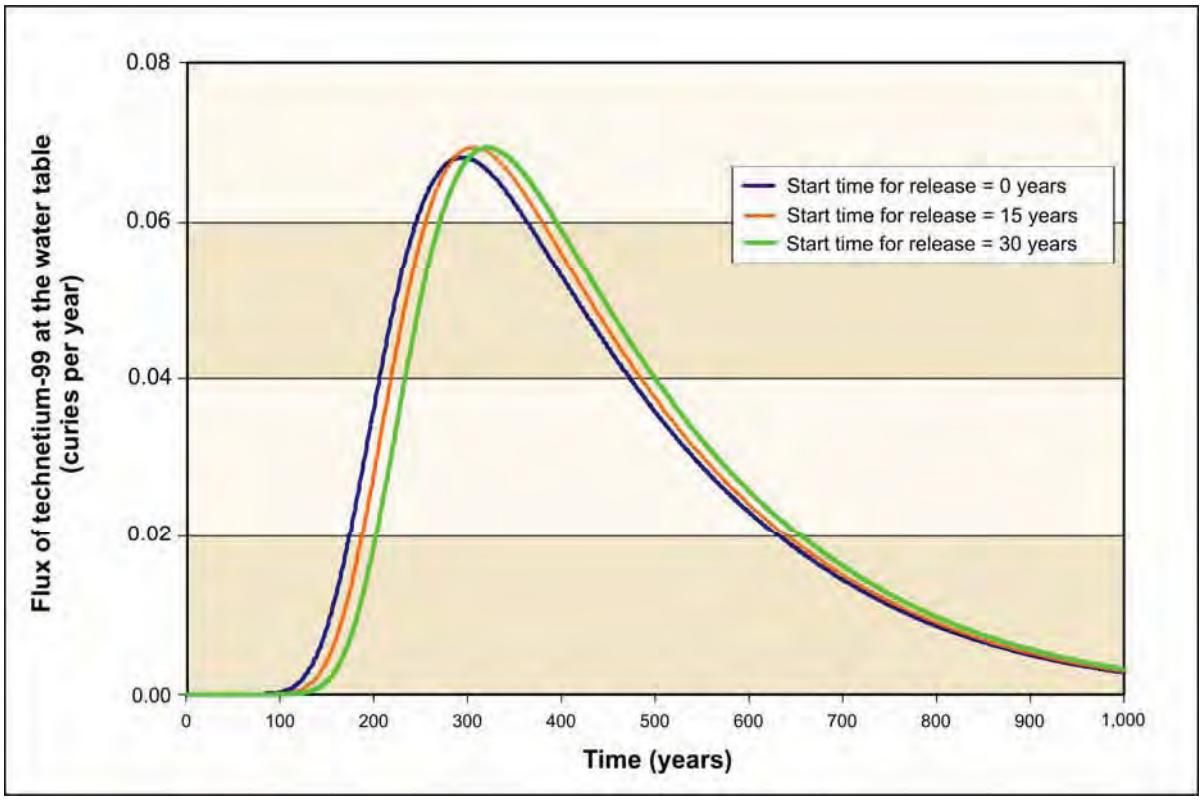


Figure M–102. Variation of Solute Flux at the Water Table with Release Timing for Local Area of Elevated Recharge

M.5.1.3 Conclusions

For cases of both extended and local areas of elevated recharge, solute flux at the water table showed low sensitivity to change in release duration and timing. Results show sensitivity to moisture conditions as the average travel time for the case of extended area of elevated recharge was approximately one-quarter the average travel time for the case of local area of elevated recharge.

M.5.2 Leaching from Supplemental Waste Forms

Activities under consideration for this *TC & WM EIS* include solidification of hazardous constituents currently stored in below ground tanks in the 200-East and 200-West Areas. The primary waste form proposed is ILAW glass. Three additional waste forms under consideration to supplement management capacity for tank constituents are: bulk vitrification glass, cast stone, and steam reforming solids. Analysis completed for Tank Closure Alternatives 3A, 3B, and 3C provides a basis for comparative evaluation of these three waste forms. Additional details on the nature of these waste forms are provided in Appendix D of this EIS, while estimates of the inventory of technetium-99 and iodine-129 for the set of waste forms for the three variants of Tank Closure Alternative 3 are summarized in Table M–17. The balance of this section presents details on the sensitivity of release rate estimates of two select radionuclides to the vadose zone to change in the type of waste form. The recharge rate selected as the basis for estimating release rates was 0.9 millimeters (0.035 inches) per year, a value recommended for the proposed IDF-East (DOE 2005).

Table M–17. Tank Closure Alternatives 3A, 3B, and 3C Summary of Waste Form Inventories of Technetium-99 and Iodine-129

Waste Form	Technetium-99 (curies)			Iodine-129 (curies)		
	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3A	Alternative 3B	Alternative 3C
Immobilized high-level radioactive waste	150	19,600	150	0	0	0
ILAW glass	8,440	84	8,440	2.8	2.8	2.8
Bulk vitrification glass	20,600[a]	N/A[b]	N/A[b]	6.8	N/A[b]	N/A[b]
Cast stone	N/A[b]	9,540	N/A[b]	N/A[b]	33.8	N/A[b]
Steam reforming solids	N/A[b]	N/A[b]	20,600	N/A[b]	N/A[b]	6.8
ETF secondary waste	50	60	46	36.9	9.9	36.9

[a] The inventory of technetium-99 in the castable refractory block is 1,340 curies with the balance of the technetium-99 in intact bulk vitrification glass.

[b] Waste form not used in this alternative.

Key: ETF=Effluent Treatment Facility; ILAW=immobilized low-activity waste; N/A= not applicable.

M.5.2.1 Tank Closure Alternative 3A

For Tank Closure Alternative 3A, the inventory of technetium-99 is largely divided between ILAW glass and bulk vitrification glass while the inventory of iodine-129 is divided between ILAW glass, bulk vitrification glass and ETF secondary waste (a grout waste form). Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–103 and M–104, respectively. Low rates of release are predicted for the intact glass of the ILAW and bulk vitrification glass waste forms. However, the portion of technetium-99 transferred to castable refractory block in the bulk vitrification container is projected to release at a much higher rate upon placement in the vadose zone. The peak in the release rate for technetium-99 from castable refractory block reflects the increase in infiltration that is specified to occur at the end of the design life of the engineered barrier. For iodine-129, the glass waste forms release at very low rates, while the ETF secondary waste releases iodine at a higher (but still low) rate.

M.5.2.2 Tank Closure Alternative 3B

For Tank Closure Alternative 3B, the inventory of technetium-99 is largely divided between immobilized high level radioactive waste glass and cast stone while the inventory of iodine-129 is divided between ILAW glass, cast stone, and ETF secondary waste. Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–105 and M-106, respectively. The small amount of technetium-99 present in the ILAW glass is estimated to release at a low rate, while the cast stone is projected to release technetium-99 at a higher rate. The entire inventory of technetium-99 in the cast stone waste form is released over a period of approximately 9,600 years. The smaller inventory of technetium-99 (60 curies) in the ETF secondary waste is released over a period of approximately 3,000 years. For iodine-129, the combined rate of release from cast stone and ETF secondary waste is comparable to that of ETF secondary waste with comparable inventory under Tank Closure Alternative 3A.

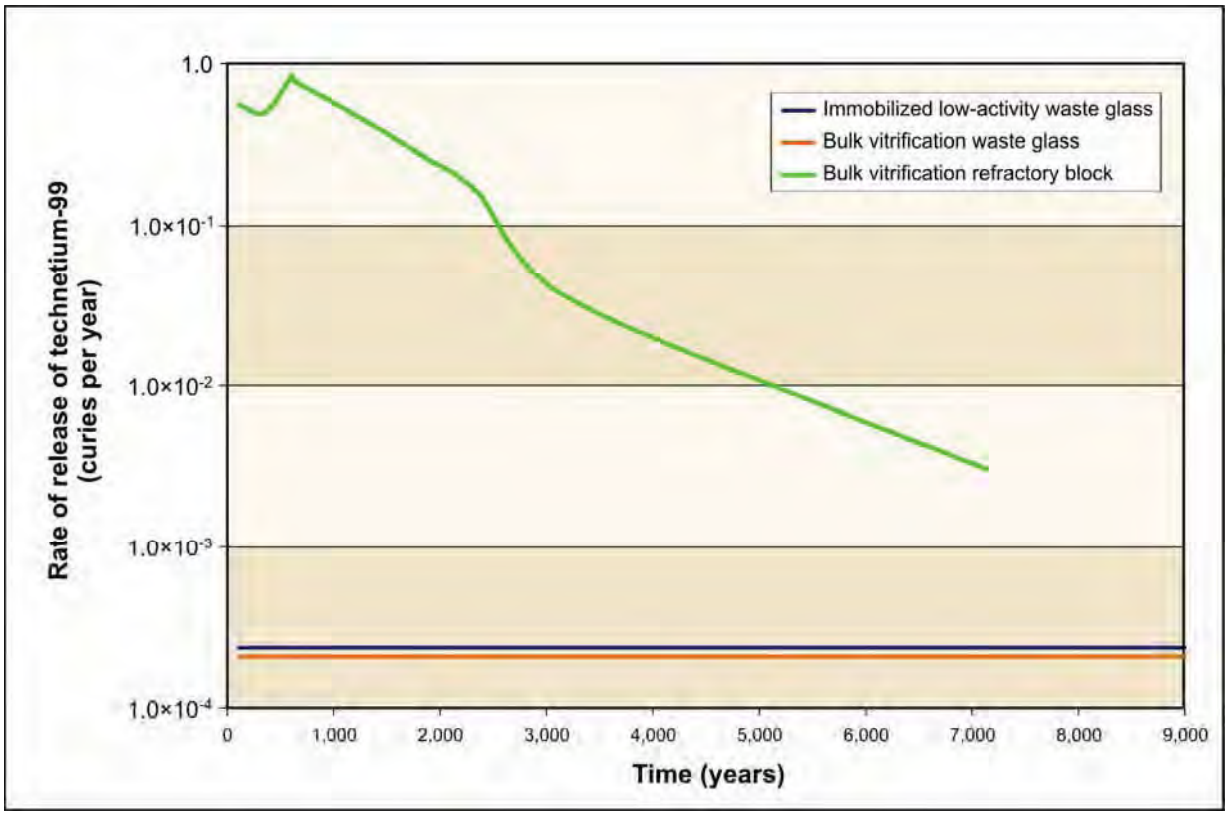


Figure M–103. Tank Closure Alternative 3A Waste Form Release Rates of Technetium-99

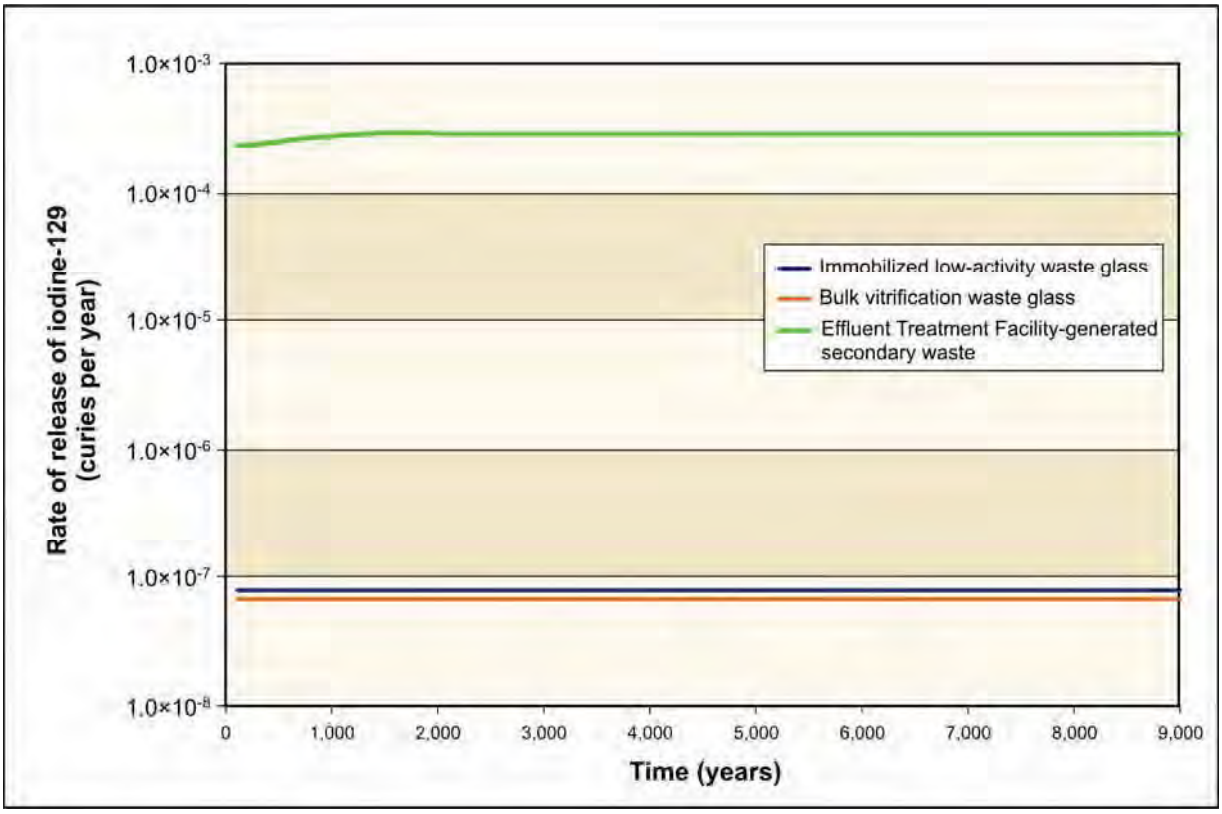


Figure M–104. Tank Closure Alternative 3A Waste Form Release Rates of Iodine-129

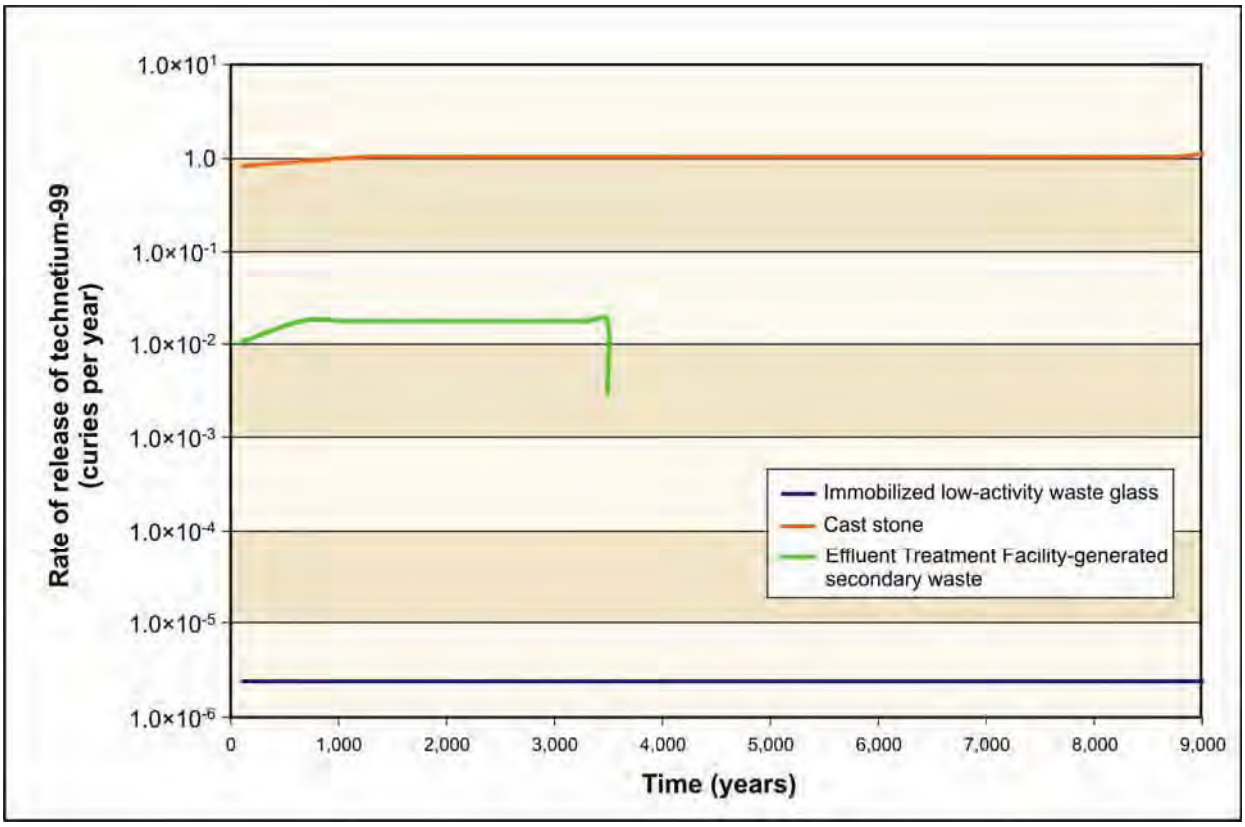


Figure M–105. Tank Closure Alternative 3B Waste Form Release Rates of Technetium-99

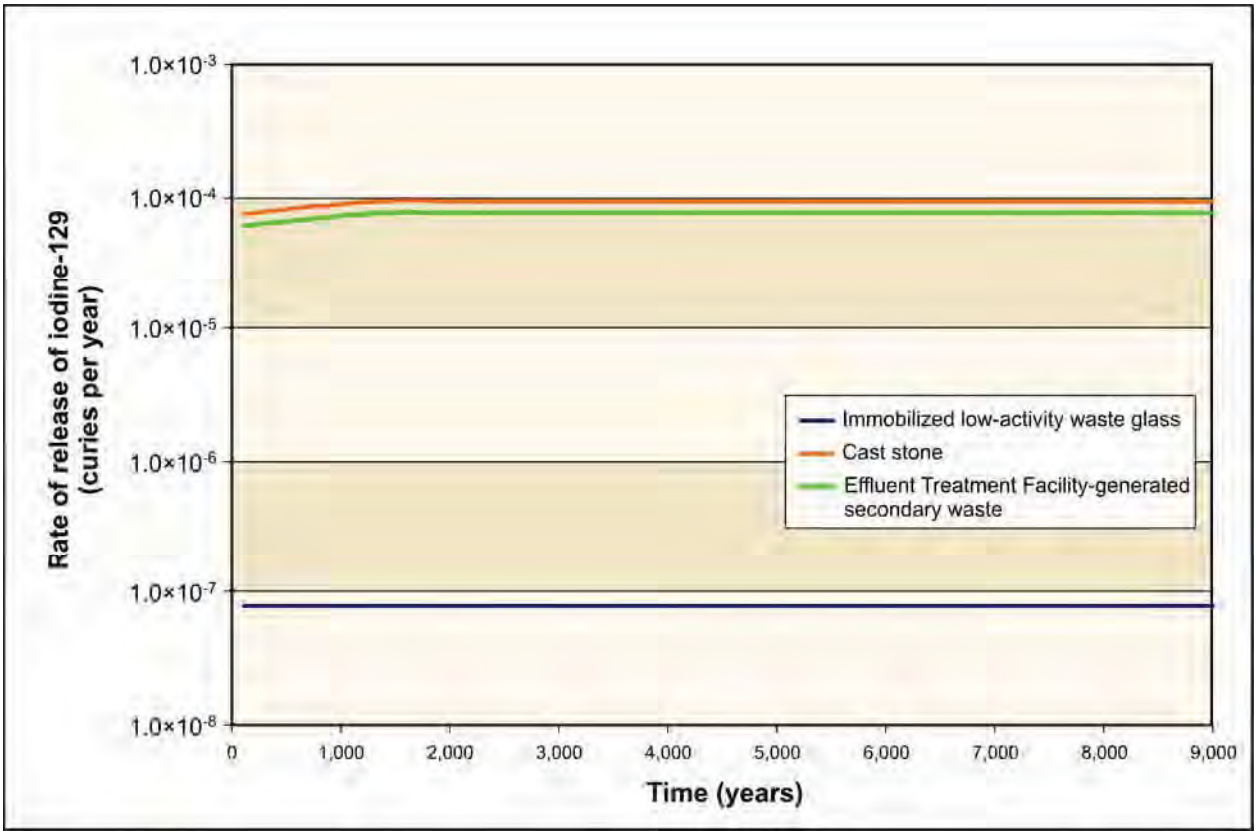


Figure M–106. Tank Closure Alternative 3B Waste Form Release Rates of Iodine-129

M.5.2.3 Tank Closure Alternative 3C

For Tank Closure Alternative 3C, the inventory of technetium-99 is largely divided between ILAW glass and steam reforming solids, while the inventory of iodine-129 is divided between ILAW glass, steam reforming solids, and ETF secondary waste. Release rate estimates of technetium-99 and iodine-129 for this alternative are presented in Figures M–107 and M–108, respectively. The estimated rate of release of both technetium-99 and iodine -129 is higher for steam reforming solids than for the ILAW glass waste form. The entire inventories would be released over a period of approximately 2,000 years.

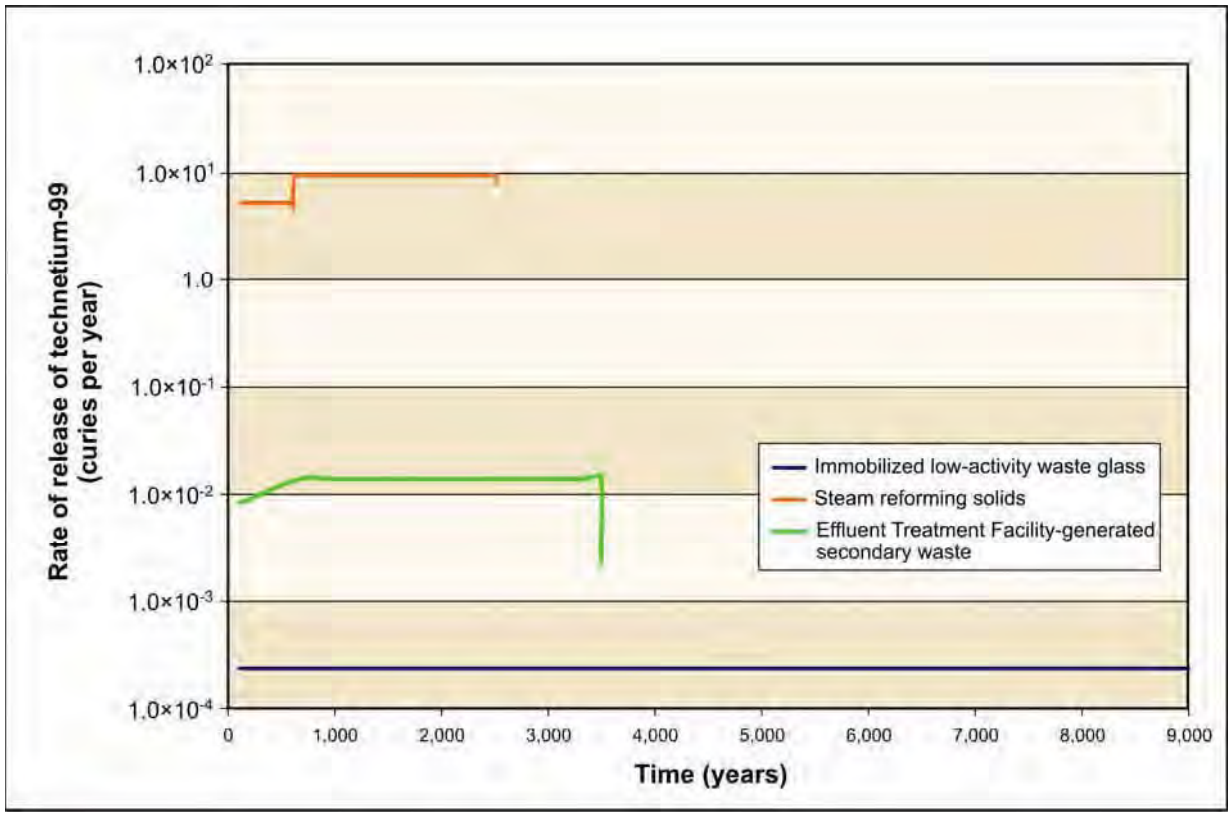


Figure M–107. Tank Closure Alternative 3C Waste Form Release Rates of Technetium-99

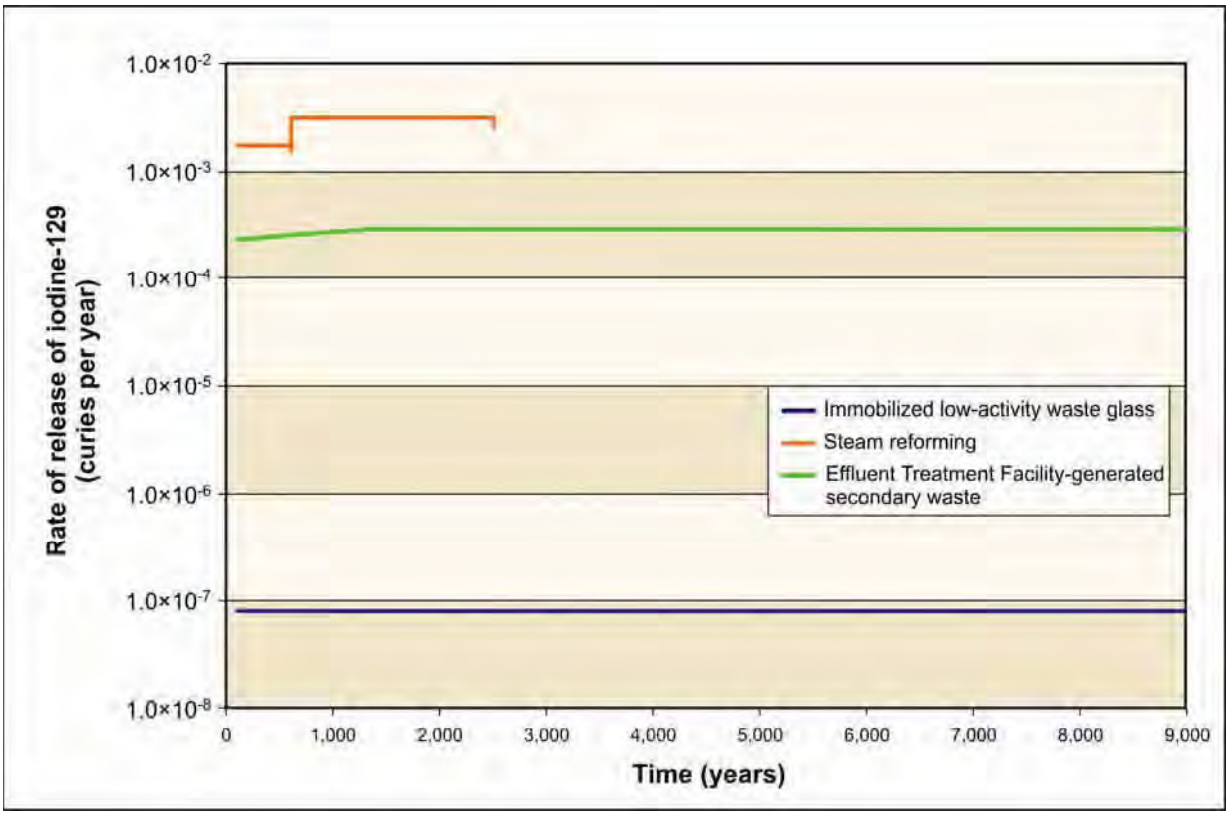


Figure M–108. Tank Closure Alternative 3C Waste Form Release Rates of Iodine-129

M.5.2.4 Conclusions

Cumulative releases of technetium-99 and iodine-129 from the combined waste forms for Tank Closure Alternatives 3A, 3B, and 3C are presented in Figure M–109 and M–110, respectively. For both technetium-99 and iodine-129, estimates of release from steam reforming solids are higher than those for the ILAW glass, bulk vitrification glass, and cast stone waste forms. This is due to use of a conservative, reactant limited-release model for the steam reforming solids. For technetium-99 and Tank Closure Alternative 3A, the majority of release is due to the castable refractory block portion of the bulk vitrification inventory, and that entire inventory is released in approximately 2,000 years. For technetium-99, cumulative release from cast stone under Tank Closure Alternative 3B is higher than for bulk vitrification glass and castable refractory block under Alternative 3A due in part to a larger initial inventory. For iodine-129, estimates of release from ILAW glass and bulk vitrification glass are comparable, although that of bulk vitrification glass is slightly lower due to smaller surface area per unit mass of the waste form.

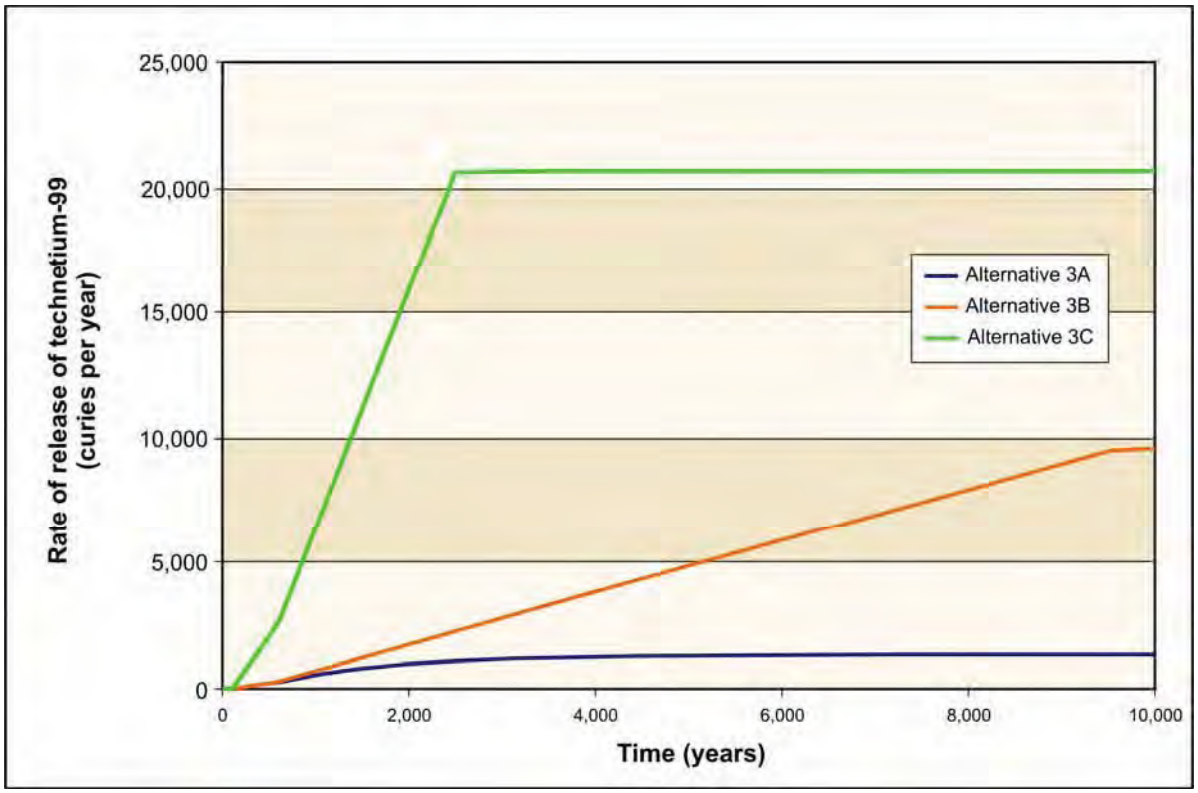


Figure M–109. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Release Rates of Technetium-99

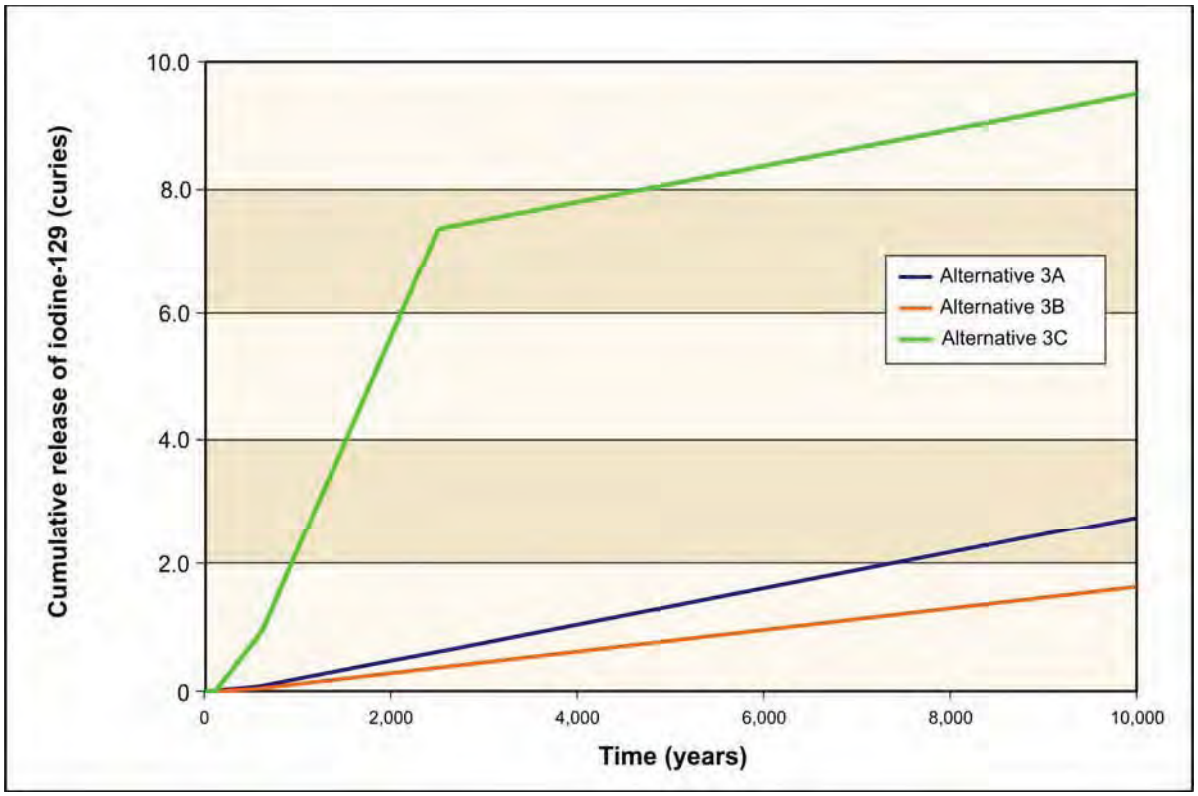


Figure M–110. Tank Closure Alternatives 3A, 3B, and 3C Waste Form Combined Release Rates of Iodine-129

M.5.3 Rate of Recharge and Diffusion Release

Grouted waste forms are proposed for both primary and secondary waste categories for Tank Closure and Waste Management alternatives. For these waste forms and the low rates of recharge projected for the waste disposal locations, release rate by the diffusion mechanism is greater than that by the convective mechanism. Also, for the diffusive model described in Section M.2.2.4, the release rate from the waste package would be limited by the accumulation of the released constituent in the vicinity of the waste form. This section investigates the dependence of the release rate to the vadose zone underlying the waste packages on the recharge rate in the vicinity of the waste form. In this example, calculation, an inventory of 9,500 curies of technetium-99 is encapsulated in 233,000 cubic meters (8,230,000 cubic feet) of grout. Stacks of packages 5.3 meters (17.4 feet) high with a package radius of 1.55 meters (5.1 feet) are placed in a rectangular array. The constituent is released by diffusion into the vadose zone adjacent to the packages and transported downward in the convective flow due to recharge. The release rates to the underlying vadose zone for varying recharge rates are presented in Figure M–111. In the limit of very high values of recharge, the release rate would be independent of the recharge rate and decrease in inverse proportion to the square root of time. The constant release rate projected for recharge rates observed at Hanford (see Figure M–105) indicates that the accumulation of the released constituent in the vadose zone adjacent to the packages limits the release rate. For the conditions adopted for this analysis, the entire inventory of technetium-99 is released during the period analyzed with the duration of time required for release increasing in proportion to the inverse of the recharge rate.

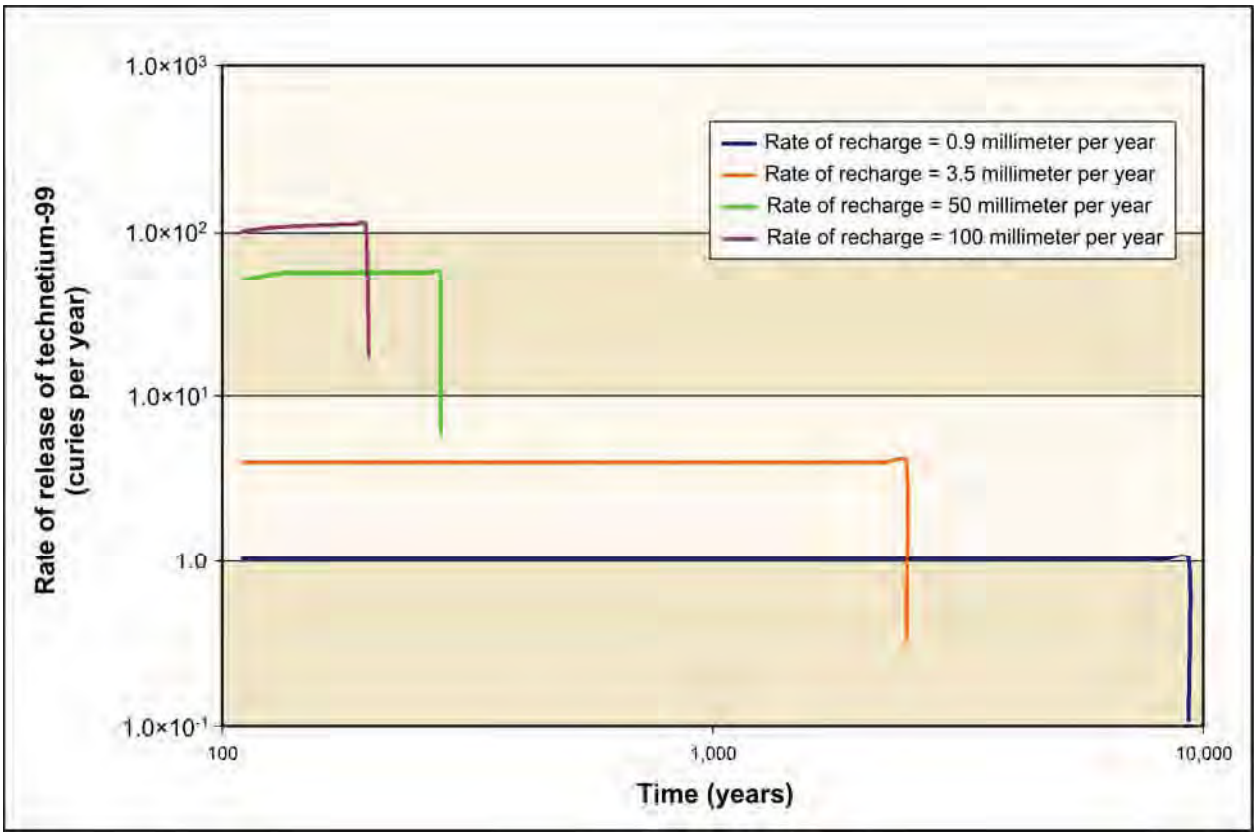


Figure M–111. Dependence of Release Rate of Technetium-99 on Rate of Recharge for Diffusive Release Model

M.6 REFERENCES

Anderson, J.D., 1990, *A History of the 200 Area Tank Farms*, WHC-MR-0132, Westinghouse Hanford Company, Richland, Washington, June.

Beyeler, W.E., W.A. Hareland, F.A. Durán, T.J. Brown, E. Kalinina, D.P. Gallegos, and P.A. Davis, 1999, *Residual Radioactive Contamination from Decommissioning, Parameter Analysis, Draft Report for Comment*, NUREG/CR-5512, Vol. 3, U.S. Nuclear Regulatory Commission, Washington, D.C., October.

CH2M HILL (CH2M HILL Hanford Group, Inc.), 2002, *Field Investigation Report for Waste Management Area S-S* , RPP-7884, Rev. 0, Richland, Washington, January 31.

DOE (U.S. Department of Energy), 2003a, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA: Tank System Closure and Facility D&D Data Package*, DOE/ORP-2005-05, Rev. 0, Office of River Protection, Richland, Washington, April 17.

DOE (U.S. Department of Energy), 2003b, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA: Inventory and Source Term Data Package*, DOE/ORP-2005-02, Rev. 0, Office of River Protection, Richland, Washington, April 17.

DOE (U.S. Department of Energy), 2003c, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA: Waste Treatment and Supplemental Technology Data Package*, DOE/ORP-2003-07, Rev. 0, Office of River Protection, Richland, Washington, April 17.

DOE (U.S. Department of Energy), 2005, *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose one and Groundwater Revised Analyses*, Final Rev. 0, Office of River Protection, Richland, Washington, March 25.

Freeze, R.A., and J.A. Cherry, 1979, *Groundwater*, Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Hanlon, B.M., 2003, *Waste Tank Summary Report for Month Ending August 31, 2003*, HNF-EP-0182, Rev. 185, CH2M HILL Hanford Group Inc., Richland, Washington, October.

Jantzen, C.M., 2006, *Fluidized Bed Steam Reformer (FBSR) Product: Monolith Formation and Characterization*, WSRC-STI-2006-00033, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina, June.

Jones, T.E., B.C. Simpson, M.I. Wood, and R.A. Corbin, 2000, *Preliminary Inventory Estimates for Single-Shell Tank Leaks in T, T , and TY Tank Farms*, RPP-7218, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, November.

Jones, T.E., B.C. Simpson, M.I. Wood, and R.A. Corbin, 2001, *Preliminary Inventory Estimates for Single-Shell Tank Leaks in B, B , and BY Tank Farms*, RPP-7389, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, February.

Knepp, A.J., 2002, *Field Investigation Report for Waste Management Area B-B -BY*, RPP-10098, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, December 13.

Lockrem, L.L., 2005, *Hanford Containerized Cast Stone Facility Task 1 – Process Testing and Development Final Test Report*, RPP-RPT-26742, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, July 15.

Lorier, T.H., J.M. Pareizs, and C.M. Jantzen, 2005, *Single-Pass Flow Through (SPFT) Testing of Fluidized-Bed Stream Reforming (FBSR) Waste Forms*, WSRC-TR-2005-00124, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina, August.

Mann, F.M., R.J. Puigh, R. Khaleel, S. Finfrock, B.P. McGrail, D.H. Bacon, and R.J. Serne, 2003, *Risk Assessment Supporting the Decision on the Initial Selection of Supplemental ILAW Technologies*, RPP-17675, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, September 29.

Mason, B., and L.G. Berry, 1968, *Elements of Mineralogy*, W.H. Freeman and Co., San Francisco, California.

McGrail, B.P., H.T. Schaef, P.F. Martin, D.H. Bacon, E.A. Rodriguez, D.E. McCready, A.N. Primak, and R.D. Orr, 2003a, *Initial Suitability Evaluation of Steam-Reformed Low Activity Waste for Direct Land Disposal*, WTP-RPT-097, Rev. 0, Bechtel National, Inc., Richland, Washington, January.

McGrail, B.P., E.M. Pierce, H.T. Schaef, E.A. Rodriguez, J.L. Steele, A.T. Owen, and D.M. Wellman, 2003b, *Laboratory Testing of Bulk Vitrified and Steam Reformed Low-Activity Waste Forms to Support a Preliminary Risk Assessment for an Integrated Disposal Facility*, PNNL-14414, Pacific Northwest National Laboratory, Richland, Washington, September.

Myers, D.A., 2005, *Field Investigation Report for Waste Management Areas T and T -TY*, RPP-23752, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, June.

Sheppard, M.I., and D.H. Thibault, 1990, "Default Soil Solid/Liquid Partition Coefficients, K_ds, for Four Major Soil types: A Compendium," *Health Physics*, Vol. 59, pp. 471–482.

THOR Treatment Technologies, 2002, *THOR^{SM} Steam Reforming Process for Hazardous and Radioactive Wastes, Technology Report*, TR-SR02-1, Rev. 1, Richland, Washington.

Weast, R.C., and S.M. Selby, eds., 1966, *CRC Handbook of Chemistry and Physics*, 47th ed., The Chemical Rubber Company, Cleveland, Ohio.

Weast, R.C., and S.M. Selby, eds., 1967, *CRC Handbook of Chemistry and Physics*, 48th ed., The Chemical Rubber Company, Cleveland, Ohio.

Wood, M.I., and T.E. Jones, 2003, *Subsurface Conditions Description of the U Waste Management Area*, RPP-15808, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, April.

Wood, M.I., T.E. Jones, B.N. Bjornstad, D.G. Horton, S.M. Narbutovskih, and R. Schalla, 2003, *Subsurface Conditions Description of the C and A-A Waste Management Area*, RPP-14430, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, April.

APPENDIX N
VADOSE ZONE FLOW AND TRANSPORT

The description of the movement of groundwater and solutes through the vadose zone from the ground surface to the water table of the underlying, unconfined aquifer is a major element in estimation of impacts on groundwater quality and human health for this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*. At the Hanford Site, past operations, current practices, and proposed future activities will affect groundwater conditions for long periods of time. For this reason, the assessment of potential impacts relies on mathematical modeling of vadose zone processes rather than monitoring or measurement of conditions. The scope of vadose zone analysis for this *TC & WM EIS* is large, including contributions from tanks and ancillary equipment at 18 high-level radioactive waste tank farms, six sets of cribs and trenches (ditches) immediately associated with tank farm activities, proposed new Integrated Disposal Facilities for radioactive and hazardous waste, and closure of the Fast Flux Test Facility. In addition, approximately 380 facilities not included in the scope of decisions of this *TC & WM EIS* are analyzed for their contribution to cumulative impacts.

The primary objective of vadose zone analysis is to estimate the rates and magnitudes of movement to the unconfined aquifer of water and solutes introduced with natural recharge, planned liquid discharges, leaks, spills, and disposals. The estimates of release to the vadose zone described in Appendix M and transport through the unconfined aquifer described in Appendix O interface closely with the vadose zone analysis described in this appendix. A secondary objective of vadose zone analysis is to provide an understanding of the influence of the proposed Black Rock Reservoir on future Hanford Site (Hanford) hydrologic conditions. Estimates of human health impacts, based on integration of estimates of the rate of release (see Appendix M) and the rate of transport through the vadose (Appendix N) and saturated (see Appendix O) zones are presented in Appendix Q. Comparisons of impacts within and across alternatives are presented in Chapters 5 and 2, respectively.

The balance of this appendix comprises a description of the technical approach to vadose zone analysis, a summarization of results for *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* alternatives, and a discussion of the sensitivity analysis of major parameters incorporated into the analysis of vadose zone processes. Although best available data and models are used to construct the analysis described in this appendix, uncertainty in results remains. This uncertainty derives from variability in natural conditions such as rates of precipitation and recharge and spatial heterogeneity of soil types, as well as lack of knowledge in areas such as the applicability of specific models to site-specific locations and conditions and the type of climate to be experienced in the future.

N.1 TECHNICAL APPROACH TO VADOSE ZONE ANALYSIS

The technical approach to vadose zone analysis involves selection of the upper-level framework for the analysis and implementation of framework specifics, including specification of the spatial extent of model study areas, characterization of geologic conditions, development of model grid configurations, and establishment of values of model parameters. The following sections describe these two elements of the vadose zone analysis.

N.1.1 Upper-Level Approach

The upper-level approach involves consideration of the boundaries of the model domain, the degree of integration of vadose and saturated zone analysis, and the establishment of initial and boundary conditions for the model. The required spatial extent of the model domain is that of the Hanford Site, approximately 1,450 square kilometers (560 square miles), with model depth ranging from 10 to 200 meters. The time frame for the analysis is from the start of site operations in calendar year 1944 out to 10,000 years in the future. The 10,000-year period of analysis is longer than the 1,000-year period

recommended in the U.S. Department of Energy (DOE) guidance for performance assessment of low-level radioactive waste and deactivated high-level radioactive waste (HLW) facility closure (DOE Guide 435.1-1) but adequate to capture the longer vadose zone travel times of select constituents of potential concern for the *TC & WM EIS* analysis.

The preferred approach to groundwater modeling is full integration of vadose and saturated zone analysis with transient location of the water table determined as part of the solution of a single model. Because of the large extent of the model domain, the small size of subareas of interest, and the long time period for analysis, the implementation of this approach is not practical with state-of-the-art computing capabilities. A second approach to integration of vadose and saturated zone analysis would be the specification of a single, large-scale saturated zone model; specification of smaller subarea models for integrated vadose and saturated zone analysis; and integration of the subarea models with the single, large-scale saturated zone model. Because of the rather small size of the required subareas and the time requirements for computation of transient water table locations for multiple subareas, this approach is also not practical at the current time. Specific issues that complicate integration of the MODFLOW (modular three-dimensional finite-difference groundwater flow model) saturated zone and STOMP (Subsurface Transport Over Multiple Phases) vadose zone–saturated zone models are the short duration of the transient period to be represented by the simulations and the spatial variation of the water table.

The upper-level approach adopted for this *TC & WM EIS* groundwater analysis is the development of a single, large-scale saturated zone model followed by the development of multiple small-scale vadose zone–only models that are coupled with the saturated zone model through equivalent specification of boundary conditions to provide a consistent, integrated analysis of transient groundwater conditions. The development, calibration, and implementation of the large-scale saturated zone model are described in Appendix L. Simulation of the vadose zone subareas is accomplished using the STOMP computer code (White and Oostrom 2000, 2006). The STOMP model uses an integrated-volume, finite-difference approach to solve nonlinear water and solute transport balances for the vadose zone. Features of the STOMP model used in the *TC & WM EIS* analysis include (1) a three-dimensional representation of geology, hydraulic properties, and grid geometry; (2) temporal and spatial variability of groundwater recharge at the ground surface; (3) temporal and spatial variability of water and solute injection at any horizontal location and vertical depth; and (4) water and solute output fluxes at specified surfaces. Three-dimensional representation was selected to incorporate spatial heterogeneity of geologic and recharge conditions and to explicitly simulate the complexity of travel time behavior due to lateral spreading and preferential flow reflecting local conditions. The relationships of moisture content and pressure and moisture content and hydraulic conductivity within the vadose zone were simulated using the van Genuchten and Mualem models (van Genuchten 1980; Mualem 1976). These models contain seven adjustable parameters: saturated moisture content, residual moisture content, saturated hydraulic conductivity for three spatial directions, and two additional empirical constants that are determined by comparison with site data.

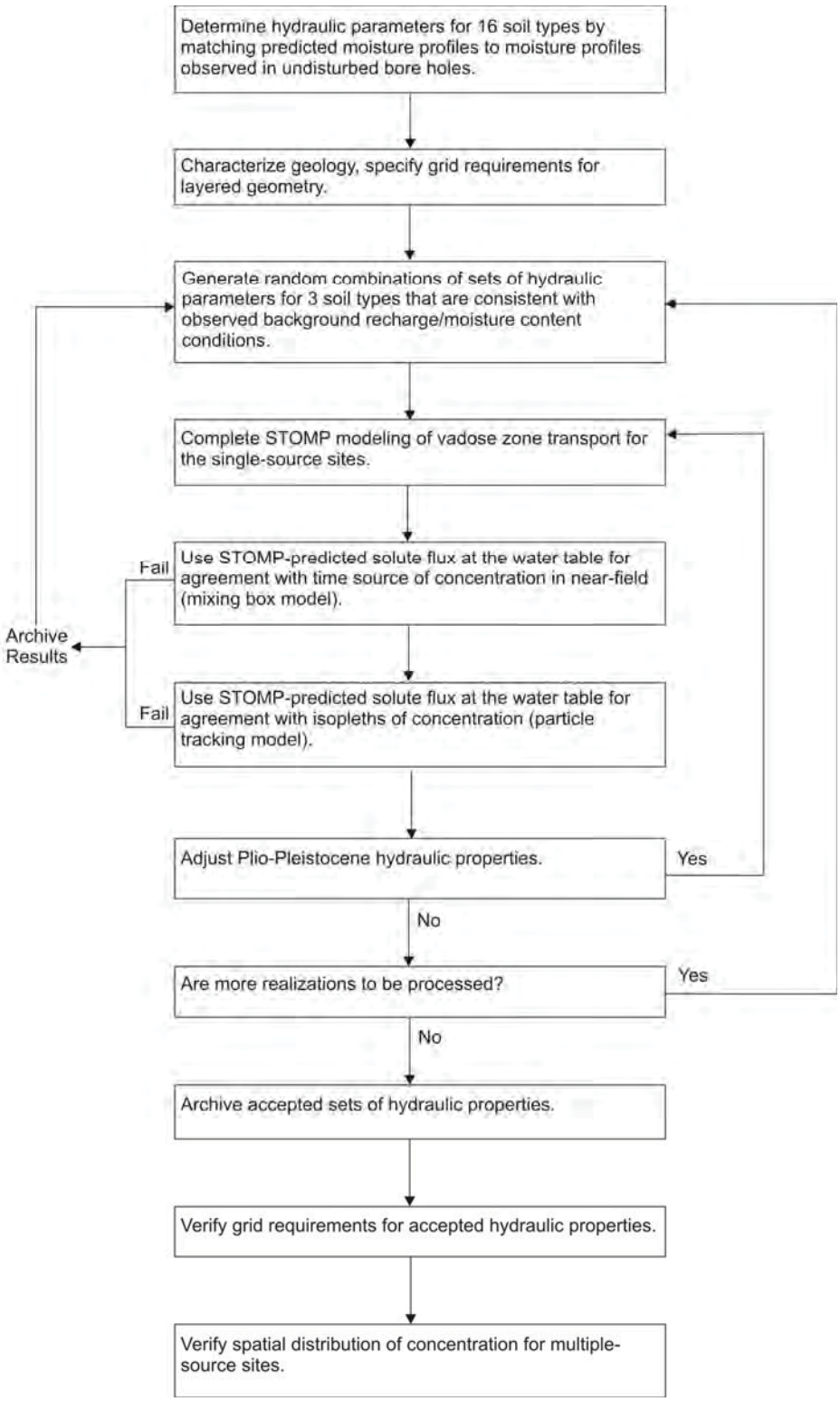
N.1.2 Vadose Zone Model Implementation

More than 400 subarea models are required for analysis of *TC & WM EIS* alternative and cumulative analysis sites. Each of these is simulated as a rectangular box where the upper surface represents the ground surface and the lower surface, the water table. The thickness of this box, different for each subarea site, is established from the long-term steady state of the unconfined aquifer model. Boundary conditions for the upper surface at each site are a specified recharge determined by technical guidance (DOE 2005) and zero flux of solute. Boundary conditions for the lower surface are atmospheric pressure and a zero gradient of solute. Boundary conditions for each of the four sides of the box are zero flow of water and solute.

The pattern of the horizontal grid for each subarea was based on the aqueous discharge from the source. The grid pattern and model extents were incorporated to limit the effect the boundary conditions and node size had on the model conditions. All nodes within the source were equal in size and were bounded by the source site boundary. Grid sizes could increase or decrease by the harmonic rule, meaning node lengths could increase or decrease by one and a half the adjacent node length. Sources with no aqueous discharge could have node length no greater than 20 meters (66 feet) within the source site. The node size could increase by the harmonic rule to at least 120 meters (39 feet) from the source boundary. Sources with aqueous recharge were categorized as moderate (<1 meter [3 feet] per year) or heavy (>1 meter [3 feet] per year). Moderate recharge sites had a grid length of no larger than 5 meters (16 feet) within the source site. The maximum 5-meter (16-foot) grid length continued to 50 meters (164 feet) from the site boundary. The grid size increased by the harmonic rule to a distance 150 meters (492 feet) from the site boundary. The heavy recharge site had a grid length of no larger than 5 meters (16 feet) within the source site. The maximum 5-meter (16-foot) grid length continued to 50 meters (164 feet) from the site boundary. The grid size increased by the harmonic rule to a distance of 170 meters (558 feet) from the site boundary.

Given these conditions, development of the model was completed by specifying values of hydraulic properties for 16 Hanford soil types and subarea-specific geology and grid dimensions. In summary, the process for the selection of hydraulic parameter values involved the matching of predicted to measured borehole moisture content profiles for all 16 soil types followed by the matching of randomly generated to observed unconfined aquifer conditions for 3 primary soil types. It also provided for consistency with values of saturated hydraulic conductivity determined in the calibration of the saturated zone model and with area-specific geology and grid size requirements. A flow diagram for the process is presented as Figure N–1, and greater detail is provided in the following paragraphs.

A stepwise, iterative procedure was applied to determine area-specific geology and grid dimensions and to identify values of hydraulic properties that best match conditions observed at the site. In an initial step, values of vadose zone parameters were determined for the 16 soil types by matching moisture content profiles predicted using the van Genuchten relationship to moisture content profiles measured in 140 undisturbed vadose zone boreholes. Values of saturated hydraulic conductivity were restricted to ranges consistent with the calibrated saturated zone model. An example of the match between predicted and observed moisture contents for an undisturbed borehole in the 200-East Area is presented as Figure N–2. The blue dots in the figure represent moisture content determined by the neutron scattering method. The red line is the model fit to the borehole data. The horizontal gray lines represent soil contact changes. The soils represented in this figure are Hanford Gravel, Hanford Sand, Plio-Pleistocene Silt, and Plio-Pleistocene Gravel. At this stage, sensitivity analysis was performed for generic 200-East and 200-West Areas to establish grid size requirements for accurate computations. Given this information, the interpretation of borehole data was applied to assign soil types for each of the approximately 400 study areas on a grid block–specific basis. An example of the interpreted borehole data is presented as Figure N–3, where the lithology of the cross-section is vertically exaggerated. Figure N–3 represents a geologist's interpretation of the subsurface geology at B- and BX-Tank Farms in the 200-East Area. Single or multiple cross sections of interpreted borehole data were used to specify a three-dimensional spatial distribution of soil types that is encoded into STOMP input files for each of the study areas. An example of this translation into STOMP input data is presented in Figure N–4 for the TX Tank Farm in the 200-West Area. The STOMP data of Figure N–4 for the 200-West Area show layers of Plio-Pleistocene soils present at the TX Tank Farm that are not present in the borehole data of Figure N–3 for the 200-East Area at the B- and BX-Tank Farms. Not all of the 16 soil types are present at all locations; within the specific cross section presented as Figure N–4, for example, only 7 of those soil types are found. This contrast is representative of the level of detail of the spatial distribution of soil types that is captured in the interpretation and translation process.



Key: STOMP=Subsurface Transport Over Multiple Phases.

Figure N–1. Flow Diagram for Selection of Values of Vadose Zone Hydraulic Parameters

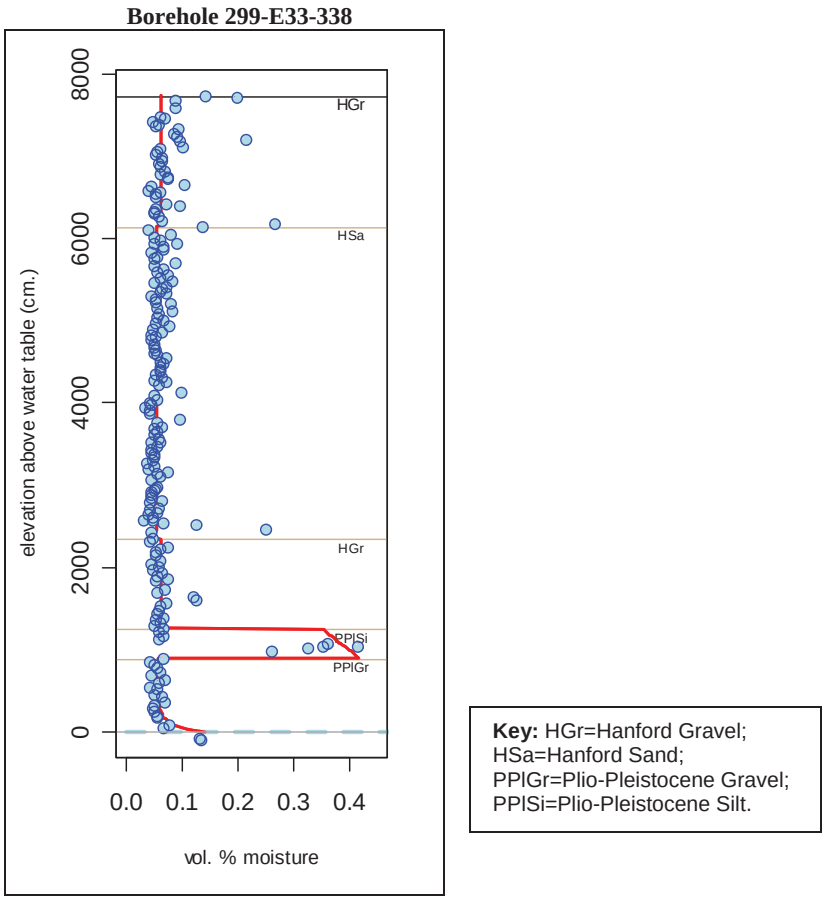


Figure N–2. Predicted and Measured Moisture Content Profiles

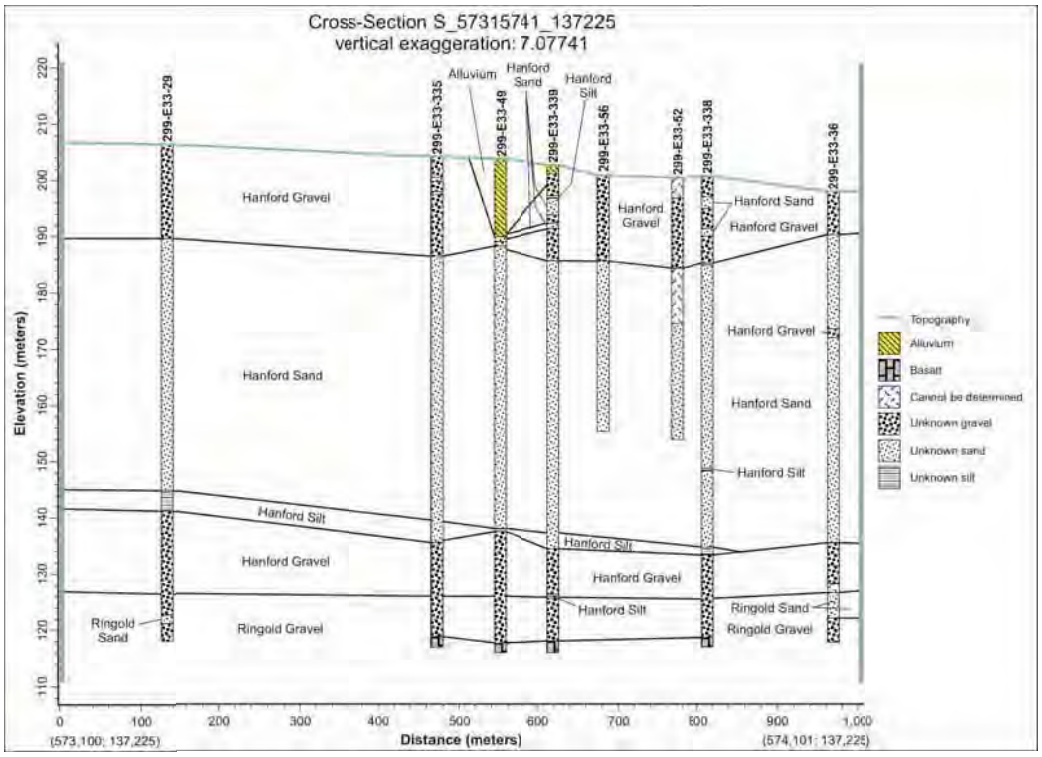


Figure N–3. Borehole Stratigraphy Data

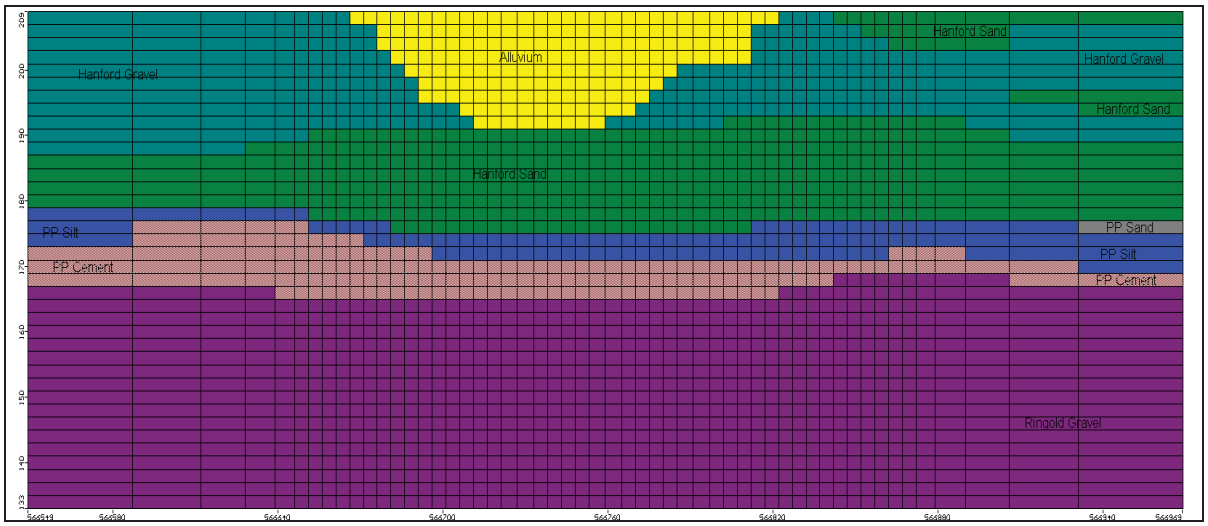


Figure N–4. Vertical Cross Section of a Grid for a STOMP Vadose Zone Model Volume for the TX Tank Farm (200-West Area)

The final element of the model development process, the establishment of final values of the van Genuchten parameters, was accomplished by selecting parameter values that match conditions observed in the unconfined aquifer. Two data sets were employed: (1) observed conditions in the unconfined aquifer that could reasonably be associated with a single source in the vadose zone; and (2) observed conditions in the unconfined aquifer, primarily concentrations of hydrogen-3 (tritium), that are associated with a group of sources. The first data set was used to select the parameter values; the second, to verify the final set of parameter values. The three sets of concentration data for the unconfined aquifer for single-source sites were (1) the concentration of beta activity below the BY Cribs, (2) the beta activity below the BC Cribs, and (3) the activity of iodine-129 in the vicinity of the 216-T-26 Crib.

The review of area-specific geology established that three soil types, Hanford Gravel, Hanford Sand, and Ringold Gravel, jointly represent more than 90 percent of the sediments present in the vadose zone at Hanford. Also, a travel time sensitivity analysis conducted for simple layered geometry established that the movement of water and solute through the vadose zone is largely controlled by these three soil types, with a secondary contribution from Plio-Pleistocene Silt in the 200-West Area. In particular, this finding is applicable for the three areas for which single-source data are available. Accordingly, the refinement of hydraulic parameter values focused on Hanford Gravel, Hanford Sand, and Ringold Gravel. For these three soil types, a systematic search of the parameter space was conducted. To ensure that the entire space of admissible parameter values was investigated, a statistical search and screening were performed. The search involved specification of the range of values for each parameter and random selection of values from uniform distributions defined over the range. The screening involved calculation of the moisture content at a specified constant rate of recharge and comparison thereof with the range of moisture content observed at the site. The step of the procedure identified 18 million combinations of sets of hydraulic parameter values that met the initial screening requirement.

The simulation of movement through the vadose at the three single-source sites was implemented using the STOMP computer code. Predicted fluxes of solute in the water were then used to estimate concentrations in the unconfined aquifer; in the near-field, a mixing-box model was used, and at distances removed from the source, a particle tracking model. At this stage, hydraulic properties of the Plio-Pleistocene Silt were adjusted as needed to match conditions at the 216-T-26 Crib. Sets of values that passed each of these tests were judged acceptable for use in vadose zone analysis. This step of the analysis is described in the following paragraphs using the BY Cribs as an example.

A time series of measurements of gross-beta activity and technetium-99 concentrations at a single location in the unconfined aquifer below the BY Cribs is presented as Figure N–5. The gross-beta data include contributions from beta-emitters other than technetium-99, while more recently, concentrations of technetium-99 have been measured separately and reported in addition to the concentrations of gross-beta activity. Using *TC & WM EIS* data for inventory of technetium-99, historical dates of aqueous discharge and current values of vadose zone hydraulic parameters, the time series of concentration of technetium-99 below the BY Cribs was estimated using the STOMP model and is presented in Figure N–6. The predicted concentration profile reflected in that figure shows an early peak due to rapid movement of the large initial aqueous discharge and a long-term plateau due to a more gradual release of technetium-99 retained in the vadose zone. The early peak of the predicted technetium-99 profile occurs at the same time as the early peak of the measured total beta profile (see Figure N–5) but is lower because of the presence of radionuclides other than technetium-99 among beta emitters. The concentration level measured and predicted for technetium-99 for the current time period are in general agreement. Thus, the predicted concentration profile for technetium-99 shows qualitative agreement with the reported concentration of gross-beta activity, supporting continued investigation of this set of values for the vadose zone hydraulic parameters.

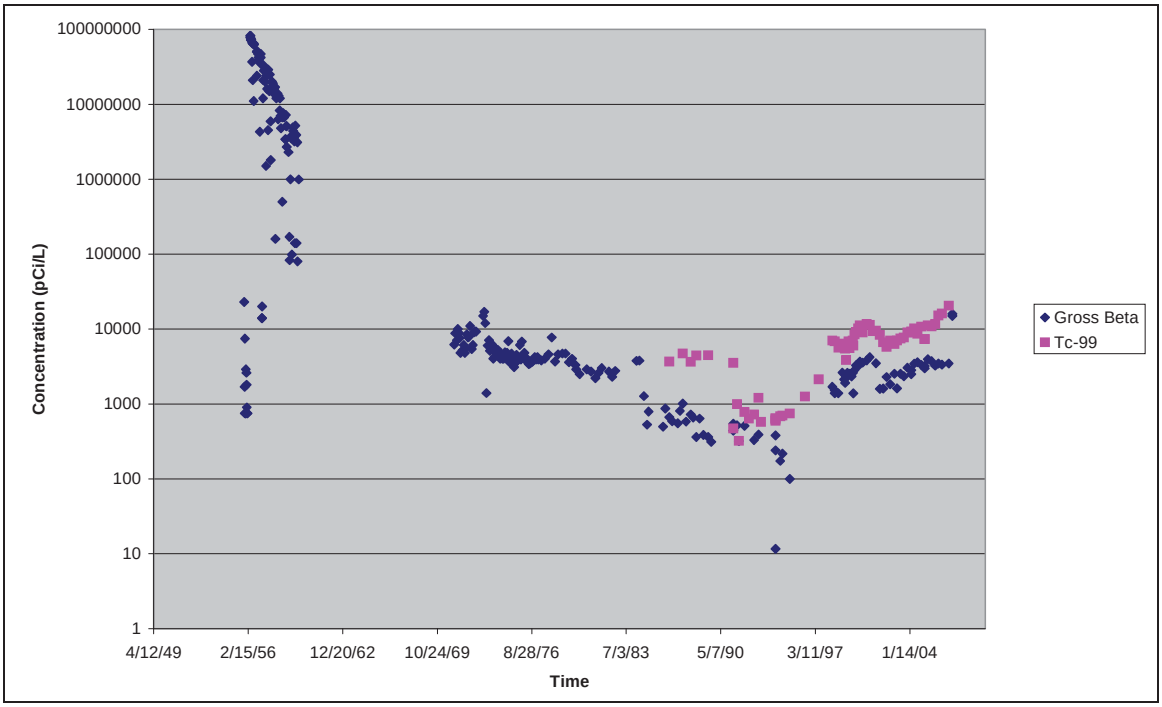


Figure N–5. Time Series of Measured Gross Beta Activity Below the BY Cribs (observed at well 299-E33-7)

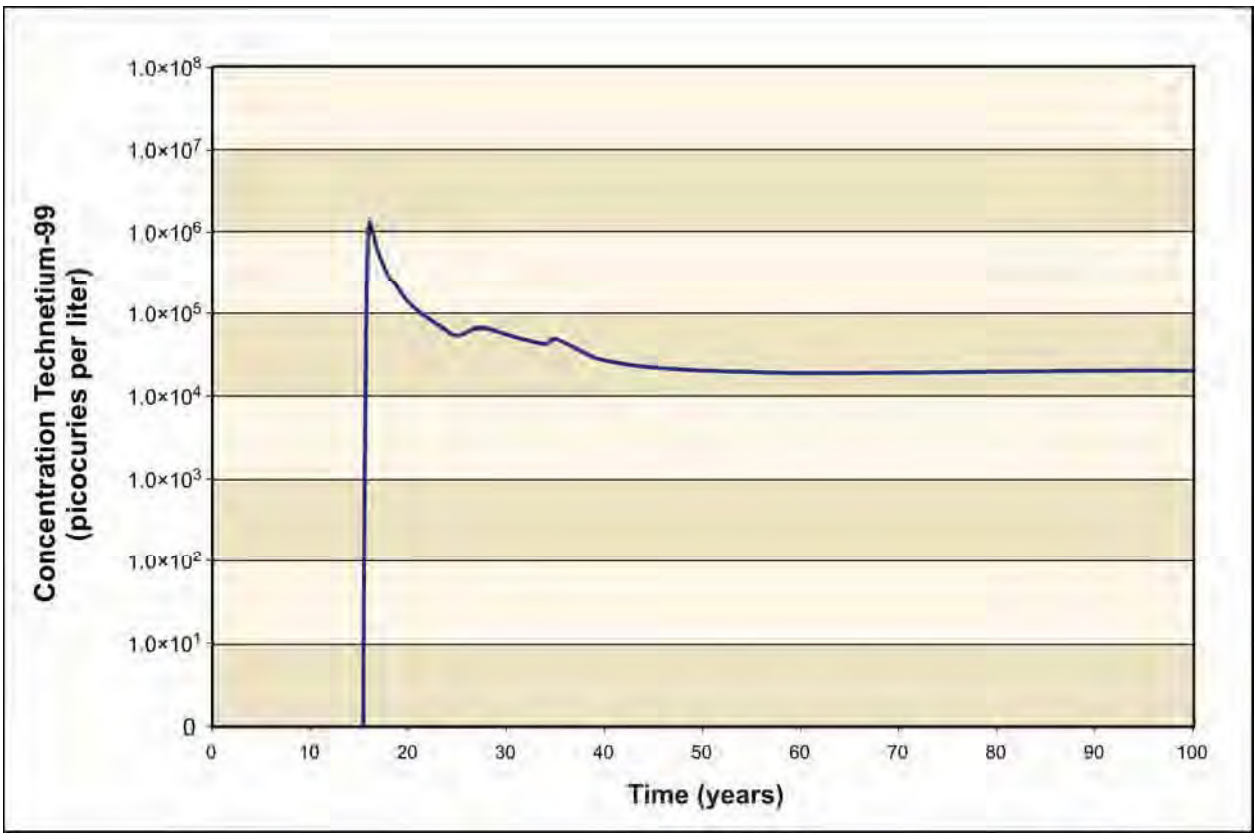
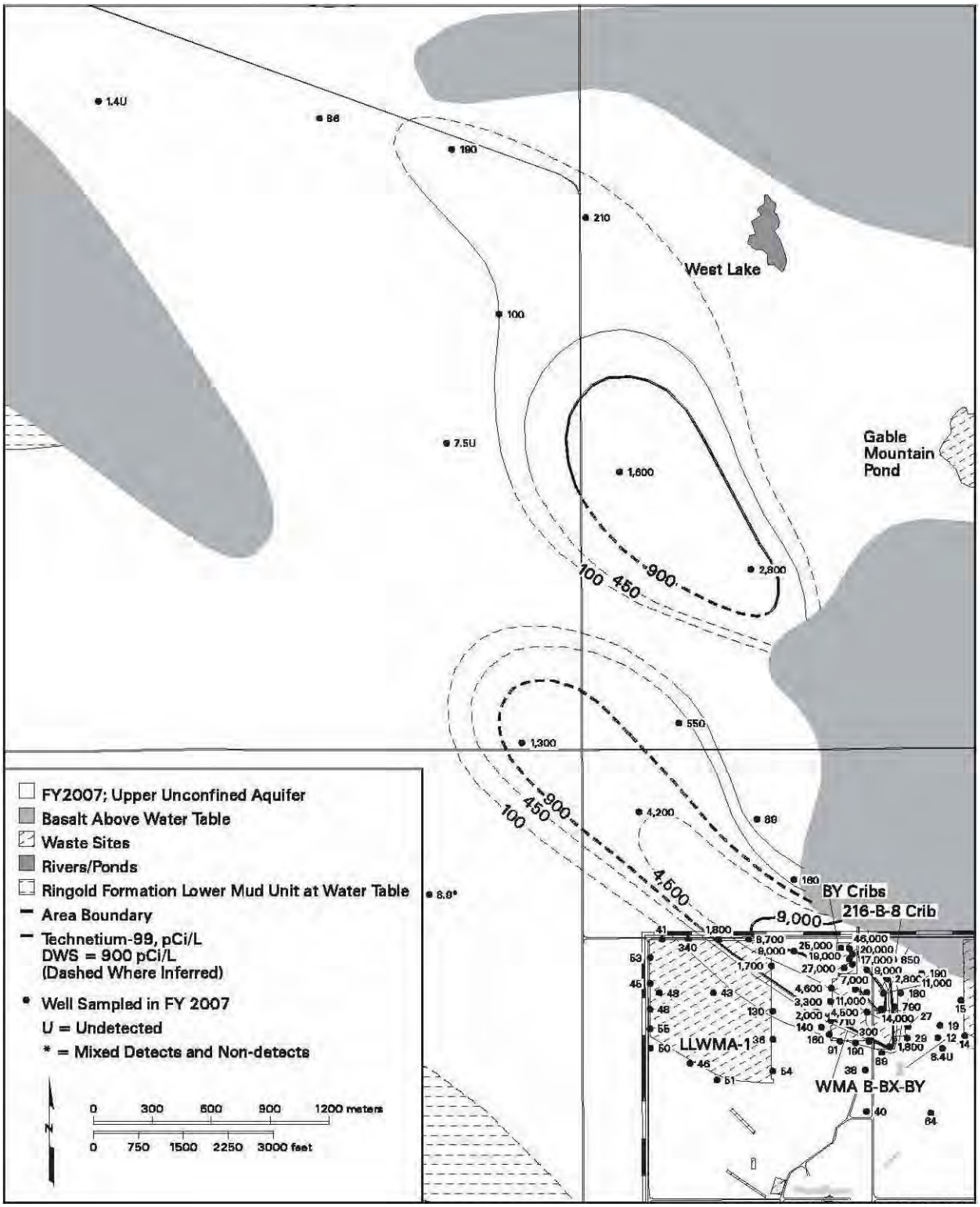


Figure N–6. Time Series of Predicted Concentration of Technetium-99 Below the BY Cribs

In addition to reports of time series of concentrations at single locations, the site monitoring program reports estimates of the spatial distribution of contaminants at specific points in time. Estimates of isopleths of concentration of technetium-99 near the BY Cribs based on measurements reported for 2007 are presented in Figure N–7. These data were used to provide additional testing of the proposed set of values of vadose zone hydraulic parameters. The approach used *TC & WM EIS* source data for the BY Cribs, the STOMP vadose zone model, the MODFLOW-predicted transient flow field, and a particle tracking transport model to predict spatial distribution of technetium-99 in the unconfined aquifer for calendar year 2005. The results of this analysis are presented in Figure N–8. The predicted concentrations show both qualitative and quantitative agreement with measured concentrations, with high levels near the sources and decreasing levels in the northwest direction. The predicted concentrations also show movement to the southeast due to transient flow in that direction under the influence of high aqueous discharges from past Hanford operations.



Key: DWS=Drinking Water Standard; LLWMA=low-level waste management area; WMA=waste management area.

Figure N–7. Isopleths of Concentration of Technetium-99 near the BY Cribs

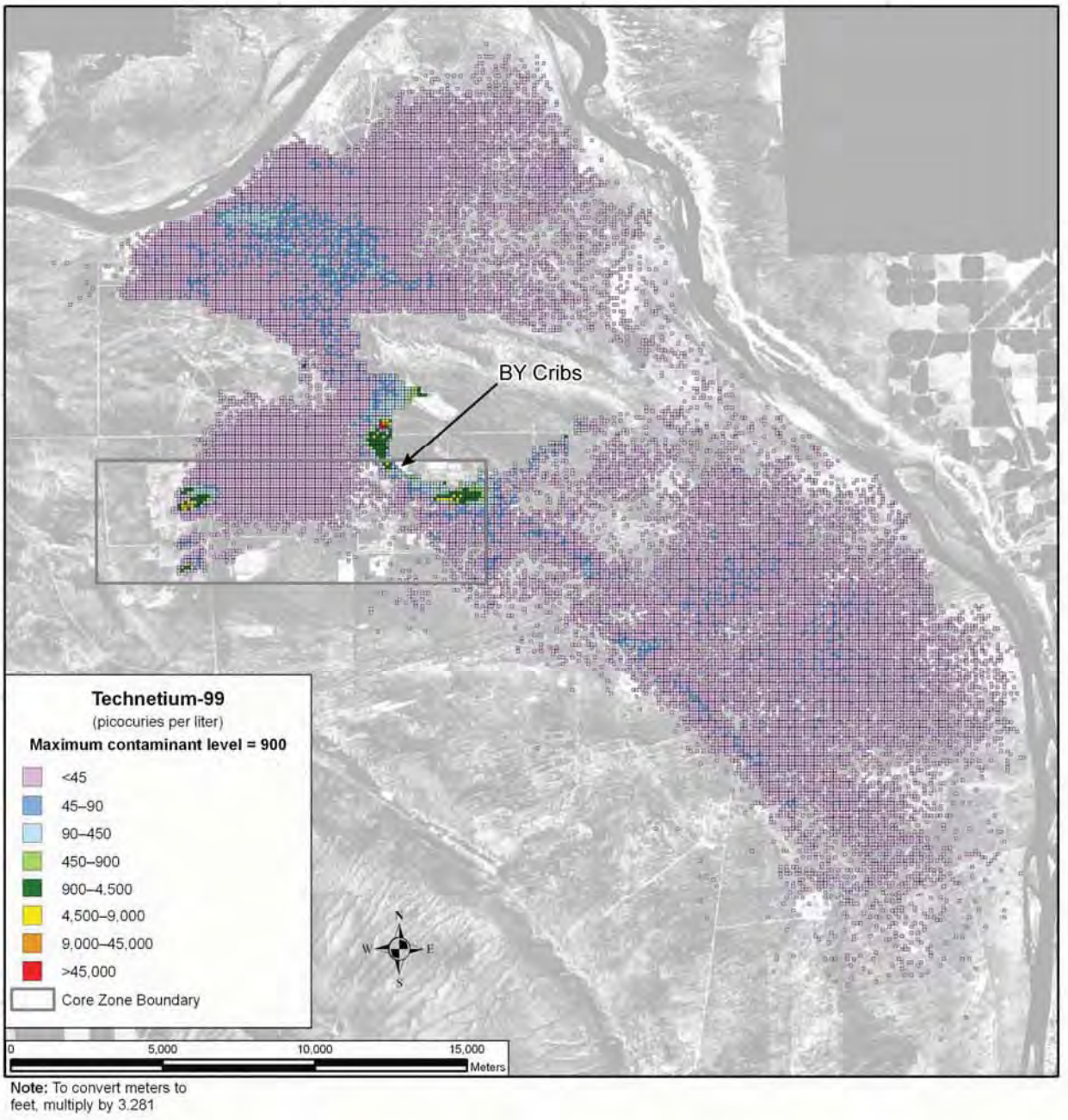


Figure N–8. Particle Tracking Model Output of Technetium-99 Concentrations for Calendar Year 2005 due to Sources at the BY Cribs

Final verification of the parameter values involved sensitivity analysis of grid size dependence and comparison of predictions with measurements for two multiple-source plumes in the unconfined aquifer. For sources associated with the Reduction-Oxidation (REDOX) Facility, a contour plot of the measured concentration of tritium in the unconfined aquifer in calendar year 2007 (Hartman and Webber 2008) is presented in Figure N–9, and the predicted spatial distribution of tritium for calendar year 2005 is presented in Figure N–10. While the predicted concentrations are higher than the measured concentrations, the plumes are similar in terms of spatial extent, continued high concentration at the source, and lengths parallel and perpendicular to the primary direction of flow to the east. On the basis of this quantitative agreement of a factor of less than five quantitative agreements, the values of vadose zone hydraulic parameters are supported by this analysis. Presented in the four plates of Figure N–11 is a groundwater monitoring report interpretation of the evolution of the tritium plume in the unconfined aquifer in the 200-East Area (Hartman, Morasch, and Webber 2004, 2006; Hartman and Webber 2008) as derived for sources associated with the Plutonium-Uranium Extraction (PUREX) Plant. The predicted spatial distribution of tritium for calendar year 2005 is presented in Figure N–12. The measured and predicted distributions of concentration have features in common, including the general shape of the overall spatial distribution, a persistence of elevated concentrations near the source in the southeastern portions of the 200-East Area, an area of elevated concentration in the northeastern lobe of the plume that is migrating toward the Columbia River, and a disruption of the southeast portion of the plume due to activities at the Energy Northwest complex near the Columbia River. The qualitative and quantitative agreement of the measured and predicted concentrations supports use of the selected values of vadose zone parameters. Values for the 16 soil types accepted for use in this *TC & WM EIS* vadose zone analysis are presented as Table N–1. Vadose zone soil parameters for three soil types (Hanford Sand, Hanford Gravel, and Ringold Gravel) are within the range of values established in calibration of the MODFLOW groundwater model. The groundwater soil parameters are described in Appendix L.

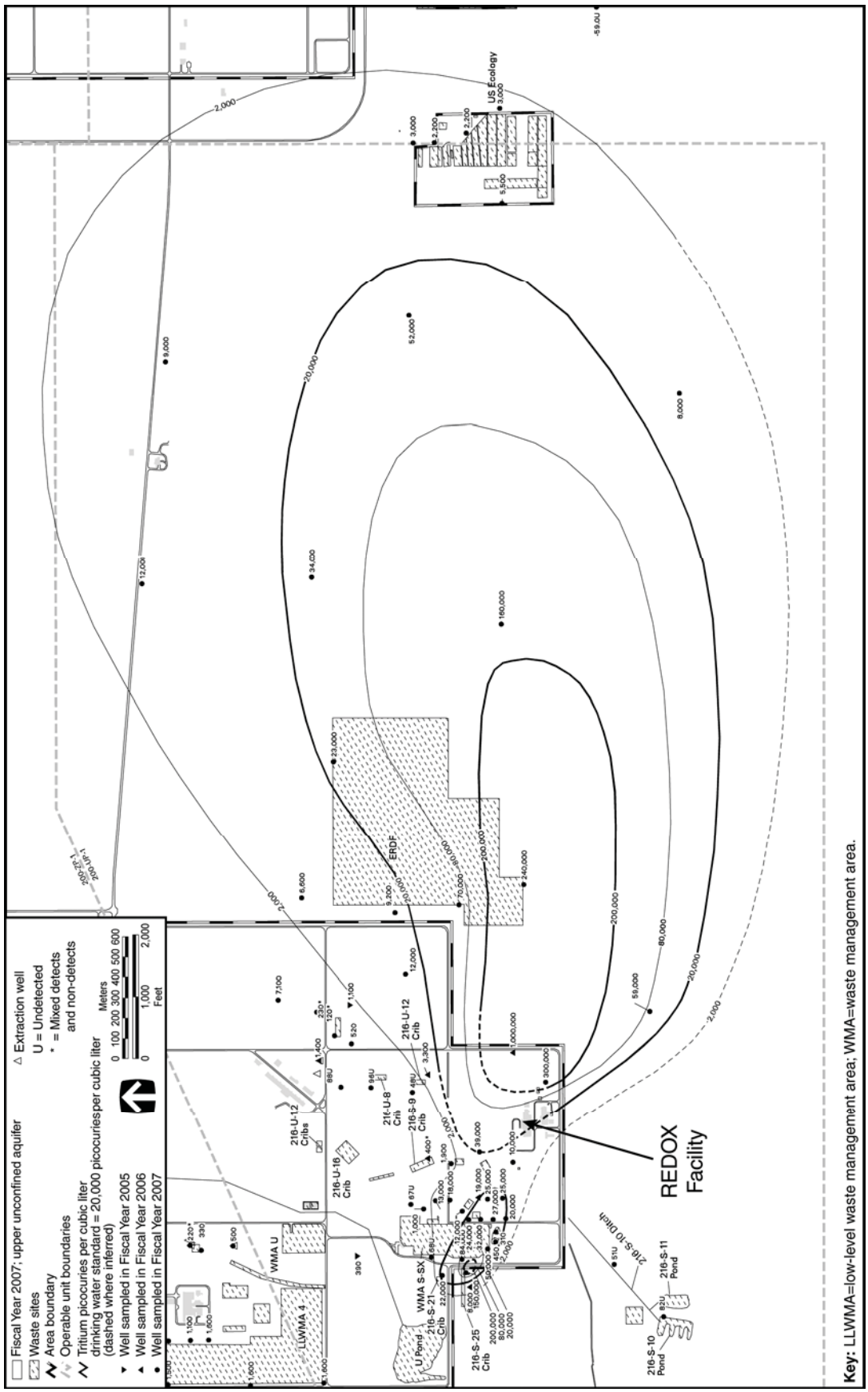


Figure N–9. Isopleths of Concentration of Hydrogen-3 (Tritium) for the Reduction-Oxidation Facility, Monitoring Program

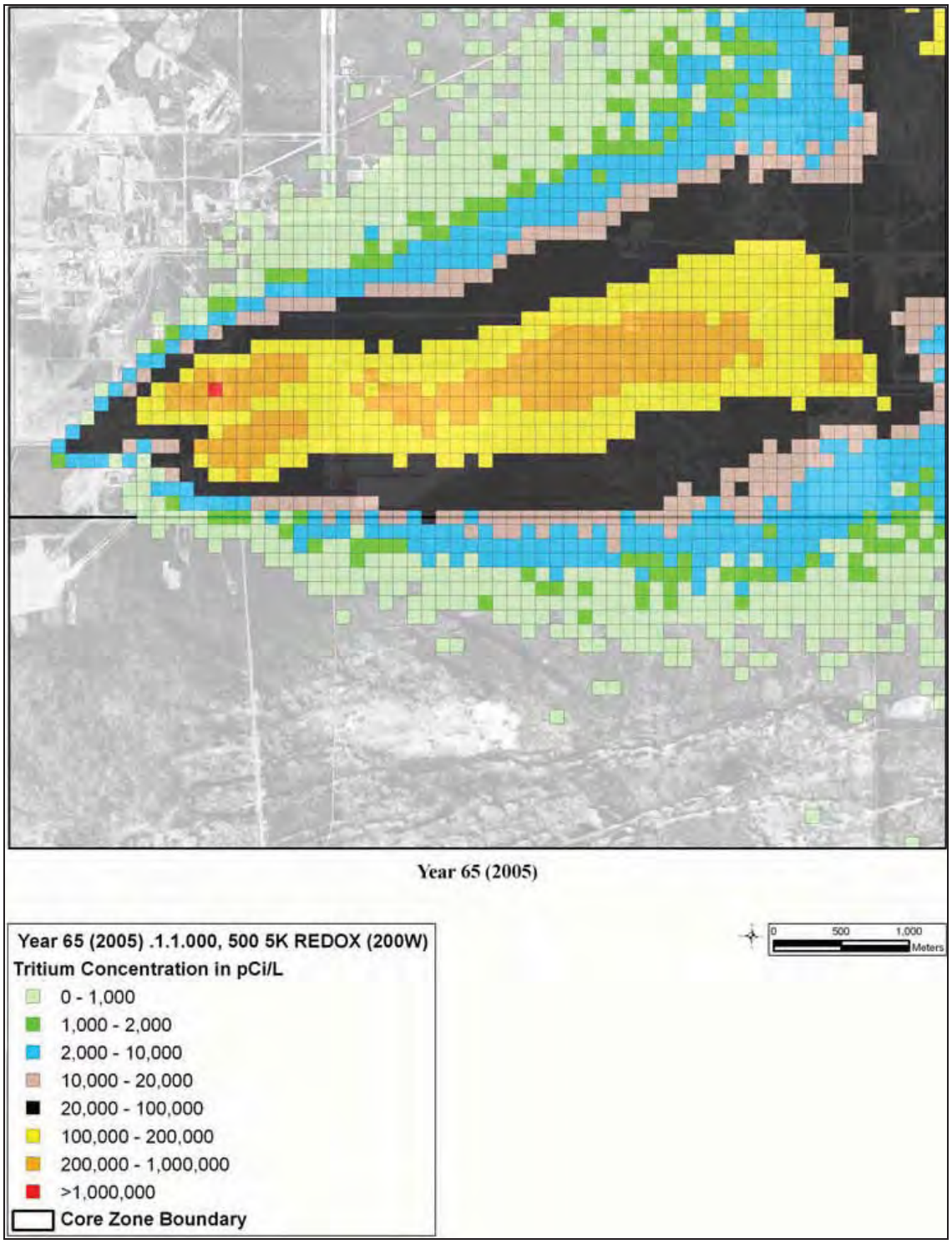
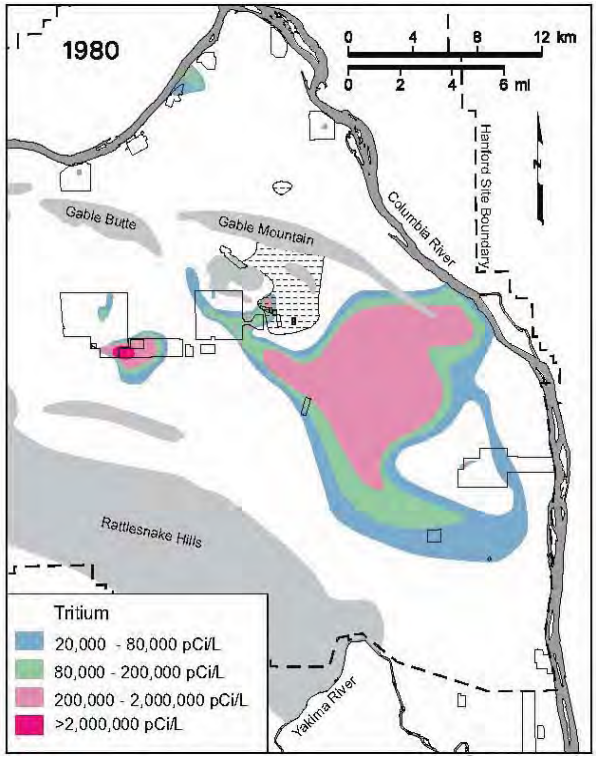
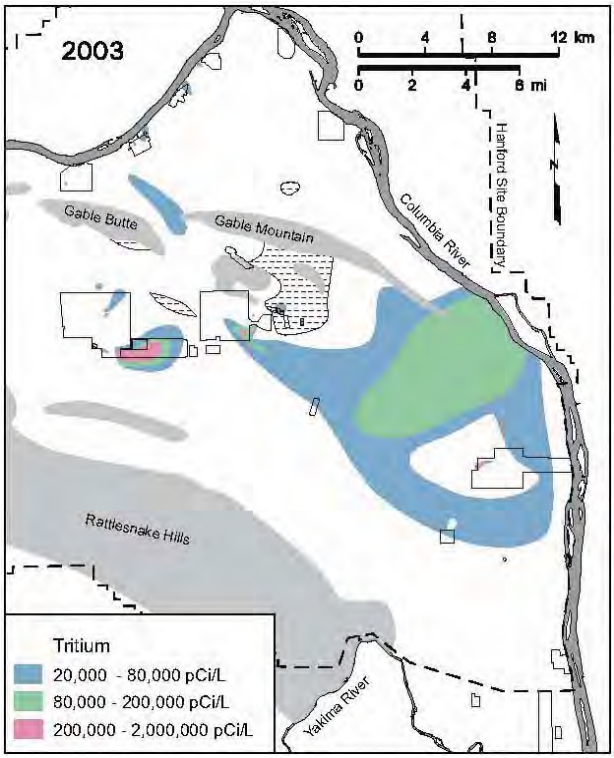


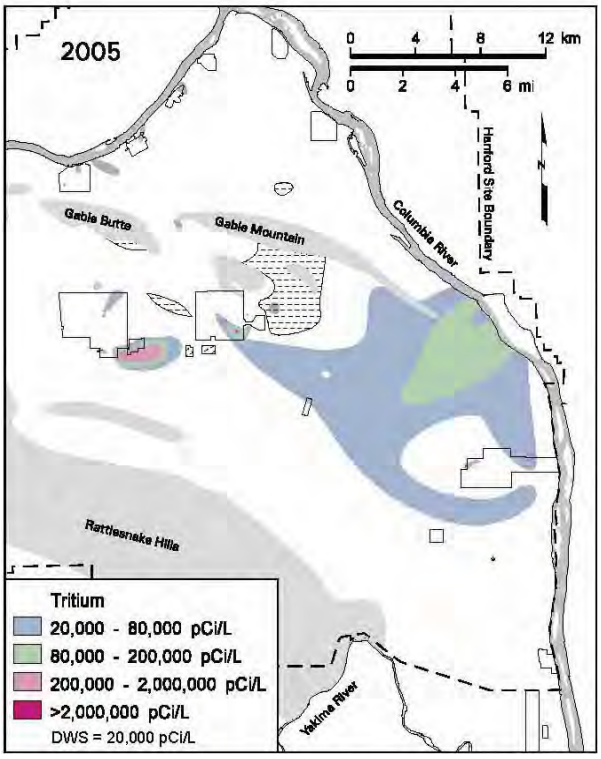
Figure N–10. Isopleths of Concentration of Hydrogen-3 (Tritium) for the Reduction-Oxidation Facility, *TC & WM EIS* Analytic Result



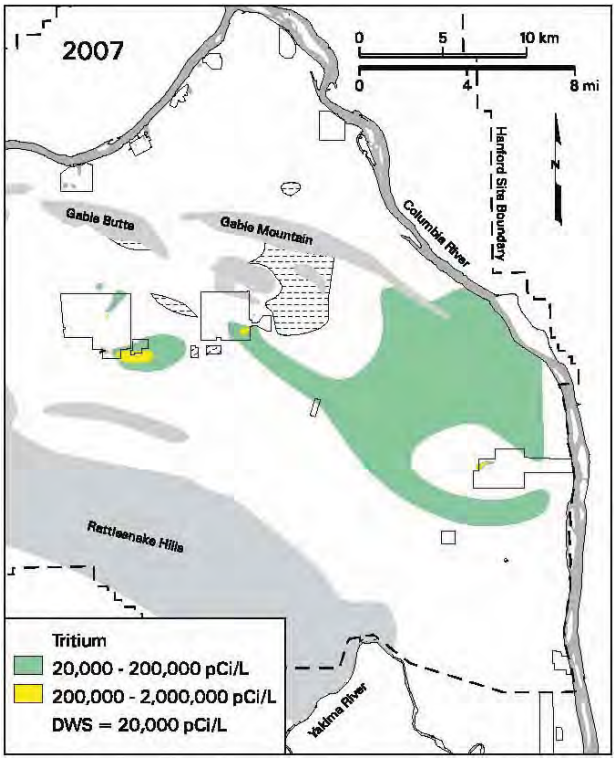
Source: Hartman, Morasch, and Webber 2004.



Source: Hartman, Morasch, and Webber 2004.



Source: Hartman, Morasch, and Webber 2006.



Source: Hartman and Webber 2008.

Figure N–11. Groundwater Monitoring-Based Interpretation of Ongoing Development of the 200-East Area Hydrogen-3 (Tritium) Plume

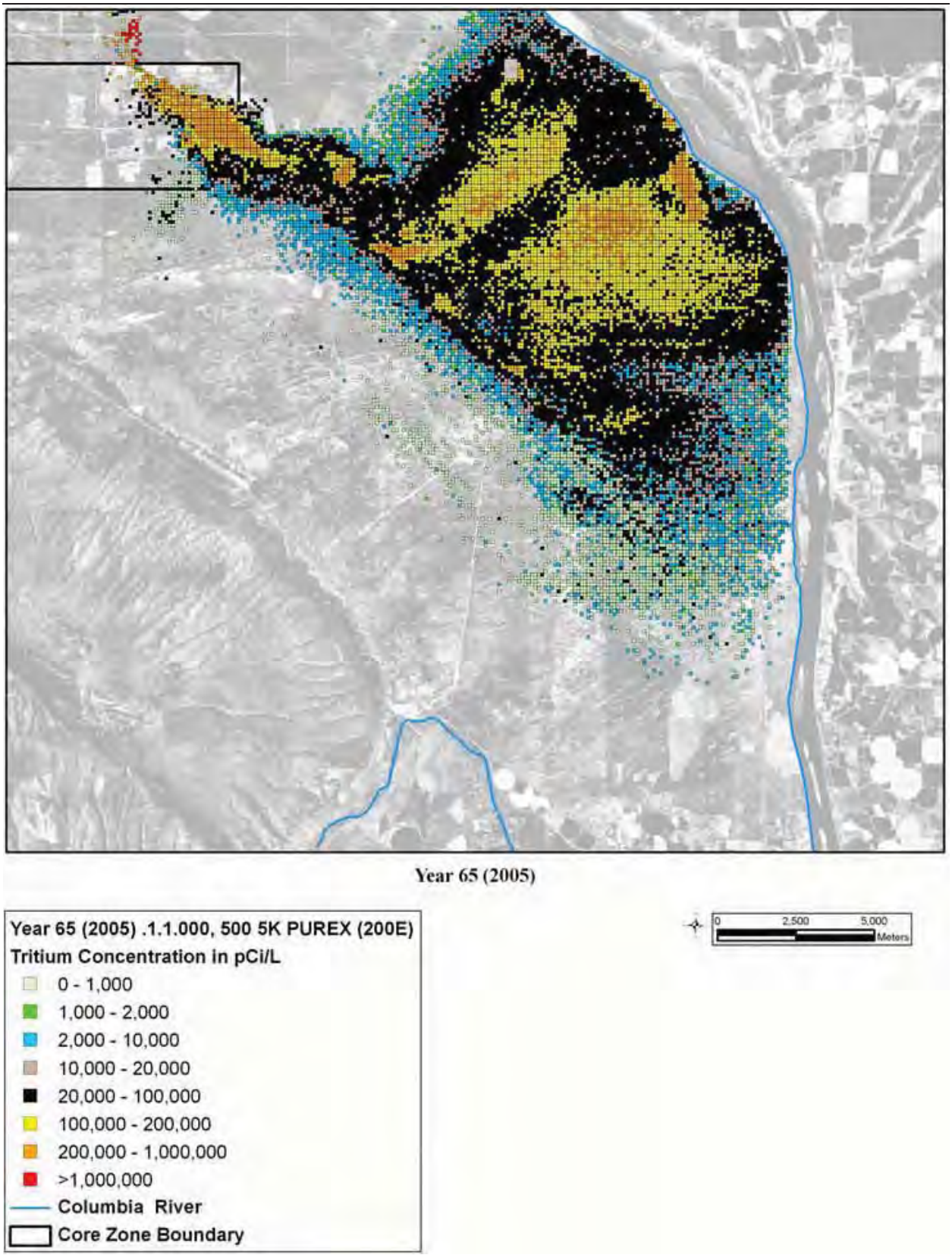


Figure N–12. Isopleths of Concentration of Hydrogen-3 (Tritium) for the Plutonium-Uranium Extraction (Plant), *TC & WM EIS* Analytic Result

Table N–1. Values of Hydraulic (van Genuchten) Parameters for *TC & WM EIS* Analysis Case

Soil Type	Saturated Porosity	Alpha	*n*	Residual Saturation	Vertical Hydraulic Conductivity (centimeters per second)
Alluvium	3.8×10^{-1}	5.0×10^{-2}	1.7	4.0×10^{-2}	8.7×10^{-3}
Hanford Gravel	2.7×10^{-1}	7.1×10^{-2}	2.0	1.7×10^{-1}	1.25×10^{-2}
Hanford Sand	3.0×10^{-1}	6.58×10^{-1}	1.6	8.0×10^{-2}	2.02×10^{-2}
Hanford Silt	3.5×10^{-1}	5.0×10^{-3}	1.8	1.89×10^{-1}	1.7×10^{-3}
Hanford Mud	5.0×10^{-1}	4.0×10^{-3}	2.1	5.0×10^{-2}	5.8×10^{-5}
Plio-Pleistocene Gravel	2.5×10^{-1}	5.0×10^{-2}	1.8	1.93×10^{-1}	8.1×10^{-2}
Plio-Pleistocene Sand	3.0×10^{-1}	9.0×10^{-2}	2.1	7.9×10^{-2}	8.7×10^{-3}
Plio-Pleistocene Silt	4.0×10^{-1}	1.0×10^{-2}	1.8	1.9×10^{-1}	1.2×10^{-3}
Plio-Pleistocene Mud	4.0×10^{-1}	1.25×10^{-3}	1.8	1.9×10^{-1}	1.2×10^{-3}
Plio-Pleistocene Cement	3.0×10^{-1}	1.0×10^{-2}	1.9	4.0×10^{-2}	1.2×10^{-3}
Cold Creek Gravel	2.5×10^{-1}	5.0×10^{-2}	1.8	1.93×10^{-1}	8.1×10^{-2}
Cold Creek Sand	3.0×10^{-1}	9.0×10^{-2}	2.1	7.9×10^{-2}	1.4×10^{-2}
Ringold Gravel	2.7×10^{-1}	7.0×10^{-2}	1.8	3.61×10^{-2}	2.0×10^{-3}
Ringold Sand	3.0×10^{-1}	2.5×10^{-2}	2.75	9.64×10^{-3}	3.94×10^{-4}
Ringold Silt	3.5×10^{-1}	1.0×10^{-2}	2.1	1.9×10^{-1}	1.3×10^{-4}
Ringold Mud	5.0×10^{-1}	5.0×10^{-3}	2.3	3.0×10^{-2}	5.8×10^{-5}

N.2 RESULTS

N.2.1 Tank Closure Alternatives

N.2.1.1 Past Leaks from Tank Farms and Releases from Cribs and Trenches (Ditches)

Under Tank Closure Alternative 1, the tank farms would be maintained in the current condition indefinitely, but, for the purpose of analysis, are assumed to fail after an institutional control period of 100 years. Potential releases to the aquifer from past leaks under Alternative 1 are indicated in Figures N–13 through N–16.

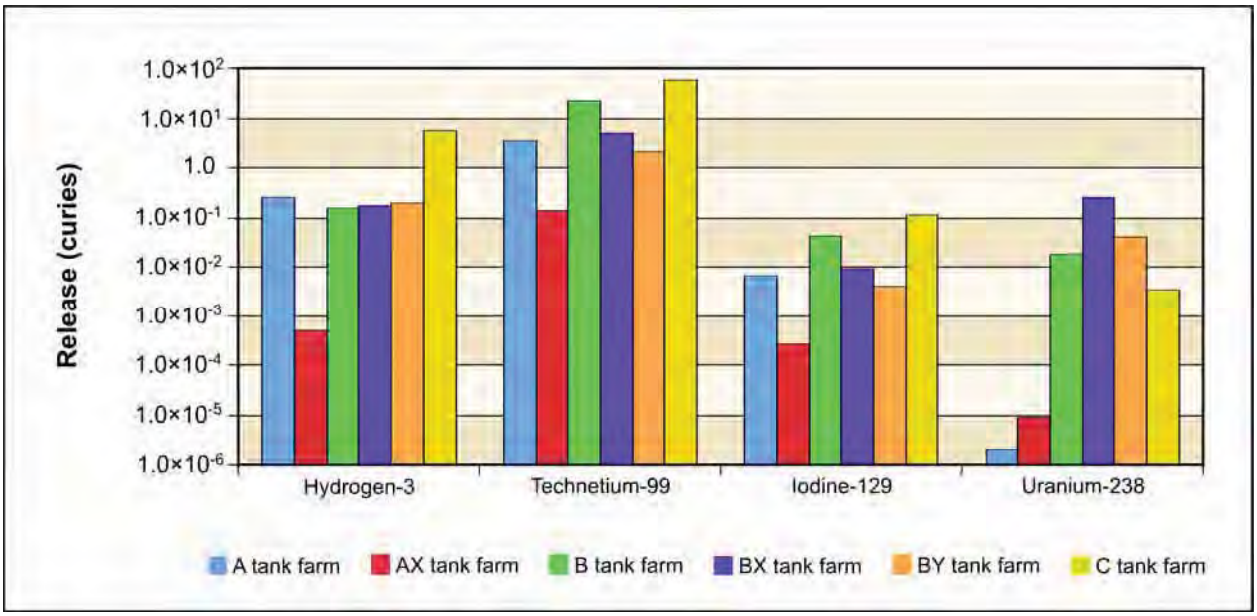


Figure N–13. Tank Closure Alternative 1 Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

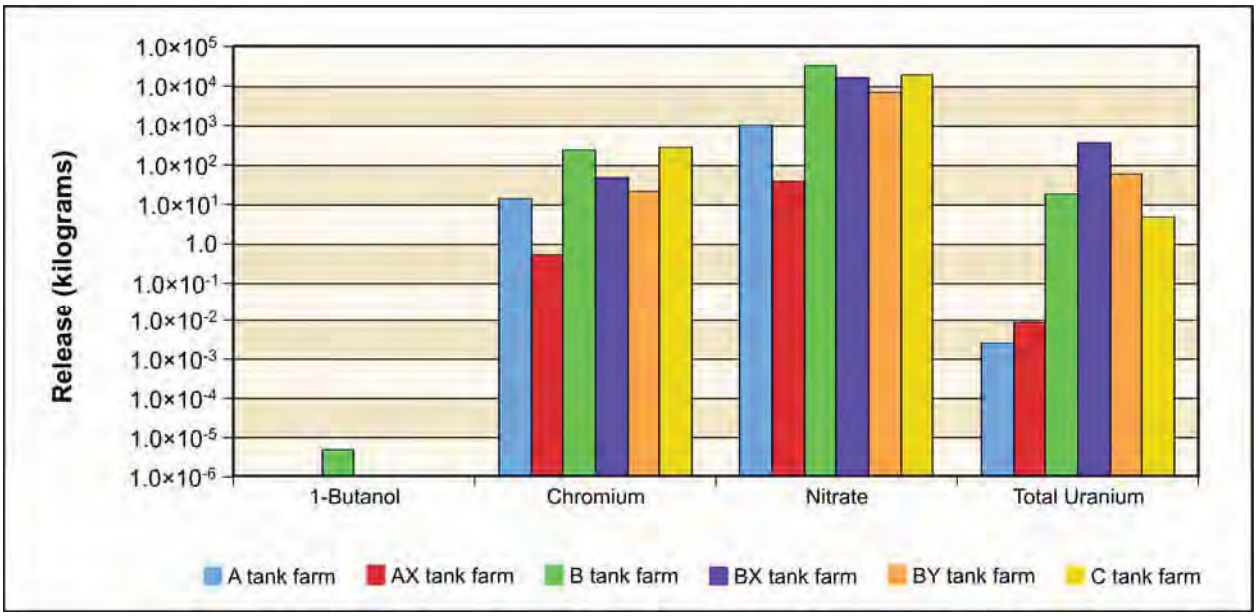


Figure N–14. Tank Closure Alternative 1 Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

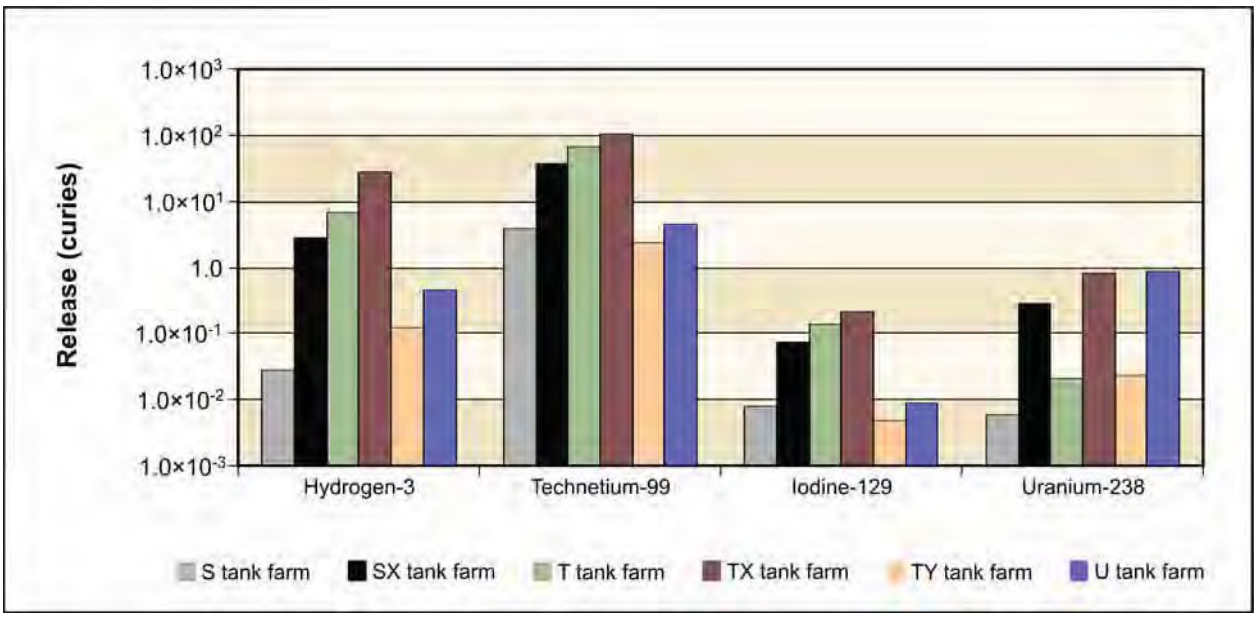


Figure N–15. Tank Closure Alternative 1 Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

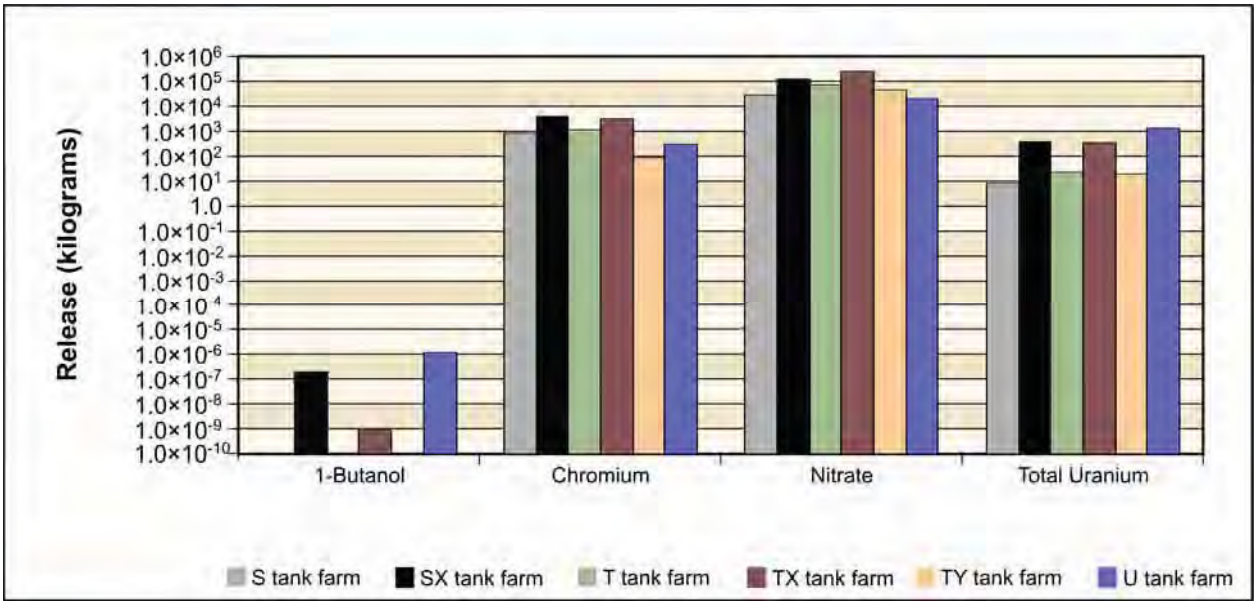


Figure N–16. Tank Closure Alternative 1 Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval. Potential releases to the aquifer from past leaks under Alternative 2A are indicated in Figures N–17 through N–20.

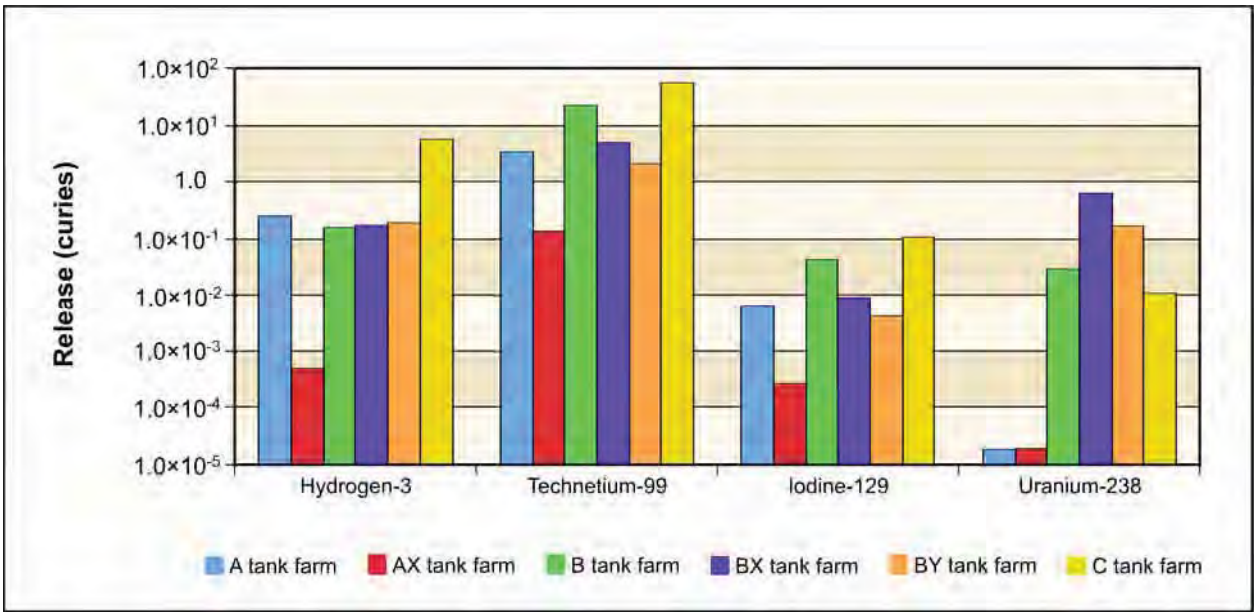


Figure N–17. Tank Closure Alternative 2A Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

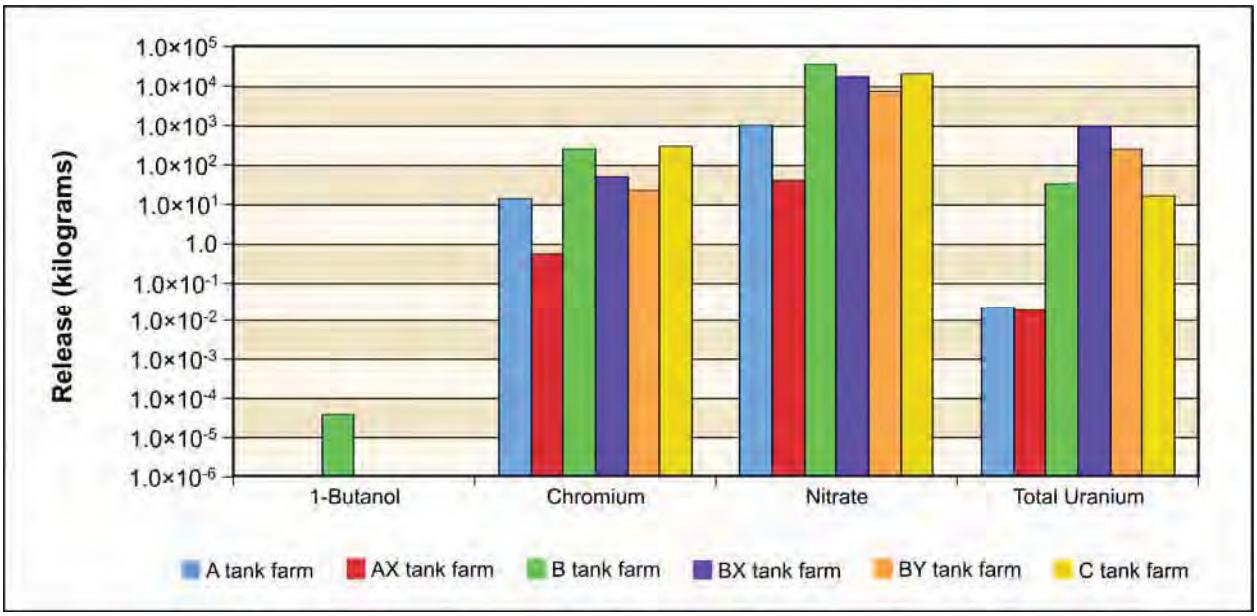


Figure N–18. Tank Closure Alternative 2A Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

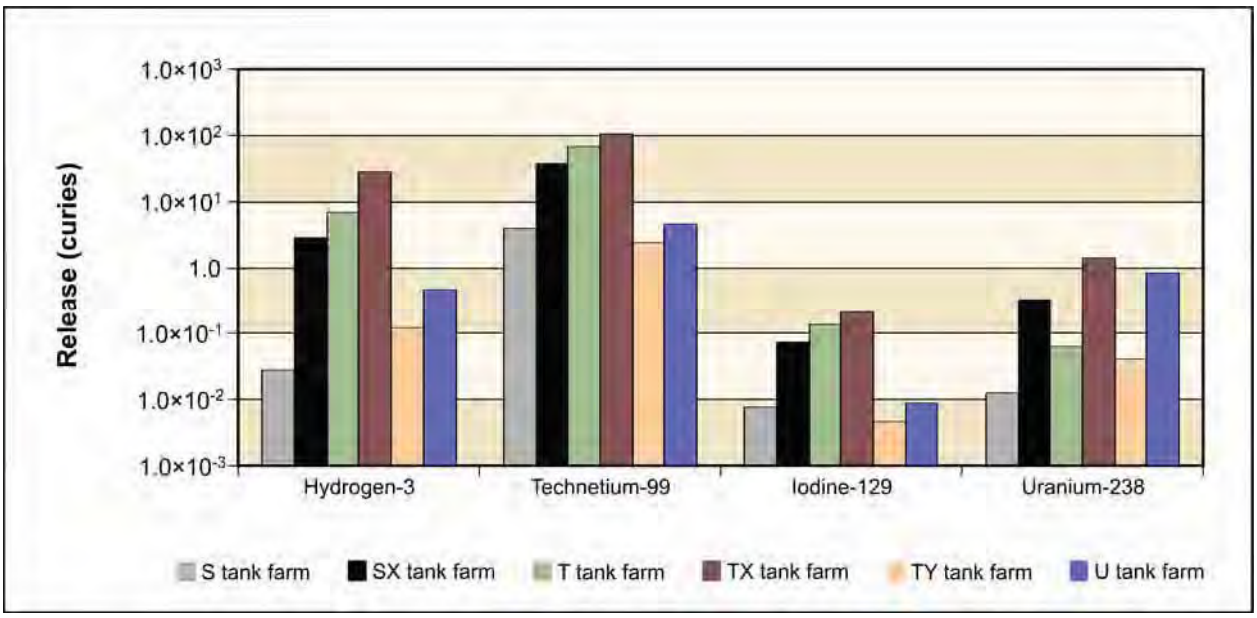


Figure N–19. Tank Closure Alternative 2A Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

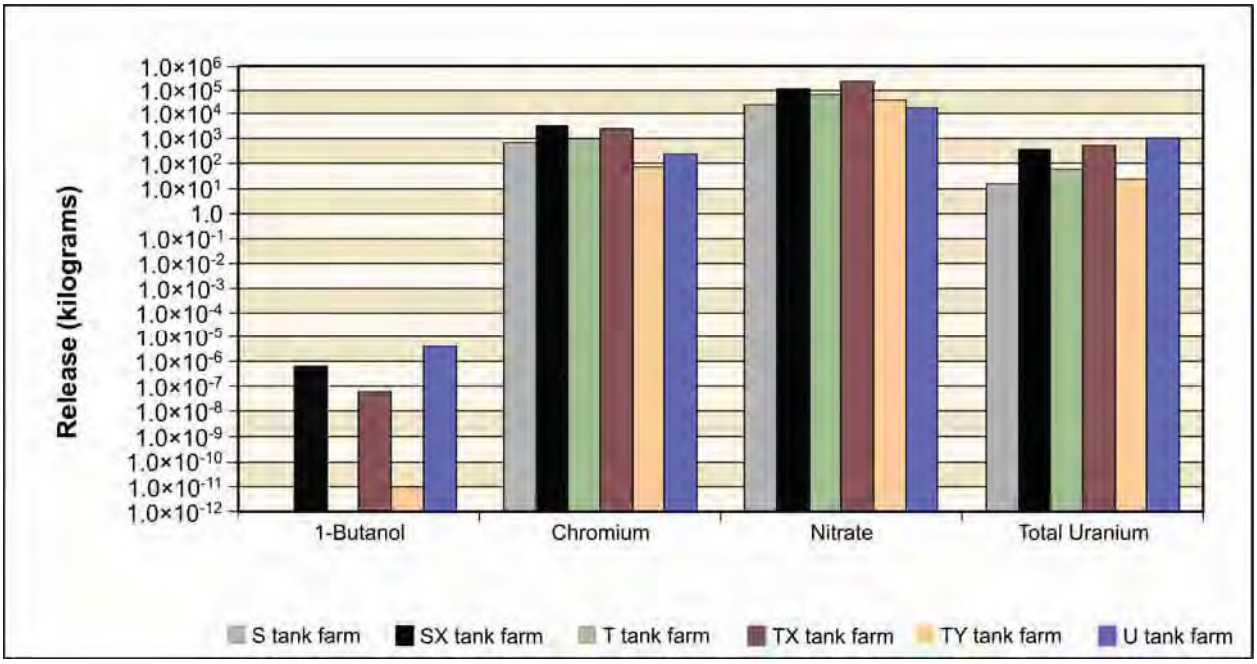


Figure N–20. Tank Closure Alternative 2A Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those of Tank Closure Alternative 2A, with the addition of an engineered modified Resource Conservation and Recovery Act (RCRA) Subtitle C barrier over the tank farms and six sets of adjacent cribs and trenches (ditches). Potential releases to the aquifer from past leaks under Alternatives 2B, 3A, 3B, 3C, and 6C are indicated in Figures N–21 through N–24.

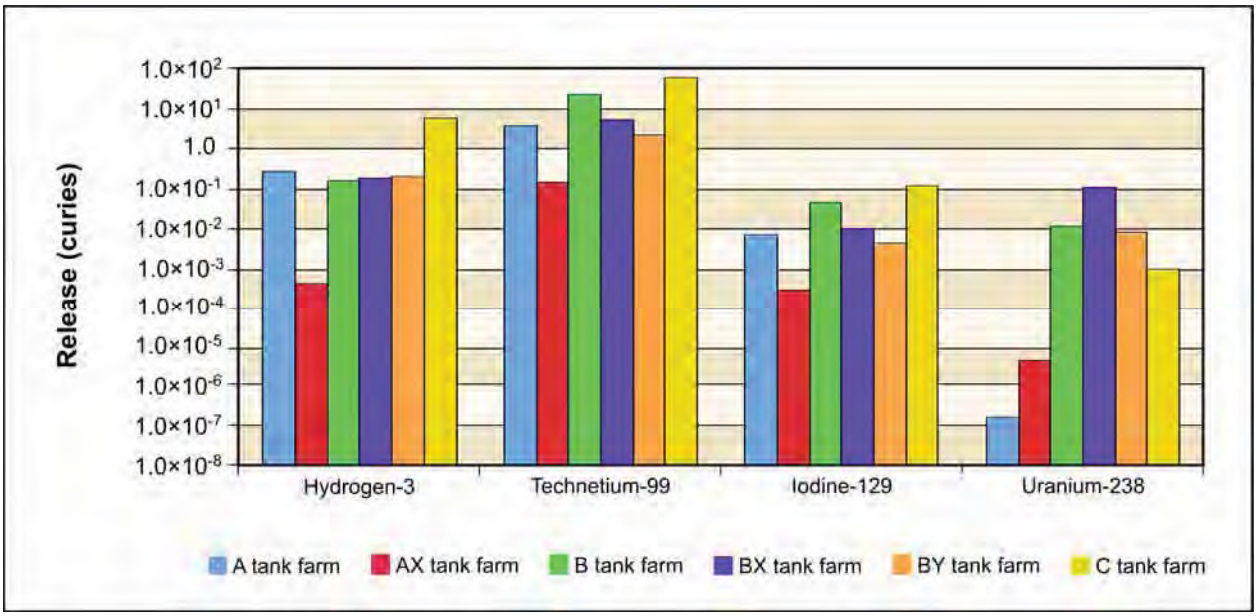


Figure N–21. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

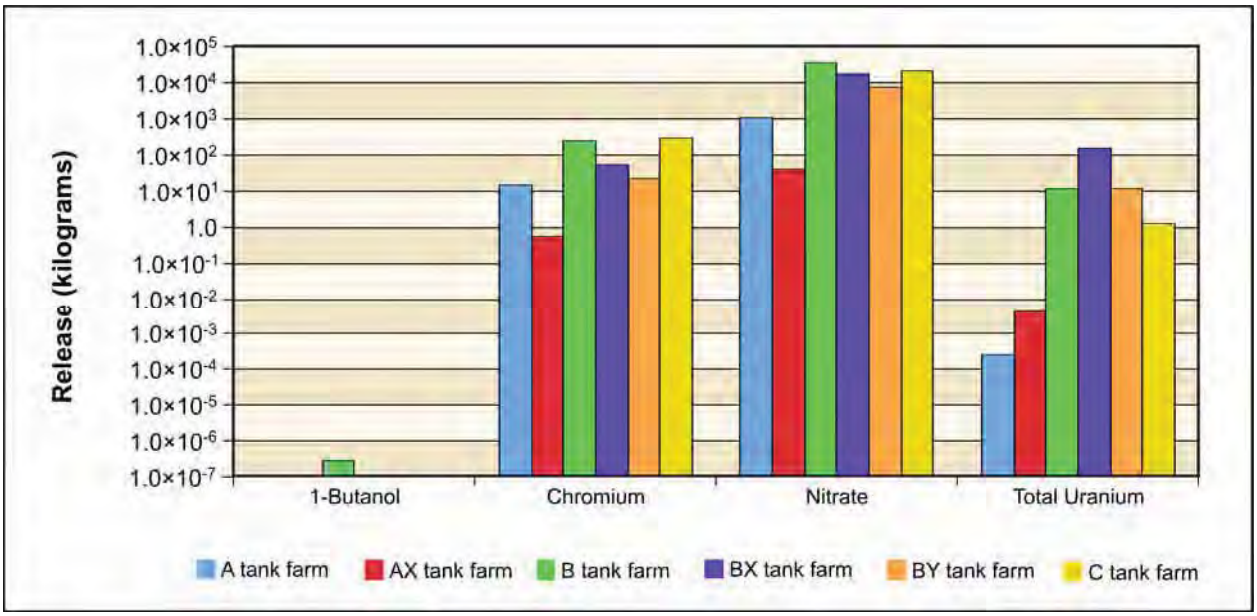


Figure N–22. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

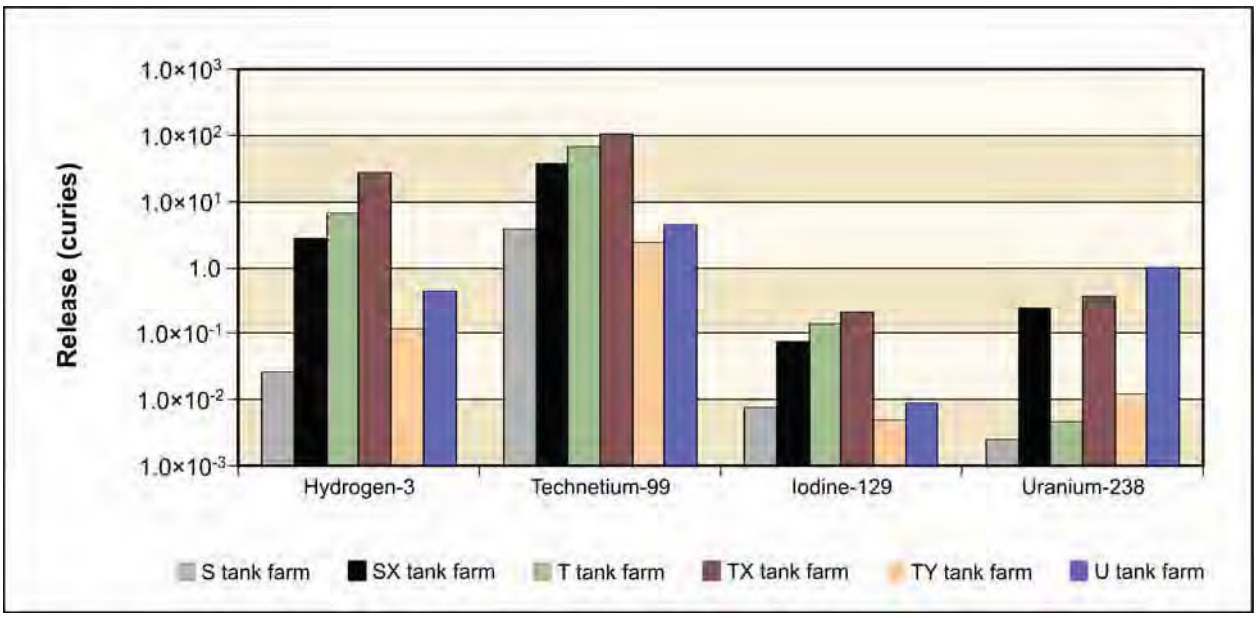


Figure N–23. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

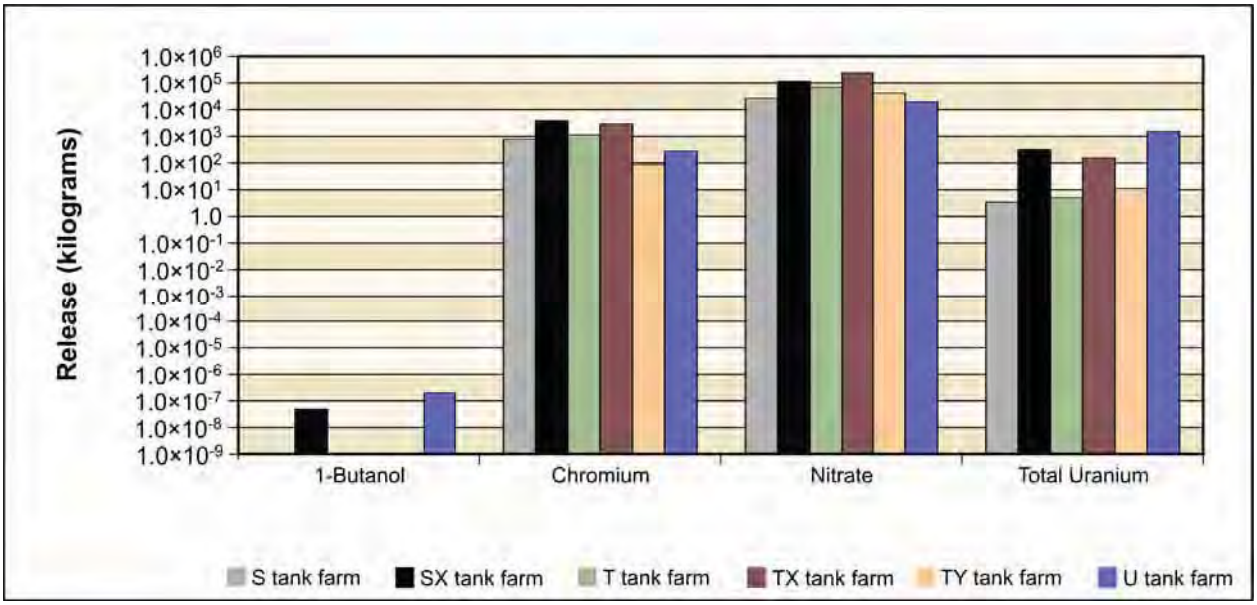


Figure N–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be clean closed by removing soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential releases to the aquifer from past leaks under Alternative 4 are indicated in Figures N–25 through N–28.

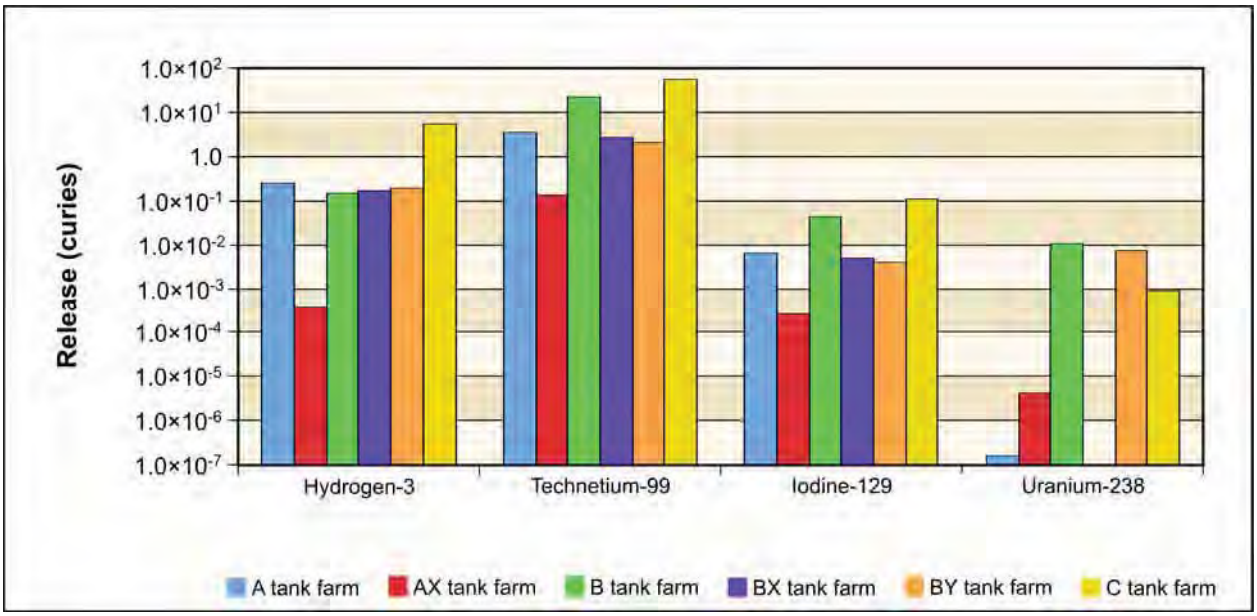


Figure N–25. Tank Closure Alternative 4 Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

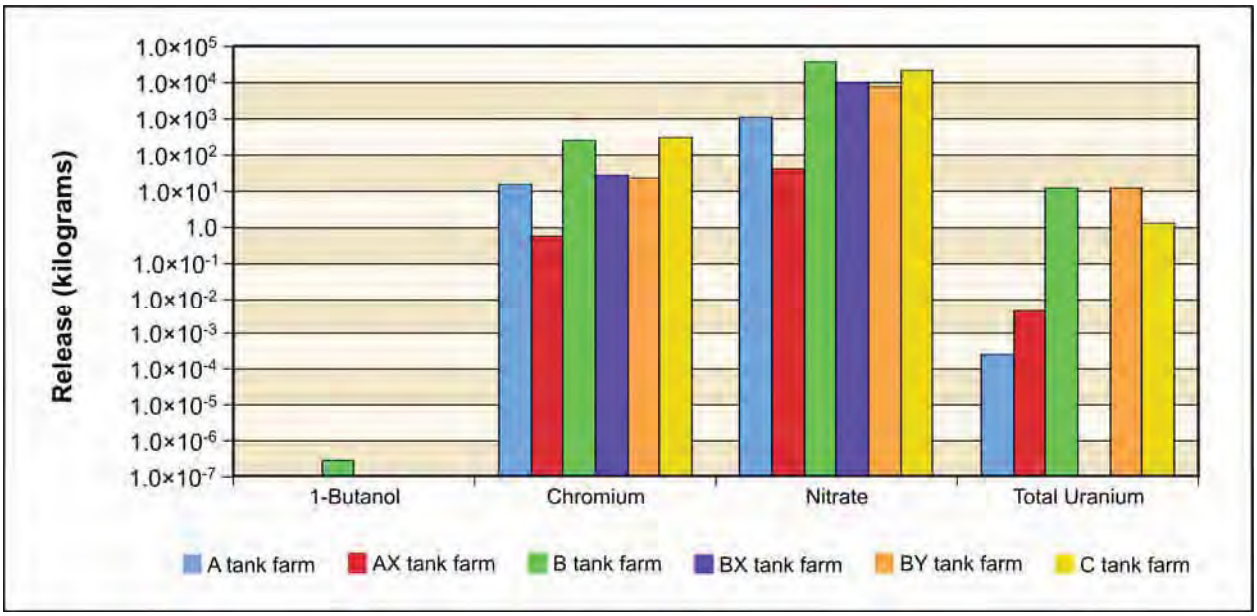


Figure N–26. Tank Closure Alternative 4 Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

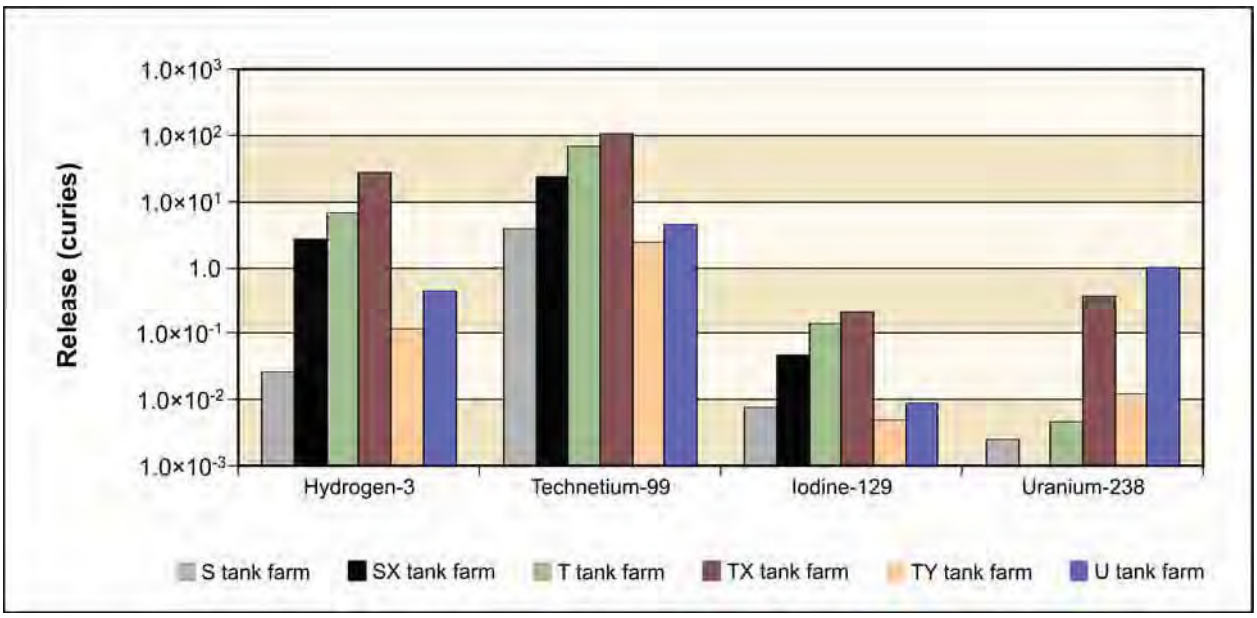


Figure N–27. Tank Closure Alternative 4 Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

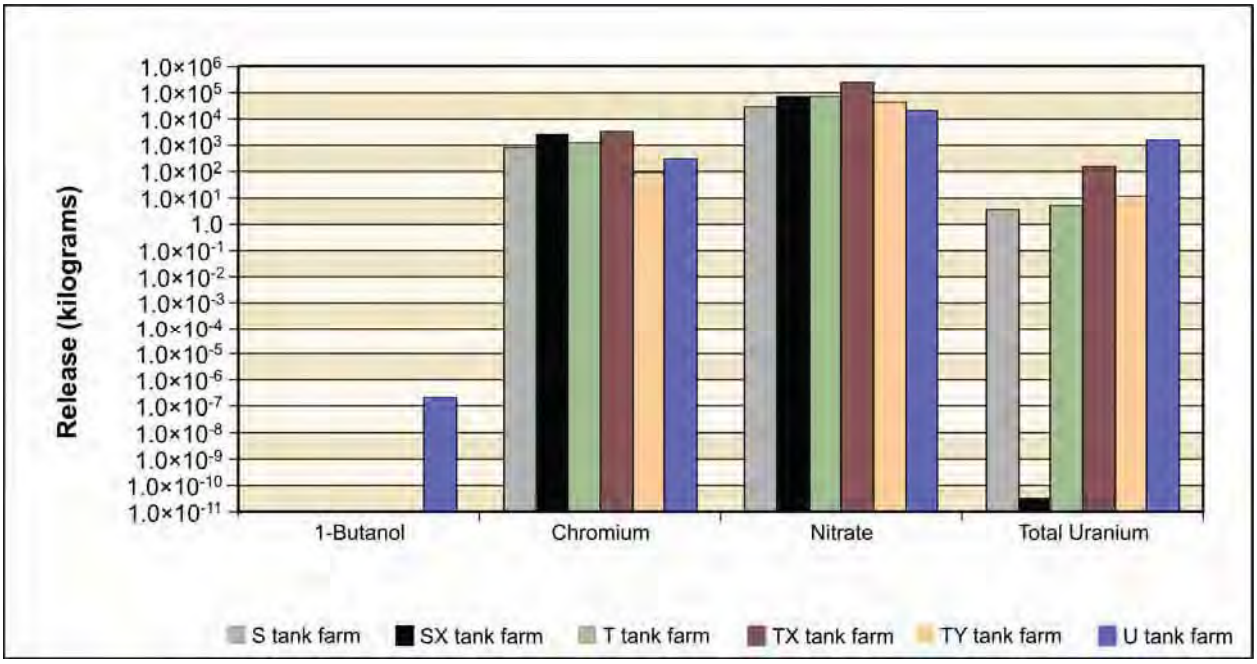


Figure N–28. Tank Closure Alternative 4 Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Under Tank Closure Alternative 5, the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential releases to the aquifer from past leaks under Alternative 5 are indicated in Figures N–29 through N–32.

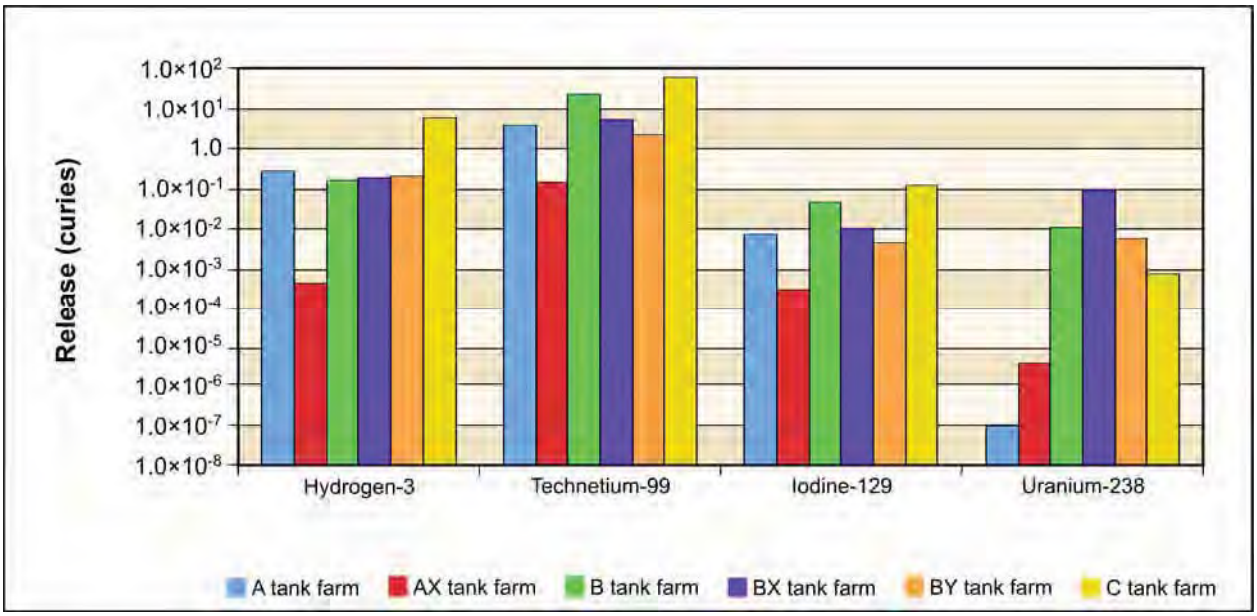


Figure N–29. Tank Closure Alternative 5 Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

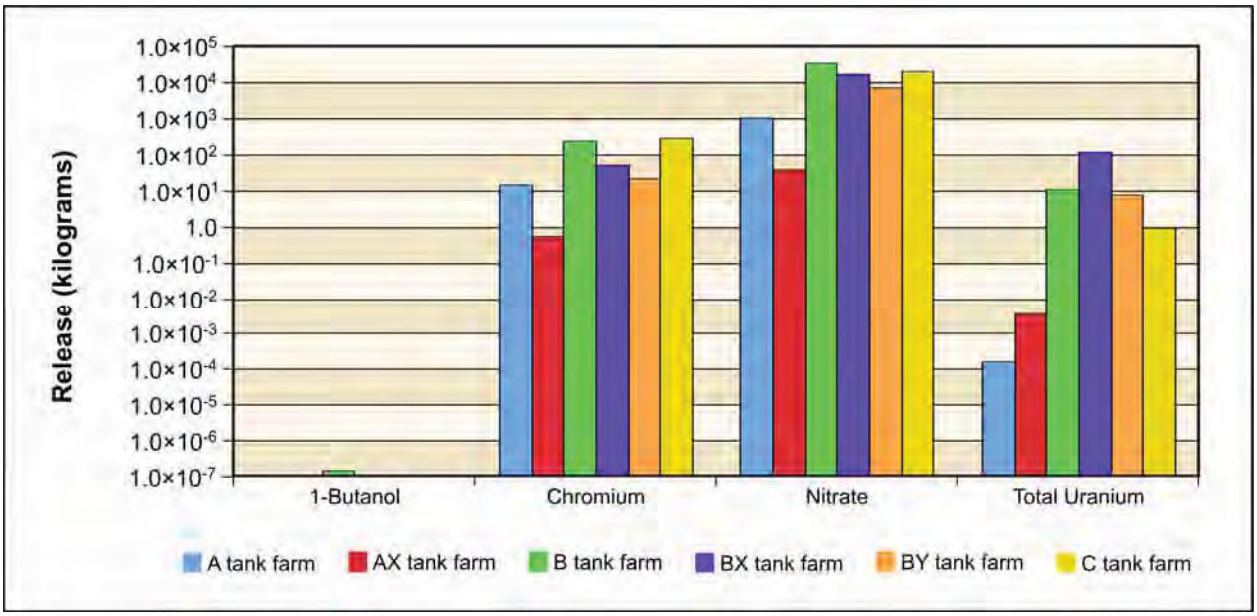


Figure N–30. Tank Closure Alternative 5 Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

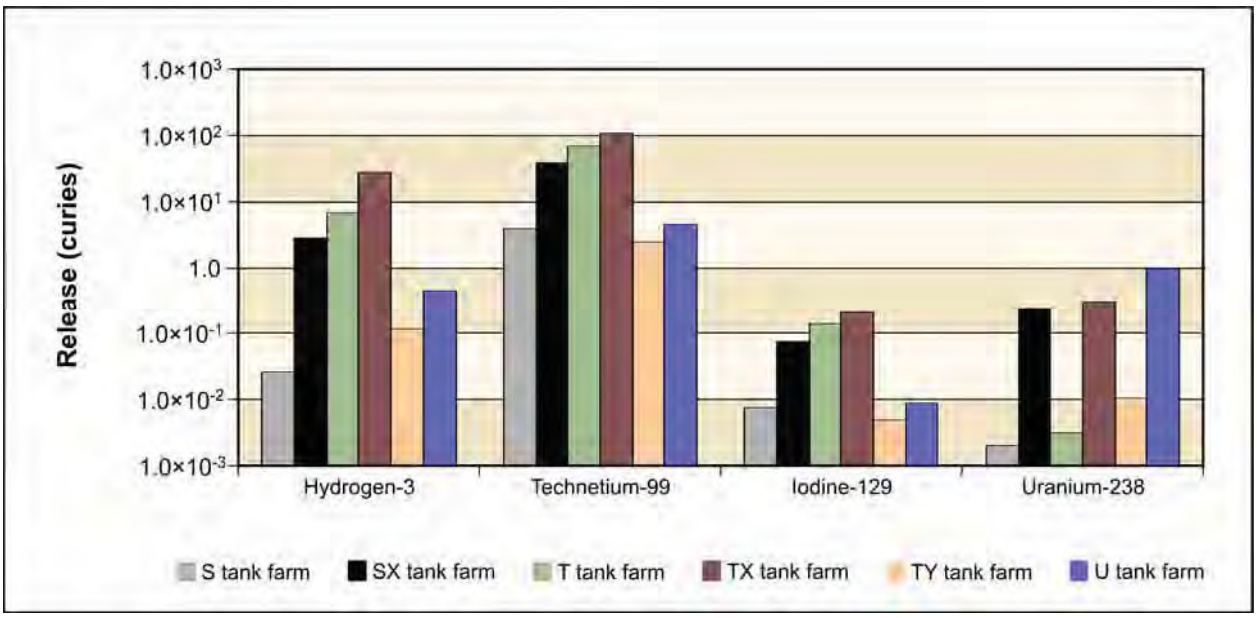


Figure N–31. Tank Closure Alternative 5 Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

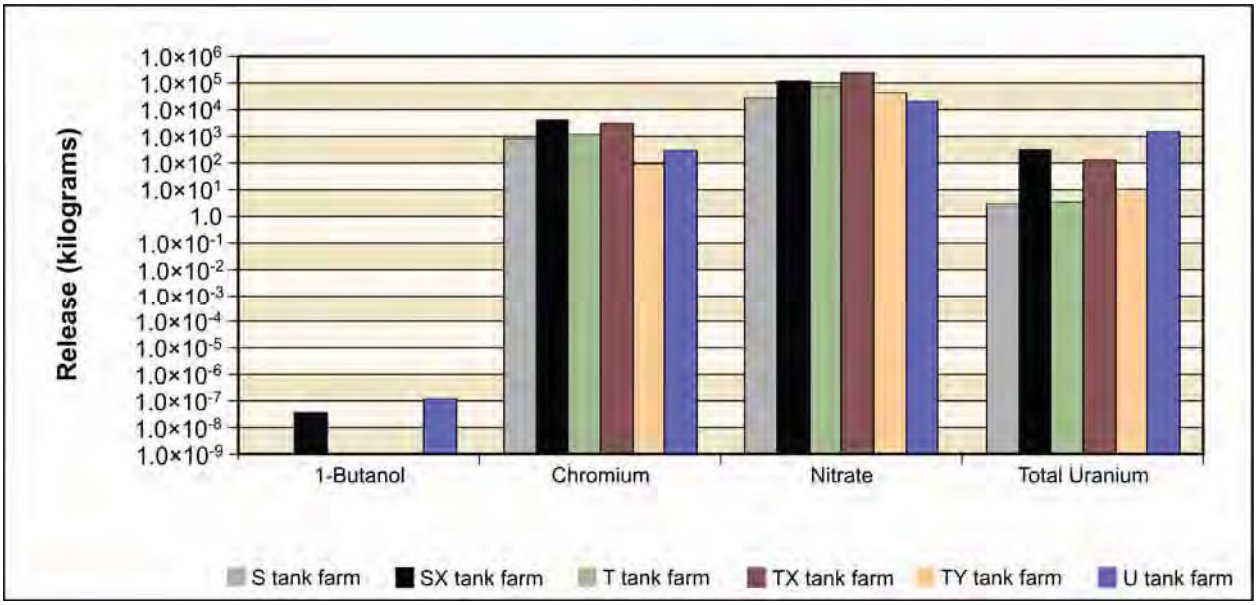


Figure N–32. Tank Closure Alternative 5 Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Under Tank Closure Alternative 6A, Base and Option Cases, all tank farms would be clean closed by removing soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential releases to the aquifer from past leaks under Alternative 6A, Base and Option Cases, are indicated in Figures N–33 through N–36.

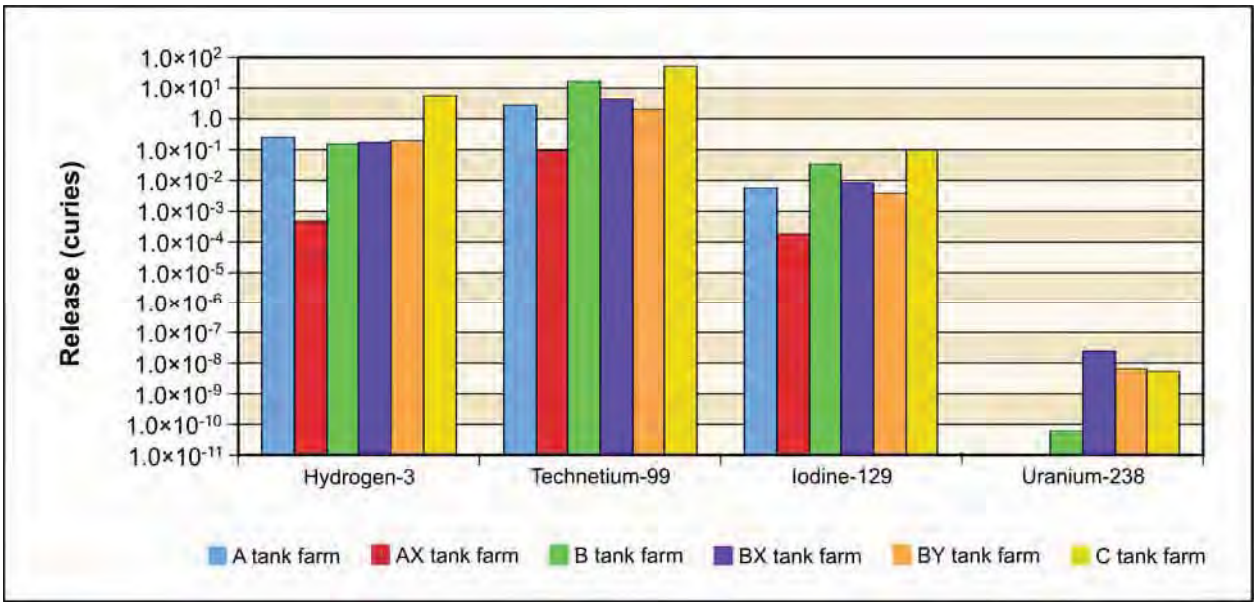


Figure N–33. Tank Closure Alternative 6A, Base and Option Cases, Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

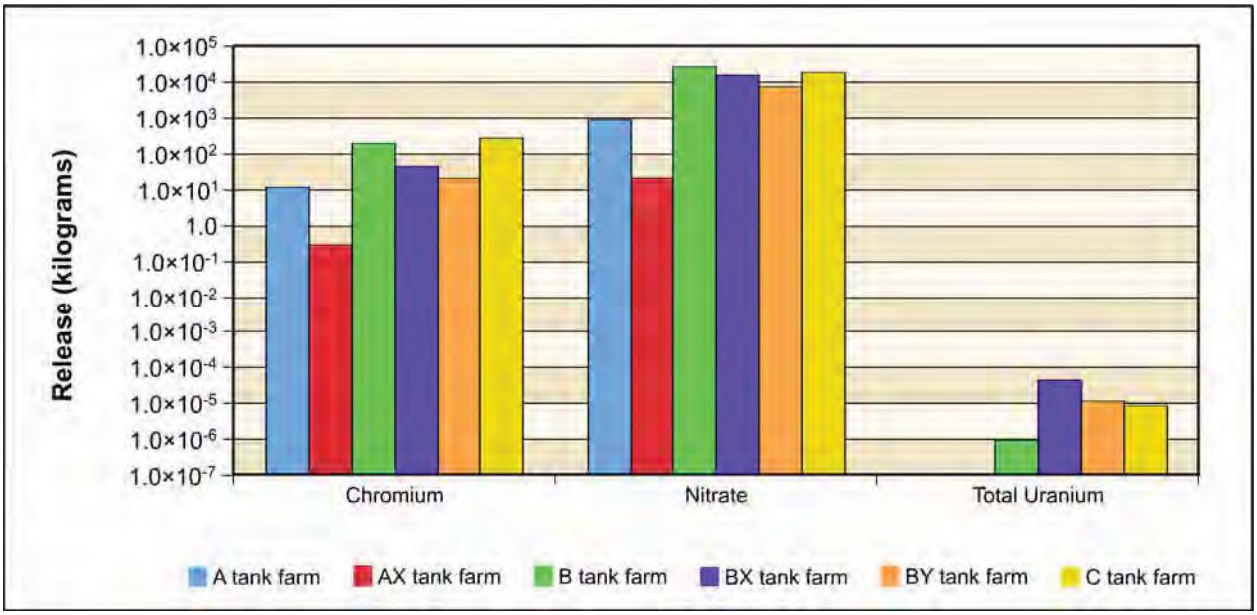


Figure N–34. Tank Closure Alternative 6A, Base and Option Cases, Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

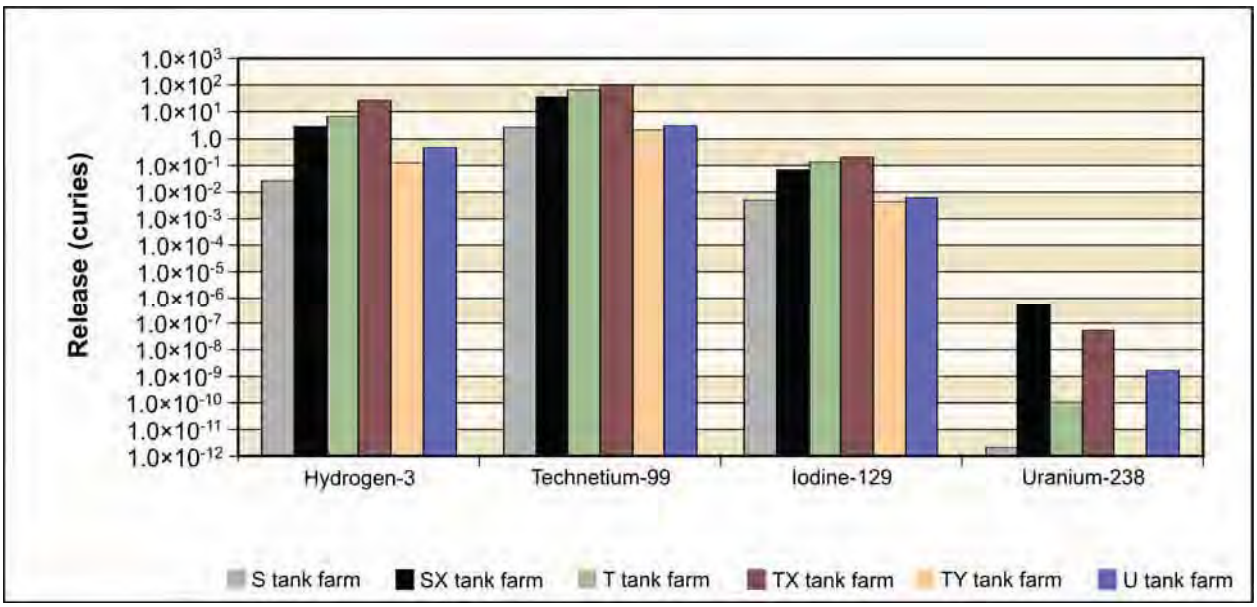


Figure N–35. Tank Closure Alternative 6A, Base and Option Cases, Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

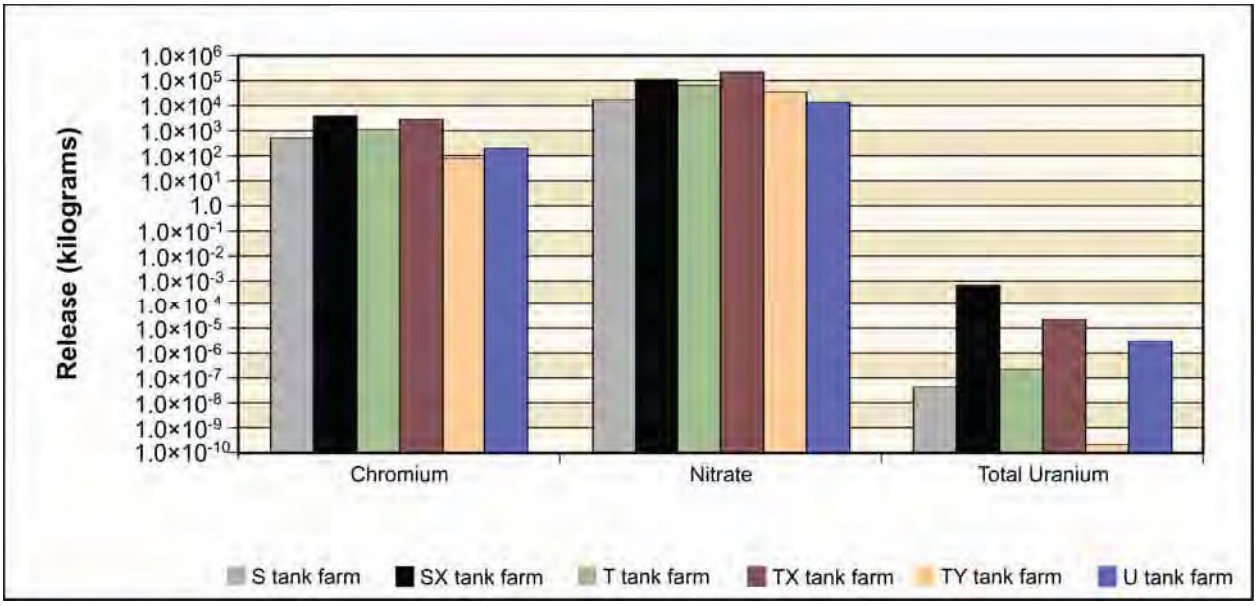


Figure N–36. Tank Closure Alternative 6A, Base and Option Cases, Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Tank Closure Alternative 6B, Base and Option Cases, resembles Tank Closure Alternative 6A, Base and Option Cases, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean closed. For the Base Case, the adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier, and for the Option Case, the adjacent cribs and trenches (ditches) would be clean closed. Potential releases to the aquifer from past leaks under Alternative 6B, Base and Option Cases, are indicated in Figures N–37 through N–40.

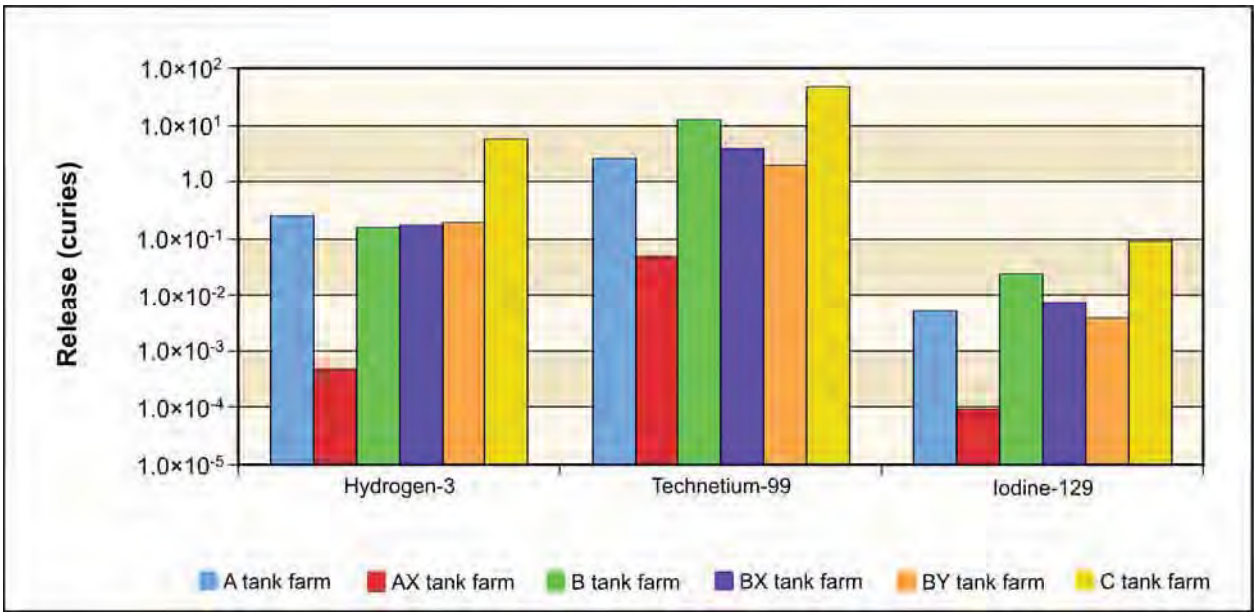


Figure N–37. Tank Closure Alternative 6B, Base and Option Cases, Past Leaks from 200-East Area Tank Farms Radiological Release to Aquifer

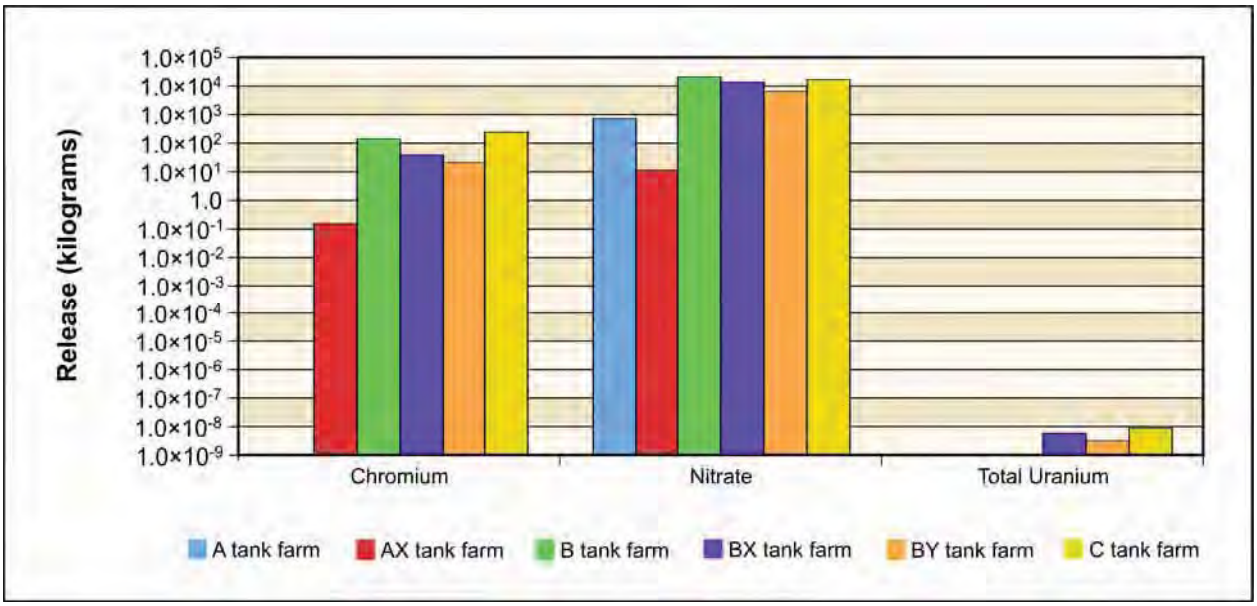


Figure N–38. Tank Closure Alternative 6B, Base and Option Cases, Past Leaks from 200-East Area Tank Farms Chemical Release to Aquifer

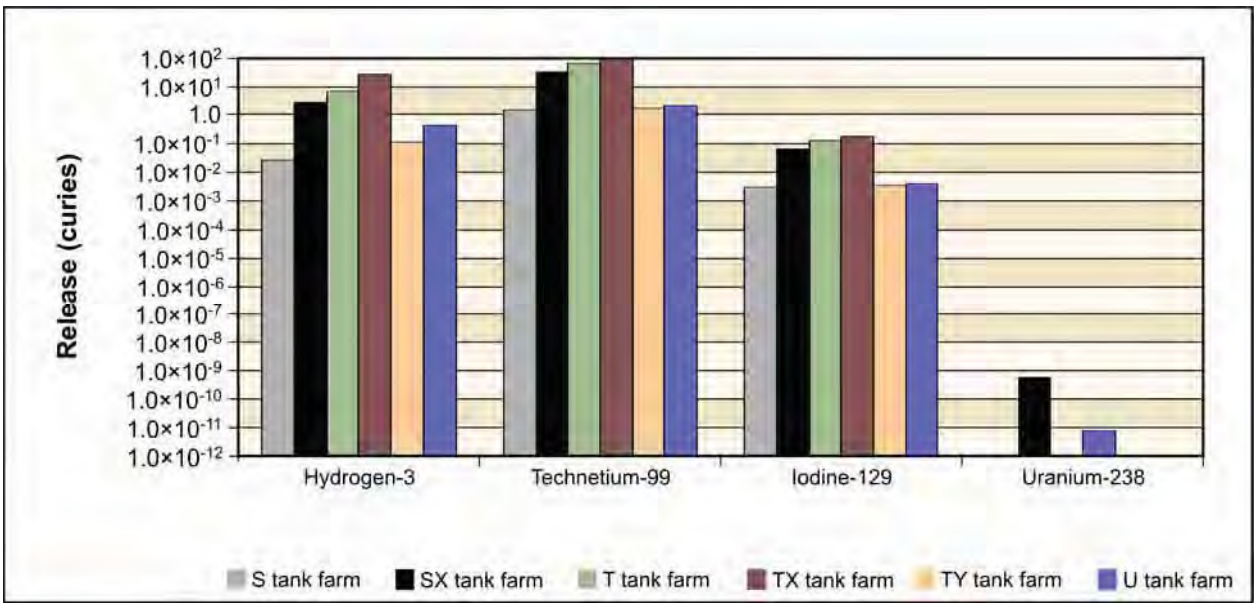


Figure N–39. Tank Closure Alternative 6B, Base and Option Cases, Past Leaks from 200-West Area Tank Farms Radiological Release to Aquifer

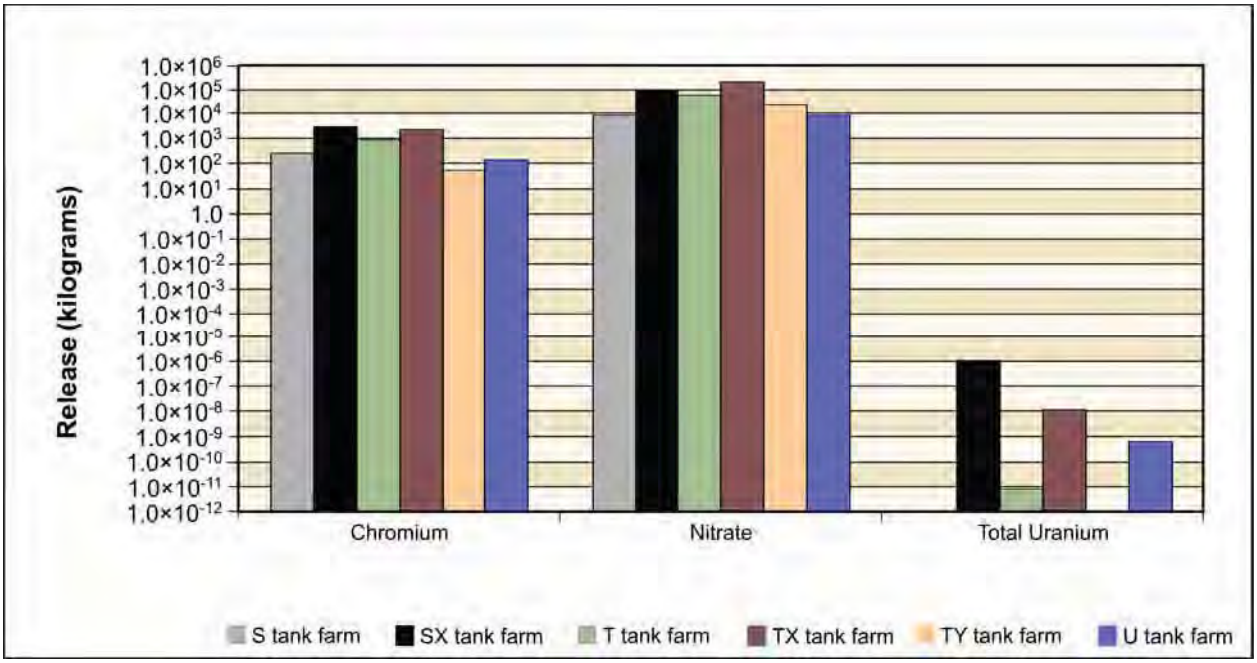


Figure N–40. Tank Closure Alternative 6B, Base and Option Cases, Past Leaks from 200-West Area Tank Farms Chemical Release to Aquifer

Under Tank Closure Alternative 1, the cribs and trenches (ditches) associated with the tank farms would be maintained in the current condition indefinitely, but, for the purpose of analysis, are assumed to fail after an institutional control period of 100 years (i.e., in calendar year 2108). Potential releases to the aquifer from cribs and trenches (ditches) under Alternative 1 are indicated in Figures N–41 and N–42.

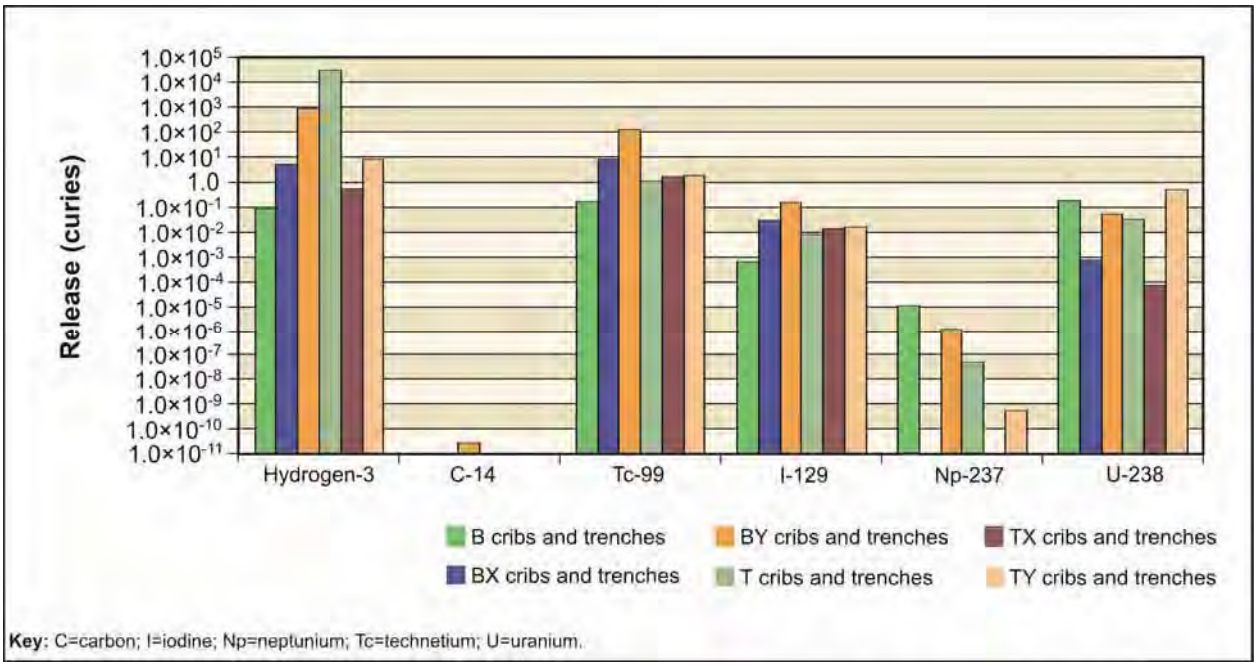


Figure N–41. Tank Closure Alternative 1, Cribs and Trenches (Ditches) Radiological Release to Aquifer

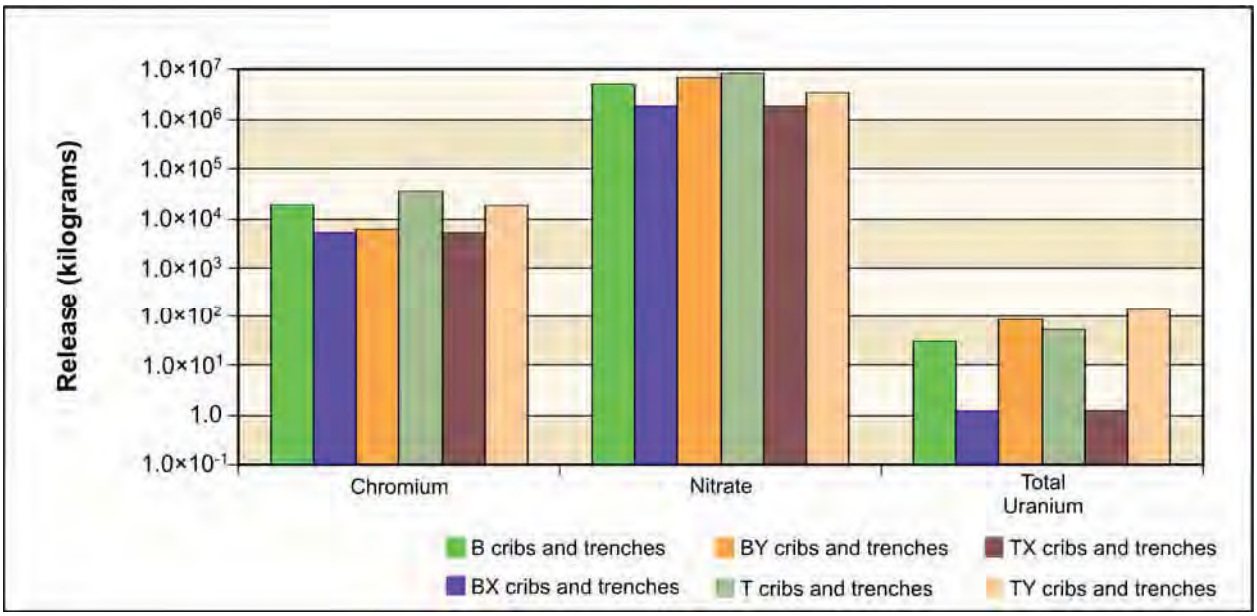


Figure N–42. Tank Closure Alternative 1, Cribs and Trenches (Ditches) Chemical Release to Aquifer

Under Tank Closure Alternative 2A, the cribs and trenches (ditches) associated with the tank farms would be maintained until the end of institutional control period, (i.e., in calendar year 2193). Potential releases to the aquifer from cribs and the trenches (ditches) under Alternative 1 are indicated in Figures N–43 and N–44.

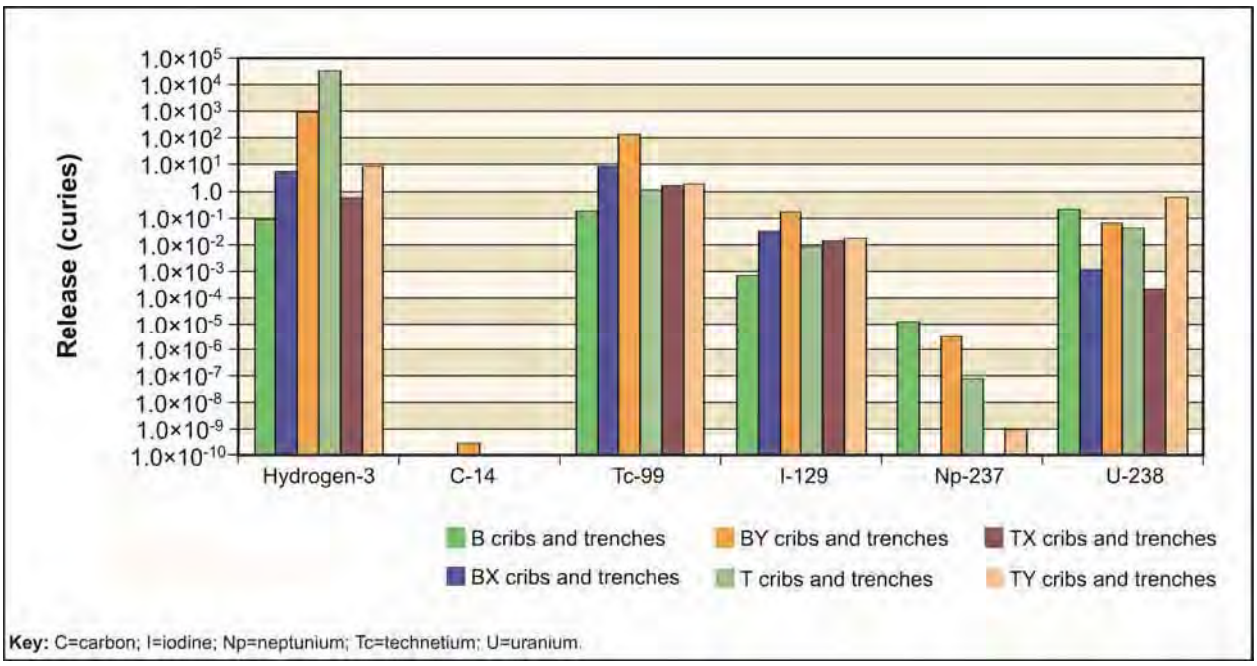


Figure N–43. Tank Closure Alternative 2A, Cribs and Trenches (Ditches) Radiological Release to Aquifer

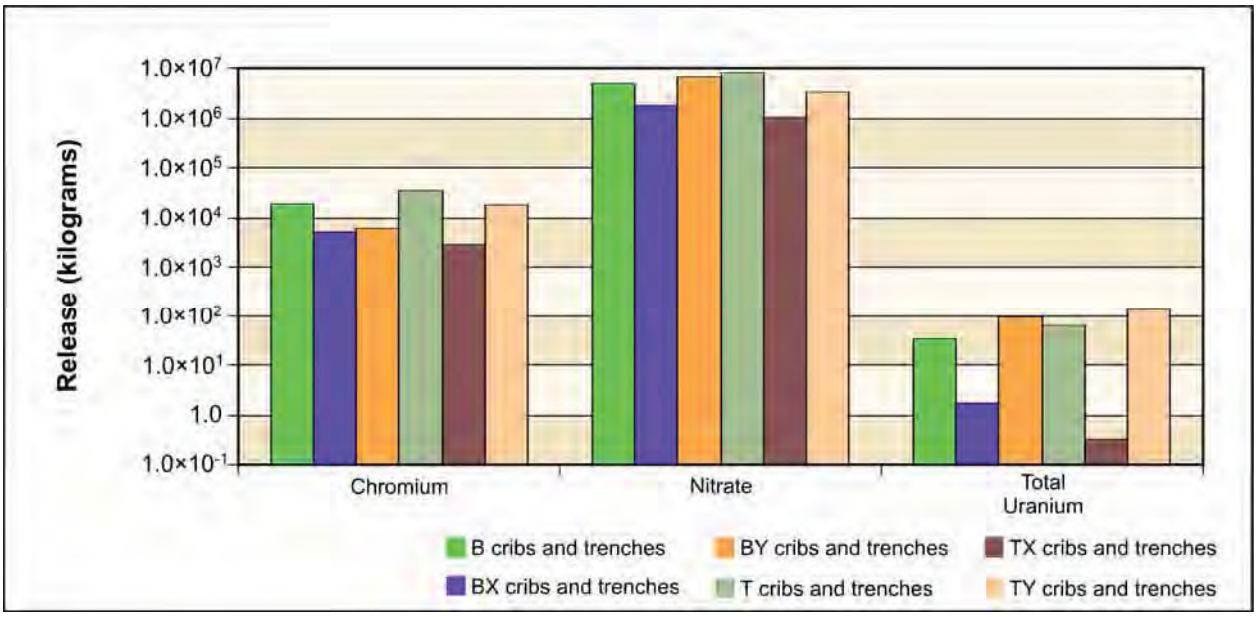


Figure N–44. Tank Closure Alternative 2A, Cribs and Trenches (Ditches) Chemical Release to Aquifer

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, 6A (Base Case), 6B (Base Case), and 6C would be similar to those of Tank Closure Alternative 2A, with the addition of an engineered modified RCRA Subtitle C barrier over six sets of adjacent cribs and trenches (ditches). Potential releases to the aquifer from cribs and trenches (ditches) under Alternatives 2B, 3A, 3B, 3C, 4, 5, 6A (Base Case), 6B (Base Case), and 6C are indicated in Figures N–45 through N–46.

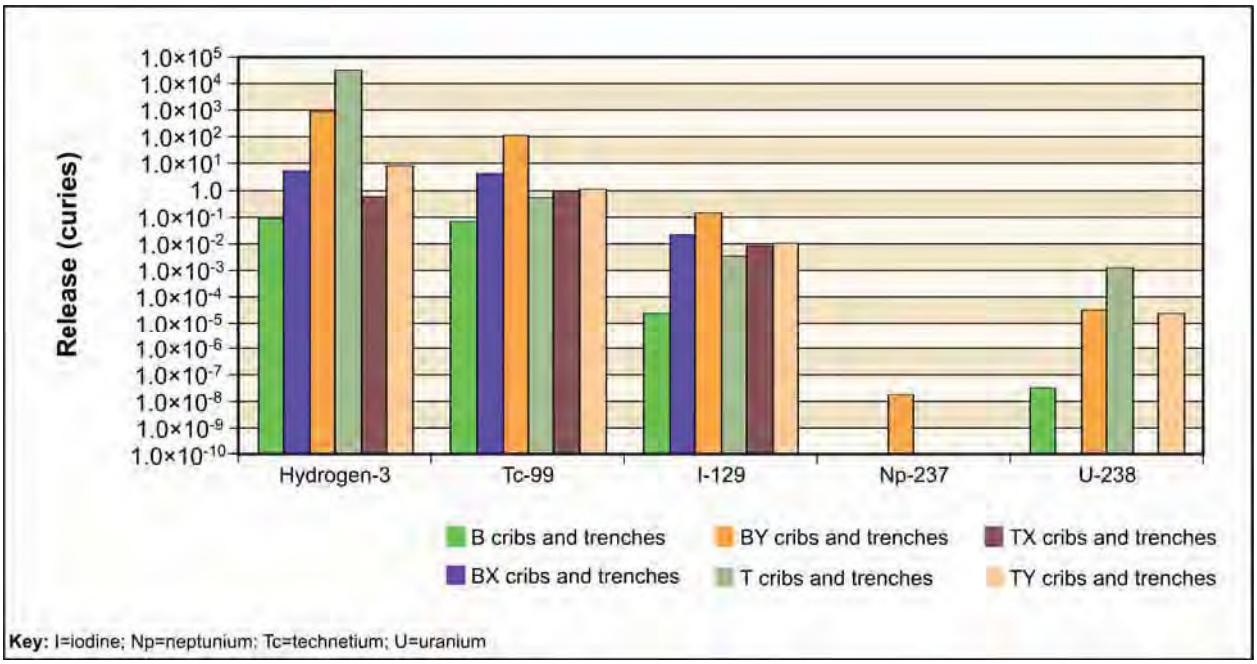


Figure N–45. Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, 6A (Base Case), 6B (Base Case) and 6C, Cribs and Trenches (Ditches) Radiological Release to Aquifer

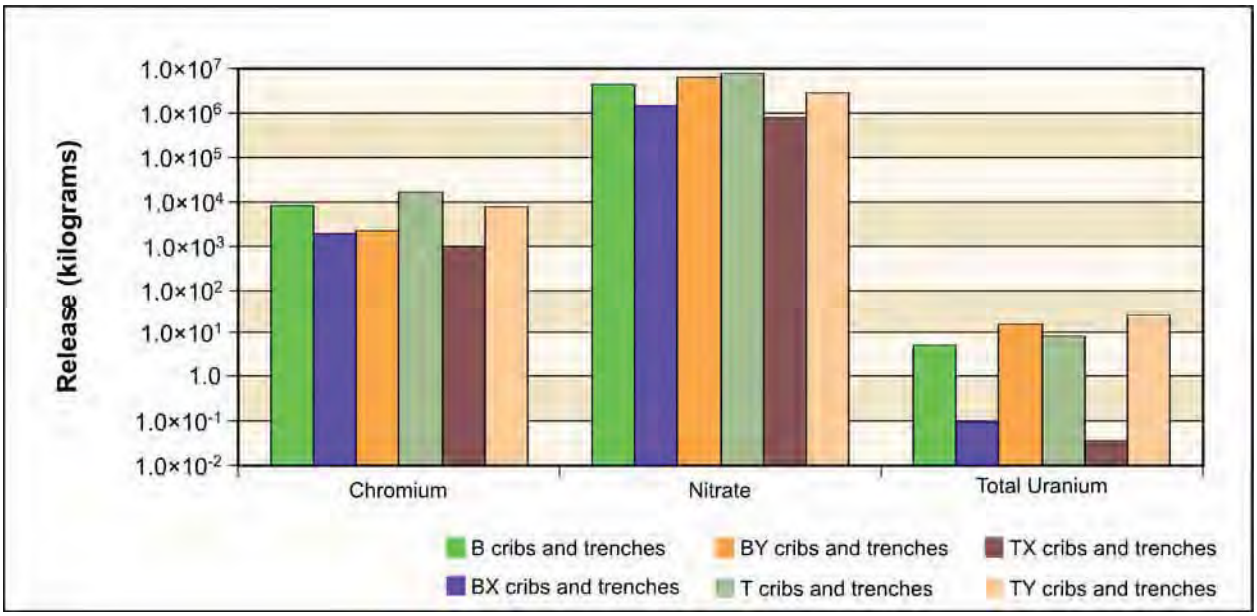


Figure N–46. Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, 6A (Base Case), 6B (Base Case) and 6C, Cribs and Trenches (Ditches) Chemical Release to Aquifer

Under Tank Closure Alternative 6A, Option Case, deep soil excavation would also be conducted to remove contamination plumes within the soil column where necessary. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential releases to the aquifer from past leaks under Alternative 6A, Option Case, are indicated in Figures N–47 through N–48.

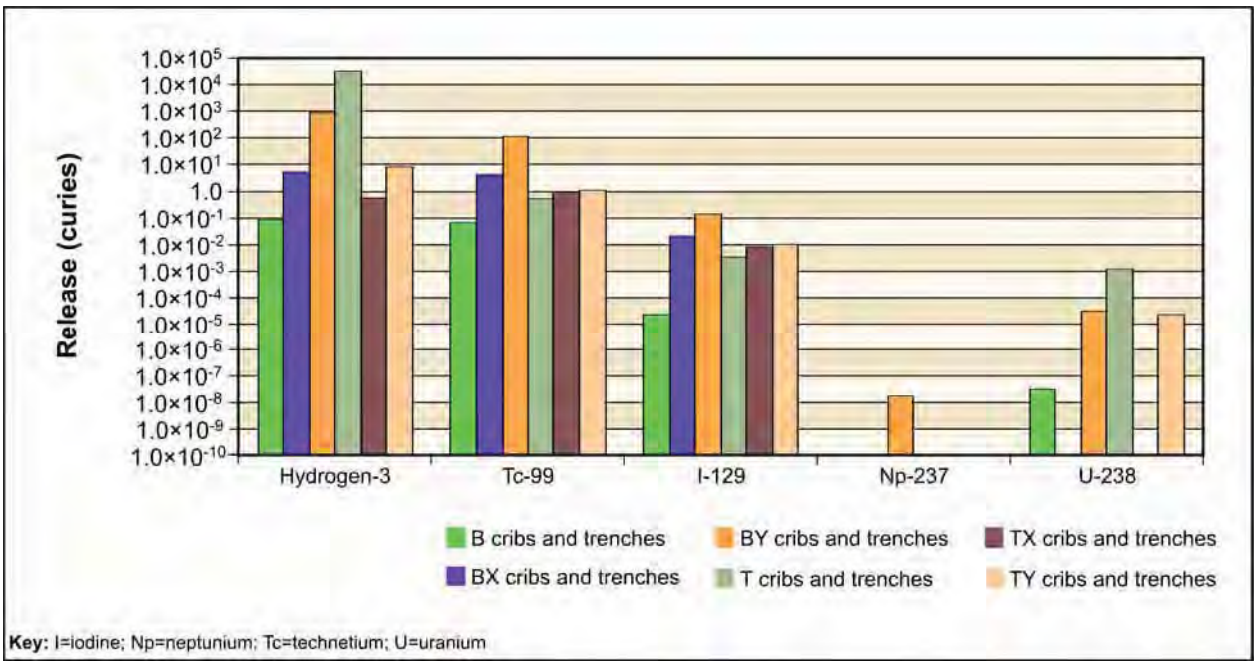


Figure N–47. Tank Closure Alternative 6A, Option Case, Cribs and Trenches (Ditches) Radiological Release to Aquifer

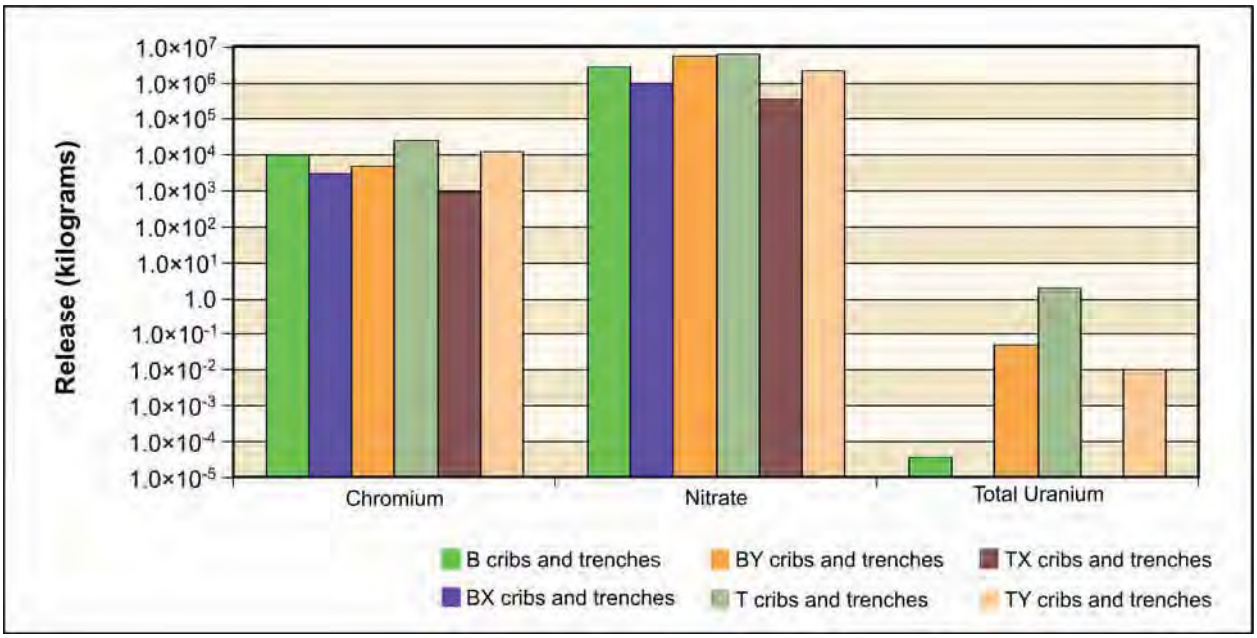


Figure N–48. Tank Closure Alternative 6A, Option Case, Cribs and Trenches (Ditches) Chemical Release to Aquifer

Tank Closure Alternative 6B, Option Case, resembles Tank Closure Alternative 6A, Option Case, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. Potential releases to the aquifer from cribs and trenches (ditches) under Alternative 6B, Option Case, are indicated in Figures N–49 through N–50.

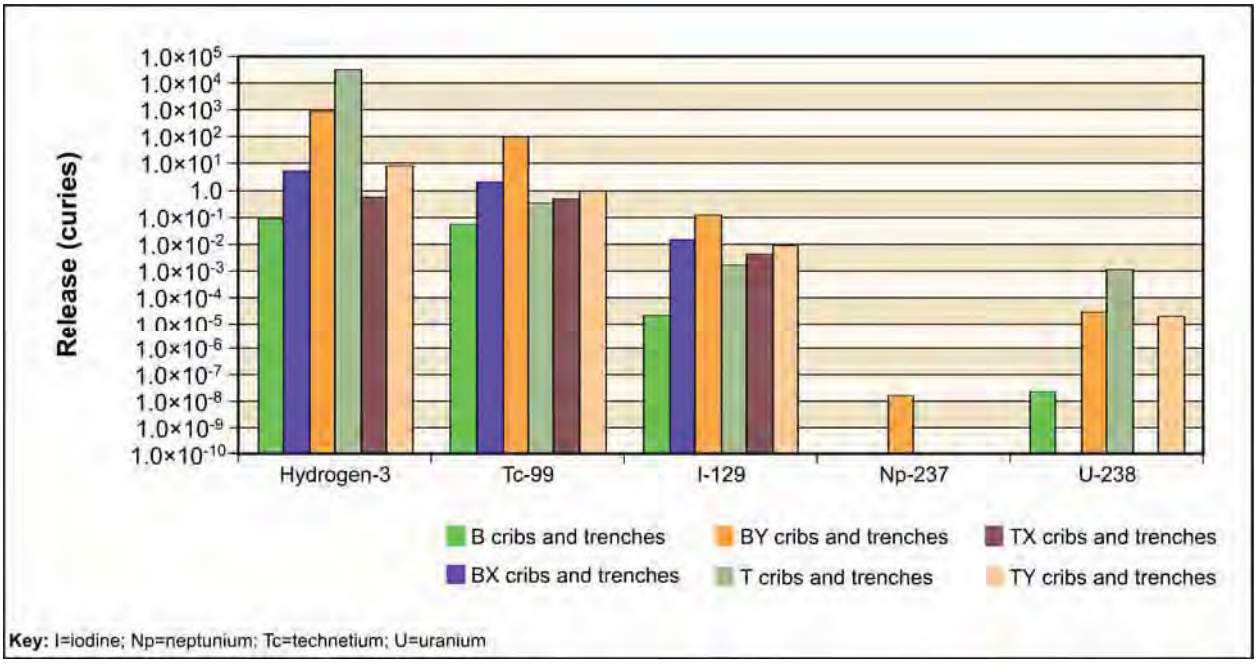


Figure N–49. Tank Closure Alternative 6B, Option Case, Cribs and Trenches (Ditches) Radiological Release to Aquifer

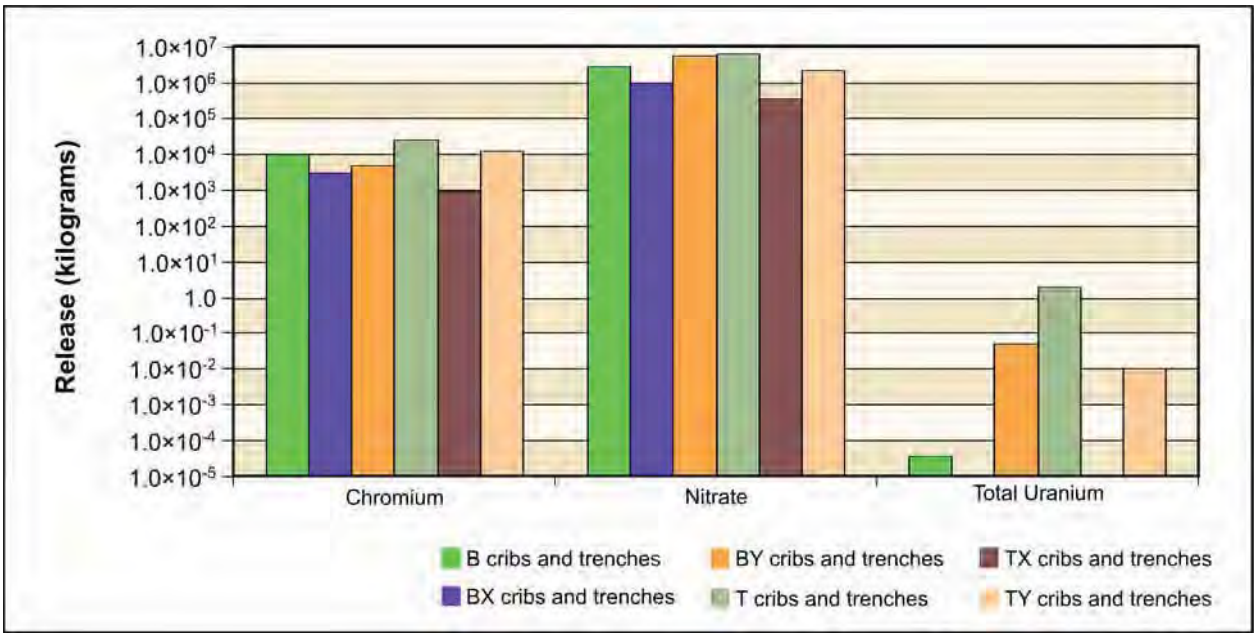


Figure N–50. Tank Closure Alternative 6B, Option Case, Cribs and Trenches (Ditches) Chemical Release to Aquifer

N.2.1.2 Release from Other Sources in the Tank Farms

Releases from other sources related to the HLW tanks, including tank residuals, retrieval leaks, and ancillary equipment, were analyzed together. The amount of constituent released to the aquifer is related to the activities under each Tank Closure alternative. Under Tank Closure Alternatives 6A and 6B, all tank farms would be closed to a clean state by removing the tanks, ancillary equipment, and soil to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Therefore, releases from other sources related to the HLW tanks were not analyzed.

Under Tank Closure Alternative 1, tank farms would be maintained in the current condition indefinitely but, for the purpose of analysis, are assumed to fail after an institutional control period of 100 years. At this time, the salt cake in single-shell tanks is assumed available for leaching into the vadose zone, and the liquid contents of double-shell tanks are assumed to be discharged directly to the vadose zone. Figures N–51 through N–56 indicate the constituent release estimated under Tank Closure Alternative 1.

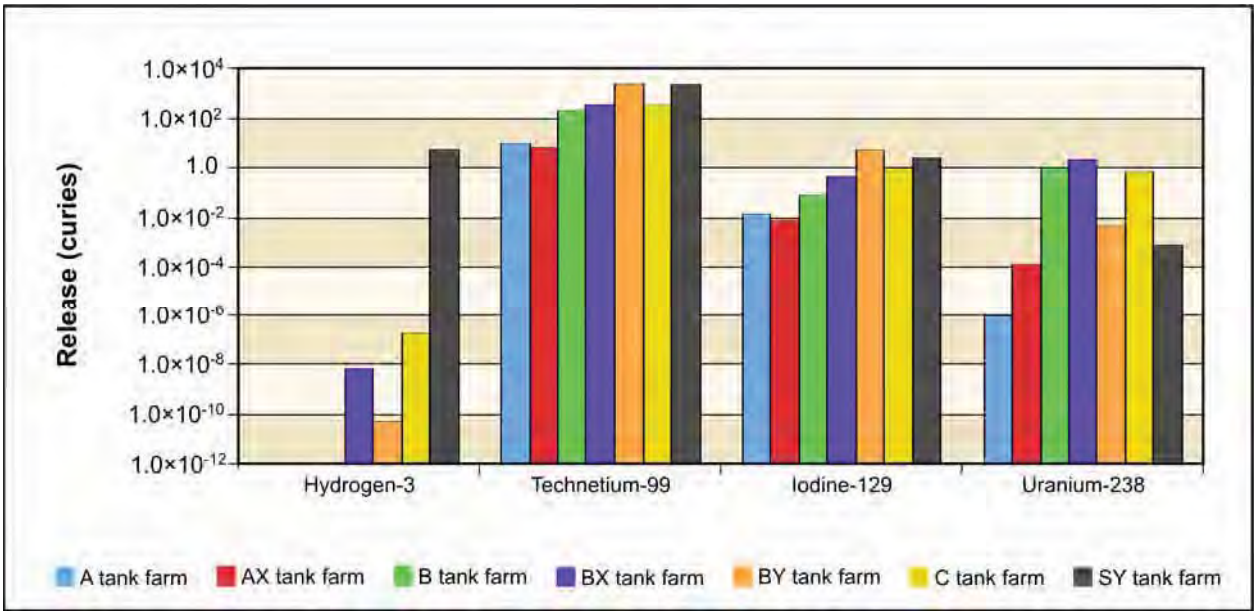


Figure N–51. Tank Closure Alternative 1 Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Radiological Release to Aquifer

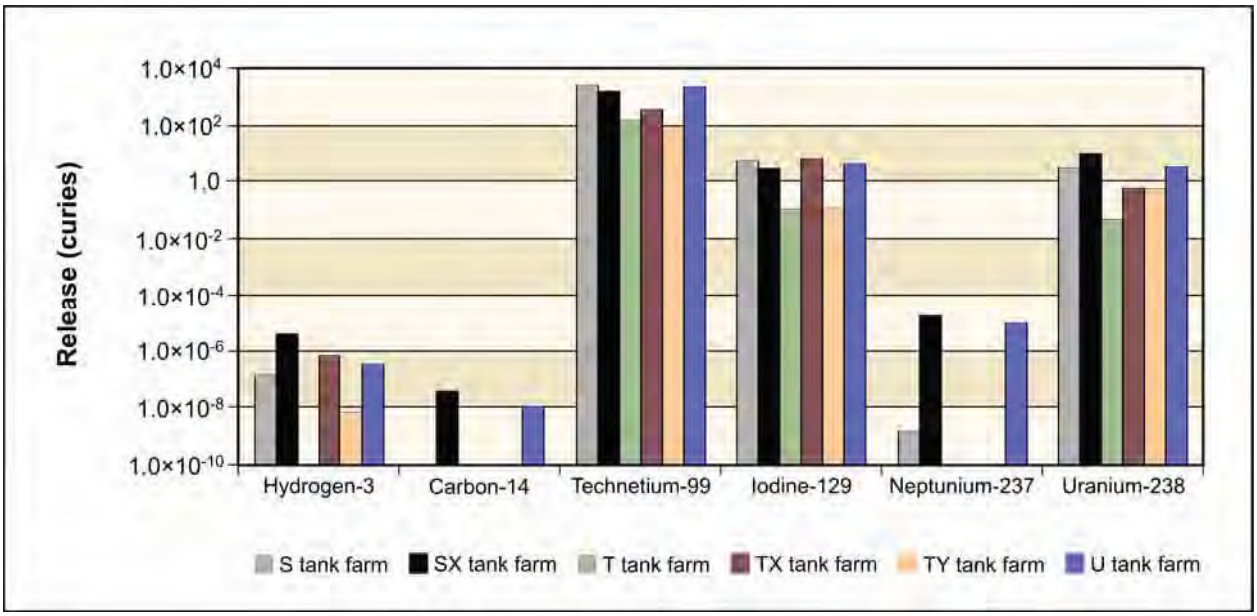


Figure N–52. Tank Closure Alternative 1 Other Sources from Tank Farms S, SX, T, TX, TY, and U Radiological Release to Aquifer

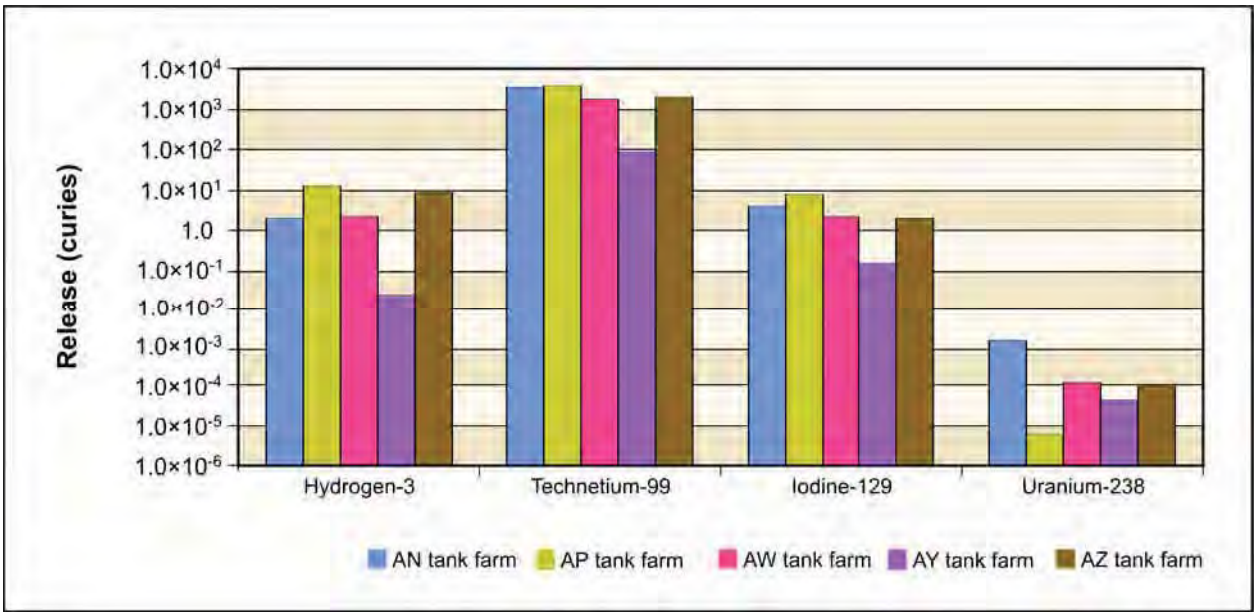


Figure N–53. Tank Closure Alternative 1 Other Sources from Tank Farms AN, AP, AW, AY and AZ Radiological Release to Aquifer

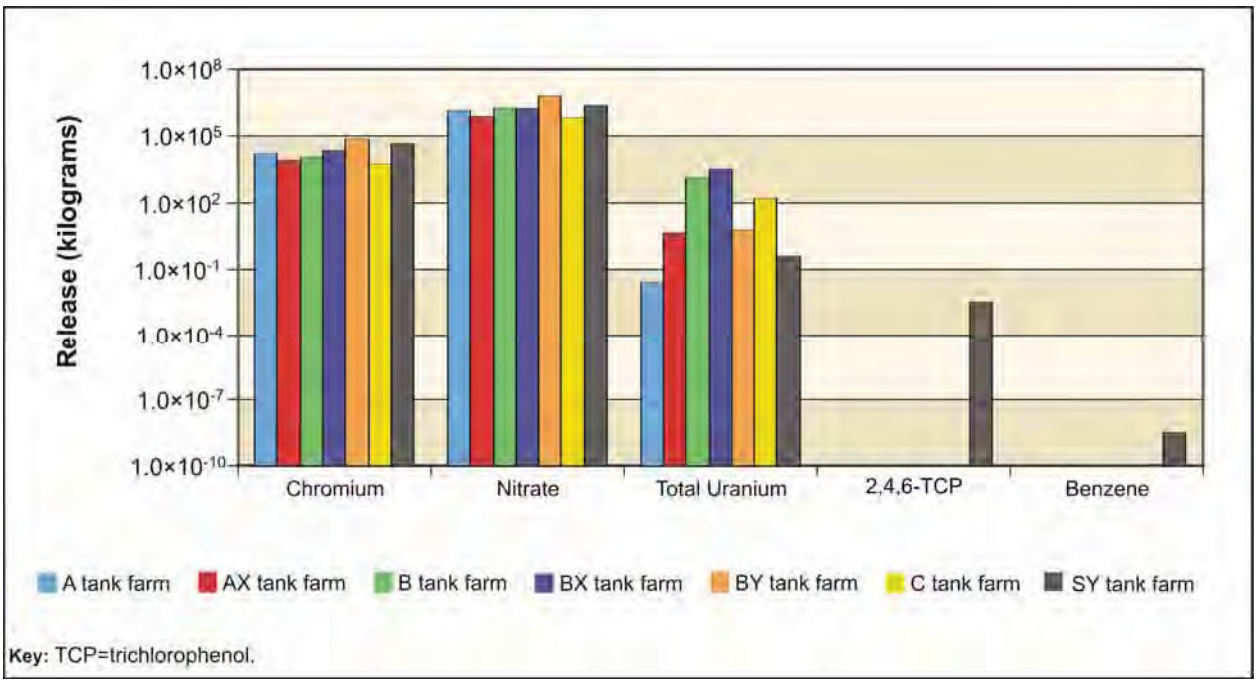


Figure N–54. Tank Closure Alternative 1 Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Chemical Release to Aquifer

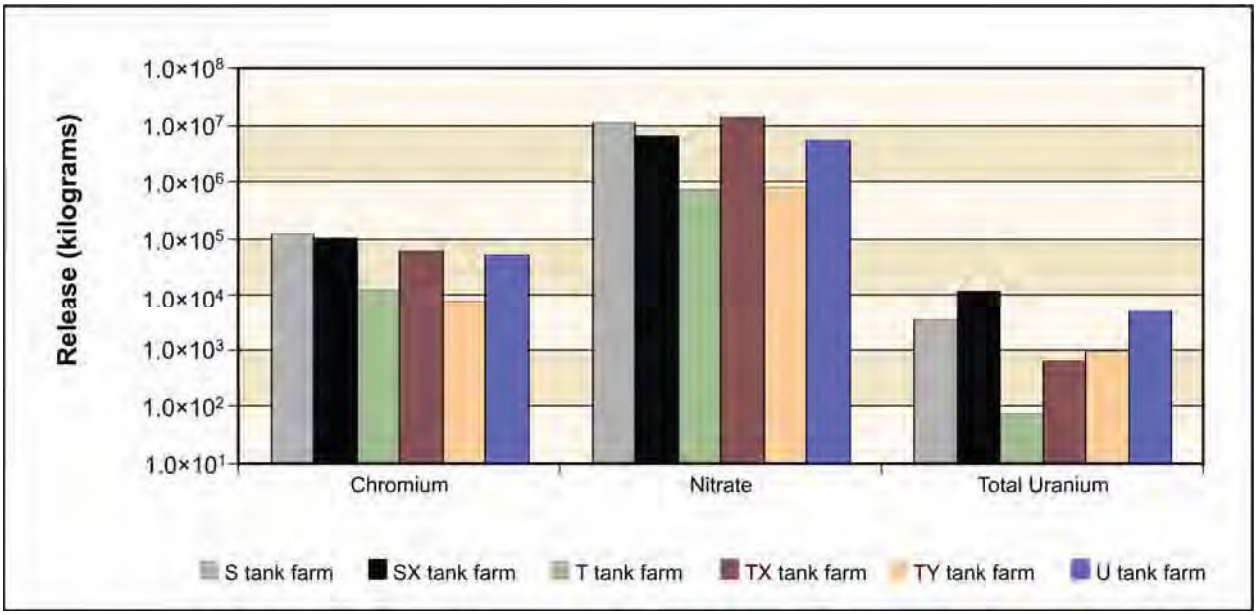


Figure N–55. Tank Closure Alternative 1 Other Sources from Tank Farms S, SX, T, TX, TY, and U Chemical Release to Aquifer

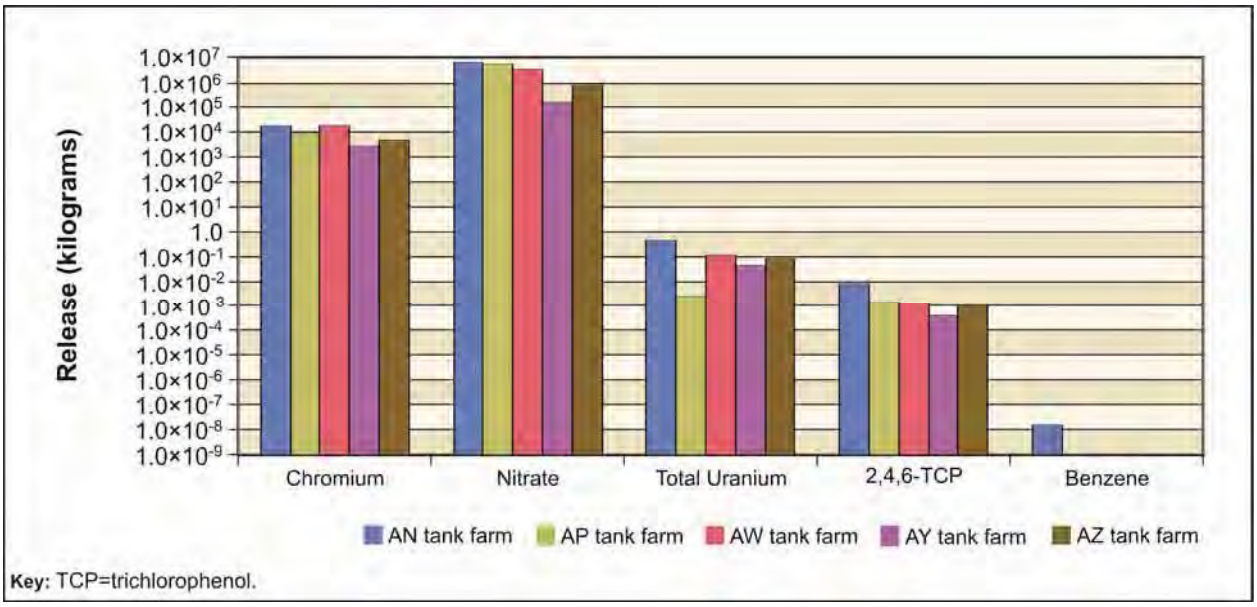


Figure N–56. Tank Closure Alternative 1 Other Sources from Tank Farms AN, AP, AW, AY, and AZ Chemical Release to Aquifer

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but residual material in tanks would not be stabilized. After an institutional control period of 100 years, the salt cake in tanks would presumably be available for dissolution in infiltrating water. Potential releases to the aquifer under Tank Closure Alternative 2A are indicated in Figures N–57 through N–62.

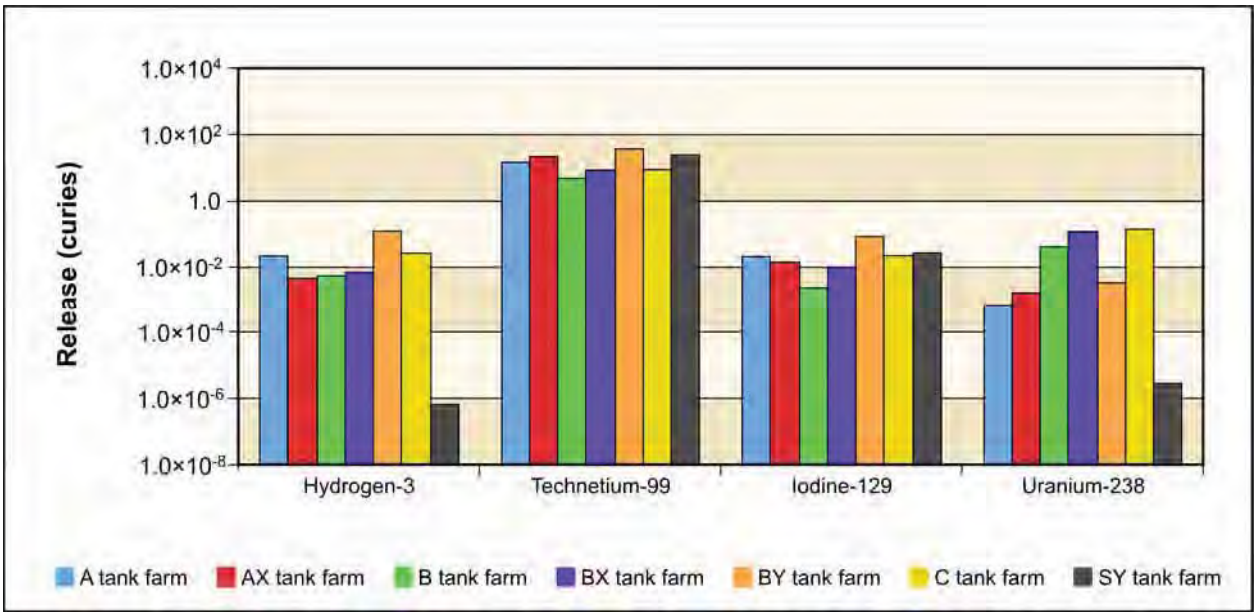


Figure N–57. Tank Closure Alternative 2A Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Radiological Release to Aquifer

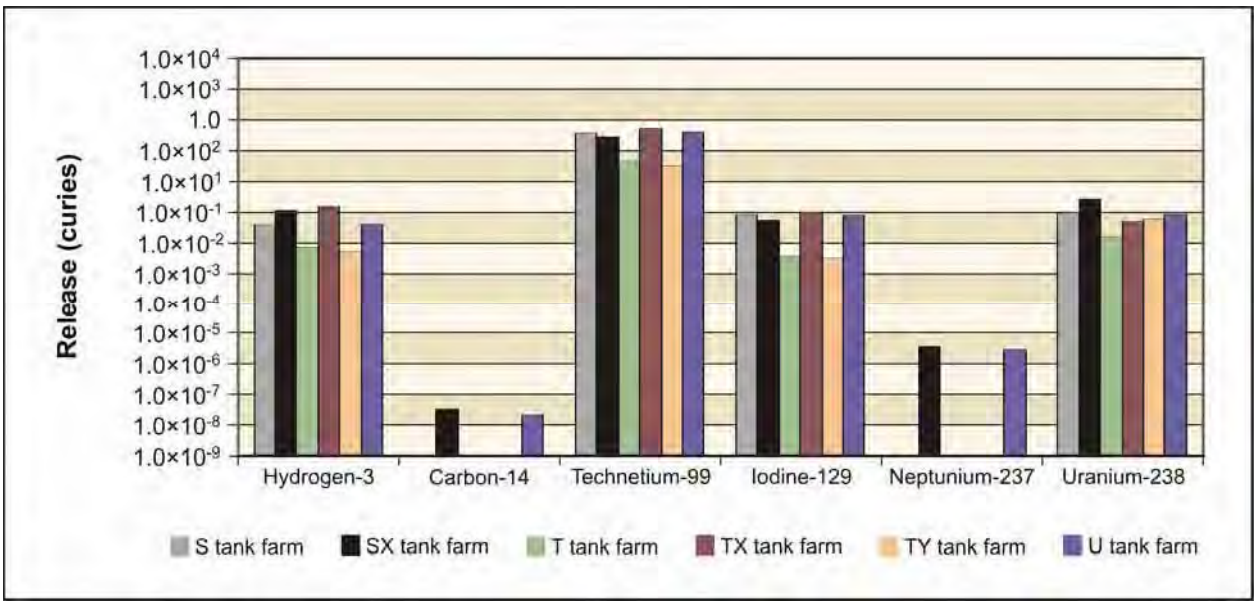


Figure N–58. Tank Closure Alternative 2A Other Sources from Tank Farms S, SX, T, TX, TY, and U Radiological Release to Aquifer

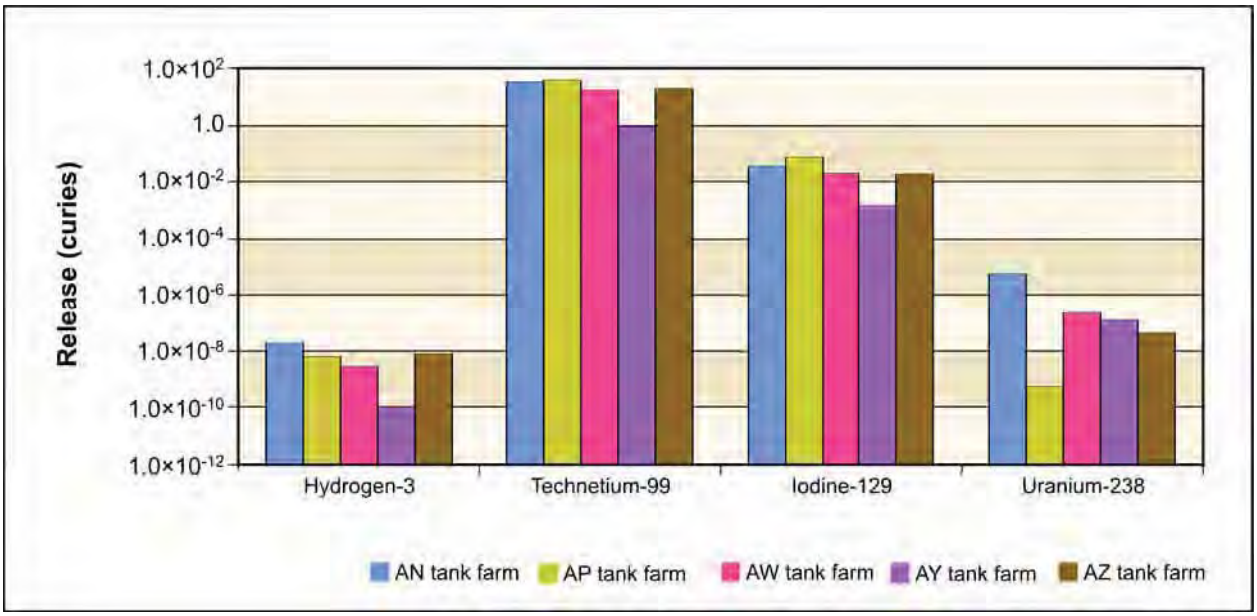


Figure N–59. Tank Closure Alternative 2A Other Sources from Tank Farms AN, AP, AW, AY, and AZ Radiological Release to Aquifer

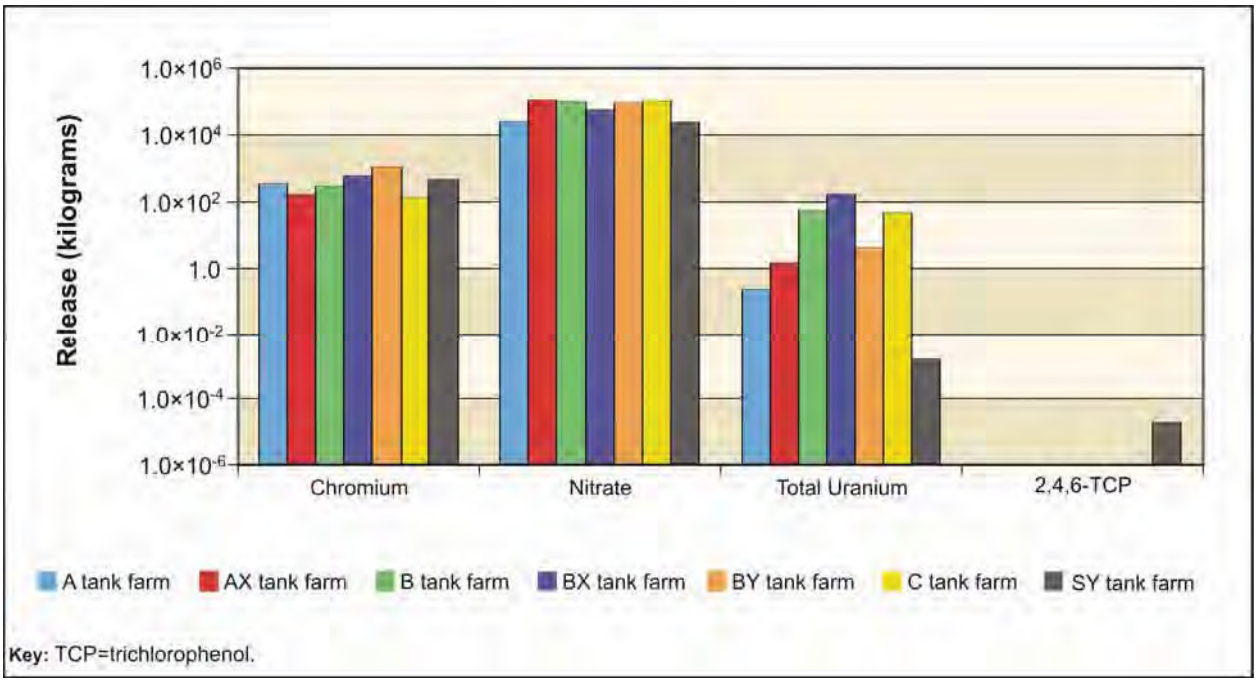


Figure N–60. Tank Closure Alternative 2A Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Chemical Release to Aquifer

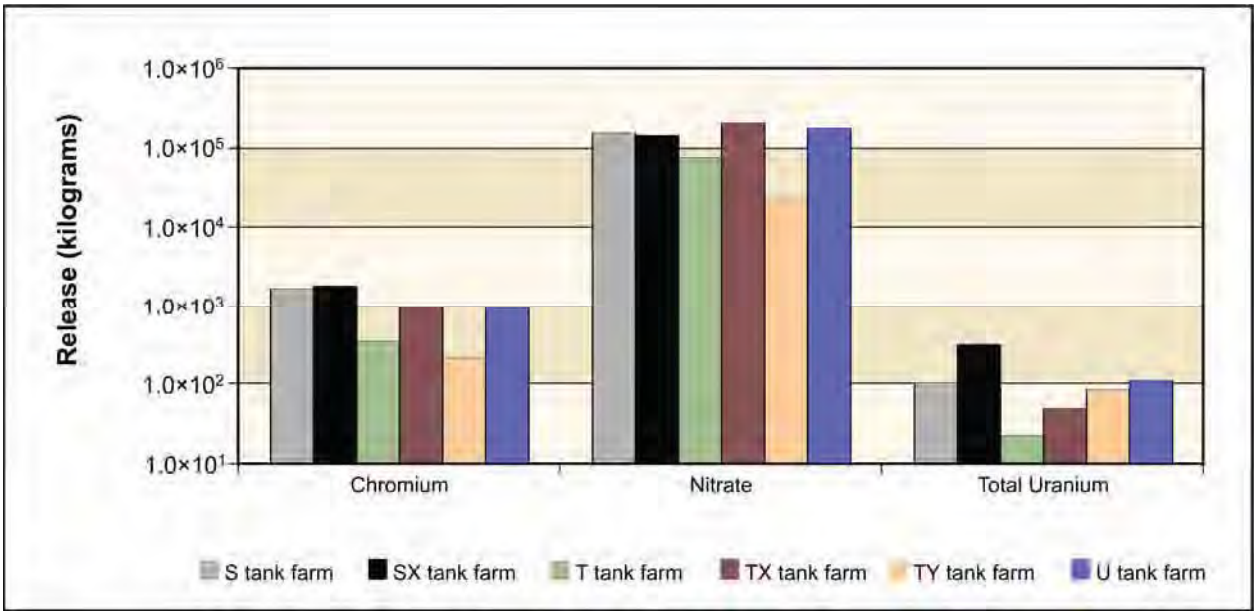


Figure N–61. Tank Closure Alternative 2A Other Sources from Tank Farms S, SX, T, TX, TY, and U Chemical Release to Aquifer

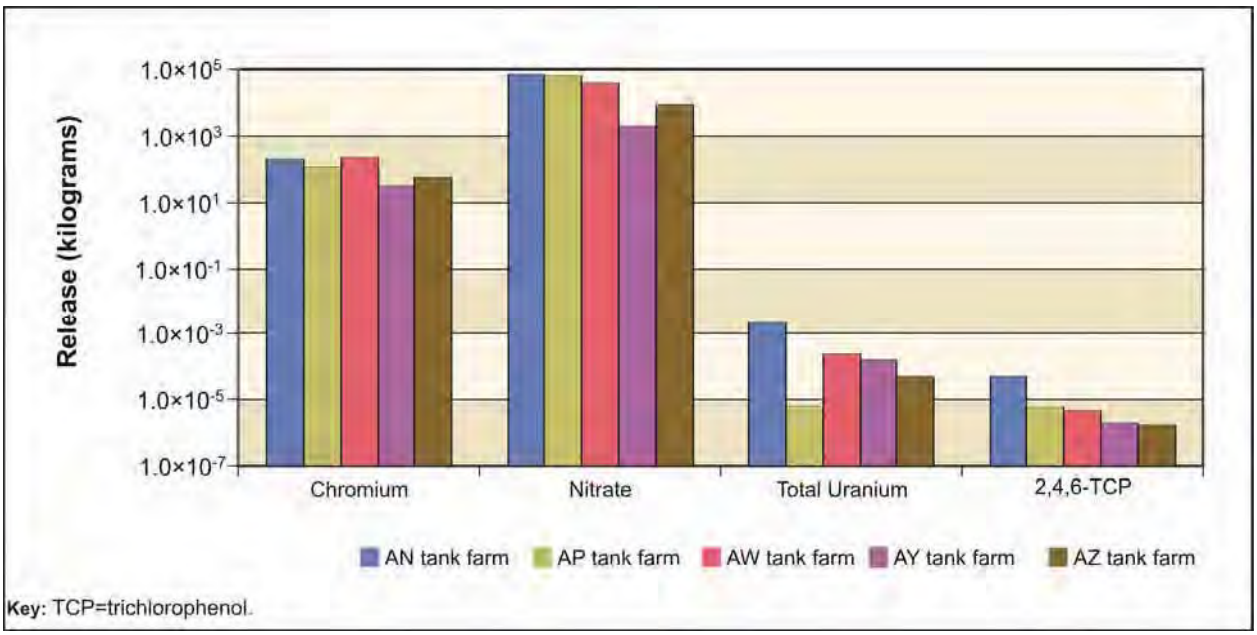


Figure N–62. Tank Closure Alternative 2A Other Sources from Tank Farms AN, AP, AW, AY, and AZ Chemical Release to Aquifer

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those of Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soil from onsite sources. Potential releases to the aquifer under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C are indicated in Figures N–63 through N–68.

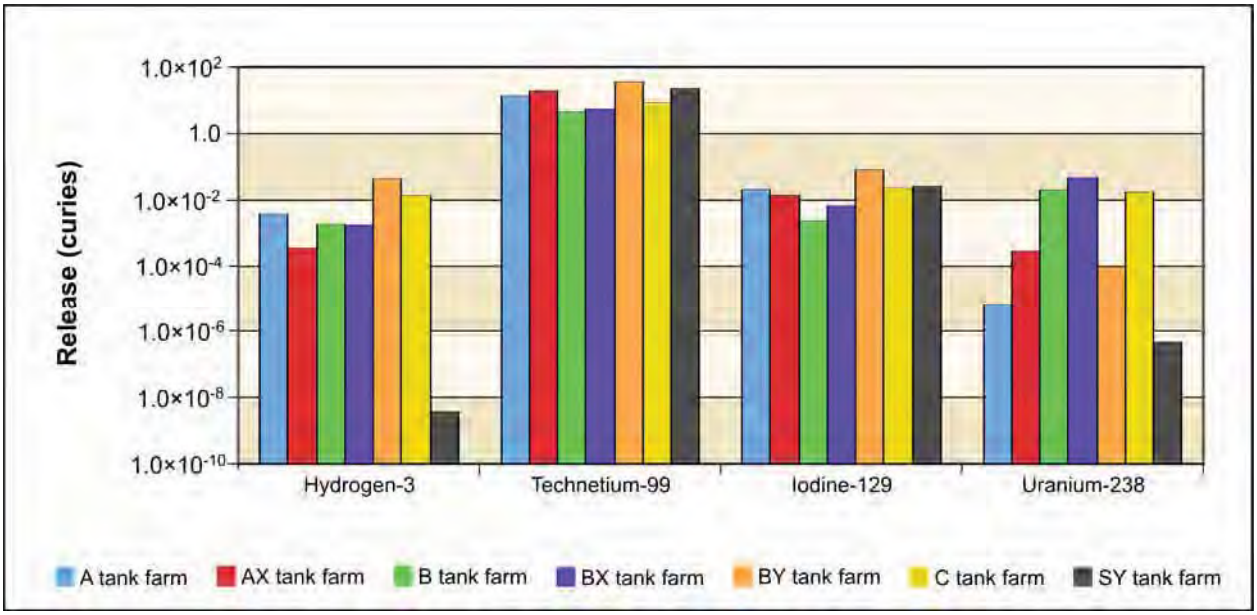


Figure N–63. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Radiological Release to Aquifer

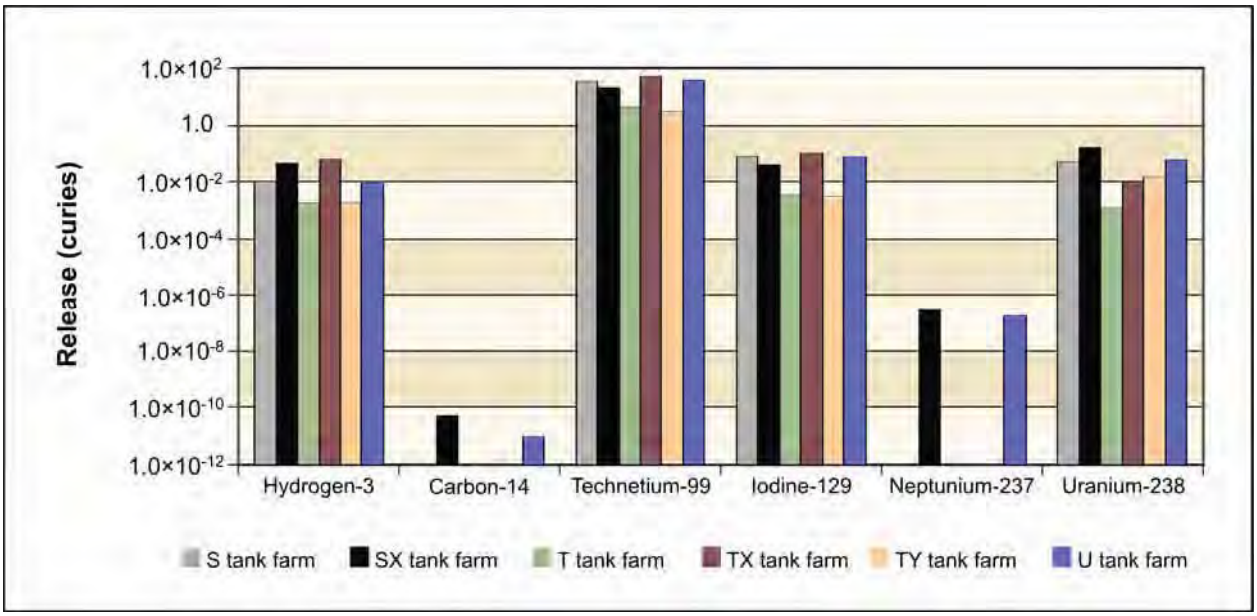


Figure N–64. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms S, SX, T, TX, TY, and U Radiological Release to Aquifer

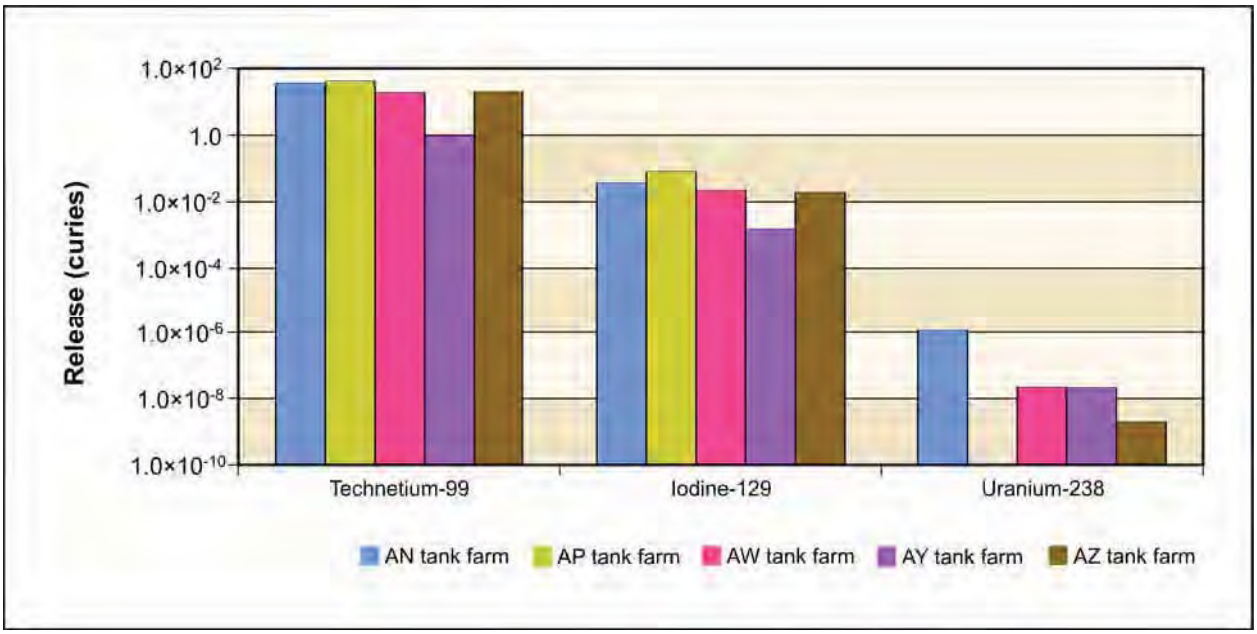


Figure N–65. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms AN, AP, AW, AY, and AZ Radiological Release to Aquifer

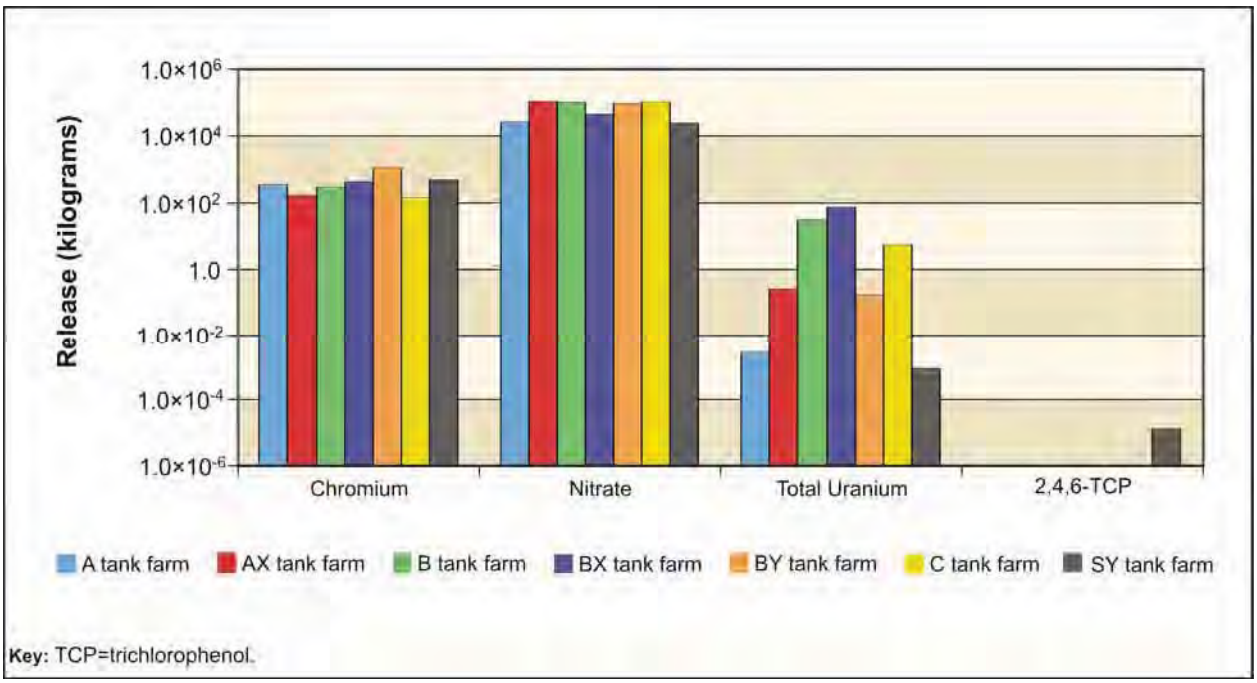


Figure N–66. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Chemical Release to Aquifer

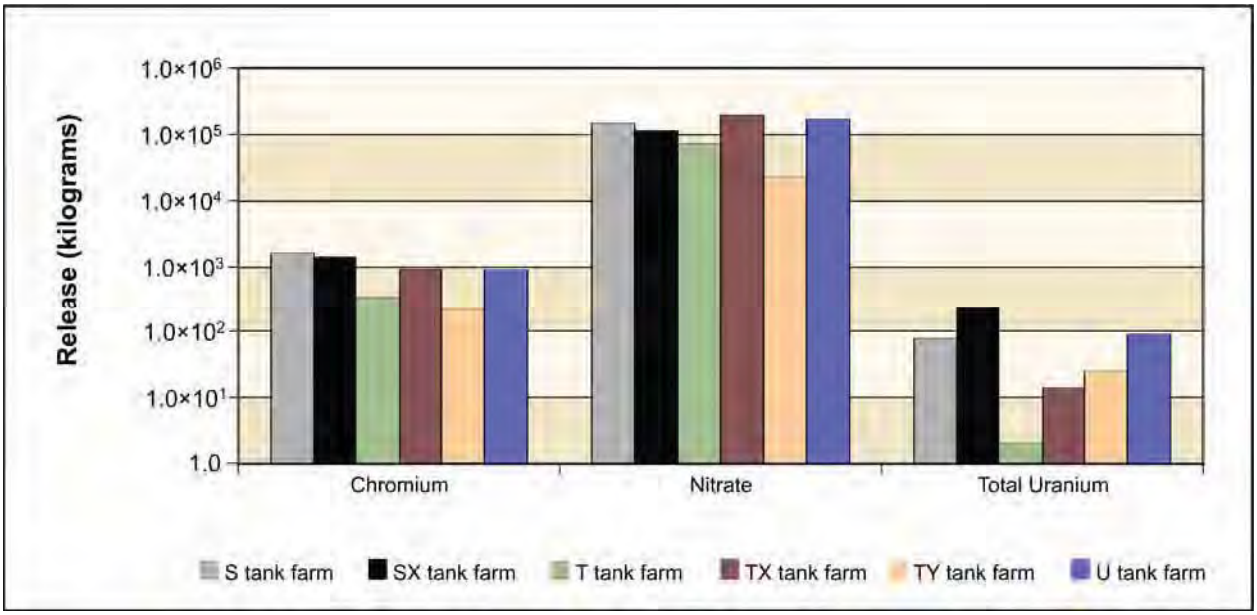


Figure N–67. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms S, SX, T, TX, TY, and U Chemical Release to Aquifer

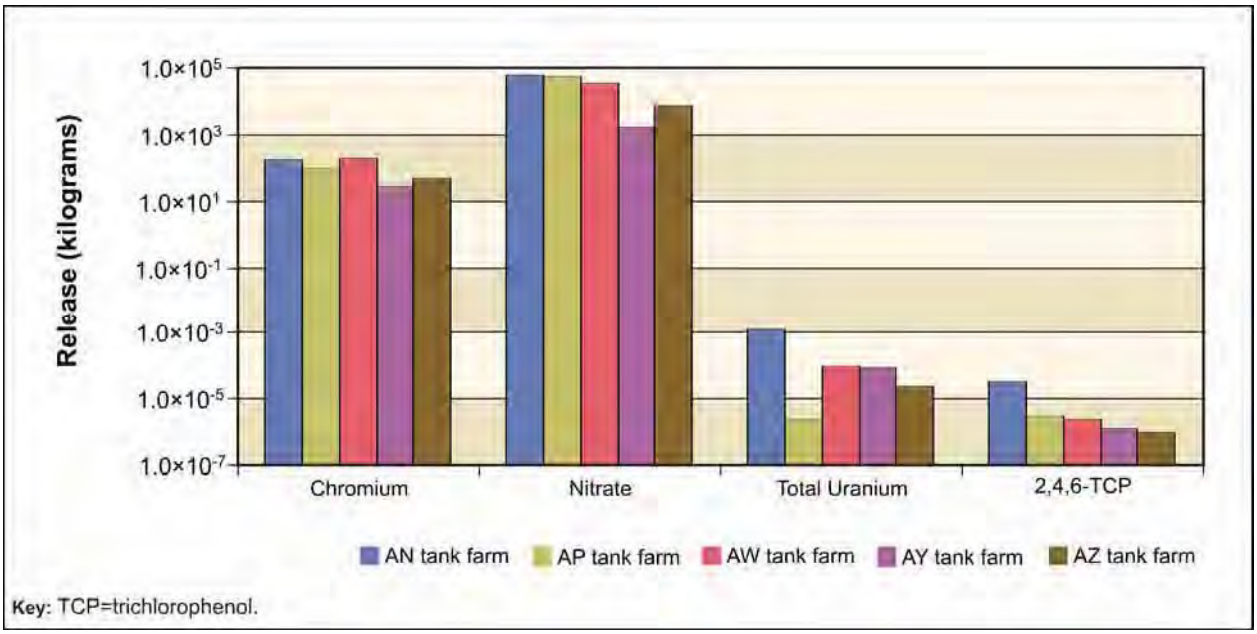


Figure N–68. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Other Sources from Tank Farms AN, AP, AW, AY, and AZ Chemical Release to Aquifer

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be closed to a clean state by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential releases to the aquifer under Tank Closure Alternative 4 are indicated in Figures N–69 through N–74.

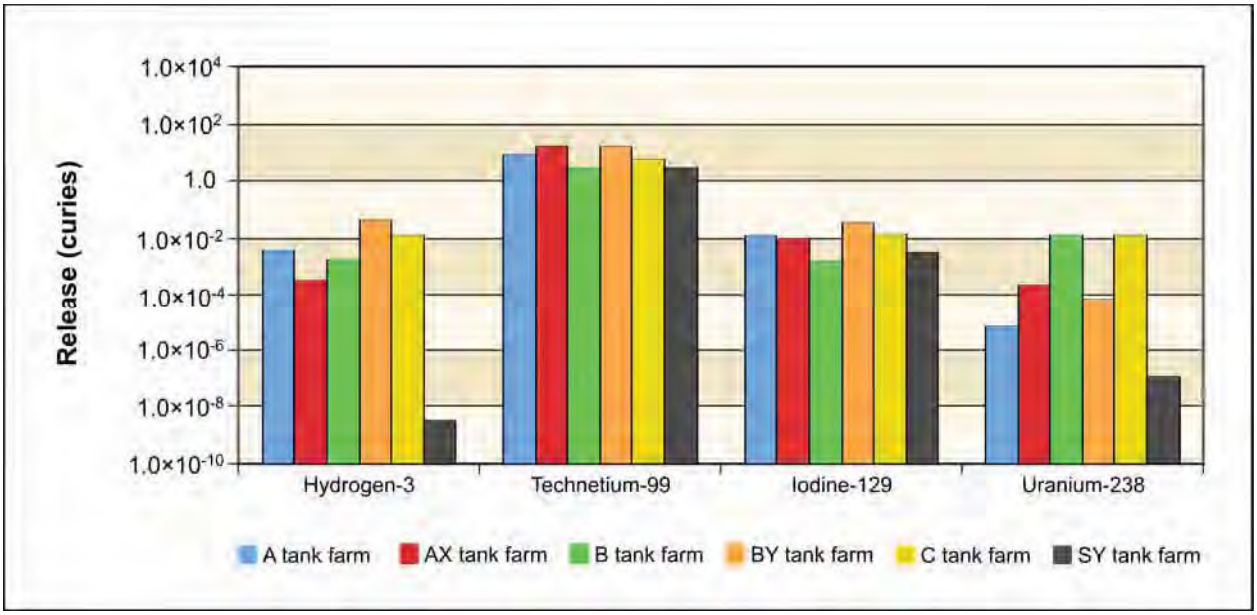


Figure N–69. Tank Closure Alternative 4 Other Sources from Tank Farms A, AX, BX, BY, C, and SY Radiological Release to Aquifer

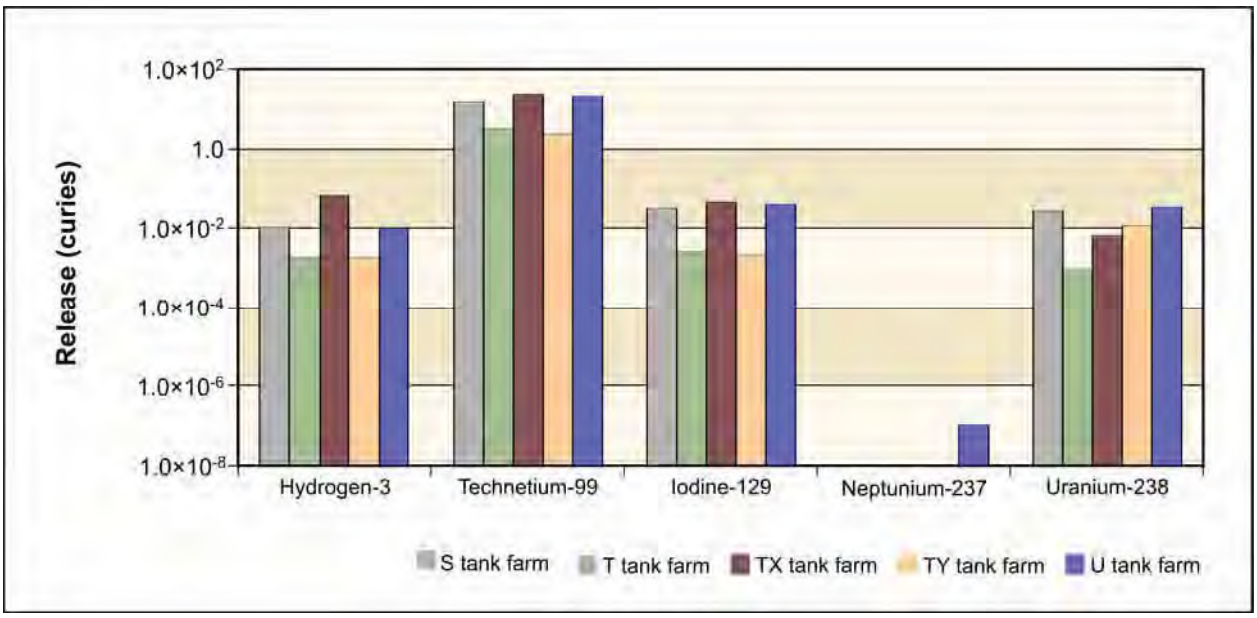


Figure N–70. Tank Closure Alternative 4 Other Sources from Tank Farms S, T, TX, TY, and U Radiological Release to Aquifer

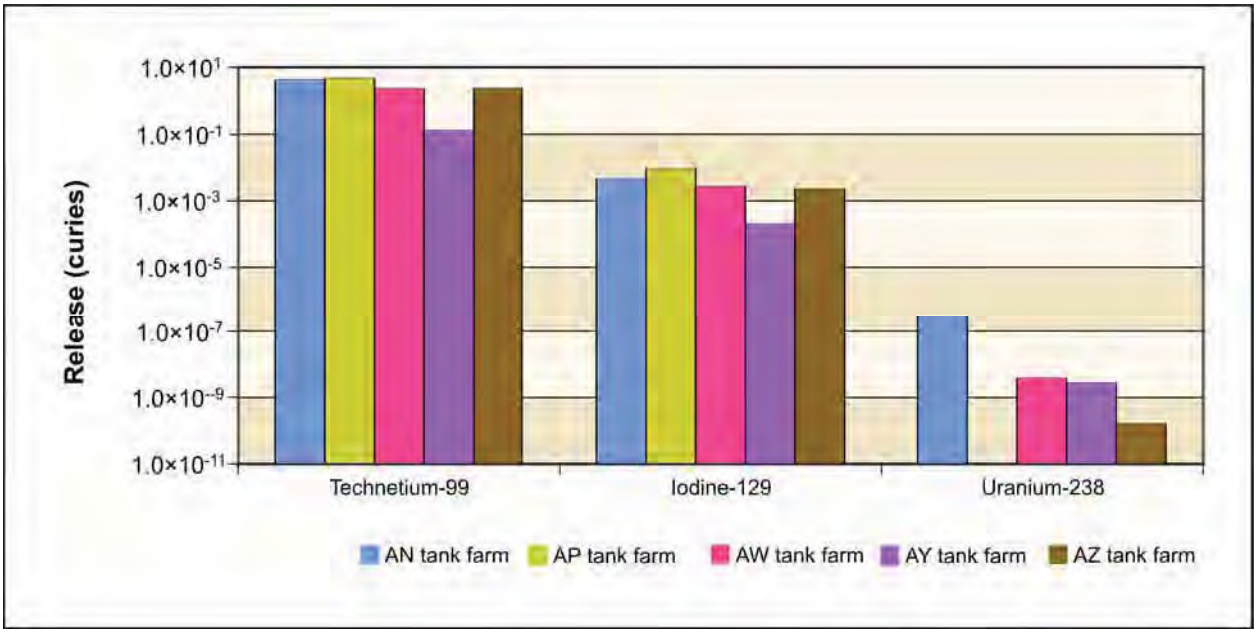


Figure N–71. Tank Closure Alternative 4 Other Sources from Tank Farms AN, AP, AW, AY, and AZ Radiological Release to Aquifer

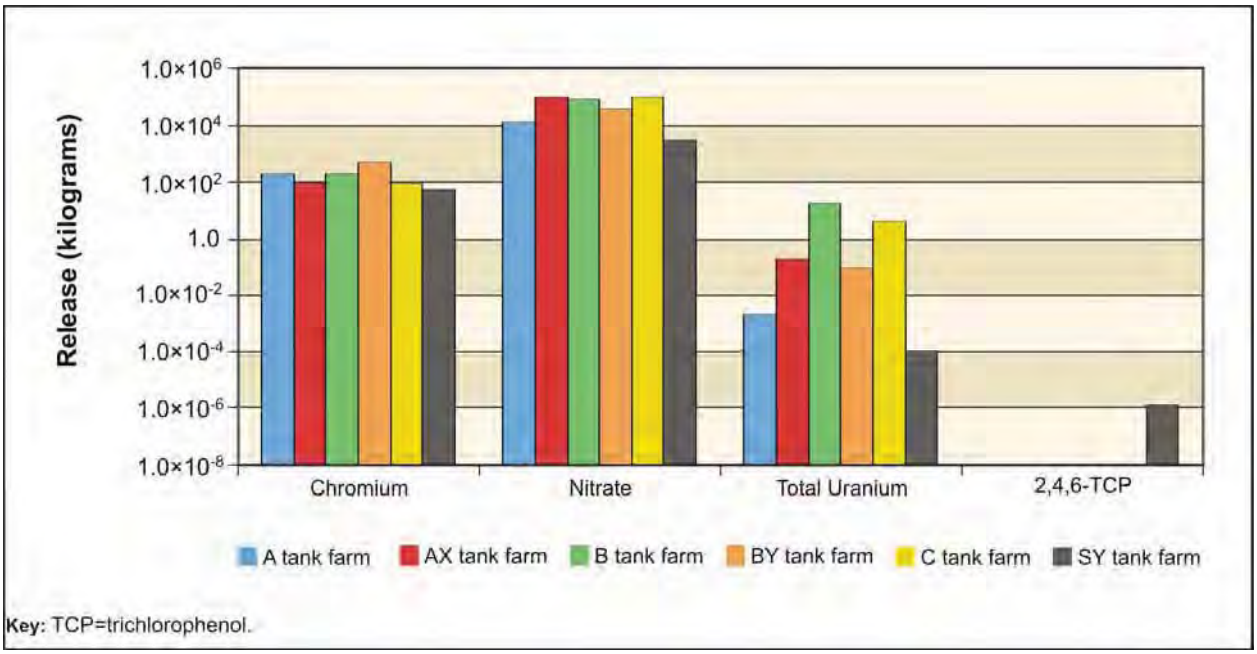


Figure N–72. Tank Closure Alternative 4 Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Chemical Release to Aquifer

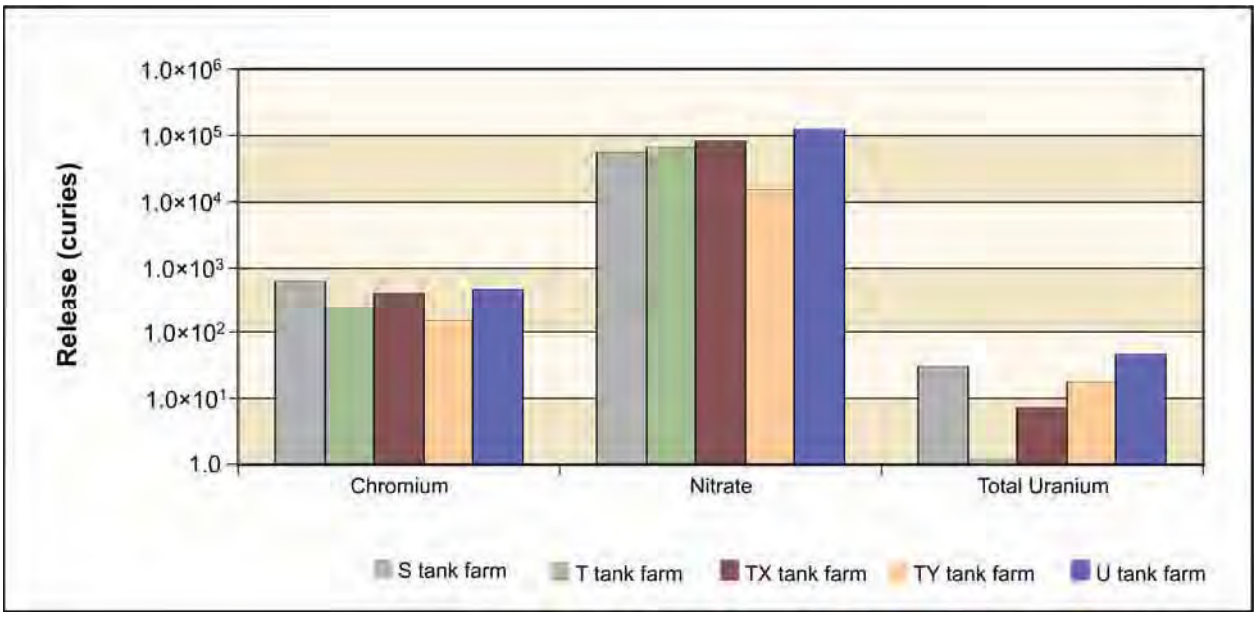


Figure N–73. Tank Closure Alternative 4 Other Sources from Tank Farms S, SX, T, TX, TY, and U Chemical Release to Aquifer

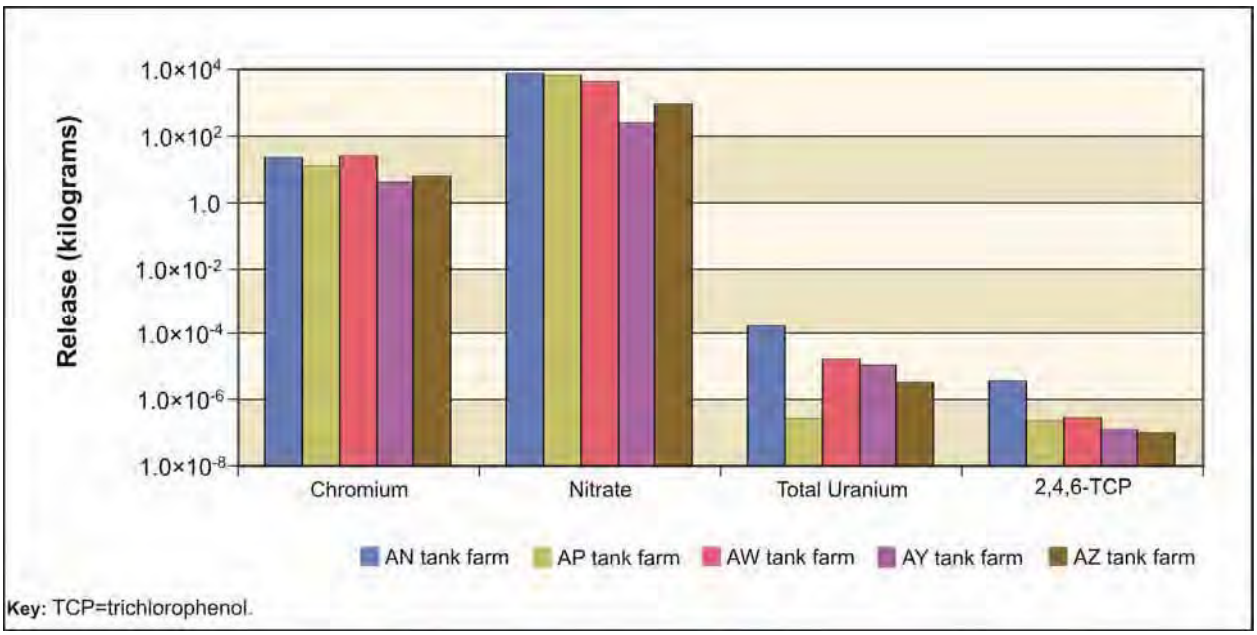


Figure N–74. Tank Closure Alternative 4 Other Sources from Tank Farms AN, AP, AW, AY, and AZ Chemical Release to Aquifer

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential releases to the aquifer under Tank Closure Alternative 5 are indicated in Figures N–75 through N–80.

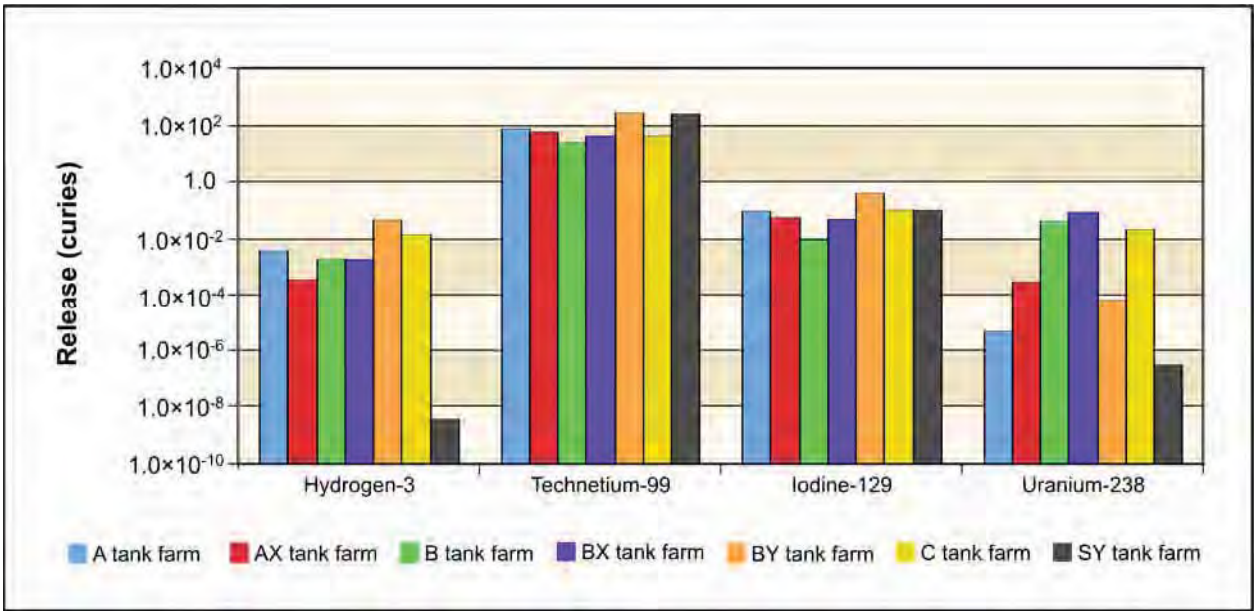


Figure N–75. Tank Closure Alternative 5 Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Radiological Release to Aquifer

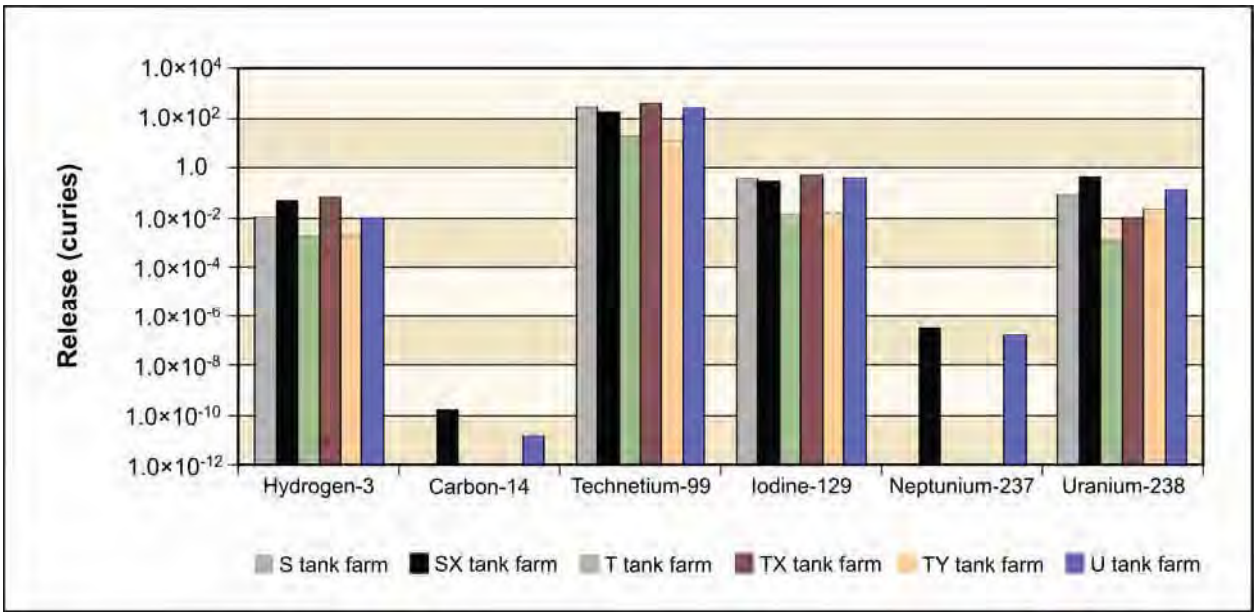


Figure N–76. Tank Closure Alternative 5 Other Sources from Tank Farms S, SX, T, TX, TY, and U Radiological Release to Aquifer

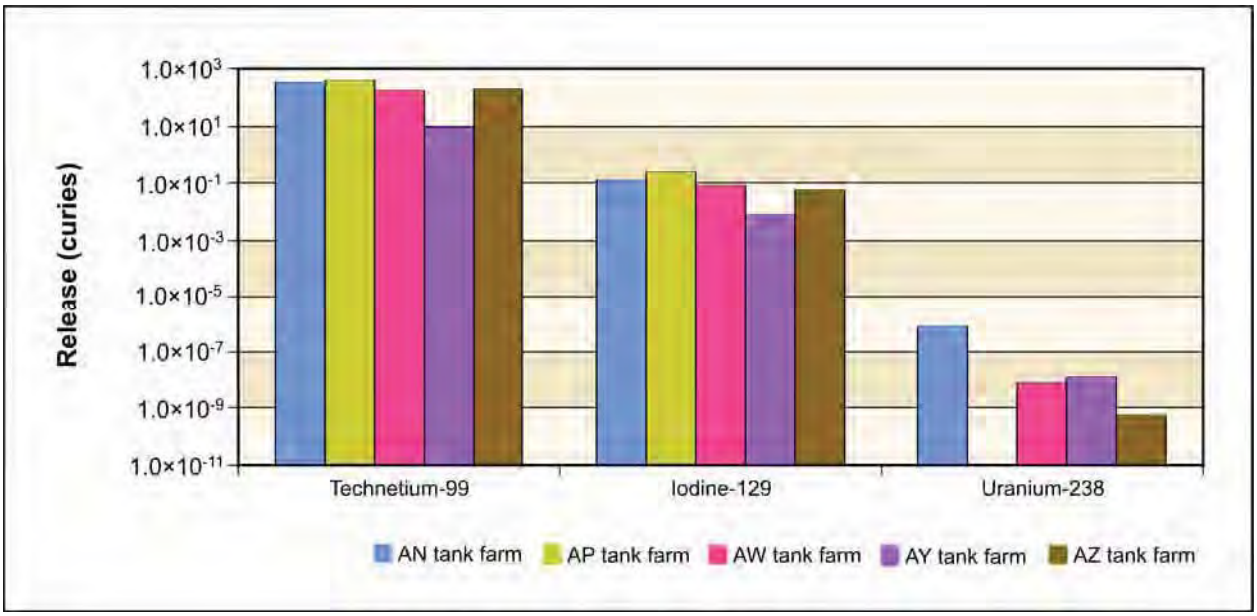


Figure N–77. Tank Closure Alternative 5 Other Sources from Tank Farms AN, AP, AW, AY, and AZ Radiological Release to Aquifer

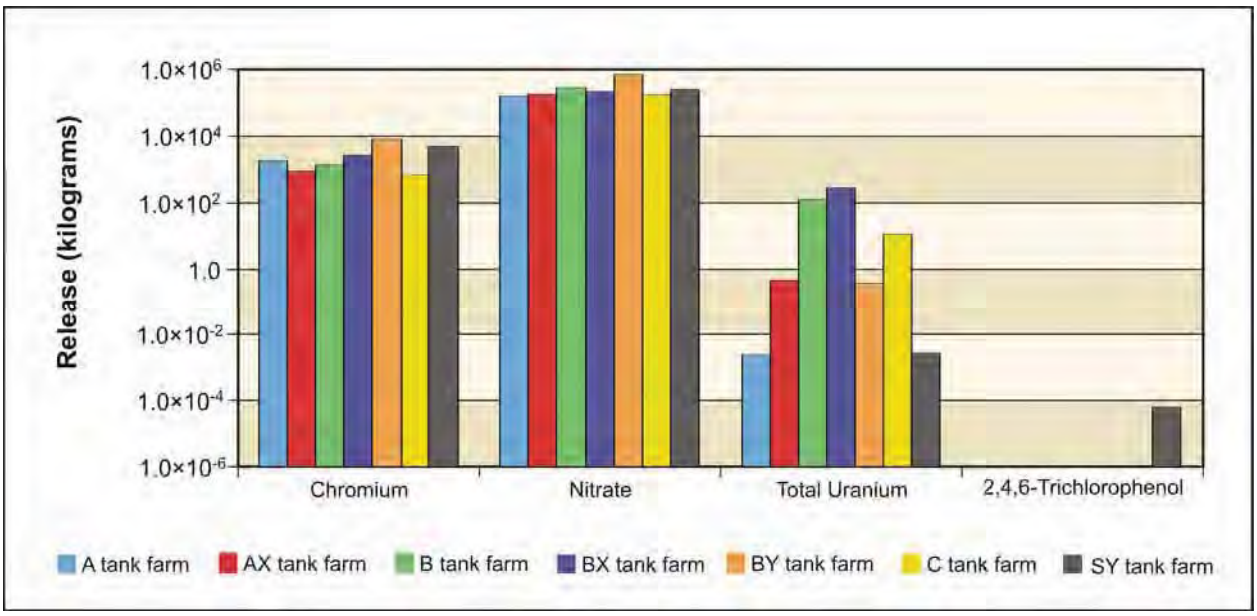


Figure N–78. Tank Closure Alternative 5 Other Sources from Tank Farms A, AX, B, BX, BY, C, and SY Chemical Release to Aquifer

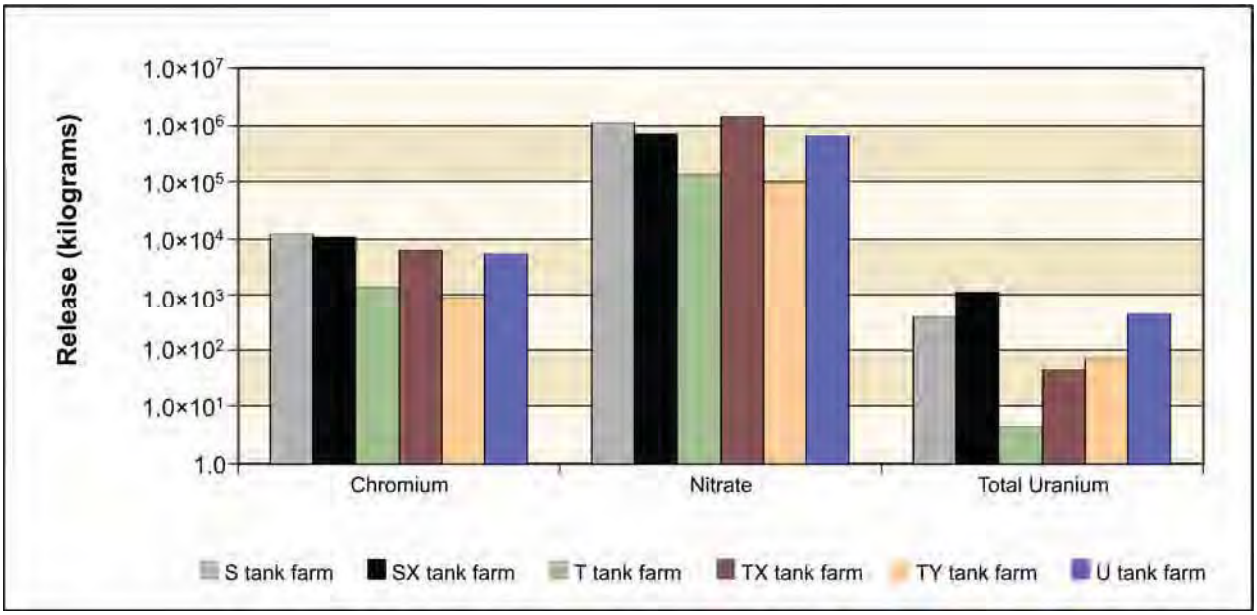


Figure N–79. Tank Closure Alternative 5 Other Sources from Tank Farms S, SX, T, TX, TY, and U Chemical Release to Aquifer

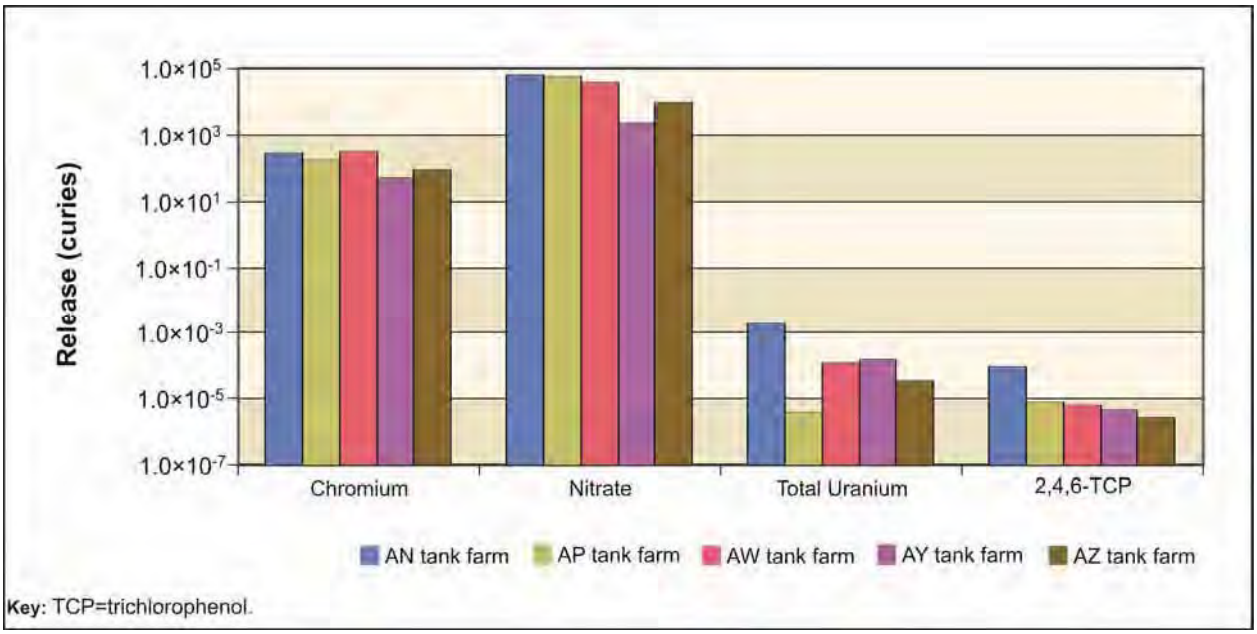


Figure N–80. Tank Closure Alternative 5 Other Sources from Tank Farms AN, AP, AW, AY, and AZ Chemical Release to Aquifer

N.2.2 FFTF Decommissioning Alternatives

N.2.2.1 FFTF Decommissioning Alternative 1: No Action

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of the Fast Flux Test Facility (FFTF) would not occur. For purpose of analysis, the remaining waste would be available for release to the environment after an institutional control period of 100 years. Potential releases to the aquifer under FFTF Decommissioning Alternative 1 are indicated in Figures N–81 and N–82.

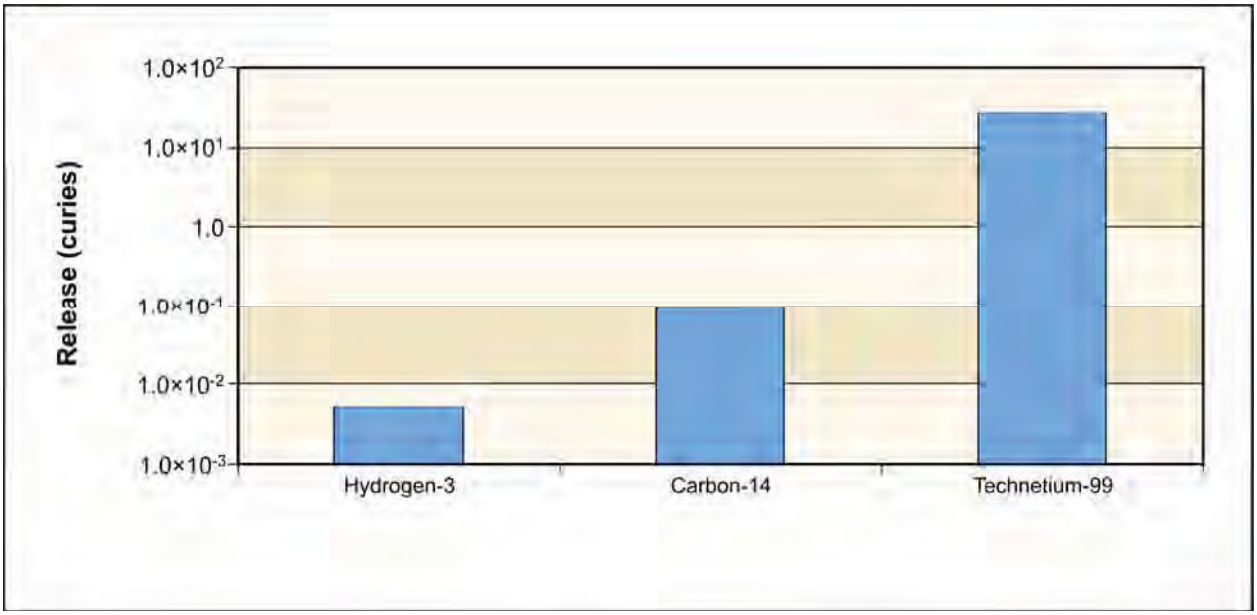


Figure N–81. FFTF Decommissioning Alternative 1 Radiological Release to Aquifer

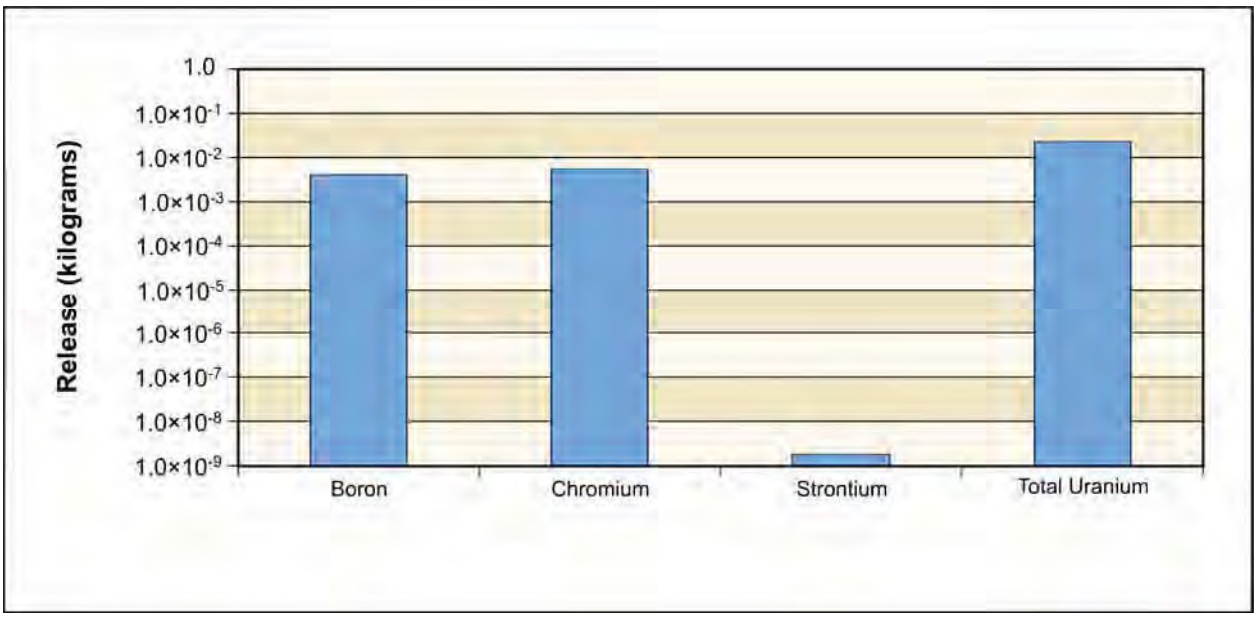


Figure N–82. FFTF Decommissioning Alternative 1 Chemical Release to Aquifer

N.2.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures (including the reactor vessel). Potential releases to the aquifer under FFTF Decommissioning Alternative 2 are indicated in Figure N–83.

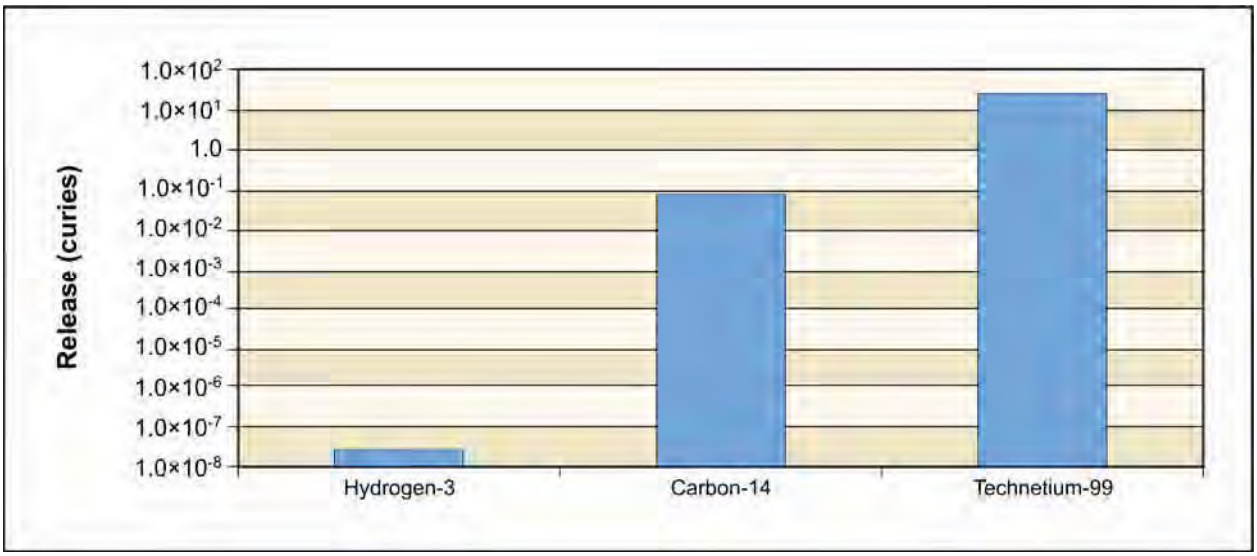


Figure N–83. FFTF Decommissioning Alternative 2 Radiological Release to Aquifer

N.2.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures and contaminated below-grade structures, equipment, and materials would be removed. Potential releases to the aquifer under FFTF Decommissioning Alternative 3 are indicated in Figure N–84.

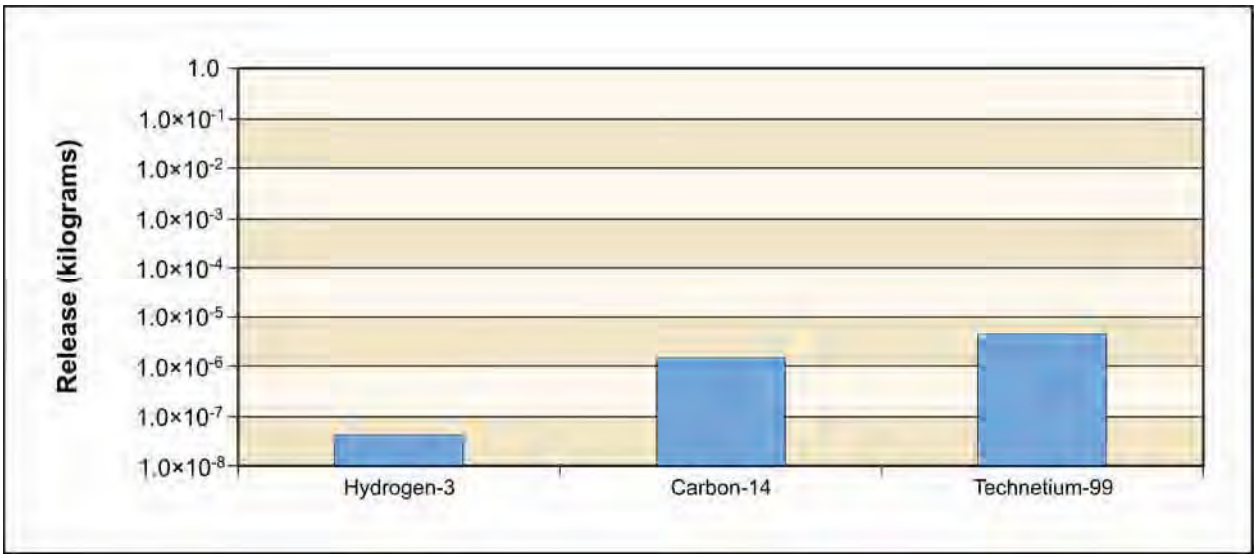


Figure N–84. FFTF Decommissioning Alternative 3 Radiological Release to Aquifer

N.2.3 Waste Management Alternatives

N.2.3.1 Waste Management Alternative 1: No Action

Under Waste Management Alternative 1, only the waste currently generated onsite at Hanford from non–Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) actions would continue to be disposed of in the low-level radioactive waste burial ground 218-W-5, trenches 31 and 34. Although short-term impacts do not address impacts associated with closure activities for this site, for purposes of analysis of long-term impacts, it is assumed that these trenches would be closed using an RCRA-compliant barrier consistent with the closure plans for these burial grounds. As a result, the non-CERCLA waste disposed of in these trenches from 2008 to 2035 would become available for release to the environment. Potential releases to the aquifer under Waste Management Alternative 1 are indicated in Figures N–85 and N–86.

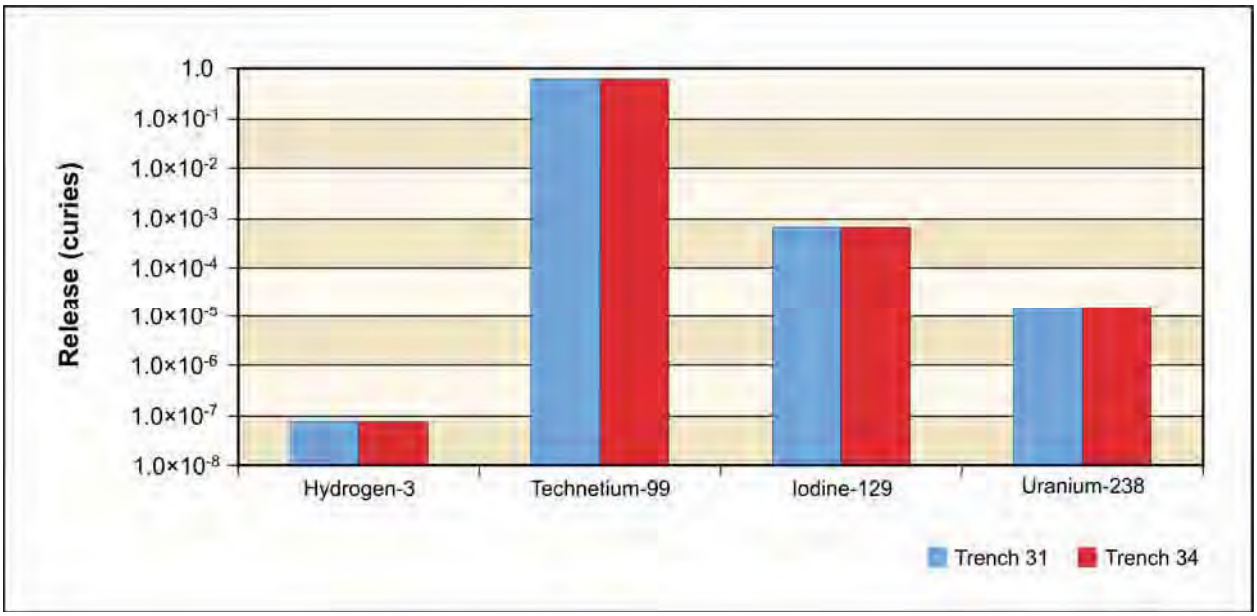


Figure N–85. Waste Management Alternative 1 Radiological Release to Aquifer

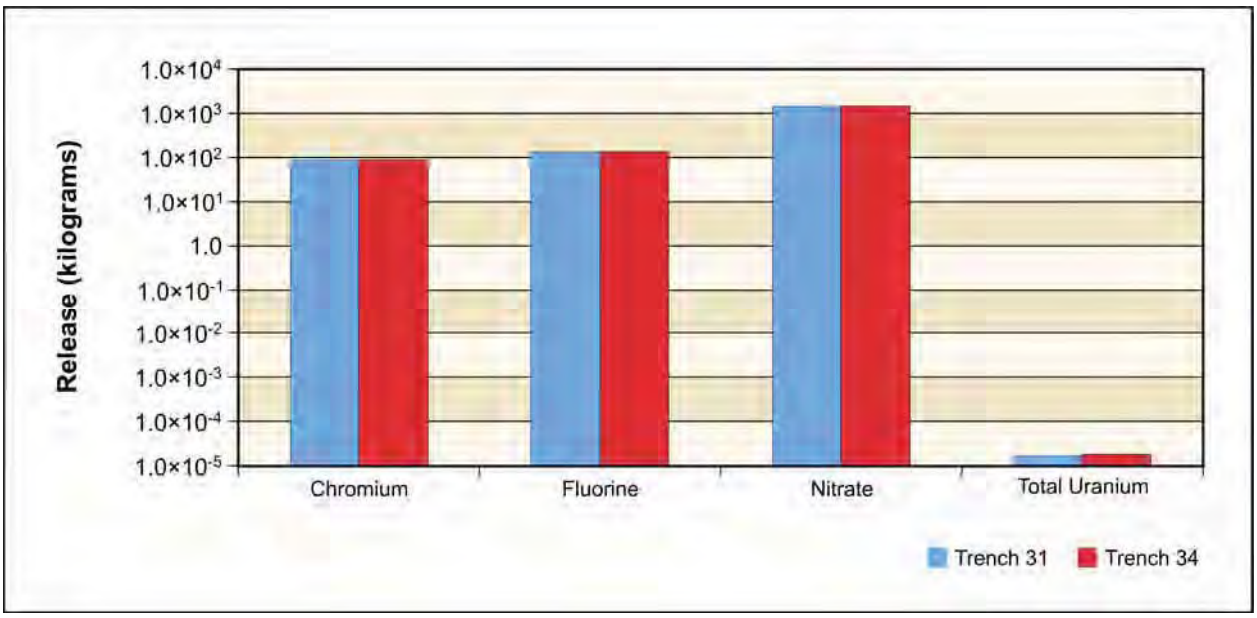


Figure N–86. Waste Management Alternative 1 Chemical Release to Aquifer

N.2.3.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only

Under Waste Management Alternative 2, waste from tank treatment operations, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in an Integrated Disposal Facility (IDF) in the 200-East Area (IDF-East). Waste from tank farm cleanup activities would be disposed of in the River Protection Project Disposal Facility (RPPDF). As a result, the waste disposed of in these two facilities would become available for release to the environment. Because different waste types would result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow for consideration of the different waste types resulting from the Tank Closure alternatives.

N.2.3.2.1 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Immobilized low-activity waste (ILAW) glass
- Low-activity waste (LAW) melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, are indicated in Figures N–87 and N–88.

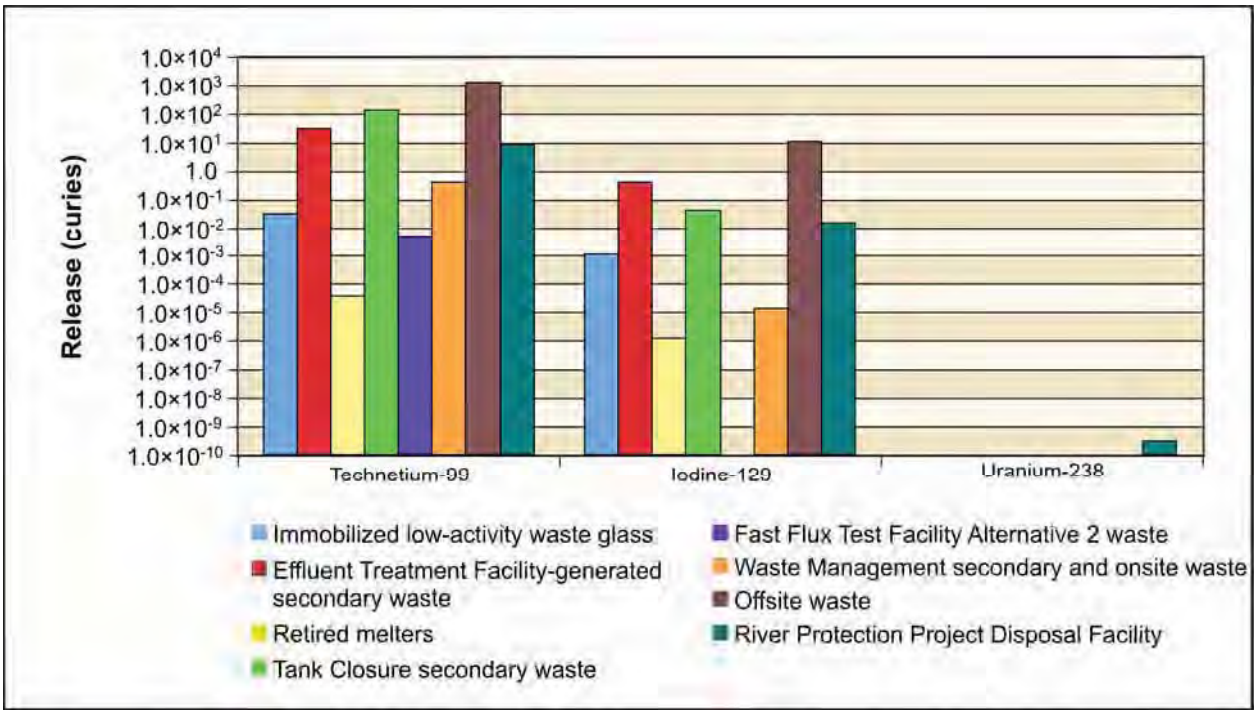


Figure N–87. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Release to Aquifer

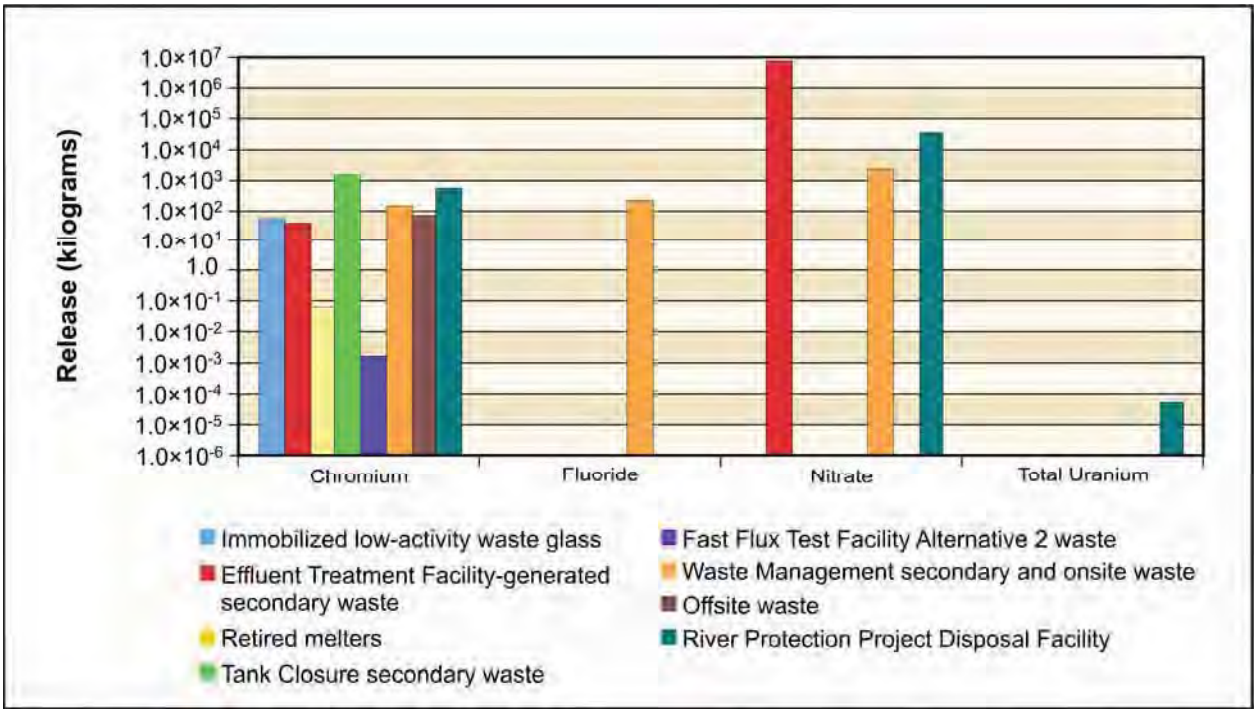


Figure N–88. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Release to Aquifer

N.2.3.2.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, are indicated in Figures N–89 and N–90.

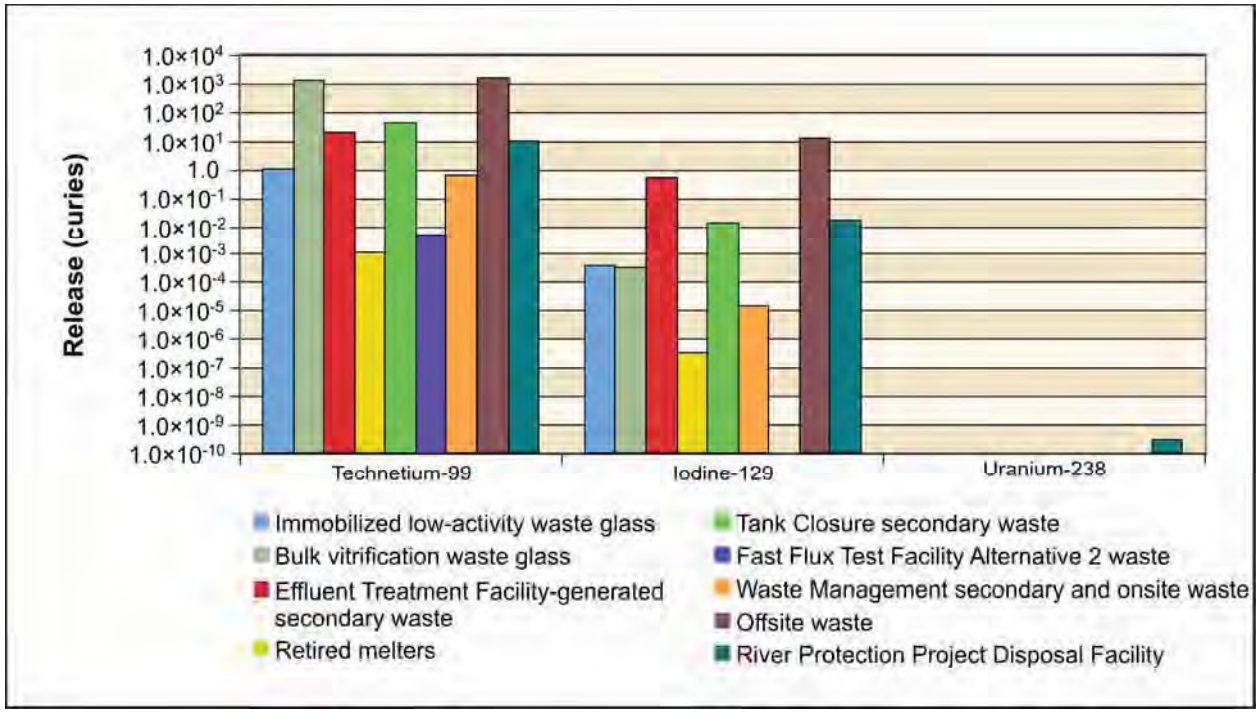


Figure N–89. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Release to Aquifer

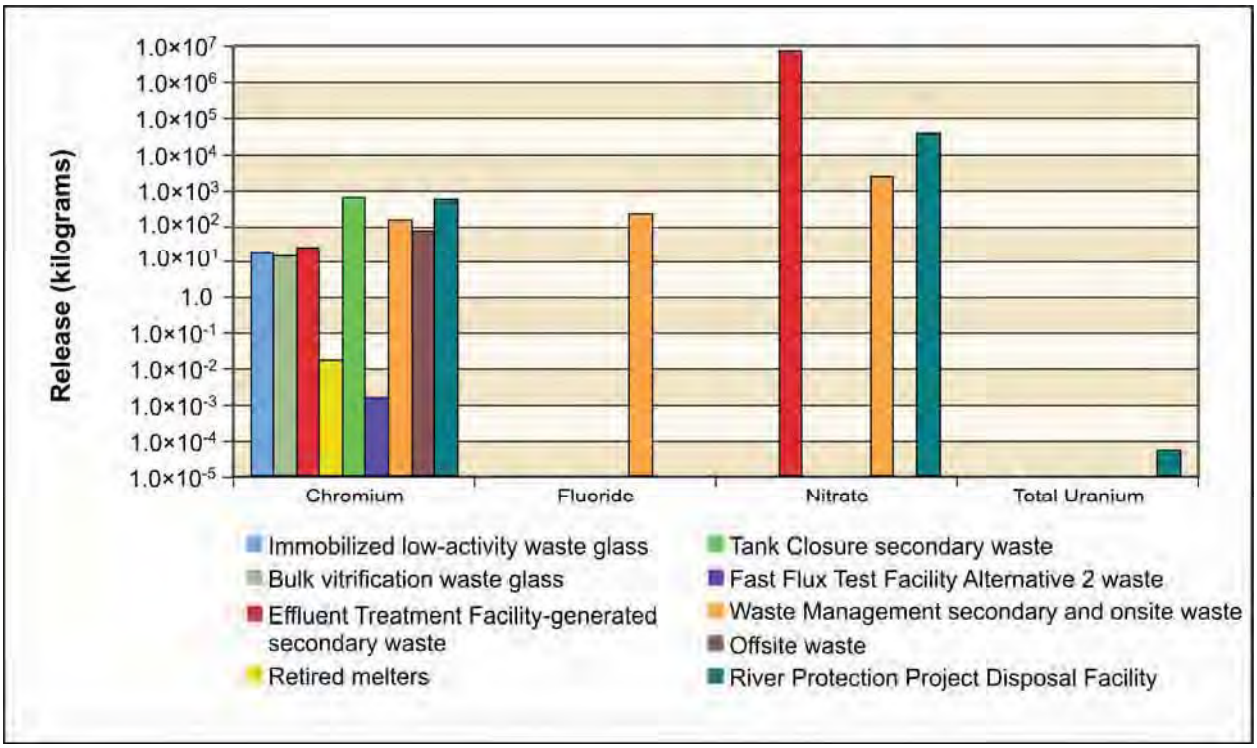


Figure N–90. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Release to Aquifer

N.2.3.2.3 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, are indicated in Figures N–91 and N–92.

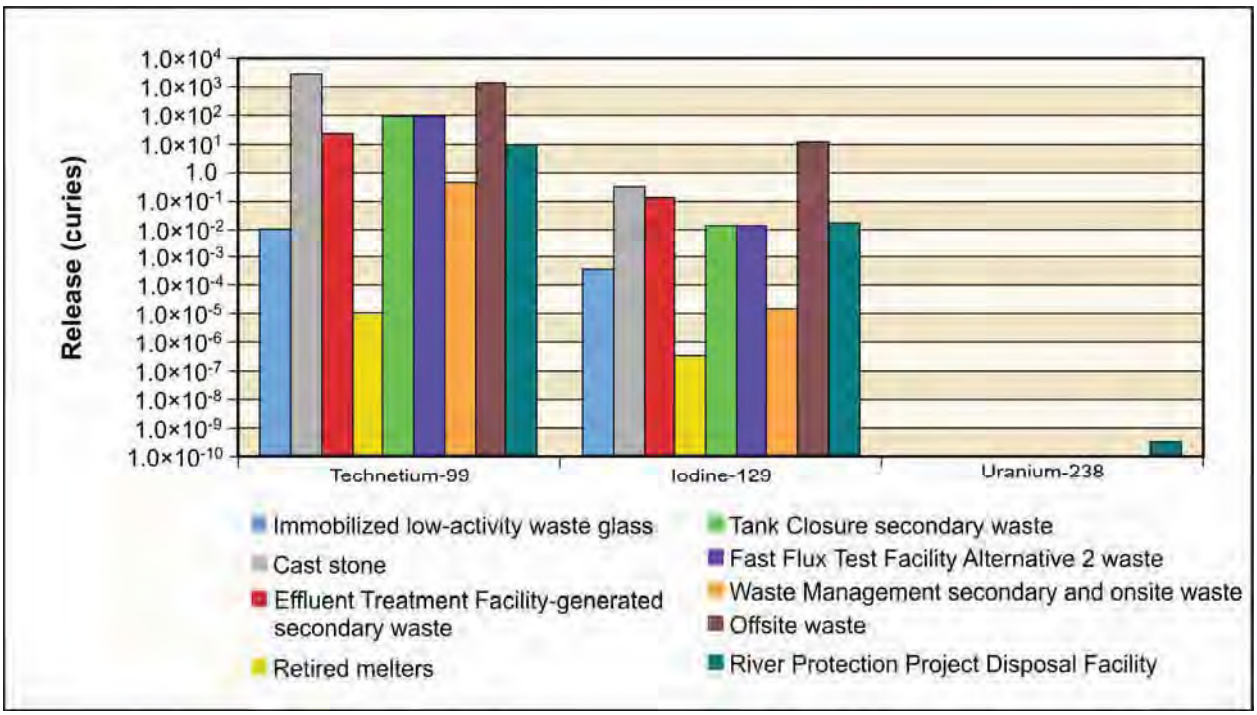


Figure N–91. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Release to Aquifer

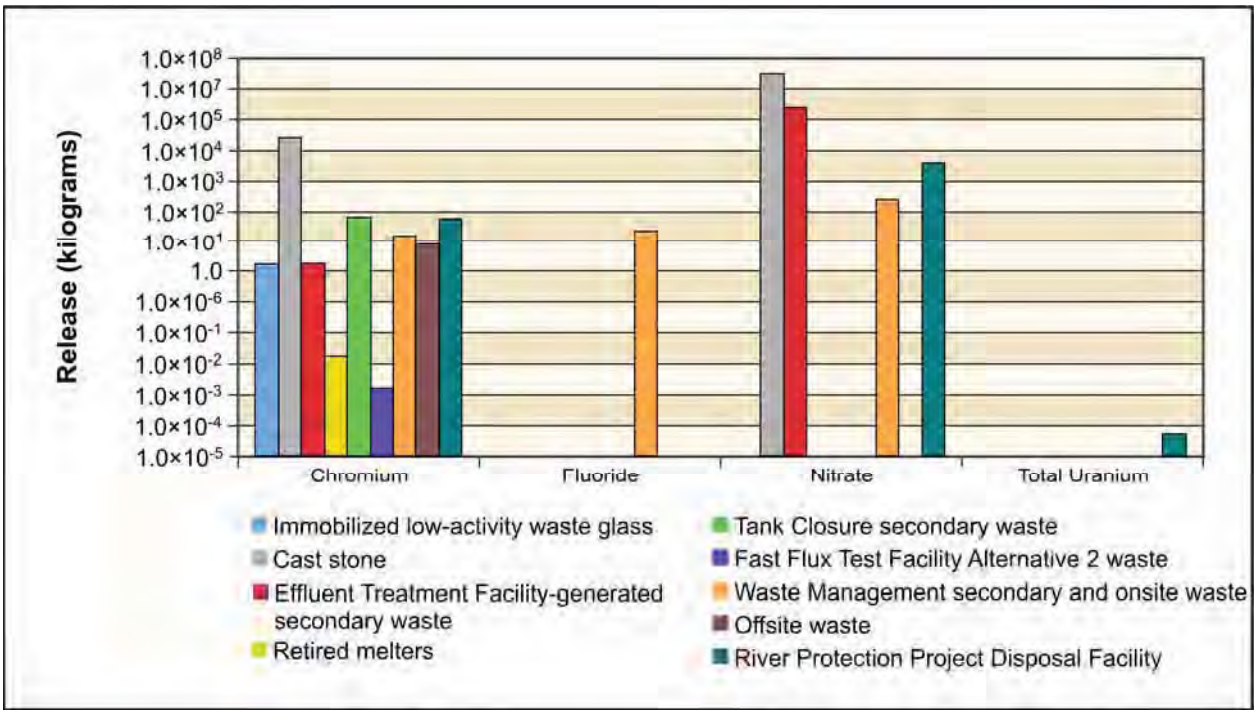


Figure N–92. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Release to Aquifer

N.2.3.2.4 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, are indicated in Figures N–93 and N–94.

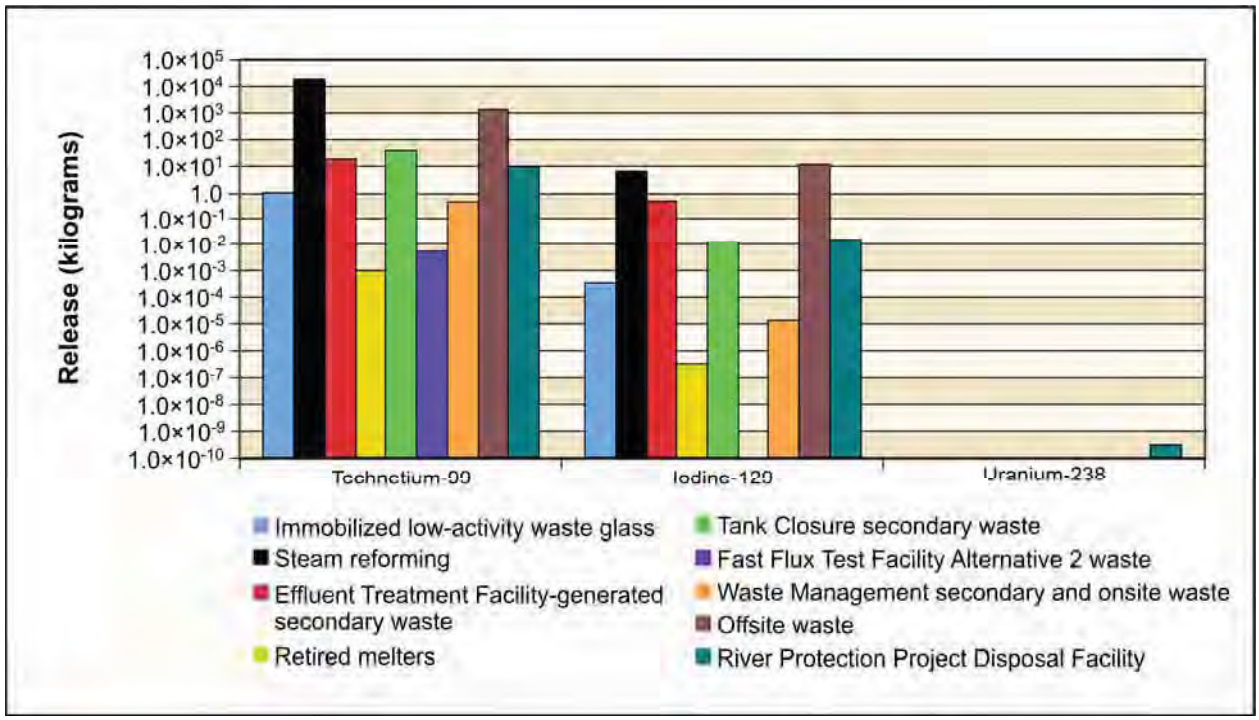


Figure N–93. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Release to Aquifer

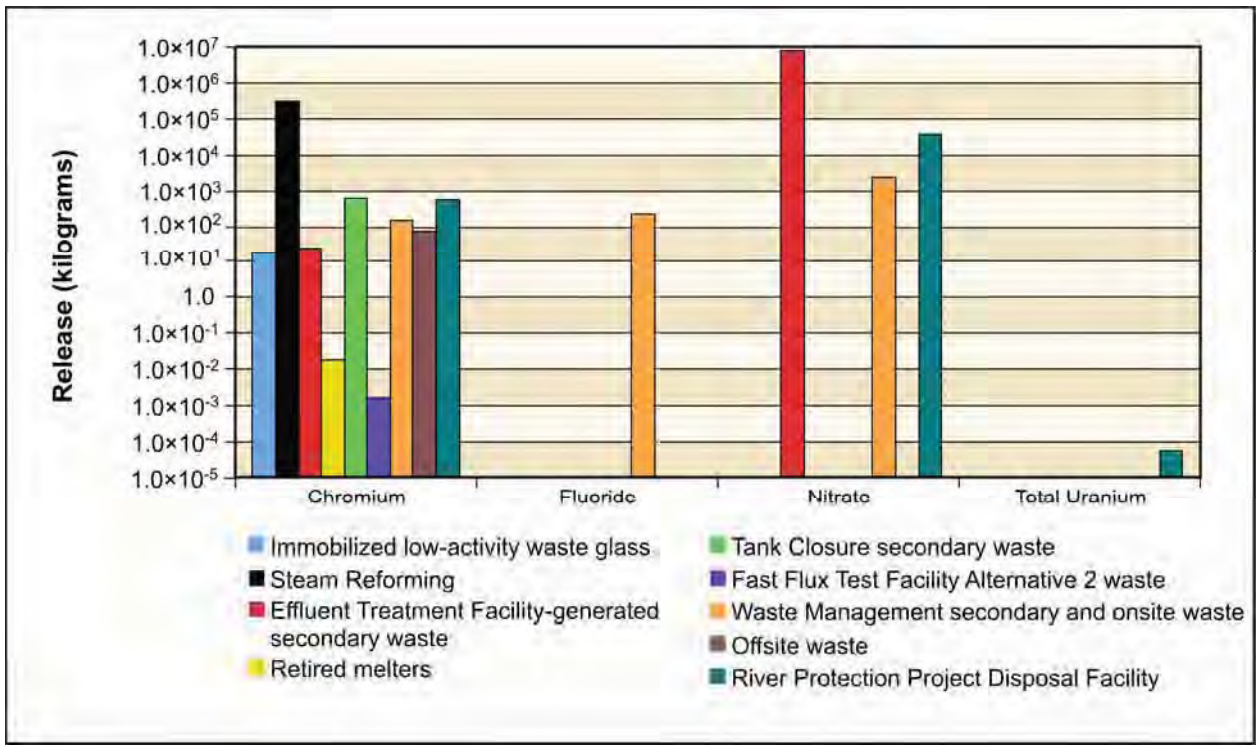


Figure N–94. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Release to Aquifer

N.2.3.2.5 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 4. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, are indicated in Figures N–95 and N–96.

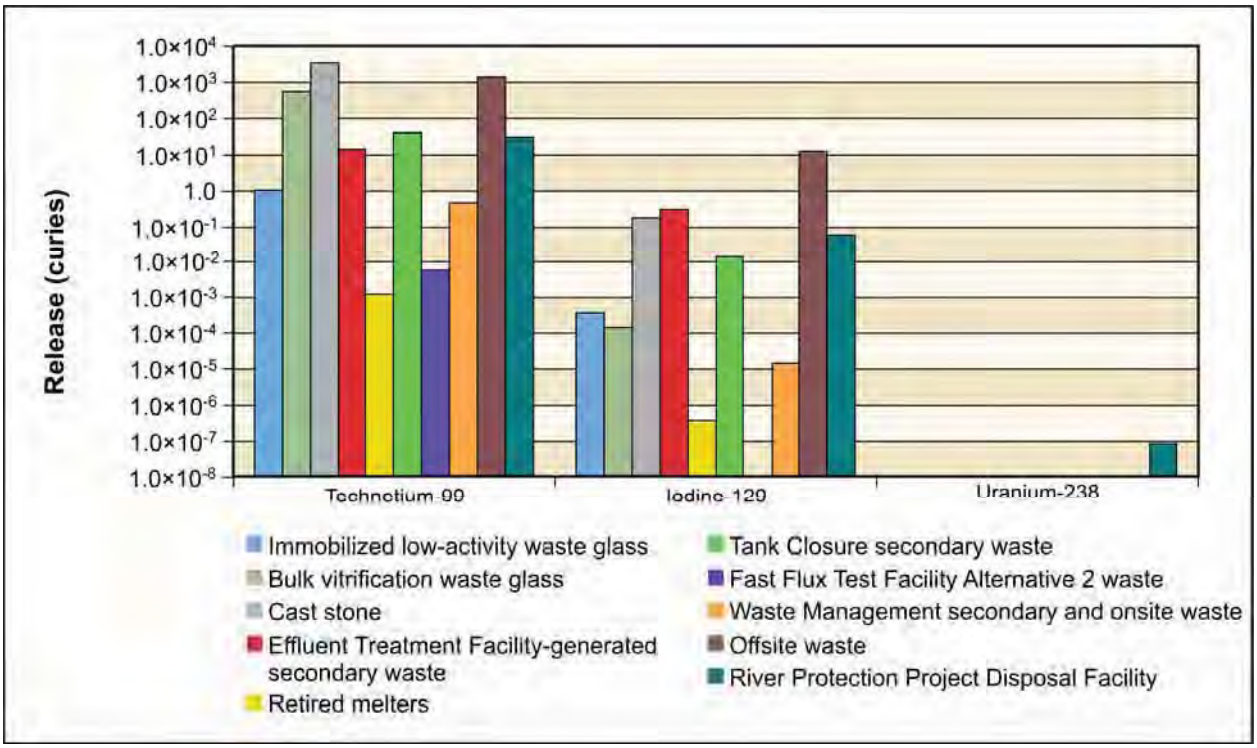


Figure N–95. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release to Vadose Zone

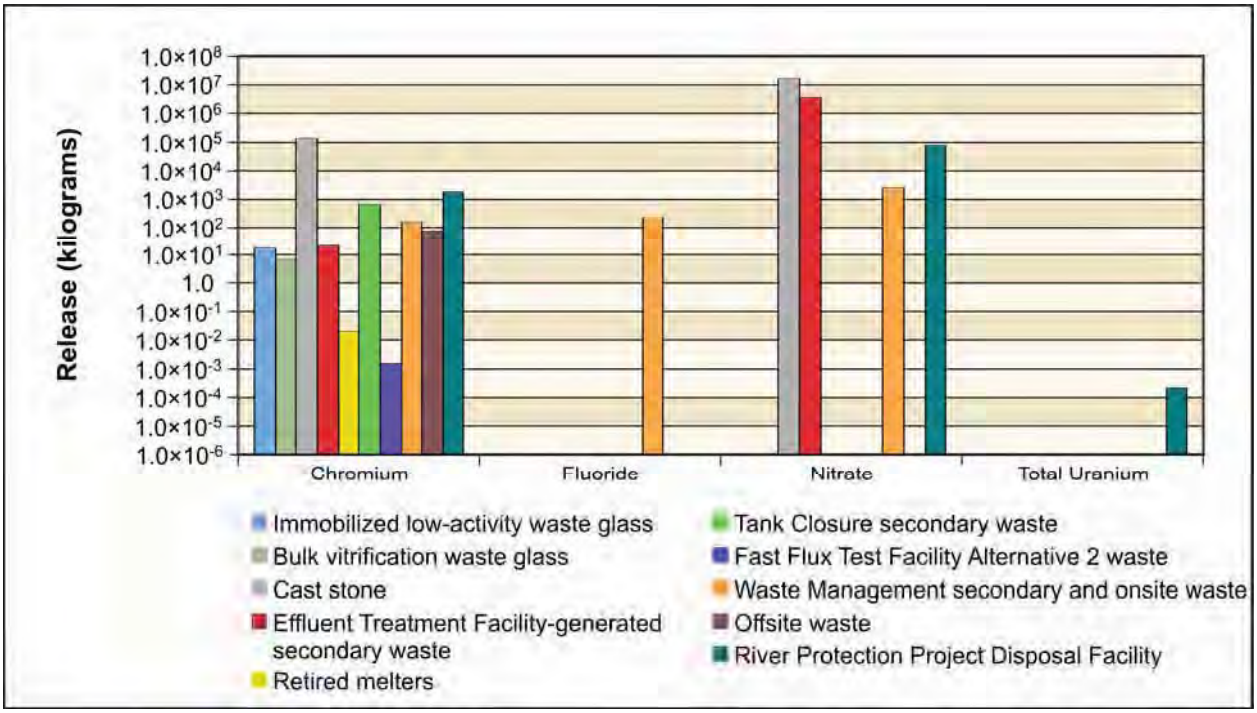


Figure N–96. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release to Aquifer

N.2.3.2.6 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, are indicated in Figures N–97 and N–98.

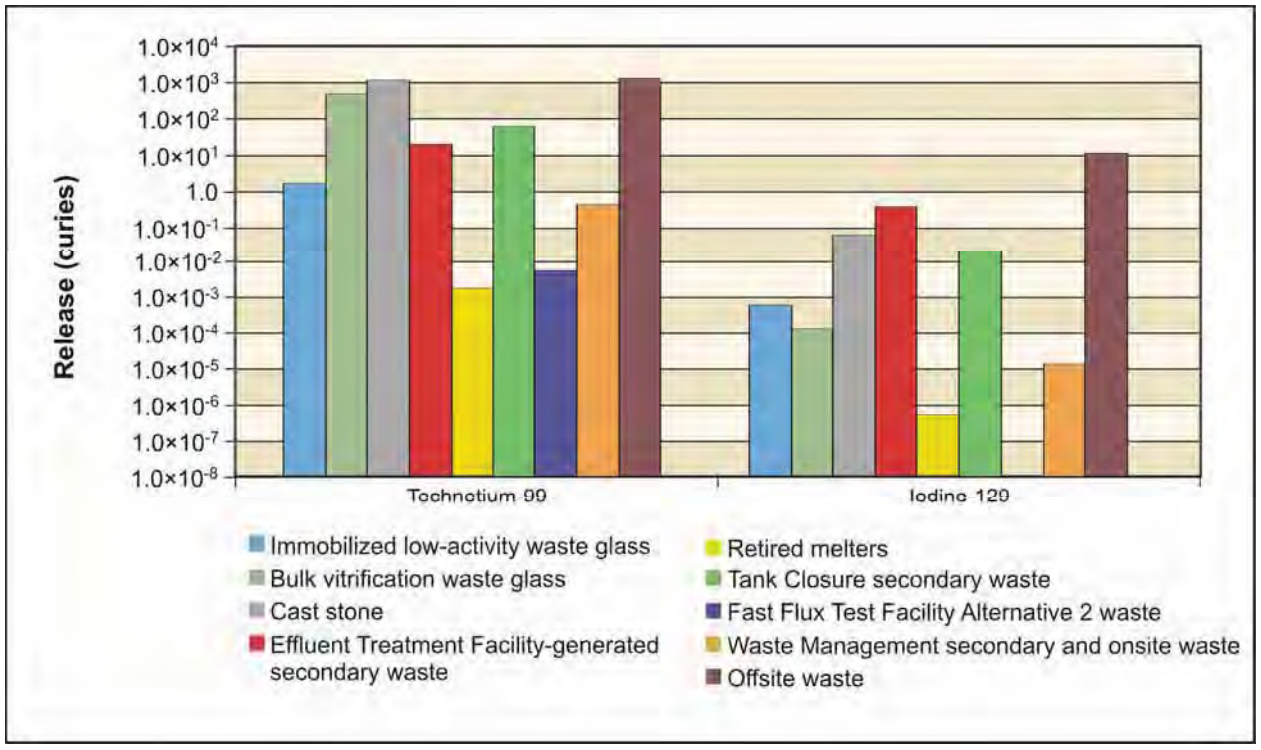


Figure N–97. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Release to Aquifer

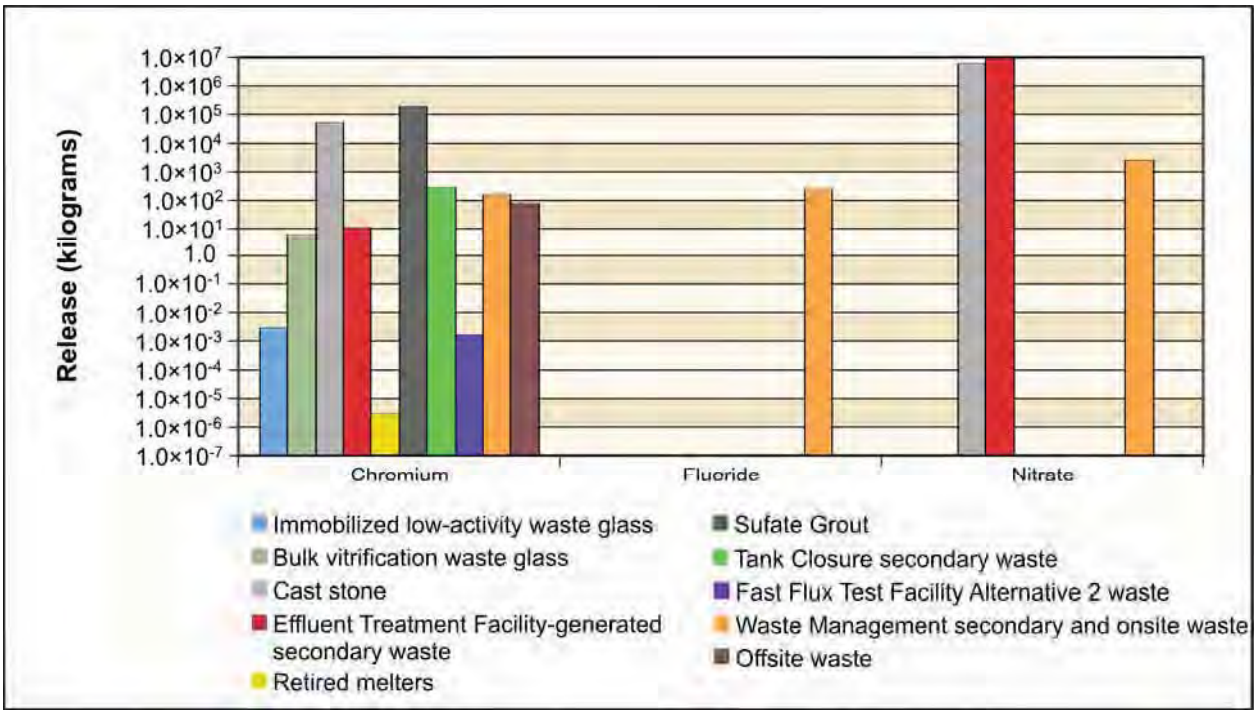


Figure N–98. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Release to Aquifer

N.2.3.2.7 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, are indicated in Figures N–99 and N–100.

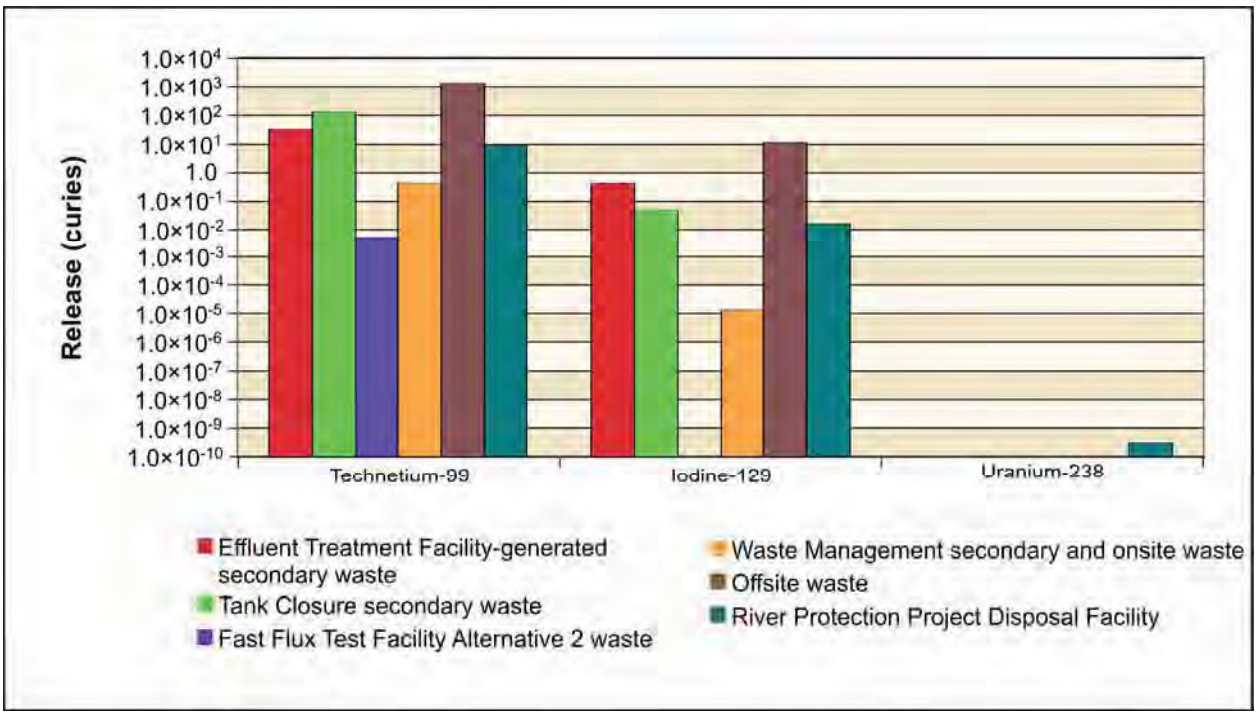


Figure N–99. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Release to Aquifer

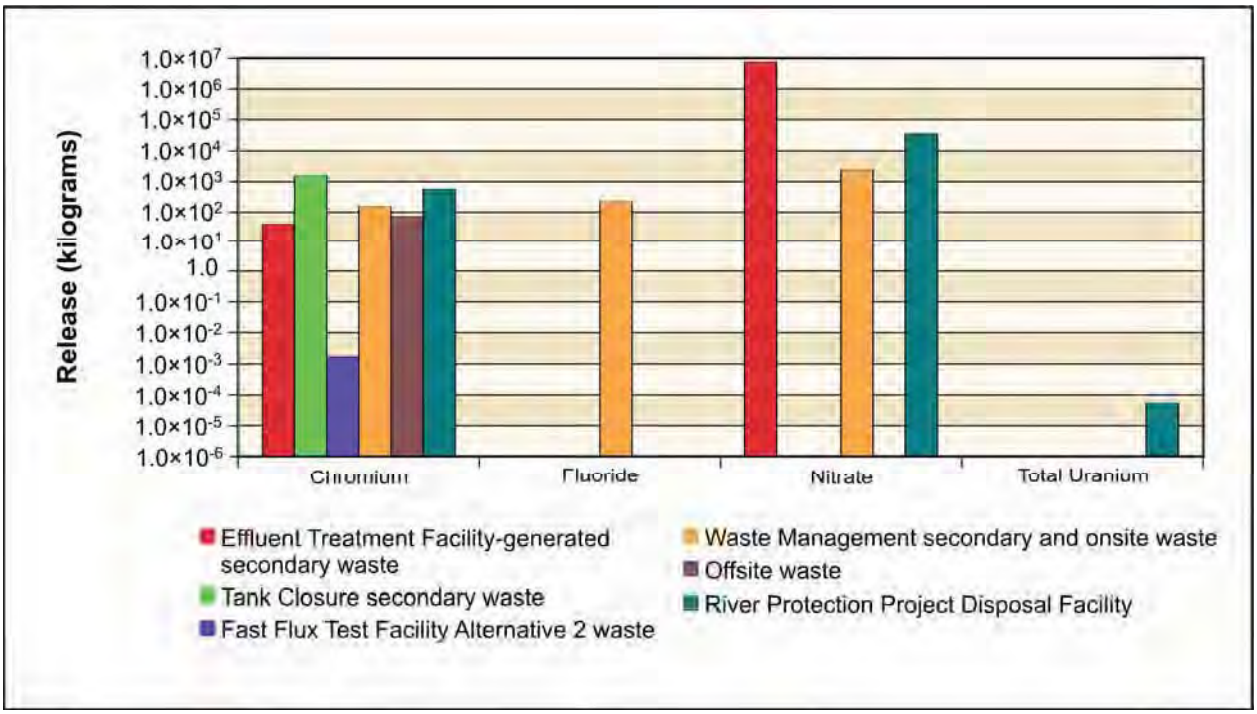


Figure N–100. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Release to Aquifer

N.2.3.2.8 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, are indicated in Figures N–101 and N–102.

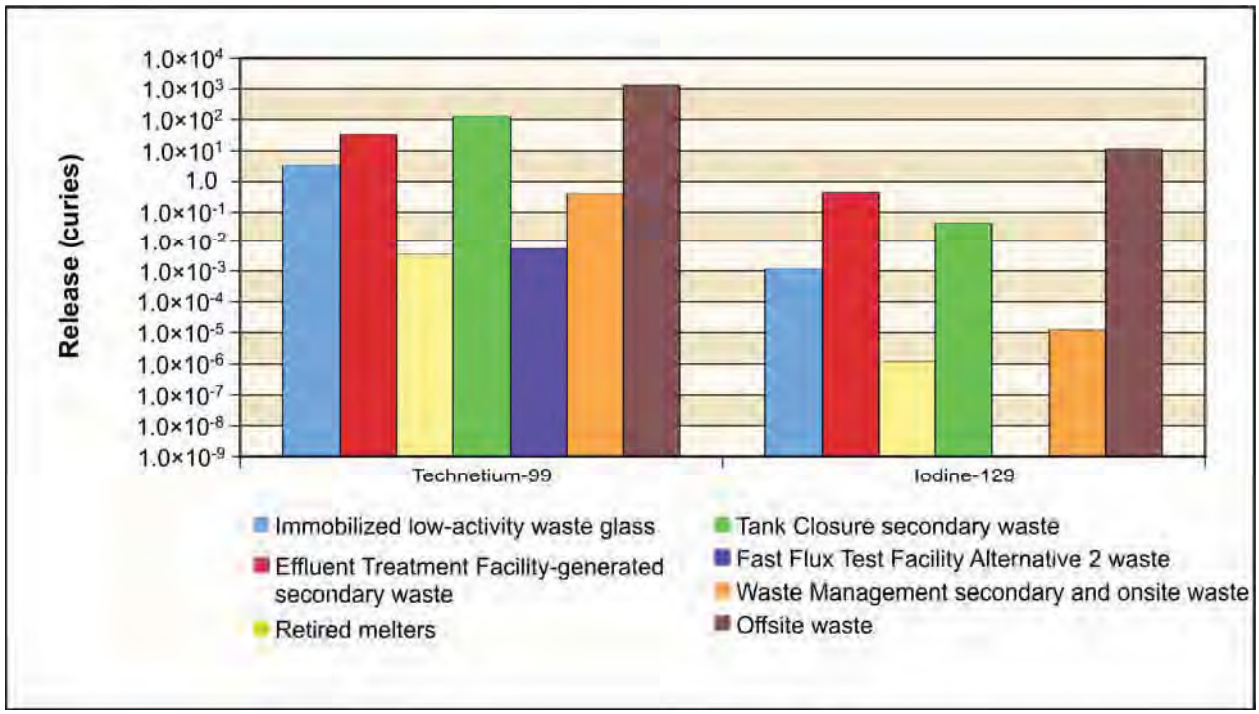


Figure N–101. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Release to Aquifer

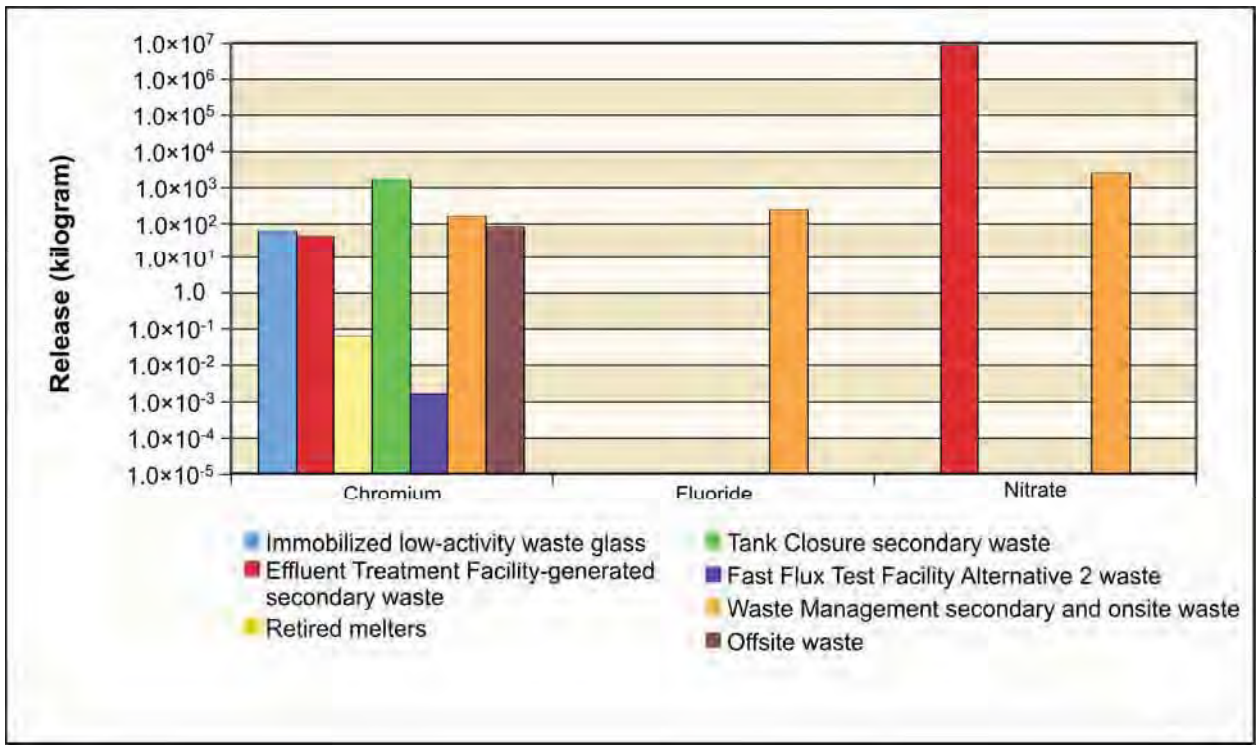


Figure N–102. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Release to Aquifer

N.2.3.2.9 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste from Tank Closure Alternative 6B (Base and Option Cases), onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Preprocessing Facility (PPF) glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures N–103 through N–106.

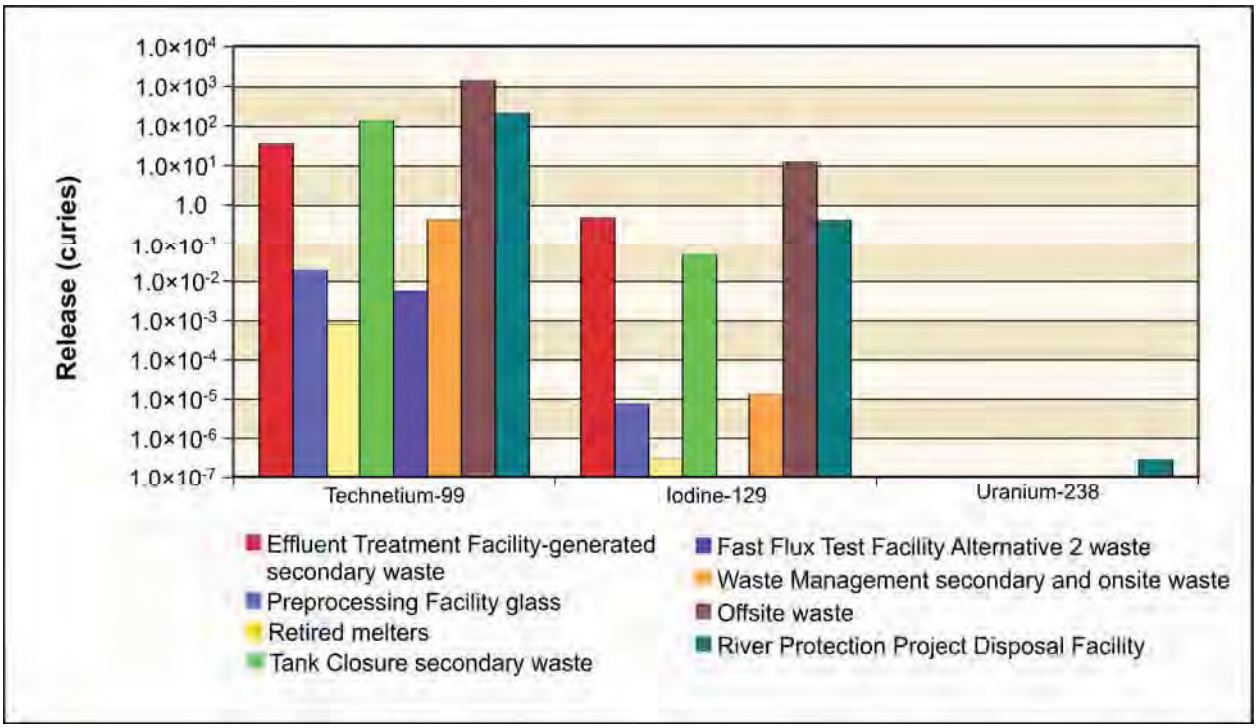


Figure N–103. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Release to Aquifer

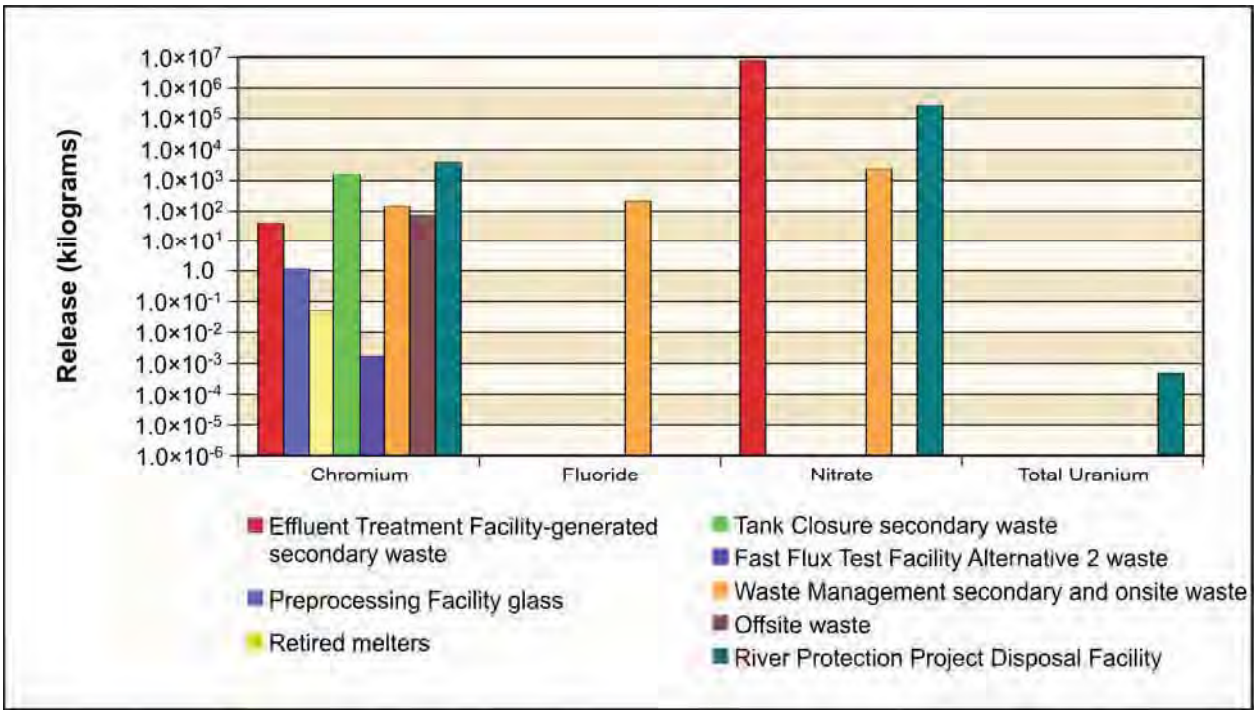


Figure N–104. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Release to Aquifer

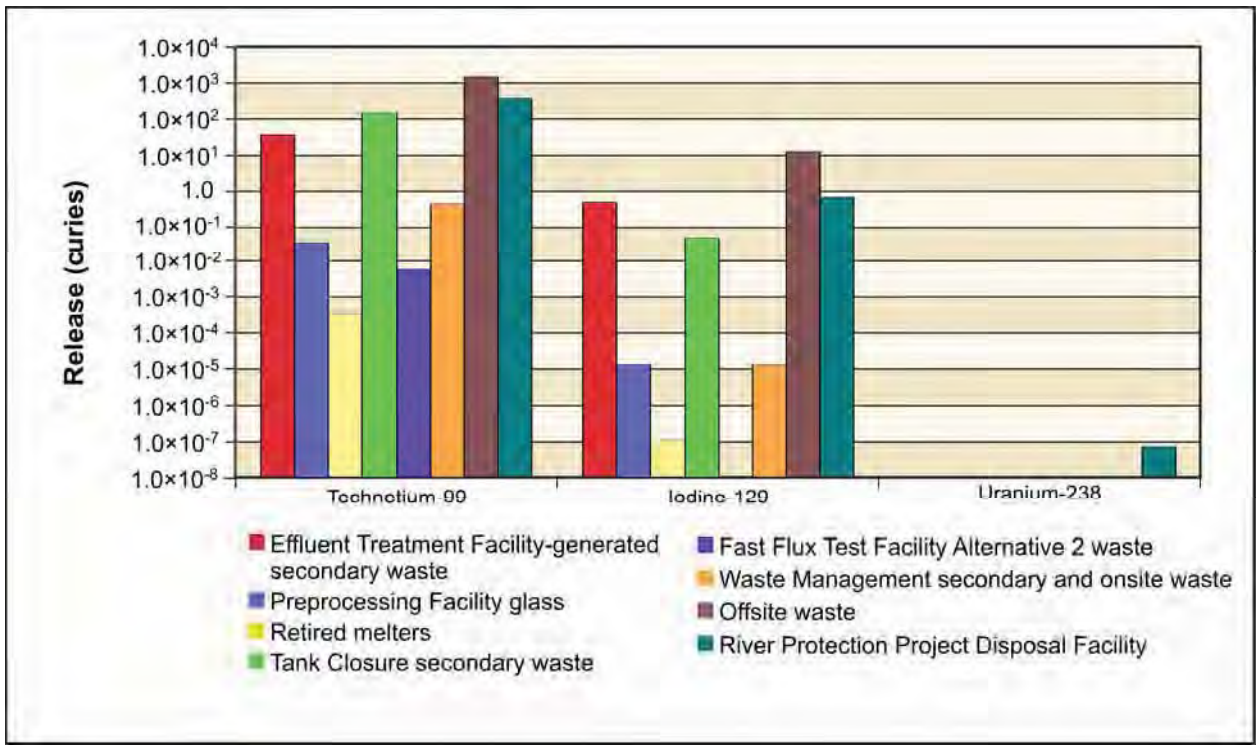


Figure N–105. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Release to Aquifer

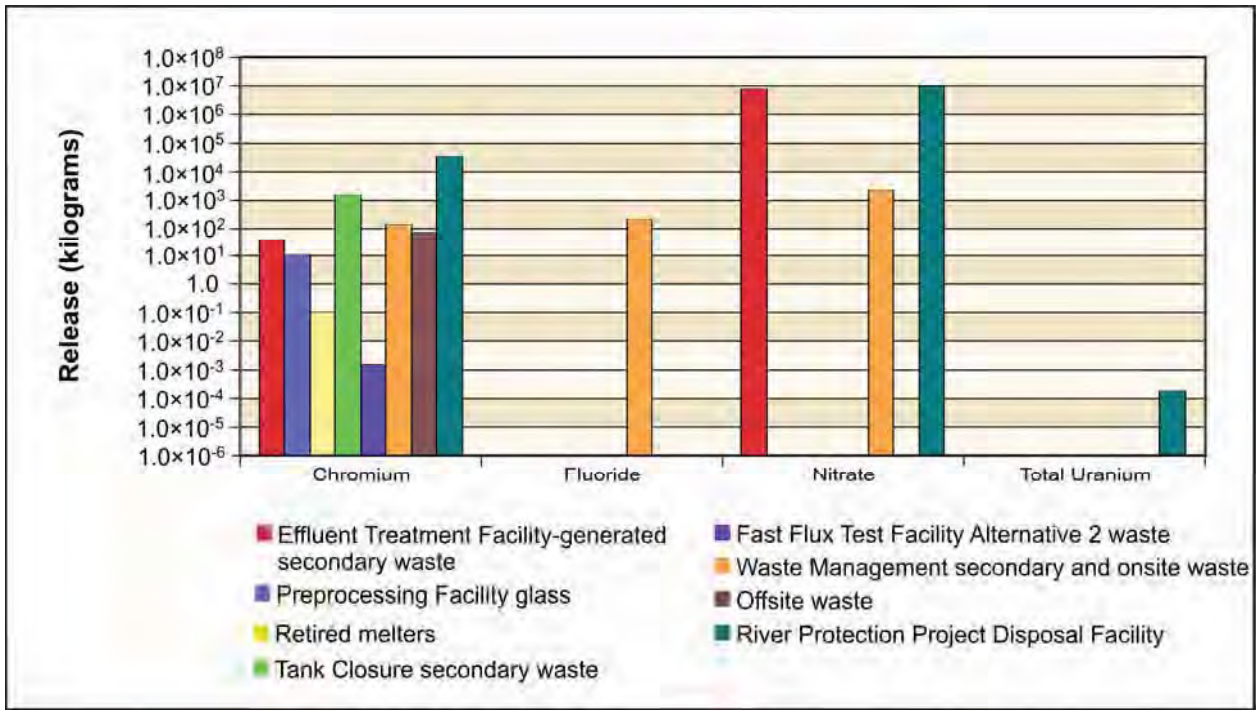


Figure N–106. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Release to Aquifer

N.2.3.2.10 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only, Disposal Group 3

Disposal Group 3 addresses the waste from Tank Closure Alternative 6A (Base and Option Cases), onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the aquifer under Waste Management Alternative 2, Disposal Group 3, Base and Option Cases, are indicated in Figures N–107 through N–110.

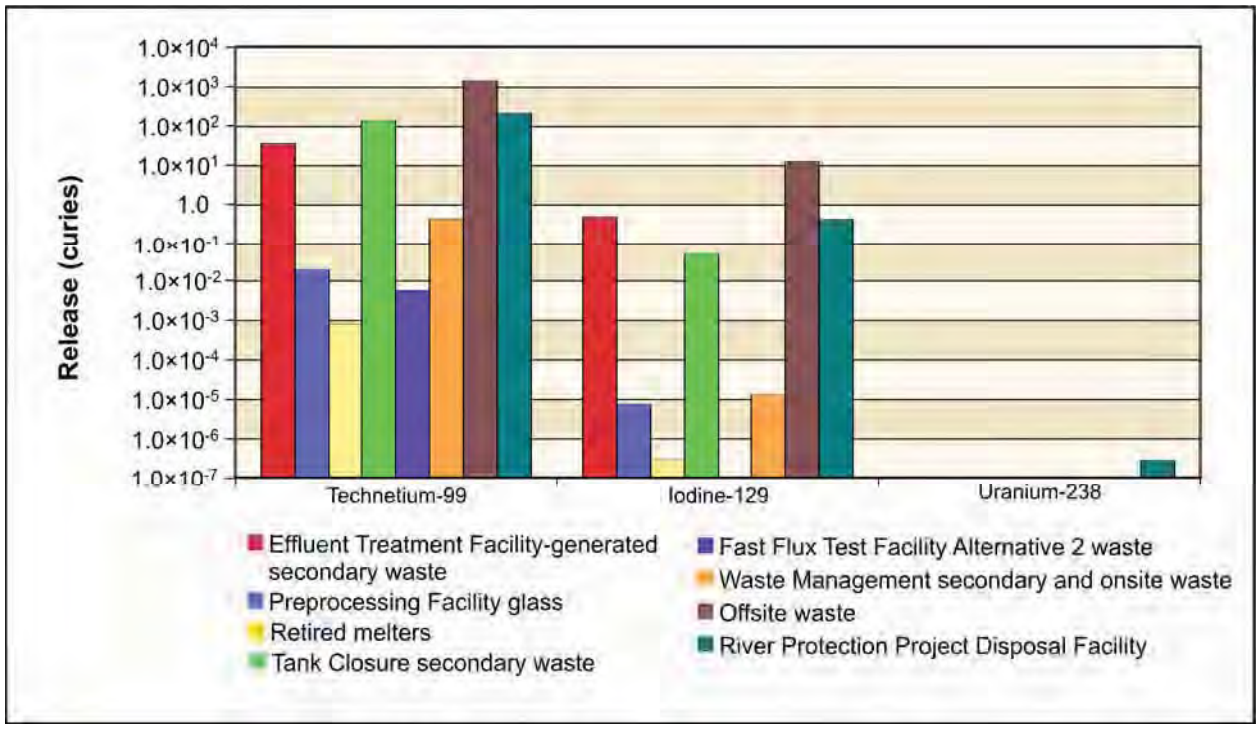


Figure N–107. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Release to Aquifer

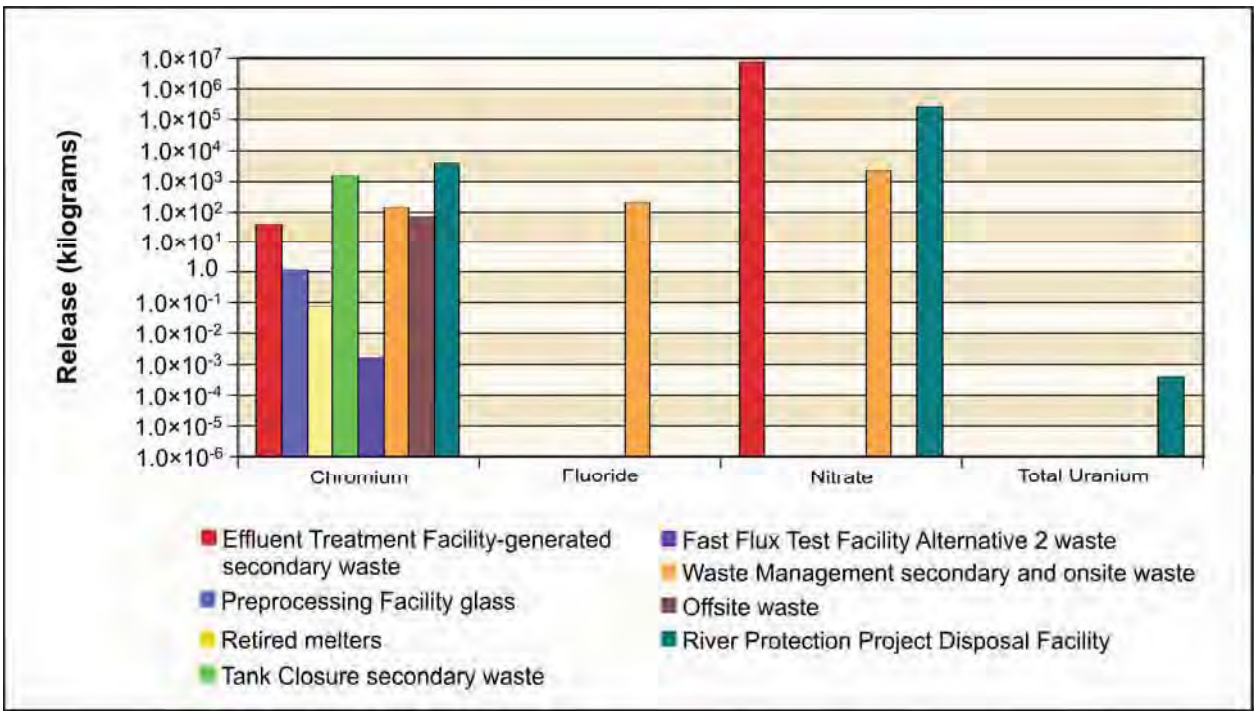


Figure N–108. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Release to Aquifer

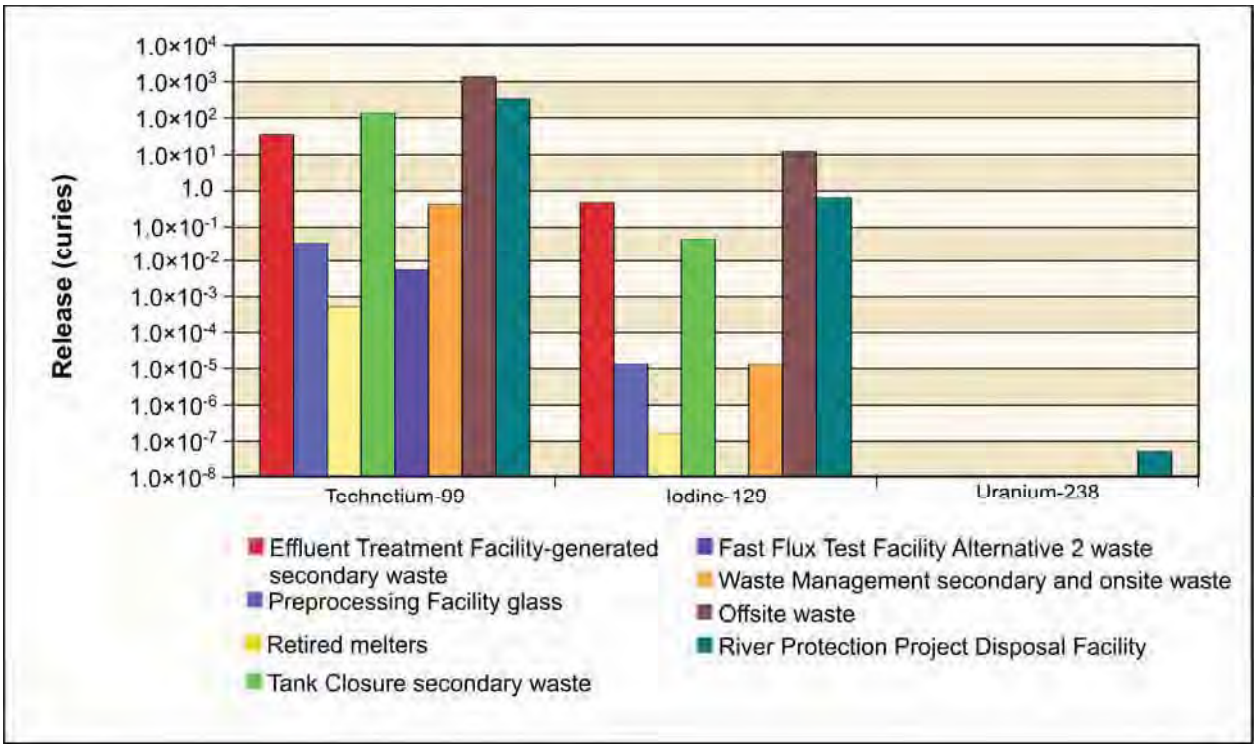


Figure N–109. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Release to Aquifer

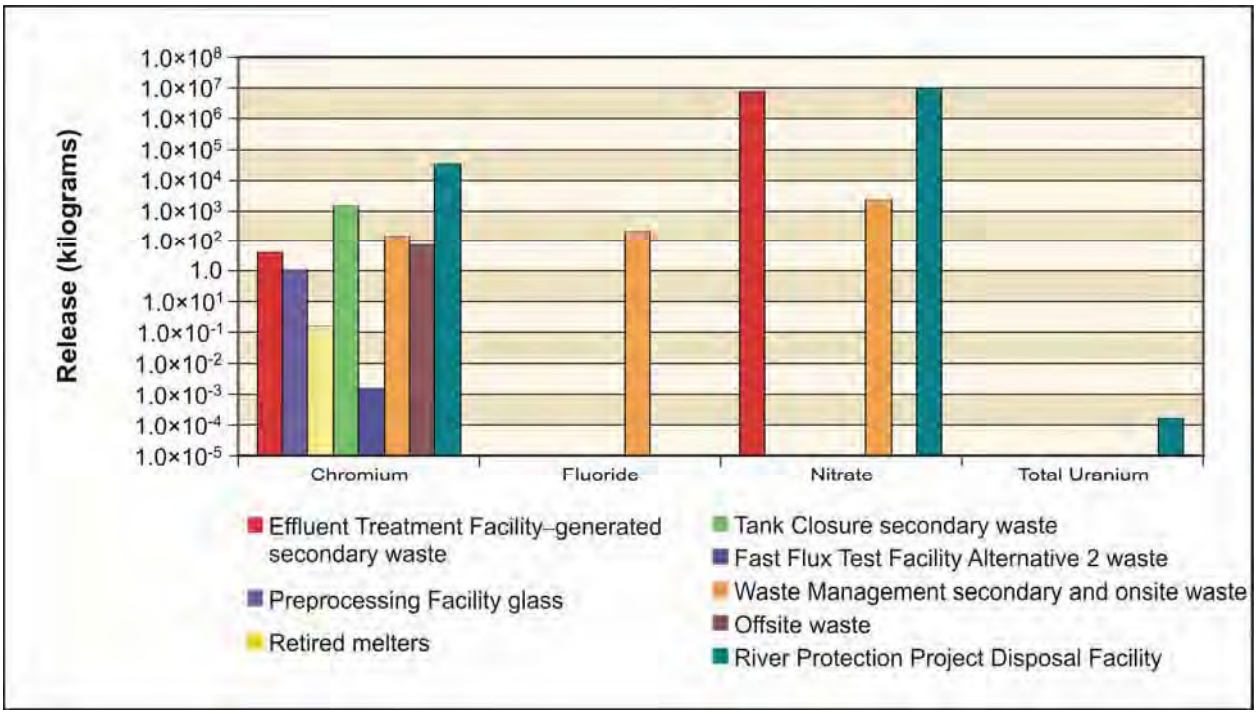


Figure N–110. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Release to Aquifer

N.2.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas

Under Waste Management Alternative 3, the waste from tank treatment operations would be disposed of in IDF-East, and that from onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in the 200-West Area IDF (IDF-West). Waste from tank farm cleanup operations would be disposed of in the RPPDF. As a result, the waste disposed of in these three facilities would become available for release to the environment. Because of the different waste types that result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives.

The amount of waste disposed of at IDF-West under each subgroup is identical. Potential releases to the aquifer from IDF-West under Waste Management Alternative 3 are indicated in Figures N–111 and N–112 and are displayed only once for all disposal groups for Waste Management Alternative 3.

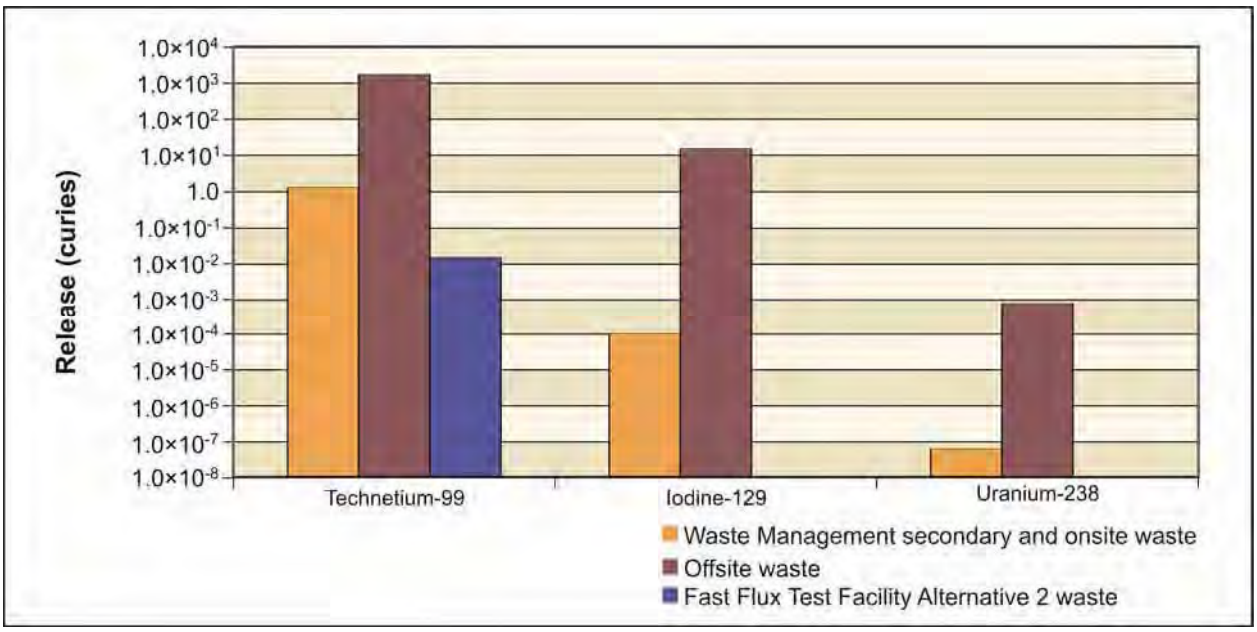


Figure N–111. Waste Management Alternative 3, 200-West Area Integrated Disposal Facility Radiological Release to Aquifer

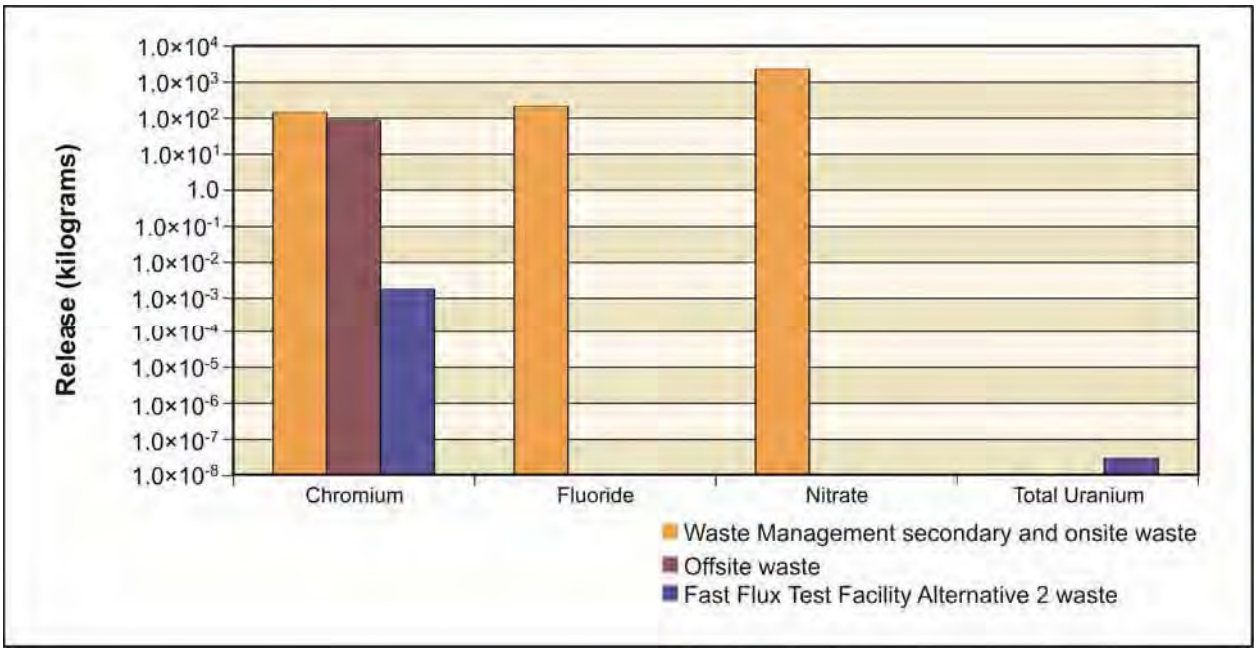


Figure N–112. Waste Management Alternative 3, 200-West Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.1 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 2B. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, are indicated in Figures N–113 and N–114.

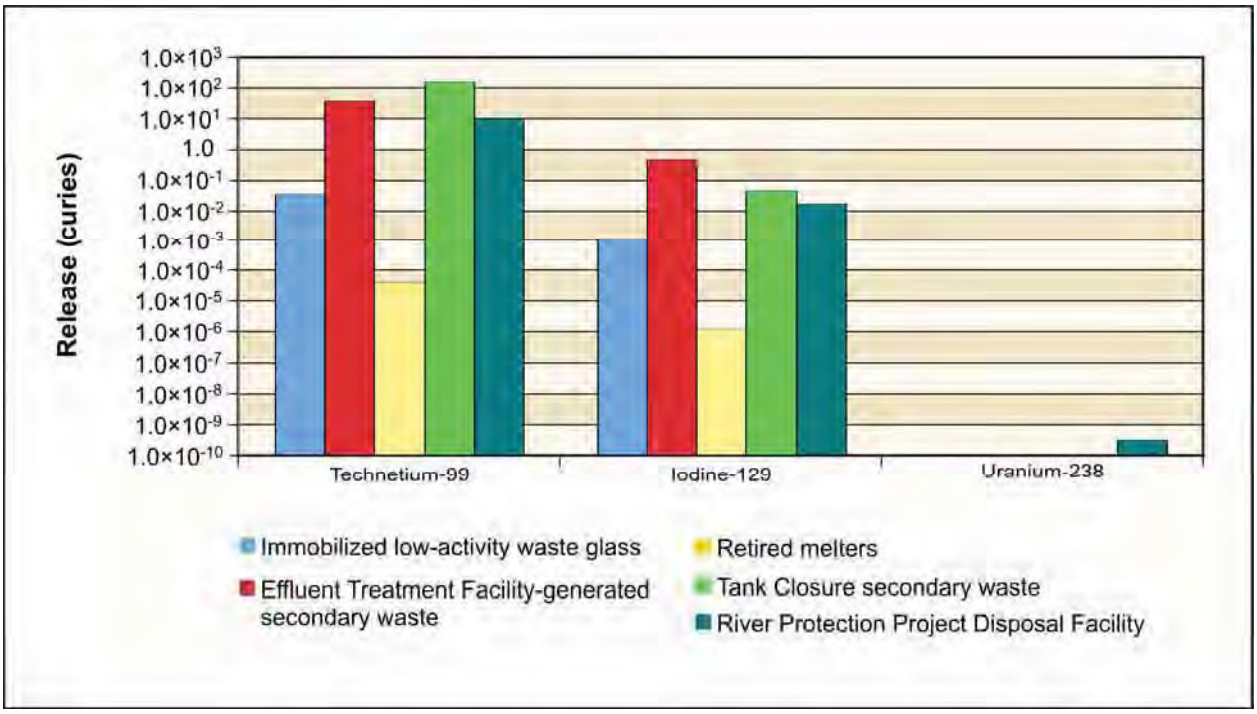


Figure N–113. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

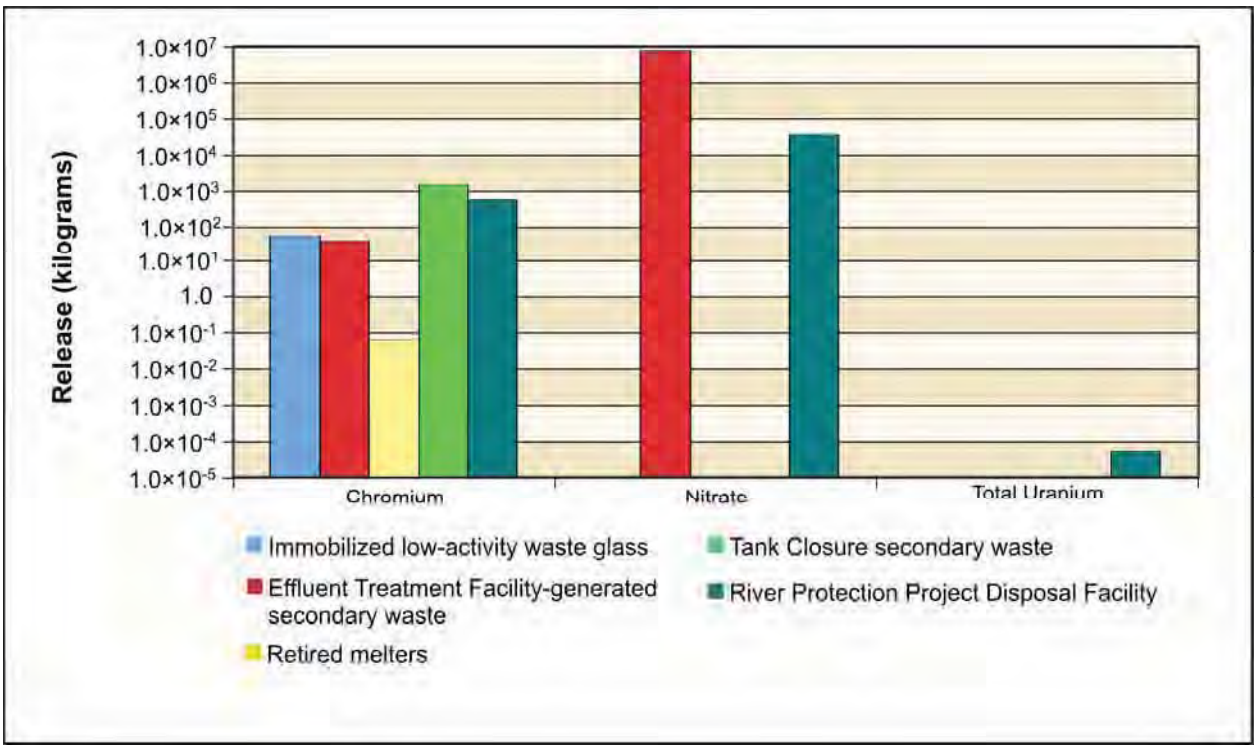


Figure N–114. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A, 200-East Area Integrated Disposal Facility Chemical Release to Vadose Zone

N.2.3.3.2 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3A. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, are indicated in Figures N–115 and N–116.

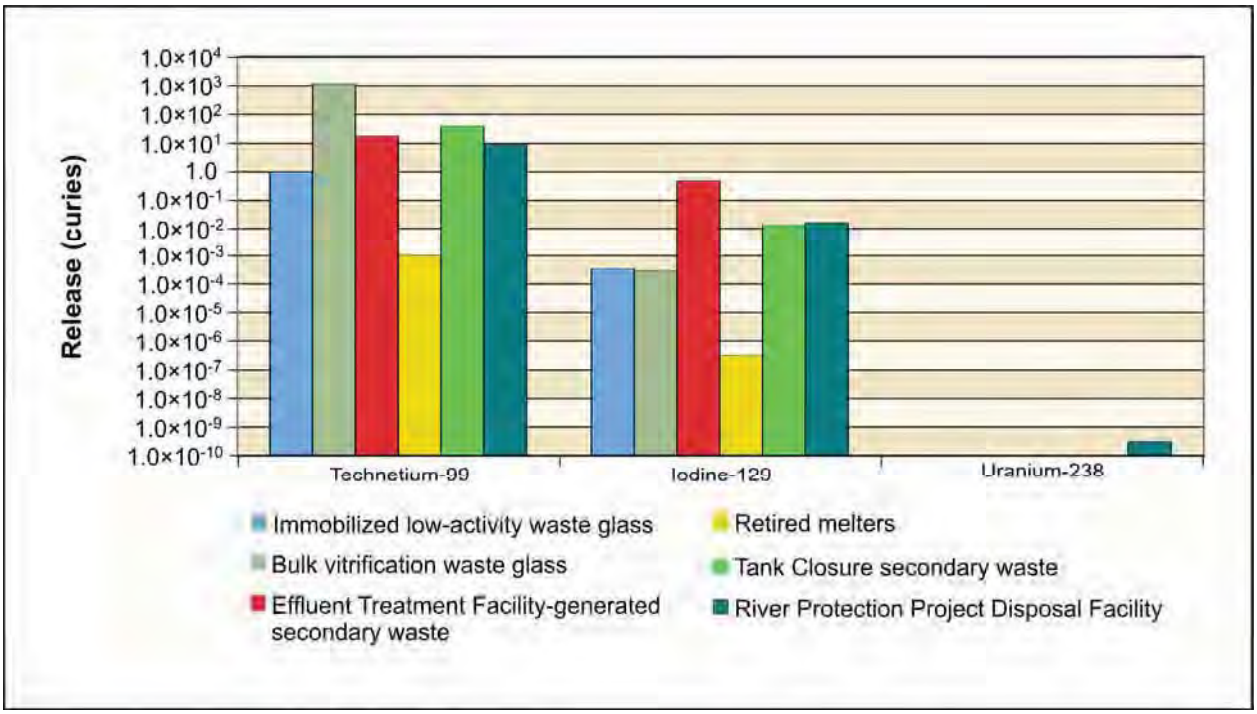


Figure N–115. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

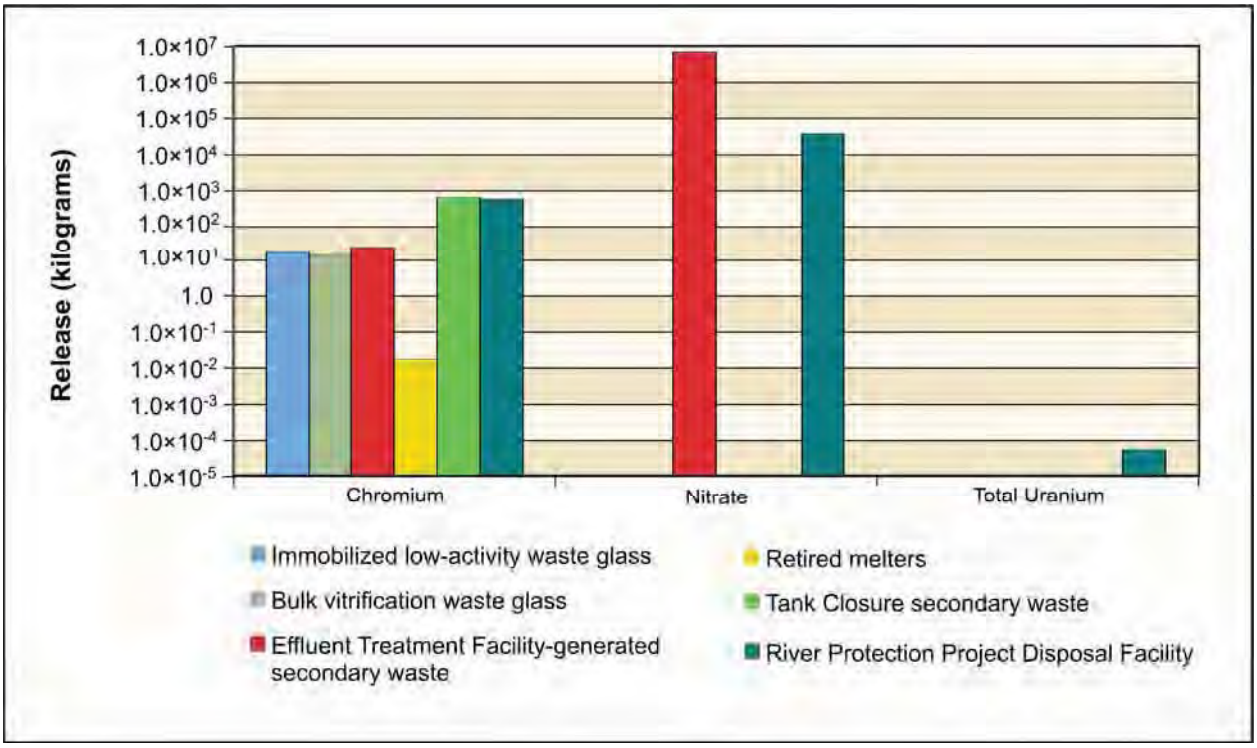


Figure N–116. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Cast stone
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3B. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, are indicated in Figures N–117 and N–118.

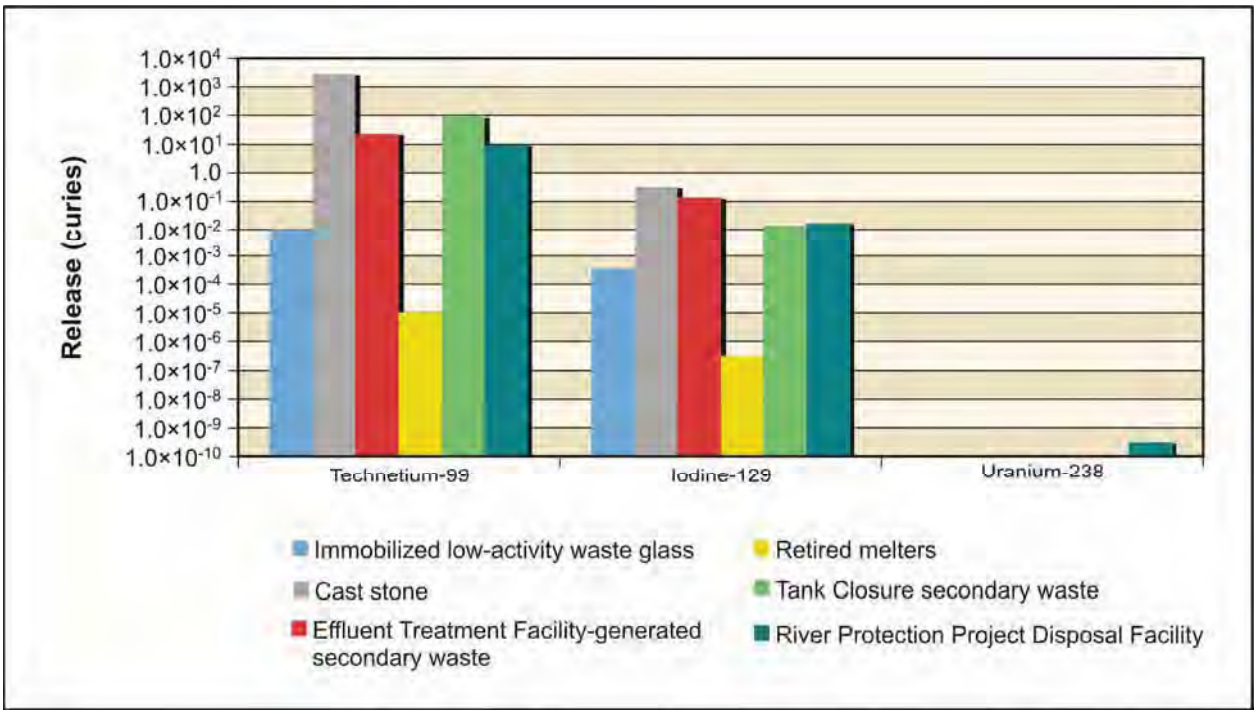


Figure N–117. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

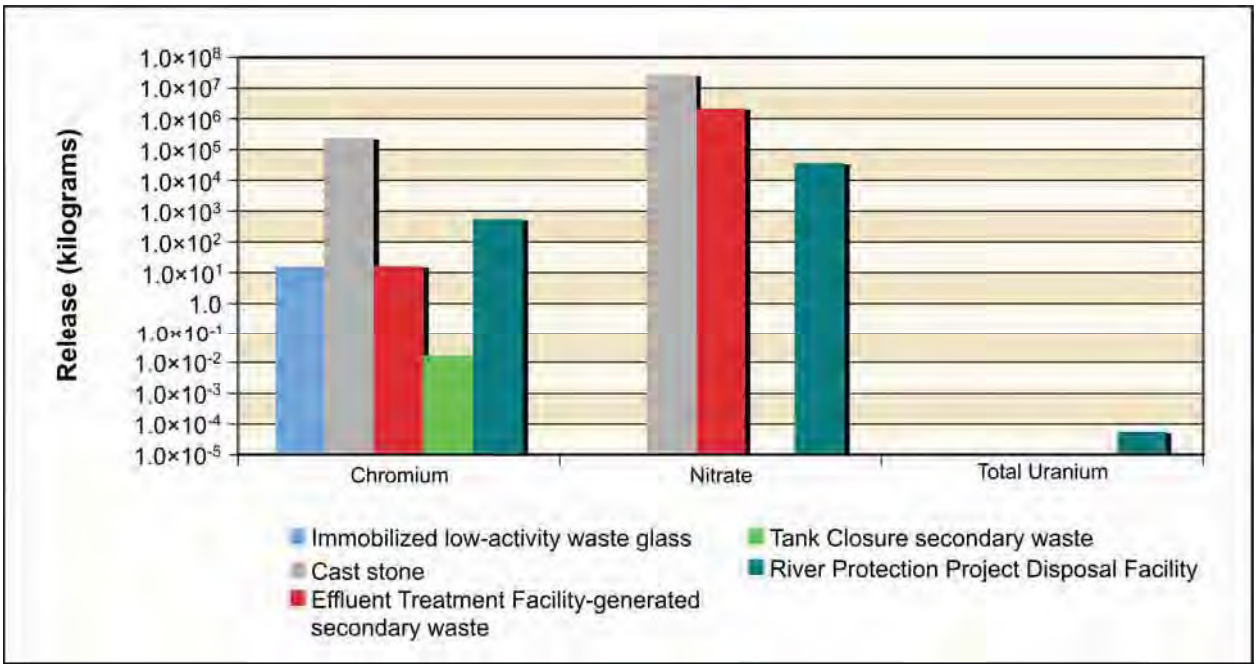


Figure N–118. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.4 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Steam reforming waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 3C. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, are indicated in Figures N–119 and N–120.

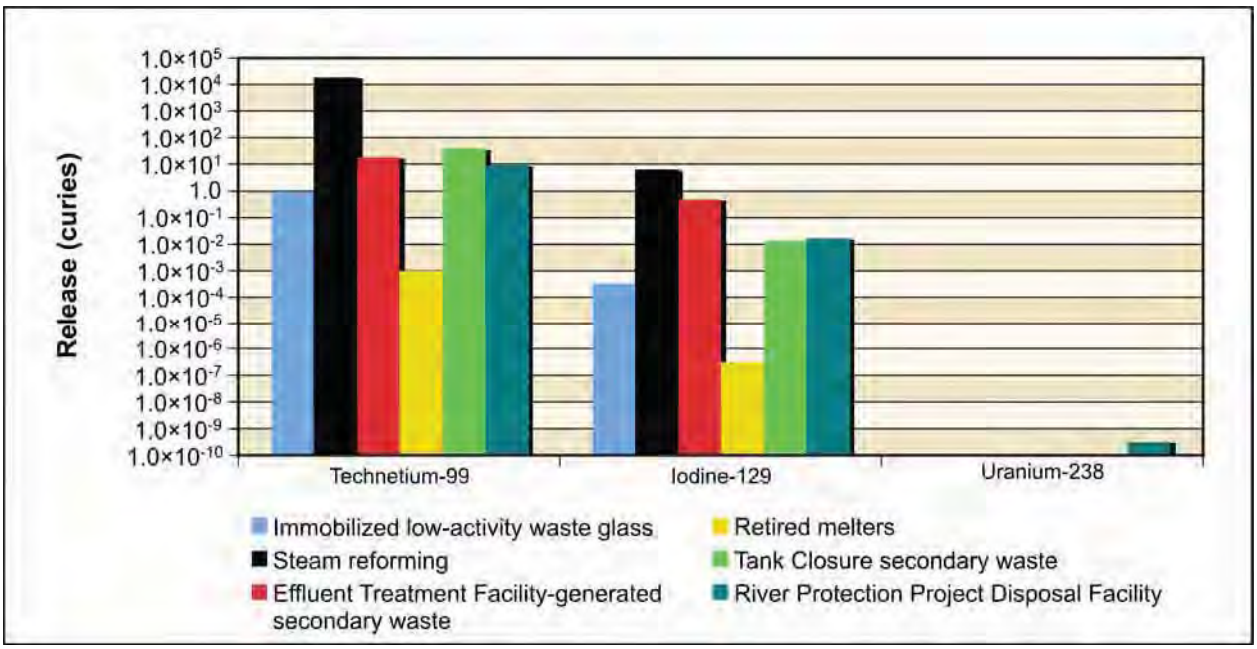


Figure N–119. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

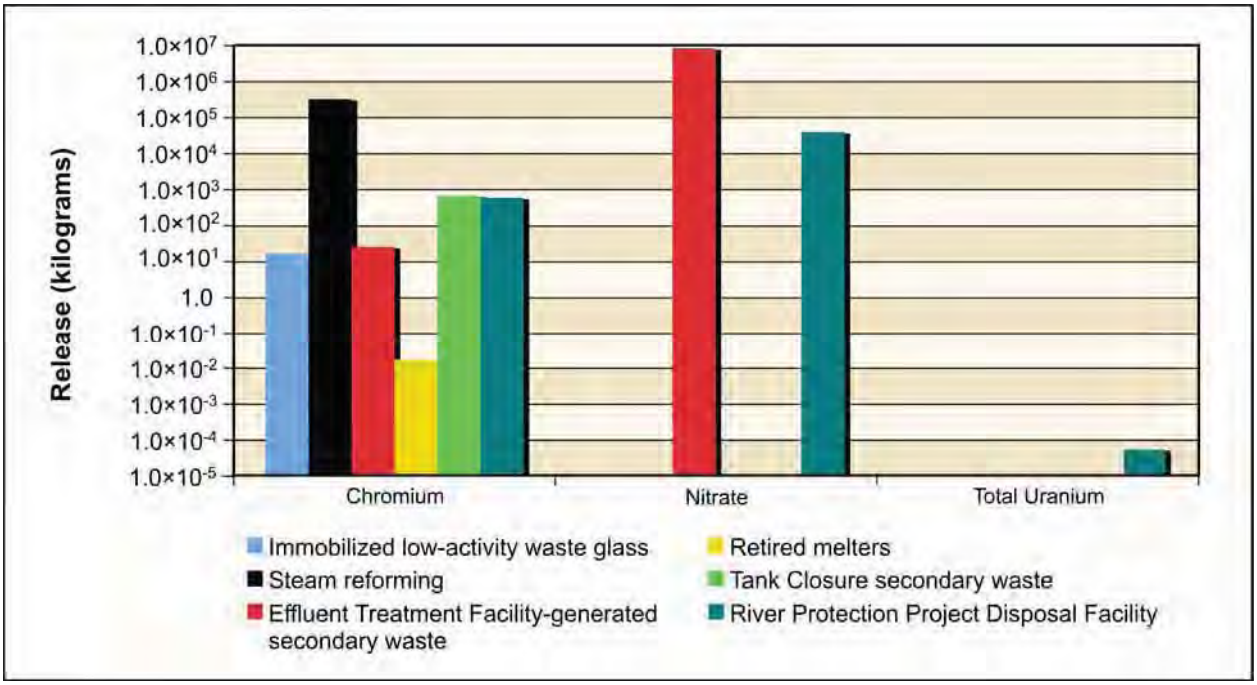


Figure N–120. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.5 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Effluent Treatment Facility (ETF) secondary solid waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 4 because tank closure cleanup activities would not be conducted. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, are indicated in Figures N–121 and N–122.

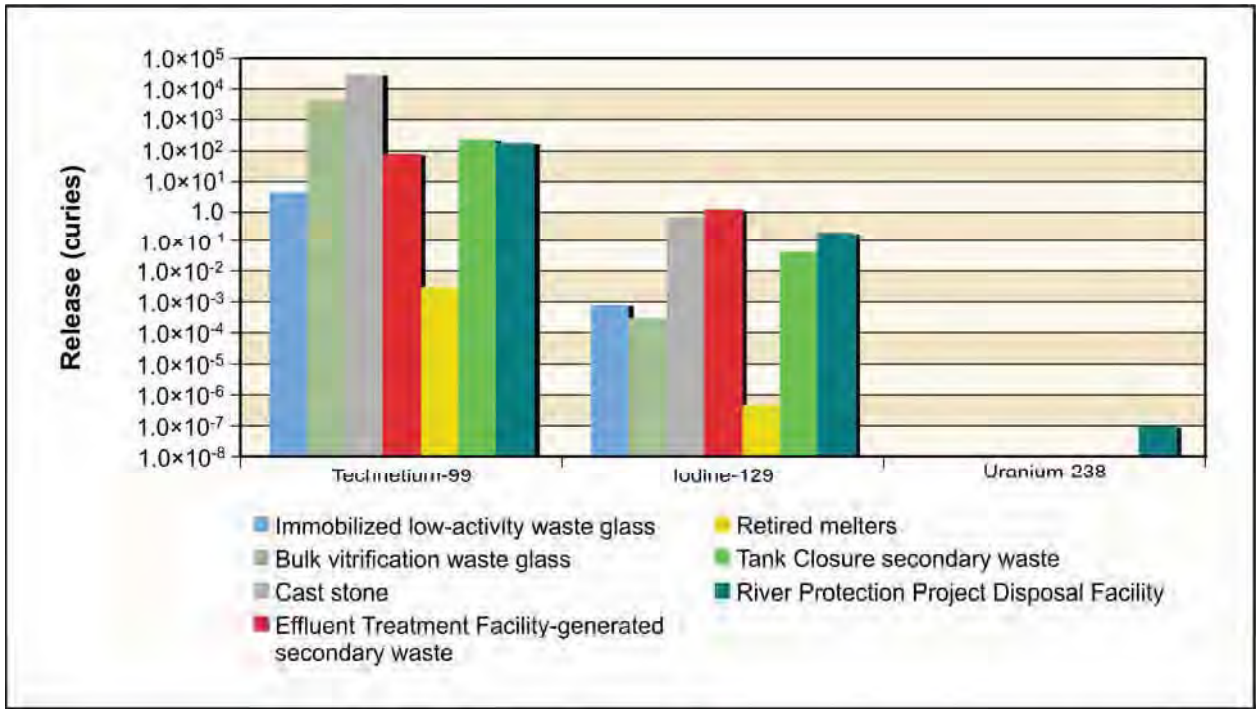


Figure N–121. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

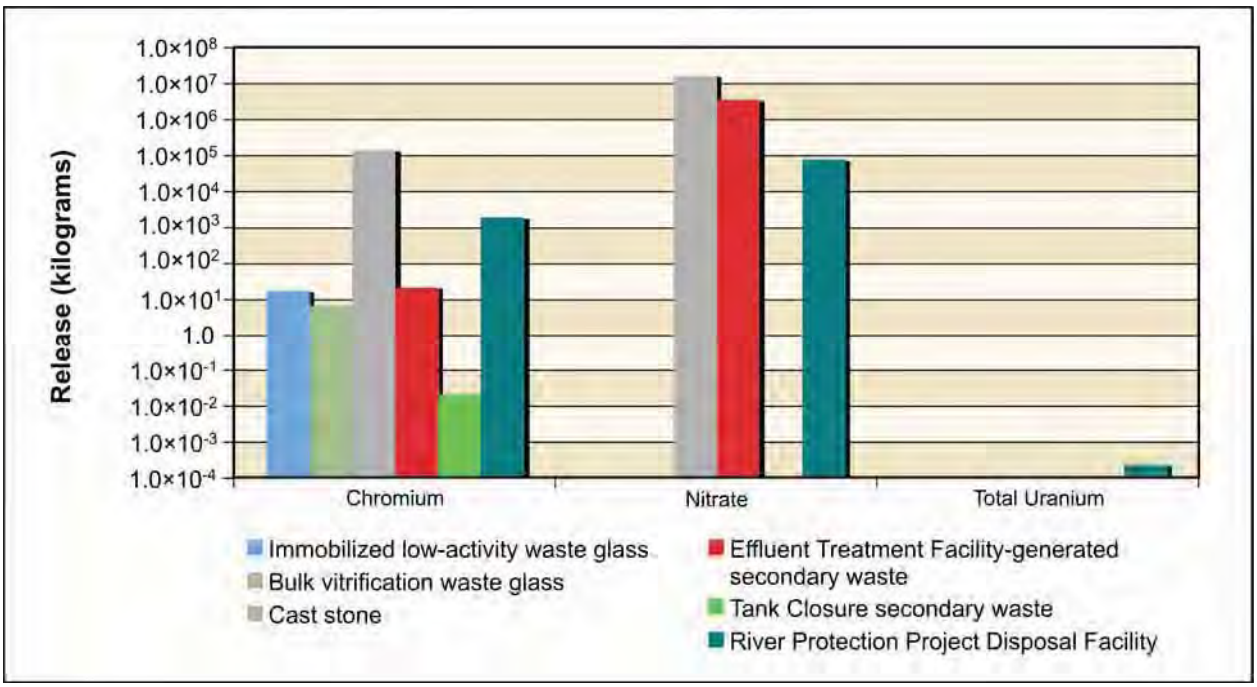


Figure N–122. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.6 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 5. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, are indicated in Figures N–123 and N–124.

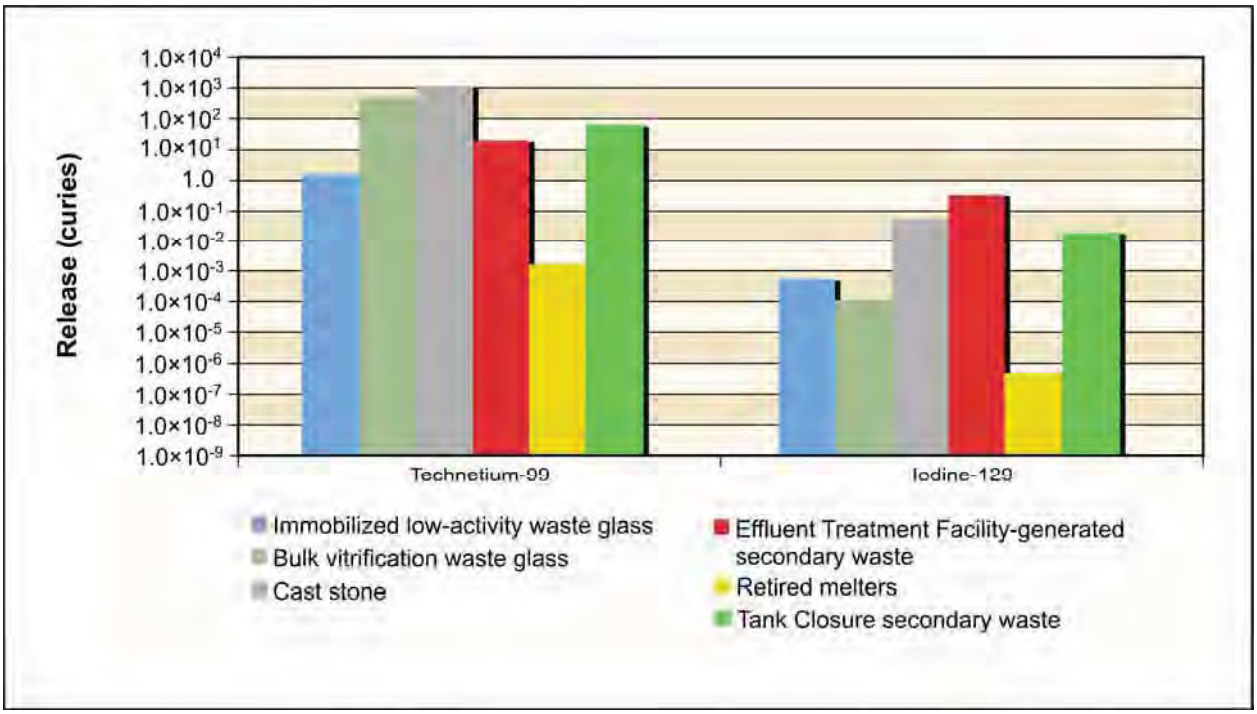


Figure N–123. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

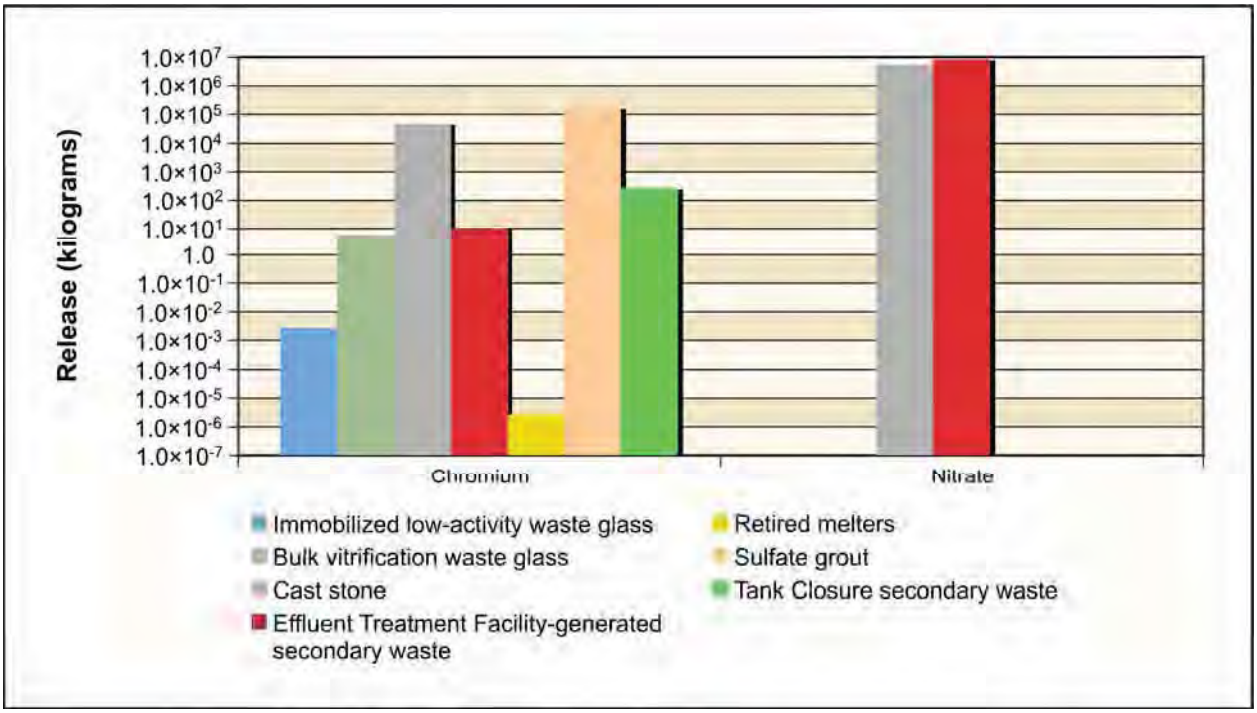


Figure N–124. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.7 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6C. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, are indicated in Figures N–125 and N–126.

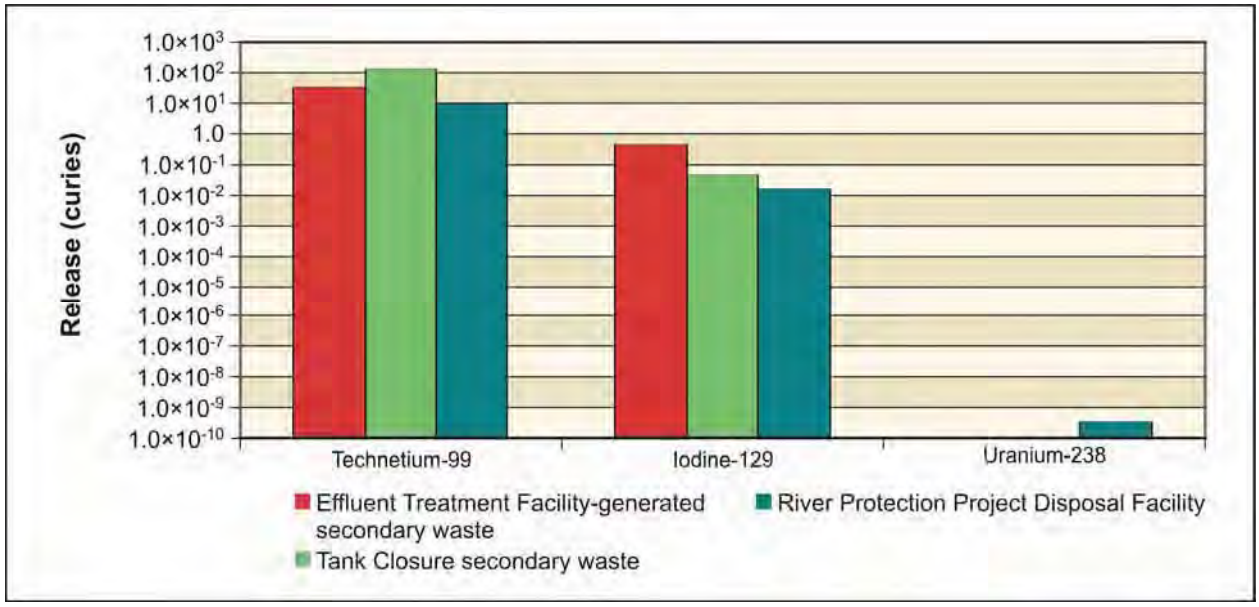


Figure N–125. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

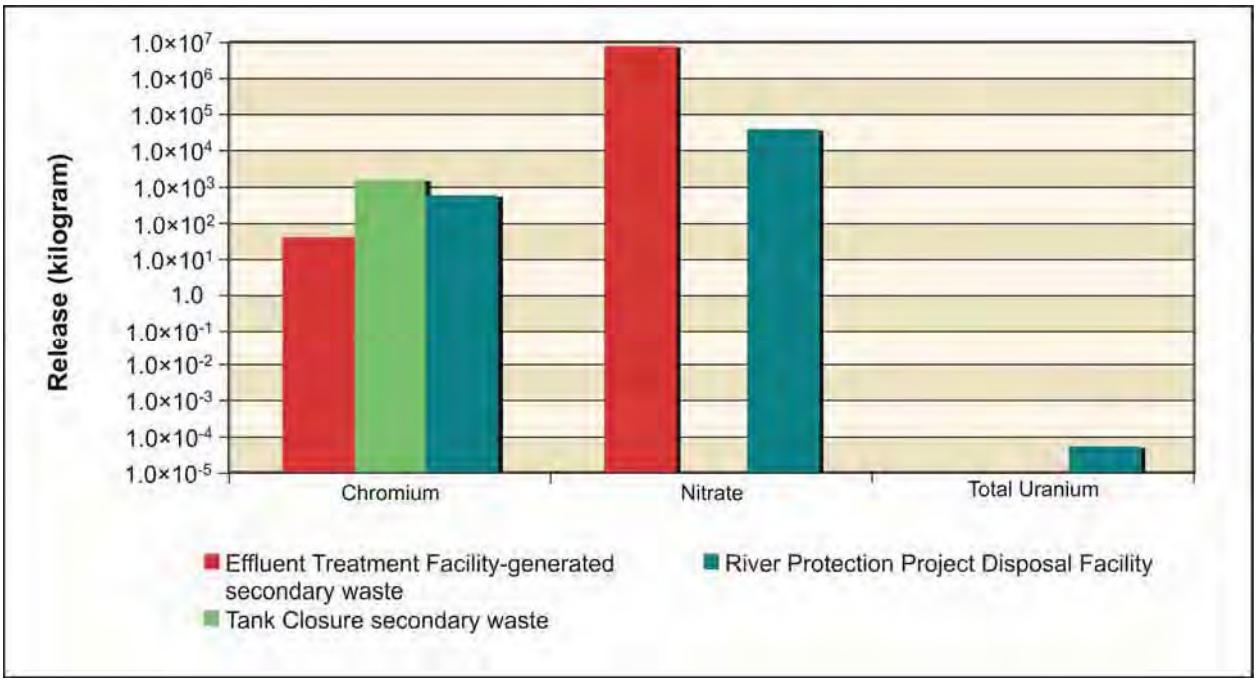


Figure N–126. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.8 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- LAW melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated for Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, are indicated in Figures N–127 and N–128.

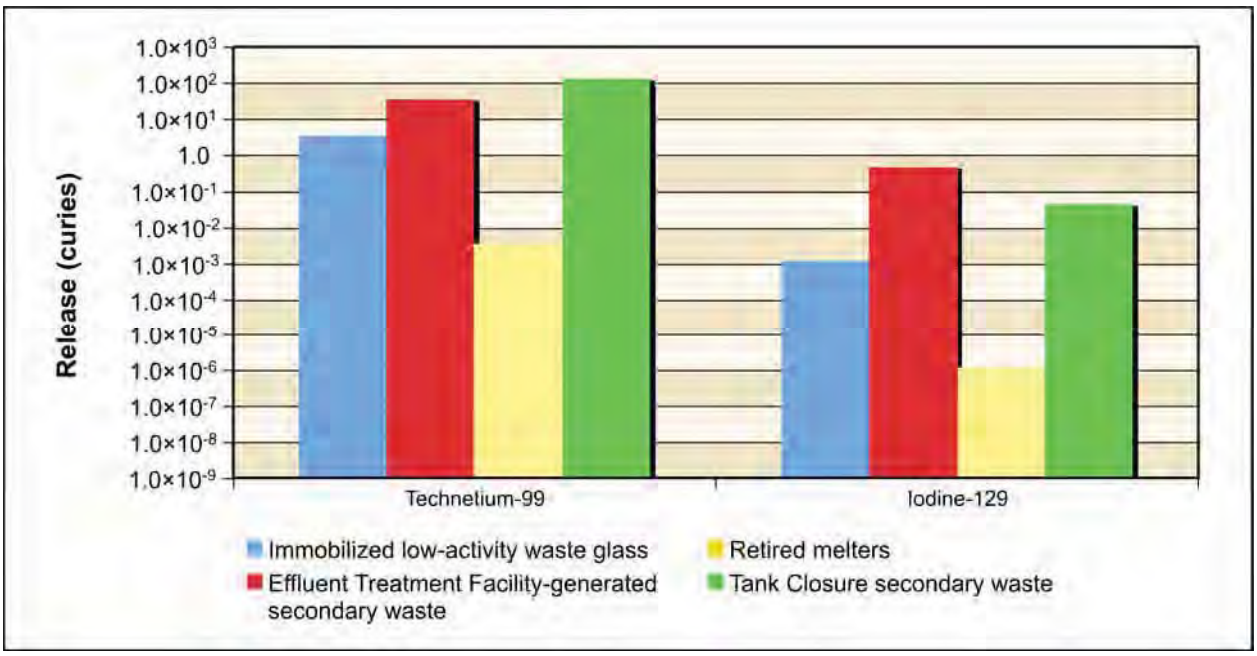


Figure N–127. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

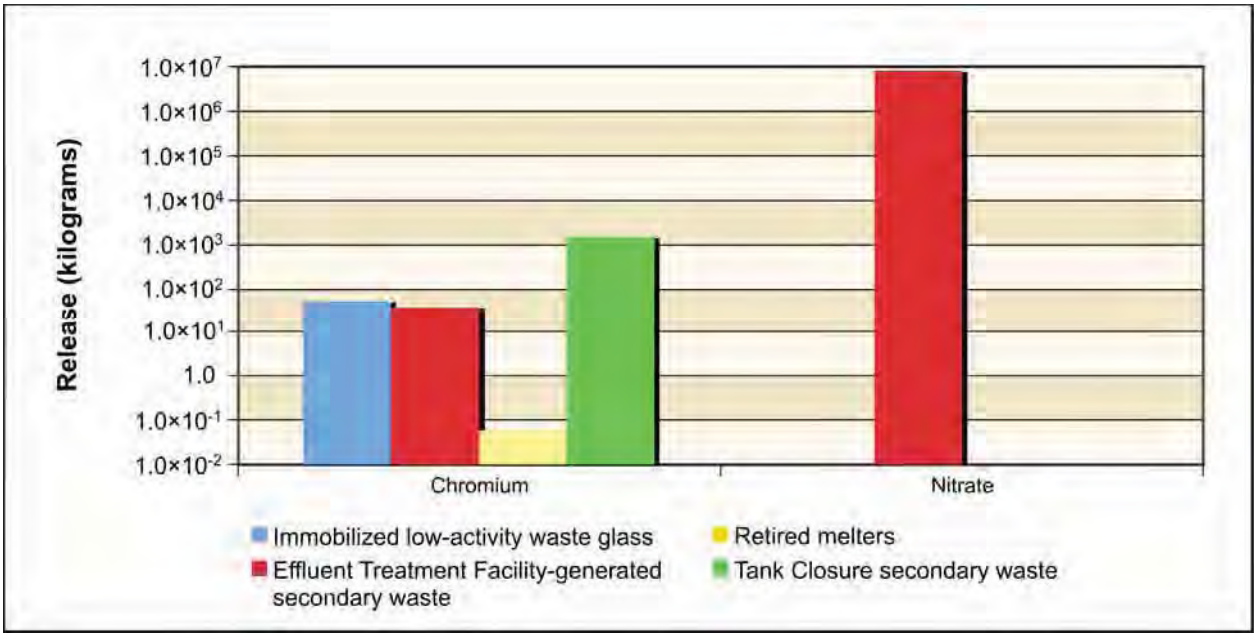


Figure N–128. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.9 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 2, Subgroup 2-B

Disposal Group 2, Subgroup 2-B, addresses the waste from Tank Closure Alternative 6B (Base and Option), onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6B, Base and Option Cases. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base and Option Cases, are indicated in Figures N–129 through N–132.

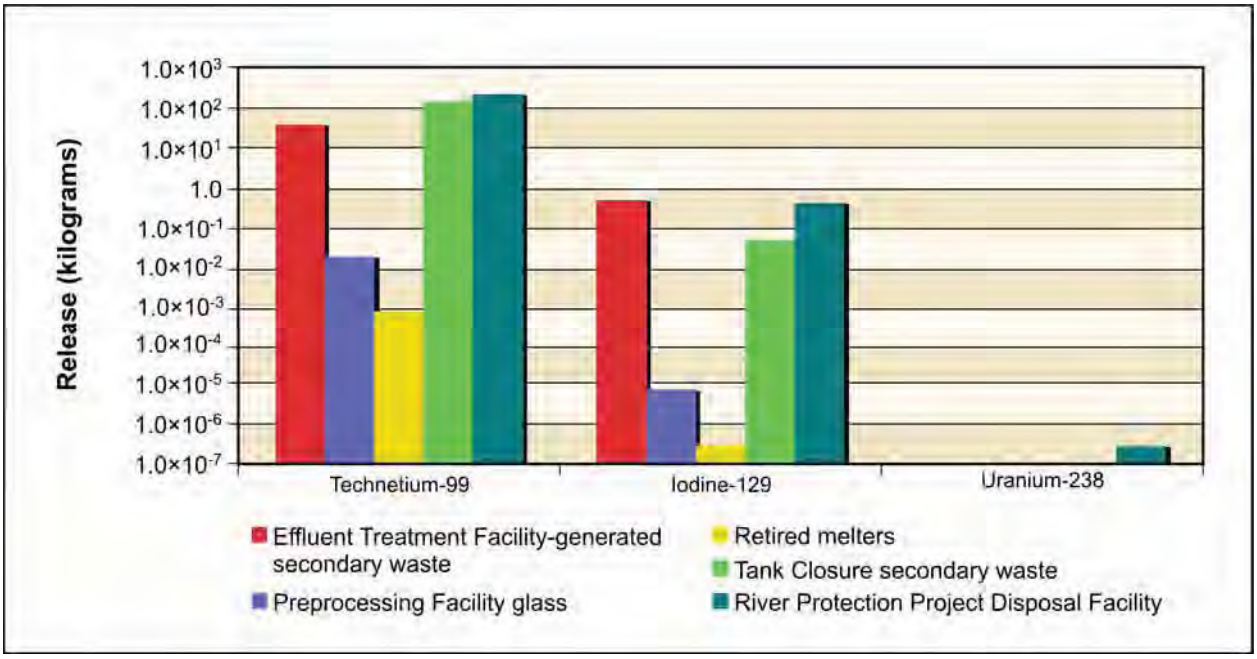


Figure N–129. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

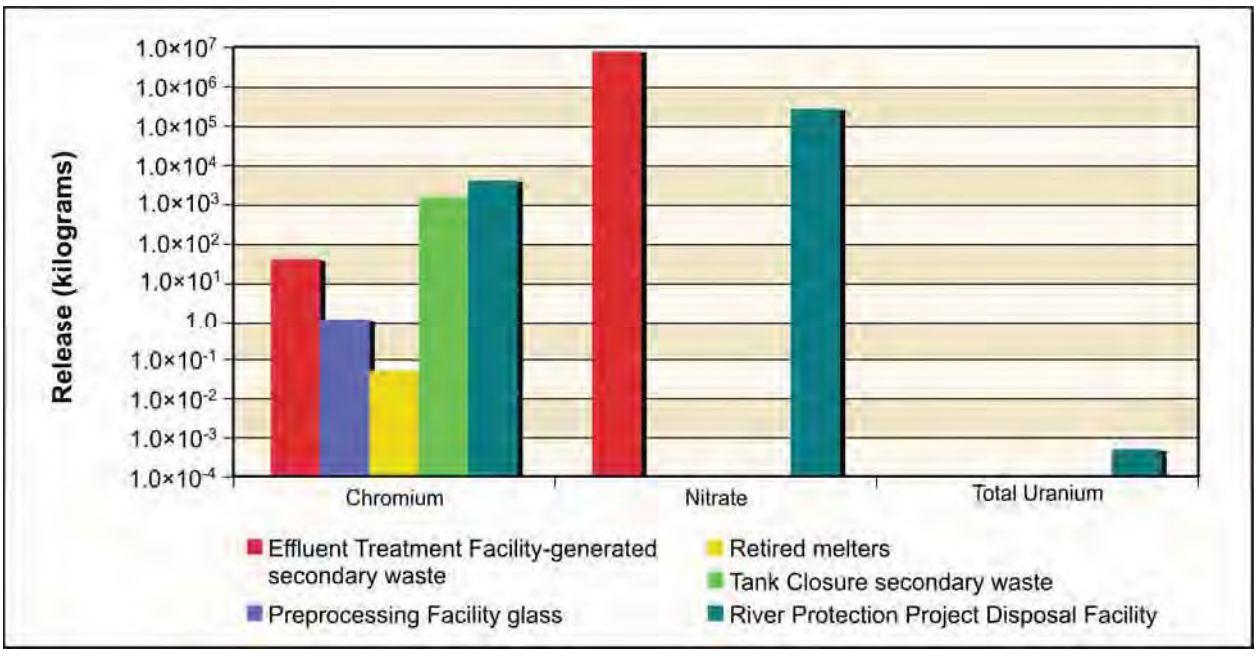


Figure N–130. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

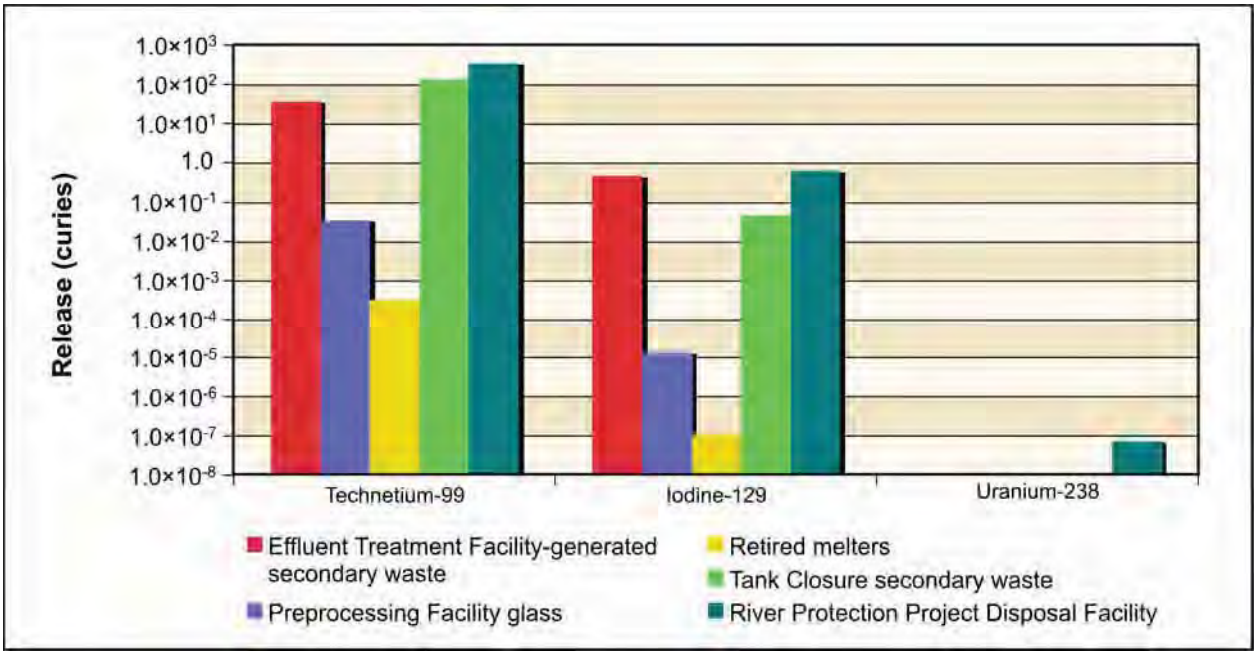


Figure N–131. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

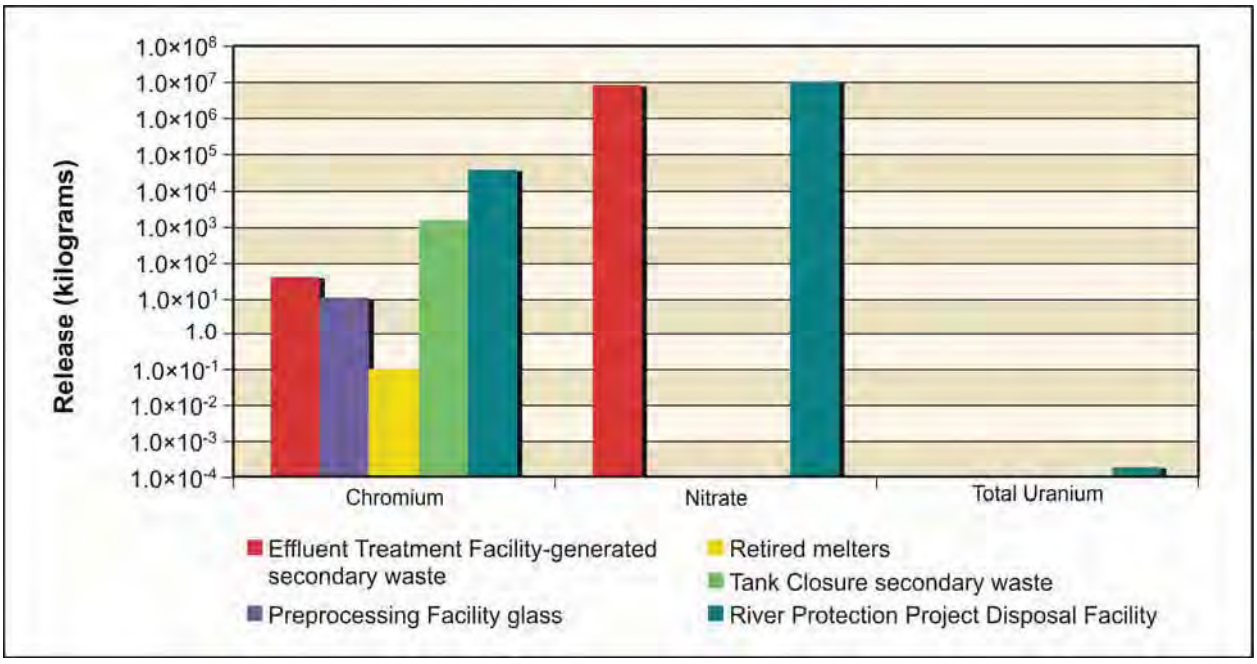


Figure N–132. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.2.3.3.10 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas, Disposal Group 3

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A (Base and Option), onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

The waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities for Tank Closure Alternative 6A, Base and Option Cases. Potential releases to the aquifer under Waste Management Alternative 3, Disposal Group 3, Base and Option Cases, are indicated in Figures N–133 through N–136.

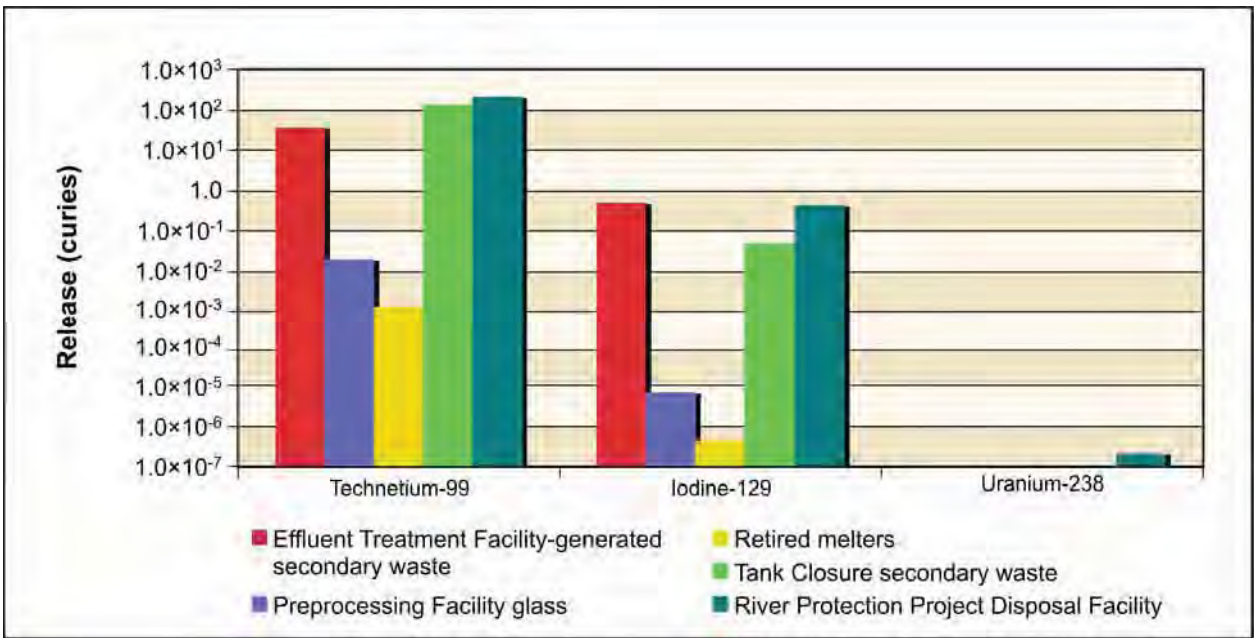


Figure N–133. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

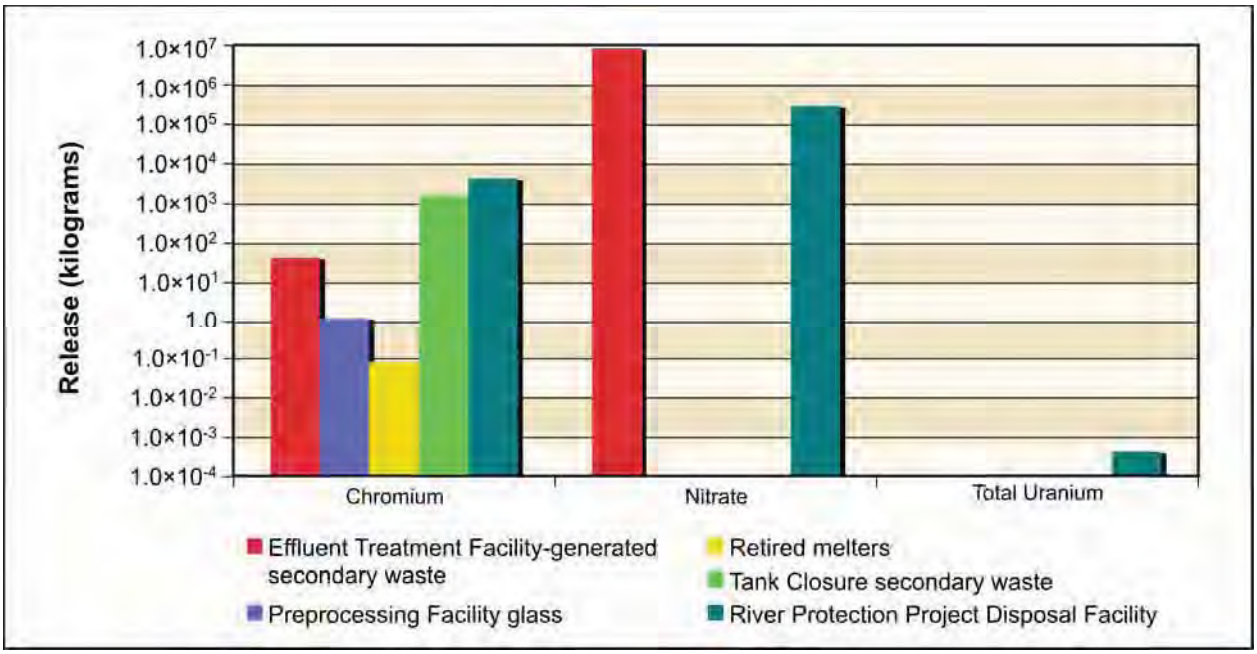


Figure N–134. Waste Management Alternative 3, Disposal Group 3, Base Case, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

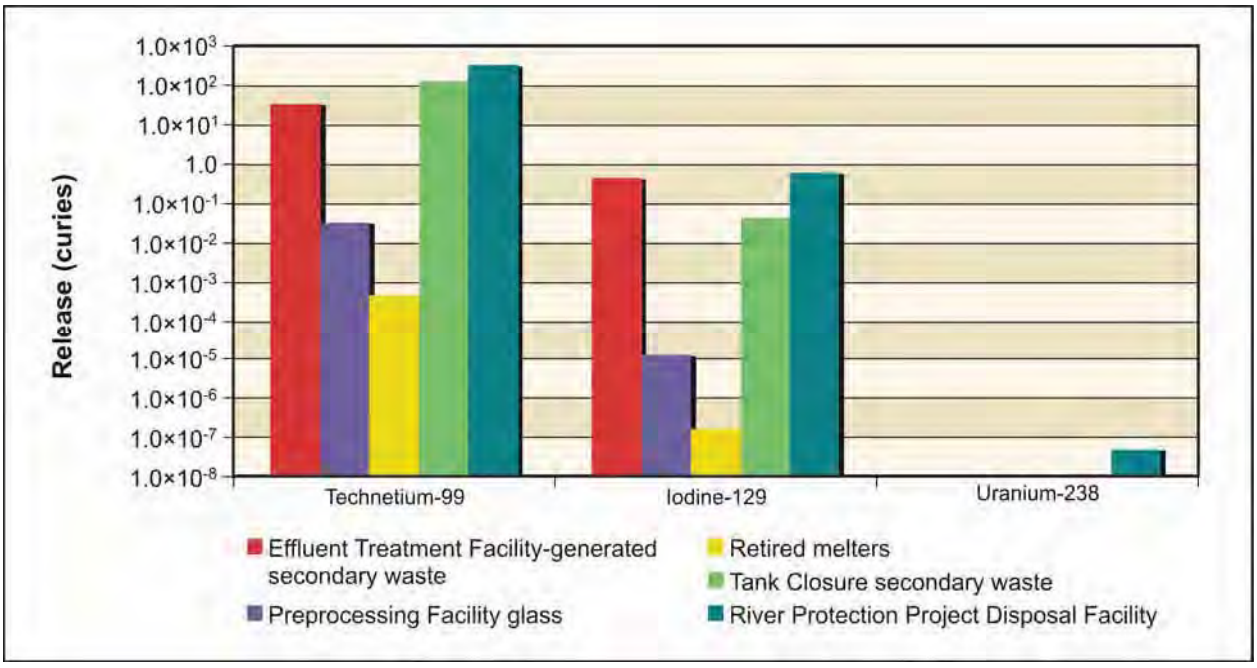


Figure N–135. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Radiological Release to Aquifer

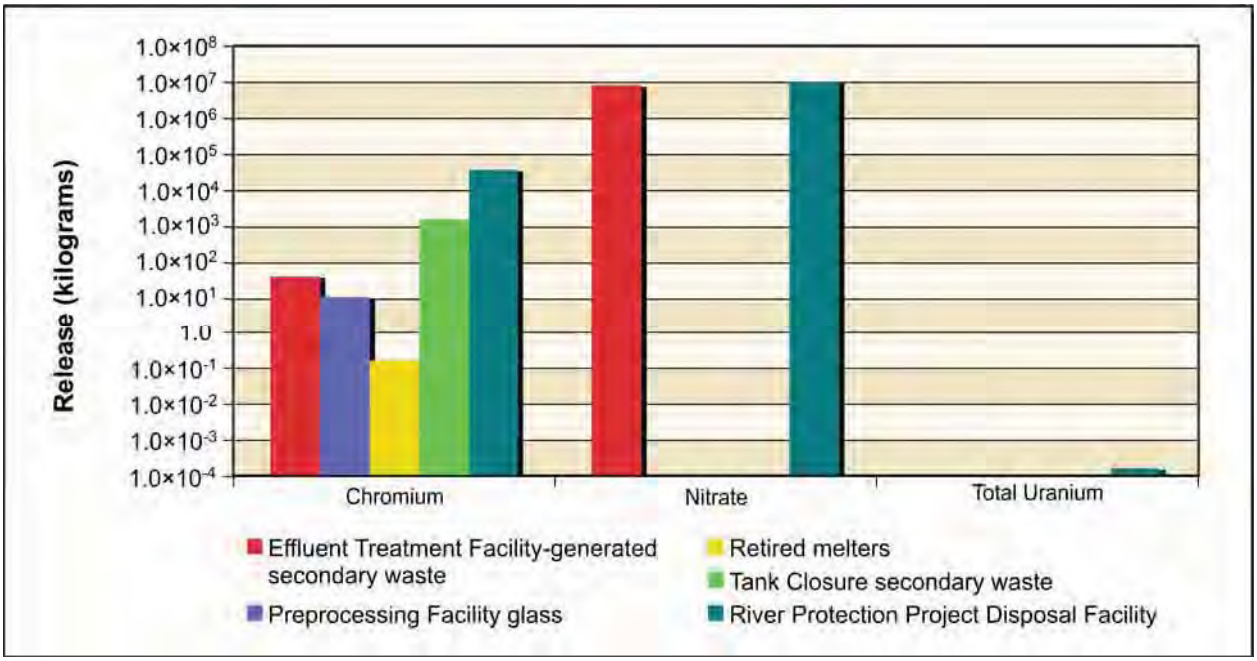


Figure N–136. Waste Management Alternative 3, Disposal Group 3, Option Case, 200-East Area Integrated Disposal Facility Chemical Release to Aquifer

N.3 SENSITIVITY ANALYSIS

The rate of movement of water and solute through the vadose zone varies in space and time, reflecting the influence of infiltration at the ground surface, source conditions, and the geology and properties of the sediments constituting the vadose zone. This section discusses the variation of these conditions and presents estimates of the sensitivity of the flux of water and solute at the water table to changes in conditions. Eight cases were assessed for the following:

- The dependence of travel time on rate of recharge
- The dependence of solute flux at the water table on the magnitude of aqueous discharge at the source
- The dependence of solute flux at the water table on the thickness of silt layers
- The role of the tilting of layers in directing flow
- The role of dikes in directing or focusing flow
- The dependence of estimates of impacts on the recharge rate for sitewide and IDF conditions
- The dependence of impacts on the magnitude of the distribution coefficient of iodine in the vadose zone
- The role of the efficiency of capture of iodine in ILAW glass

N.3.1 Travel Time and Rate of Recharge

The rate of groundwater movement through the vadose zone under steady state conditions varies with the geology and related hydraulic properties of the vadose zone and the rate of recharge initiating the flow. The background rate of recharge varies locally and is a function of geology, the amount of precipitation, and the degree of evapotranspiration mediated by the type of ground cover (Fayer and Walters 1995). This section presents estimates of travel time through the vadose zone for rates of recharge recommended for Hanford (DOE 2005) using the values of hydraulic properties identified in Appendix M. The magnitude of travel time is important because it influences the timing and flux of solutes at the water table with respect to potential remediation actions or placement of caps. A range of recharge conditions is considered to investigate uncertainty related to surface and subsurface soil conditions and variability in evapotranspiration moderated by vegetation. The range of recharge rate considered depends on (1) background conditions at the undisturbed IDF-East site in the southeast portion of the 200-East Area (0.9 millimeters per year), (2) background conditions at undisturbed locations over the balance of the 200-East and 200-West Areas (3.5 millimeters per year), (3) disturbed conditions at cribs and trenches (ditches) (50 millimeters per year), and (4) disturbed conditions at tank farms (100 millimeters per year). Two cases are considered: geology representative of the 200-East Area and geology representative of the 200-West Area. In each case, the recharge rate is constant in time and uniform across the study area, and the soil layers constituting the vadose zone are horizontal and of uniform thickness. Representative geology for the 200-East Area includes an upper layer of Hanford Gravel, a center layer of Hanford Sand, and a lower layer of Ringold Gravel. For the 200-West Area, layers of Hanford Gravel, Hanford Sand, Plio-Pleistocene Silt, and Ringold Gravel extend from the ground surface to the water table. The thicknesses of the vadose zone assumed for these calculations are 78 and 70 meters (256 and 230 feet) for the 200-East and 200-West Areas, respectively.

Plots of the frequency distribution of travel time for the 200-East and 200-West Areas are presented as Figures N–137 and N–138, respectively. Results indicate very long travel times for low recharge rates but travel times as short as 60 years for disturbed conditions at tank farms. Estimates of average travel time, ranging from 63 to 4,270 years, as summarized in Table N–2, are slightly lower for the 200-East Area than for the 200-West Area. The difference in travel time is due primarily to difference in hydraulic properties between soil types in the 200-East and 200-West Areas, and to the presence of the Plio-Pleistocene soil type in the 200-West Area. The short travel times estimated for higher recharge sites indicate that the timing of the release and placement of the cap may play a role in conjunction with the

short travel time in comparison of alternatives. The significance of this effect would be determined through review of the time series of health impacts (see Appendix Q) for the alternatives under comparison.

Table N–2. Estimates of Travel Time in the Vadose Zone for Differing Rates of Recharge

Rate of Recharge (millimeters per year)	Average Travel Time (years)	
	200-East Area	200-West Area
0.9	4,270	Not applicable
3.5	1,240	1,300
50	115	118
100	63	64

Note: Technical basis for recharge rate of 0.9 millimeters per year is available for the 200-East Area Integrated Disposal Facility, but is not available for any portion of the 200-West Area.

N.3.2 Aqueous Discharge near the Ground Surface

Past operations at Hanford have resulted in spills, leaks, and planned discharges that deposited aqueous fluids and solutes into vadose zone sediments at or near the ground surface. The elevated moisture content caused by these discharges could lead to rapid movement of solutes to the water table with degradation of groundwater quality in the unconfined aquifer. The case evaluated in this section, discharge of a volume of liquid to the vadose zone, is comparable to a past leak at a tank farm, with aqueous discharge ranging from 4 cubic meters (1,057 gallons) to 400 cubic meters (105,700 gallons). This range corresponds to current estimates of volumes of past leaks (Hanlon 2003) and reflects the degree of uncertainty in estimates of leak volumes that is related to difficulty in measurement of volume of material in large underground tanks. The geology is that of the 200-East Area with an upper layer of Hanford Gravel, a center layer of Hanford Sand, and a lower layer of Ringold Gravel. The area of the discharge has a horizontal extent of 20 meters (66 feet) in each direction, the approximate cross-sectional area of a single tank, and the overall thickness of the vadose zone for this simulation is 78 meters (256 feet). Recharge conditions are the uniform background rate of 3.5 millimeters per year across the study area prior to discharge, with an increase to 100 millimeters per year at the time of discharge. The discharge of water and solute is assumed to occur over a period of 1 year. Given the above conditions, the recharge rate to the immediate area of the discharge is 40 cubic meters (10,570 gallons) per year for the period of time following the discharge.

Time series of the flux of solute at the water table for three values of aqueous discharge are presented as Figure N–139. Results show almost no dependence of solute flux on the volume of the discharge when that volume is comparable to or smaller than the annual rate of recharge. A small decrease in travel time is predicted when the discharge is larger than the annual rate of recharge. Time to arrival of peak flux is approximately 60 years, indicating that the transition of background recharge from 3.5 to 100 millimeters per year does not delay movement of solute relative to that expected for steady state conditions at the higher rate of recharge. A minor dependence of solute flux at the water table on the duration of release was indicated in the analysis presented in Appendix M. The results indicate that comparison of alternatives would not be significantly biased by uncertainty in estimates of aqueous volume of past leaks.

N.3.3 Influence of a Silt Layer

One difference between geologies of the 200-East and 200-West Areas is the increased frequency of laterally extensive Plio-Pleistocene Silt layers in the 200-West Area. Because silt layers are known to retain water and facilitate spreading of infiltrating water and solute, silt layers may be important in estimation of the magnitude and time of solute flux at the water table and related human health impacts.

The potential influence of silt layers was evaluated in simulations that varied the thickness from 0 (not present) to 8 meters (26 feet). The analysis considered layers of Hanford Gravel, Hanford Sand, Plio-Pleistocene Silt, and Ringold Gravel extending from the ground surface to the water table at a depth of 70 meters (230 feet). Recharge and discharge conditions correspond to that of a crib with a horizontal dimension of 20 meters (66 feet) in each direction. The initial steady state moisture distribution is for background recharge of 3.5 millimeters per year, transitioning to 50 millimeters per year starting at the time of discharge. An aqueous discharge of 4,000 cubic meters (10,570 gallons) was specified to occur over a period of 1 year.

The time series of solute flux at the water table for a range of silt layer thicknesses are presented as Figure N–140. Results indicate that the absence or presence of the silt layer is more significant than the absolute thickness of the layer. Each of the time series shows two peaks, the first corresponding to an early arrival of solute associated with the large aqueous discharge, and the second associated with the moisture front due to the increase of recharge rate from 3.5 to 50 millimeters per year. The separation of the peaks is most pronounced when the silt layer is absent and muted when the silt layer is present. The results support inclusion of silt layers in the vadose zone models.

N.3.4 Tilt of Geologic Layers

Interspersed layers of sediment with differing hydraulic properties is one of the features of the large-scale structure of the vadose zone at Hanford. The downward movement of water to the unconfined aquifer will be influenced by the difference in the magnitude of values (offset) in hydraulic properties that occurs at the interface between adjacent layers. The accumulation of water above the interface, spreading of water at the interface, and preferential movement of water along the interface are possible consequences of the offset in hydraulic properties at the interface. This effect could be important on its own or in combination with dikes in forming a preferential path for potential flow of water and solute. This section investigates the effect of interface tilting between two layers on the redistribution of solute flux originating at a local source near the ground surface. A plan view of the large-scale structure of the vadose zone for the study area is presented as Figure N–141. The figure shows an interface between an upper layer of Hanford Gravel and an underlying Hanford Sand that is tilted with respect to a horizontal plane. For the purpose of analysis, two cases were considered: (1) the interface is level (not tilted), and (2) the interface is tilted. The assumed slope of the interface is 0.1 with a related angle of tilt of7 approximately 6 degrees from the horizontal plane. The geology of the study area is that of the 200-East Area with an upper layer of Hanford Gravel, a center layer of Hanford Sand, and a lower layer of Hanford Gravel. The area of the discharge has a horizontal extent of 5 meters (16 feet) in each direction (the area of a small crib), and the overall thickness of the vadose zone for this simulation is 80 meters (262 feet). Recharge conditions are uniform background across the study area of 3.5 millimeters per year for both the initial steady state condition and the transient portion of the analysis. For the transient simulation, a single 250-cubic-meter (66,052 gallons) discharge of water with 100 curies of technetium-99 is assumed to occur over a 1-year period.

For the purpose of reporting results, the horizontal or tilted plane at the water table is divided into release areas. The first area has the same dimension as the source and is immediately below the source. An additional four release areas are defined as concentric rectangles surrounding the first release area, as shown in Figure N–142. The size of each release area and the cumulative solute flux reaching the water table through that release area are presented as Table N–3. The time series of solute flux for release area 1 immediately below the source and for the total study area are presented as Figures N–143 and N–144, respectively. Results show that tilting of the interface directs solute away from the immediate location of the source, but that the effect is minor; nearly the entire release reaches the water table within 50 meters (165 feet) (of the source, tilting of the interface notwithstanding. The arrival of no solute at the water table through release areas 4 and 5 indicates that the study area was large enough so that effects due to boundary conditions for the sides of the study volume did not influence results. Lateral spreading due

to capillary forces plays a greater role than the tilt of the interface in moving water and solute away from the immediate area of the release.

Table N–3. Spatial Distribution of Solute Flux at the Water Table with Upper Geologic Layer Tilted

Release Area	Area (square meters)	Cumulative Flux of Technetium-99 at the Water Table (curies)	
		Level Interface	Tilted Interface
1	25	9.36	6.16
2	3,000	56.93	58.41
3	8,000	0.01	0.04
4	13,000	0	0
5	41,000	0	0

Note: To convert square meters to square feet, multiply by 10.7639.

N.3.5 Influence of a Dike

Examples of complex geology that could affect the movement of water and solutes through the vadose zone have been identified at Hanford. Included are vertically oriented sand and silt bands (clastic dikes) that cut across the primary, horizontally oriented sedimentary layers. Generally, the dikes have the same mineral content as the host sediments but a smaller grain size that may contribute to a faster advance of wetting fronts (Murray, Ward, and Wilson 2003). Average width as great as 1 to 3 meters (3 to 10 feet) and average length of 60 meters (197 feet) are reported for dikes at Hanford (Murray, Ward, and Wilson 2003). The presence of dikes could be important either as isolated features or in combination with local structure such as tilting of interfaces in forming preferred flow paths for water and solutes.

This section investigates the effect of a dike intersecting a source area near the ground surface on the distribution of water and solute flux reaching the water table. An elevation view of the large-scale structure of the vadose zone for the study area is presented as Figure N–145. The figure shows three horizontal layers—i.e., Hanford Gravel, Hanford Sand, and Hanford Gravel—and a vertically oriented dike in the center of the study volume. The study volume extends 430 meters (1,410 feet) in both horizontal directions and to a depth of 80 meters (262 feet). For the purpose of analysis, two cases were considered: (1) the dike is not present, and (2) the dike is present. The dike has a width of 2 meters (7 feet) and extends the full width and depth of the study volume. The simulations were run in two steps: an initial calculation with constant recharge and no source to establish background moisture and water flow conditions, and a second step to investigate transient behavior attributable to constant recharge from a specific source. The source of the discharge has a horizontal extent of 6 meters (20 feet) in each direction (the area of a small crib), and the dike passes through the center of the source area. Calculation of the background moisture and water flow was completed for uniform recharge rates of 3.5 and 100 millimeters per year. Recharge was applied at the ground surface at the same rate horizontally across the study area. For the transient simulation, the recharge rate of 100 millimeters per year was applied, and a single 54-cubic-meter (1,907-cubic-foot) discharge of water with 150 curies of technetium-99 was assumed to occur over a 1-year period. The hydraulic properties of the Hanford Gravel and Hanford Sand are those reported in Appendix M. For these horizontally oriented layers, the magnitude of the vertical component of hydraulic conductivity is one-tenth the magnitude of the horizontal component. The dike is assumed to have the same hydraulic properties as the Hanford Sand, with the exception that the magnitude of the vertical component of hydraulic conductivity is a factor of 10 greater than the magnitude of the horizontal component.

For the purpose of reporting results, two sets of release areas located in the horizontal plane at the water table are constructed. For the background moisture and water flow calculation, the study area is divided into five release areas, as shown in Figure N–146. The third release area has the same dimension as the

dike and is immediately below the dike. The additional four release areas are defined as rectangular strips on each side of the central area and below the dike. Results for the spatial distribution of recharge at the water table are presented as Table N–4 for the cases of spatially uniform recharge at the ground surface of 3.5 and 100 millimeters per year. Absent the dike, recharge at the water table is spatially uniform. In the case of the dike, flow to the water table is not spatially uniform; it is highest under the dike and slightly reduced outside the dike.

Table N–4. Spatial Distribution of Background Recharge for Study Area Intersected by a Dike

Recharge Area	Area (square meters)	Recharge at the Ground Surface (millimeters per year)	
		Aqueous Flux at the Water Table: 3.5 millimeters per year	Aqueous Flux at the Water Table: 100 millimeters per year
1	86,000	3.49	99.92
2	6,020	3.51	95.91
3	860	5.71	174.17
4	6,020	3.51	95.91
5	86,000	3.49	99.92

Note: To convert square meters to square feet, multiply by 10.7639.

The distribution of release areas for the transient simulation with the source present is presented as Figure N–142. The first release area has the same horizontal dimensions as the source and is immediately below the source, and the remaining areas are concentric rectangular areas around the first. Presented as Table N–5 are the size of each release area and the cumulative solute flux reaching the water table through that release area. The time series of solute flux for release area 1 immediately below the source and for the total study area are presented as Figures N–147 and N–148, respectively. Results show that the dike focuses flow toward the area of the dike. Peak annual flux of solute below the source increases by approximately 30 percent. Cumulative flux for the area outside the dike is reduced by approximately 10 percent. The arrival of no solute at the water table through release areas 4 and 5 indicates that the study area was large enough so that effects due to boundary conditions for the sides of the study volume did not influence results.

Table N–5. Spatial Distribution of Solute Flux at the Water Table for Study Area Intersected by a Dike

Release Area	Area (square meters)	Cumulative Flux of Technetium-99 at the Water Table (curies)	
		Without Dike	With Dike
1	36	32.32	43.42
2	864	116.49	101.46
3	16,000	1.03	0.69
4	36,000	0	0
5	148,900	0	0

Note: To convert square meters to square feet, multiply by 10.7639.

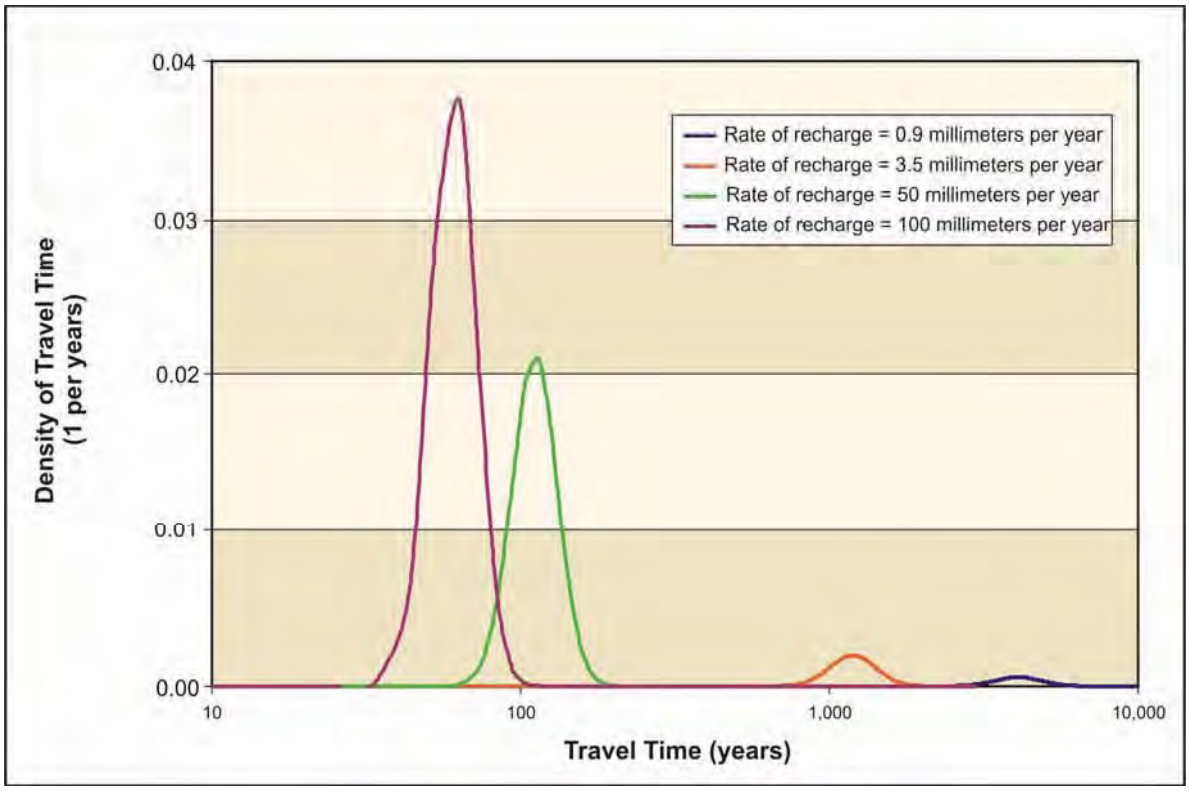


Figure N–137. Distribution of Travel Time in the Vadose Zone for the 200-East Area

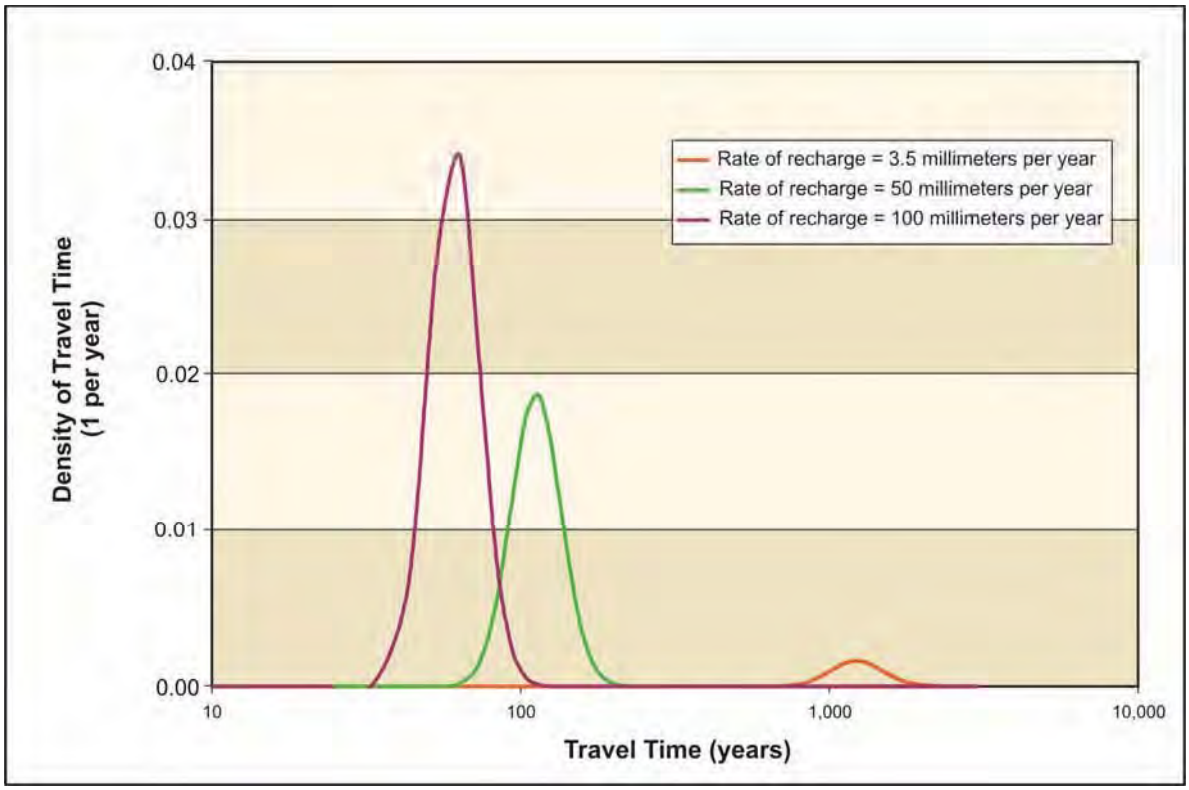


Figure N–138. Distribution of Travel Time in the Vadose Zone for the 200-West Area

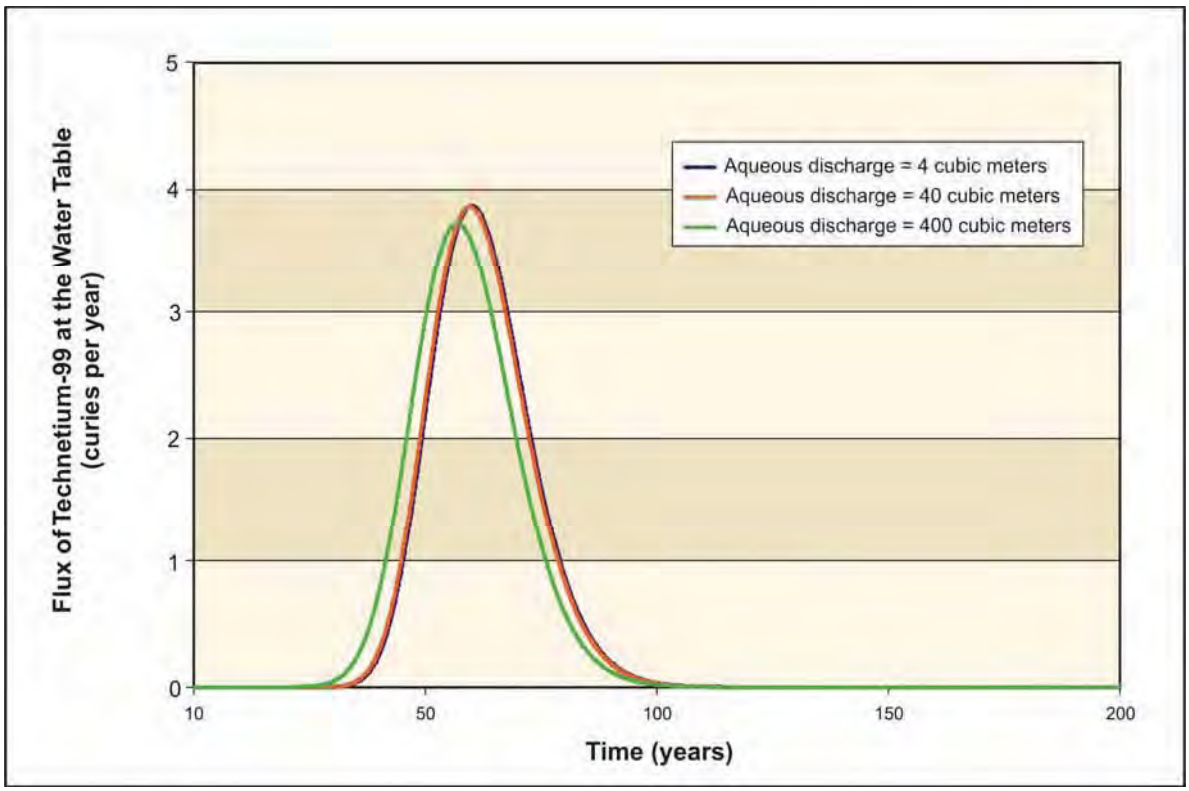


Figure N–139. Dependence of Flux of Solute at the Water Table on Magnitude of Aqueous Discharge

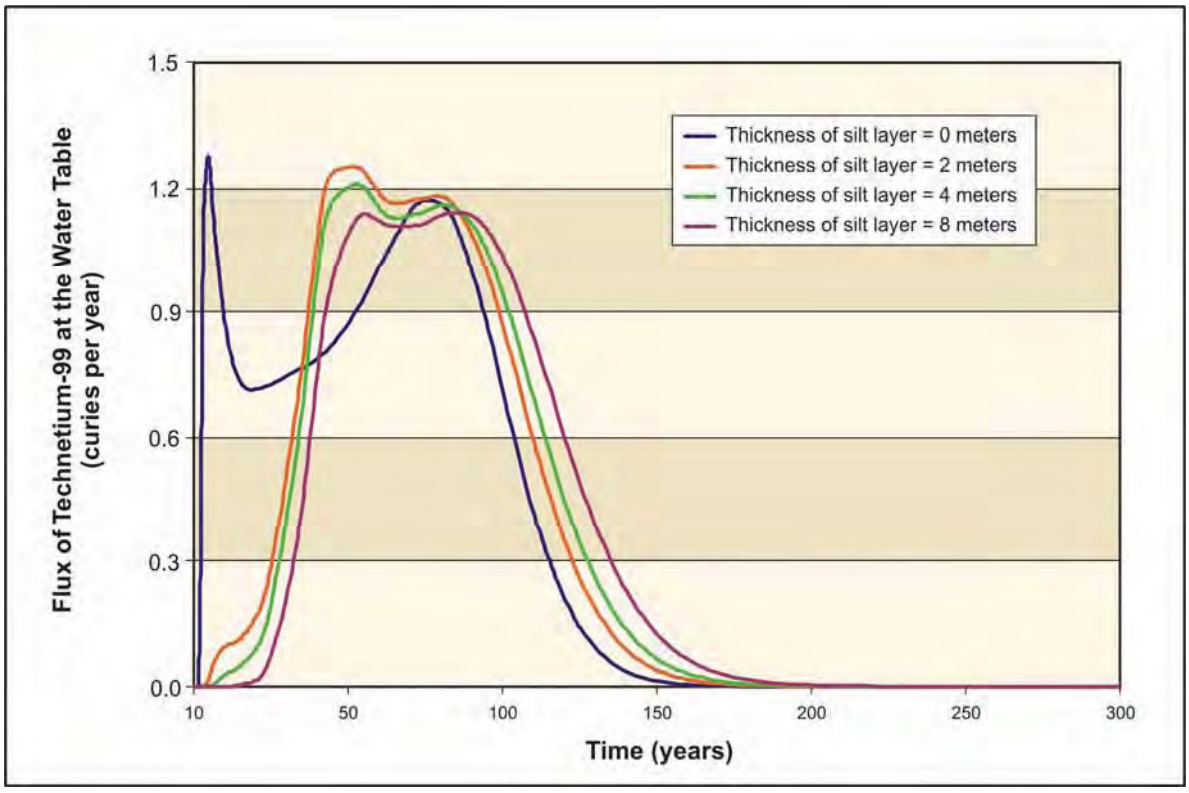


Figure N–140. Dependence of Solute Flux on Thickness of a Silt Layer

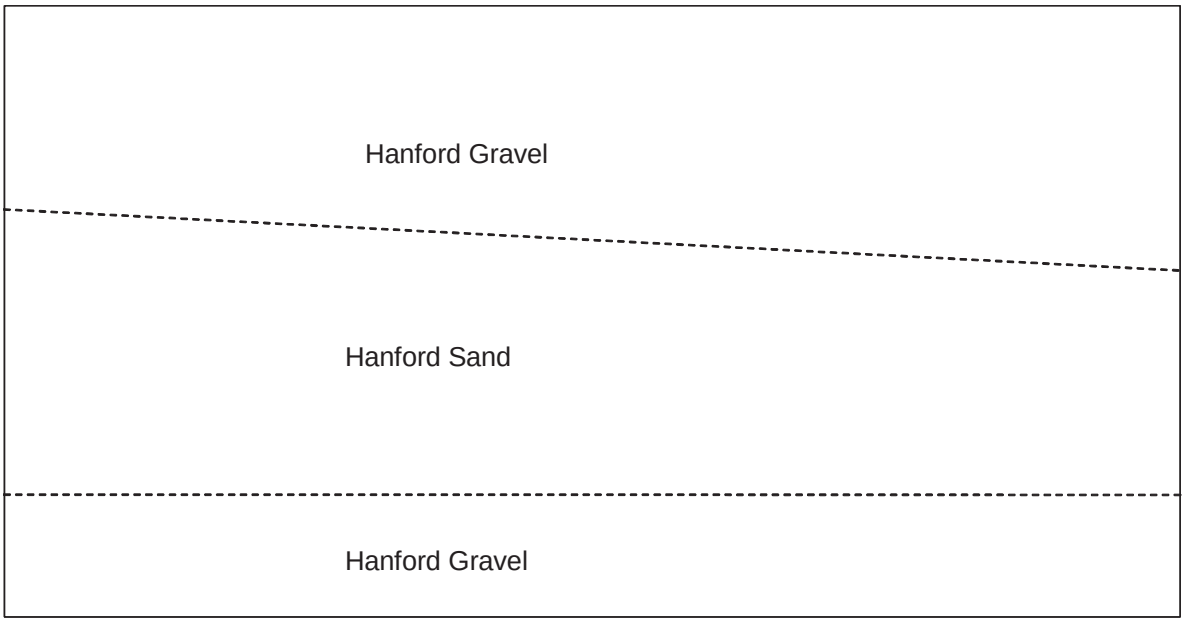


Figure N–141. Schematic of a Tilted Geologic Layer

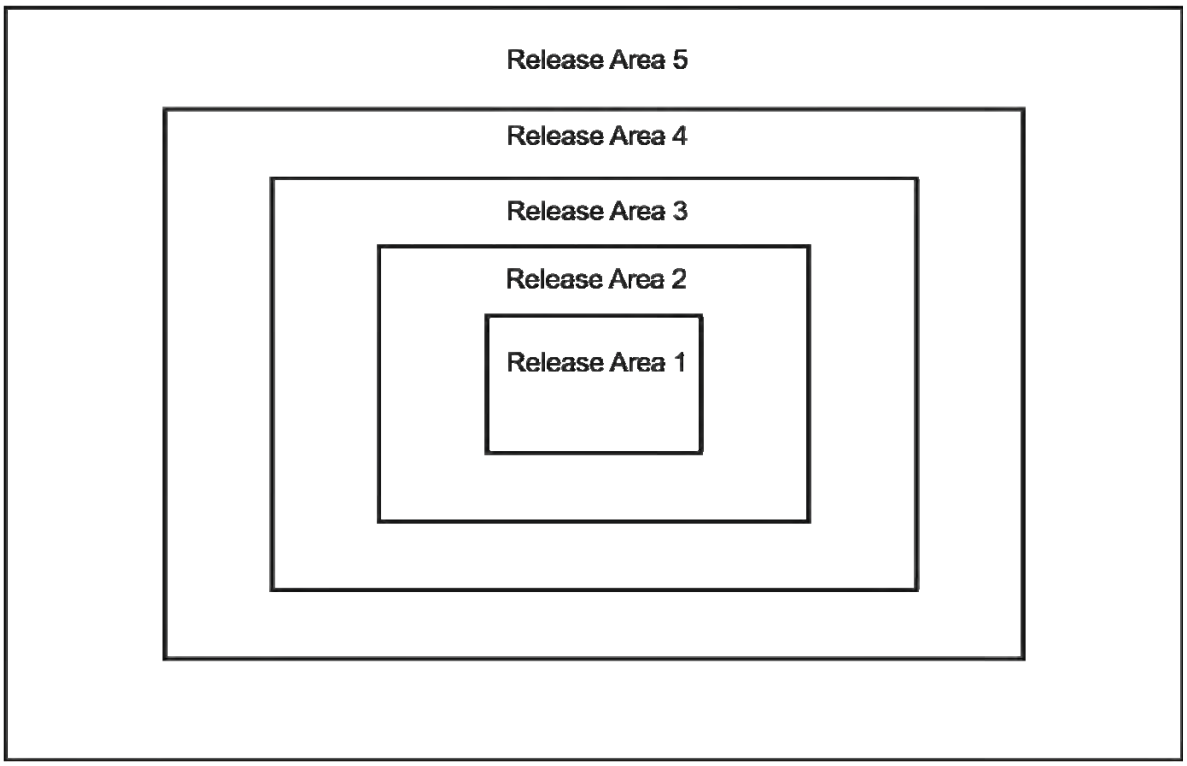


Figure N–142. Schematic of Configuration of Vadose Zone Release Areas at the Water Table, Upper Geologic Layer Tilted

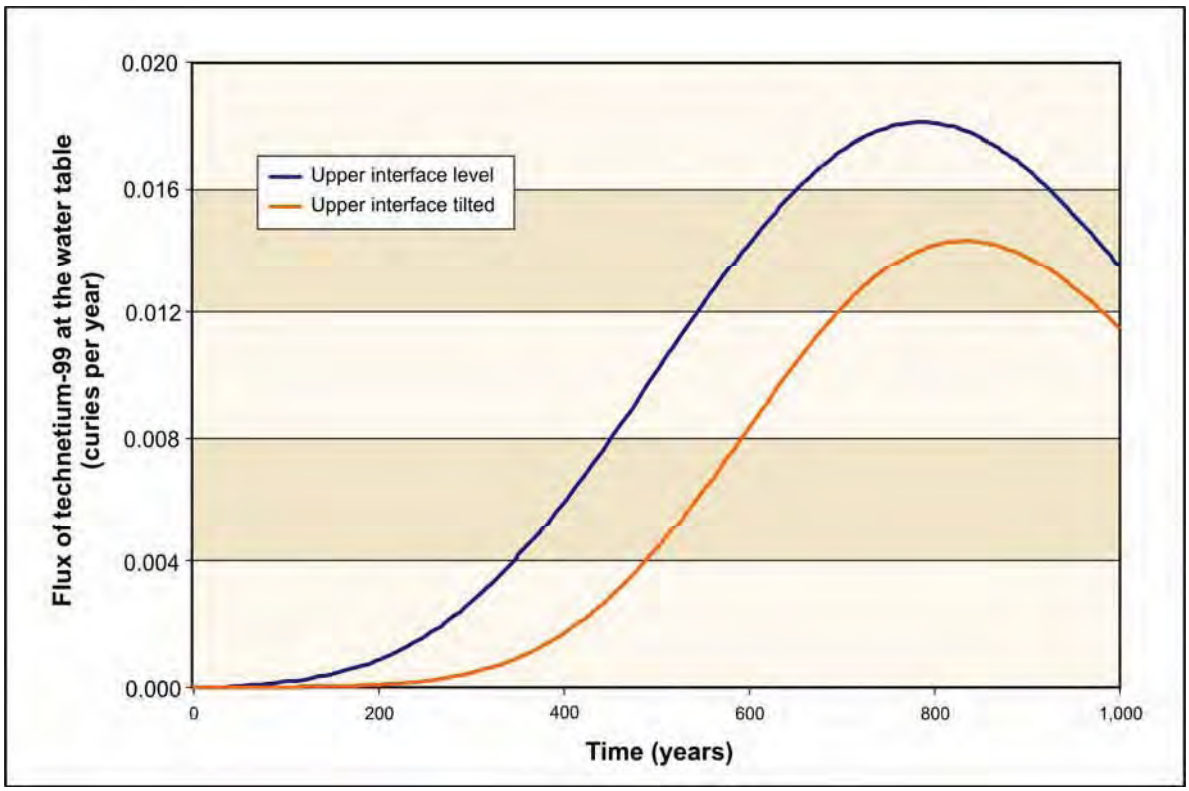


Figure N–143. Time Series of Solute Flux Immediately Below the Source, Upper Geologic Layer Tilted

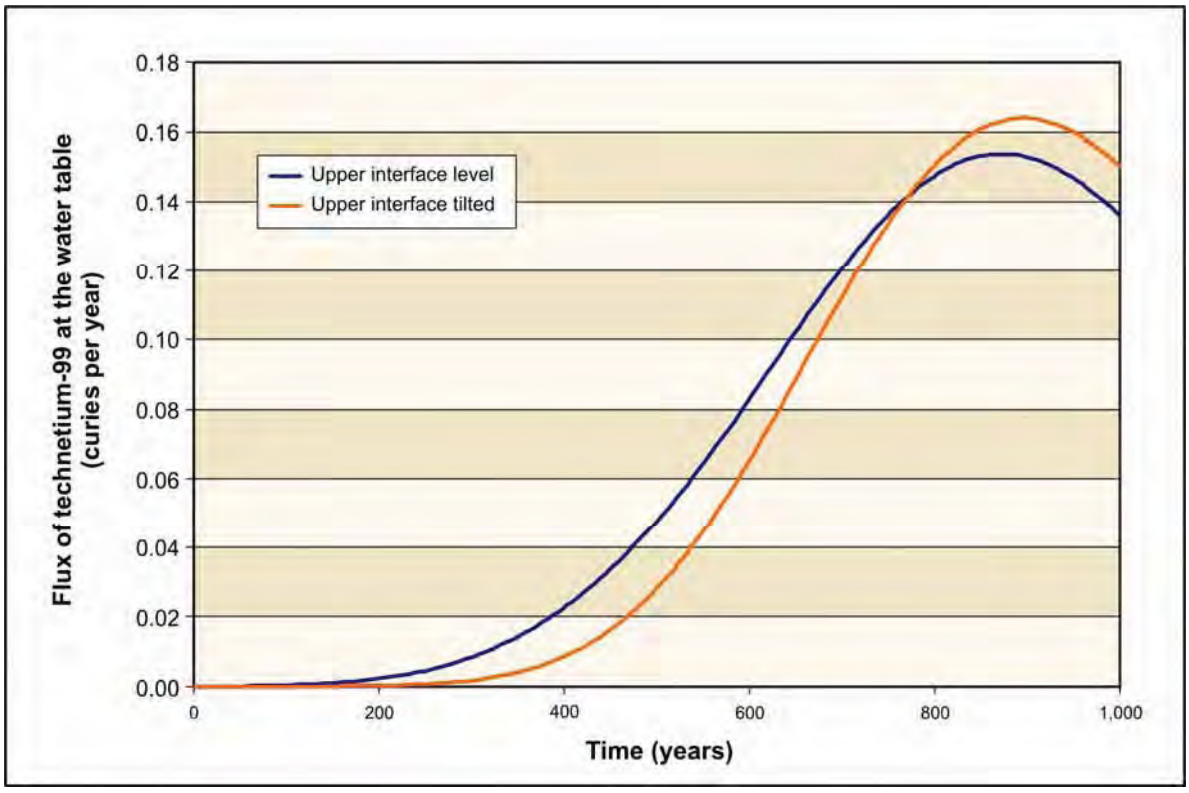


Figure N–144. Time Series of Solute Flux Below the Entire Study Area, Upper Geologic Layer Tilted

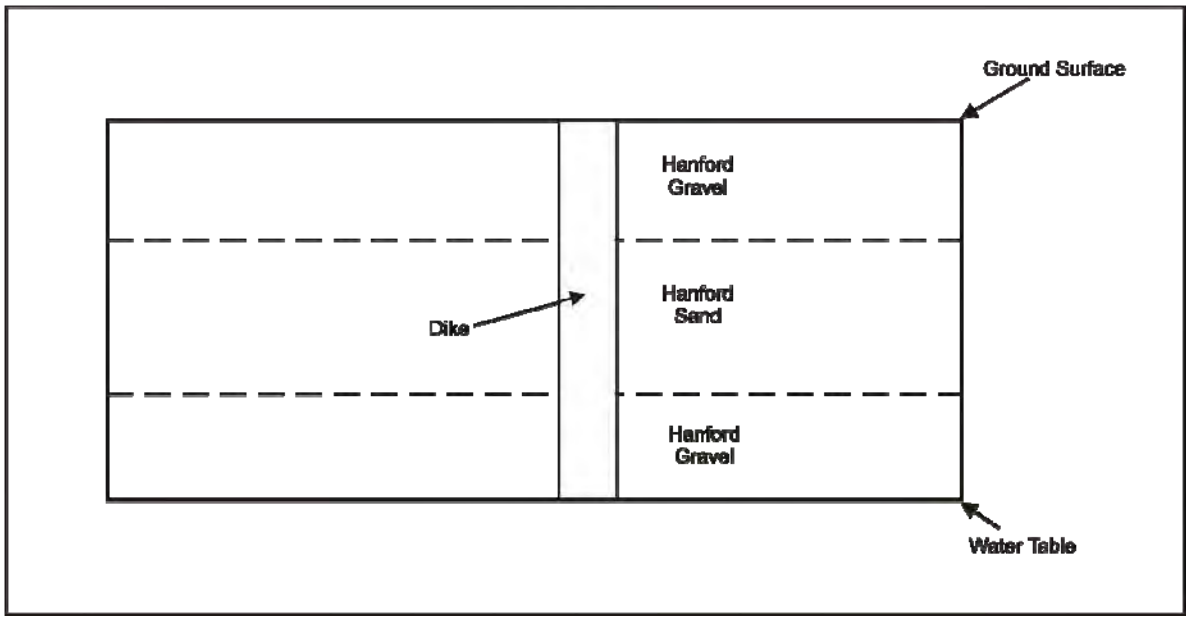


Figure N–145. Schematic of an Elevation View of the Vadose Zone with the Study Volume Intersected by a Dike

Figure N–146. Schematic of Plan View of Recharge Areas with Study Area Intersected by a Dike

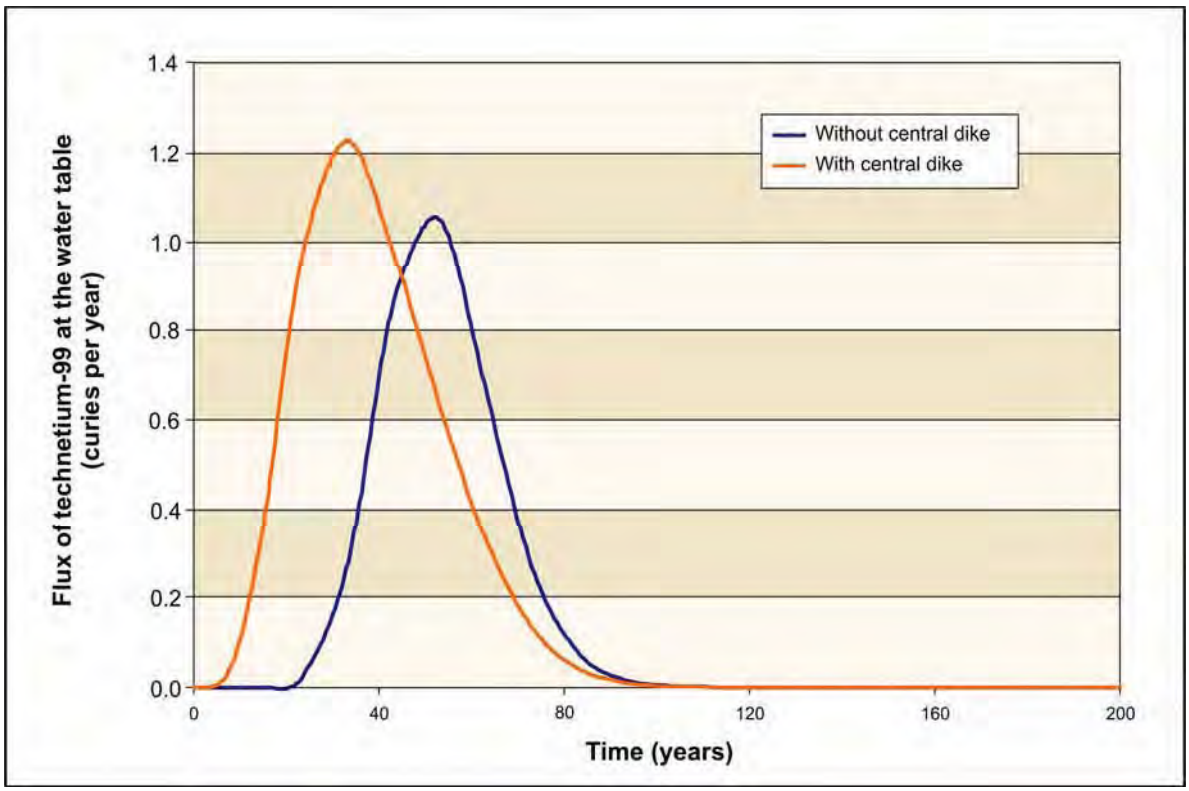


Figure N–147. Time Series of Solute Flux Immediately Below a Source Intersected by a Dike

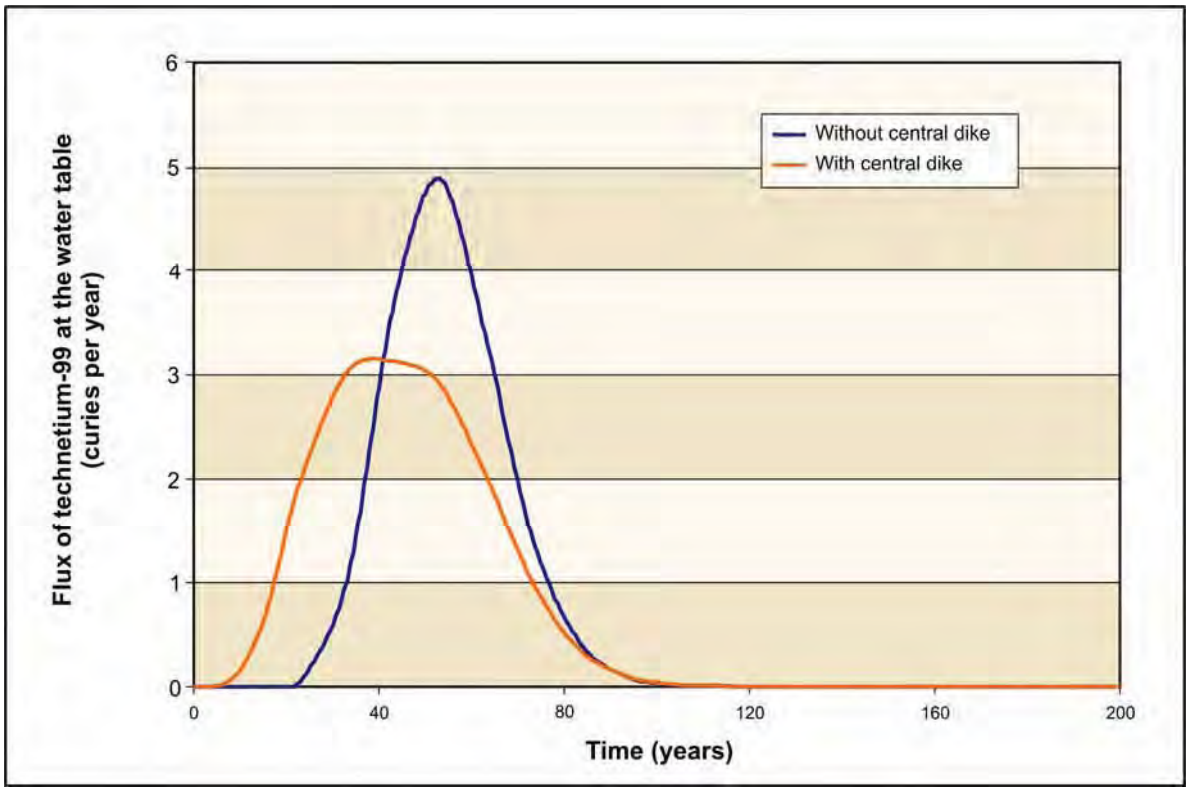


Figure N–148. Time Series of Solute Flux Below Entire Study Area with Source Intersected by a Dike

N.3.6 Rate of Release for a Sitewide Barrier

For engineered disposal facilities, the release rate of solutes from solid waste forms to the vadose zone and the subsequent movement of water and solutes through the vadose zone depend on the time series of the recharge rate through the barriers. As discussed above, the background recharge rate varies locally and is a function of several variables. This variability introduces uncertainty into estimates of impacts on groundwater quality. As recommended in guidance developed for this *TC & WM EIS* (DOE 2005), this section investigates the dependence of estimates of release rate on the magnitude of recharge. The rates of release of solute to the vadose zone and of solute fluxes to the unconfined aquifer were selected as measures of the sensitivity. Two sets of recharge conditions are considered, the first representative of sitewide conditions and the second representative of conditions at IDF-East in the southeast portion of the 200-East Area. Time series of rates of recharge for the sitewide and IDF-East barriers are presented as Table N–6. The following analysis investigates the dependence of rates of release at a location with a sitewide barrier and at a location with an IDF-East barrier on variation of the recharge through the barrier at each location.

Table N–6. Time Series of Rate of Recharge for Sitewide and Integrated Disposal Facility Conditions (millimeters per year)

Condition	*TC & WM EIS* Analysis Case	Sensitivity Case 1	Sensitivity Case 2
Sitewide Barrier			
Background	3.5	3.5	5.0
Design life	0.5	0.5	1.0
Post–design life	3.5	1.0	5.0
200-East Area Integrated Disposal Facility Barrier			
Background	0.9	3.5	5.0
Design life	0.5	0.5	0.9
Post–design life	0.9	0.9	5.0

Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Waste volumes and inventories selected for the analysis are those of Tank Closure Alternative 3C. For this case, soil and rubble disposed of at the RPPDF are a single source of material under a barrier experiencing sitewide background recharge conditions, and ETF secondary waste is a single source under a barrier experiencing IDF-East recharge conditions. For the purpose of analysis, nitrate in the soil and rubble at RPPDF and iodine-129 in the ETF secondary waste at IDF-East were selected as the constituents of interest. The release mechanism for the soil and rubble was partitioning-limited convective flow, while the release mechanism for the ETF secondary waste was waste form diffusion limited release coupled with vadose zone convection limited flows. For each of the cases, the site receives the background recharge rate prior to year 110 in the analysis, the engineered cap–reduced rate for the next 500 years, and the long-term rate after year 610. The geology was that of the 200-East Area, and thicknesses of the vadose zone at the RPPDF and IDF-East sites were 90 and 100 meters (295 and 328 feet), respectively. Values of hydraulic properties for the vadose zone used in this analysis were those identified in Appendix M.

The release rate of nitrate to the vadose zone and the nitrate flux at the water table for the RPPDF site and recharge conditions are presented in Figures N–149 and N–150, respectively. Results for the release to the vadose zone show the highest early release for the highest recharge rate (Sensitivity Case 2, 5 millimeters per year). Results for the *TC & WM EIS* Analysis Case and Sensitivity Case 1 show identical release to the vadose zone and recharge conditions prior to year 610, but they diverge after that time due to difference in recharge rate for the long-term period for these two cases. Results for the flux at the water table show an increase in time to peak dose with a decrease in long-term recharge rate, but nonlinear dependence of peak flux on recharge conditions. In general, for a comparison between alternatives with a partitioning-limited convective flow release mechanism, rates of release and related human health impacts would vary in approximate relation to variation in recharge data.

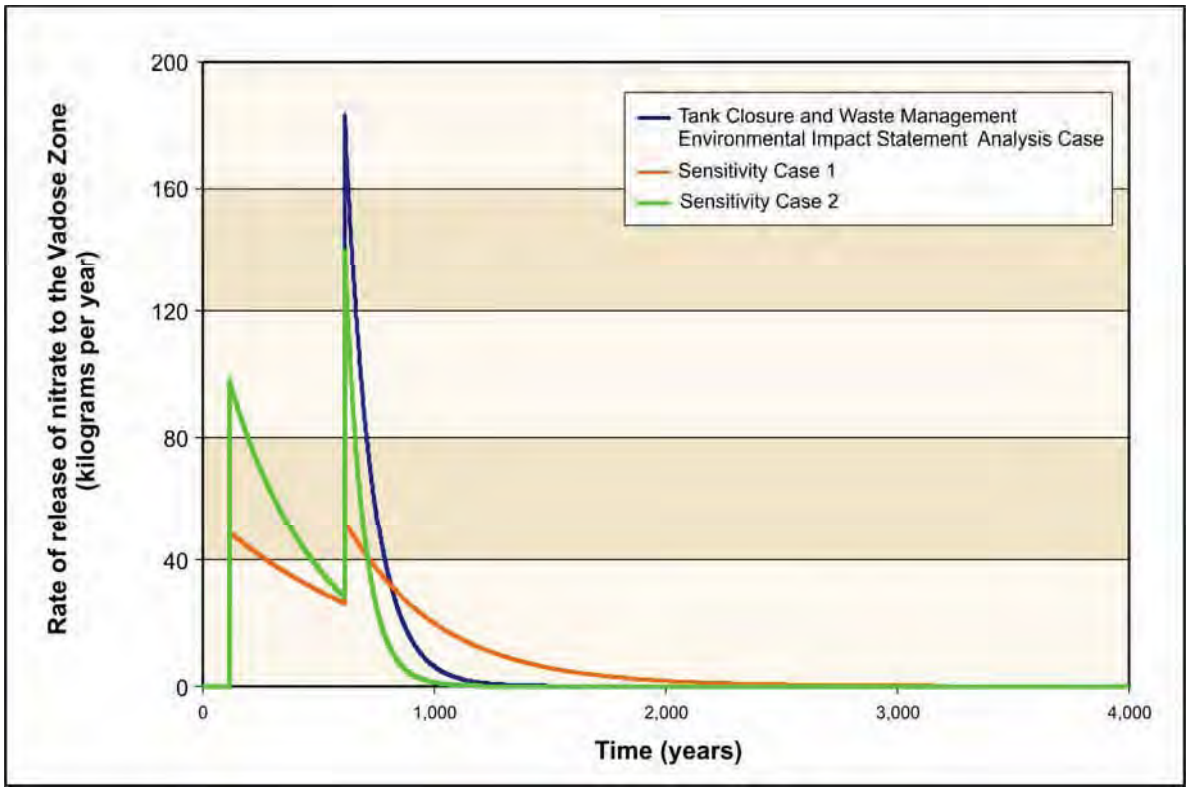


Figure N–149. Rate of Release of Nitrate to the Vadose Zone for River Protection Project Disposal Facility Barrier Conditions

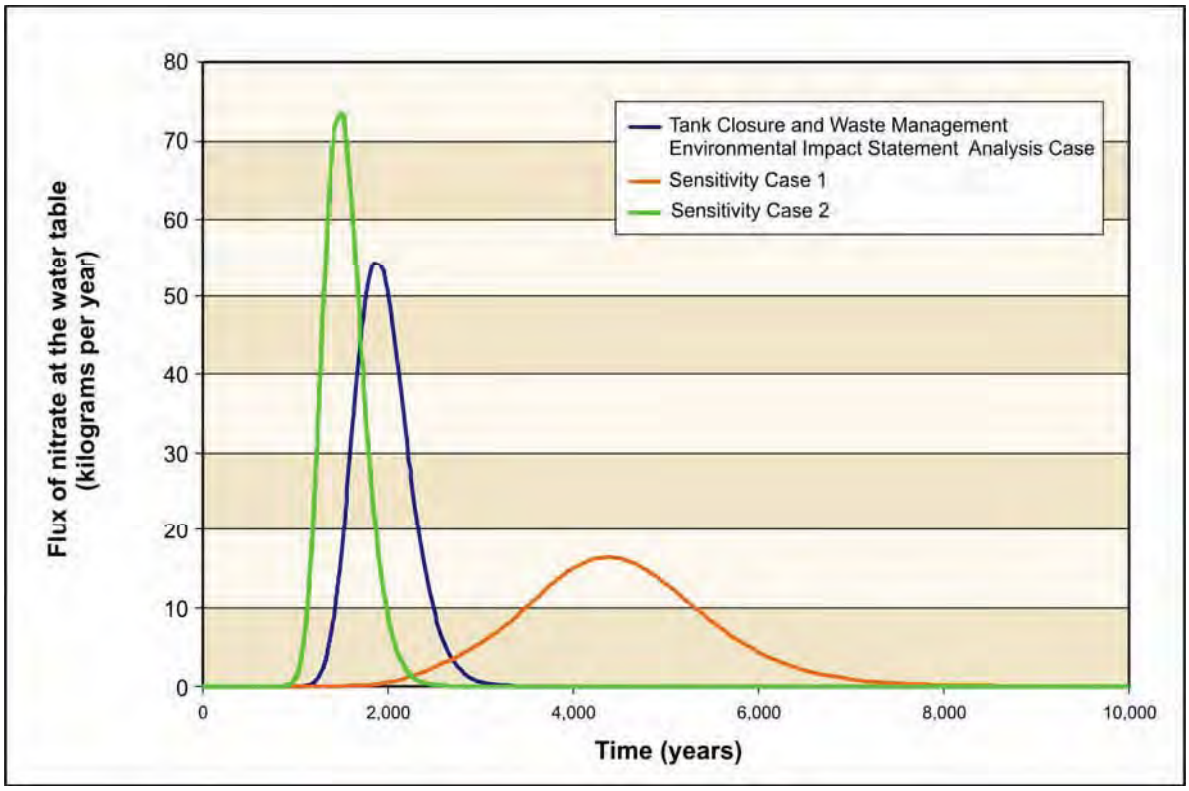


Figure N–150. Flux of Nitrate at the Water Table Zone for River Protection Project Disposal Facility Barrier Conditions

The release rate of iodine-129 to the vadose zone and the iodine-129 flux at the water table for the IDF-East site and recharge conditions are presented in Figures N–151 and N–152, respectively. Results for release to the vadose zone show that the release rate from the waste package by diffusion is rapid relative to the convective flow, proportional to the recharge rate, and nearly constant at a given rate of recharge. Results for the *TC & WM EIS* Analysis Case and Sensitivity Case 1 show identical recharge conditions after initiation of the release and nearly identical results. Results for the flux at the water table also show a flux that is proportional to the recharge rate. Sensitivity Case 2 shows a greater difference between the cap design–limited recharge rate and the long-term recharge rate than the *TC & WM EIS* Analysis Case, a circumstance reflected in the transient behavior of the flux at the water table.

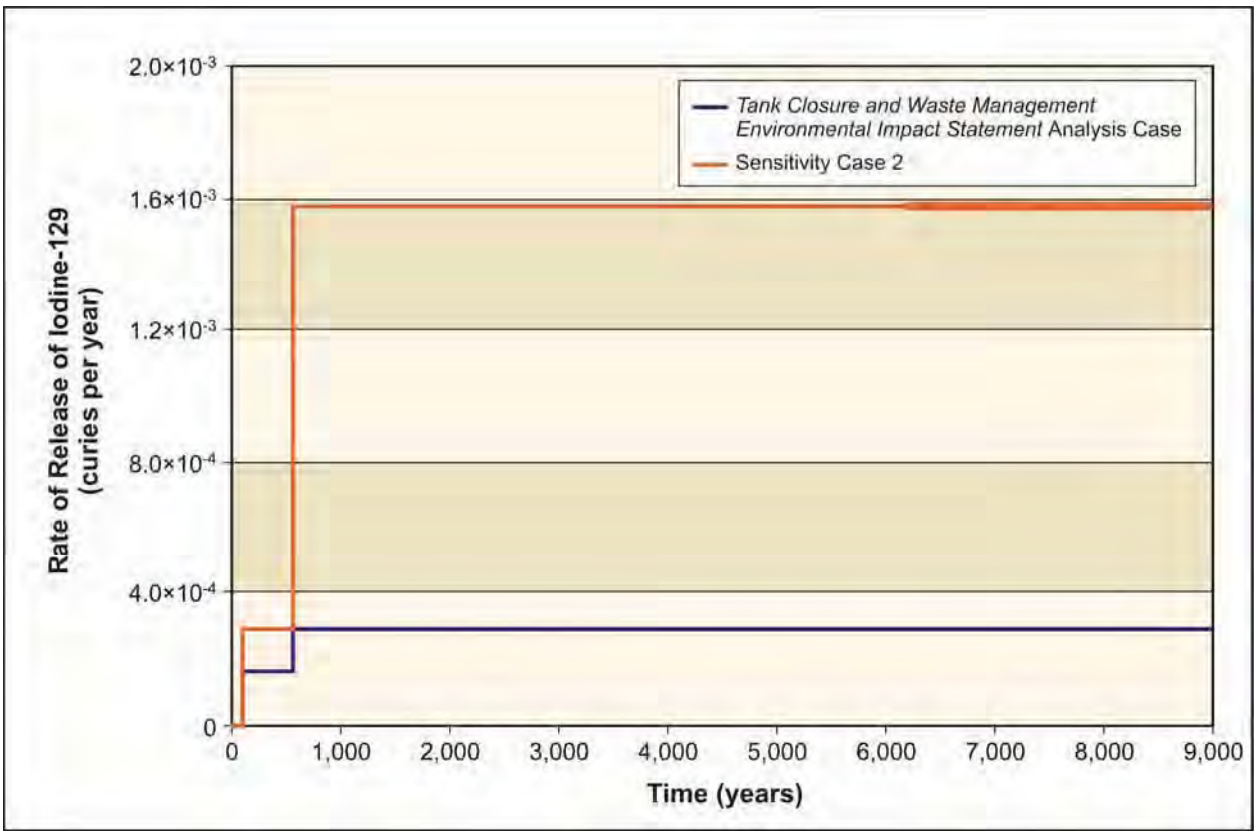


Figure N–151. Rate of Release of Iodine-129 to the Vadose Zone for 200-East Area Integrated Disposal Facility Conditions

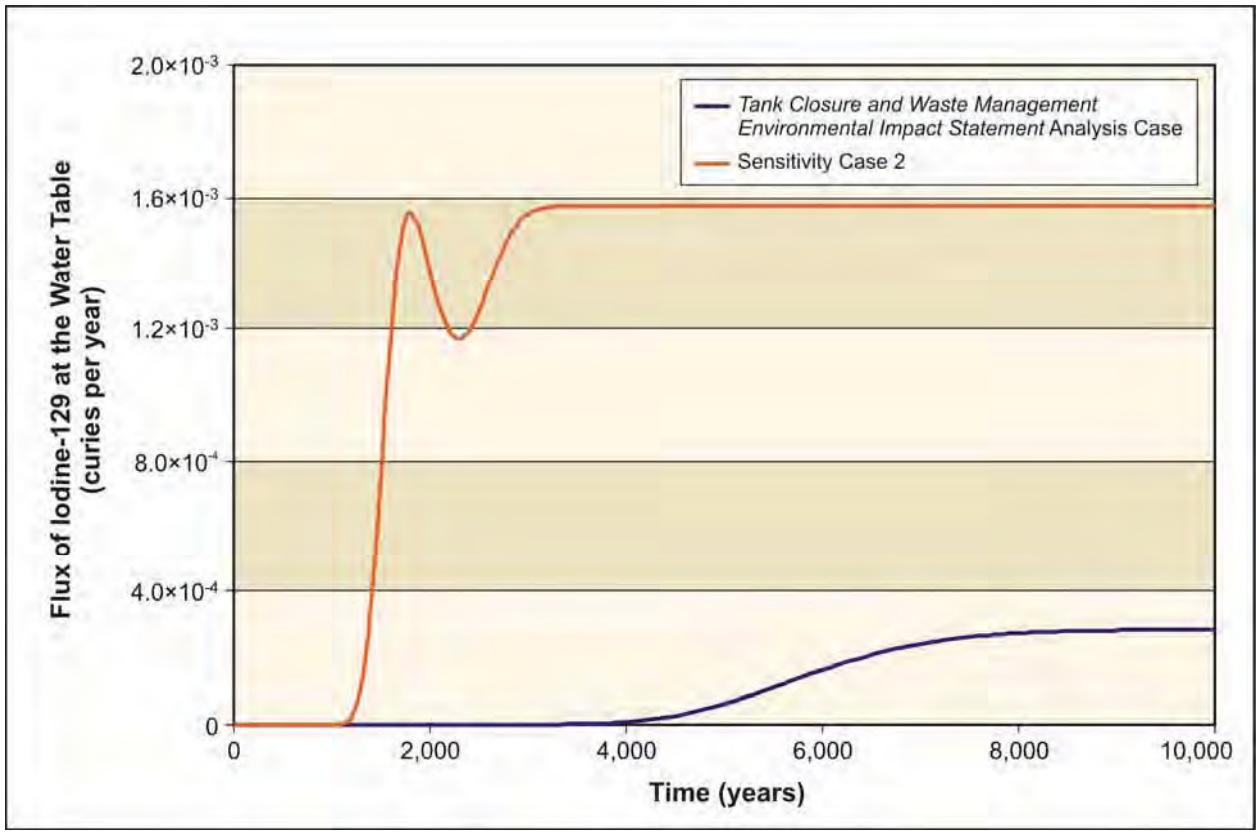


Figure N–152. Flux of Iodine-129 at the Water Table for Integrated Disposal Facility Conditions

N.3.7 Distribution Coefficient and Flux at the Water Table

The rate of movement of solutes through the vadose zone depends on the degree of interaction between the species of the solute in the groundwater and adsorption sites on the surfaces of sediments in the vadose zone. In analysis performed for this *TC & WM EIS*, this interaction is represented as having a linear relation between solute concentration in the groundwater and solute concentration in the solid phase. The constant that expresses the strength of the interaction is termed the distribution coefficient of the solute. As recommended in guidance for this *TC & WM EIS* (DOE 2005), this section evaluates the dependence of estimates of the flux of iodine-129 at the water table on the magnitude of the distribution coefficient of iodine. Two recommended values of the distribution coefficient, 0 and 0.2 milliliters per gram, were adopted for this analysis (DOE 2005) consistent with the variability in this parameter observed in site-specific measurements (Cantrell, Serne, and Last 2003). This variation is selected to reflect the uncertainty in transport rate that derives from spatial variability in soil type and degree of solute-soil interaction as well as lack of knowledge of the mechanism of interaction. Other conditions adopted for this analysis are the same as those described in Section N.3.6 for release from ETF secondary waste at the IDF-East. Results of the analysis, the flux of iodine-129 at the water table for two values of the distribution coefficient of iodine, are presented in Figure N–153. These results show that interaction with the solid delays the arrival of iodine-129 at the water table but does not reduce the peak flux predicted to reach the water table.

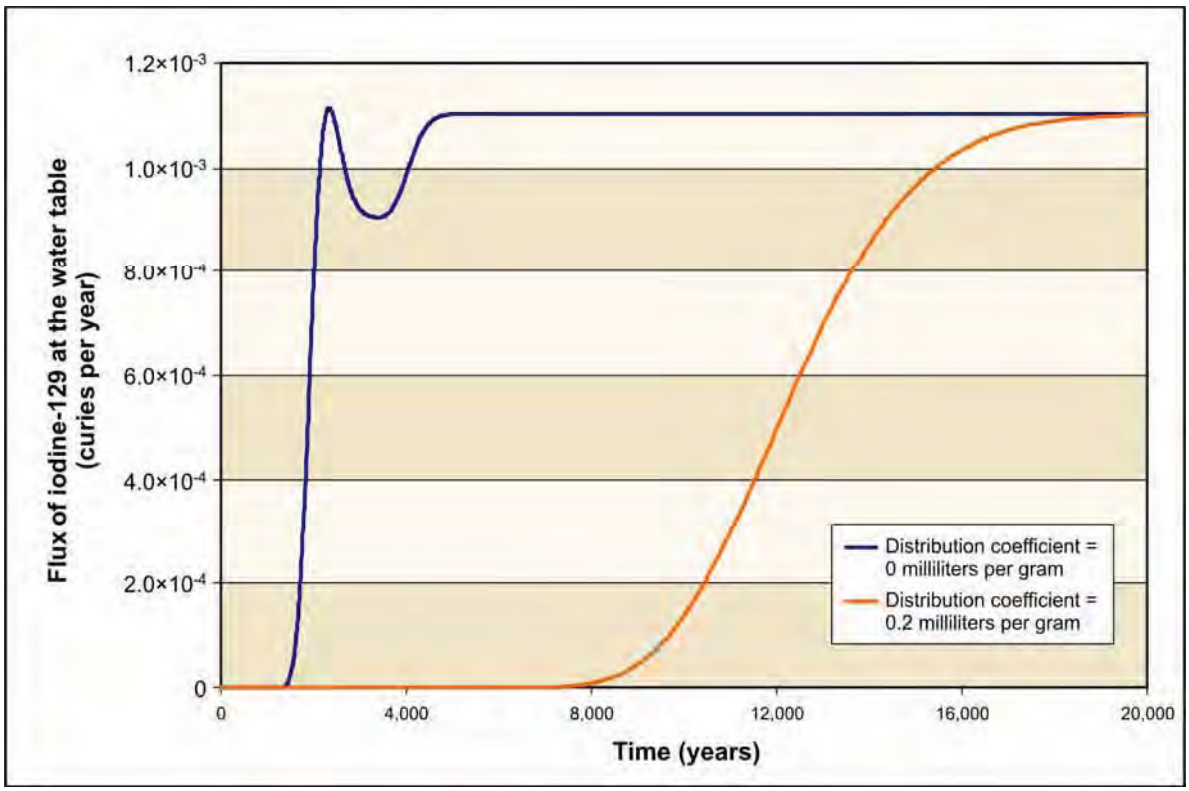


Figure N–153. Dependence of Flux of Iodine-129 at the Water Table on Magnitude of Distribution Coefficient

N.3.8 Retention of Iodine in Immobilized Low-Activity Waste Glass

Waste retrieved from the tank farms would be processed through the Waste Treatment Plant (WTP) for incorporation into a set of candidate waste forms. Among this retrieved waste is approximately 48 curies of iodine-129 that could be distributed across glass, grout, or steam reforming solid waste forms. The distribution among the waste forms varies with tank closure alternative and potentially with the operational design of the WTP. The sensitivity analysis presented in this section investigates an option for operation of the WTP that distributes the iodine inventory between the ILAW glass and a grout waste form. The conditions of Tank Closure Alternative 2B were adopted for this analysis. In this alternative, the primary waste form is ILAW glass and secondary waste is encapsulated in grout. In particular, iodine-129 volatilized in the production of ILAW glass is processed through the ETF and captured in ETF secondary waste, a grout waste form. In the base case analyzed in this *TC & WM EIS*, 20 percent of the iodine entering the ILAW melter is assumed to be retained in the ILAW glass, and the remaining 80 percent is captured in ETF secondary waste. Under an alternative processing option, process streams around the ILAW melter could be recycled to increase the portion of iodine entering the vitrification process that would be retained in the ILAW glass waste form. For this analysis, it is assumed that WTP operational conditions could be such that 70 percent of the iodine-129 entering the vitrification process would be retained in the ILAW glass and the remaining 30 percent captured in ETF secondary waste. A primary objective of the analysis is determination of the sensitivity of flux of iodine-139 at the water table to the retention rate in the glass with potential application to comparison of alternatives with differing supplemental waste forms.

The measure of effectiveness of the iodine-129 distribution among the waste forms is the flux of iodine-129 reaching the water table. Under Tank Closure Alternative 2B, the ILAW glass and ETF secondary waste would be disposed of in IDF-East. Thus, release models described in Appendix M, that is, fractional release for ILAW glass and diffusion-limited release for ETF secondary waste, would be

used in conjunction with the STOMP vadose zone transport model to estimate the flux at the water table. The vadose zone geology is primarily layered Hanford Gravel, Hanford Sand, and Ringold Gravel, and the background recharge rate is 0.9 millimeters per year.

For the case involving 20 percent partition to ILAW glass, 9.6 curies of iodine-129 would be present in ILAW glass and 33.6 curies in ETF secondary waste. The estimated fluxes of iodine-129 at the water table for the two waste forms for this case are presented as Figure N–154. Cumulative fluxes over the 10,000-year period of analysis are 0.001 and 1.08 for the ILAW glass and ETF secondary waste forms, respectively.

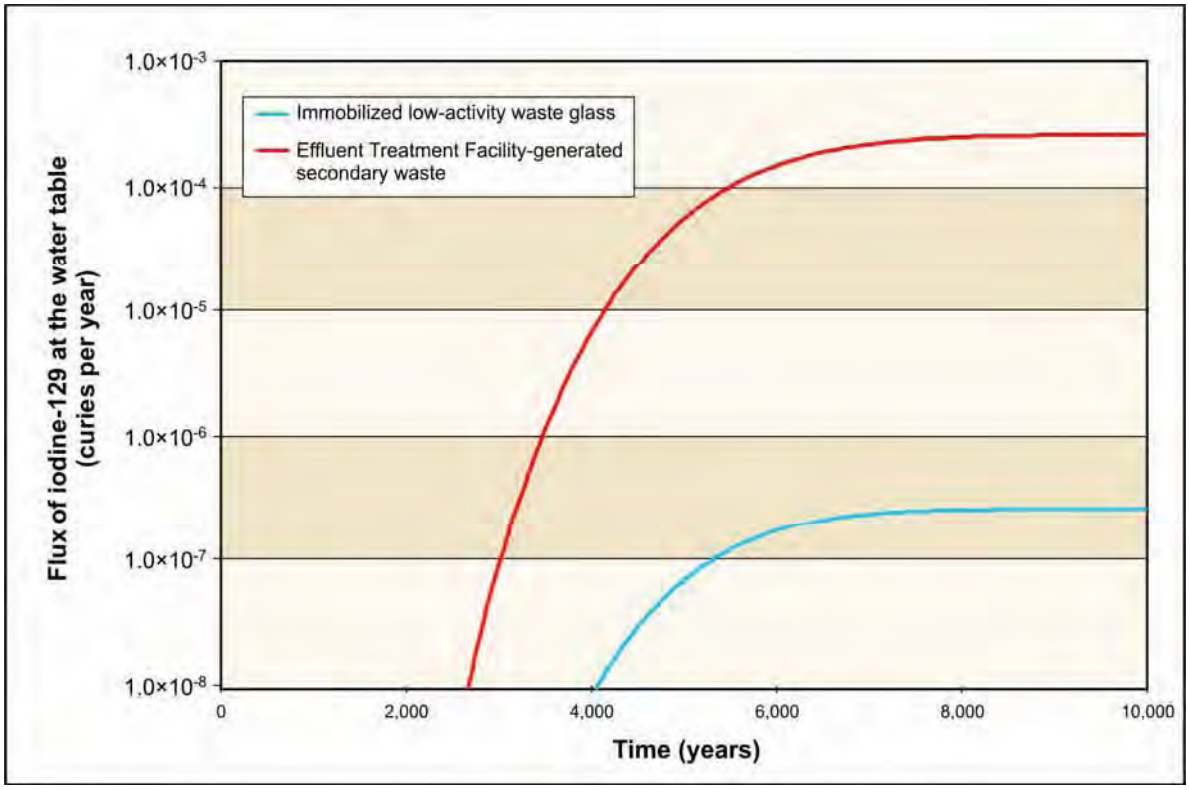


Figure N–154. Fluxes of Iodine-129 at the Water Table for Two Waste Forms for the 20 Percent Partition to Immobilized Low-Activity Waste Glass Case

For the case involving 70 percent partition to ILAW glass, 33.5 curies of iodine-129 would be present in ILAW glass and 12.6 curies in ETF secondary waste. The estimated fluxes of iodine-129 at the water table for the two waste forms for this case are presented as Figure N–155. Cumulative fluxes over the 10,000-year period of analysis are 0.004 and 0.41 for the ILAW glass and ETF secondary waste forms, respectively. The estimated fluxes of iodine-129 at the water table for the cases of 20 and 70 percent partition to ILAW glass are presented as Figure N–156. The results indicate that increasing the portion of the iodine in the ILAW glass from 20 to 70 percent could lead to a reduction in the flux of iodine-129 at the water table by a factor between two and three. The results indicate that implementation of increased retention of iodine-129 in ILAW glass would improve the performance of such an alternative in comparison with alternatives having supplemental waste forms that could not benefit from an equivalent change in process design.

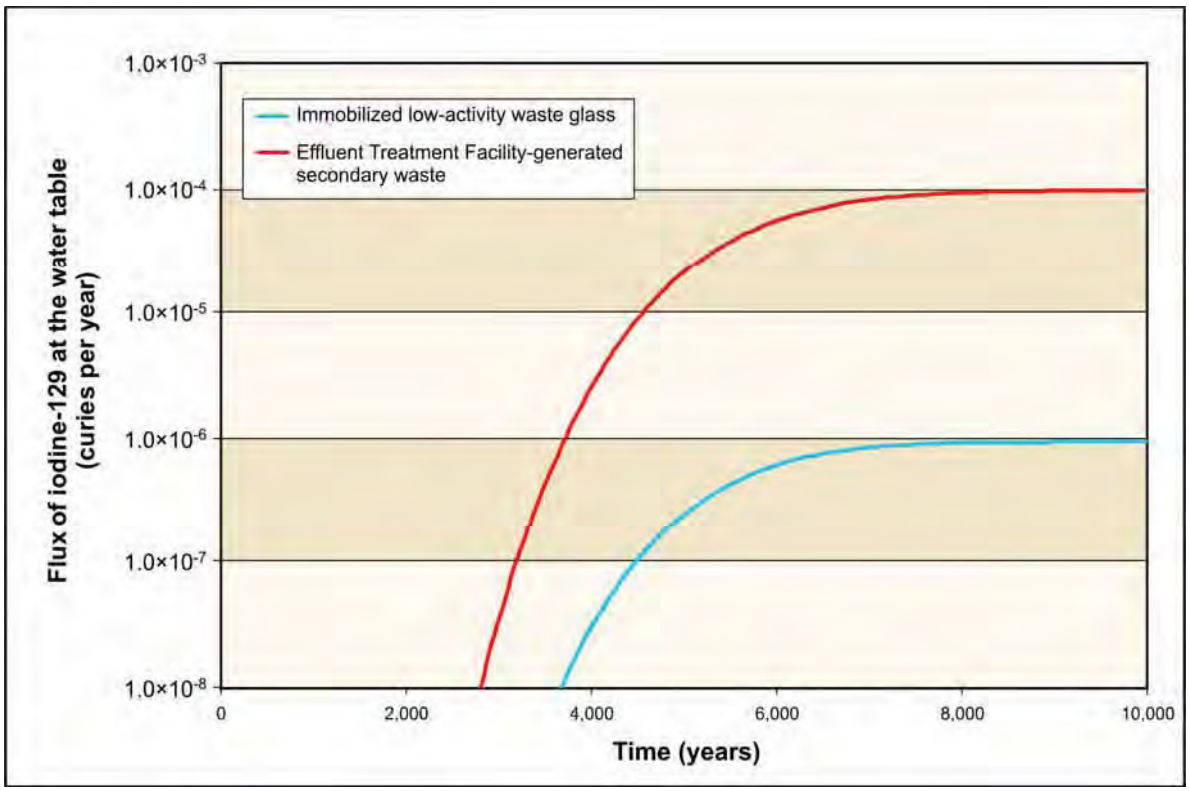


Figure N–155. Fluxes of Iodine-129 at the Water Table for Two Waste Forms for the 70 Percent Partition to Immobilized Low-Activity Waste Glass Case

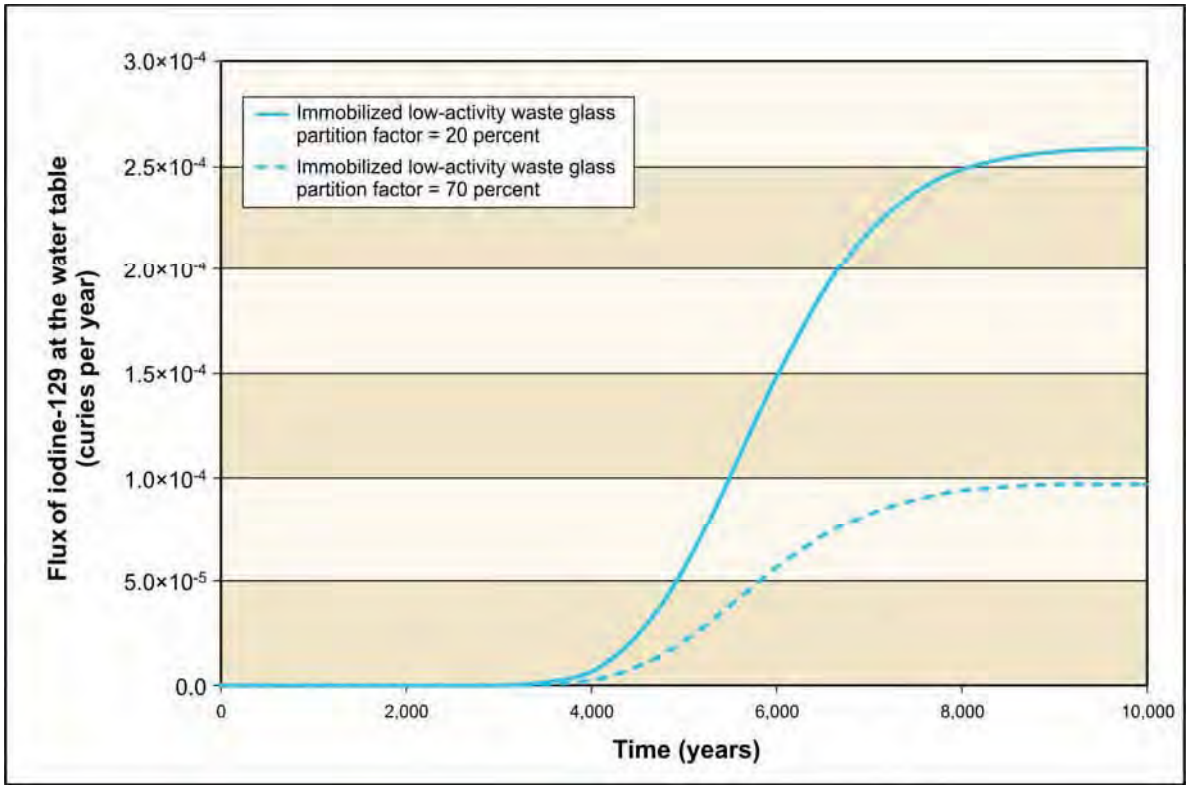


Figure N–156. Fluxes of Iodine-129 at the Water Table for the 20 Percent and 70 Percent Partition to Immobilized Low-Activity Waste Glass Cases

N.4 REFERENCES

Cantrell, K.J., R.J. Serne, and G.V. Last, 2003, *Hanford Contaminant Distribution Coefficient Database and User's Guide*, PNNL-13895, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington, June.

DOE (U.S. Department of Energy), 2005, *Technical Guidance Document for Tank Closure Environmental Impact Statement, Vadose and Groundwater Revised Analyses*, Final Rev. 0, Office of River Protection, Richland, Washington, March 25.

Fayer, M.J., and T.B. Walters, 1995, *Estimated Recharge Rates at the Hanford Site*, PNL-10285, Pacific Northwest Laboratory, Richland, Washington, February.

Hanlon, B.M., 2003, *Waste Tank Summary Report for Month Ending August 31, 2003*, HNF-EP-0182, Rev. 185, CH2M HILL Hanford Group, Inc., Richland, Washington, October.

Hartman, M.J., L.F. Morasch, and W.D. Webber, eds., 2004, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*, PNNL-14548, Pacific Northwest National Laboratory, Richland, Washington, March.

Hartman, M.J., L.F. Morasch, and W.D. Webber, eds., 2006, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, PNNL-15670, Pacific Northwest National Laboratory, Richland, Washington, March.

Hartman, M.J., and W.D. Webber, eds., 2008, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*, DOE/RL-2008-01, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington, March.

Mualem, Y., 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research*, Vol. 12, pp. 513–522.

Murray, C., A. Ward, and J. Wilson, 2003, *Influence of Clastic Dikes on Vertical Migration of Contaminants in the Vadose Zone at Hanford*, PNNL-14224, Pacific Northwest National Laboratory, Richland, Washington, March.

Van Genuchten, M. Th., 1980, "A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," *Soil Science Society of America Journal*, Vol. 44, pp. 892–898.

White, M.D., and M. Oostrom, 2000, *STOMP Subsurface Transport Over Multiple Phases, Version 2.0: Theory Guide*, PNNL-12030, Pacific Northwest National Laboratory, Richland, Washington, March.

White, M.D., and M. Oostrom, 2006, *STOMP Subsurface Transport Over Multiple Phases, Version 4.0: User's Guide*, PNNL-15782, Pacific Northwest National Laboratory, Richland, Washington, June.

U.S. Department of Energy Guide

DOE Guide 435.1-1, *Implementation Guide for Use with DOE M 435.1-1*, July 9, 1999.

APPENDIX O
GROUNDWATER TRANSPORT ANALYSIS

This appendix presents groundwater transport analysis as it relates to groundwater transport model development and results.

O.1 INTRODUCTION

The groundwater transport analysis for the *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* focuses on groundwater quality and its relationship to long-term human health impacts. Groundwater quality is affected when discharges from facilities reach groundwater beneath the facilities. Contaminants from these discharges can be transported through the unconfined aquifer beneath the facilities and may enter the Columbia River. This appendix presents groundwater transport analysis as it relates to groundwater transport model development and groundwater transport model results. These results include a comparison of the projected water quality to a benchmark value derived from relevant regulatory standards, including the Clean Water Act, Safe Drinking Water Act, and Washington State regulations, as means of assessing long-term human health impacts.

O.1.1 Purpose

The purpose of groundwater transport analysis is to project the concentrations of contaminants released under each *TC & WM EIS* alternative from Hanford Site (Hanford) source locations through the unconfined aquifer to potential receptor locations (i.e., lines of analysis that include facility boundaries, barriers, the Core Zone Boundary, and the Columbia River) and to compare those results to relevant regulatory standards as means of assessing the long-term human health impacts. To achieve this purpose, the contaminant transport model links information from the groundwater flow field (which describes the directions and rates of groundwater flow; see Appendix L) and information from the vadose-zone transport model (which describes the rate of introduction of contaminants into the unconfined aquifer, see Appendix N). Output from the contaminant transport model includes concentrations of contaminants as a function of time at specified lines of analyses and maps of spatial distributions of contaminants at selected times.

O.1.2 Scope and Methodology

This section describes the scope of this appendix and the methodology used for the groundwater transport analysis conducted for this *TC & WM EIS*. Section O.2 summarizes the aspects of the particle-tracking method used to implement the contaminant transport model that are unique to this *TC & WM EIS* (citations are provided for general aspects of the method that are not unique to this *TC & WM EIS*). Groundwater transport modeling results for the Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives are contained in Sections O.3, O.4, and O.5, respectively. Section O.6 contains results that illustrate the effects of uncertainties in the input data on calculated results.

For each of the *TC & WM EIS* alternatives, data packages were developed to identify source locations within the Hanford study area and associated contaminant discharges to groundwater. Overall, this process resulted in approximately 1,700 individual groundwater contaminant transport runs. The inputs for the groundwater contaminant transport runs were based on outputs from vadose zone flow and transport runs that were calculated using the STOMP [Subsurface Transport Over Multiple Phases] computer modeling code (Nichols et al. 1997; White and Oostrom 1996, 1997). The STOMP code is discussed in Appendix N. Contaminants were excluded from groundwater transport runs if their STOMP results produced zero flux or peak fluxes that were less than 10×10^{-8} curies for radionuclide

contaminants or 10×10^{-8} grams for chemical contaminants. Peak fluxes smaller than these values resulted in maximum contaminant concentrations that were 2 orders of magnitude lower than benchmark values.

The particle-tracking code (see Section O.2) and the MODFLOW [modular three-dimensional finite-difference groundwater flow model] Base Case flow field (see Appendix L) were used to calculate a fully three-dimensional transient analysis of groundwater transport over a period of 10,000 years for each source location. The radionuclide and chemical contaminants included in this analysis are listed in Table O–1.

Table O–1. Contaminants Selected for Groundwater Transport Analysis

Americium-241	Benzene
Carbon-14	Boron and compounds
Cesium-137	Cadmium
Gadolinium-152	Carbon tetrachloride
Hydrogen-3 (tritium)	Chromium
Iodine-129	Dichloromethane
Potassium-40	Fluoride
Neptunium-237	Hydrazine/hydrazine sulfate
Plutonium-239 (includes plutonium-239 and -240)	Lead
Strontium-90	Manganese
Technetium-99	Mercury
Thorium-232	Molybdenum
Uranium-238 (includes uranium-233, -234, -235, and -238)	Nickel (soluble salts)
Zirconium-93	Nitrate
1,2-Dichloroethane	Polychlorinated biphenyls
1,4-Dioxane	Silver
1-Butanol	Strontium (stable)
Trichlorophenol	Trichloroethylene
Acetonitrile	Uranium total
Arsenic, inorganic	Vinyl chloride

Note: Groundwater transport analyses were also performed using consistent methodology for the long-term cumulative site and Black Rock Reservoir discharges. The long-term cumulative site results are included in Appendix U, while the Black Rock Reservoir results are included in Appendix V.

O.1.2.1 Source Locations

The source locations for the *TC & WM EIS* Tank Closure, FFTF Decommissioning, and Waste Management alternatives include contaminant discharges from the following:

- Cribs and trenches (ditches) closely associated with the tank farms (the B, BX, BY, T, TX, and TY cribs and trenches [ditches])
- 18 tanks farms (the A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, and U tank farms)
- FFTF

- Low-level radioactive waste burial ground (LLBG) 218-W-5 trenches 31 and 34 (Waste Management Alternative 1)

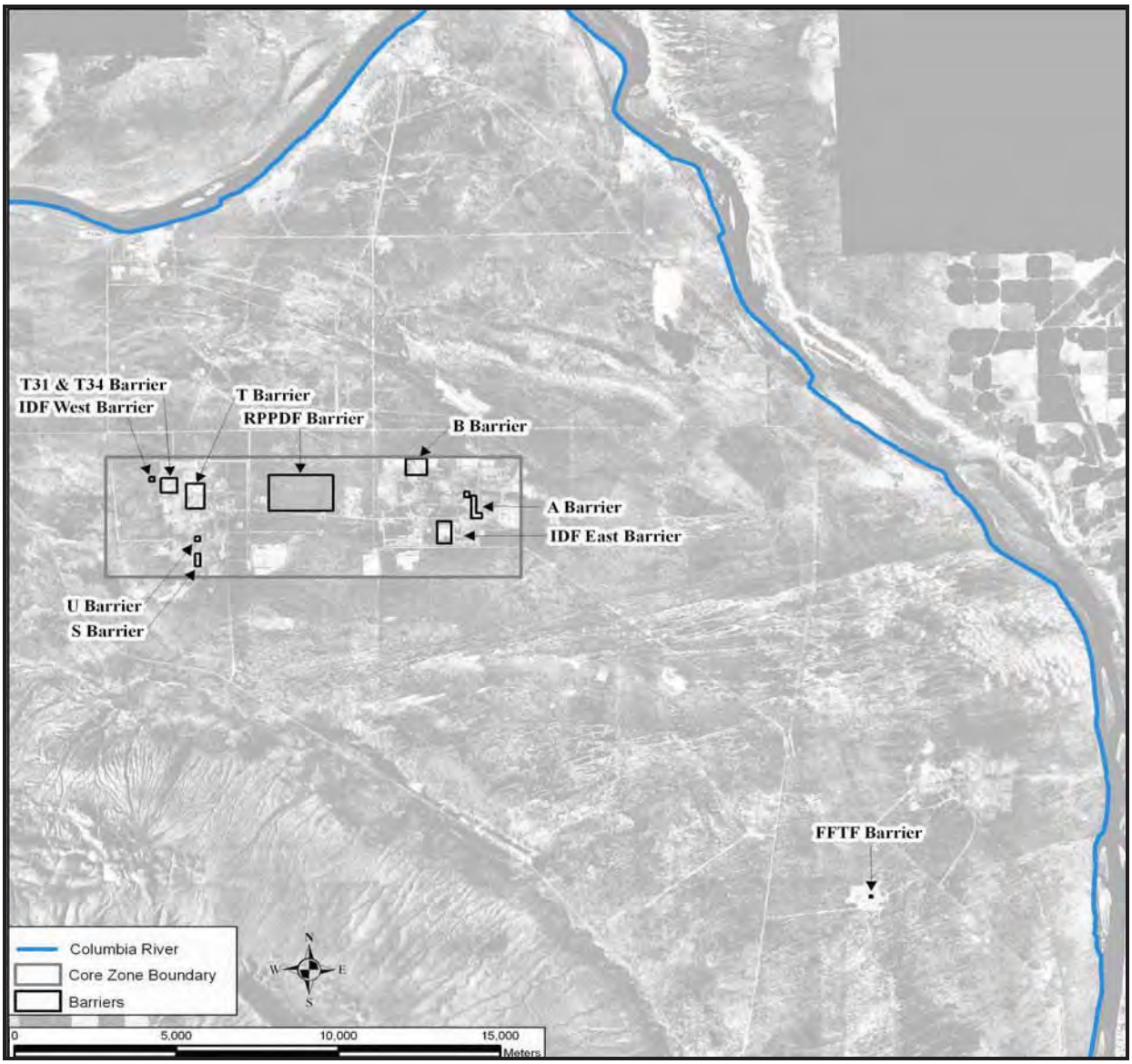
- Numerous waste forms, including immobilized low-activity waste (ILAW) glass, bulk vitrification glass, cast stone, steam reforming waste, Effluent Treatment Facility-generated secondary waste, other secondary waste, and offsite waste, discharged from an Integrated Disposal Facility (IDF) (Waste Management Alternatives 2 and 3)

- Waste from tank farm closure operations (e.g., from the River Protection Project Disposal Facility [RPPDF])

The locations of these facilities and areas were taken from the Hanford Site Atlas (BHI 2001).

O.1.2.2 Contaminant Reporting–Lines of Analysis

For the *TC & WM EIS* groundwater transport analyses, maximum concentrations were reported as a function of time along lines of analysis representing locations of interest within the Hanford study area. Near-field (i.e., close to the source location) lines of analysis include barrier boundaries (i.e., the edges of infiltration barriers constructed over disposal areas that are within 100 meters of facility fence lines). The near-field lines of analysis include the A, B, S, T, and U Barriers constructed over the tank farms and the closely associated cribs and trenches (ditches); the FFTF barrier; the 200-East Area IDF (IDF-East) and 200-West Area IDF (IDF-West) barriers; the LLBG 218-W-5 trench 31 and 34 barrier; and the RPPDF barrier. The midfield line of analysis is the Core Zone Boundary (see Chapter 2, Section 2.9.1.1). The far-field line of analysis is the Columbia River nearshore. The simulated contaminant concentrations along each line of analysis were evaluated for each time step and the highest concentration was tabulated. The locations of the lines of analysis are shown in Figure O–1.



Key: FFTF=Fast Flux Test Facility; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility; T31 & T34=trenches 31 and 34.

Figure O–1. Hanford Site Map Showing Locations of Lines of Analysis

O.1.3 Technical Guidance

In accordance with the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* (DOE 2005), two flow fields were developed. The Base Case flow field represented a condition in which long-term flow direction would be predominantly eastward; the Alternate Case, predominantly northward. The development of these flow fields is discussed in Appendix L. The results of the groundwater transport analysis presented in this appendix were calculated using the Base Case flow field. The results from the Alternate Case flow field were compared to those from the Base Case flow field as part of a sensitivity analysis for both the operational and postoperational time periods. The data from these sensitivity analyses are presented in Section O.6.

O.2 PARTICLE-TRACKING METHODOLOGY AND PARAMETER ESTIMATION

This section summarizes those aspects of the particle-tracking method used to implement the contaminant transport model that are unique to this *TC & WM EIS* (citations are provided for general aspects of the method that are not unique to this *TC & WM EIS*). The particle-tracking method models contaminant transport in the saturated zone that is under the influence of the groundwater flow field (advection), hydrodynamic dispersion, retardation, and radioactive decay. Development, validation, and applications of the particle-tracking method to evaluate contaminant transport are described in numerous open-literature publications (e.g., Ahlstrom et al. 1977; Prickett, Naymik, and Lonnquist 1981; Kinzelbach 1986: 298-315; Uffink 1983; LaBolle, Quastel, and Fogg 1998). This method is explicitly mass-conserving, has no numeric convergence issues, and is suitable for use in advection-dominated situations.

The following additions to the general particle-tracking methodology were developed for this *TC & WM EIS*:

- An interface with the vadose-zone contaminant transport model (STOMP)
- An evaluation of contaminant concentrations along lines of analysis
- A Gelhar description of the scale-dependence of dispersivity (Gelhar 1986)

These modifications are discussed in Sections O.2.1 through O.2.3. Section O.2.4 discusses the parameters that were used to model contaminant transport in the unconfined aquifer.

O.2.1 Interface with STOMP

The vadose-zone transport model (STOMP; see Appendix N) provides the contaminant flux to the particle-tracking model. Thus, each particle-tracking simulation must be preceded by a vadose zone simulation. An interface was developed to transfer the contaminant flux from the STOMP simulations to the particle-tracking model. Each STOMP simulation models a specific source that contains three release areas (see Appendix N). These areas are rectangular in shape and are numbered from 1 to 3, as shown in Figure O–2. In particular, area 1 is entirely contained within area 2, which in turn is completely contained within area 3. The collection of areas can then be rotated by an angle, θ, about the southwest corner, with θ measured in the positive clockwise direction.

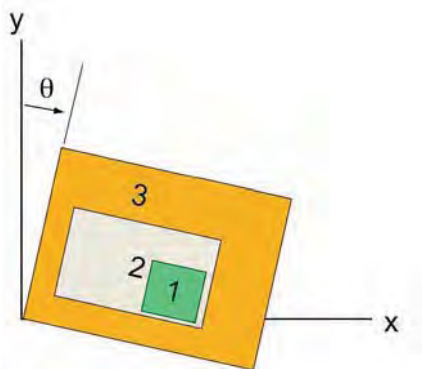


Figure O–2. Configuration of Release Areas for a Given Source

The flux through each release area as a function of time is calculated by STOMP. This time series of fluxes are read by the particle-tracking code, which describes the release of contaminants into the aquifer.

O.2.2 Reporting Concentration Along Lines of Analysis

After each time step, a grid of concentration values is calculated across the simulation domain using standard particle-tracking methodology (e.g., Kinzelbach 1986). The geographic definition of each line of analysis (i.e., the locations of the points along the line of analysis) is used to search the associated concentration grid elements to find the maximum concentration. In general, the location of the peak concentration along a line of analysis changes from time step to time step because the contaminant spatial distribution varies with time.

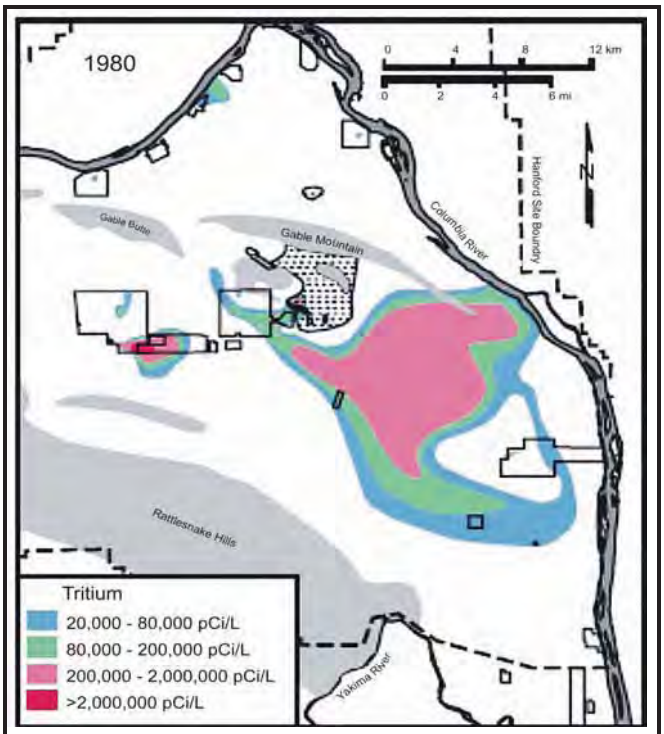
O.2.3 Scale-Dependent Dispersivity

Dispersivity is a measure of the degree of spreading of a contaminant plume. In the standard implementation of the particle-tracking method, the dispersivity is a constant and does not depend on distance from the source (scale). This *TC & WM EIS* uses a regional-scale model, which was considered important to describe the scale dependence of dispersivity. The Gelhar method (Gelhar 1986) was implemented in the particle-tracking model. The dispersivity increases linearly with distance from the source location up to a specified threshold. At distances greater than this threshold, the dispersivity remains constant at its maximum value.

O.2.4 Calibration Tests

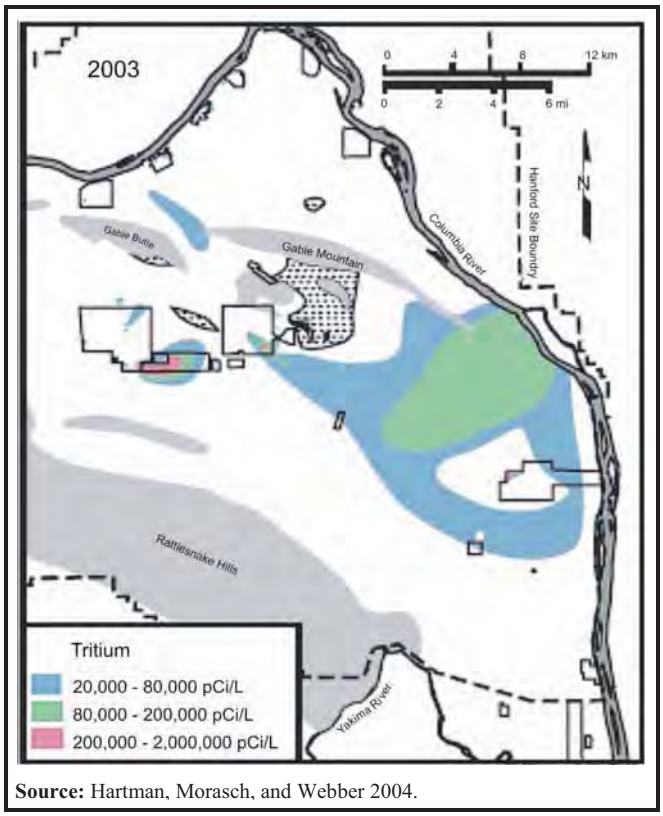
The particle-tracking model requires several parameters that describe physical properties of the unconfined aquifer. To obtain these parameters, a series of calibration tests were performed by varying the aquifer properties, initial injection depth, and well screen depth; calculating contaminant spatial distributions for two regional-scale contaminant plumes (the Plutonium-Uranium Extraction [PUREX] waste site and Reduction-Oxidation [REDOX] waste site hydrogen-3 [tritium] plumes, so called because of proximity for the respective facilities but composed of other waste discharge sources also); and adjusting the parameters to obtain a qualitative fit to observed tritium concentrations. Resulting tritium plume maps were generated for the years 1980, 1990, and 2005. These maps were visually compared to associated tritium plume maps provided in *Hanford Site Groundwater Monitoring for Fiscal Year 2003* (Hartman, Morasch, and Webber 2004).

Figures O–3 and O–4 are qualitative interpretations of the spatial distribution of tritium plumes in 1980 and 2003. The PUREX waste site plume is larger than the REDOX waste site plume, and its source location is in the southwest portion of 200-East Area. The REDOX waste site plume (to the west of the PUREX waste site plume) extends from the southern part of the 200-West Area through the center of the Central Plateau. Note that, by 1980, tritium concentrations greater than 20,000 picocuries per liter had reached the Columbia River and the 400 Area (FFTF). Peak concentrations in both the PUREX and REDOX waste site plumes are in excess of 2 million picocuries per liter. The PUREX waste site plume is approximately five times larger than the REDOX waste site plume, reflecting the higher hydraulic conductivity of the aquifer materials east of the Central Plateau (see Appendix L). By 2003 (Figure O-4), radioactive decay had attenuated peak concentrations in both plumes; however, the areas in excess of 20,000 picocuries per liter are approximately the same as in 1980. These are the principal features of the plumes against which the calibration test results were compared.



Source: Hartman, Morasch, and Webber 2004.

Figure O–3. Sitewide Hydrogen-3 (Tritium) Plumes, Calendar Year 1980



Source: Hartman, Morasch, and Webber 2004.

Figure O–4. Sitewide Hydrogen-3 (Tritium) Plumes, Calendar Year 2003

O.2.4.1 Sensitivity to Dispersivity Parameters

Longitudinal dispersivities of 100, 500, and 1,000 meters were examined to determine the effects on PUREX and REDOX waste site tritium plume concentrations. Each parameter set explored as part of these calibration tests is included in Table O–2 and Table O–3. The best overall fit with the groundwater monitoring data was based on tritium concentrations values reported at the Core Zone and Columbia River. As a result of these calibration tests, the values from Runs P10 and R10 were selected as the best fit parameter set. This selection was based on visual comparison of the tritium plume maps generated from these runs (Figures O–5 through O–10) to associated tritium plume maps provided in *Hanford Site Groundwater Monitoring for Fiscal Year 2003* (Figures O–3 and O–4) (Hartman, Morasch, and Webber 2004).

O.2.4.2 Sensitivity to Well Screen Depth for Calculating Concentration

Well screen depths of 10 and 40 meters were examined to determine the effects on PUREX and REDOX waste site tritium plume concentrations. Each parameter set explored as part of these calibration tests is included in Table O–2 and Table O–3. The best overall fit with the groundwater monitoring data was based on tritium concentrations values reported at the Core Zone and Columbia River. As a result of these calibration tests, the values from Runs P10 and R10 were selected as the best fit parameter set. This selection was based on visual comparison of the tritium plume maps generated from these runs (Figures O–5 through O–10) to associated tritium plume maps shown from *Hanford Site Groundwater Monitoring for Fiscal Year 2003* (Figures O–3 and O–4) (Hartman, Morasch, and Webber 2004).

O.2.4.3 Sensitivity to Initial Particle Injection Depth

Particle injection depths of 1, 5, 10, and 15 meters were examined to determine the effects on PUREX and REDOX waste site tritium plume concentrations. Each parameter set explored as part of these calibration tests is included in Tables O–2 and O–3. [The values presented in red represent parameters for each calibration run.] The best overall fit with the groundwater monitoring data was based on tritium concentrations values reported at the Core Zone and Columbia River. As a result of these calibration tests, the values from Runs P10 and R10 were selected as the best fit parameter set. This selection was based on the visual comparison of the tritium plume maps generated from these runs (Figures O–5 through O–10) to associated tritium plume maps provided in *Hanford Site Groundwater Monitoring for Fiscal Year 2003* (Figures O–3 and O–4) (Hartman, Morasch, and Webber 2004).

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P1)	**100**	**1,000**	**0.1**	**0.01**	**0.001**	**1**	**40**
216-A-4	100	1,000	0.1	0.01	0.001	1	40
216-A-5	100	1,000	0.1	0.01	0.001	1	40
216-A-6	100	1,000	0.1	0.01	0.001	1	40
216-A-8	100	1,000	0.1	0.01	0.001	1	40
216-A-10	100	1,000	0.1	0.01	0.001	1	40
216-A-21	100	1,000	0.1	0.01	0.001	1	40
216-A-24	100	1,000	0.1	0.01	0.001	1	40
216-A-27	100	1,000	0.1	0.01	0.001	1	40
216-A-30	100	1,000	0.1	0.01	0.001	1	40
216-A-36-B	100	1,000	0.1	0.01	0.001	1	40
216-A-37-1	100	1,000	0.1	0.01	0.001	1	40
216-A-37-2	100	1,000	0.1	0.01	0.001	1	40
216-A-45	100	1,000	0.1	0.01	0.001	1	40
Run (P2)	**100**	**1,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-A-4	100	1,000	0.1	0.1	0.001	1	40
216-A-5	100	1,000	0.1	0.1	0.001	1	40
216-A-6	100	1,000	0.1	0.1	0.001	1	40
216-A-8	100	1,000	0.1	0.1	0.001	1	40
216-A-10	100	1,000	0.1	0.1	0.001	1	40
216-A-21	100	1,000	0.1	0.1	0.001	1	40
216-A-24	100	1,000	0.1	0.1	0.001	1	40
216-A-27	100	1,000	0.1	0.1	0.001	1	40
216-A-30	100	1,000	0.1	0.1	0.001	1	40
216-A-36-B	100	1,000	0.1	0.1	0.001	1	40
216-A-37-1	100	1,000	0.1	0.1	0.001	1	40
216-A-37-2	100	1,000	0.1	0.1	0.001	1	40
216-A-45	100	1,000	0.1	0.1	0.001	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P3)	**100**	**1,000**	**0.1**	**0.1**	**0.1**	**1**	**40**
216-A-4	100	1,000	0.1	0.1	0.1	1	40
216-A-5	100	1,000	0.1	0.1	0.1	1	40
216-A-6	100	1,000	0.1	0.1	0.1	1	40
216-A-8	100	1,000	0.1	0.1	0.1	1	40
216-A-10	100	1,000	0.1	0.1	0.1	1	40
216-A-21	100	1,000	0.1	0.1	0.1	1	40
216-A-24	100	1,000	0.1	0.1	0.1	1	40
216-A-27	100	1,000	0.1	0.1	0.1	1	40
216-A-30	100	1,000	0.1	0.1	0.1	1	40
216-A-36-B	100	1,000	0.1	0.1	0.1	1	40
216-A-37-1	100	1,000	0.1	0.1	0.1	1	40
216-A-37-2	100	1,000	0.1	0.1	0.1	1	40
216-A-45	100	1,000	0.1	0.1	0.1	1	40
Run (P4)	**100**	**1,000**	**0.1**	**0.01**	**0.002**	**1**	**40**
216-A-4	100	1,000	0.1	0.01	0.002	1	40
216-A-5	100	1,000	0.1	0.01	0.002	1	40
216-A-6	100	1,000	0.1	0.01	0.002	1	40
216-A-8	100	1,000	0.1	0.01	0.002	1	40
216-A-10	100	1,000	0.1	0.01	0.002	1	40
216-A-21	100	1,000	0.1	0.01	0.002	1	40
216-A-24	100	1,000	0.1	0.01	0.002	1	40
216-A-27	100	1,000	0.1	0.01	0.002	1	40
216-A-30	100	1,000	0.1	0.01	0.002	1	40
216-A-36-B	100	1,000	0.1	0.01	0.002	1	40
216-A-37-1	100	1,000	0.1	0.01	0.002	1	40
216-A-37-2	100	1,000	0.1	0.01	0.002	1	40
216-A-45	100	1,000	0.1	0.01	0.002	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P5)	**100**	**1,000**	**0.1**	**0.01**	**0.005**	**1**	**40**
216-A-4	100	1,000	0.1	0.01	0.005	1	40
216-A-5	100	1,000	0.1	0.01	0.005	1	40
216-A-6	100	1,000	0.1	0.01	0.005	1	40
216-A-8	100	1,000	0.1	0.01	0.005	1	40
216-A-10	100	1,000	0.1	0.01	0.005	1	40
216-A-21	100	1,000	0.1	0.01	0.005	1	40
216-A-24	100	1,000	0.1	0.01	0.005	1	40
216-A-27	100	1,000	0.1	0.01	0.005	1	40
216-A-30	100	1,000	0.1	0.01	0.005	1	40
216-A-36-B	100	1,000	0.1	0.01	0.005	1	40
216-A-37-1	100	1,000	0.1	0.01	0.005	1	40
216-A-37-2	100	1,000	0.1	0.01	0.005	1	40
216-A-45	100	1,000	0.1	0.01	0.005	1	40
Run (P6)	**100**	**1,000**	**0.1**	**0.02**	**0.005**	**1**	**40**
216-A-4	100	1,000	0.1	0.02	0.005	1	40
216-A-5	100	1,000	0.1	0.02	0.005	1	40
216-A-6	100	1,000	0.1	0.02	0.005	1	40
216-A-8	100	1,000	0.1	0.02	0.005	1	40
216-A-10	100	1,000	0.1	0.02	0.005	1	40
216-A-21	100	1,000	0.1	0.02	0.005	1	40
216-A-24	100	1,000	0.1	0.02	0.005	1	40
216-A-27	100	1,000	0.1	0.02	0.005	1	40
216-A-30	100	1,000	0.1	0.02	0.005	1	40
216-A-36-B	100	1,000	0.1	0.02	0.005	1	40
216-A-37-1	100	1,000	0.1	0.02	0.005	1	40
216-A-37-2	100	1,000	0.1	0.02	0.005	1	40
216-A-45	100	1,000	0.1	0.02	0.005	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P7)	**100**	**1,000**	**0.1**	**0.05**	**0.005**	**1**	**40**
216-A-4	100	1,000	0.1	0.05	0.005	1	40
216-A-5	100	1,000	0.1	0.05	0.005	1	40
216-A-6	100	1,000	0.1	0.05	0.005	1	40
216-A-8	100	1,000	0.1	0.05	0.005	1	40
216-A-10	100	1,000	0.1	0.05	0.005	1	40
216-A-21	100	1,000	0.1	0.05	0.005	1	40
216-A-24	100	1,000	0.1	0.05	0.005	1	40
216-A-27	100	1,000	0.1	0.05	0.005	1	40
216-A-30	100	1,000	0.1	0.05	0.005	1	40
216-A-36-B	100	1,000	0.1	0.05	0.005	1	40
216-A-37-1	100	1,000	0.1	0.05	0.005	1	40
216-A-37-2	100	1,000	0.1	0.05	0.005	1	40
216-A-45	100	1,000	0.1	0.05	0.005	1	40
Run (P8) Runs 1-6							
P8 Run 1	**100**	**1,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-A-8	100	1,000	0.1	0.1	0.001	1	40
P8 Run 2	**100**	**1,000**	**0.1**	**0.1**	**0.01**	**1**	**40**
216-A-8	100	1,000	0.1	0.1	0.01	1	40
P8 Run 3	**100**	**1,000**	**0.1**	**0.01**	**0.002**	**1**	**40**
216-A-8	100	1,000	0.1	0.01	0.002	1	40
P8 Run 4	**100**	**1,000**	**0.1**	**0.1**	**0.002**	**1**	**40**
216-A-8	100	1,000	0.1	0.1	0.002	1	40
P8 Run 5	**100**	**1,000**	**0.1**	**0.01**	**0.005**	**1**	**40**
216-A-8	100	1,000	0.1	0.01	0.005	1	40
P8 Run 6	**100**	**1,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-A-8	100	1,000	0.1	0.1	0.005	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P9)	**500**	**5,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-A-4	500	5,000	0.1	0.1	0.005	1	40
216-A-5	500	5,000	0.1	0.1	0.005	1	40
216-A-6	500	5,000	0.1	0.1	0.005	1	40
216-A-8	500	5,000	0.1	0.1	0.005	1	40
216-A-10	500	5,000	0.1	0.1	0.005	1	40
216-A-21	500	5,000	0.1	0.1	0.005	1	40
216-A-24	500	5,000	0.1	0.1	0.005	1	40
216-A-27	500	5,000	0.1	0.1	0.005	1	40
216-A-30	500	5,000	0.1	0.1	0.005	1	40
216-A-36-B	500	5,000	0.1	0.1	0.005	1	40
216-A-37-1	500	5,000	0.1	0.1	0.005	1	40
216-A-37-2	500	5,000	0.1	0.1	0.005	1	40
216-A-45	500	5,000	0.1	0.1	0.005	1	40
Run (P10)	**500**	**5,000**	**0.1**	**0.1**	**0**	**1**	**40**
216-A-4	500	5,000	0.1	0.1	0	1	40
216-A-5	500	5,000	0.1	0.1	0	1	40
216-A-6	500	5,000	0.1	0.1	0	1	40
216-A-8	500	5,000	0.1	0.1	0	1	40
216-A-10	500	5,000	0.1	0.1	0	1	40
216-A-21	500	5,000	0.1	0.1	0	1	40
216-A-24	500	5,000	0.1	0.1	0	1	40
216-A-27	500	5,000	0.1	0.1	0	1	40
216-A-30	500	5,000	0.1	0.1	0	1	40
216-A-36-B	500	5,000	0.1	0.1	0	1	40
216-A-37-1	500	5,000	0.1	0.1	0	1	40
216-A-37-2	500	5,000	0.1	0.1	0	1	40
216-A-45	500	5,000	0.1	0.1	0	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P11)	**500**	**5,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-A-4	500	5,000	0.1	0.1	0.001	1	40
216-A-5	500	5,000	0.1	0.1	0.001	1	40
216-A-6	500	5,000	0.1	0.1	0.001	1	40
216-A-8	500	5,000	0.1	0.1	0.001	1	40
216-A-10	500	5,000	0.1	0.1	0.001	1	40
216-A-21	500	5,000	0.1	0.1	0.001	1	40
216-A-24	500	5,000	0.1	0.1	0.001	1	40
216-A-27	500	5,000	0.1	0.1	0.001	1	40
216-A-30	500	5,000	0.1	0.1	0.001	1	40
216-A-36-B	500	5,000	0.1	0.1	0.001	1	40
216-A-37-1	500	5,000	0.1	0.1	0.001	1	40
216-A-37-2	500	5,000	0.1	0.1	0.001	1	40
216-A-45	500	5,000	0.1	0.1	0.001	1	40
Run (P12)	**500**	**5,000**	**0.1**	**0.1**	**0**	**10**	**40**
216-A-4	500	5,000	0.1	0.1	0	10	40
216-A-5	500	5,000	0.1	0.1	0	10	40
216-A-6	500	5,000	0.1	0.1	0	10	40
216-A-8	500	5,000	0.1	0.1	0	10	40
216-A-10	500	5,000	0.1	0.1	0	10	40
216-A-21	500	5,000	0.1	0.1	0	10	40
216-A-24	500	5,000	0.1	0.1	0	10	40
216-A-27	500	5,000	0.1	0.1	0	10	40
216-A-30	500	5,000	0.1	0.1	0	10	40
216-A-36-B	500	5,000	0.1	0.1	0	10	40
216-A-37-1	500	5,000	0.1	0.1	0	10	40
216-A-37-2	500	5,000	0.1	0.1	0	10	40
216-A-45	500	5,000	0.1	0.1	0	10	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P13)	**500**	**5,000**	**0.1**	**0.1**	**0**	**15**	**40**
216-A-4	500	5,000	0.1	0.1	0	15	40
216-A-5	500	5,000	0.1	0.1	0	15	40
216-A-6	500	5,000	0.1	0.1	0	15	40
216-A-8	500	5,000	0.1	0.1	0	15	40
216-A-10	500	5,000	0.1	0.1	0	15	40
216-A-21	500	5,000	0.1	0.1	0	15	40
216-A-24	500	5,000	0.1	0.1	0	15	40
216-A-27	500	5,000	0.1	0.1	0	15	40
216-A-30	500	5,000	0.1	0.1	0	15	40
216-A-36-B	500	5,000	0.1	0.1	0	15	40
216-A-37-1	500	5,000	0.1	0.1	0	15	40
216-A-37-2	500	5,000	0.1	0.1	0	15	40
216-A-45	500	5,000	0.1	0.1	0	15	40
Run (P14)	**1,000**	**10,000**	**0.1**	**0.1**	**0**	**1**	**40**
216-A-4	1,000	10,000	0.1	0.1	0	1	40
216-A-5	1,000	10,000	0.1	0.1	0	1	40
216-A-6	1,000	10,000	0.1	0.1	0	1	40
216-A-8	1,000	10,000	0.1	0.1	0	1	40
216-A-10	1,000	10,000	0.1	0.1	0	1	40
216-A-21	1,000	10,000	0.1	0.1	0	1	40
216-A-24	1,000	10,000	0.1	0.1	0	1	40
216-A-27	1,000	10,000	0.1	0.1	0	1	40
216-A-30	1,000	10,000	0.1	0.1	0	1	40
216-A-36-B	1,000	10,000	0.1	0.1	0	1	40
216-A-37-1	1,000	10,000	0.1	0.1	0	1	40
216-A-37-2	1,000	10,000	0.1	0.1	0	1	40
216-A-45	1,000	10,000	0.1	0.1	0	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P15)	**100**	**1,000**	**0.1**	**0.1**	**0.01**	**1**	**40**
216-A-4	100	1,000	0.1	0.1	0.01	1	40
216-A-5	100	1,000	0.1	0.1	0.01	1	40
216-A-6	100	1,000	0.1	0.1	0.01	1	40
216-A-8	100	1,000	0.1	0.1	0.01	1	40
216-A-10	100	1,000	0.1	0.1	0.01	1	40
216-A-21	100	1,000	0.1	0.1	0.01	1	40
216-A-24	100	1,000	0.1	0.1	0.01	1	40
216-A-27	100	1,000	0.1	0.1	0.01	1	40
216-A-30	100	1,000	0.1	0.1	0.01	1	40
216-A-36-B	100	1,000	0.1	0.1	0.01	1	40
216-A-37-1	100	1,000	0.1	0.1	0.01	1	40
216-A-37-2	100	1,000	0.1	0.1	0.01	1	40
216-A-45	100	1,000	0.1	0.1	0.01	1	40
Run (P16)	**100**	**1,000**	**0.1**	**0.1**	**0.002**	**1**	**40**
216-A-4	100	1,000	0.1	0.1	0.002	1	40
216-A-5	100	1,000	0.1	0.1	0.002	1	40
216-A-6	100	1,000	0.1	0.1	0.002	1	40
216-A-8	100	1,000	0.1	0.1	0.002	1	40
216-A-10	100	1,000	0.1	0.1	0.002	1	40
216-A-21	100	1,000	0.1	0.1	0.002	1	40
216-A-24	100	1,000	0.1	0.1	0.002	1	40
216-A-27	100	1,000	0.1	0.1	0.002	1	40
216-A-30	100	1,000	0.1	0.1	0.002	1	40
216-A-36-B	100	1,000	0.1	0.1	0.002	1	40
216-A-37-1	100	1,000	0.1	0.1	0.002	1	40
216-A-37-2	100	1,000	0.1	0.1	0.002	1	40
216-A-45	100	1,000	0.1	0.1	0.002	1	40

Table O–2. Calibration Test Matrix for Plutonium-Uranium Extraction (PUREX) Plant Sites *(continued)*

PUREX Plant Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (P17)	**100**	**1,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-A-4	100	1,000	0.1	0.1	0.005	1	40
216-A-5	100	1,000	0.1	0.1	0.005	1	40
216-A-6	100	1,000	0.1	0.1	0.005	1	40
216-A-8	100	1,000	0.1	0.1	0.005	1	40
216-A-10	100	1,000	0.1	0.1	0.005	1	40
216-A-21	100	1,000	0.1	0.1	0.005	1	40
216-A-24	100	1,000	0.1	0.1	0.005	1	40
216-A-27	100	1,000	0.1	0.1	0.005	1	40
216-A-30	100	1,000	0.1	0.1	0.005	1	40
216-A-36-B	100	1,000	0.1	0.1	0.005	1	40
216-A-37-1	100	1,000	0.1	0.1	0.005	1	40
216-A-37-2	100	1,000	0.1	0.1	0.005	1	40
216-A-45	100	1,000	0.1	0.1	0.005	1	40
Run (P18)	**500**	**5,000**	**0.1**	**0.1**	**0**	**5**	**40**
216-A-4	500	5,000	0.1	0.1	0	5	40
216-A-5	500	5,000	0.1	0.1	0	5	40
216-A-6	500	5,000	0.1	0.1	0	5	40
216-A-8	500	5,000	0.1	0.1	0	5	40
216-A-10	500	5,000	0.1	0.1	0	5	40
216-A-21	500	5,000	0.1	0.1	0	5	40
216-A-24	500	5,000	0.1	0.1	0	5	40
216-A-27	500	5,000	0.1	0.1	0	5	40
216-A-30	500	5,000	0.1	0.1	0	5	40
216-A-36-B	500	5,000	0.1	0.1	0	5	40
216-A-37-1	500	5,000	0.1	0.1	0	5	40
216-A-37-2	500	5,000	0.1	0.1	0	5	40
216-A-45	500	5,000	0.1	0.1	0	5	40

Note: The values presented in red represent parameters modified for each calibration run. To convert meters to feet, multiply by 3.281.

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (R1)	**100**	**1,000**	**0.1**	**0.01**	**0.001**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.01	0.001	1	40
216-S-7	100	1,000	0.1	0.01	0.001	1	40
216-S-9	100	1,000	0.1	0.01	0.001	1	40
216-S-13	100	1,000	0.1	0.01	0.001	1	40
216-S-20	100	1,000	0.1	0.01	0.001	1	40
216-S-21	100	1,000	0.1	0.01	0.001	1	40
216-S-25	100	1,000	0.1	0.01	0.001	1	40
216-S-26	100	1,000	0.1	0.01	0.001	1	40
216-U-8	100	1,000	0.1	0.01	0.001	1	40
216-U-12	100	1,000	0.1	0.01	0.001	1	40
Run (R2)	**100**	**1,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.1	0.001	1	40
216-S-7	100	1,000	0.1	0.1	0.001	1	40
216-S-9	100	1,000	0.1	0.1	0.001	1	40
216-S-13	100	1,000	0.1	0.1	0.001	1	40
216-S-20	100	1,000	0.1	0.1	0.001	1	40
216-S-21	100	1,000	0.1	0.1	0.001	1	40
216-S-25	100	1,000	0.1	0.1	0.001	1	40
216-S-26	100	1,000	0.1	0.1	0.001	1	40
216-U-8	100	1,000	0.1	0.1	0.001	1	40
216-U-12	100	1,000	0.1	0.1	0.001	1	40
Run (R3)	**100**	**1,000**	**0.1**	**0.1**	**0.1**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.1	0.1	1	40
216-S-7	100	1,000	0.1	0.1	0.1	1	40
216-S-9	100	1,000	0.1	0.1	0.1	1	40
216-S-13	100	1,000	0.1	0.1	0.1	1	40
216-S-20	100	1,000	0.1	0.1	0.1	1	40
216-S-21	100	1,000	0.1	0.1	0.1	1	40
216-S-25	100	1,000	0.1	0.1	0.1	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
216-S-26	100	1,000	0.1	0.1	0.1	1	40
216-U-8	100	1,000	0.1	0.1	0.1	1	40
216-U-12	100	1,000	0.1	0.1	0.1	1	40
Run (R4)	**100**	**1,000**	**0.1**	**0.01**	**0.002**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.01	0.002	1	40
216-S-7	100	1,000	0.1	0.01	0.002	1	40
216-S-9	100	1,000	0.1	0.01	0.002	1	40
216-S-13	100	1,000	0.1	0.01	0.002	1	40
216-S-20	100	1,000	0.1	0.01	0.002	1	40
216-S-21	100	1,000	0.1	0.01	0.002	1	40
216-S-25	100	1,000	0.1	0.01	0.002	1	40
216-S-26	100	1,000	0.1	0.01	0.002	1	40
216-U-8	100	1,000	0.1	0.01	0.002	1	40
216-U-12	100	1,000	0.1	0.01	0.002	1	40
Run (R5)	**100**	**1,000**	**0.1**	**0.01**	**0.005**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.01	0.005	1	40
216-S-7	100	1,000	0.1	0.01	0.005	1	40
216-S-9	100	1,000	0.1	0.01	0.005	1	40
216-S-13	100	1,000	0.1	0.01	0.005	1	40
216-S-20	100	1,000	0.1	0.01	0.005	1	40
216-S-21	100	1,000	0.1	0.01	0.005	1	40
216-S-25	100	1,000	0.1	0.01	0.005	1	40
216-S-26	100	1,000	0.1	0.01	0.005	1	40
216-U-8	100	1,000	0.1	0.01	0.005	1	40
216-U-12	100	1,000	0.1	0.01	0.005	1	40
Run (R6)	**100**	**1,000**	**0.1**	**0.02**	**0.005**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.02	0.005	1	40
216-S-7	100	1,000	0.1	0.02	0.005	1	40
216-S-9	100	1,000	0.1	0.02	0.005	1	40
216-S-13	100	1,000	0.1	0.02	0.005	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
216-S-20	100	1,000	0.1	0.02	0.005	1	40
216-S-21	100	1,000	0.1	0.02	0.005	1	40
216-S-25	100	1,000	0.1	0.02	0.005	1	40
216-S-26	100	1,000	0.1	0.02	0.005	1	40
216-U-8	100	1,000	0.1	0.02	0.005	1	40
216-U-12	100	1,000	0.1	0.02	0.005	1	40
Run (R7)	**100**	**1,000**	**0.1**	**0.05**	**0.005**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.05	0.005	1	40
216-S-7	100	1,000	0.1	0.05	0.005	1	40
216-S-9	100	1,000	0.1	0.05	0.005	1	40
216-S-13	100	1,000	0.1	0.05	0.005	1	40
216-S-20	100	1,000	0.1	0.05	0.005	1	40
216-S-21	100	1,000	0.1	0.05	0.005	1	40
216-S-25	100	1,000	0.1	0.05	0.005	1	40
216-S-26	100	1,000	0.1	0.05	0.005	1	40
216-U-8	100	1,000	0.1	0.05	0.005	1	40
216-U-12	100	1,000	0.1	0.05	0.005	1	40
Run (R8) Runs 1-6							
R8 Run 1	**100**	**1,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-S-20	100	1,000	0.1	0.1	0.001	1	40
R8 Run 2	**100**	**1,000**	**0.1**	**0.1**	**0.01**	**1**	**40**
216-S-20	100	1,000	0.1	0.1	0.01	1	40
R8 Run 3	**100**	**1,000**	**0.1**	**0.01**	**0.002**	**1**	**40**
216-S-20	100	1,000	0.1	0.01	0.002	1	40
R8 Run 4	**100**	**1,000**	**0.1**	**0.1**	**0.002**	**1**	**40**
216-S-20	100	1,000	0.1	0.1	0.002	1	40
R8 Run 5	**100**	**1,000**	**0.1**	**0.01**	**0.005**	**1**	**40**
216-S-20	100	1,000	0.1	0.01	0.005	1	40
R8 Run 6	**100**	**1,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-S-20	100	1,000	0.1	0.1	0.005	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
Run (R9)	**500**	**5,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0.005	1	40
216-S-7	500	5,000	0.1	0.1	0.005	1	40
216-S-9	500	5,000	0.1	0.1	0.005	1	40
216-S-13	500	5,000	0.1	0.1	0.005	1	40
216-S-20	500	5,000	0.1	0.1	0.005	1	40
216-S-21	500	5,000	0.1	0.1	0.005	1	40
216-S-25	500	5,000	0.1	0.1	0.005	1	40
216-S-26	500	5,000	0.1	0.1	0.005	1	40
216-U-8	500	5,000	0.1	0.1	0.005	1	40
216-U-12	500	5,000	0.1	0.1	0.005	1	40
Run (R10)	**500**	**5,000**	**0.1**	**0.1**	**0**	**1**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0	1	40
216-S-7	500	5,000	0.1	0.1	0	1	40
216-S-9	500	5,000	0.1	0.1	0	1	40
216-S-13	500	5,000	0.1	0.1	0	1	40
216-S-20	500	5,000	0.1	0.1	0	1	40
216-S-21	500	5,000	0.1	0.1	0	1	40
216-S-25	500	5,000	0.1	0.1	0	1	40
216-S-26	500	5,000	0.1	0.1	0	1	40
216-U-8	500	5,000	0.1	0.1	0	1	40
216-U-12	500	5,000	0.1	0.1	0	1	40
Run (R11)	**500**	**5,000**	**0.1**	**0.1**	**0.001**	**1**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0.001	1	40
216-S-7	500	5,000	0.1	0.1	0.001	1	40
216-S-9	500	5,000	0.1	0.1	0.001	1	40
216-S-13	500	5,000	0.1	0.1	0.001	1	40
216-S-20	500	5,000	0.1	0.1	0.001	1	40
216-S-21	500	5,000	0.1	0.1	0.001	1	40
216-S-25	500	5,000	0.1	0.1	0.001	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
216-S-26	500	5,000	0.1	0.1	0.001	1	40
216-U-8	500	5,000	0.1	0.1	0.001	1	40
216-U-12	500	5,000	0.1	0.1	0.001	1	40
Run (R12)	**500**	**5,000**	**0.1**	**0.1**	**0**	**10**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0	10	40
216-S-7	500	5,000	0.1	0.1	0	10	40
216-S-9	500	5,000	0.1	0.1	0	10	40
216-S-13	500	5,000	0.1	0.1	0	10	40
216-S-20	500	5,000	0.1	0.1	0	10	40
216-S-21	500	5,000	0.1	0.1	0	10	40
216-S-25	500	5,000	0.1	0.1	0	10	40
216-S-26	500	5,000	0.1	0.1	0	10	40
216-U-8	500	5,000	0.1	0.1	0	10	40
216-U-12	500	5,000	0.1	0.1	0	10	40
Run (R13)	**500**	**5,000**	**0.1**	**0.1**	**0**	**15**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0	15	40
216-S-7	500	5,000	0.1	0.1	0	15	40
216-S-9	500	5,000	0.1	0.1	0	15	40
216-S-13	500	5,000	0.1	0.1	0	15	40
216-S-20	500	5,000	0.1	0.1	0	15	40
216-S-21	500	5,000	0.1	0.1	0	15	40
216-S-25	500	5,000	0.1	0.1	0	15	40
216-S-26	500	5,000	0.1	0.1	0	15	40
216-U-8	500	5,000	0.1	0.1	0	15	40
216-U-12	500	5,000	0.1	0.1	0	15	40
Run (R14)	**1,000**	**10,000**	**0.1**	**0.1**	**0**	**1**	**40**
216-S-1 & -2	1,000	10,000	0.1	0.1	0	1	40
216-S-7	1,000	10,000	0.1	0.1	0	1	40
216-S-9	1,000	10,000	0.1	0.1	0	1	40
216-S-13	1,000	10,000	0.1	0.1	0	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
216-S-20	1,000	10,000	0.1	0.1	0	1	40
216-S-21	1,000	10,000	0.1	0.1	0	1	40
216-S-25	1,000	10,000	0.1	0.1	0	1	40
216-S-26	1,000	10,000	0.1	0.1	0	1	40
216-U-8	1,000	10,000	0.1	0.1	0	1	40
216-U-12	1,000	10,000	0.1	0.1	0	1	40
Run (R15)	**100**	**1,000**	**0.1**	**0.1**	**0.01**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.1	0.01	1	40
216-S-7	100	1,000	0.1	0.1	0.01	1	40
216-S-9	100	1,000	0.1	0.1	0.01	1	40
216-S-13	100	1,000	0.1	0.1	0.01	1	40
216-S-20	100	1,000	0.1	0.1	0.01	1	40
216-S-21	100	1,000	0.1	0.1	0.01	1	40
216-S-25	100	1,000	0.1	0.1	0.01	1	40
216-S-26	100	1,000	0.1	0.1	0.01	1	40
216-U-8	100	1,000	0.1	0.1	0.01	1	40
216-U-12	100	1,000	0.1	0.1	0.01	1	40
Run (R16)	**100**	**1,000**	**0.1**	**0.1**	**0.002**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.1	0.002	1	40
216-S-7	100	1,000	0.1	0.1	0.002	1	40
216-S-9	100	1,000	0.1	0.1	0.002	1	40
216-S-13	100	1,000	0.1	0.1	0.002	1	40
216-S-20	100	1,000	0.1	0.1	0.002	1	40
216-S-21	100	1,000	0.1	0.1	0.002	1	40
216-S-25	100	1,000	0.1	0.1	0.002	1	40
216-S-26	100	1,000	0.1	0.1	0.002	1	40
216-U-8	100	1,000	0.1	0.1	0.002	1	40
216-U-12	100	1,000	0.1	0.1	0.002	1	40
Run (R17)	**100**	**1,000**	**0.1**	**0.1**	**0.005**	**1**	**40**
216-S-1 & -2	100	1,000	0.1	0.1	0.005	1	40

Table O–3. Calibration Test Matrix for Reduction-Oxidation (REDOX) Facility Sites *(continued)*

REDOX Facility Site Name	Maximum Longitudinal Dispersivity (meters)	Dispersivity Threshold (meters)	Longitudinal Dispersivity Scaling Factor (unitless)	Ratio of Transverse to Longitudinal Dispersivity (unitless)	Ratio of Vertical to Transverse Dispersivity (unitless)	Initial Injection Depth (meters)	Well Screen Depth for Calculating Concentration (meters)
216-S-7	100	1,000	0.1	0.1	0.005	1	40
216-S-9	100	1,000	0.1	0.1	0.005	1	40
216-S-13	100	1,000	0.1	0.1	0.005	1	40
216-S-20	100	1,000	0.1	0.1	0.005	1	40
216-S-21	100	1,000	0.1	0.1	0.005	1	40
216-S-25	100	1,000	0.1	0.1	0.005	1	40
216-S-26	100	1,000	0.1	0.1	0.005	1	40
216-U-8	100	1,000	0.1	0.1	0.005	1	40
216-U-12	100	1,000	0.1	0.1	0.005	1	40
Run (R18)	**500**	**5,000**	**0.1**	**0.1**	**0**	**5**	**40**
216-S-1 & -2	500	5,000	0.1	0.1	0	5	40
216-S-7	500	5,000	0.1	0.1	0	5	40
216-S-9	500	5,000	0.1	0.1	0	5	40
216-S-13	500	5,000	0.1	0.1	0	5	40
216-S-20	500	5,000	0.1	0.1	0	5	40
216-S-21	500	5,000	0.1	0.1	0	5	40
216-S-25	500	5,000	0.1	0.1	0	5	40
216-S-26	500	5,000	0.1	0.1	0	5	40
216-U-8	500	5,000	0.1	0.1	0	5	40
216-U-12	500	5,000	0.1	0.1	0	5	40

Note: The values presented in red represent parameters modified for each calibration run. To convert meters to feet, multiply by 3.281.

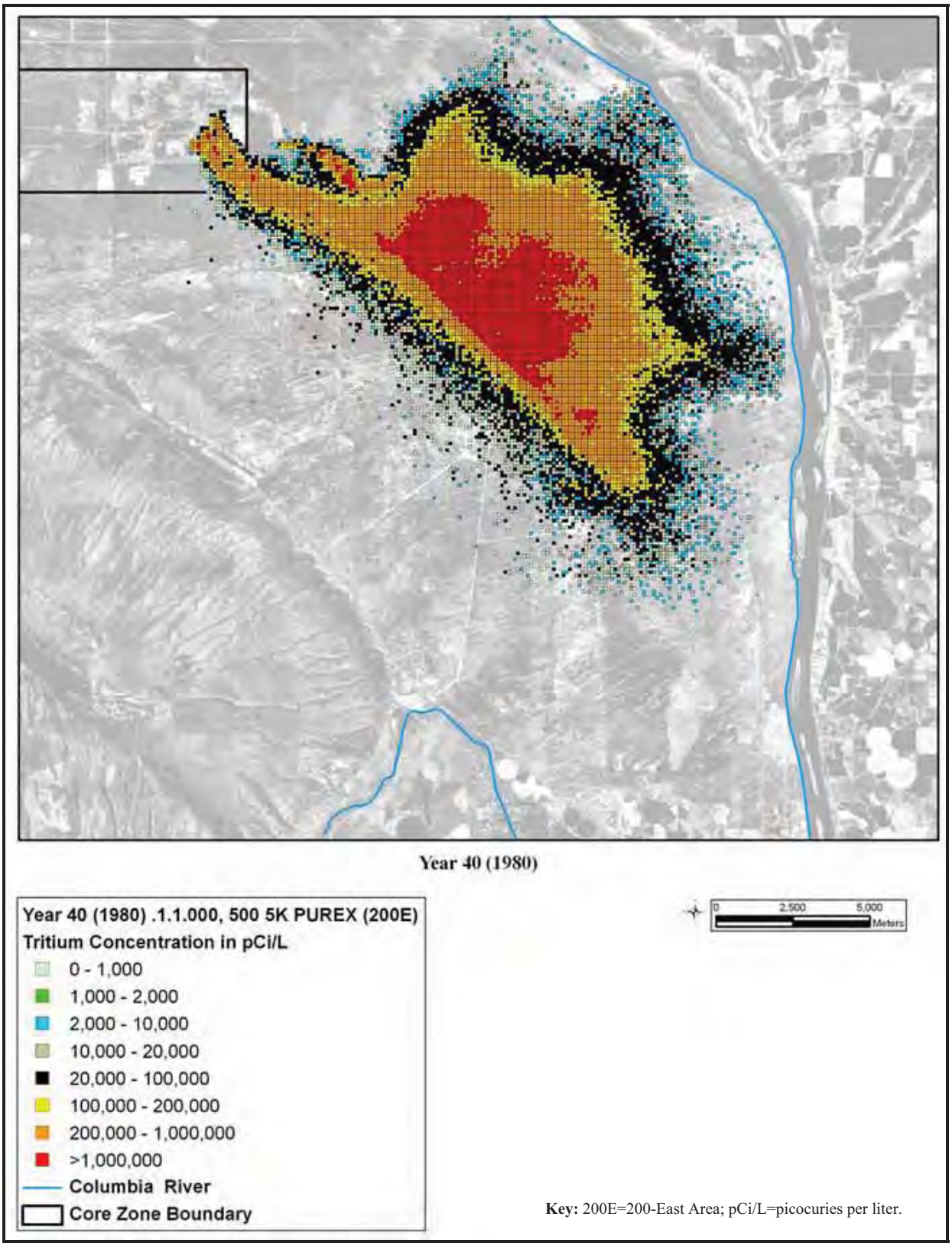


Figure O–5. Plutonium-Uranium Extraction (PUREX) Waste Site Hydrogen-3 (Tritium) Plume for Run P10, Calendar Year 1980

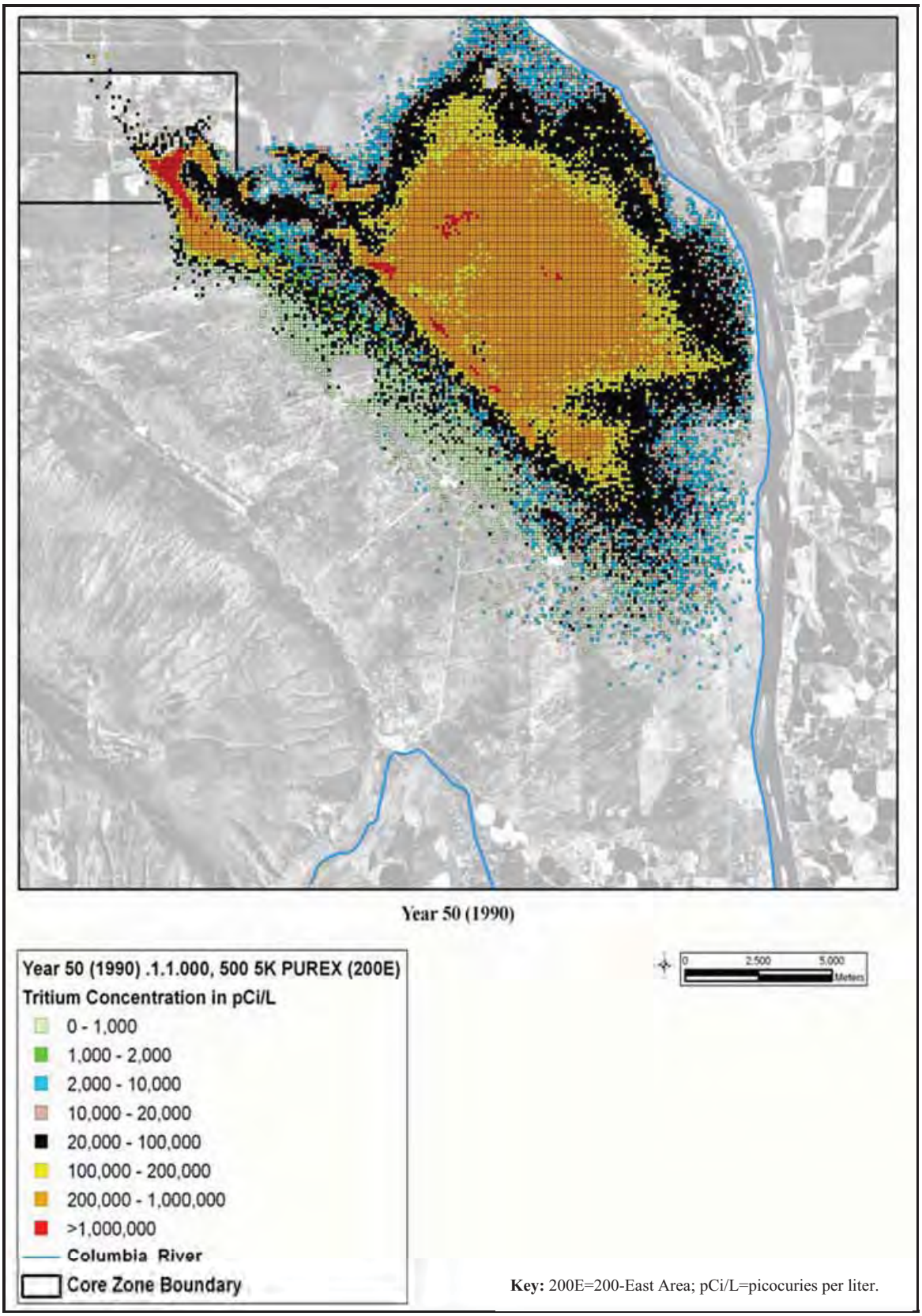


Figure O–6. Plutonium-Uranium Extraction (PUREX) Waste Site Hydrogen-3 (Tritium) Plume for Run P10, Calendar Year 1990

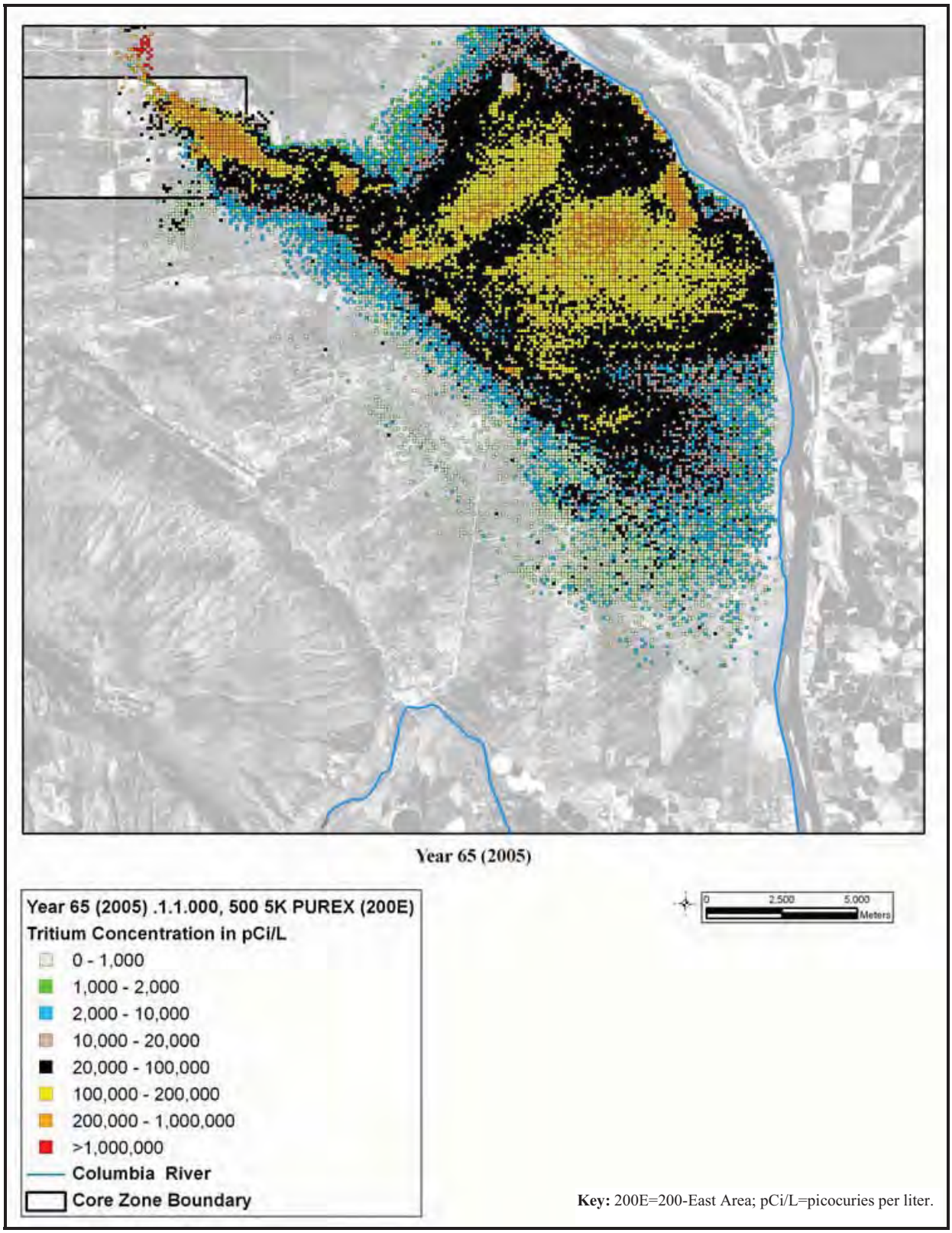


Figure O–7. Plutonium-Uranium Extraction (PUREX) Waste Site Hydrogen-3 (Tritium) Plume for Run P10, Calendar Year 2005

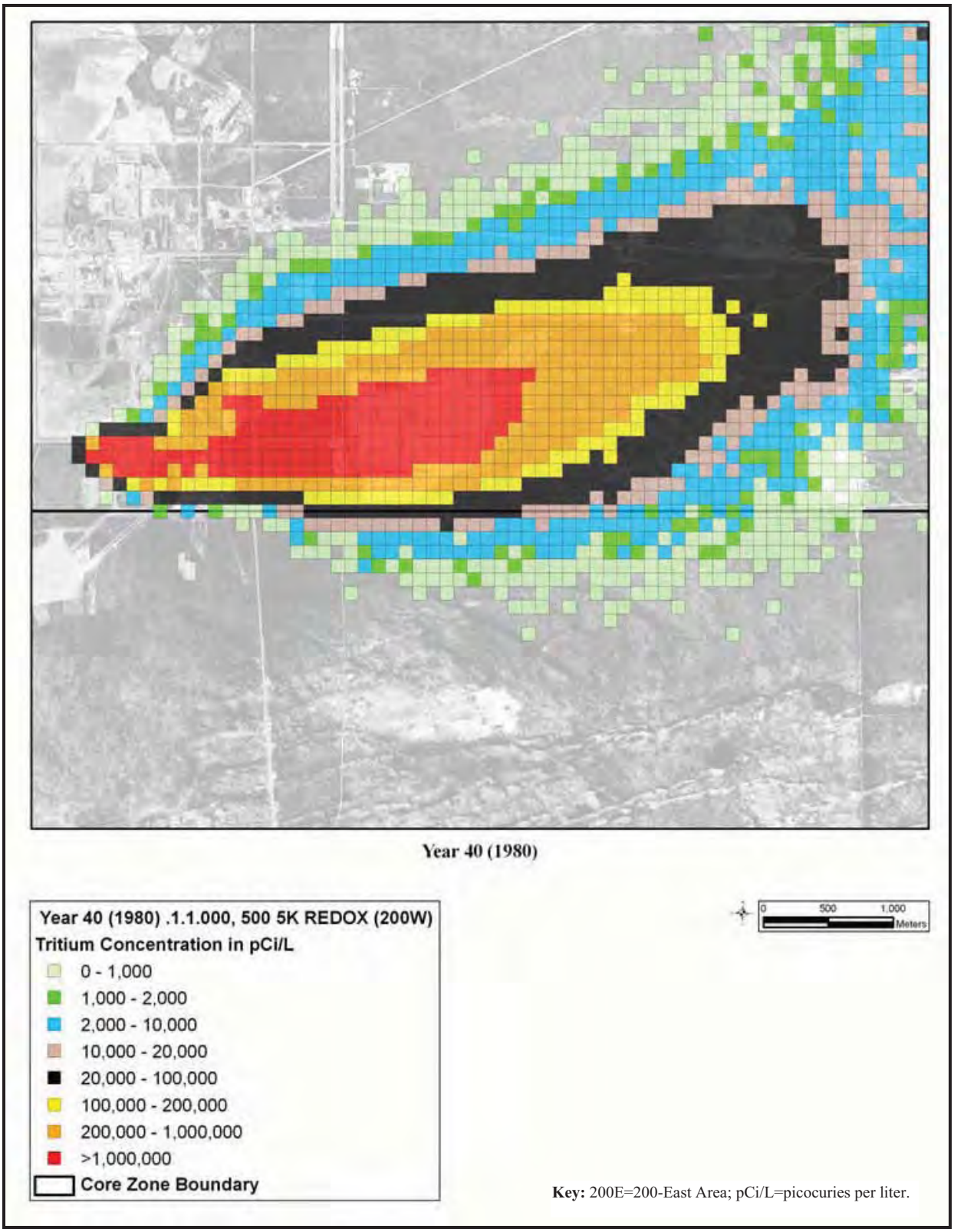


Figure O–8. Reduction-Oxidation (REDOX) Waste Site Hydrogen-3 (Tritium) Plume for Run R10, Calendar Year 1980

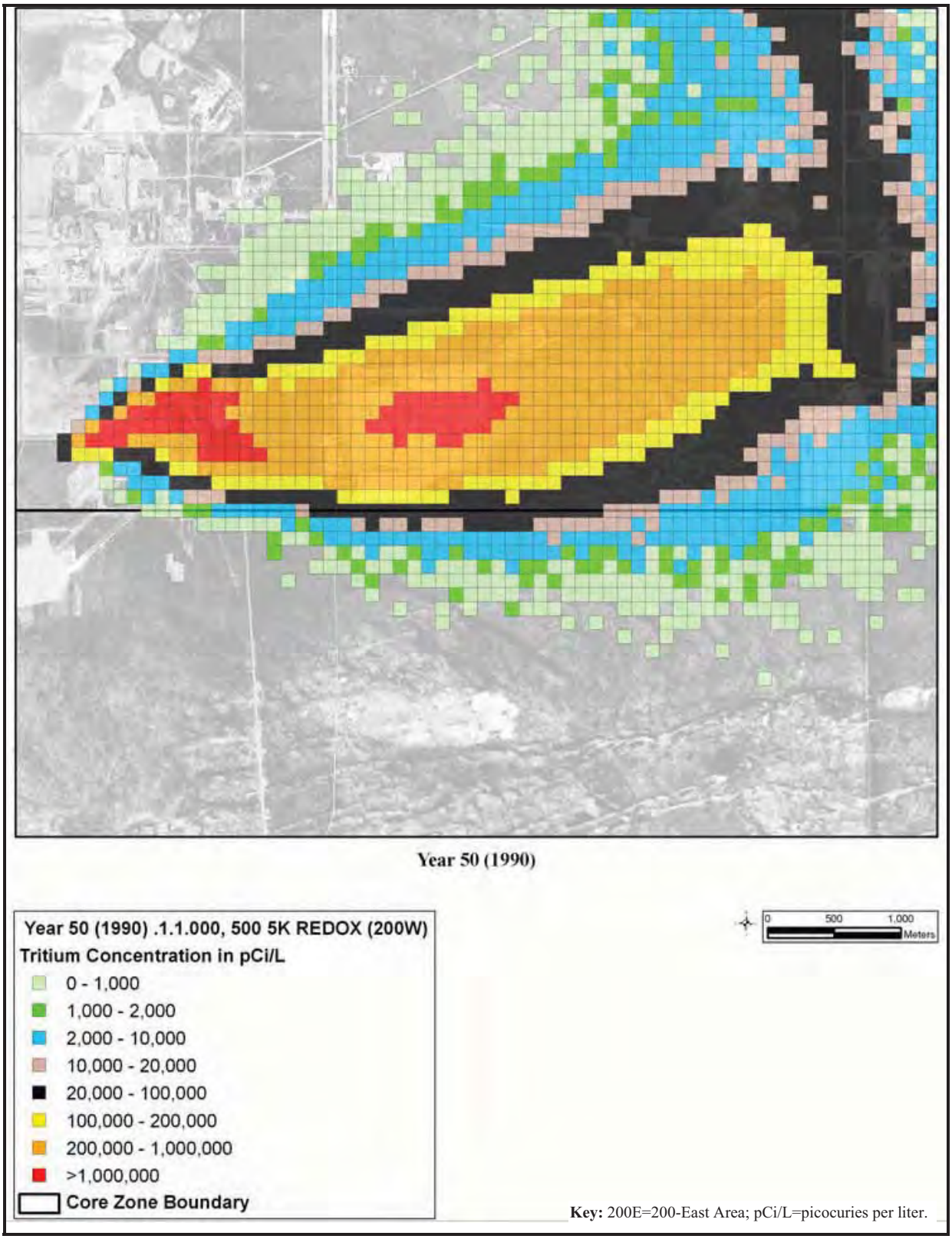


Figure O–9. Reduction-Oxidation (REDOX) Waste Site Hydrogen-3 (Tritium) Plume for Run R10, Calendar Year 1990

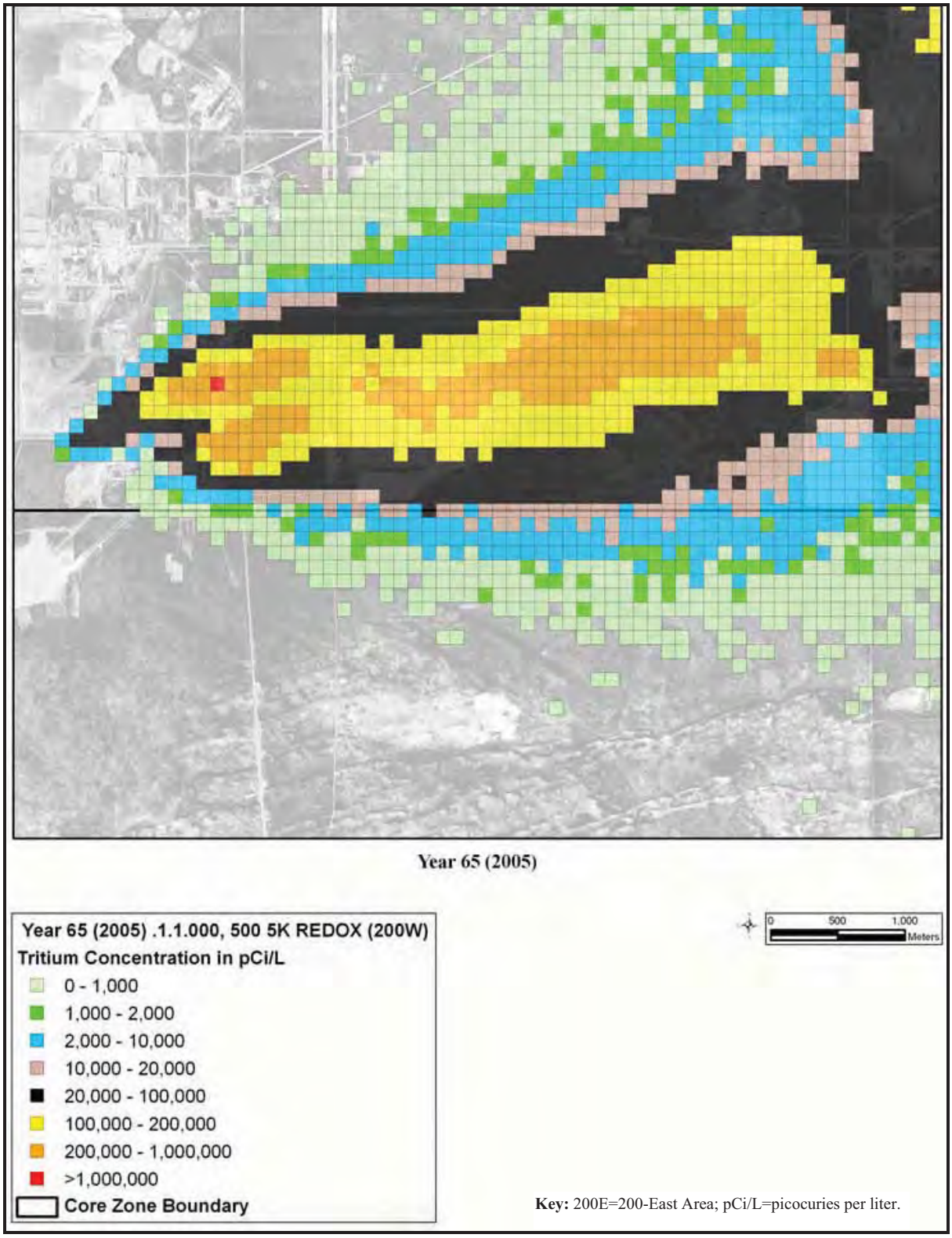


Figure O–10. Reduction-Oxidation (REDOX) Waste Site Hydrogen-3 (Tritium) Plume for Run R10, Calendar Year 2005

Comparison of the results from the selected parameter set against the observed contaminant distribution suggests the following:

- Modeled contaminant velocities from the 200-East Area are greater than from the 200-West Area, in agreement with the hydraulic conductivity distribution.

- The overall shape and area of the modeled plumes are similar to the observed field distribution, particularly for the PUREX waste site plume. The modeled REDOX waste site plume is larger and extends more northerly than the actual plume (note that the effects of the pump-and-treat remediation system installed in the 200-West Area are not reflected in the *TC & WM EIS* groundwater flow and transport calculations).

- Modeled peak concentration values are similar to field measurements in 1980 for the both the PUREX and REDOX waste site plumes. The modeled PUREX waste site plume attenuates slightly less than the field measurements indicate by 2003, while the REDOX waste site plume attenuates slightly more than the field measurements indicate.

These results suggest that the *TC & WM EIS* integrated inventory, release, vadose-zone, and groundwater models compare within a close order of magnitude with field observations for the two regional-scale contaminant plumes.

O.3 GROUNDWATER TRANSPORT RESULTS FOR THE TANK CLOSURE ALTERNATIVES

Groundwater transport results for the *TC & WM EIS* alternatives were reported in picocuries per liter for radionuclides and micrograms per liter for chemicals. To facilitate evaluation of these results, benchmark concentrations for the constituents of potential concern (COPCs) were developed based on regulatory standards and guidance. The health-based benchmark concentrations for radionuclides and chemical (inorganic and organic) constituents are presented in Tables O–4 and O–5, respectively. These benchmark concentrations apply to the Tank Closure alternatives analysis (this section), the FFTF Decommissioning alternatives analysis (see Section O.4), and the Waste Management alternatives analysis (see Section O.5).

Table O–4. Benchmark Concentrations for Radionuclides

Radionuclide	Benchmark Concentration (picocuries per liter)	Reference
Hydrogen-3 (tritium)	20,000	EPA 2002
Carbon-14	2,000	EPA 2002
Potassium-40	280	DOE Order 5400.5
Strontium-90	8	EPA 2002
Zirconium-93	2,000	EPA 2002
Technetium-99	900	EPA 2002
Iodine-129	1	EPA 2002
Cesium-137	200	EPA 2002
Gadolinium-152	15	EPA 2009a
Thorium-232	15	EPA 2009a
Uranium-238[a]	15	EPA 2009a
Neptunium-237	15	EPA 2009a
Plutonium-239[b]	15	EPA 2009a
Americium-241	15	EPA 2009a

[a] Includes uranium-233, -234, -235, and -238.
[b] Includes plutonium-239 and -240.

Table O–5. Benchmark Concentrations for Chemical Constituents

Constituent		Benchmark Concentration (micrograms per liter)	Reference
Arsenic	As	10	EPA 2009a
Boron and compounds	B	7,000	EPA 2006
Cadmium	Cd	5	EPA 2009a
Chromium	Cr	100	EPA 2009a
Fluoride	F	4,000	EPA 2009a
Lead	Pb	15	EPA 2009a
Manganese	Mn	1,600	EPA 2006
Mercury	Hg	2	EPA 2009a
Molybdenum	Mo	200	EPA 2006
Nickel (soluble salts)	Ni	700	EPA 2006
Nitrate[a]	NO_3	45,000	EPA 2009a
Silver	Ag	200	EPA 2006
Strontium (stable)	Sr	20,000	EPA 2006
Uranium (total)	Utot	30	EPA 2009a
Acetonitrile	CH_3CN	100	EPA 2009b
Benzene	C_6H_6	5	EPA 2009a
1-Butanol	C_4H_9OH	3,600	EPA 2009b
Carbon tetrachloride	CCl_4	5	EPA 2009a
1,2-Dichloroethane	1,2-DCA	5	EPA 2009a
Dichloromethane	CH_2C_{12}	5	EPA 2009a
1,4-Dioxane	1,4-Dioxane	6.1	EPA 2009b
Hydrazine	H_4N_2	0.022	EPA 2009b
Polychlorinated biphenyls	PCB	0.5	EPA 2009a
Trichloroethylene	TCE	5	EPA 2009a
2,4,6-Trichlorophenol	2,4,6-TCP	10	EPA 2006
Vinyl chloride	C_2H_3Cl	2	EPA 2009a

[a] The U.S. Environmental Protection Agency's published maximum contaminant level for nitrate is 10 milligrams per liter as nitrogen. The tabulated value includes conversion to compare as weight of nitrate.

Tables O–6 through O–32 summarize the maximum concentration and corresponding calendar year (shown in parentheses) of occurrence for each contaminant in the unconfined aquifer. These concentrations and times are reported at the Columbia River for each of the 13 Tank Closure alternatives (presented as 9 alternatives because Alternatives 2B, 3A, 3B, 3C, and 6C have been combined).

Tables O–6, O–9, O–12, O–15, O–18, O–21, O–24, O–27, and O–30 include the maximum concentrations and times as reported at the Core Zone Boundary, applicable barrier, and Columbia River related to cribs and trenches (ditches) after year 1940.

Tables O–7, O–10, O–13, O–16, O–19, O–22, O–25, O–28, and O–31 include the maximum concentrations and times as reported at the Core Zone Boundary, applicable barrier, and Columbia River for past leaks after year 1940.

Tables O–8, O–11, O–14, O–17, O–20, O–23, O–26, O–29, and O–32 include maximum concentrations and times as reported at the Core Zone Boundary, applicable barrier, and Columbia River for a combination of past leaks, cribs and trenches (ditches), and other tank farm sources after year 2050.

The benchmark concentration for each contaminant is provided in the right-hand column for comparison purposes.

The COPCs for the Tank Closure alternatives include tritium; carbon-14; strontium-90; technetium-99; iodine-129; cesium-137; uranium-238 (reported as uranium isotopes); neptunium-237; plutonium-239; 1-butanol; 2,4,6-trichlorophenol; acetonitrile; benzene; chromium; lead; mercury; nitrate; polychlorinated biphenyls (PCBs); and total uranium. Zero values were reported when COPC concentrations were below minimum thresholds based on a percentage of the benchmark concentration. If the concentration value for a COPC was zero at all lines of analysis, the COPC was not reported for brevity.

O.3.1 Tank Closure Alternative 1

Under Tank Closure Alternative 1, the tank farms would be maintained in the current condition indefinitely; however, for analysis purposes, the tank farms were assumed to fail after an institutional control period of 100 years. At this time, the salt cake in the single-shell tanks was assumed to be available for leaching into the vadose zone, and the liquid contents of the double-shell tanks were assumed to be discharged directly to the vadose zone.

Groundwater transport results (anticipated maximum contaminant concentrations) for this alternative related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–6 through O–8.

Table O–6. Tank Closure Alternative 1 Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,855,631	12,350,337	2,855,631	1,723	20,000
	(1956)	(1975)	(1956)	(1998)	
Technetium-99	143,880	435	143,880	79	900
	(1956)	(1966)	(1956)	(2457)	
Iodine-129	187.8	3.5	187.8	0.1	1
	(1956)	(1966)	(1956)	(2768)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	14	10	0	15
	(11,757)	(11,707)	(11,714)	(11,370)	
Chemicals in micrograms per liter					
Chromium	50,531	9,007	28,686	33	100
	(1955)	(1961)	(1956)	(2408)	
Nitrate	17,182,820	2,099,621	13,364,821	9,999	45,000
	(1955)	(1961)	(1956)	(2417)	
Total uranium	11	4	8	0	30
	(11,790)	(11,755)	(10,719)	(10,356)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–7. Tank Closure Alternative 1 Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,653	198	463	5,628	61	511	1	20,000
	(1999)	(2018)	(2013)	(2005)	(2011)	(2008)	(2050)	
Technetium-99	12,347	9,107	3,984	23,125	153	5,471	146	900
	(1999)	(2052)	(2022)	(2029)	(2065)	(2310)	(2211)	
Iodine-129	23.3	16.5	7.7	45.1	0.3	9.9	0.3	1
	(1999)	(2045)	(2030)	(2027)	(2048)	(2327)	(2252)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	45	3	22	8	74	1	15
	(11,774)	(11,793)	(10,108)	(11,726)	(11,759)	(11,837)	(11,573)	
Chemicals in micrograms per liter								
Chromium	59	103	419	539	13	449	4	100
	(1999)	(2051)	(2030)	(2025)	(2020)	(2271)	(2137)	
Nitrate	4,272	18,235	11,747	40,118	689	14,997	259	45,000
	(1999)	(2040)	(2024)	(2021)	(2048)	(2271)	(2708)	
Total uranium	0	67	4	10	11	92	1	30
	(11,828)	(11,772)	(9820)	(11,799)	(11,573)	(11,570)	(11,382)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–8. Tank Closure Alternative 1 Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	4,186	2,686	2,458	5,570	12	3,793	180	20,000
	(2112)	(2052)	(2117)	(2052)	(2051)	(2102)	(2054)	
Technetium-99	70,050	175,426	38,734	14,980	14,824	349,996	5,231	900
	(2114)	(3837)	(3238)	(2051)	(3536)	(3837)	(4032)	
Iodine-129	71.2	397.6	67.0	71.1	29.2	682.2	13.0	1
	(2114)	(3801)	(3312)	(3756)	(3536)	(3801)	(4411)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	23	490	259	102	40	1,066	6	15
	(11,789)	(11,749)	(11,730)	(11,820)	(11,758)	(11,683)	(11,918)	
Chemicals in micrograms per liter								
Chromium	284	5,053	1,651	911	308	12,190	165	100
	(2114)	(3628)	(3172)	(2050)	(3587)	(3524)	(4019)	
Nitrate	69,566	1,743,875	107,499	200,810	34,949	1,126,141	23,484	45,000
	(2119)	(2087)	(3138)	(2088)	(3654)	(2059)	(3911)	
Total uranium	5	695	281	96	51	1,220	8	30
	(11,769)	(11,762)	(11,762)	(11,836)	(11,739)	(11,648)	(11,591)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.2 Tank Closure Alternative 2A

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but the residual material in tanks would not be stabilized. After an institutional control period of 100 years, salt cake in the tanks was assumed to be available for dissolution in infiltrating water.

Groundwater transport results for this alternative as related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–9 through O–11.

Table O–9. Tank Closure Alternative 2A Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,955,633	12,264,698	2,955,633	1,383	20,000
	(1956)	(1975)	(1956)	(1998)	
Technetium-99	148,565	437	148,565	67	900
	(1956)	(1966)	(1956)	(2645)	
Iodine-129	194.6	3.5	194.6	0.1	1
	(1956)	(1966)	(1956)	(2536)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	38	15	12	0	15
	(11,754)	(11,776)	(11,809)	(113,02)	
Chemicals in micrograms per liter					
Chromium	45,892	9,116	27,172	29	100
	(1955)	(1961)	(1956)	(2603)	
Nitrate	18,103,786	2,115,355	13,492,655	8,743	45,000
	(1955)	(1961)	(1956)	(2400)	
Total uranium	12	5	8	0	30
	(11,608)	(11,782)	(11,752)	(11,663)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–10. Tank Closure Alternative 2A Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,531	198	479	5,564	60	449	1	20,000
	(1999)	(2019)	(2011)	(2009)	(2009)	(2009)	(2023)	
Technetium-99	11,891	9,473	3,942	22,779	153	5,031	143	900
	(1999)	(2052)	(2028)	(2026)	(2064)	(2275)	(2406)	
Iodine-129	23.2	16.8	7.6	44.7	0.3	9.1	0.2	1
	(1999)	(2058)	(2029)	(2026)	(2036)	(2269)	(2227)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	95	3	26	10	110	1	15
	(11,770)	(11,814)	(8018)	(11,365)	(11,763)	(11,837)	(11,336)	

Table O–10. Tank Closure Alternative 2A Maximum COPC Concentrations Related to Past Leaks *(continued)*

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Chemicals in micrograms per liter								
Chromium	59	96	407	529	14	497	4	100
	(1999)	(2052)	(2026)	(2026)	(2028)	(2277)	(2500)	
Nitrate	4,127	18,874	11,889	39,689	689	14,373	276	45,000
	(1999)	(2039)	(2023)	(2027)	(2029)	(2249)	(2338)	
Total uranium	0	163	4	12	14	164	1	30
	(11,819)	(11,836)	(8011)	(11,709)	(11,082)	(11,624)	(11,809)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–11. Tank Closure Alternative 2A Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	35	5,034	51	5,215	13	5,633	135	20,000
	(2052)	(2051)	(2050)	(2061)	(2050)	(2051)	(2050)	
Technetium-99	1,586	31,656	2,821	15,036	546	27,833	204	900
	(2055)	(2076)	(2050)	(2051)	(2096)	(2076)	(3464)	
Iodine-129	3.2	50.0	4.8	30.3	1.1	43.0	0.4	1
	(2057)	(2072)	(2050)	(2051)	(2089)	(2072)	(3355)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	3	142	7	42	11	148	1	15
	(11,707)	(11,814)	(11,714)	(11,799)	(11,763)	(11,828)	(11,783)	
Chemicals in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3341)	(1940)	(3417)	(1940)	(1940)	(3551)	(3617)	
Chromium	12	4,264	290	800	17	1,958	32	100
	(2070)	(2085)	(2050)	(2050)	(2086)	(2066)	(2603)	
Nitrate	11,617	1,639,900	9,956	167,605	5,796	1,099,667	9,102	45,000
	(2068)	(2081)	(2073)	(2086)	(2083)	(2059)	(2400)	
Total uranium	1	190	8	20	15	196	1	30
	(11,805)	(11,836)	(9863)	(11,709)	(10,978)	(11,624)	(11,809)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.3 Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar to those under Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) at the BX and SX tank farms and replaced with clean soils from onsite sources. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified Resource Conservation and Recovery Act (RCRA) Subtitle C barrier.

Groundwater transport results for these alternatives as related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–12 through O–14.

Table O–12. Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, and 6C ─ Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,823,299	12,499,824	2,823,299	1,279	20,000
	(1956)	(1974)	(1956)	(1994)	
Technetium-99	144,196	441	144,196	89	900
	(1956)	(1966)	(1956)	(2025)	
Iodine-129	187.0	3.6	187.0	0.1	1
	(1956)	(1966)	(1956)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	13	10	0	15
	(11,742)	(11,780)	(11,758)	(11,844)	
Chemicals in micrograms per liter					
Chromium	50,842	9,325	28,041	31	100
	(1955)	(1961)	(1956)	(2695)	
Nitrate	17,418,627	2,112,423	12,890,767	8,272	45,000
	(1955)	(1961)	(1956)	(2450)	
Total uranium	10	4	7	0	30
	(11,678)	(11,755)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–13. Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, and 6C ─ Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,634	198	466	5,516	62	542	1	20,000
	(1999)	(2018)	(2013)	(2004)	(2011)	(2008)	(2048)	
Technetium-99	11,600	8,416	4,096	22,631	144	4,859	140	900
	(1999)	(2050)	(2026)	(2029)	(2050)	(2034)	(2480)	
Iodine-129	23.6	16.8	7.7	45.1	0.3	9.1	0.3	1
	(1999)	(2052)	(2026)	(2028)	(2052)	(2040)	(2184)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	20	3	14	8	54	1	15
	(11,766)	(11,823)	(9474)	(11,792)	(11,441)	(11,527)	(11,147)	
Chemicals in micrograms per liter								
Chromium	61	96	413	528	14	403	4	100
	(1999)	(2047)	(2030)	(2027)	(2028)	(2258)	(2190)	
Nitrate	4,173	17,926	12,098	41,069	709	12,917	258	45,000
	(1999)	(2048)	(2030)	(2028)	(2030)	(2215)	(2789)	
Total uranium	0	29	4	6	12	81	1	30
	(11,806)	(11,792)	(10,052)	(11,800)	(11,599)	(11,689)	(11,146)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–14. Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, and 6C ─ Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	28	5,078	52	7,272	13	6,079	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	1,449	29,966	2,661	15,221	284	25,890	205	900
	(2058)	(2050)	(2050)	(2050)	(3499)	(2050)	(2480)	
Iodine-129	2.6	39.9	5.0	29.6	0.4	33.6	0.4	1
	(2053)	(2057)	(2050)	(2050)	(3708)	(2057)	(2876)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	55	6	27	8	73	1	15
	(11,755)	(11,739)	(11,765)	(11,780)	(11,441)	(11,691)	(11,871)	
Chemicals in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3701)	(1940)	(3566)	(1940)	(1940)	(3829)	(4021)	
Chromium	9	3,229	271	768	10	1,667	34	100
	(2057)	(2055)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,650	1,542,362	8,954	132,754	1,379	1,010,240	8,576	45,000
	(2057)	(2050)	(2050)	(2054)	(2068)	(2050)	(2450)	
Total uranium	0	46	8	11	12	103	1	30
	(11,795)	(11,792)	(11,602)	(11,840)	(11,599)	(11,683)	(11,146)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.4 Tank Closure Alternative 4

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would undergo clean closure by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column.

Groundwater transport results for this alternative as related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–15 through O–17.

Table O–15. Tank Closure Alternative 4 Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,823,299	12,499,824	2,823,299	1,279	20,000
	(1956)	(1974)	(1956)	(1994)	
Technetium-99	144,196	441	144,196	89	900
	(1956)	(1966)	(1956)	(2025)	
Iodine-129	187.0	3.6	187.0	0.1	1
	(1956)	(1966)	(1956)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	13	10	0	15
	(11,742)	(11,780)	(11,758)	(11,844)	
Chemicals in micrograms per liter					
Chromium	50,842	9,325	28,041	31	100
	(1955)	(1961)	(1956)	(2695)	
Nitrate	17,418,627	2,112,423	12,890,767	8,272	45,000
	(1955)	(1961)	(1956)	(2450)	
Total uranium	10	4	7	0	30
	(11,678)	(11,755)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–16. Tank Closure Alternative 4 Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,634	196	469	5,516	62	535	1	20,000
	(1999)	(2018)	(2008)	(2004)	(2011)	(2008)	(2048)	
Technetium-99	11,600	7,657	3,837	22,631	144	4,951	133	900
	(1999)	(2044)	(2022)	(2029)	(2050)	(2034)	(2480)	
Iodine-129	23.6	15.3	7.7	45.1	0.3	9.1	0.3	1
	(1999)	(2041)	(2026)	(2028)	(2052)	(2024)	(2184)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	2	0	14	8	38	1	15
	(11,766)	(11,760)	(11,785)	(11,792)	(11,441)	(10,975)	(11,147)	
Chemicals in micrograms per liter								
Chromium	61	6	397	528	14	255	3	100
	(1999)	(2043)	(2030)	(2027)	(2028)	(2197)	(2382)	
Nitrate	4,173	17,479	11,964	41,069	709	10,858	257	45,000
	(1999)	(2038)	(2030)	(2028)	(2030)	(2028)	(2789)	
Total uranium	0	3	0	6	12	56	1	30
	(11,806)	(11,814)	(11,758)	(11,800)	(11,599)	(11,690)	(11,577)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–17. Tank Closure Alternative 4 Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	28	5,063	4	7,272	13	6,062	178	20,000
	(2051)	(2054)	(2062)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	1,457	28,163	214	15,249	180	24,055	191	900
	(2058)	(2050)	(2060)	(2050)	(2060)	(2050)	(2480)	
Iodine-129	2.7	37.6	0.4	29.6	0.3	31.2	0.3	1
	(2053)	(2057)	(2052)	(2050)	(2052)	(2057)	(2181)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	36	1	26	8	48	1	15
	(11,814)	(11,742)	(11,795)	(11,780)	(11,441)	(11,529)	(11,891)	
Chemicals in micrograms per liter								
Chromium	9	3,217	36	768	10	1,647	34	100
	(2057)	(2055)	(2057)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,531	1,537,421	1,403	132,582	1,233	1,005,408	8,490	45,000
	(2056)	(2050)	(2059)	(2054)	(2067)	(2050)	(2450)	
Total uranium	0	14	1	11	12	63	1	30
	(11,819)	(11,678)	(11,828)	(11,840)	(11,599)	(11,690)	(11,577)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.5 Tank Closure Alternative 5

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval. Residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier.

Groundwater transport results for this alternative as related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–18 through O–20.

Table O–18. Tank Closure Alternative 5 Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,823,299	12,499,824	2,823,299	1,279	20,000
	(1956)	(1974)	(1956)	(1994)	
Technetium-99	144,196	441	144,196	89	900
	(1956)	(1966)	(1956)	(2025)	
Iodine-129	187.0	3.6	187.0	0.1	1
	(1956)	(1966)	(1956)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	13	10	0	15
	(11,742)	(11,780)	(11,758)	(11,844)	
Chemicals in micrograms per liter					
Chromium	50,842	9,325	28,041	31	100
	(1955)	(1961)	(1956)	(2695)	
Nitrate	17,418,627	2,112,423	12,890,767	8,272	45,000
	(1955)	(1961)	(1956)	(2450)	
Total uranium	10	4	7	0	30
	(11,678)	(11,755)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–19. Tank Closure Alternative 5 Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,634	198	466	5,516	62	542	1	20,000
	(1999)	(2018)	(2013)	(2004)	(2011)	(2008)	(2048)	
Technetium-99	12,353	2,128	4,053	23,597	146	5,071	121	900
	(1999)	(2027)	(2030)	(2027)	(2048)	(2247)	(2153)	
Iodine-129	23.2	16.4	7.6	22.7	0.3	9.3	0.3	1
	(1999)	(2047)	(2030)	(2041)	(2041)	(2032)	(2132)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	15	3	12	8	57	1	15
	(11,825)	(11,799)	(10,284)	(11,854)	(11,750)	(11,704)	(11,594)	
Chemicals in micrograms per liter								
Chromium	62	97	421	527	14	452	5	100
	(1999)	(2051)	(2026)	(2026)	(2025)	(2244)	(2503)	
Nitrate	4,171	19,053	11,682	40,309	690	12,798	283	45,000
	(1999)	(2050)	(2022)	(2026)	(2033)	(2281)	(2474)	
Total uranium	0	22	4	5	12	77	1	30
	(11,813)	(11,807)	(9966)	(11,854)	(11,051)	(11,835)	(11,936)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–20. Tank Closure Alternative 5 Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	28	5,072	52	7,272	13	6,072	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	3,037	22,529	3,336	15,319	1,776	35,748	724	900
	(4338)	(2050)	(3931)	(2050)	(4022)	(4326)	(5017)	
Iodine-129	2.8	41.6	4.9	18.9	0.8	33.7	0.5	1
	(2059)	(2057)	(2050)	(2051)	(4694)	(2057)	(7030)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	67	15	25	9	102	1	15
	(11,845)	(11,739)	(11,727)	(11,780)	(11,750)	(11,735)	(11,594)	
Chemicals in micrograms per liter								
Acetonitrile	8	0	2	0	0	12	1	100
	(4221)	(1940)	(4208)	(1940)	(1940)	(4510)	(4297)	
Chromium	29	3,205	289	782	36	1,728	35	100
	(4094)	(2055)	(2050)	(2050)	(3847)	(3891)	(2695)	
Nitrate	6,509	1,543,074	13,211	132,603	4,507	1,010,081	8,748	45,000
	(4099)	(2050)	(3586)	(2054)	(3794)	(2050)	(2450)	
Total uranium	0	83	33	15	15	204	1	30
	(11,795)	(11,798)	(11,473)	(11,815)	(11,821)	(11,805)	(11,935)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.6 Tank Closure Alternative 6A, Base Case

Under Tank Closure Alternative 6A, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. All tanks farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier.

Groundwater transport results for this alternative as related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–21 through O–23.

Table O–21. Tank Closure Alternative 6A, Base Case, Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,823,299	12,499,824	2,823,299	1,279	20,000
	(1956)	(1974)	(1956)	(1994)	
Technetium-99	144,196	441	144,196	89	900
	(1956)	(1966)	(1956)	(2025)	
Iodine-129	187.0	3.6	187.0	0.1	1
	(1956)	(1966)	(1956)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	13	10	0	15
	(11,742)	(11,780)	(11,758)	(11,844)	
Chemicals in micrograms per liter					
Chromium	50,842	9,325	28,041	31	100
	(1955)	(1961)	(1956)	(2695)	
Nitrate	17,418,627	2,112,423	12,890,767	8,272	45,000
	(1955)	(1961)	(1956)	(2450)	
Total uranium	10	4	7	0	30
	(11,678)	(11,755)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–22. Tank Closure Alternative 6A, Base Case, Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,577	194	467	5,570	61	451	1	20,000
	(1999)	(2018)	(2011)	(2004)	(2011)	(2007)	(2044)	
Technetium-99	11,954	8,332	3,963	22,765	150	4,916	147	900
	(1999)	(2049)	(2027)	(2026)	(2064)	(2292)	(2502)	
Iodine-129	23.3	16.9	8.0	43.7	0.3	10.1	0.3	1
	(1999)	(2050)	(2027)	(2028)	(2040)	(2252)	(2308)	
Chemicals in micrograms per liter								
Chromium	61	93	397	533	13	401	4	100
	(1999)	(2048)	(2026)	(2026)	(2024)	(2251)	(2413)	
Nitrate	4,335	18,149	11,732	40,194	684	14,256	291	45,000
	(1999)	(2046)	(2030)	(2023)	(2026)	(2234)	(2669)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–23. Tank Closure Alternative 6A, Base Case, Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	26	4,995	51	7,311	13	5,996	178	20,000
	(2052)	(2054)	(2050)	(2055)	(2052)	(2054)	(2050)	
Technetium-99	1,352	29,050	2,679	15,197	150	24,661	169	900
	(2056)	(2050)	(2050)	(2051)	(2064)	(2050)	(2515)	
Iodine-129	2.7	40.9	5.1	30.9	0.3	31.3	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	34	0	13	0	10	0	15
	(1940)	(11,742)	(2166)	(11,780)	(1940)	(11,758)	(11,844)	
Chemicals in micrograms per liter								
Chromium	8	3,175	289	761	10	1,660	33	100
	(2050)	(2050)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	475	1,540,345	8,547	132,510	667	1,008,775	8,409	45,000
	(2051)	(2050)	(2050)	(2054)	(2054)	(2050)	(2450)	
Total uranium	0	10	0	4	0	7	0	30
	(2160)	(11,678)	(2166)	(11,755)	(2167)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.7 Tank Closure Alternative 6A, Option Case

Under Tank Closure Alternative 6A, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. All tanks farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed.

Groundwater transport results for this alternative related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–24 through O–26.

Table O–24. Tank Closure Alternative 6A, Option Case, Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,835,466	12,350,299	2,835,466	1,267	20,000
	(1956)	(1975)	(1956)	(2016)	
Technetium-99	144,526	423	144,526	67	900
	(1956)	(1966)	(1956)	(2477)	
Iodine-129	188.4	3.5	188.4	0.1	1
	(1956)	(1966)	(1956)	(1967)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	2	1	0	15
	(1981)	(1980)	(1981)	(4077)	
Chemicals in micrograms per liter					
Chromium	50,965	8,860	28,382	26	100
	(1955)	(1961)	(1956)	(2256)	
Nitrate	17,327,249	2,097,467	13,367,907	7,772	45,000
	(1955)	(1961)	(1956)	(2460)	
Total uranium	1	3	1	0	30
	(1981)	(1980)	(1981)	(4581)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–25. Tank Closure Alternative 6A, Option Case, Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,577	194	467	5,570	61	451	1	20,000
	(1999)	(2018)	(2011)	(2004)	(2011)	(2007)	(2044)	
Technetium-99	11,954	8,332	3,963	22,765	150	4,916	147	900
	(1999)	(2049)	(2027)	(2026)	(2064)	(2292)	(2502)	
Iodine-129	23.3	16.9	8.0	43.7	0.3	10.1	0.3	1
	(1999)	(2050)	(2027)	(2028)	(2040)	(2252)	(2308)	
Chemicals in micrograms per liter								
Chromium	61	93	397	533	13	401	4	100
	(1999)	(2048)	(2026)	(2026)	(2024)	(2251)	(2413)	
Nitrate	4,335	18,149	11,732	40,194	684	14,256	291	45,000
	(1999)	(2046)	(2030)	(2023)	(2026)	(2234)	(2669)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–26. Tank Closure Alternative 6A, Option Case, Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	26	5,135	51	5,191	13	6,991	170	20,000
	(2052)	(2050)	(2050)	(2050)	(2052)	(2050)	(2057)	
Technetium-99	1,352	25,018	2,679	15,197	150	20,975	181	900
	(2056)	(2055)	(2050)	(2051)	(2064)	(2056)	(2502)	
Iodine-129	2.7	44.7	5.1	30.9	0.3	35.2	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2308)	
Chemicals in micrograms per liter								
Chromium	8	3,787	289	772	10	1,663	29	100
	(2050)	(2088)	(2050)	(2051)	(2050)	(2051)	(2256)	
Nitrate	475	1,665,075	8,547	153,923	667	1,184,388	7,933	45,000
	(2051)	(2056)	(2050)	(2102)	(2054)	(2056)	(2460)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.3.8 Tank Closure Alternative 6B, Base and Option Cases

The Tank Closure Alternative 6B, Base and Option Cases, resemble the Tank Closure Alternative 6A, Base and Option Cases, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean-closed. Under the Base Case, the adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Under the Option Case, the adjacent cribs and trenches (ditches) would be clean-closed.

Groundwater transport results for the Tank Closure Alternative 6B, Base and Option Cases, related to cribs and trenches (ditches), past leaks, and other sources (e.g., tank residuals, ancillary equipment) are summarized in Tables O–27 through O–32.

Table O–27. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,823,299	12,499,824	2,823,299	1,279	20,000
	(1956)	(1974)	(1956)	(1994)	
Technetium-99	144,196	441	144,196	89	900
	(1956)	(1966)	(1956)	(2025)	
Iodine-129	187.0	3.6	187.0	0.1	1
	(1956)	(1966)	(1956)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	34	13	10	0	15
	(11,742)	(11,780)	(11,758)	(11,844)	

Table O–27. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations Related to Cribs and Trenches (Ditches) *(continued)*

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Chemicals in micrograms per liter					
Chromium	50,842	9,325	28,041	31	100
	(1955)	(1961)	(1956)	(2695)	
Nitrate	17,418,627	2,112,423	12,890,767	8,272	45,000
	(1955)	(1961)	(1956)	(2450)	
Total uranium	10	4	7	0	30
	(11,678)	(11,755)	(11,678)	(11,508)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–28. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,609	198	478	5,476	64	458	1	20,000
	(1999)	(2018)	(2013)	(2012)	(2011)	(2011)	(2054)	
Technetium-99	12,380	8,553	3,897	23,468	142	4,593	142	900
	(1999)	(2050)	(2030)	(2026)	(2049)	(2034)	(2133)	
Iodine-129	23.9	17.3	7.6	44.8	0.3	9.0	0.3	1
	(1999)	(2051)	(2030)	(2027)	(2054)	(2038)	(2319)	
Chemicals in micrograms per liter								
Chromium	63	91	407	532	14	417	4	100
	(1999)	(2049)	(2029)	(2027)	(2026)	(2224)	(2152)	
Nitrate	4,193	17,879	11,766	39,627	683	13,264	237	45,000
	(1999)	(2048)	(2028)	(2020)	(2040)	(2253)	(2204)	

Note: Corresponding calendar years shown are in parentheses.
Key: COPC=constituent of potential concern.

Table O–29. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	30	5,006	46	7,299	20,000
	(2051)	(2054)	(2050)	(2055)	
Technetium-99	1,386	29,281	2,562	15,519	900
	(2050)	(2050)	(2050)	(2051)	
Iodine-129	2.7	39.4	4.8	29.4	1
	(2050)	(2057)	(2050)	(2050)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	34	0	13	15
	(1940)	(11,742)	(1940)	(11,780)	
Chemicals in micrograms per liter					
Chromium	7	3,177	283	771	100
	(2050)	(2055)	(2050)	(2050)	
Nitrate	511	1,540,147	8,652	132,564	45,000
	(2059)	(2050)	(2050)	(2051)	
Total uranium	0	10	0	4	30
	(1940)	(11,678)	(1940)	(11,755)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–30. Tank Closure Alternative 6B, Option Case, Maximum Contaminant Concentrations Related to Cribs and Trenches (Ditches)

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Hydrogen-3 (tritium)	2,843,651	12,440,075	2,843,651	1,607	20,000
	(1956)	(1974)	(1956)	(1997)	
Technetium-99	143,823	430	143,823	60	900
	(1956)	(1966)	(1956)	(2461)	
Iodine-129	187.3	3.5	187.3	0.1	1
	(1956)	(1966)	(1956)	(2030)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	1	1	0	15
	(1981)	(1980)	(1981)	(3268)	
Chemicals in micrograms per liter					
Chromium	51,235	9,139	28,338	26	100
	(1955)	(1961)	(1956)	(2166)	
Nitrate	17,805,762	2,135,491	13,709,300	7,075	45,000
	(1955)	(1961)	(1956)	(2056)	
Total uranium	1	3	1	0	30
	(1981)	(1980)	(1981)	(3972)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–31. Tank Closure Alternative 6B, Option Case, Maximum COPC Concentrations Related to Past Leaks

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	3,609	198	478	5,476	64	458	1	20,000
	(1999)	(2018)	(2013)	(2012)	(2011)	(2011)	(2054)	
Technetium-99	12,380	8,553	3,897	23,468	142	4,593	142	900
	(1999)	(2050)	(2030)	(2026)	(2049)	(2034)	(2133)	
Iodine-129	23.9	17.3	7.6	44.8	0.3	9.0	0.3	1
	(1999)	(2051)	(2030)	(2027)	(2054)	(2038)	(2319)	
Chemicals in micrograms per liter								
Chromium	63	91	407	532	14	417	4	100
	(1999)	(2049)	(2029)	(2027)	(2026)	(2224)	(2152)	
Nitrate	4,193	17,879	11,766	39,627	683	13,264	237	45,000
	(1999)	(2048)	(2028)	(2020)	(2040)	(2253)	(2204)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

Table O–32. Tank Closure Alternative 6B, Option Case, Maximum COPC Concentrations Related to Past Leaks, Cribs and Trenches (Ditches), and Other Sources After Calendar Year 2050

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter								
Hydrogen-3 (tritium)	30	4,867	46	6,681	13	5,189	172	20,000
	(2051)	(2073)	(2050)	(2067)	(2052)	(2073)	(2088)	
Technetium-99	1,386	27,036	2,562	15,521	140	22,693	162	900
	(2050)	(2058)	(2050)	(2051)	(2060)	(2058)	(2304)	
Iodine-129	2.7	38.3	4.8	29.4	0.3	29.5	0.3	1
	(2050)	(2051)	(2050)	(2050)	(2054)	(2052)	(2319)	
Chemicals in micrograms per liter								
Chromium	7	3,769	283	778	9	1,762	28	100
	(2050)	(2087)	(2050)	(2050)	(2050)	(2061)	(2166)	
Nitrate	511	1,691,829	8,652	153,825	624	1,227,849	7,107	45,000
	(2059)	(2053)	(2050)	(2084)	(2057)	(2053)	(2056)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.4 GROUNDWATER TRANSPORT RESULTS FOR THE FFTF DECOMMISSIONING ALTERNATIVE

Tables O–33 and O–34 summarize the maximum concentration and corresponding calendar year (shown in parentheses) of occurrence for each contaminant in the unconfined aquifer as a result of FFTF Decommissioning Alternatives 1 and 2 (under FFTF Decommissioning Alternative 3, all contaminated materials would be removed, resulting in no impacts on groundwater or human health). The concentrations and years of occurrence shown in Tables O–33 and O–34 are reported at the Columbia River, Core Zone Boundary, and the FFTF barrier for each of these two FFTF Decommissioning alternatives. As expected, the concentration values at the Core Zone were zero due to its distance from

FFTF. The benchmark concentration for each contaminant is provided in the right-hand column for comparison purposes.

The COPCs for the FFTF Decommissioning alternatives include tritium, carbon-14, potassium-40; strontium-90; zirconium-93; technetium-99; iodine-129; cesium-137; gadolinium-152; thorium-232; uranium-238 (reported as uranium isotopes); neptunium-237; plutonium-239; americium-241; 1,2-dichloroethane; 1,4-dioxane; 1-butanol; 2,4,6-trichlorophenol; acetonitrile; arsenic; benzene; boron; cadmium; carbon tetrachloride; chromium; dichloromethane; fluoride; hydrazine; lead; manganese; mercury; molybdenum; nickel; nitrate; PCBs; silver; strontium; total uranium; trichloroethylene; and vinyl chloride. Zero values were reported when COPC concentrations were below minimum thresholds based on a percentage of the benchmark concentration. If the concentration value for a COPC was zero at all lines of analysis, the COPC was not reported for brevity.

O.4.1 FFTF Decommissioning Alternative 1

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous U.S. Department of Energy (DOE) National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For analysis purposes, the remaining waste would be available for release to the environment after an institutional control period of 100 years.

Groundwater transport results for this alternative are summarized in Table O–33.

Table O–33. FFTF Decommissioning Alternative 1 Maximum COPC Concentrations

Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter			
Carbon-14	16	0	2,000
	(11,889)	(11,811)	
Technetium-99	416	12	900
	(2425)	(2702)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

O.4.2 FFTF Decommissioning Alternative 2

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures (including the reactor vessel).

Groundwater transport results for this alternative are summarized in Table O–34.

Table O–34. FFTF Decommissioning Alternative 2 Maximum COPC Concentrations

Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter			
Carbon-14	15	0	2,000
	(11,898)	(11,741)	
Technetium-99	407	12	900
	(2819)	(2965)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

O.4.3 FFTF Decommissioning Alternative 3

Under FFTF Decommissioning Alternative 3, all aboveground structures, and all contaminated below-grade structures, equipment, and materials would be removed, resulting in zero impacts on groundwater and human health.

O.5 GROUNDWATER TRANSPORT RESULTS FOR THE WASTE MANAGEMENT ALTERNATIVES INCLUDING DISPOSAL GROUPS

Tables O–35 through O–59 summarize the maximum concentration and corresponding calendar year (shown in parentheses) of occurrence for each contaminant in the unconfined aquifer. These concentrations and times shown in the tables are reported at the Columbia River, Core Zone Boundary and applicable barrier(s) for each of the Waste Management alternatives including the disposal groups. The benchmark concentration for each contaminant is provided in the right-hand column for comparison purposes.

The COPCs for the Waste Management alternatives include tritium; carbon-14; potassium-40; strontium-90; zirconium-93; technetium-99; iodine-129; cesium-137; gadolinium-152; thorium-232; uranium-238 (reported as uranium isotopes); neptunium-237; plutonium-239; americium-241; 1,2-dichloroethane, 1,4-dioxane, 1-butanol; 2,4,6-trichlorophenol; acetonitrile; arsenic; benzene; boron; cadmium; carbon tetrachloride; chromium; dichloromethane; fluoride; hydrazine; lead; manganese; mercury; molybdenum; nickel; nitrate; PCBs; silver; strontium; total uranium; trichloroethylene; and vinyl chloride. Zero values were reported when COPC concentrations were below minimum thresholds based on a percentage of the benchmark concentration. If the concentration value for a COPC was zero at all lines of analysis, the COPC was not reported for brevity.

O.5.1 Waste Management Alternative 1

Under Waste Management Alternative 1, only those wastes currently generated on site at Hanford from non–Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) actions would continue to be disposed of in LLBG 218-W-5 trenches 31 and 34. Although the short-term impacts do not address the impacts associated with closure activities for this site, for long-term impacts analysis purposes, it was assumed that these trenches would be closed using an RCRA-compliant barrier consistent with the closure plans for these burial grounds. As a result, the non-CERCLA waste disposed of in these trenches from 2008 to 2035 would become available for release to the environment.

Groundwater transport results for this alternative are summarized in Table O–35.

Table O–35. Waste Management Alternative 1 Maximum COPC Concentrations

Contaminant	Trenches 31 and 34 Barrier	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	22	N/A	4	1	900
	(3499)		(3474)	(3974)	
Chemicals in micrograms per liter					
Chromium	3	N/A	1	0	100
	(3526)		(3615)	(4353)	
Fluoride	4	N/A	1	0	4,000
	(3545)		(3661)	(4592)	
Nitrate	47	N/A	9	2	45,000
	(3534)		(3600)	(4417)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern.

O.5.2 Waste Management Alternative 2

Under Waste Management Alternative 2, waste from tank treatment operations, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-East. Waste from tank farm cleanup activities would be disposed of in the RPPDF. As a result, the waste disposed of in these two facilities would become available for release to the environment. Because different waste types would result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives. Groundwater transport results of these subgroups under this alternative are discussed in the following sections.

O.5.2.1 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 2B.

Groundwater transport results for this alternative are summarized in Table O–36.

Table O–36. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,041	33	1,178	675	900
	(9004)	(3825)	(9155)	(9451)	
Iodine-129	18.7	0.1	8.5	7.0	1
	(8739)	(3772)	(8858)	(8700)	
Chemicals in micrograms per liter					
Chromium	4	2	2	1	100
	(8511)	(3856)	(3889)	(8898)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,245	149	5,630	2,444	45,000
	(8522)	(3811)	(9653)	(8827)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.2 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3A.

Groundwater transport results for this alternative are summarized in Table O–37.

Table O–37. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,878	33	1,253	815	900
	(8486)	(3825)	(7998)	(8273)	
Iodine-129	18.4	0.1	8.4	7.0	1
	(8195)	(3772)	(8858)	(8700)	
Chemicals in micrograms per liter					
Chromium	2	2	2	0	100
	(8278)	(3856)	(3889)	(4826)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,384	149	5,859	3,681	45,000
	(7821)	(3811)	(8905)	(8144)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.3 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste

- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3B.

Groundwater transport results for this alternative are summarized in Table O–38.

Table O–38. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	5,659	33	8,156	1,686	900
	(9048)	(3825)	(9163)	(8927)	
Iodine-129	18.2	0.1	8.4	7.0	1
	(8491)	(3772)	(8858)	(8700)	
Chemicals in micrograms per liter					
Acetonitrile	25	0	9	7	100
	(8281)	(1940)	(8313)	(8973)	
Chromium	437	2	265	116	100
	(8940)	(3856)	(8760)	(9311)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	50,237	149	21,194	14,132	45,000
	(8665)	(3811)	(8290)	(9453)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.4 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Steam reforming waste
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3C.

Groundwater transport results for this alternative are summarized in Table O–39.

Table O–39. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	30,126	33	24,782	7,608	900
	(9032)	(3825)	(9067)	(8274)	
Iodine-129	24.0	0.1	15.5	8.2	1
	(8195)	(3772)	(8082)	(8699)	
Chemicals in micrograms per liter					
Acetonitrile	436	2	174	116	100
	(9071)	(3856)	(8397)	(9878)	
Chromium	0	0	1	0	100
	(8035)	(1940)	(7258)	(8913)	
Fluoride	14,514	149	4,971	3,318	4,000
	(7859)	(3811)	(7269)	(7744)	
Nitrate	436	2	174	116	45,000
	(9071)	(3856)	(8397)	(9878)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.5 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Cast stone
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 4.

Groundwater transport results for this alternative are summarized in Table O–40.

Table O–40. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	6,494	103	3,094	2,030	900
	(9035)	(3822)	(9499)	(8117)	
Iodine-129	18.4	0.2	8.4	7.0	1
	(8491)	(3940)	(8858)	(8699)	
Chemicals in micrograms per liter					
Acetonitrile	16	0	5	4	100
	(7959)	(1940)	(7381)	(6849)	
Chromium	224	6	96	64	100
	(9069)	(3804)	(8643)	(8079)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	28,997	229	13,920	6,384	45,000
	(9330)	(4042)	(8994)	(8673)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.6 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted.

Groundwater transport results for this alternative are summarized in Table O–41.

Table O–41. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	3,513	N/A	1,497	891	900
	(8276)		(9155)	(8090)	
Iodine-129	18.4	N/A	8.4	7.0	1
	(8195)		(8858)	(8699)	
Chemicals in micrograms per liter					
Acetonitrile	5	N/A	2	1	100
	(8475)		(9519)	(8575)	
Chromium	335	N/A	148	110	100
	(8735)		(8764)	(8819)	
Fluoride	0	N/A	1	0	4,000
	(8035)		(7258)	(8913)	
Nitrate	21,393	N/A	7,417	4,560	45,000
	(8448)		(8887)	(8787)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.7 Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6C.

Groundwater transport results for this alternative are summarized in Table O–42.

Table O–42. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,185	33	1,152	674	900
	(9004)	(3825)	(9155)	(9451)	
Iodine-129	18.7	0.1	8.5	7.0	1
	(8739)	(3772)	(8858)	(8699)	
Chemicals in micrograms per liter					
Chromium	4	2	2	1	100
	(8618)	(3856)	(3889)	(8528)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,245	149	5,630	2,444	45,000
	(8522)	(3811)	(9653)	(8827)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.8 Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted.

Groundwater transport results for this alternative are summarized in Table O–43.

Table O–43. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,824	N/A	1,145	671	900
	(8580)		(8365)	(8478)	
Iodine-129	23.8	N/A	9.7	5.6	1
	(9058)		(9178)	(9652)	
Chemicals in micrograms per liter					
Chromium	3	N/A	2	1	100
	(9308)		(8982)	(8354)	
Nitrate	15,512	N/A	5,695	4,068	45,000
	(8055)		(7905)	(8056)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.9 Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base and Option Cases

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Preprocessing Facility (PPF) glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6B, Base and Option Cases.

Groundwater transport results for this alternative are summarized in Tables O–44 and O–45.

Table O–44. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,894	283	1,138	703	900
	(8580)	(3889)	(8365)	(8477)	
Iodine-129	24.1	0.5	9.6	5.6	1
	(9058)	(4089)	(9188)	(9652)	
Chemicals in micrograms per liter					
Chromium	3	6	11	2	100
	(8281)	(3868)	(11,232)	(5035)	
Nitrate	16,645	353	5,751	3,313	45,000
	(8162)	(3996)	(8245)	(7837)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

Table O–45. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	2,894	340	1,351	717	900
	(8580)	(4213)	(4466)	(8477)	
Iodine-129	24.1	0.6	9.6	5.7	1
	(9058)	(4176)	(9188)	(9652)	
Chemicals in micrograms per liter					
Chromium	3	33	97	17	100
	(8281)	(4118)	(10,533)	(5522)	
Nitrate	16,645	9,073	28,374	5,696	45,000
	(8162)	(3962)	(9305)	(4618)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.2.10 Waste Management Alternative 2, Disposal Group 3, Base and Option Cases

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste
- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6A, Base and Option Cases.

Groundwater transport results for this alternative are summarized in Tables O–46 and O–47.

Table O–46. Waste Management Alternative 2, Disposal Group 3, Base Case, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	3,039	303	1,180	848	900
	(8646)	(3987)	(8173)	(9284)	
Iodine-129	22.3	0.5	11.2	5.6	1
	(8850)	(4073)	(11,300)	(8985)	
Chemicals in micrograms per liter					
Chromium	3	6	11	3	100
	(8561)	(4109)	(6384)	(4877)	
Nitrate	16,640	404	6,550	3,312	45,000
	(7367)	(4001)	(6859)	(7741)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

Table O–47. Waste Management Alternative 2, Disposal Group 3, Option Case, Maximum COPC Concentrations

Contaminant	IDF-East	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter					
Technetium-99	3,039	386	1,180	861	900
	(8646)	(4013)	(8173)	(9284)	
Iodine-129	22.3	0.6	11.2	5.7	1
	(8850)	(4172)	(11,300)	(8985)	
Chemicals in micrograms per liter					
Chromium	3	36	125	20	100
	(8561)	(3878)	(6610)	(6701)	
Nitrate	16,640	10,251	30,238	5,616	45,000
	(7367)	(4544)	(4627)	(6522)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility.

O.5.3 Waste Management Alternative 3

Under Waste Management Alternative 3, the waste from tank treatment operations would be disposed of in IDF-East, and waste from onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites would be disposed of in IDF-West. Waste from tank farm cleanup operations would be disposed of in the RPPDF. As a result, the waste disposed of in these three facilities would become available for release to the environment. Because of the different waste types that result from the Tank Closure action alternatives, three disposal groups were considered to account for the different IDF-East sizes and operational time periods. In addition, within these three disposal groups, subgroups were identified to allow consideration of the different waste types resulting from the Tank Closure alternatives.

Groundwater transport results of these subgroups under this alternative are discussed in the following section.

O.5.3.1 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-A

Disposal Group 1, Subgroup 1-A, addresses the waste resulting from Tank Closure Alternative 2B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 2B.

Groundwater transport results for this alternative are summarized in Table O–48.

Table O–48. Waste Management-Alternative 3, Disposal Group 1, Subgroup 1-A, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	471	20,209	33	7,555	1,129	900
	(8991)	(3713)	(3825)	(3690)	(4528)	
Iodine-129	1.4	172.6	0.1	60.3	8.3	1
	(11,243)	(3797)	(3772)	(3853)	(4729)	
Chemicals in micrograms per liter						
Chromium	4	2	2	3	1	100
	(8511)	(3696)	(3856)	(3628)	(8879)	
Fluoride	0	1	0	1	0	100
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	14,243	17	149	5,630	2,443	45,000
	(8522)	(3703)	(3811)	(9653)	(8043)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.2 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B

Disposal Group 1, Subgroup 1-B, addresses the waste resulting from Tank Closure Alternative 3A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3A.

Groundwater transport results for this alternative are summarized in Table O–49.

Table O–49. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-B, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	1,604	20,209	33	7,555	1,129	900
	(8486)	(3713)	(3825)	(3690)	(4528)	
Iodine-129	1.7	172.6	0.1	60.3	8.3	1
	(11,284)	(3797)	(3772)	(3853)	(4729)	
Chemicals in micrograms per liter						
Chromium	2	2	2	3	0	100
	(8278)	(3696)	(3856)	(3628)	(4812)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	14,381	17	149	5,858	3,680	45,000
	(7821)	(3703)	(3811)	(8905)	(8144)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.3 Waste Management Alternative 3 Disposal Group 1, Subgroup 1-C

Disposal Group 1, Subgroup 1-C, addresses the waste resulting from Tank Closure Alternative 3B, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters

- Cast stone
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3B.

Groundwater transport results for this alternative are summarized in Table O–50.

Table O–50. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	5,022	20,209	33	7,838	1,689	900
	(9048)	(3713)	(3825)	(9163)	(8939)	
Iodine-129	0.7	172.6	0.1	60.3	8.3	1
	(10,915)	(3797)	(3772)	(3853)	(4729)	
Chemicals in micrograms per liter						
Acetonitrile	25	0	0	9	7	100
	(8281)	(1940)	(1940)	(8313)	(8973)	
Chromium	436	2	2	265	116	100
	(8940)	(3696)	(3856)	(8760)	(9311)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	50,234	17	149	21,193	14,132	45,000
	(8665)	(3703)	(3811)	(8290)	(9453)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.4 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D

Disposal Group 1, Subgroup 1-D, addresses the waste resulting from Tank Closure Alternative 3C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Steam reforming waste
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 3C.

Groundwater transport results for this alternative are summarized in Table O–51.

Table O–51. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-D, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	29,171	20,209	33	24,626	7,451	900
	(9032)	(3713)	(3825)	(9067)	(9206)	
Iodine-129	10.7	172.6	0.1	60.3	8.3	1
	(8514)	(3797)	(3772)	(3853)	(4729)	
Chemicals in micrograms per liter						
Chromium	436	2	2	174	116	100
	(9071)	(3696)	(3856)	(8397)	(9878)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	14,512	17	149	4,971	3,318	45,000
	(7859)	(3703)	(3811)	(7269)	(7528)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.5 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E

Disposal Group 1, Subgroup 1-E, addresses the waste resulting from Tank Closure Alternative 4, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Cast stone
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 4.

Groundwater transport results for this alternative are summarized in Table O–52.

Table O–52. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-E, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	5,638	20,209	103	7,596	2,031	900
	(9826)	(3713)	(3822)	(3690)	(8117)	
Iodine-129	1.1	172.6	0.2	60.4	8.3	1
	(11,228)	(3797)	(3940)	(3853)	(4728)	
Chemicals in micrograms per liter						
Chromium	223	2	6	96	64	100
	(9069)	(3696)	(3804)	(8643)	(8079)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	28,995	17	229	13,919	6,384	45,000
	(9330)	(3703)	(4042)	(8994)	(8673)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.6 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F

Disposal Group 1, Subgroup 1-F, addresses the waste resulting from Tank Closure Alternative 5, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Bulk vitrification glass
- Cast stone
- Sulfate grout
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 5 because tank closure cleanup activities would not be conducted.

Groundwater transport results for this alternative are summarized in Table O–53.

Table O–53. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-F, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	2,388	20,209	N/A	7,537	1,125	900
	(9701)	(3713)		(3690)	(4528)	
Iodine-129	1.2	172.6	N/A	60.3	8.3	1
	(11,711)	(3797)		(3853)	(4729)	
Chemicals in micrograms per liter						
Acetonitrile	5	0	N/A	2	1	100
	(8475)	(1940)		(9519)	(8575)	
Chromium	335	2	N/A	148	110	100
	(8735)	(3696)		(8764)	(8819)	
Fluoride	0	1	N/A	1	0	4,000
	(1940)	(3684)		(3907)	(4555)	
Nitrate	21,390	17	N/A	7,417	4,559	45,000
	(8448)	(3703)		(8887)	(8787)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.7 Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G

Disposal Group 1, Subgroup 1-G, addresses the waste resulting from Tank Closure Alternative 6C, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6C.

Groundwater transport results for this alternative are summarized in Table O–54.

Table O–54. Waste Management Alternative 3, Disposal Group 1, Subgroup 1-G, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	414	20,209	33	7,555	1,129	900
	(10,032)	(3713)	(3825)	(3690)	(4528)	
Iodine-129	1.4	172.6	0.1	60.3	8.3	1
	(11,243)	(3797)	(3772)	(3853)	(4729)	
Chemicals in micrograms per liter						
Chromium	4	2	2	3	1	100
	(8618)	(3696)	(3856)	(3628)	(8204)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	14,243	17	149	5,630	2,443	45,000
	(8522)	(3703)	(3811)	(9653)	(8043)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.8 Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A

Disposal Group 2, Subgroup 2-A, addresses the waste resulting from Tank Closure Alternative 2A, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- ILAW glass
- ILAW melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

The RPPDF would not be constructed or operated under Tank Closure Alternative 2A because tank closure cleanup activities would not be conducted.

Groundwater transport results for this alternative are summarized in Table O–55.

Table O–55. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	334	20,209	N/A	7,537	1,125	900
	(9823)	(3713)		(3690)	(4528)	
Iodine-129	1.7	172.6	N/A	60.3	8.3	1
	(10,498)	(3797)		(3853)	(4729)	
Chemicals in micrograms per liter						
Chromium	3	2	N/A	2	1	100
	(9308)	(3696)		(8982)	(8353)	
Fluoride	0	1	N/A	1	0	4,000
	(1940)	(3684)		(3907)	(4555)	
Nitrate	15,510	17	N/A	5,695	4,067	45,000
	(7977)	(3703)		(7905)	(8056)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.9 Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base and Option Cases

Disposal Group 2, Subgroup 2-B, addresses the waste resulting from Tank Closure Alternative 6B, Base and Option Cases, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6B, Base and Option Cases.

Groundwater transport results for this alternative are summarized in Tables O–56 and O–57.

Table O–56. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Base Case, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	347	20,209	283	7,747	1,179	900
	(10,643)	(3713)	(3889)	(3690)	(3884)	
Iodine-129	1.6	172.6	0.5	60.7	8.4	1
	(11,363)	(3797)	(4089)	(3853)	(4392)	
Chemicals in micrograms per liter						
Chromium	3	2	6	12	2	100
	(8281)	(3696)	(3868)	(4042)	(4714)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	16,643	17	353	5,751	3,313	45,000
	(8162)	(3703)	(3996)	(8245)	(7831)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

Table O–57. Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	347	20,209	340	7,586	1,188	900
	(10,643)	(3713)	(4213)	(3690)	(4191)	
Iodine-129	1.6	172.6	0.6	60.8	8.4	1
	(11,363)	(3797)	(4176)	(3853)	(4392)	
Chemicals in micrograms per liter						
Chromium	3	2	33	97	17	100
	(8281)	(3696)	(4118)	(10,533)	(5522)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	16,643	17	9,073	28,373	5,697	45,000
	(8162)	(3703)	(3962)	(9305)	(4618)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.5.3.10 Waste Management Alternative 3, Disposal Group 3, Subgroup 3-A, Base and Option Cases

Disposal Group 3 addresses the waste resulting from Tank Closure Alternative 6A, Base and Option Cases, onsite non-CERCLA sources, FFTF decommissioning, waste management, and other DOE sites. Waste forms for IDF-East include the following:

- PPF glass
- PPF melters
- Tank closure secondary waste

Waste forms for IDF-West include the following:

- FFTF decommissioning secondary waste
- Waste management secondary waste
- Offsite waste
- Onsite non-CERCLA waste

Waste forms for the RPPDF include those resulting from tank closure cleanup activities under Tank Closure Alternative 6A, Base and Option Cases.

Groundwater transport results for this alternative are summarized in Tables O–58 and O–59.

Table O–58. Waste Management Alternative 3, Disposal Group 3, Base Case, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	389	20,209	303	7,765	1,181	900
	(9324)	(3713)	(3987)	(3690)	(4186)	
Iodine-129	1.6	172.6	0.5	60.7	8.4	1
	(11,096)	(3797)	(4073)	(3853)	(4392)	
Chemicals in micrograms per liter						
Chromium	3	2	6	12	3	100
	(8037)	(3696)	(4109)	(4035)	(4877)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	16,640	17	404	6,550	3,312	45,000
	(7367)	(3703)	(4001)	(6859)	(7717)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

Table O–59. Waste Management Alternative 3, Disposal Group 3, Option Case, Maximum COPC Concentrations

Contaminant	IDF-East	IDF-West	River Protection Project Disposal Facility	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclides in picocuries per liter						
Technetium-99	389	20,209	386	7,935	1,219	900
	(9324)	(3713)	(4013)	(3690)	(4066)	
Iodine-129	1.6	172.6	0.6	60.9	8.4	1
	(11,096)	(3797)	(4172)	(3853)	(4728)	
Chemicals in micrograms per liter						
Chromium	3	2	36	125	20	100
	(8037)	(3696)	(3878)	(6610)	(6701)	
Fluoride	0	1	0	1	0	4,000
	(1940)	(3684)	(1940)	(3907)	(4555)	
Nitrate	16,640	17	10,251	30,238	5,616	45,000
	(7367)	(3703)	(4544)	(4627)	(6522)	

Note: Corresponding calendar years are shown in parentheses.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.

O.6 SENSITIVITY ANALYSIS

The calibrated parameter set for the Base Case flow and transport models provide plume simulations that agree with regional-scale field distributions to a close order of magnitude (see Section O.2.4). In this section, the sensitivity of the results to uncertainties in key parameters is discussed. The focus is on the sensitivity to the Base and Alternate Case flow fields, distribution coefficient for iodine-129, length of analysis period, and contaminant inventory and release.

O.6.1 Comparison of Base Case and Alternate Case Flow Fields During Hanford Operational Period

Two groundwater flow fields were developed for this *TC & WM EIS* (see Appendix L). These flow fields reflect uncertainty in the top of basalt surface in the Gable Mountain–Gable Butte area, and consequent variation in predominant flow direction from the Central Plateau. The groundwater flow analysis suggested that, within the uncertainty of the top of the basalt surface, flow fields could be developed that (1) compare equally well to field measurements during the operational period (1944–2006) and (2) simulate different groundwater flow pathways in the post-Hanford period. In this section, the Base and Alternate Case flow fields are used to illustrate the sensitivity of contaminant transport results.

O.6.1.1 Past Leaks from Tank Farms, Discharges to Cribs and Trenches (Ditches)

Particle-tracking analyses were performed to compare the results of the Base and Alternate Case flow fields during Hanford's operational period (1944–2006). Contaminant transport of chromium, nitrate, iodine-129, and technetium-99 due to past leaks from tank farms and discharges to cribs and trenches (ditches) were selected as the basis for this comparison. Figures O–11 through O–18 show the spatial distribution of each contaminant for the Base and Alternate Case flow fields near the end of the operational period (year 2005). These results suggest that regional-scale contaminant plumes (i.e., areas of groundwater contaminated above benchmark values) from *TC & WM EIS* alternative analysis sources are similar for the Base and Alternate Case flow models.

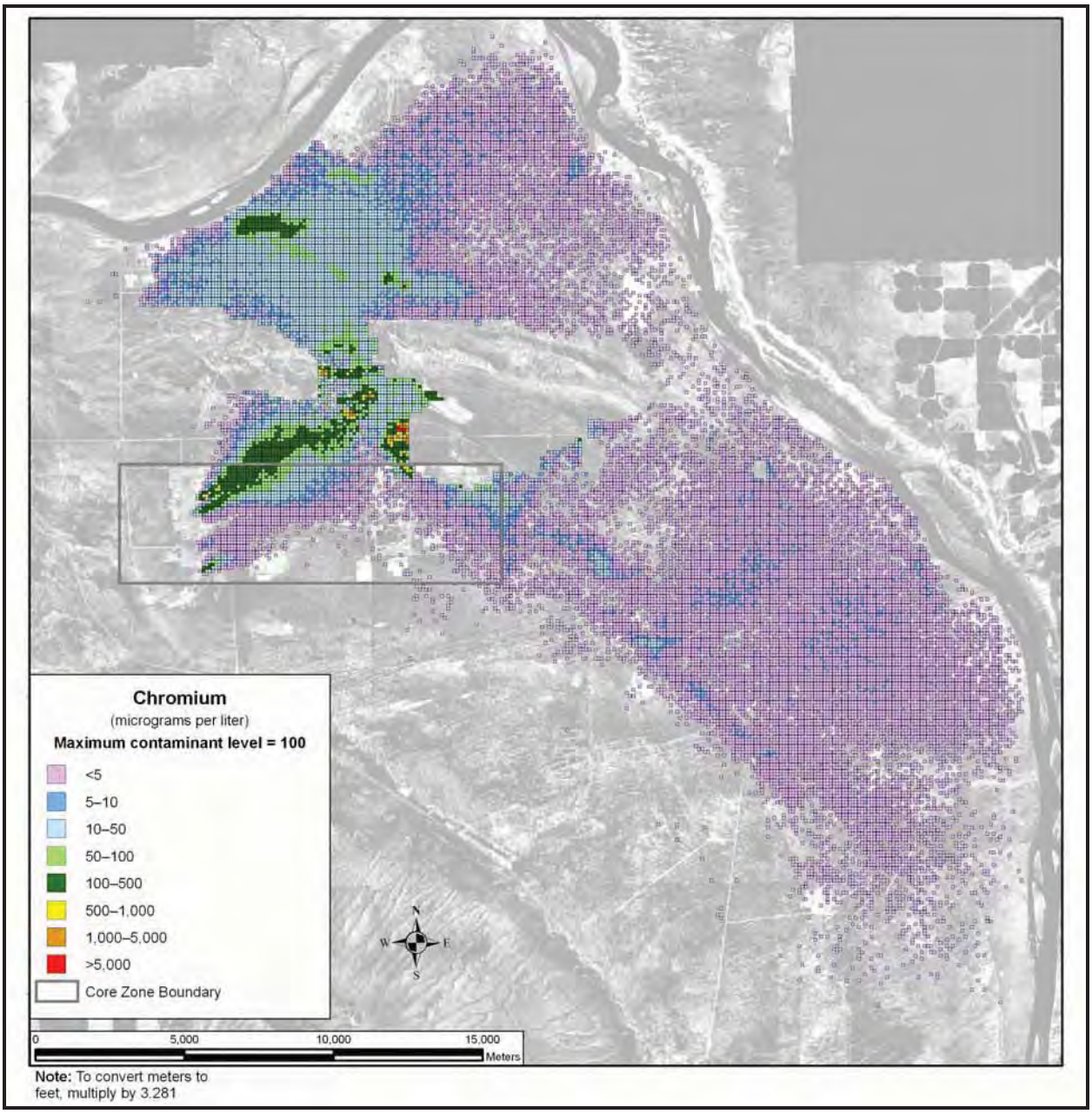


Figure O–11. Base Case Operational Period Chromium Plume Map, Calendar Year 2005

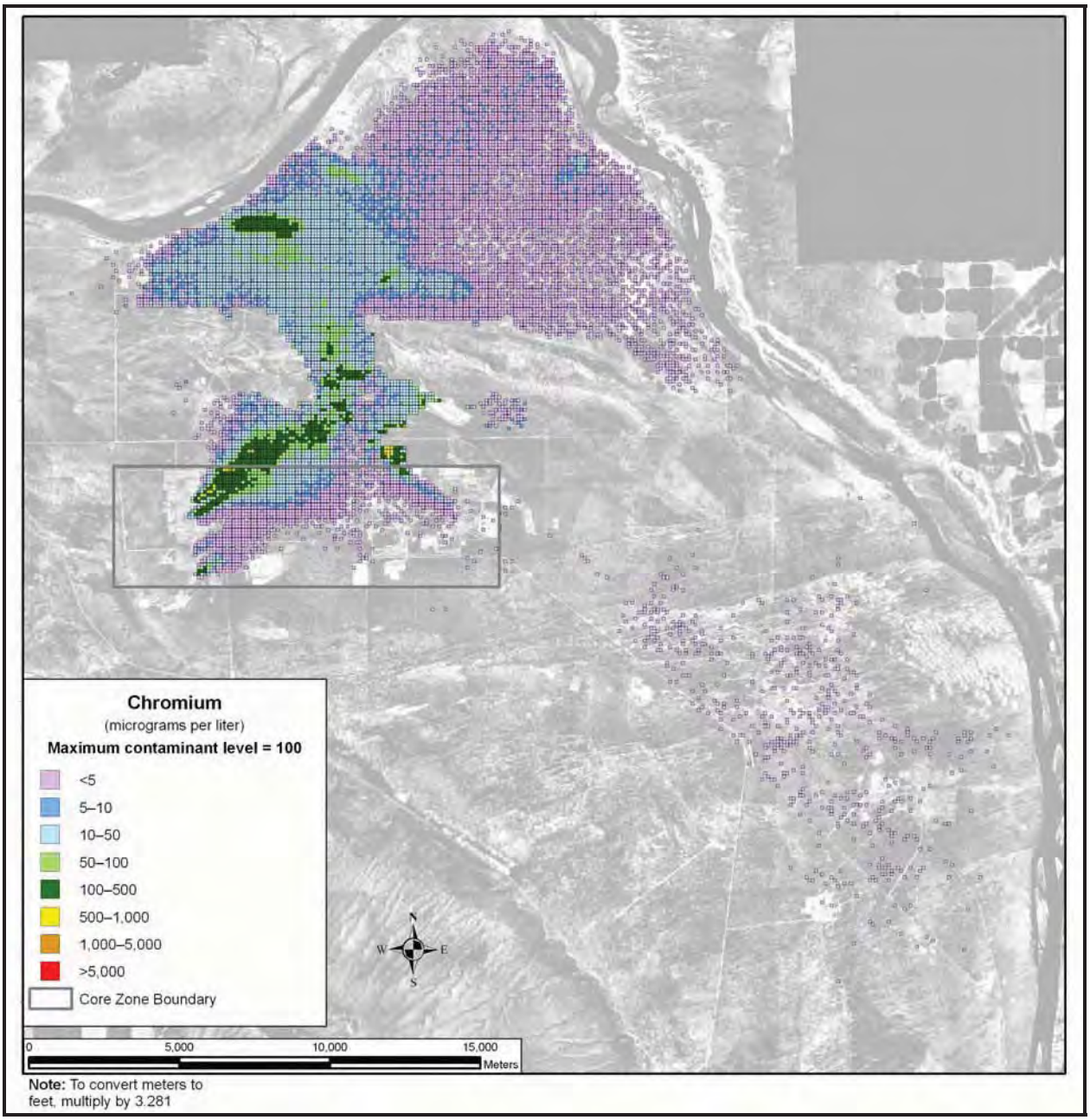


Figure O–12. Alternate Case Operational Period Chromium Plume Map, Calendar Year 2005

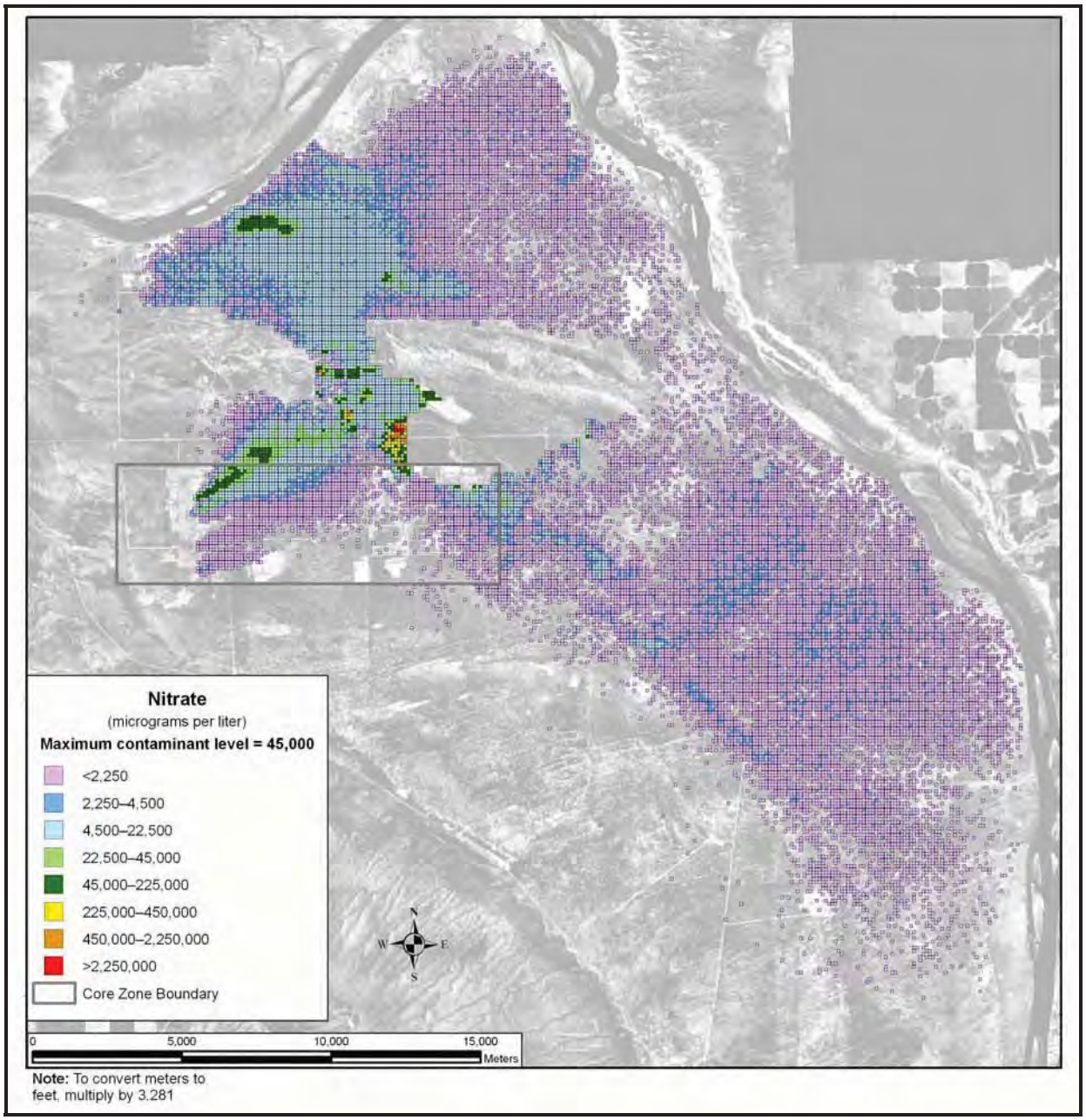


Figure O–13. Base Case Operational Period Nitrate Plume Map, Calendar Year 2005

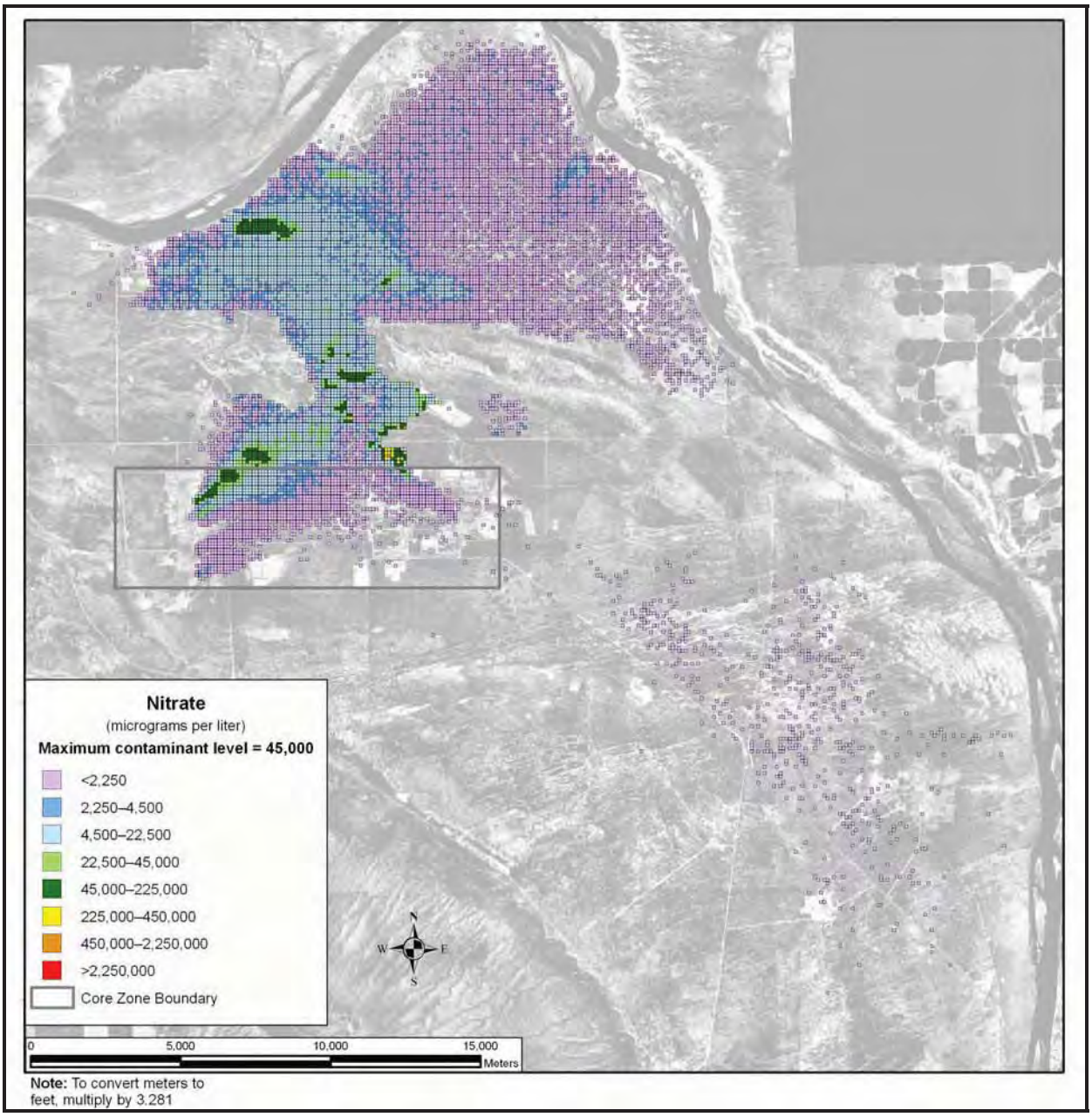


Figure O–14. Alternate Case Operational Period Nitrate Plume Map, Calendar Year 2005

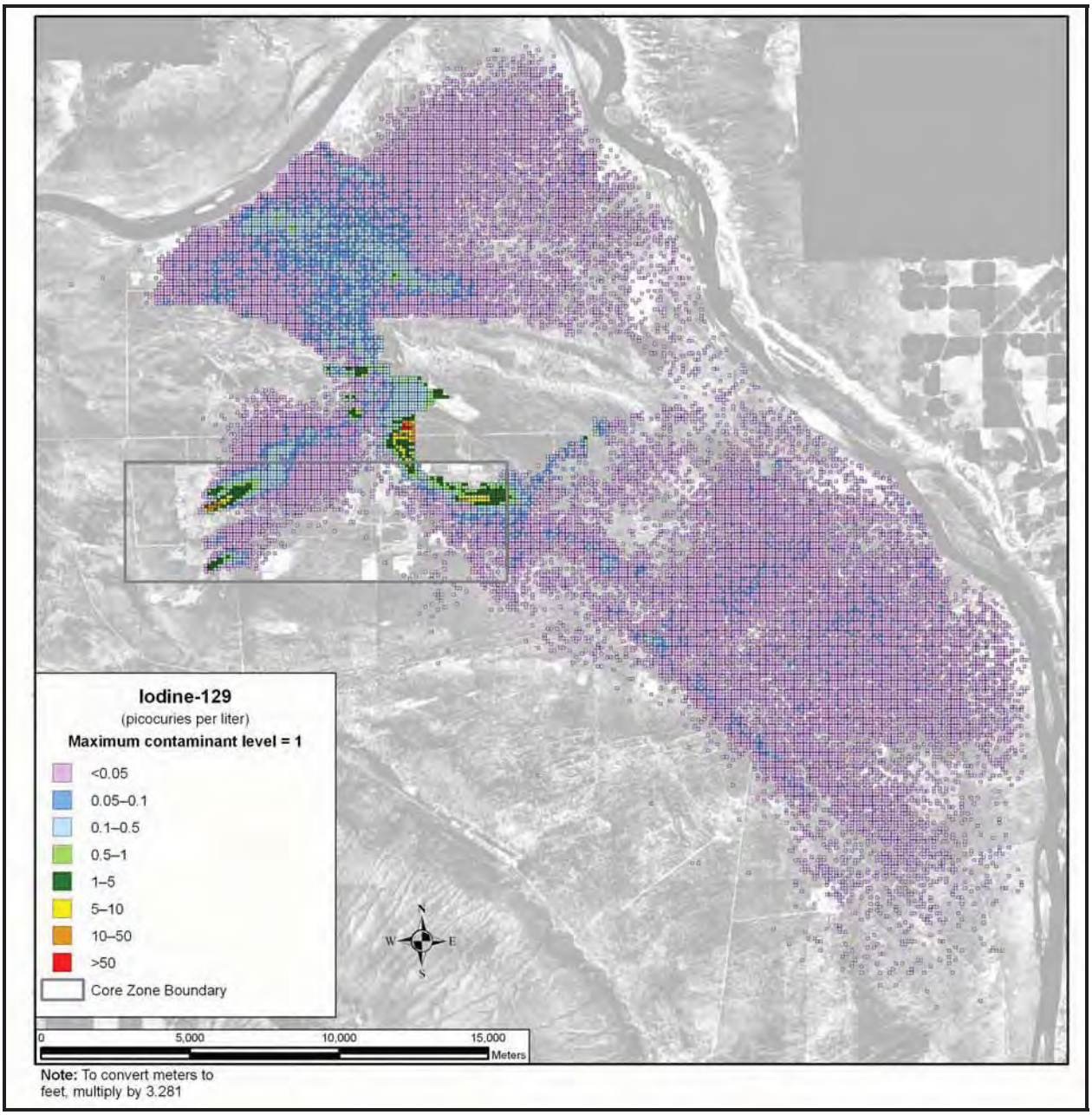


Figure O–15. Base Case Operational Period Iodine-129 Plume Map, Calendar Year 2005

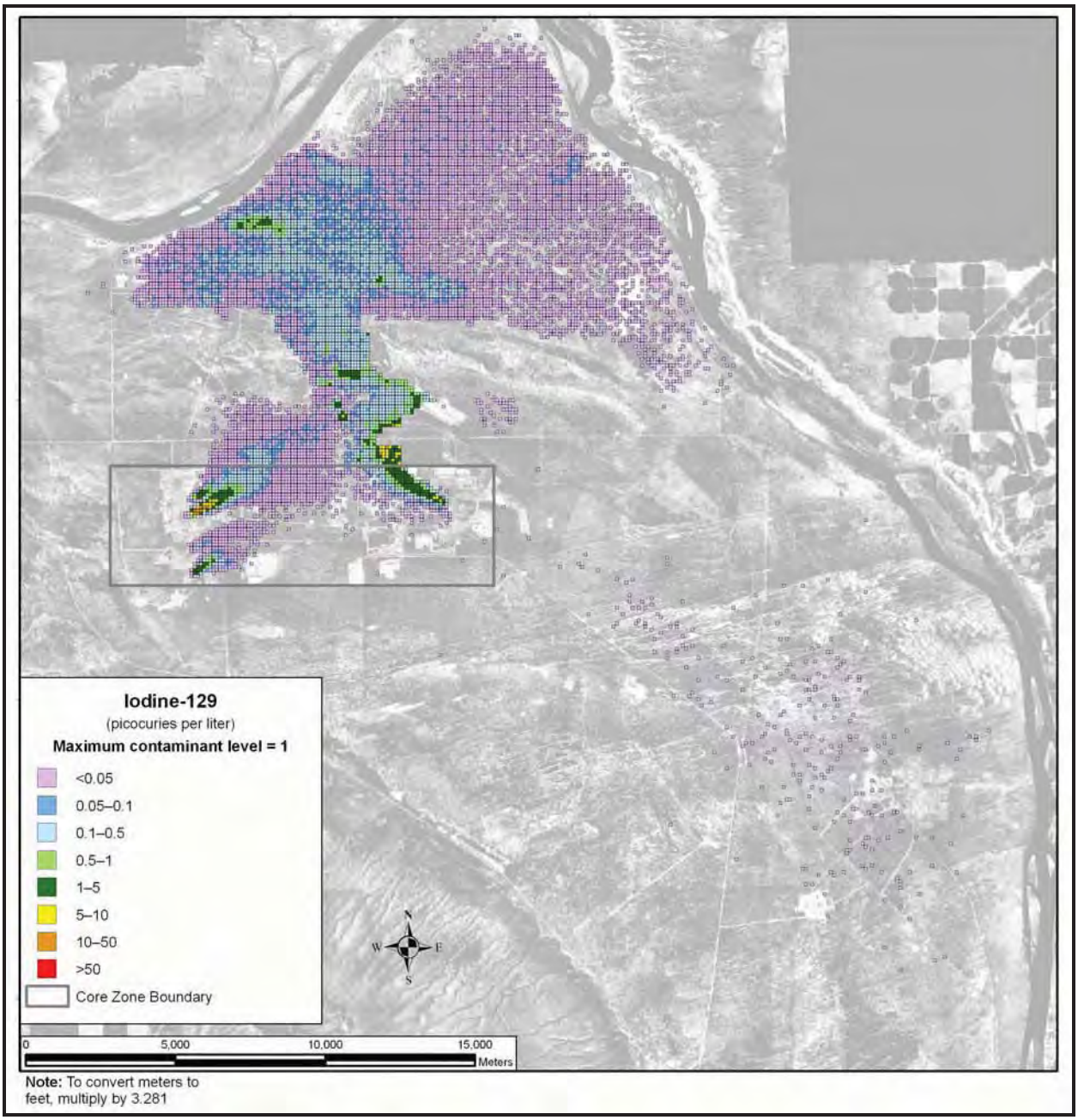


Figure O–16. Alternate Case Operational Period Iodine-129 Plume Map, Calendar Year 2005

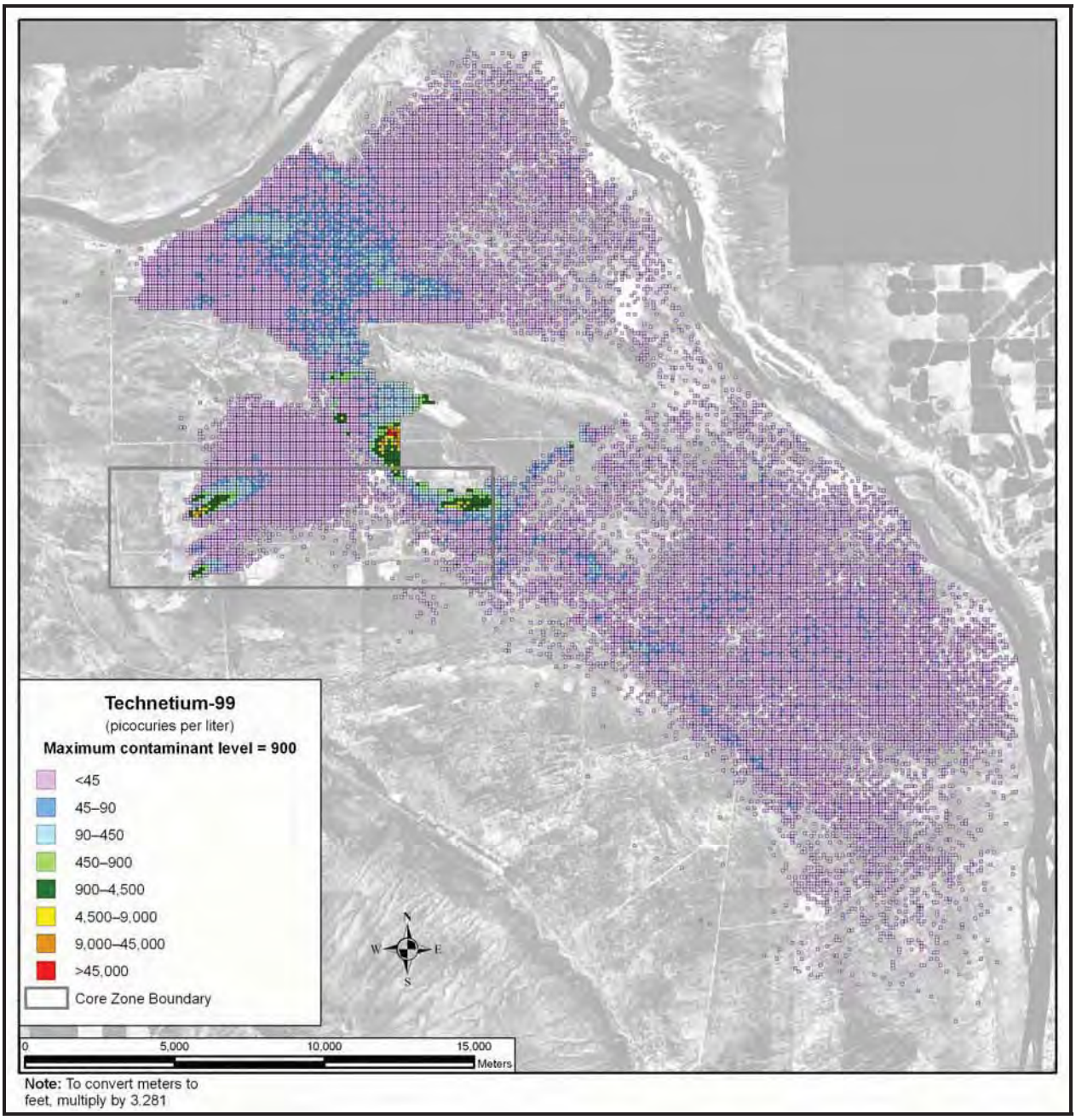


Figure O–17. Base Case Operational Period Technetium-99 Plume Map, Calendar Year 2005

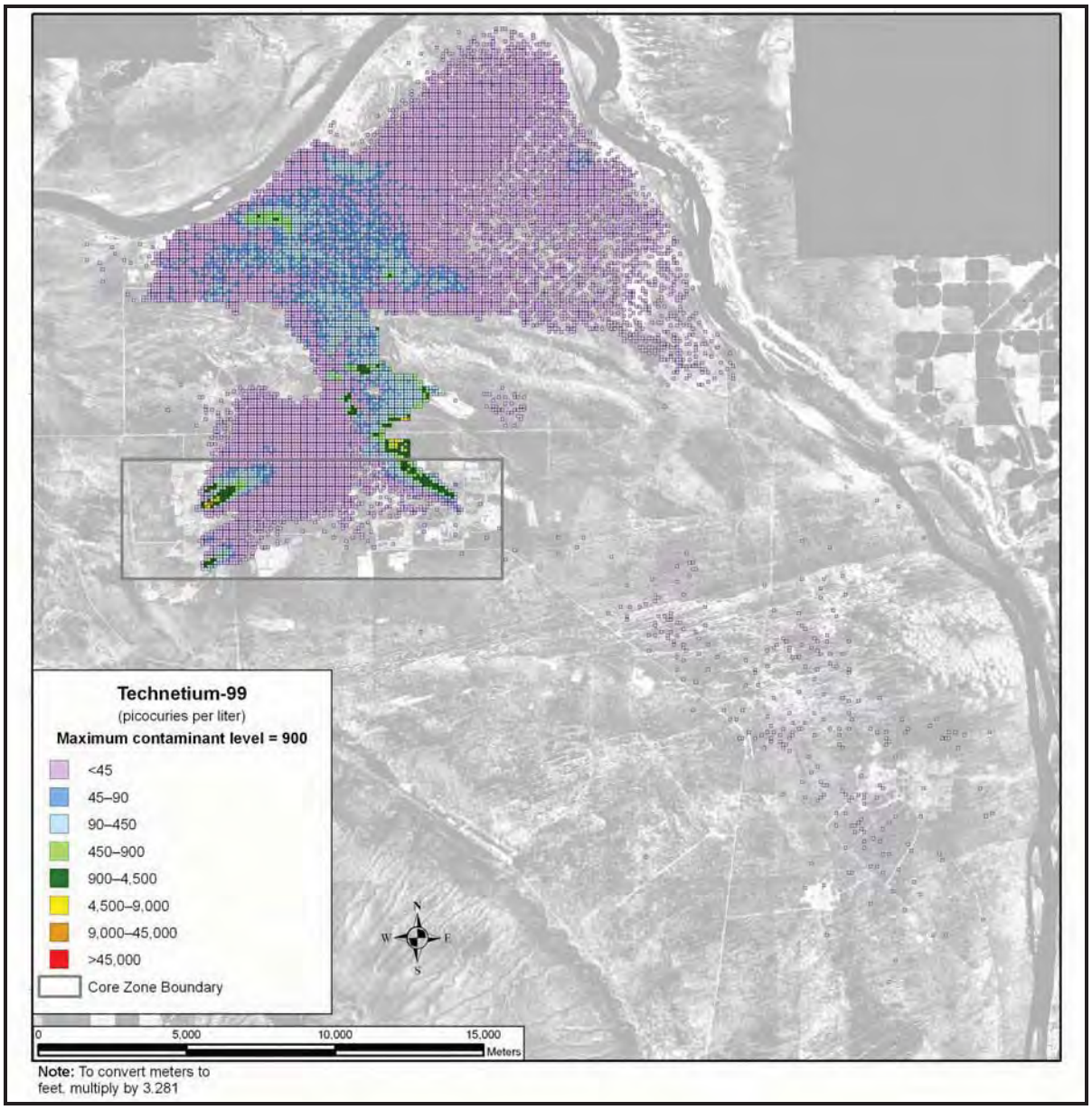


Figure O–18. Alternate Case Operational Period Technetium-99 Plume Map, Calendar Year 2005

O.6.1.2 PUREX Waste Site Hydrogen-3 (Tritium) Plume

Particle-tracking analyses were performed to compare the results of the Base and Alternate Case flow fields during Hanford's operational period (1944–2006). This comparison included the PUREX waste sites that make up the 200-East Area tritium plume, including 216-A-10, 216-A-21, 216-A-24, 216-A-27, 216-A-30, 216-A-36B, 216-A-37-1, 216-A-37-2, 216-A-4, 216-A-45, 216-A-5, 216-A-6, and 216-A-8. Figures O–19 and O–20 respectively show the spatial distribution of the PUREX waste site tritium plume for the Base and Alternate Case flow fields near the end of the operational period (year 2005). These results suggest that regional-scale contaminant plumes (i.e., areas of groundwater contaminated above benchmark values) from *TC & WM EIS* cumulative analysis sources in the 200-East Area are somewhat different for the Base and Alternate Case flow fields. The Base Case flow field simulates a tritium plume with peak concentrations and spatial distribution in qualitatively better agreement with field measurements.

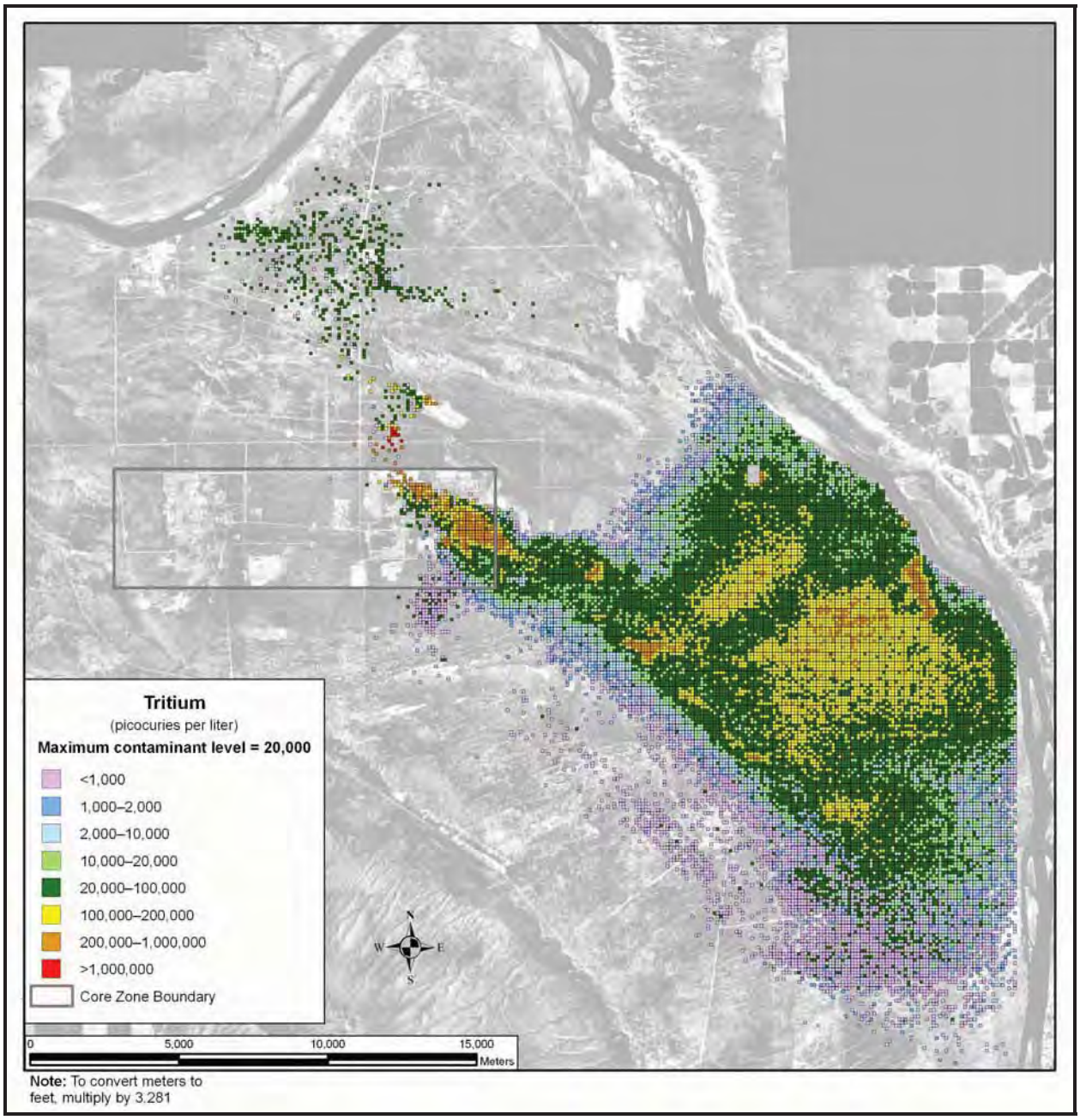


Figure O–19. Base Case Operational Period Plutonium-Uranium Extraction (PUREX) Waste Site Hydrogen-3 (Tritium) Plume Map, Calendar Year 2005

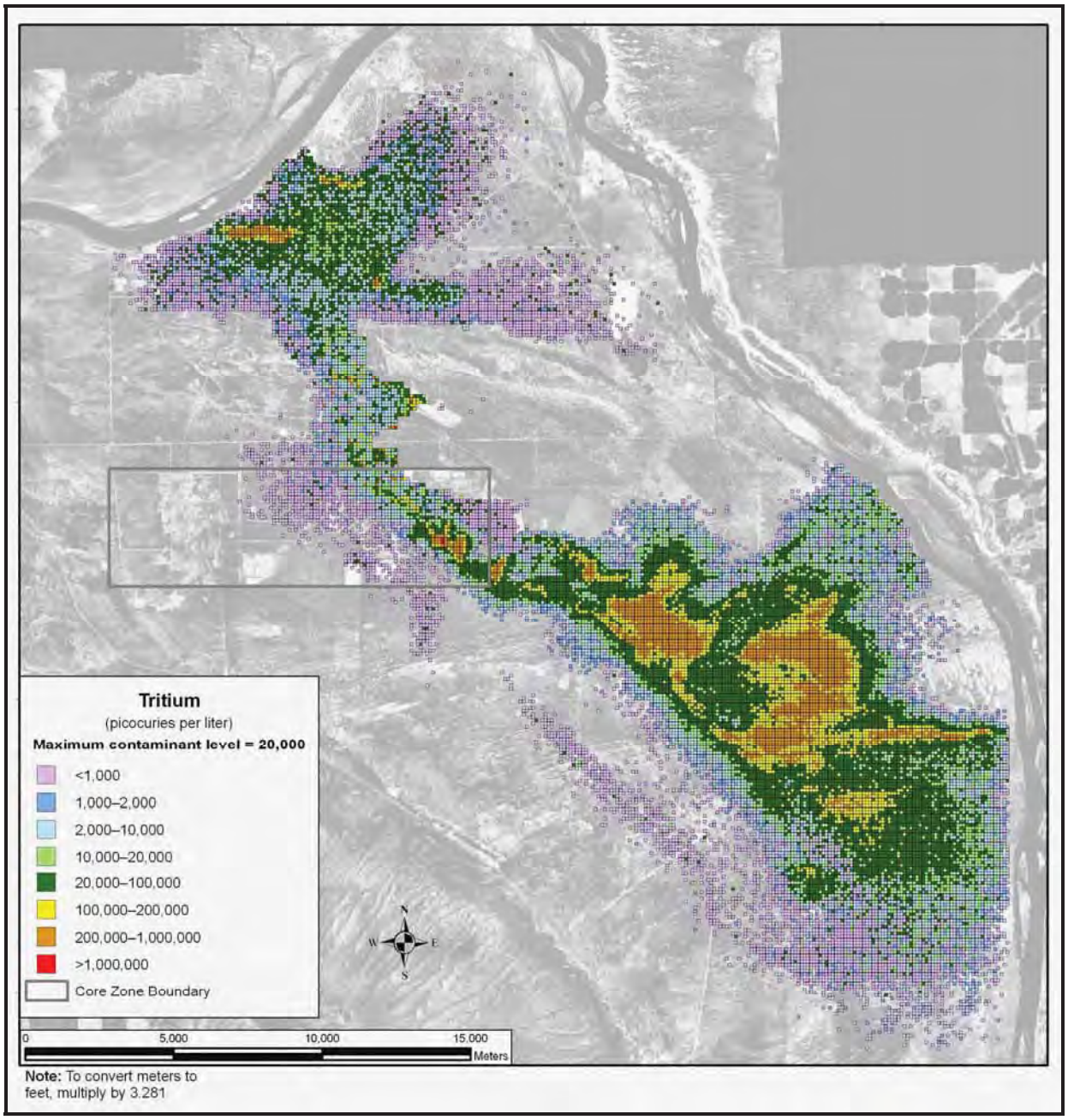


Figure O–20. Alternate Case Operational Period Plutonium-Uranium Extraction (PUREX) Waste Site Hydrogen-3 (Tritium) Plume Map, Calendar Year 2005

O.6.1.3 REDOX Waste Site Hydrogen-3 (Tritium) Plume

Particle-tracking analyses were performed to compare the results of the Base and Alternate Case flow fields during Hanford's operational period (1944–2006). This comparison included the REDOX waste site sites that make up the 200-West Area tritium plume, including 216-S1 and 2, 216-S-13, 216-S-20, 216-S-25, 216-S-26, 216-S-7, 216-S-9, 216-S-21, 216-U-12, and 216-U-8. Figures O–21 and O–22 respectively show the spatial distribution of the REDOX waste site tritium plume for the Base and Alternate Case flow fields near the end of the operational period (year 2005). These results suggest that regional-scale contaminant plumes (i.e., areas of groundwater contaminated above benchmark values) from *TC & WM EIS* cumulative analysis sources in the 200-West Area are similar for the Base and Alternate Case flow fields.

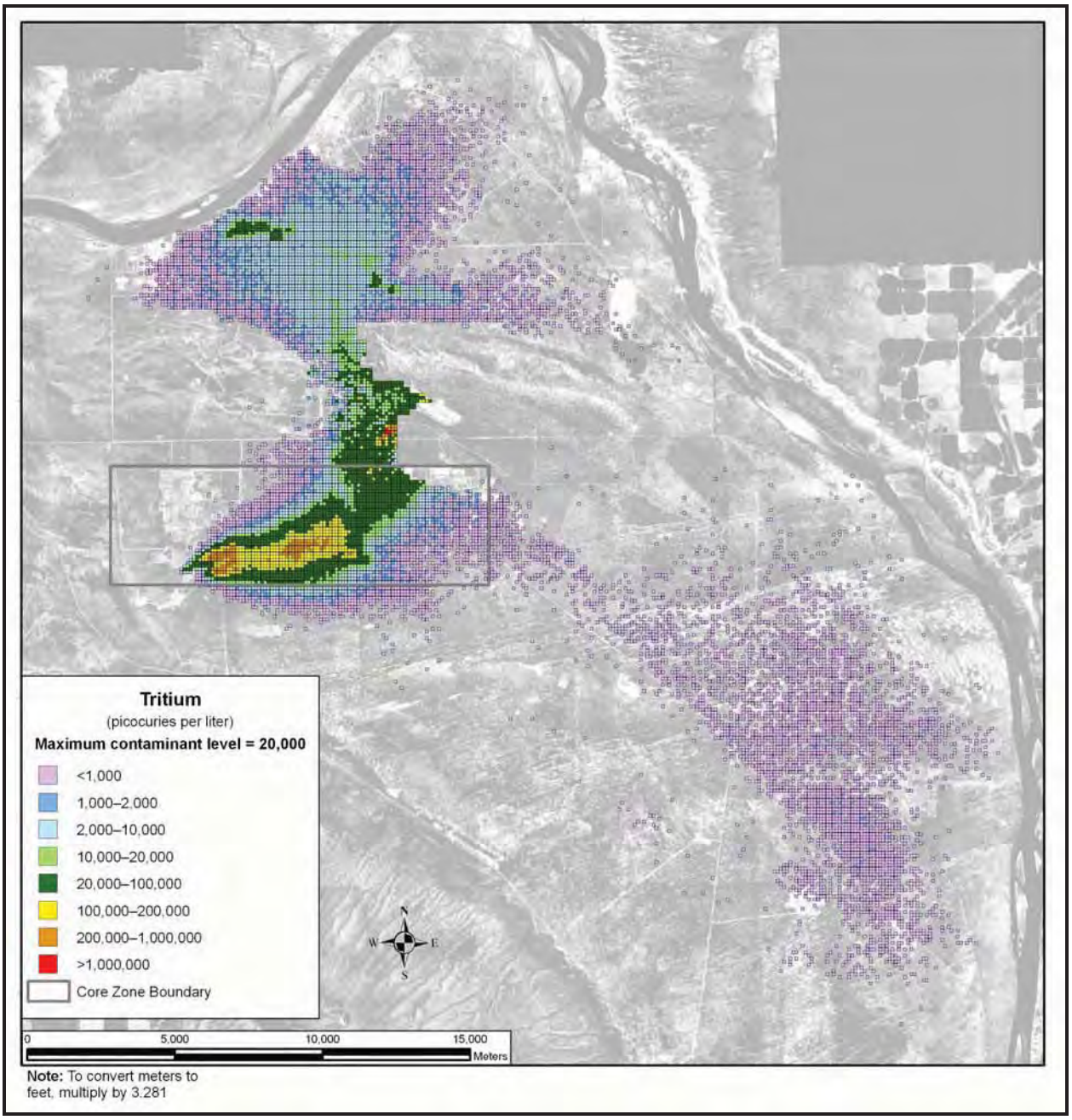


Figure O–21. Base Case Operational Period Reduction-Oxidation (REDOX) Waste Site Hydrogen-3 (Tritium) Plume Map, Calendar Year 2005

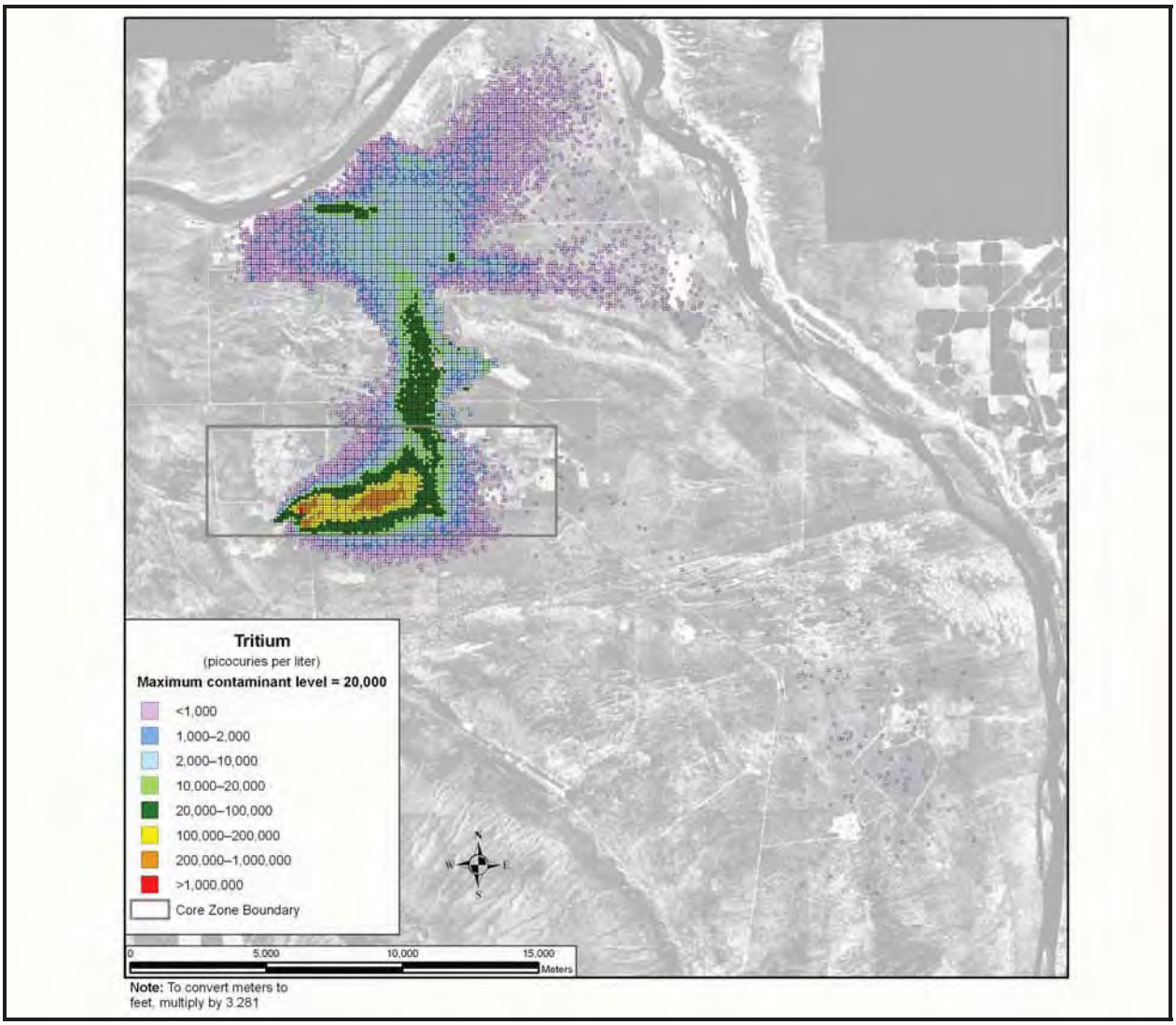


Figure O–22. Alternate Case Operational Period Reduction-Oxidation (REDOX) Waste Site Hydrogen-3 (Tritium) Plume Map, Calendar Year 2005

O.6.2 Comparison of Base Case and Alternate Case Flow Fields During Hanford Postoperational Period

The Base Case flow field was also compared to the Alternate Case flow field for the post-operational period. Particle-tracking analyses were performed to compare the concentration results for technetium-99 at the Columbia River for the Base and Alternate Case flow fields over a 500-year period (1940–2440). This comparison was based on the release of 1 curie of technetium-99 from each of the 10 source areas that are included in this *TC & WM EIS* alternatives analysis (the A, B, S, T, and U tank farms; LLBG 218-W-5 trenches 31 and 34; IDF-East; IDF-West; FFTF; and RPPDF). The releases were assumed to occur within a single year (2100). The peak concentrations of technetium-99 at the Columbia River for both the Base and Alternate Case flow fields are shown in Table O–60 for each source area. Note that, in general, the Alternate Case flow field predicts maximum concentrations at the Columbia River that are 50 to 100 percent greater than the Base Case. This suggests that, in general, the Alternate Case flow field, with greater postoperational flows through Gable Gap, attenuates contaminant mass in the far field to a smaller extent than the Base Case flow field. Figures O–23 through O–32 compares concentration versus time for technetium-99 at the Columbia River for both the Base and Alternate Cases

for each source area during these simulations. The comparison of the Base and Alternate Case flow fields for contaminant transport suggests that the two flow fields yield mostly similar results during the operational period (with the Base Case in somewhat better agreement with field observations), but differ during the postoperational period by up to a factor of 3. Overall, both flow fields predict peak concentrations and spatial distributions within a close order of magnitude of each other and with field data.

Table O–60. Barrier Analysis Results for Hanford Site Postoperational Time Period

Technetium-99 Peak Concentration at the Columbia River in picocuries per liter		
Barrier	**Base Case**	**Alternate Case**
A	6.44×10^{-1} (2206)	1.19 (2273–2313)
B	1.09 (2207)	1.34 (2281)
Fast Flux Test Facility	9.05×10^{-2} (2171–2436)	9.06×10^{-2} (2401–2402)
200-East Area Integrated Disposal Facility	3.89 (2149)	1.02 (2250–2265)
200-West Area Integrated Disposal Facility	1.20 (2201–2203)	1.36 (2160)
River Protection Project Disposal Facility	1.02 (2191–2192)	1.91 (2109)
S	5.94×10^{-1} (2373)	9.98×10^{-1} (2161)
Low-level radioactive waste burial ground 218-W-5 trenches 31 and 34	1.30 (2238)	1.09 (2166)
T	1.02 (2211)	1.45 (2144)
U	7.52×10^{-1} (2242)	8.20×10^{-1} (2261)

Note: Corresponding calendar years are shown in parentheses.

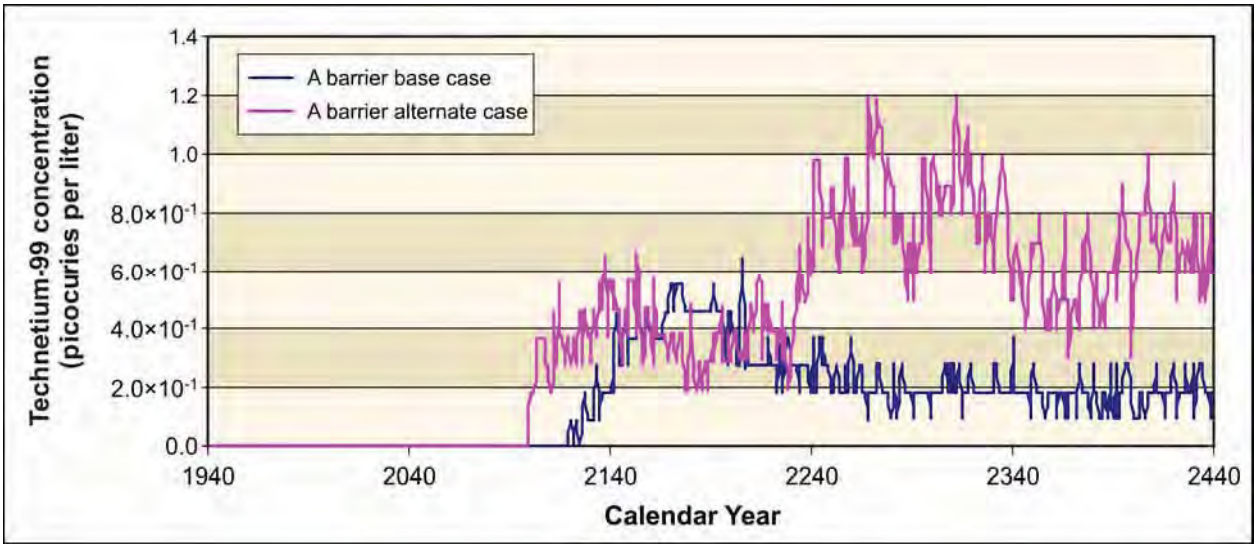


Figure O–23. A Barrier, Hanford Site Postoperational Period

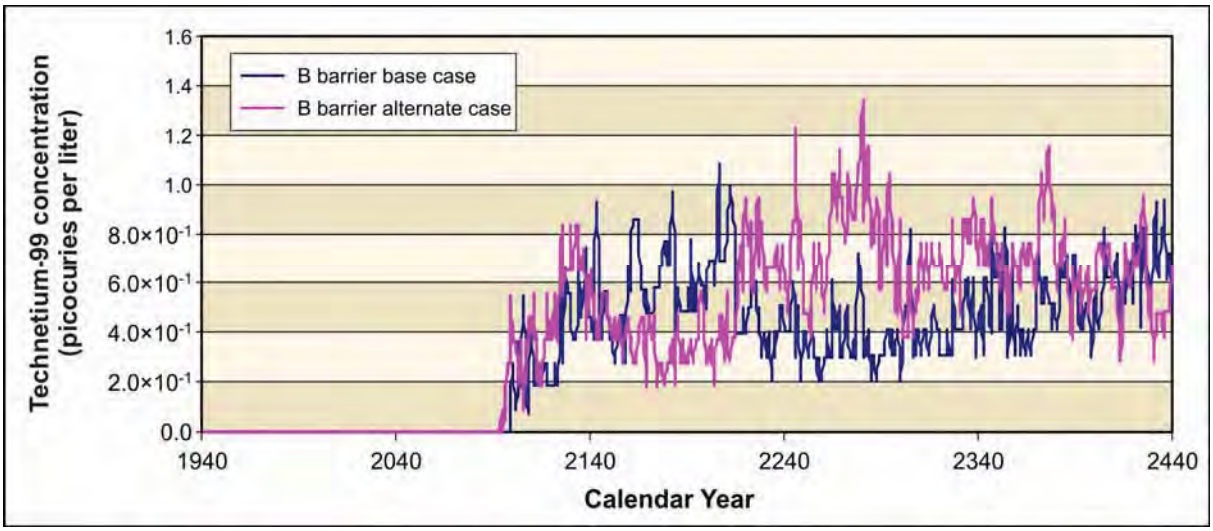


Figure O–24. B Barrier, Hanford Site Postoperational Period

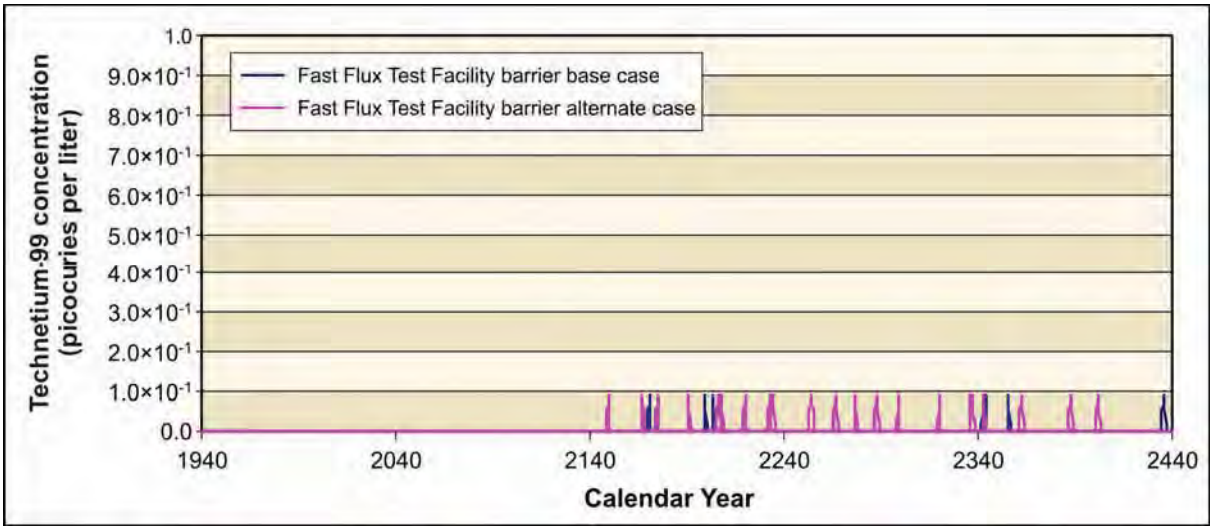


Figure O–25. Fast Flux Test Facility Barrier, Hanford Site Postoperational Period

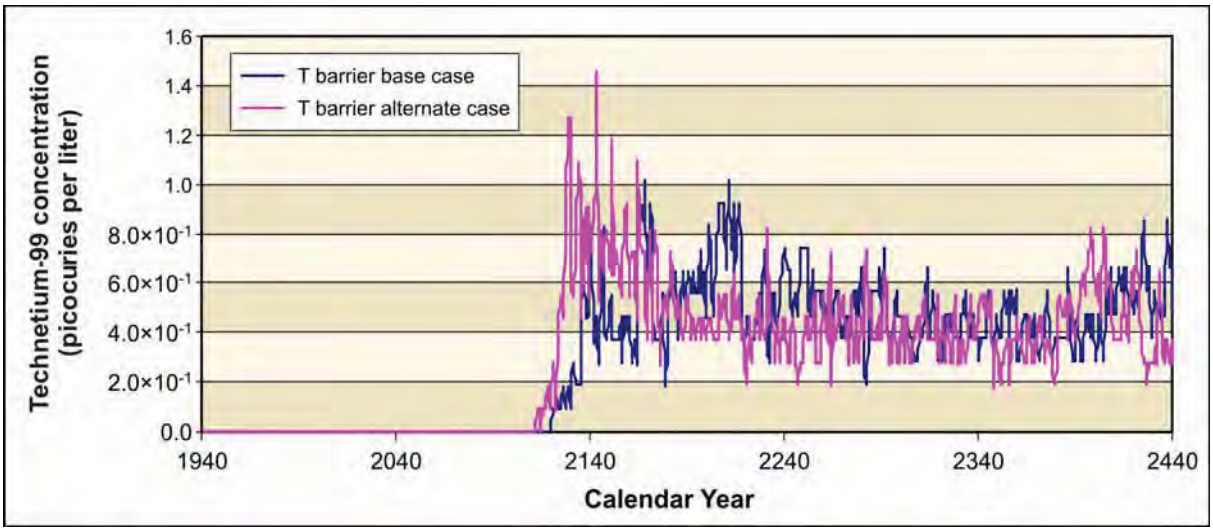


Figure O–26. T Barrier, Hanford Site Postoperational Period

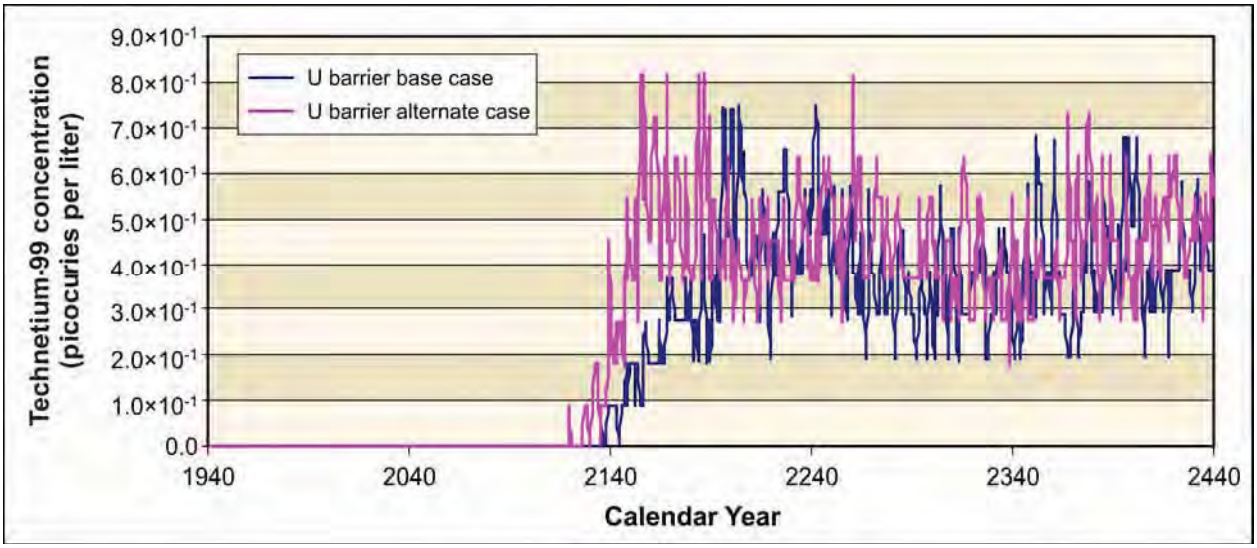


Figure O–27. U Barrier, Hanford Site Postoperational Period

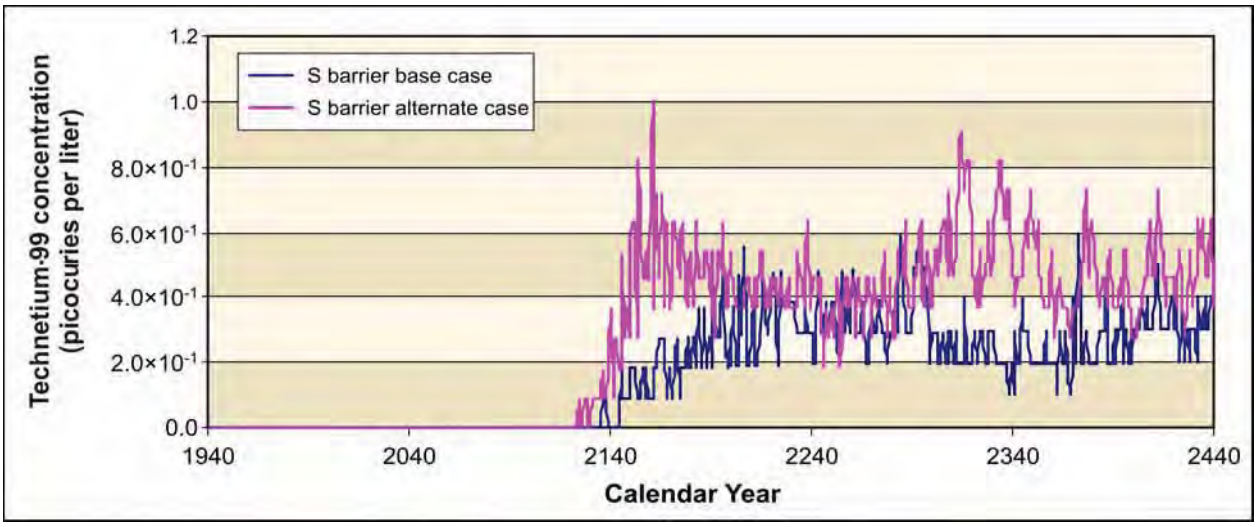


Figure O–28. S Barrier, Hanford Site Postoperational Period

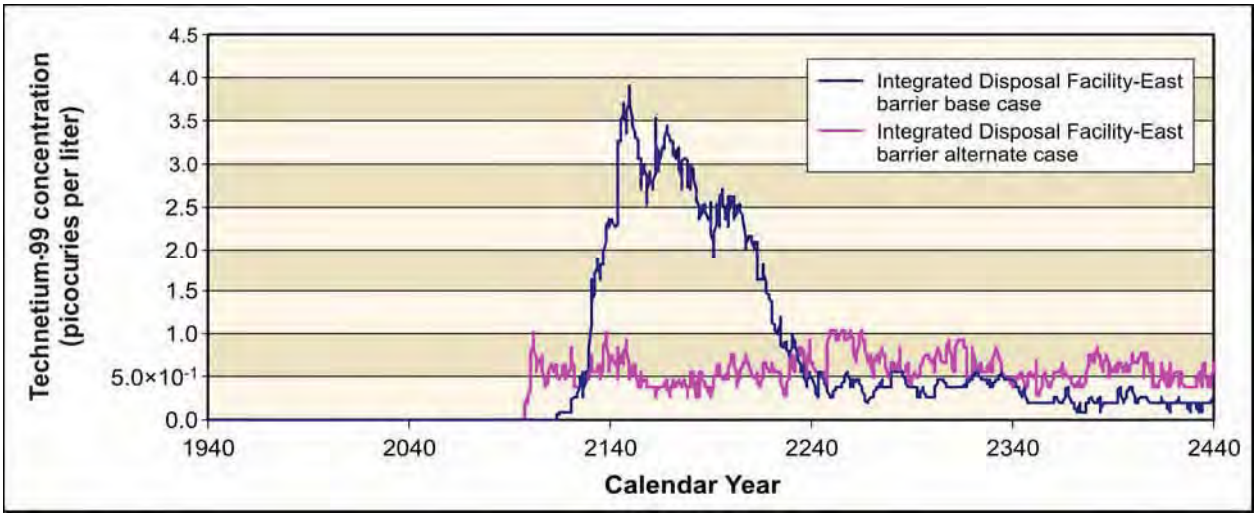


Figure O–29. 200-East Area Integrated Disposal Facility Barrier, Hanford Site Postoperational Period

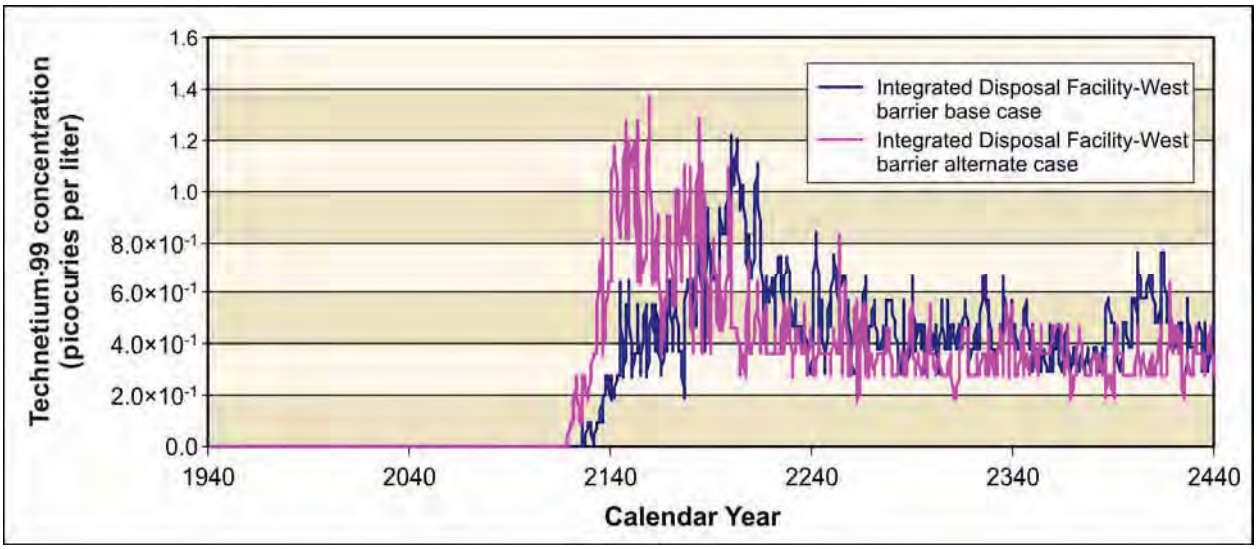


Figure O–30. 200-West Area Integrated Disposal Facility Barrier, Hanford Site Postoperational Period

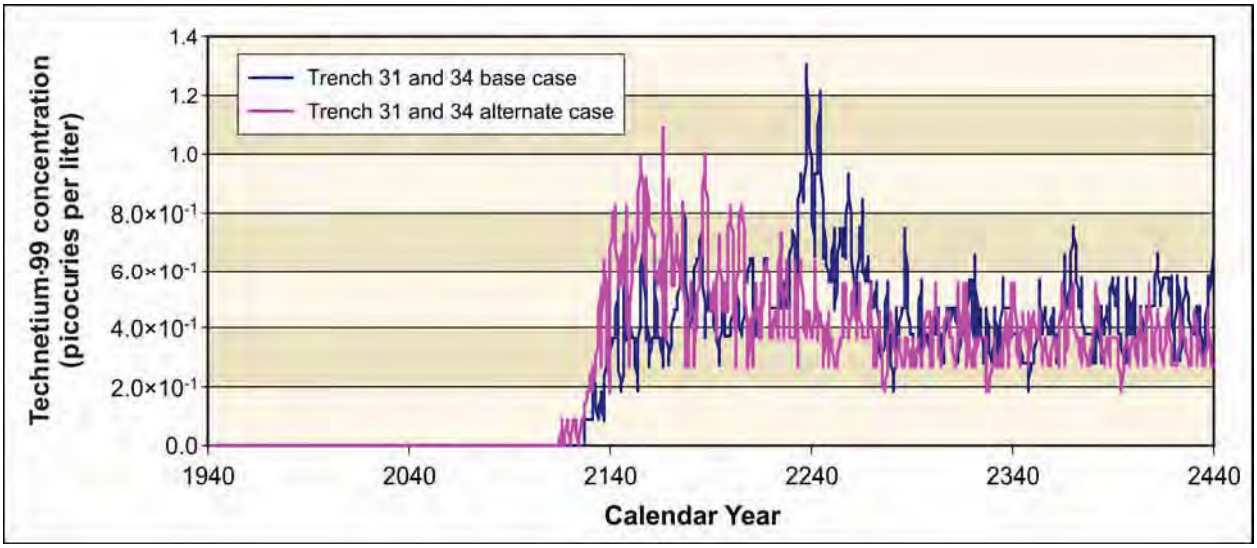


Figure O–31. Low-Level Radioactive Waste Burial Ground Trenches 31 and 34 Barrier, Hanford Site Postoperational Period

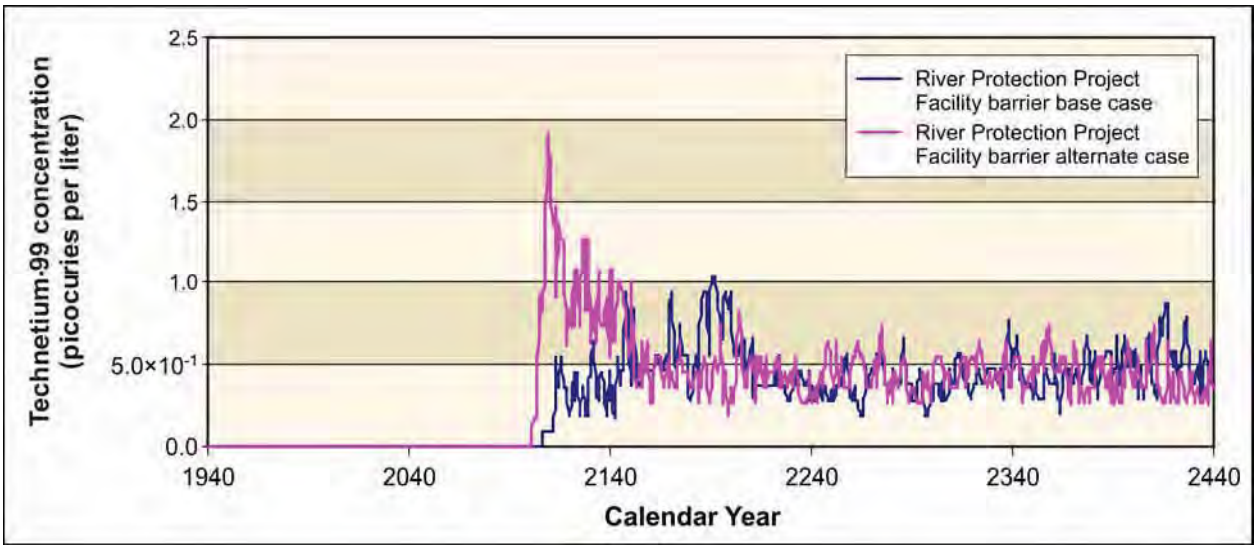


Figure O–32. River Protection Project Disposal Facility Barrier, Hanford Site Postoperational Period

O.6.3 Iodine-129 Distribution Coefficient Sensitivity Analysis

The purpose of the groundwater transport analysis was to project contaminant concentrations in the aquifer from the initial release locations to points of assessment such as the Core Zone Boundary and the Columbia River. Contaminants moving through an aquifer system are affected by a variety of physical and chemical processes. One of these processes includes retardation, which was modeled using the standard distribution coefficient (K_d) approach.

The purpose of this analysis was to demonstrate the sensitivity of contaminant transport relative to changes in the distribution coefficient. The distribution coefficients for iodine-129 were specified in the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* (DOE 2005) as 0 milliliters per gram (Base Case) and 0.2 milliliters per gram (sensitivity case). These values resulted in retardation factors (R) of approximately 1 and 3 for the bulk density (2.6 grams per cubic centimeter) and porosity (0.25) assumed for the unconfined aquifer.

Table O–61 compares the groundwater transport results for each condition (R = 1 and R = 3), showing the peak concentration of iodine-129 and the year of occurrence at the Columbia River and Core Zone Boundary.

Table O–61. Iodine-129 Distribution Coefficient Sensitivity Results

Area	Columbia River in picocuries per liter		Core Zone in picocuries per liter	
	R = 1	R = 3	R = 1	R = 3
BY Cribs	1.97×10^{-1}	1.87×10^{-1}	1.87×10^{2}	6.86×10^{2}
	(2015)	(4071)	(1957)	(1957)
TY Cribs	1.58×10^{-2}	1.75×10^{-2}	1.50×10^{-1}	2.49×10^{-1}
	(3344)	(3900–3905)	(2002)	(2035)

Note: The health-based benchmark for iodine-129 is 1 picocurie per liter (EPA 2002). Corresponding calendar years are shown in parentheses.

Key: R=retardation factor.

For the BY Cribs, the results showed a near-field (Core Zone) increase in the peak concentration of iodine-129 by a factor of 3.5 when the retardation factor was higher (3 versus 1). In both cases, the peak concentrations of iodine-129 occurred at the same time (1957). This was during the operational period, when flow field changes in velocity and direction occurred due to changes in the anthropogenic recharge (see Appendix L). By comparison, the peak concentrations of iodine-129 in the far field (Columbia River) were very similar, with the exception that the peak concentrations occurred much later for the higher retardation factor (3 versus 1).

For the TY Cribs, the results showed a significantly later arrival time for the peak concentrations in the near field (Core Zone) when the retardation factor was higher (3 versus 1). Additionally, the peak concentrations of iodine-129 were higher by a factor of 1.5 when the retardation factor was higher.

By comparison, the peak concentrations of iodine-129 in the far field (Columbia River) were very similar, with the exception that the peak concentrations occurred much later for the higher retardation factor (3 versus 1). These arrival times may be comparatively insignificant because both times were greater than 1,000 years beyond the start of the simulation.

Overall, the iodine-129 K_d sensitivity analysis showed a greater impact with respect to peak concentrations and arrival times for sources located near the Core Zone and the Columbia River than for sources located a greater distance away. Plume maps showing the results of the spatial distribution of iodine-129 for each condition (R = 1 and R = 3) at the BY Cribs and TY Cribs at years 2005, 3500, and 7010 are provided in Figures O–33 through O–44.

These results suggest that changes in transport velocity induced by different retardation factors interact with changes in flow field direction to produce short-term differences in peak concentrations in the near-field. The iodine-129 retardation factor of 1 is in slightly better agreement with the field observations from the BY Cribs; however the iodine-129 retardation factor of 3 is in better agreement with field observations from the TY Cribs in 2005. Overall, the results are in a close order of magnitude agreement for the range of retardation factors investigated.

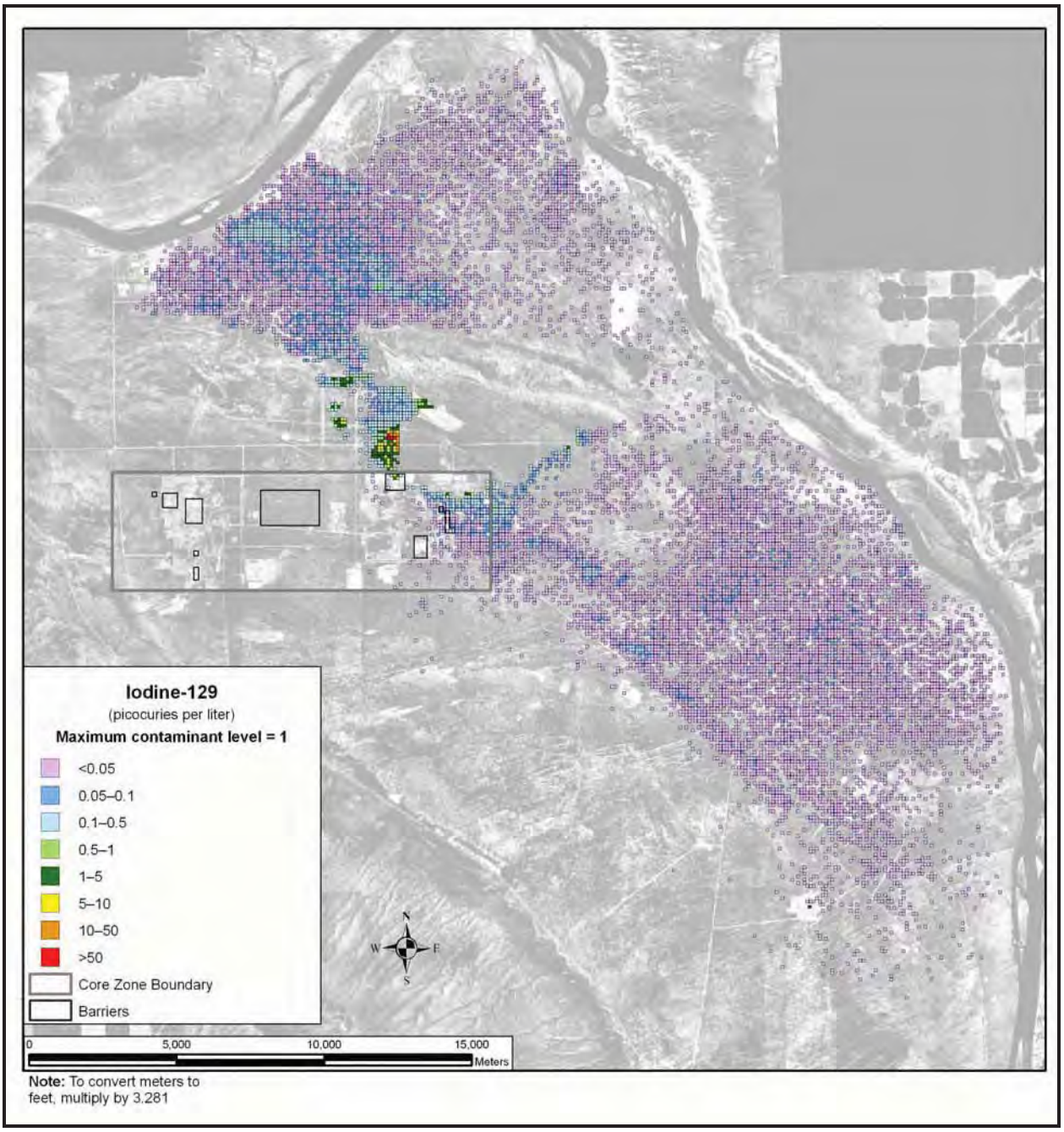


Figure O–33. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 2005 – Retardation Factor of One

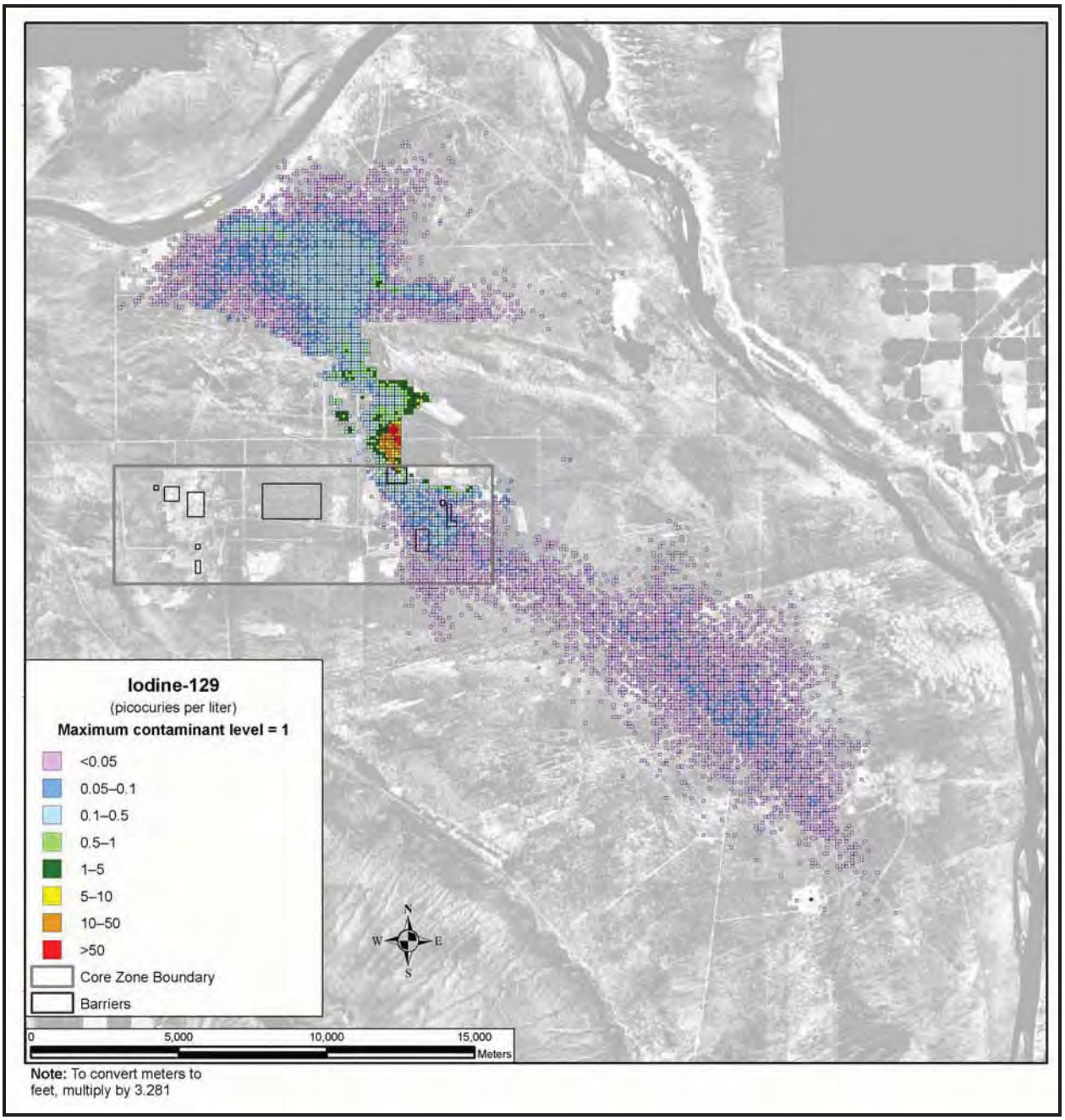


Figure O–34. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 2005 – Retardation Factor of Three

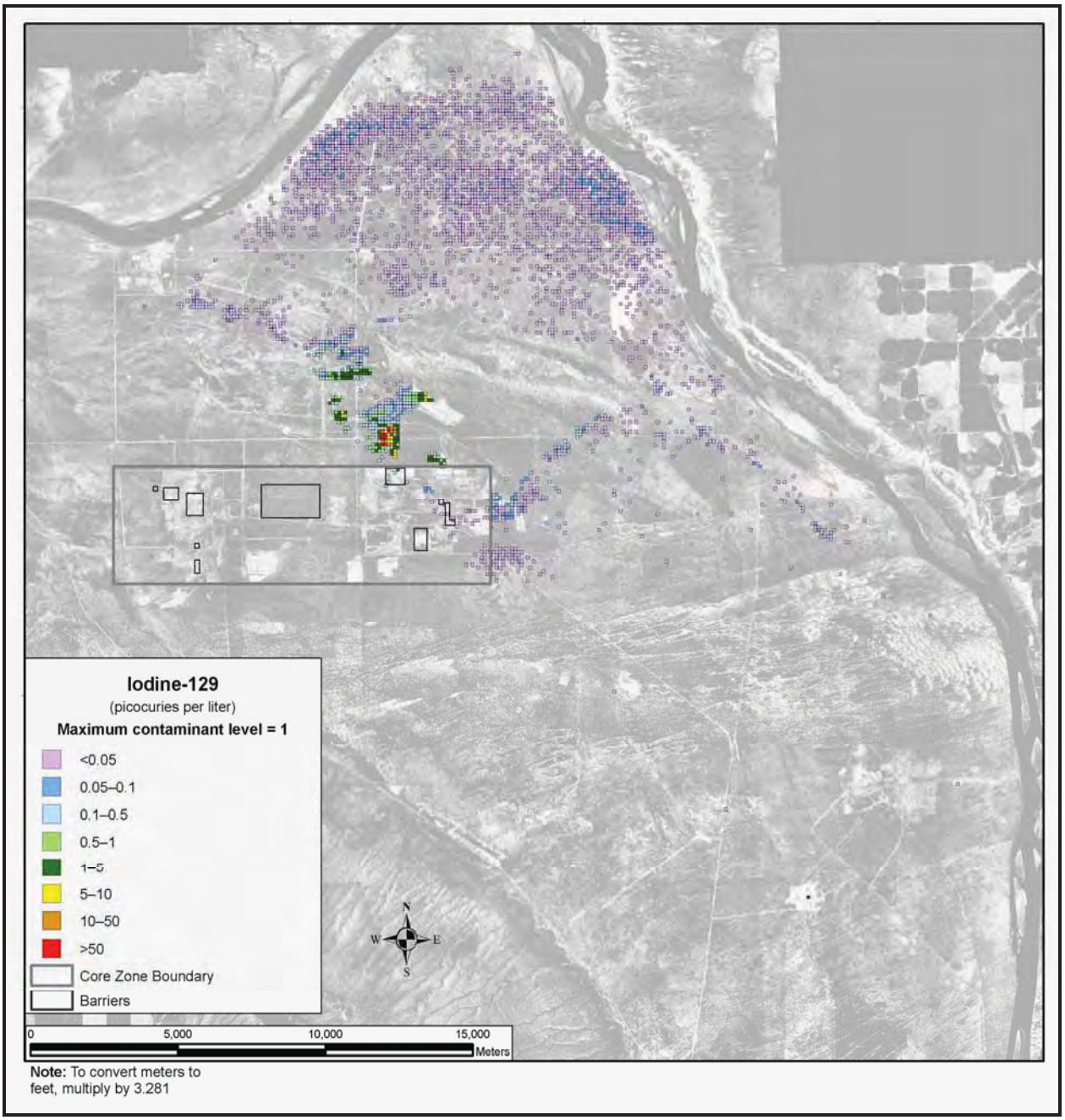


Figure O–35. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 3500 – Retardation Factor of One

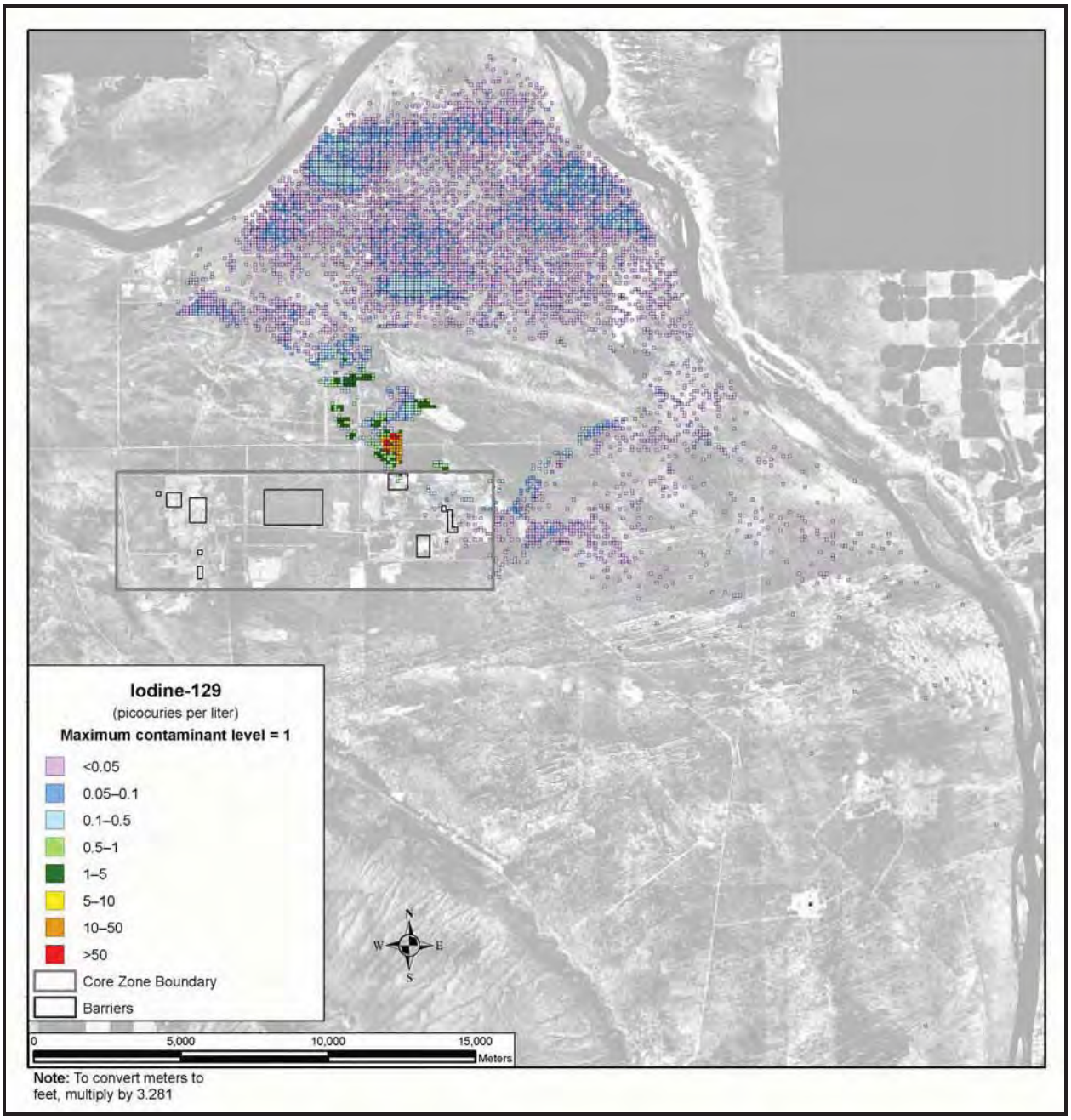


Figure O–36. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 3500 – Retardation Factor of Three

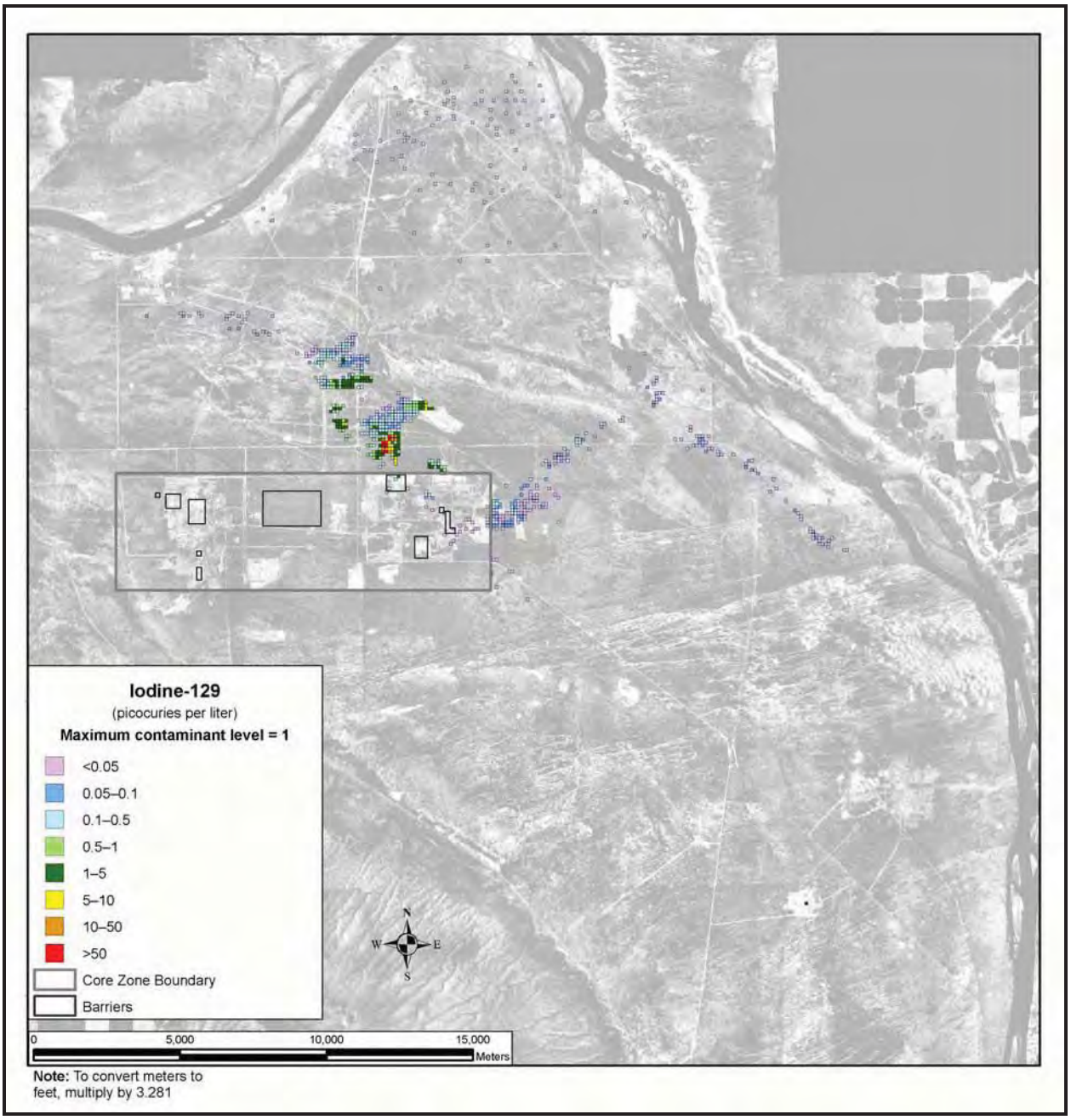


Figure O–37. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 7010 – Retardation Factor of One

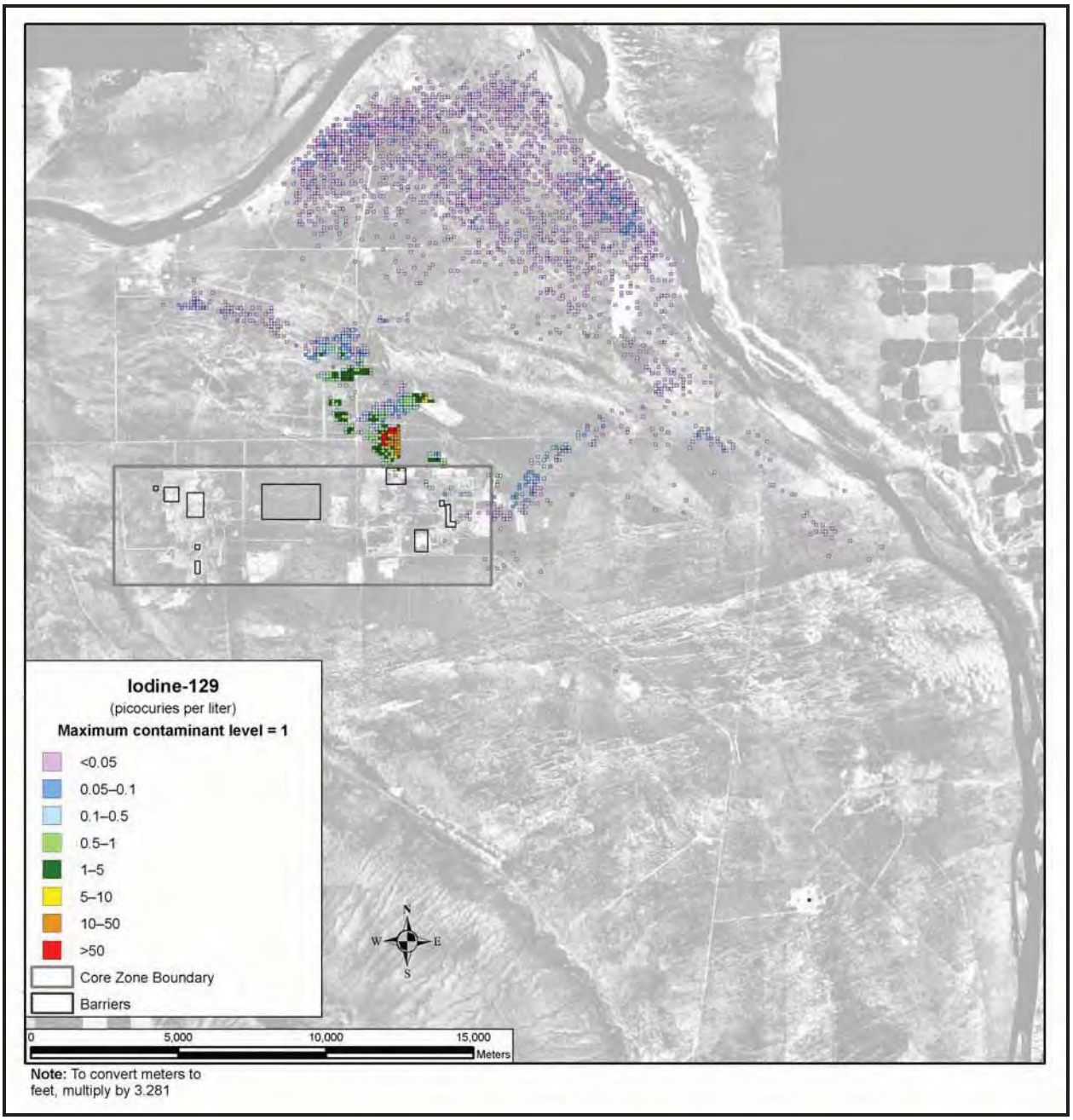


Figure O–38. Spatial Distribution of Groundwater Iodine-129 Concentration at BY Cribs, Calendar Year 7010 – Retardation Factor of Three

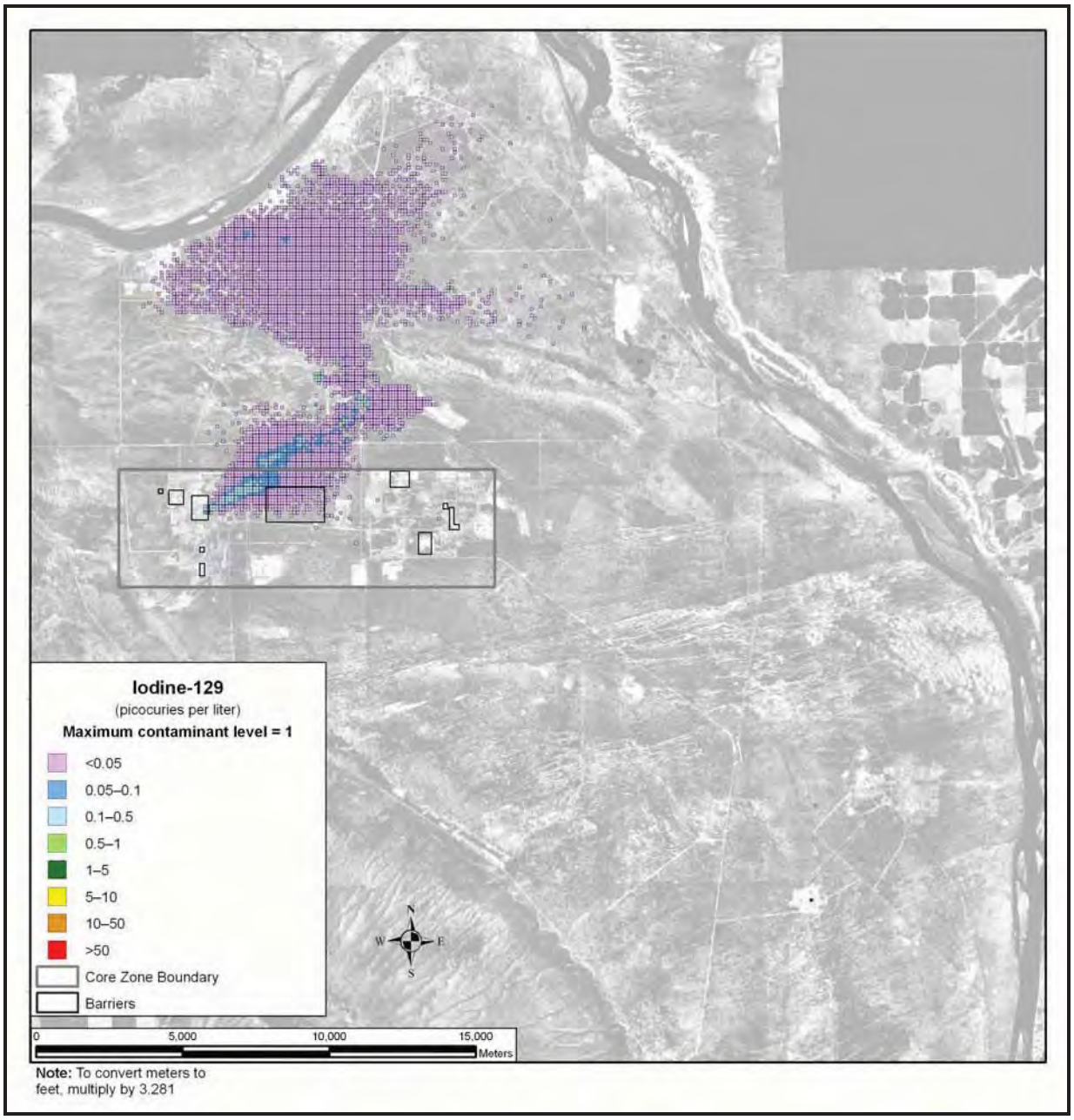


Figure O–39. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 2005 – Retardation Factor of One

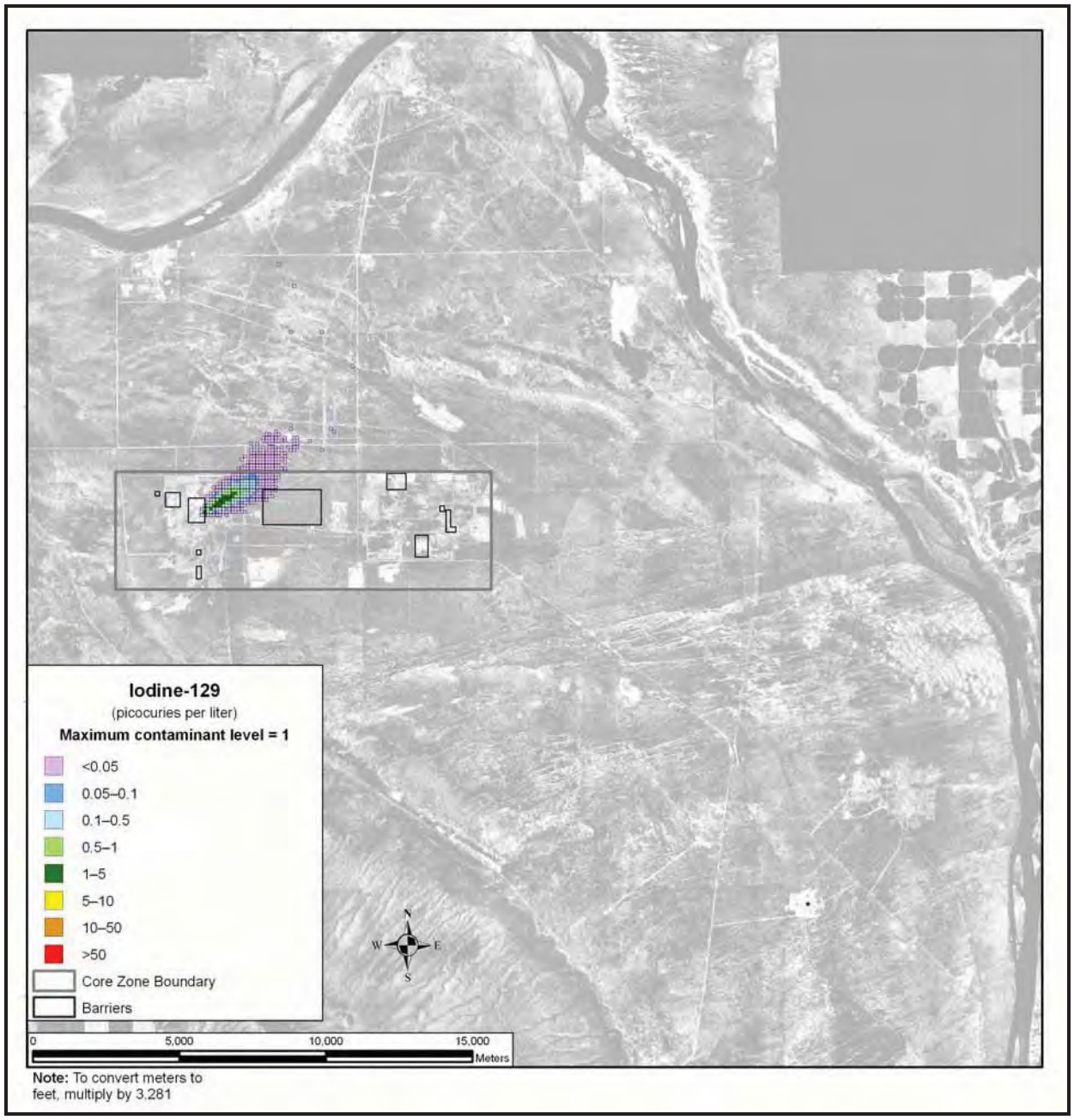


Figure O–40. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 2005 – Retardation Factor of Three

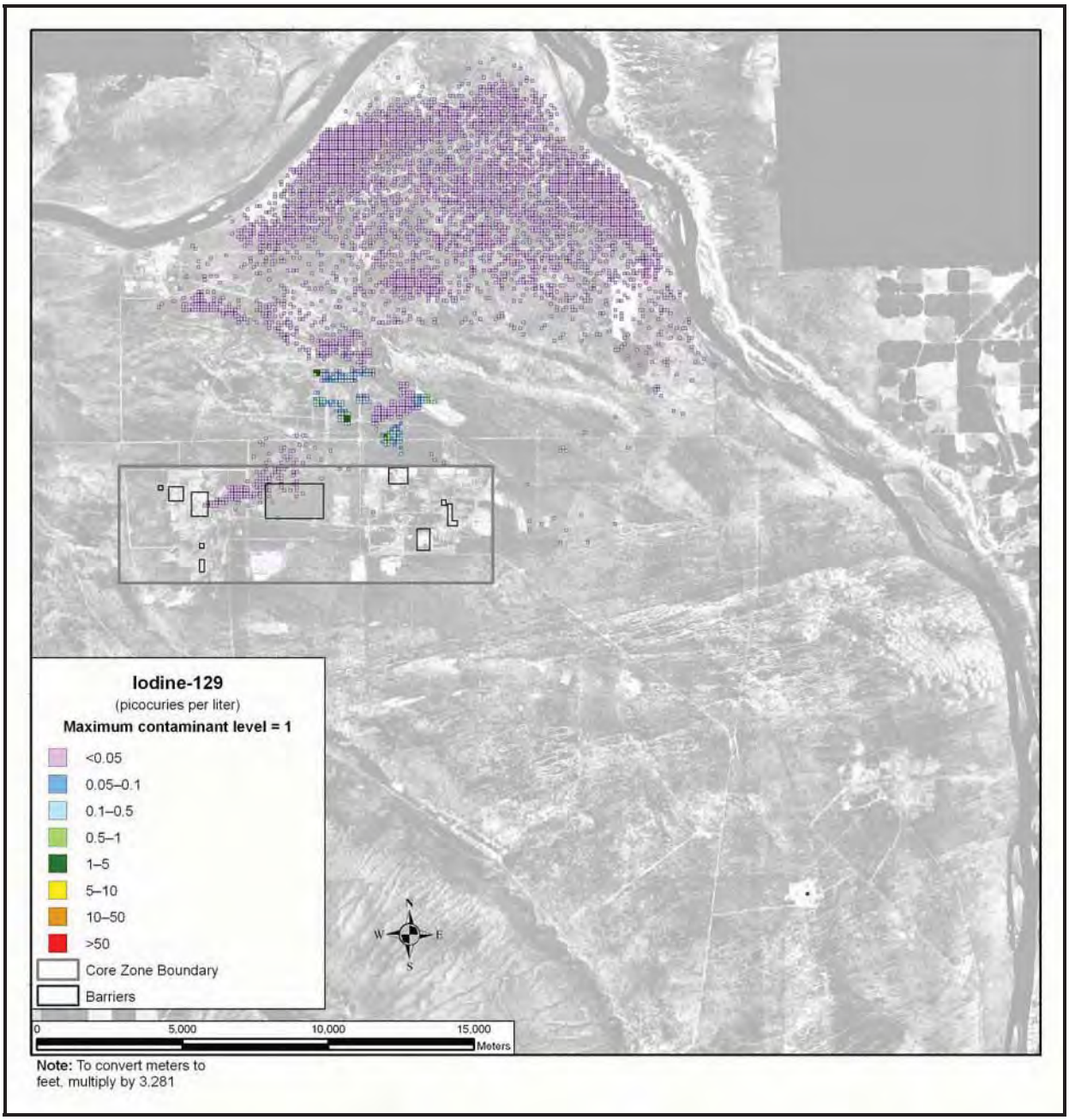


Figure O–41. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 3500 – Retardation Factor of One

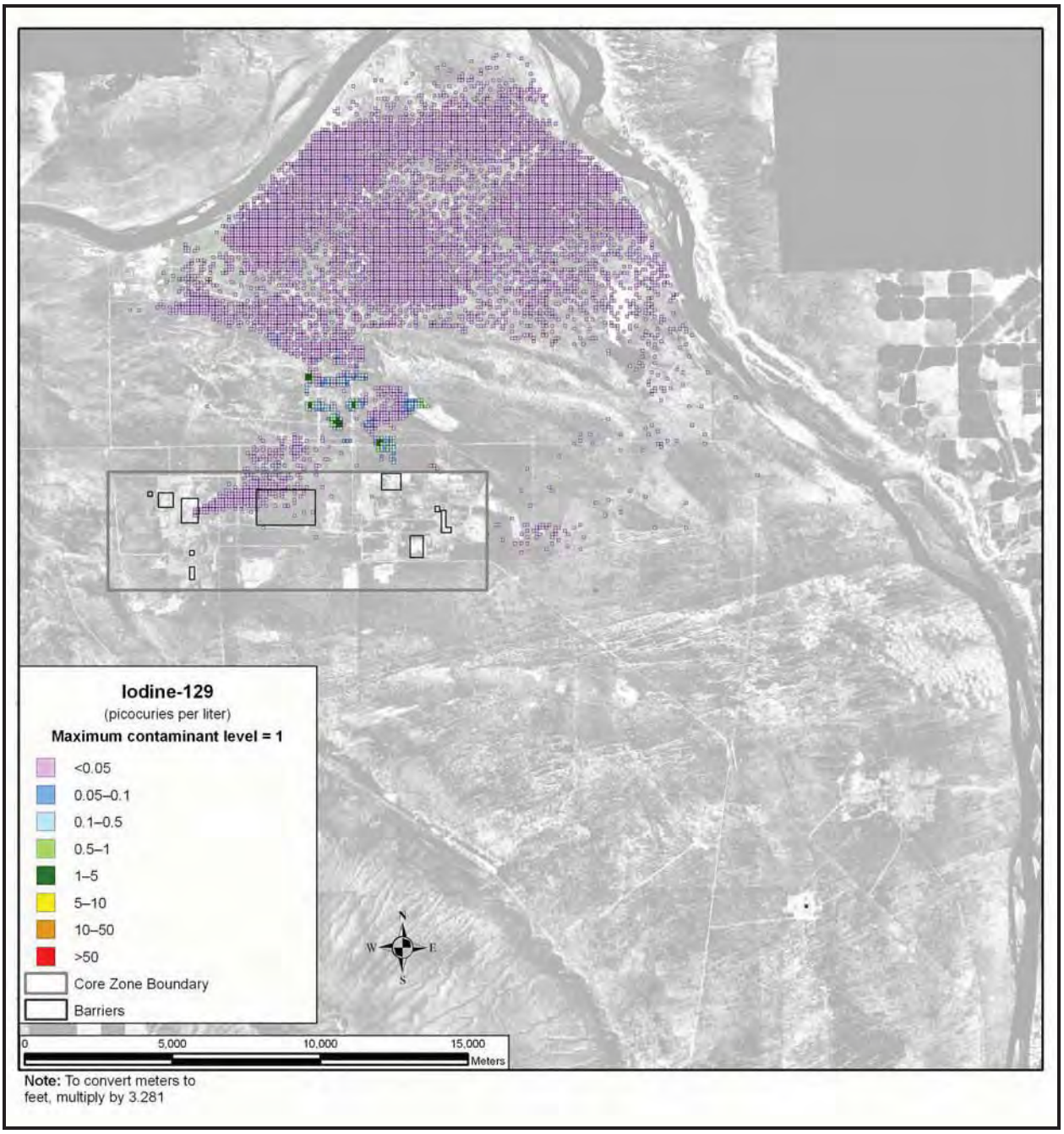


Figure O–42. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 3500 – Retardation Factor of Three

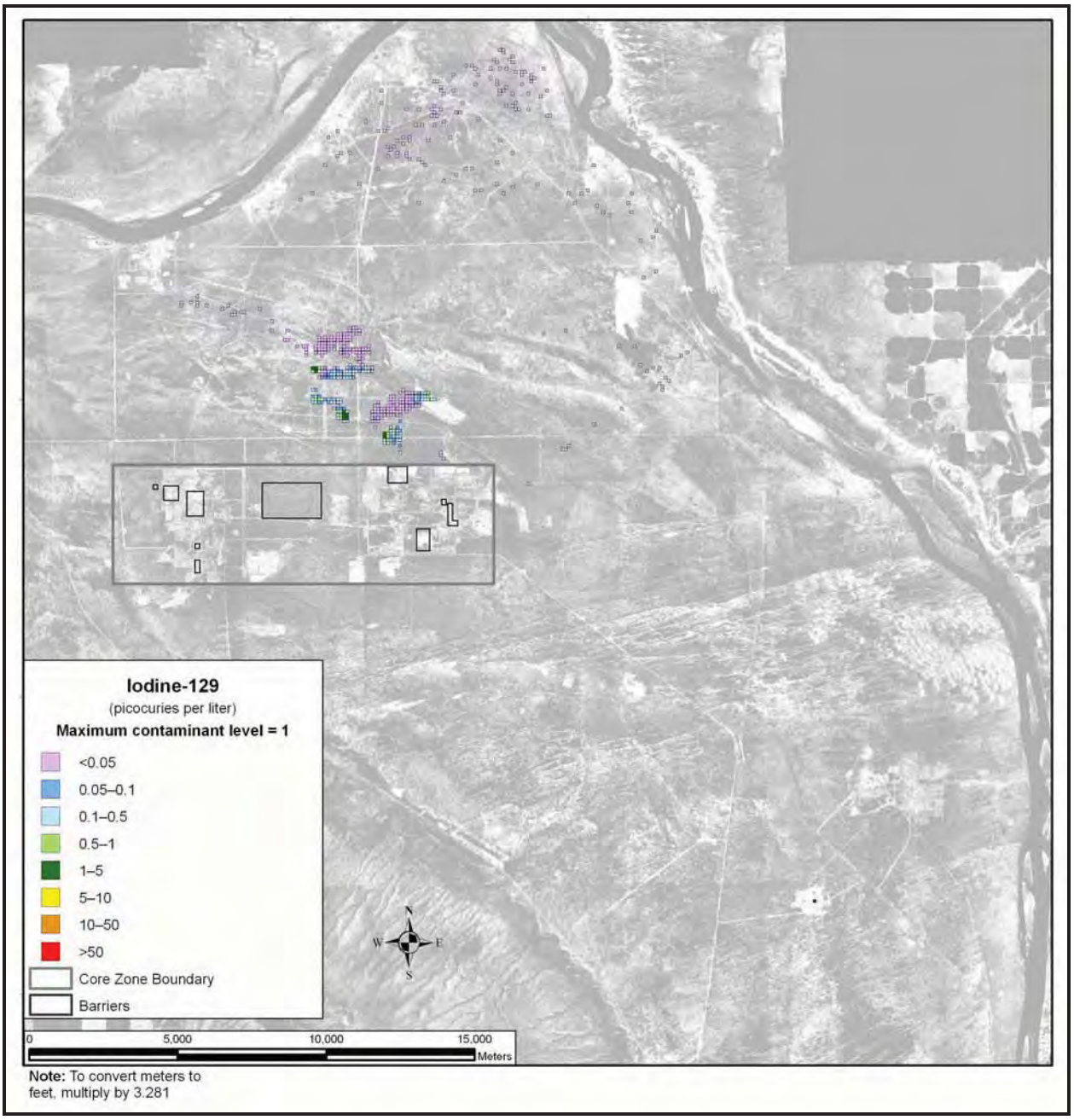


Figure O–43. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 7010 – Retardation Factor of One

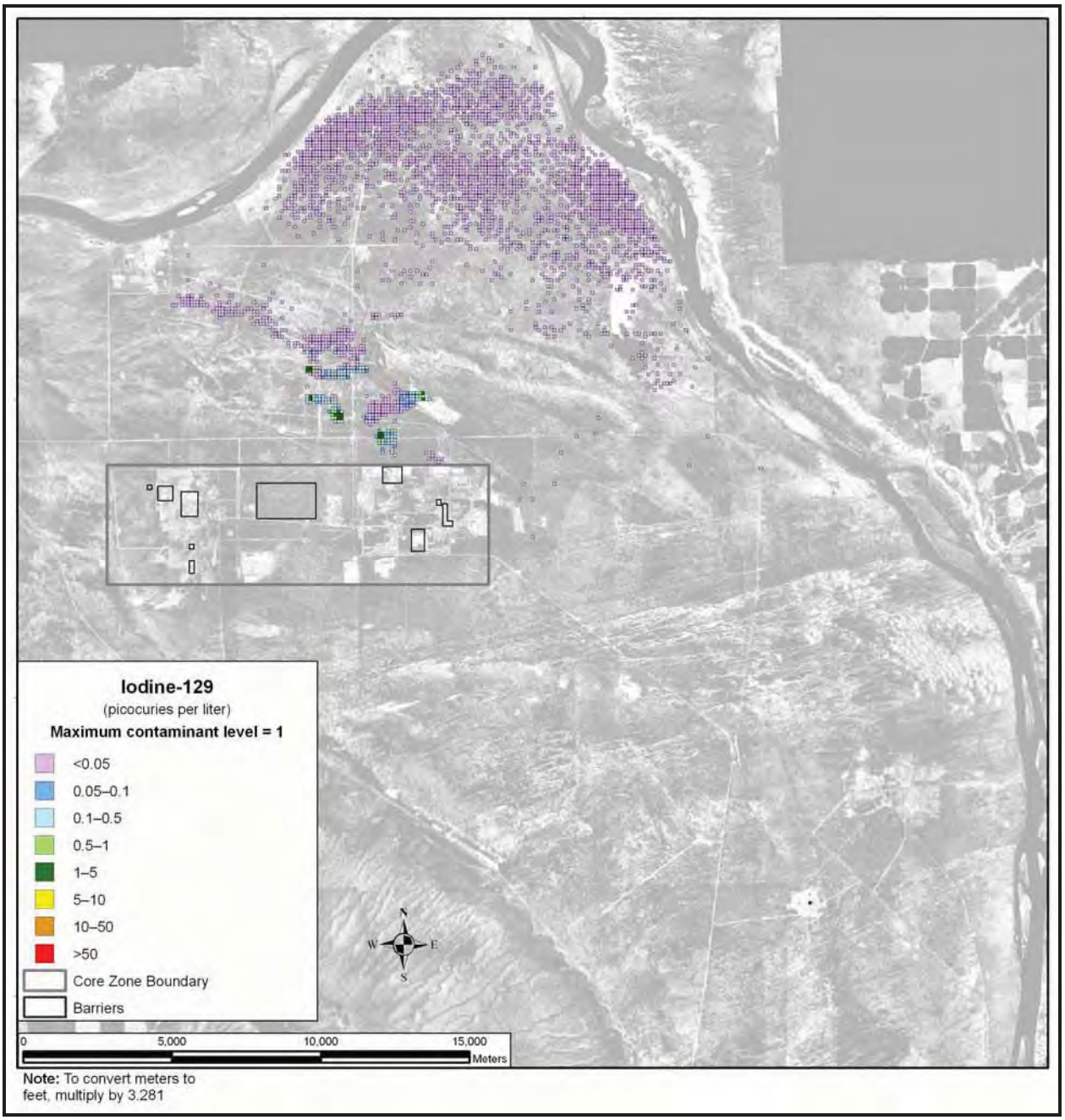


Figure O–44. Spatial Distribution of Groundwater Iodine-129 Concentration at TY Cribs, Calendar Year 7010 – Retardation Factor of Three

O.6.4 Long-Term Analysis of Uranium-238

Many of the results from standard groundwater transport runs showed increases in uranium-238 concentrations at the end of the analysis period. It is uncertain whether peak concentrations of uranium-238 were captured during this standard analysis period of 10,000 years. Therefore, it was necessary to increase the analysis period to 30,000 years to observe whether peak concentrations of uranium-238 occurred beyond the standard analysis period. The particle-tracking code calculated uranium-238 concentrations using a retardation factor of 7.24 (K_d = 0.6) and a half-life of 4.47×10^9 years.

Uranium-238 from the SX tank farm was selected for this test case. First, the vadose zone (STOMP) analysis was modified to run for 30,000 years. The results of the standard and modified STOMP analysis were as follows:

Standard (10,000 years)

Flux in = 2.97×10^{1} curies
Flux out = 1.05×10^{1} curies
Accumulated solute = 1.93×10^{1} curies
Decay (percent) = 4.04×10^{-5}

Modified (30,000 years)

Flux in = 2.97×10^{1} curies
Flux out = 2.81×10^{1} curies
Accumulated solute = 1.65 curies
Decay (percent) = 5.69×10^{-5}

Groundwater transport analysis was performed using the results from the modified STOMP analysis. The results of the standard and modified groundwater transport runs were as follows:

Standard (10,000 years)

Release to groundwater = 1.02×10^{1} curies
Release to Columbia River = 2.83×10 curies

Modified (30,000 years)

Release to groundwater = 2.8×10^{1} curies
Release to Columbia River = 2.50×10^{1} curies

The maximum concentrations and years of occurrence for uranium-238 for both conditions (10,000 years and 30,000 years) are shown in Figures O–45 and O–46 and Table O–62.

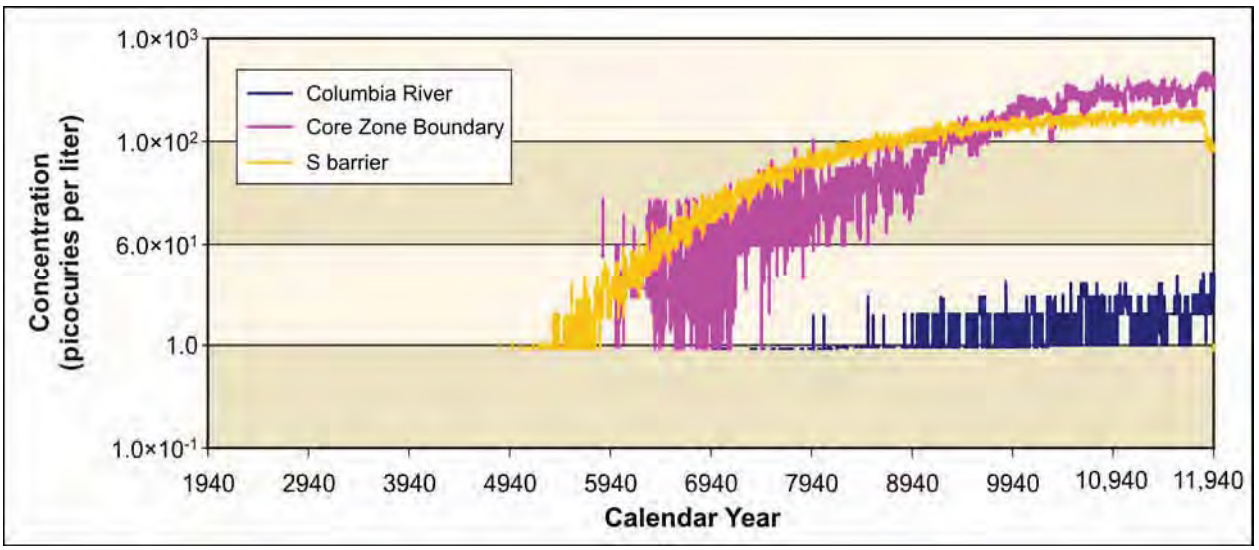


Figure O–45. Concentration of Uranium-238 for Standard 10,000-Year Period

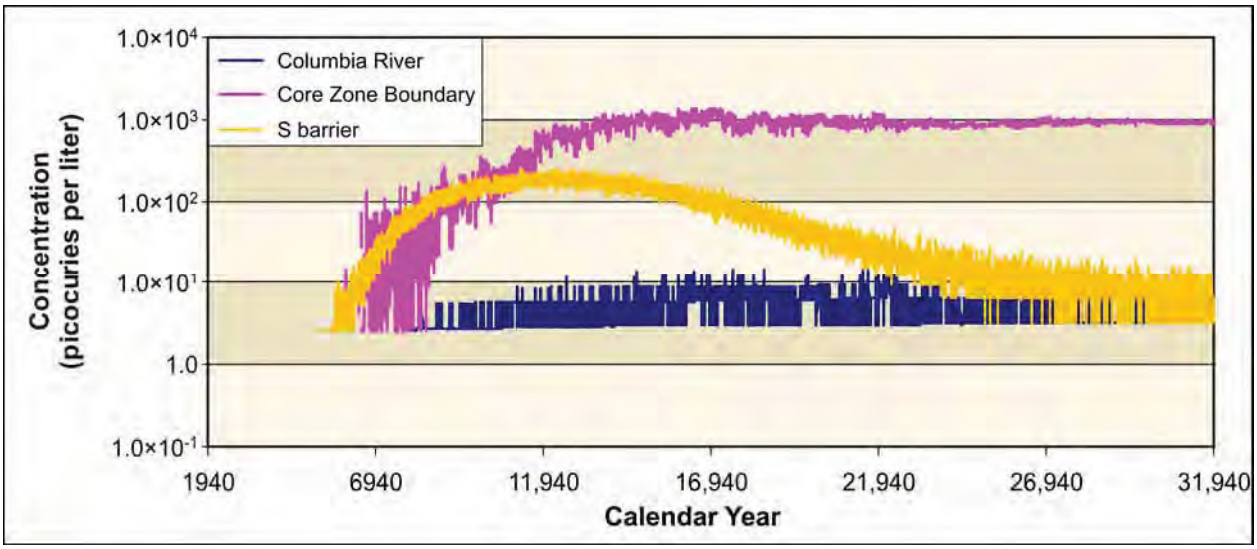


Figure O–46. Concentration of Uranium-238 for Modified 30,000-Year Period

Table O–62. Summary of Maximum Uranium-238 Concentrations (10,000- Versus 30,000-Year Periods)

Maximum Concentration of U-238 in picocuries per liter				
Run Duration (years)	**Uranium-238 Release to Groundwater in Curies**	**S Barrier**	**Core Zone**	**Columbia River**
10,000	1.02×10^{1}	2.12×10^{2} (11,399–11,743)	4.82×10^{2} (11,869)	5.05 (11,934)
30,000	2.80×10^{1}	2.40×10^{2} (12,114–13,118)	1.36×10^{3} (16,880–17,040)	1.52×10^{1} (22,162–22,238)

Note: The health-based benchmark for uranium-238 (includes uranium-233, -234, -235 and -238) is 15 picocuries per liter (EPA 2009a).

By comparison, the groundwater transport behavior of uranium-238 was different when reported over a 30,000-year period versus the standard 10,000-year period. The first notable difference was the much higher release of uranium-238 to groundwater from the vadose zone (three times).

The near-field (S Barrier) results for both time periods showed very similar peak concentration values and slightly slower arrival times. The far-field results (Core Zone and Columbia River) for the 30,000-year period showed peak concentration values that were consistently higher by an order of magnitude. Additionally, the results for the 30,000-year period showed much later peak arrival times (1,000 to 10,000 years).

O.6.5 Sensitivity to Contaminant Inventory Variations

One of the biggest uncertainties in the alternative impact groundwater analyses is the time history of contaminant flux entering the aquifer from a particular source. This flux history is uncertain because of uncertainties in inventories, release mechanisms, and infiltration histories (see Appendices M and N). Expectations are that uncertainties in the rate of release from a source will result in consequent variations in the predictions of concentrations in the far field (at the Columbia River nearshore). This sensitivity analysis reflects how those uncertainties were propagated through the model.

The purpose of this analysis was to demonstrate the sensitivity of contaminant transport results due to uncertainties in the flux discharged to the unconfined aquifer. Flux files (produced from STOMP output, see Appendix N) for technetium-99 were selected from the BY and TY Crib areas from the Base Case alternatives impact analysis. To reflect uncertainties in inventory, 100 variants of the Base Case were generated. For each variant, the flux history predicted by STOMP was multiplied by a uniformly distributed random number ranging from 0.5 to 1.5. This roughly reflects a 50 percent uncertainty in inventory. The randomly generated scaling factors are shown in Table O–63.

Each realization was run for 500 years (1940–2440) using the Base Case flow field.

Figures O–47 through O–49 show the resulting technetium-99 concentrations for all BY Crib realizations at the Columbia River, Core Zone Boundary, and B Barrier.

Figures O–50 through O–52 show the resulting technetium-99 concentrations for all TY Crib realizations at the Columbia River, Core Zone Boundary, and T Barrier.

These results suggest that variations of source strength on the order of 50 percent would result in large variations in the near field (at the barriers surrounding the sources). This effect would be greater at the B Barrier (with resulting variations in concentration of over an order of magnitude) than at the T Barrier (with resulting variations in concentration of about 50 percent). For both the T and B Barriers, the concentration variations would diminish with distance from the source. The results further suggest that uncertainties in source strength would translate roughly linearly into variations in concentrations at the Columbia River.

Evaluations of the differences among the alternatives were performed by comparing the groundwater concentrations for combinations of sources at the barriers, the Core Zone Boundary, and the Columbia River. These evaluations were developed from information containing uncertainties in source strength that were roughly on the order of about 50 percent. The model propagated these uncertainties into uncertainties in concentration predictions that were roughly less than or equal to an order of magnitude. The uncertainties in concentration prediction are expected to be greater for sources in the 200-East Area than in the 200-West Area because of greater temporal and spatial variations in the flow field.

The data demonstrated that, for the range of scaling factors applied to each flux input (0.559–1.631), the fluctuation in flux out at the barriers, Core Zone Boundary, and Columbia River would lead to variations in concentration predictions ranging from 50 to 100 percent over the 500-year span.

Table O–63. Randomly Generated Scaling Factors Used to Demonstrate Sensitivity to Flux Uncertainty

Realization	Scaling Factor Applied	Realization	Scaling Factor Applied	Realization	Scaling Factor Applied	Realization	Scaling Factor Applied
1	0.796	26	0.887	51	1.063	76	0.985
2	0.794	27	0.819	52	1.056	77	0.917
3	1.000	28*	0.559	53	1.089	78	0.982
4	1.008	29	1.411	54	1.117	79	1.386
5	1.587	30	0.947	55	1.054	80	0.977
6	1.369	31	1.147	56	0.881	81*	1.631
7	0.890	32	0.821	57	1.158	82	0.594
8	0.952	33	0.721	58	1.164	83	0.986
9	1.158	34	1.018	59	1.182	84	0.714
10	1.017	35	0.932	60	1.021	85	0.56
11	1.044	36	1.263	61	0.904	86	1.067
12	1.059	37	0.666	62	0.606	87	1.087
13	1.002	38	0.843	63	1.318	88	0.875
14	1.295	39	0.65	64	0.801	89	1.12
15	1.507	40	1.288	65	0.731	90	0.876
16	1.231	41	0.926	66	0.934	91	1.181
17	1.103	42	0.932	67	1.252	92	1.018
18	1.392	43	0.913	68	0.84	93	1.279
19	1.337	44	1.147	69	0.889	94	1.234
20	1.251	45	0.897	70	0.563	95	1.21
21	1.128	46	1.088	71	0.679	96	0.957
22	0.831	47	0.893	72	1.353	97	0.836
23	1.135	48	0.983	73	0.725	98	0.621
24	0.819	49	0.891	74	0.8	99	0.842
25	1.143	50	1.102	75	1.067	100	0.911

Note: These cases represent the highest and lowest scaling factors applied.

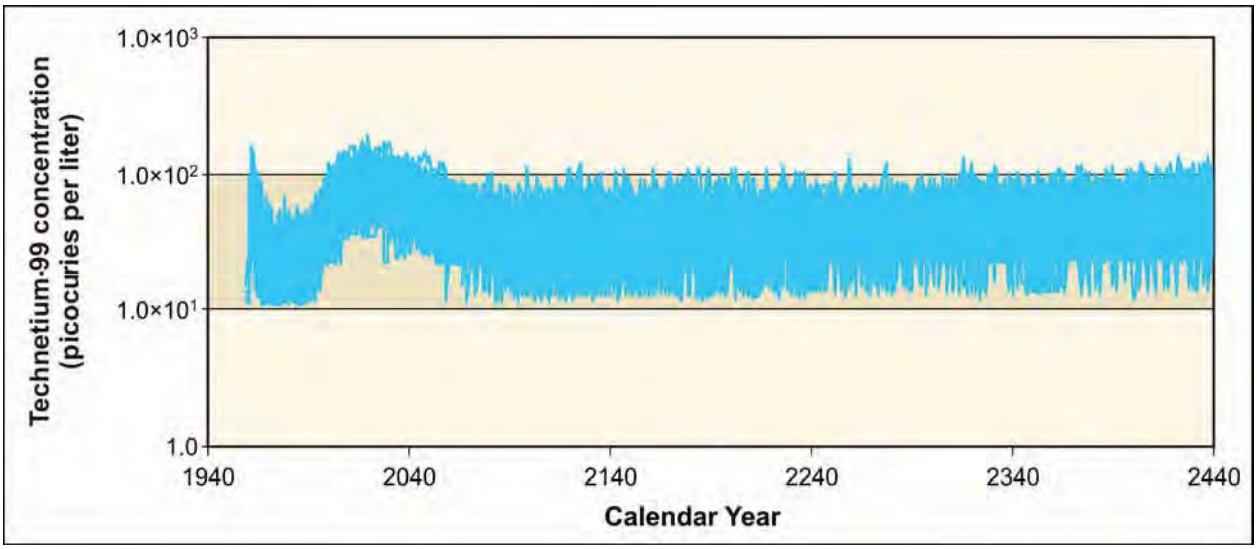


Figure O–47. Realizations for BY Cribs at the Columbia River

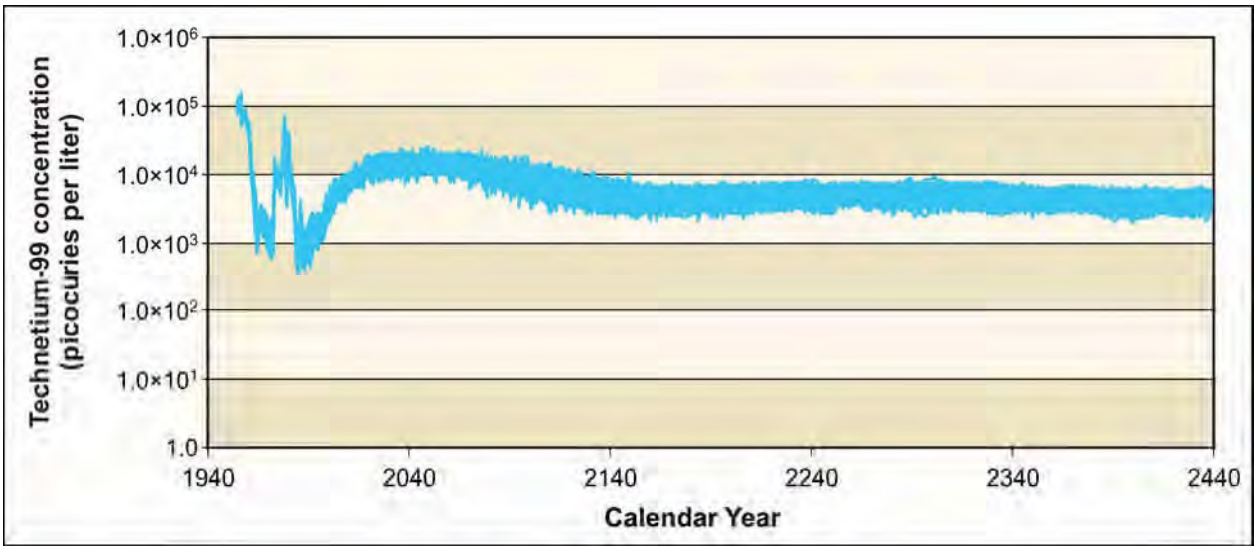


Figure O–48. Realizations for BY Cribs at the Core Zone Boundary

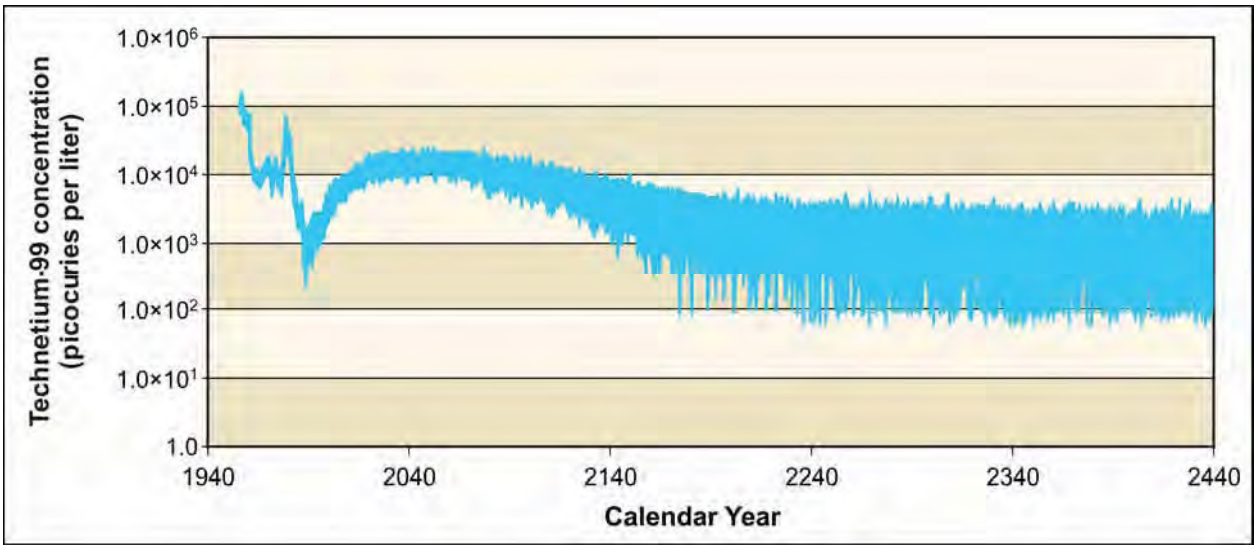


Figure O–49. Realizations for BY Cribs at the B Barrier

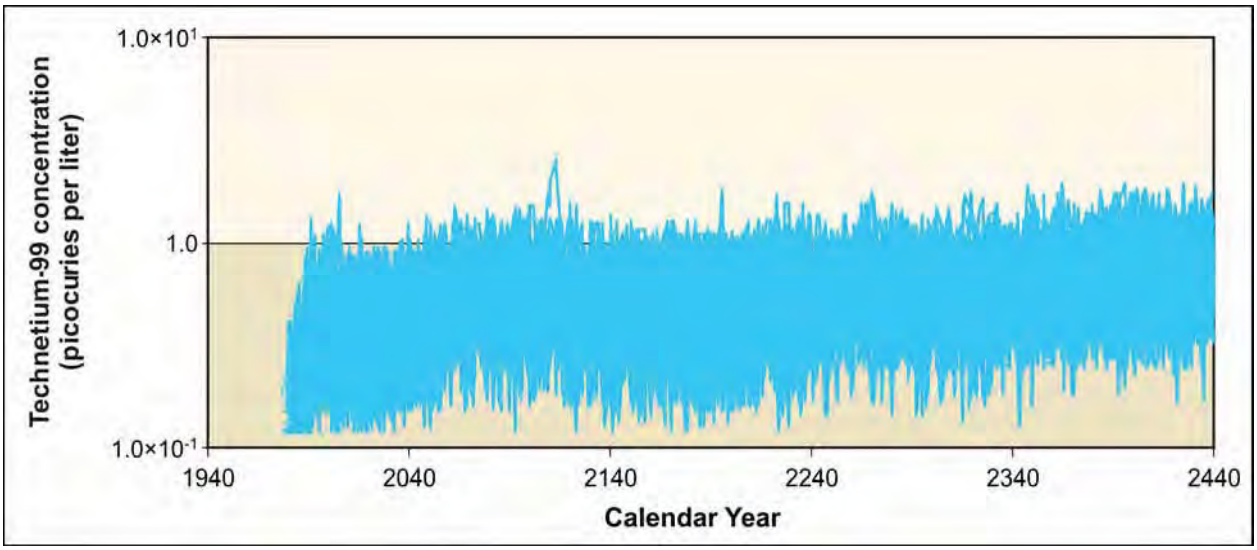


Figure O–50. Realizations for TY Cribs at the Columbia River

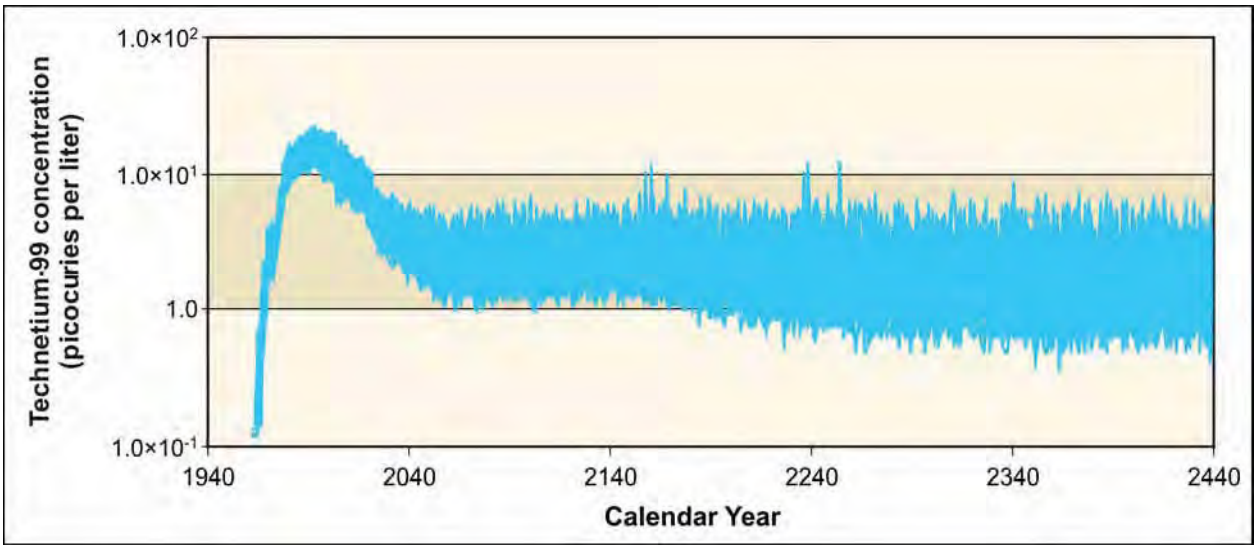


Figure O–51. Realizations for TY Cribs at the Core Zone Boundary

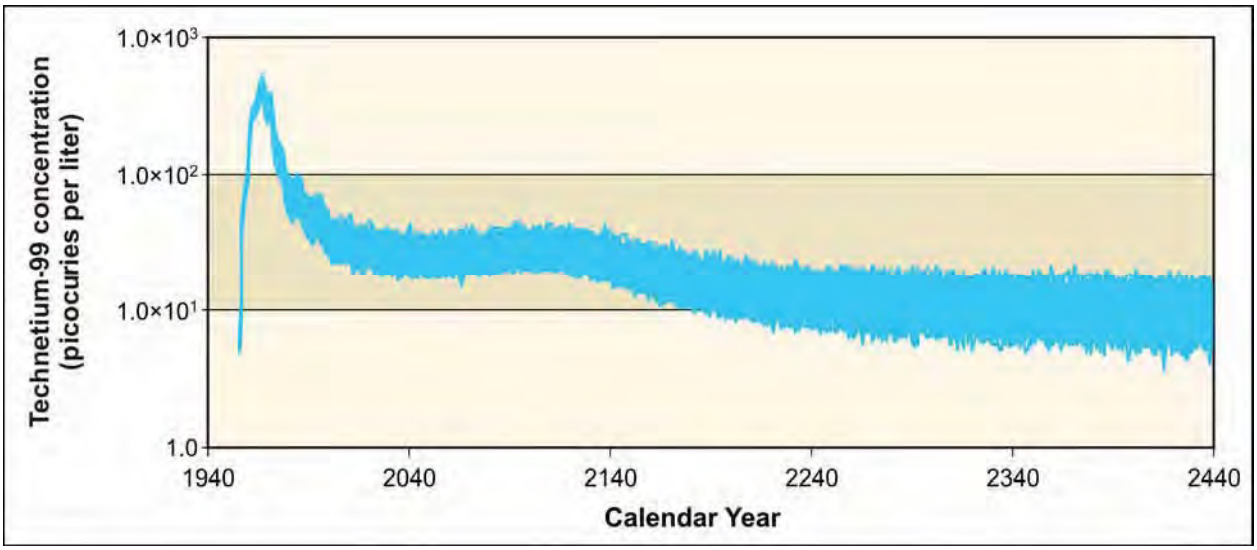


Figure O–52. Realizations for TY Cribs at the T Barrier

O.7 SUMMARY

A three-dimensional contaminant transport model was developed to support the *TC & WM EIS* analyses of alternatives and cumulative impacts. The transport model used a particle-tracking algorithm to predict the temporal and spatial distribution of groundwater contaminants from sources across Hanford. The flow field for the contaminant transport model was obtained from MODFLOW calculations using methods described in Appendix L. The source terms for each of the alternative and cumulative impact sources were obtained from STOMP using the methods described in Appendix N. The particle-tracking code used this information, in conjunction with standard equations for groundwater transport, to model the effects of advection, dispersion, retardation, and radioactive decay as contaminants migrate from their source areas to the Columbia River.

The model is mildly sensitive to concentration measurement parameters and dispersivity assumptions. These parameters were calibrated against several well-known plumes at Hanford. Independent testing showed that the model could produce results that compared reasonably well to measured concentrations in groundwater from sources significant to the *TC & WM EIS* alternatives and cumulative impacts analysis.

For the purposes of this *TC & WM EIS*, an accurate estimate of the uncertainty in the model was an important objective. Accordingly, an effort was made to estimate the propagation of uncertainties in the source data through the model. The model is sensitive to the flow field; as suggested by the results discussed in Appendix L, both the Base and Alternate Case flow fields yielded similar results during the operational period (1944 through 2006). However, the Alternate Case flow field, with significantly higher flow through Gable Gap, generally predicted less attenuation and greater concentrations at the Columbia River nearshore. The model is also sensitive to the source term flux history. Uncertainties of 50 percent in the source flux can lead to variations in concentration predictions ranging from 50 to 100 percent.

O.8 REFERENCES

Ahlstrom, S.W., H.P. Foote, R.C. Arnett, C.R. Cole, and R.J. Serne, 1977, *Multicomponent Mass Transport Model: Theory and Numerical Implementation (Discrete-Particle-Random-Walk Version)*, BNWL-2127, Battelle, Pacific Northwest Laboratories, Richland, Washington, May.

BHI (Bechtel Hanford, Inc.), 2001. This reference is for Official Use Only.

DOE (U.S. Department of Energy), 2005, *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses*, Final Rev. 0, Office of River Protection, Richland, Washington, March 25.

EPA (U.S. Environmental Protection Agency), 2002, *Implementation Guidance for Radionuclides*, EPA 816-F-00-002, Office of Ground Water and Drinking Water, Washington, D.C., March.

EPA (U.S. Environmental Protection Agency), 2006, *200 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-R-06-013, Office of Water, Washington, D.C., August.

EPA (U.S. Environmental Protection Agency), 2009a, *National Primary Drinking Water Regulations*, accessed through http://www.epa.gov/safewater/contaminants/index.html, May 21.

EPA (U.S. Environmental Protection Agency), 2009b, *Preliminary Remediation Goals*, accessed through http://www.epa.gov/region09/waste/sfund/prg/index.html, May 27.

Gelhar, L.W., 1986, "Stochastic Subsurface Hydrology from Theory to Applications," *Water Resources Research*, Vol. 22, pp. 135S–145S.

Hartman, M.J., L.F. Morasch, and W.D. Webber, eds., 2004, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*, PNNL-14548, Pacific Northwest National Laboratory, Richland, Washington, March.

Kinzelbach, W., 1986, "Groundwater Modelling: An Introduction with Sample Programs in BASIC," *Developments in Water Science*, pp. 298–315, Elsevier Science Publishing Company, Inc., New York, New York.

LaBolle, E.M., J. Quastel, and G.E. Fogg, 1998, "Diffusion Theory for Transport in Porous Media: Transition-Probability Densities of Diffusion Processes Corresponding to Advection-Dispersion Equations," *Water Resources Research*, Vol. 34, pp. 1685–1693.

Nichols, W.E., N.J. Aimo, M. Oostrom, and M.D. White, 1997, *STOMP: Subsurface Transport Over Multiple Phases: Application Guide*, PNNL-11216, Pacific Northwest National Laboratory, Richland, Washington, October.

Prickett, T.A., T.B. Naymik, and C.G. Lonnquist, 1981, *Random-Walk Solute Transport Model for Selected Groundwater uality Evaluations*, Bulletin 65, Illinois State Water Survey Division, Champaign, Illinois, pp. 65, 103.

Uffink, G.J.M., 1983, "A Random Walk Method for the Simulation of Macrodispersion in a Stratified Aquifer," Hamburg Symposium, Relation of Groundwater Quantity and Quality, IAHS Publ. No. 146, pp. 103–114.

White, M.D., and M. Oostrom, 1996, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*, PNNL-11217, Pacific Northwest National Laboratory, Richland, Washington, October.

White, M.D., and M. Oostrom, 1997, *STOMP Subsurface Transport Over Multiple Phases: User's Guide*, PNNL-11218, Pacific Northwest National Laboratory, Richland, Washington, October.

U.S. Department of Energy Orders

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, Change 2, January 7, 1993.

APPENDIX P
ECOLOGICAL RESOURCES AND RISK ANALYSIS

This appendix presents the ecological resources (see Section P.1) at the Hanford Site and lists the plants and animals evaluated in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. Potential impacts of airborne releases during operations and of groundwater discharge under the various alternatives are evaluated in this appendix. The purpose of the risk analysis is to compare alternatives quantitatively. The modeling and risk methods used to evaluate ecological impacts of the proposed alternatives to terrestrial resources are presented in Section P.2. The modeling and risk methods used to evaluate impacts on aquatic resources are presented in Section P.3.

Although impacts on ecological resources from air and groundwater releases are considered long-term impacts for the purposes of this environmental impact statement, some would occur during the near future, at the completion of waste management operations. Short-term impacts on ecological resources are evaluated in Chapter 4. Air emissions and their subsequent deposition on soils would be possible under all action alternatives, as well as the Tank Closure No Action Alternative. Immediately following operations, cumulative soil concentrations of radionuclides and chemicals would be at their maximum levels after accumulating during operations and then attenuating following the completion of operations. Thus, impacts would represent conservative estimates of impacts from exposure to contaminated soils in the more distant future. Potential adverse impacts on Columbia River aquatic and riparian resources would be more likely to occur in the more distant future after waste management operations have been terminated and chemical and radioactive constituents have migrated through the groundwater to the Columbia River.

P.1 ECOLOGICAL RESOURCES

The ecological resources at the Hanford Site (Hanford) are described in detail in Chapter 3. The scientific names of plant and animal species cited in Chapter 3 and throughout this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* are listed in Table P–1. Species are grouped by common name and listed in alphabetical order. The habitat type found most commonly between the 200 Areas and the Columbia River to the east and northeast is shrub-steppe desert, characterized by widely spaced, low-brush grasslands (see Chapter 3, Figure 3–13). Most of these communities are dominated by various species of sagebrush and rabbitbrush. Pristine shrub-steppe habitat is considered a priority habitat by the Washington State Department of Ecology because of its relative scarcity in the state and because it is home to a number of sensitive species, e.g., Piper's daisy and the small-flowered evening primrose. Chapter 3, Section 3.9.4.1 and Table 3–8 provide information on threatened and endangered species occurring at Hanford. Information on threatened and endangered species occurring in the 200 Areas is provided in Chapter 3, Section 3.9.4.2. Vegetation along the Columbia River shoreline consists of various grasses and herbaceous species, as well as some trees, including willow, mulberry, and elm. Riparian habitat along the river is the home to a number of sensitive species, including Canadian St. John's wort, persistent sepal yellowcress, and shining flatsedge. Additional unique habitats found along the river include the White Bluffs, the islands of the river, and the dune areas near the Energy Northwest complex. These are described in Chapter 3, along with some of the species that occur there.

Table P–1. Scientific Names of Plant and Animal Species

Common Name	Scientific Name
Plants	
Alkali saltgrass	*Distichlis spicata*
Big sagebrush	*Artemisia tridentata*
Bitterbrush	*Purshia tridentate*
Black greasewood	*Sacrobatus vermiculatus*
Black locust	*Robinia pseudoacaci*
Bluebunch wheatgrass	*Agropyron spicatum*
Bulbous bluegrass	*Poa bulbosa*
Bullrush	*Scirpus* sp.
Canadian St. John's wort	*Hypericum ma us*
Cattail	*Typha* sp.
Cheatgrass	*romus tectorum*
Cottonwood	*Populus* sp.
Crested wheatgrass	*Agropyron desertorum (cristatum)*
Gray rabbitbrush	*Chrysothamnus nauseosus*
Green rabbitbrush	*Chrysothamnus viscidiflorus*
Hoover's desert parley	*omatium tuberosum*
Indian ricegrass	*Ory opsis hymenoides*
Lupine	*upinus* spp.
Mugwort	*Artemisia vulgaris*
Mulberry	*Morus* sp.
Needle-and-thread grass	*Stipa comata*
Peachleaf willow	*Salix amygdaloides*
Persistent sepal yellowcress	*Rorippa columbiae*
Plantain	*Plantago* spp.
Pondweed	*Potamogeton* spp.
Poplar	*Populus* sp.
Reed canary grass	*Phalaris arundinacea*
Rigid sagebrush	*Artemisia rigida*
Rock buckwheat	*Eriogonum sphaerocephalum*
Rush	*Juncus* spp.
Russian olive	*Elaeagnus angustifolia*
Russian thistle	*Salsola kali*
Sagebrush	*Artemisia* spp.
Saltgrass	*Distichlis stricta*
Salt rattlepod	*Swainsona salsula*
Sand dropseed	*Sporobolus cryptandrus*
Sandberg's bluegrass	*Poa sandbergii (secunda)*
Scrufpea	*Psoralidium tenuiflorum*
Sedge	*Carex* sp.
Shining flatsedge	*Cyperus bipartitus (rivularis)*
Siberian elm	*Ulmus pumila*
Snow buckwheat	*Eriogonum niveum*
Spike rush	*Eleocharis* spp.
Spiny hopsage	*Grayia spinosa*
Sycamore	*Platanus occidentalis*

Table P–1. Scientific Names of Plant and Animal Species *(continued)*

Common Name	Scientific Name
Plants *(continued)*	
Thickspike wheatgrass	*Agropyron dasytachyum*
Threetip sagebrush	*Artemisia tripartite*
Thymeleaf buckwheat	*Eriogonum thymoides*
Water smartweed	*Polygonum amphibium*
White Bluffs bladderpod	*es uerella tuplashensis*
Willow	*Salix* spp.
Winterfat	*Eurotia lanata*
Yarrow	*Achillea millefolium*
Fish	
American shad	*Alosa sapidissima*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Common carp	*Cyprinus carpio*
Crappie	*Pomoxis* spp.
Mountain whitefish	*Prosopium williamsoni*
Northern pikeminnow (squawfish)	*Ptychocheilus oregonensis*
Redside shiner	*Richardsonius balteatus*
Smallmouth bass	*Micropterus dolomieui*
Sockeye salmon	*Oncorhynchus nerka*
Steelhead trout	*Oncorhynchus mykiss*
Walleye	*Sti ostedion vitreum*
White sturgeon	*Acipenser transmontanus*
Yellow perch	*Perca flavescens*
Amphibians	
Bullfrog	*Rana catesbeiana*
Great Basin spadefoot toad	*Scaphiopus intermontanus*
Pacific tree frog	*Pseudacris regilla*
Tiger salamander	*Ambystoma tigrinum*
Woodhouse's toad	*ufo woodhousei*
Reptiles	
Great Basin gopher snake	*Pituophis melanoleucus*
Western rattlesnake	*Crotalus viridis*
Side-blotched lizard	*Uta stansburiana*
Western yellow-bellied racer	*Coluber constrictor*
Birds	
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
Bald eagle	*Haliaeetus leucocephalus*
Black-billed magpie	*Pica pica*
Black-crowned night heron	*Nycticorax nycticorax*
Burrowing owl	*Athene cunicularia*
California gull	*arus californicus*
Canada goose	*ranta canadensis*
Common raven	*Corvus corax*

Table P–1. Scientific Names of Plant and Animal Species *(continued)*

Common Name	Scientific Name
Birds *(continued)*	
Cliff swallow	*Hirundo pyrrhonota*
Dark-eyed junco	*Junco hyemalis*
Ferruginous hawk	*uteo regalis*
Forster's tern	*Sterna forsteri*
Golden eagle	*A uila chrysaetos*
Great blue heron	*Ardea herodias*
Horned lark	*Eremophila alpestris*
Killdeer	*Charadrius vociferous*
Loggerhead shrike	*anius ludovicianus*
Long-billed curlew	*Numenius americanus*
Mourning dove	*Zenaida macroura*
Northern harrier	*Circus cyaneus*
Peregrine falcon	*Falco peregrinus*
Prairie falcon	*Falco mexicanus*
Red-tailed hawk	*uteo amaicensis*
Ring-billed gull	*arus delawarensis*
Rough-winged swallow	*Stelgidopteryx serripennis*
Sage sparrow	*Amphispi a belli*
Say's phoebe	*Sayornis saya*
Song sparrow	*Melospi a melodia*
Spotted sandpiper	*Actitis macularia*
Swainson's hawk	*uteo swainsoni*
Vesper sparrow	*Pooecetes gramineus*
Western meadowlark	*Sturnella neglecta*
Mammals	
Badger	*Taxidea taxus*
Black-tailed jackrabbit	*epus californicus*
Bobcat	*ynx rufus*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Great Basin pocket mouse	*Perognathus parvus*
Ground squirrel	*Citellus* sp.
Harvest mouse	*Reithrodontomys megalotis*
Least weasel	*Mustela nivalis*
Mink	*Mustela vison*
Mule deer	*Odocoileus hemionus*
Muskrat	*Ondatra ibethica*
Porcupine	*Erethi on dorsatum*
Raccoon	*Procyon lotor*
Rocky Mountain elk	*Cervus elaphus*

P.2 IMPACTS ON TERRESTRIAL RESOURCES RESULTING FROM CONTAMINANT RELEASES

Terrestrial ecological resources at Hanford would be potentially adversely impacted by surface disturbances and contaminant releases during site and Waste Treatment Plant (WTP) operations under the various Tank Closure, Fast Flux Test Facility (FFTF) Decommissioning, and Waste Management alternatives. These different alternatives would result in different surface disturbances in the vicinity of the 200 Areas. The different actions also would result in different amounts and timing of air emissions and their dispersion to terrestrial habitats at Hanford as described in Section P.2. Potential impacts on terrestrial ecological resources at onsite and offsite locations of chemical and radionuclide releases to air during site and WTP operations are evaluated in Sections P.2.2.1 and P.2.2.2. Potential impacts of air releases during operations and groundwater releases in the future on Columbia River aquatic and riparian ecological resources are evaluated in Section P.3.

The potential for adverse effects on terrestrial ecological resources of radionuclide- and chemical-modeled air releases under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives was evaluated primarily using a quantitative ecological risk assessment approach (EPA 1992, 1997). Concentrations of radionuclides and chemicals resulting from deposition of airborne contaminants were predicted, as described in Appendix G. These predicted release concentrations were used to evaluate the impacts on terrestrial ecological resources at Hanford during operations and in the distant future following operations. The general approach to the assessment of the potential for adverse effects or impacts on ecological resources is discussed in Section P.2.1.

Terrestrial ecological resources would be potentially impacted by contaminant releases to air and soil "on site," i.e., within the Hanford boundaries, and "off site," i.e., outside the Hanford boundaries. Potential impacts on terrestrial ecological resources from exposure to contaminants in soil and air were evaluated using the maximum average annual air concentration and cumulative soil concentrations resulting from air deposition. The onsite maximum-exposure location would be in the vicinity of the tank farms and the 200 Areas because the WTP and ground-level facilities are located adjacent to the 200 Areas, the air dispersion model is a Gaussian plume, and air concentrations decrease in magnitude moving away from the source. For consistency with other *TC & WM EIS* assessments of long-term impacts, the line of analysis for the onsite maximum-exposure location is the Core Zone Boundary in the predominant downwind direction. The offsite maximum-exposure location would be at the Columbia River because the river forms the Hanford boundary in the predominant downwind direction.

Air emissions and their subsequent deposition on soils would be possible under all action alternatives, as well as the Tank Closure No Action Alternative (Tank Closure Alternative 1). Radionuclides and chemicals emitted to the air during operations would be potentially transported away from the source to onsite and offsite locations (e.g., the Columbia River floodplain), where they could impact terrestrial resources, and the Columbia River, where they could impact aquatic and riparian resources. The evaluation of impacts at these locations was made at a single point in time, that is, what would be the completion of operations. The duration of operations would vary by alternative (see Chapter 4). Immediately following operations, cumulative soil concentrations are expected to be at their maximum level, accumulating during operations and attenuating following completion of operations. Therefore, ignoring losses from soil and radioactive decay is a conservative approach. The evaluation of potential adverse impacts on aquatic and riparian ecological resources at the Columbia River is described in Section P.3. The evaluation of potential impacts on terrestrial ecological resources of contaminants released to air under the various alternatives is discussed in the following subsections.

P.2.1 Methods

The potential for adverse effects on ecological resources of potential radionuclide and chemical releases under the different alternatives was evaluated using quantitative modeling (ANL 1999; DOE 1995, 1998; DOE Standard 1153-2002; Eslinger et al. 2002). The general approach was to estimate the exposure of ecological receptors to radionuclides and chemicals that would result from operations and actions under each alternative and then to compare the estimated doses to benchmark doses, i.e., doses associated with a known level of adverse effect. Dose estimates were made for selected receptor organisms judged to be representative of groups of species known to occur and be exposed at Hanford, including federally and state-listed protected species; to be sensitive to chemicals and radionuclides potentially released; and to be among the highest exposed in their groups (ANL 1999). The benchmark doses used in this approach are associated with no or minimal adverse effect, so they are expected to be protective of all ecological resources, including special status species that may occur at Hanford (see Chapter 3, Section 3.2.7.4). Special status species are species protected by Federal and state laws, e.g., the Endangered Species Act of 1973. Exposure estimates and Hazard Quotients allow the impacts under the different alternatives to be compared, as required by the National Environmental Policy Act. Comparing alternatives is the primary purpose of the ecological risk analysis in this *TC & WM EIS*.

A secondary purpose of the ecological risk analysis in this *TC & WM EIS* is to identify alternatives that would be unlikely to result in unacceptable risk to ecological receptors. Assessing the risk to highly exposed receptors and using conservative exposure assumptions and benchmarks allows those alternatives unlikely to result in adverse impacts on ecological resources to be identified with a high degree of confidence. In other words, if a conservatively estimated dose does not exceed the benchmark dose, then there would be very likely no adverse impact from the exposure. On the other hand, this approach cannot be used to unequivocally conclude that any alternative would result in an unacceptable probability of an adverse impact on ecological resources. A conservatively estimated dose exceeding a benchmark dose does not imply that the receptor would be adversely impacted by the exposure because the actual dose may be less than the benchmark dose. In such a case, a more precise evaluation would be required to resolve the uncertainty. This "screening" approach is consistent with U.S. Environmental Protection Agency (EPA) (EPA 1997, 1999) and U.S. Department of Energy (DOE) guidelines (ANL 1999; DOE Standard 1153-2002; Eslinger et al. 2002) and is appropriate for prospective risk assessments for actions that have not yet occurred (Suter 1993).

Exposure was calculated using models that are consistent with EPA and DOE guidelines and with the Ecological Contaminant Exposure Model (ECEM), which was described in the *User Instructions for the Systems Assessment Capability, Rev. 0, Computer Codes*, Volume 2, *Impact Modules* (Eslinger et al. 2002) and used in the *Screening Assessment and Re uirements for a Comprehensive Assessment, Columbia River Comprehensive Impact Assessment (CRCIA)* (DOE 1998); and the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE and Ecology 1996). The model exposure equations are consistent with those used in the DOE technical standard, *A Graded Approach for Evaluating Radiation Doses to A uatic and Terrestrial iota* (DOE Standard 1153-2002). These are equilibrium steady state models, as opposed to dynamic time-varying models (Eslinger et al. 2002). The ECEM software was not used to make exposure calculations; however, the exposure calculations in this *TC & WM EIS* are functionally equivalent. Wherever possible, the representative receptors were selected from the ECEM model receptors, and the same receptor exposure parameters were used in this assessment. The selected receptors are presented in Table P–2.

Table P–2. Receptors and Exposure Pathways Evaluated for Long-Term Impacts of Air and Groundwater Releases

Receptor	Ingestion					Inhalation of Suspended Soil	Internal Exposure	Soil Exposure		Air Exposure	Near Water	Immersion		Sediment Surface Contact
	Plants	Soil/ Sediment Biota[a]	Vertebrate Prey[b]	Solid Substrate[c]	Surface Water[d]			Above Ground	Below Ground			Water	Sediment	
Terrestrial														
Plants	—	—	—	—	—	—	A	A	A[e]	—	—	—	—	—
Soil-dwelling invertebrates	—	—	—	—	—	—	A	A	A[e]	—	—	—	—	—
Side-blotched lizard	—	A	—	A	—	A	A	A	A	A	—	—	—	—
Mule deer	A	—	—	A	—	A	A	A	—	A	—	—	—	—
Mourning dove	A	—	—	A	—	A	A	A	—	A	—	—	—	—
Great Basin pocket mouse	A	A	—	A	—	A	A	A	A	A	—	—	—	—
Western meadowlark	A	A	—	A	—	A	A	A	A	A	—	—	—	—
Coyote	—	—	A	A	—	A	A	A	A	A	—	—	—	—
Burrowing owl	—	—	A	A	—	A	A	A	A	A	—	—	—	—
Riparian														
Woodhouse's toad	—	A	—	A	—	A	A	A	A	A	—	—	—	—
Muskrat	—	—	—	—	GW	—	GW	GW	GW	—	—	—	—	—
Aquatic														
Benthic invertebrates	—	—	—	—	—	—	A, GW	—	—	—	—	A, GW	A[e], GW	—
Aquatic biota	—	—	—	—	—	—	A, GW	—	—	—	—	A[e], GW	—	A, GW
Salmonid	—	—	—	—	—	—	A, GW	—	—	—	—	A[e], GW	—	A, GW
Raccoon	—	A, GW	—	A, GW	A, GW	—	A, GW	A	A	—	A, GW	—	—	—
Spotted sandpiper	—	A, GW	—	A, GW	A, GW	—	A, GW	A	—	—	A, GW	—	—	—
Least weasel	—	—	A, GW	A, GW	A, GW	—	A, GW	A	A	—	A, GW	A, GW	—	—
Bald eagle	—	—	A, GW	A, GW	A, GW	—	A, GW	—	—	—	A, GW	—	—	—

[a] Soil-dwelling invertebrates for terrestrial and riparian; benthic invertebrates for aquatic.
[b] Small mammals for terrestrial; fish for aquatic.
[c] Surface soil for terrestrial; sediment for aquatic.
[d] For future impacts of groundwater release, water ingested was assumed to be groundwater discharging at seeps along Columbia River; otherwise it is nearshore surface water.
[e] For chemicals.

Note: Includes all direct and indirect exposure pathways.

Key: — =pathway not evaluated; A=pathway evaluated for air releases; GW=pathway evaluated for groundwater releases.

The combined total dose from internal and external exposures to all radionuclides was calculated using equations based on those in *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the A uatic Environment* (Baker and Soldat 1992) and using the dose conversion factors, activation energies, and other radionuclide parameters used in the ECEM. Chemical doses were calculated using published rates of ingestion of different media and estimated concentrations in the ingested media. Body burdens of chemicals and radionuclides were estimated using concentrations in ambient or ingested media and bioaccumulation factors (BAFs) for the receptor and the radionuclide or chemical in the media. As with the ECEM model (Eslinger et al. 2002), BAFs for animal receptors are constants at steady state, reflecting the net result of ingestion, inhalation, absorption, excretion, and elimination. For this assessment, inhalation of radionuclides and chemicals was estimated where possible, even though the dose from inhalation by biota would be small compared to ingestion and direct external radiation (DOE Standard 1153-2002). Dermal exposure was calculated only for external doses from radionuclides because dermal uptake of chemicals was judged to be small in comparison to the direct exposure to chemicals in soil by incidental ingestion and the indirect exposure by ingestion of contaminated biota. The exposure of animals to chemicals in soil by dermal contact would likely be small due to barriers of fur, feather, and epidermis (EPA 2000).

The exposure model equations are presented in the sections for each of the impact assessments. The modeled pathways were assumed to be the largest exposure pathways for the receptors because of the habitat associated with each alternative and the source of contamination that was present. Partial doses were calculated where there was insufficient information to calculate the total dose. For example, an uptake or excretion parameter required to estimate the dose from inhalation might not have been available for a receptor, so inhalation could not be calculated for that receptor for any contaminant. The resulting underestimates of dose and risk were balanced by overestimates resulting from conservative exposure assumptions. Calculated doses were adequate for comparing alternatives because they were consistent across alternatives for a given receptor.

The benchmarks for combined internal and external exposure from all radionuclides are associated with no adverse impact (IAEA 1992; NCRP 1991) and were those used in the DOE technical standard for evaluating radiation doses (DOE Standard 1153-2002). The chemical benchmarks for plants; soil-dwelling invertebrates; aquatic biota including salmonids (e.g., salmon, trout, char); and sediment biota exposed to soil, water, and sediment, as appropriate, come from a variety of sources. The chemical benchmarks for wildlife are doses associated with no observed adverse effect levels measured in laboratory toxicity tests on test species (EPA 2009; Sample, Opresko, and Suter 1996). Data are available for mammals and birds for some of the chemical contaminants potentially released to air or groundwater that are evaluated in this *TC & WM EIS*. For this *TC & WM EIS*, data for birds were used for amphibians and lizards without adjustment. Unlike radionuclides, impacts from exposure to chemicals were evaluated individually and doses from different chemicals were not summed or otherwise mathematically combined.

The assumptions, receptors, exposure pathways and uptake mechanisms (routes), predicted soil concentrations, exposure model equations, and benchmarks used to model exposure for terrestrial ecological resources potentially impacted by contaminant releases are described in the relevant sections below. The calculated Hazard Quotients, Hazard Indices, and other quantitative evaluations of long-term adverse impacts on terrestrial resources from air releases are summarized and discussed in Section P.2.2. Impacts of deposition of oxides of sulfur and nitrogen on the soil's pH were evaluated based on buffering capacity and predicted concentrations.

P.2.1.1 Key Assumptions

The following key assumptions were made in the evaluation of potential impacts on terrestrial resources of exposure to radionuclides and chemicals released to air during operations:

- Ecological receptors would not be exposed to onsite soil after operations once any proposed soil cover is in place.
- Major exposure pathways were evaluated.
- Toxicity benchmarks were protective.
- No loss, biological or chemical degradation, or radiological decay of constituents of potential concern (COPCs) would occur in soil.

P.2.1.2 Receptors and Exposure Pathways and Routes

The receptors that were selected to represent the terrestrial ecological resources are listed in Table P–2. They are a subset of those listed in Table P–1. Representative receptors were selected because they were expected to have higher exposures than those not selected from their group, due to their higher ingestion rates per unit body weight for prey, water, and soil. The selected representative receptors were expected to be as highly exposed and/or sensitive as any other species. The receptors included plants and soil-dwelling invertebrates, as well as the side-blotched lizard/Woodhouse's toad, mule deer, mourning dove, Great Basin pocket mouse, western meadowlark, coyote, and burrowing owl. Plants and soil-dwelling invertebrates live in close contact with soil and are important food items for other receptors. The mourning dove, Great Basin pocket mouse, western meadowlark, and burrowing owl are not among the 52 ECEM receptors because the ECEM focuses on Columbia River riparian habitats more than the surrounding shrub-steppe habitat, where these four receptors occur. The Great Basin pocket mouse was selected as a receptor for terrestrial habitats in the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE and Ecology 1996) and is expected to be an important prey item for coyotes and burrowing owls. The mourning dove, western meadowlark, and burrowing owl are representative of birds exposed in terrestrial habitats at Hanford. Terrestrial receptors in common with the ECEM are the side-blotched lizard, mule deer, and coyote. Woodhouse's toad was evaluated instead of the side-blotched lizard for the offsite maximum-exposure location (the Columbia River) because side-blotched lizards are unlikely to occur in the Columbia River floodplain.

The exposure pathways evaluated in the ecological risk analysis for this *TC & WM EIS* are shown in Table P–2 for all ecological receptors. The exposure medium, exposure route, and receptor are indicated for each pathway evaluated in the analysis of impacts on terrestrial resources from releases to air.

P.2.1.3 Predicted Soil and Air Concentrations

The cumulative surface-soil and maximum air concentrations under Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1, 2, and 3 (Hanford and Idaho Options); and Waste Management Alternatives 1, 2, and 3 were calculated from the modeled air deposition rates resulting from site and WTP operations (see Appendix G). The onsite soil concentrations were calculated from the maximum modeled air deposition rates. The modeled soil concentrations assumed persistence of existing soil contamination and accumulation of deposited contamination over the duration of the operations period. The surface-soil concentrations were calculated assuming that the amount of material deposited on the soil surface over the operations period would be mixed throughout the upper 1 centimeter (0.39 inches) of soil. The deposition flux per unit area (grams per square meter per year or curies per square meter per year) was multiplied by the duration of operations (years) and divided by the mass of soil per unit area (grams per square meter) to estimate the concentration (grams per grams or curies per

grams), and these results were converted to milligrams per kilogram or picocuries per grams. The mass of soil per unit area was estimated as the depth of soil (0.01 meters) times the soil density (1.7×10^6 grams per cubic meters). The instantaneous air concentration (milligrams per cubic meter or picocuries per cubic meters) was estimated as the annual average deposition flux (milligrams per second or picocuries per second) divided by the unitized flux rate (cubic meters per second). The conservative estimates of surface-soil concentrations for radionuclides were used for both aboveground and belowground external exposures.

Air concentrations at the ground surface resulting from resuspension of soil were calculated for each location for which soil concentrations were predicted. Modeled air concentrations of radionuclides were used to calculate external exposure to terrestrial ecological resources.

Soil and air concentrations were used as the source term in the exposure model described below.

P.2.1.4 Exposure Model Calculations

The exposure model calculated external and internal doses from radiological COPCs for all receptors and ingestion and inhalation doses from chemical COPCs for all wildlife receptors. To calculate internal doses for radiological COPCs in receptors exposed by direct contact with soil (plants and soil-dwelling invertebrates) and to calculate the ingested doses for wildlife receptors exposed by ingestion of these biota to chemical COPCs, the concentrations in these biota were required.

For plants, the concentration was calculated as follows:

$$C_p = P_v \quad P_r$$

where:

$$P_v = (D/\rho) \quad v \quad Fv \quad VG \quad 0.2$$

and

$$P_r = C_{soil} \quad SP \quad 0.2$$

and where:

C_p	=	concentration in plants, milligrams per kilogram or picocuries per gram
P_v	=	concentration in plants from vapor, milligrams or picocuries per gram
P_r	=	concentration in plants from root uptake, milligrams per kilogram or picocuries per gram
D	=	concentration in air, milligrams per cubic meter or picocuries per cubic meter
ρ	=	air density, 1.2 kilograms per cubic meter for chemical COPCs and 1,200 grams per cubic meter for radiological COPCs
v	=	air-to-plant uptake factor, unitless
Fv	=	vapor fraction, 0 or 1
VG	=	empirical correction factor for air-to-plant transfer (1 for chemical COPCs and radiological COPCs with a log $_{ow} < 4$ or no log $_{ow}$ [63 FR 26846]), unitless
0.2	=	dry weight–to–wet weight conversion factor (moisture content of plants assumed to be 0.8), unitless
C_{soil}	=	concentration in soil, milligrams per kilogram or picocuries per gram dry soil
SP	=	soil-to-plant uptake factor, unitless

Soil-to-plant uptake factors were used for all radiological COPCs except carbon-14 and hydrogen-3 (tritium). For carbon-14 and tritium, internal activities were based on equilibrium with stable isotopes in tissue and water, as discussed in Section P.2.1.4.2.

For soil-dwelling invertebrates, the concentration was calculated as follows:

$$C_a = C_{soil} \quad AF\text{-}S$$

where:

C_a = concentration in soil-dwelling invertebrates, milligrams per kilogram or picocuries per gram
C_{soil} = concentration in soil, milligrams per kilogram or picocuries per gram dry soil
AF-S = soil-to-soil invertebrate bioaccumulation factor, unitless

Per the *Screening evel Ecological Risk Assessment Protocol for Ha ardous Waste Combustion Facilities* (EPA 1999), *AF-S* values for organic chemical COPCs were derived from water-to-tissue bioconcentration factors (BCFs) for daphnids (EPA 1999) because there are no published values based on soil measurements. This approach assumed that soil-dwelling invertebrates are exposed to soil pore water in equilibrium with soil. The *AF-S* values for the organic chemical COPCs were calculated as the daphnia BCF for the chemical COPC divided by the product of the equilibrium partitioning coefficient ($_{oc}$) and soil organic carbon content, which was assumed to be 0.01 (DOE 1998). The *AF-S* value for inorganic chemical COPCs was the arithmetic mean of the recommended values for those inorganic substances with empirical data available: arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc (EPA 1999).

P.2.1.4.1 External Dose from Radionuclides

External radiation doses from air, soil, water, and sediment were calculated by methods presented in *Methodology for Estimating Radiation Dose Rates to Freshwater iota Exposed to Radionuclides in the Environment* (Blaylock, Frank, and O'Neal 1993) and *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al. 1997), based on *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the A uatic Environment* (Baker and Soldat 1992). External irradiation by immersion in air containing radiological COPCs and by standing, sitting, or lying on the soil surface (aboveground radiation) was modeled using external dose conversion factors (DCFs), which are presented in *External Exposure to Radionuclides in Air, Water, and Soil* (Eckerman and Ryman 1993), and the activity of radiological COPCs in the medium. Aboveground external radiation from soil was adjusted for the fraction of time the receptor was assumed to spend on the soil surface or for the fraction of the receptor's body located above ground. Those fractions (based on professional judgment) are: plants, 0.5; soil-dwelling invertebrates, 0.5; side-blotched lizard, 0.5; mule deer, 1; mourning dove, 1; Great Basin pocket mouse, 0.3; western meadowlark, 1; coyote, 0.7; and burrowing owl, 0.5. The DCFs used for the Woodhouse's toad were extrapolated from values for similarly sized receptors presented in *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al. 1997). The Woodhouse's toad's fraction of time above ground and fraction of time below ground were 0.5 and 0.5, respectively.

A roughness factor (F_{ruf}) was used to correct for absorption of radiation by uneven soil contours, and an elevation correction factor (ECF) was used to adjust DCFs to account for most ecological receptors whose bodies are closer to the ground than the humans for which the DCFs were derived. The F_{ruf} for all receptors was set at 0.7, which was assumed to be a representative average correction for ground roughness (1.0 equates to a paved surface, whereas 0.5 equates to a deeply plowed field). The ECF was 2 for all receptors except the mule deer, which are large enough to receive radiation at approximately the same height as humans (Sample et al. 1997).

Belowground external radiation from soil was modeled by using the decay energies and tissue absorption fractions. Equations to calculate belowground external exposure are presented in *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al. 1997). Belowground and aboveground external exposure equations were combined to form the external exposure equation below. Belowground exposure was adjusted for the fraction of time the receptor was assumed to be exposed underground or the fraction of the body located above ground. Those fractions (based on professional judgment) are: plants, 0.5; soil-dwelling invertebrates, 0.5; the side-blotched lizard, 0.5; the Woodhouse's toad, 0.5; the mule deer, 0; the mourning dove, 0; the Great Basin pocket mouse, 0.7; the western meadowlark, 0; the coyote, 0.3; and the burrowing owl, 0.5.

Therefore, the external dose from radionuclides in soil and air (RD_{Ext}) was calculated as follows:

$$RD_{Ext} = RD_{Ext\text{-}soil} \quad RD_{Ext\text{-}air}$$

where:

$RD_{Ext\text{-}soil}$ = external radiation dose from soil, rad per day
$RD_{Ext\text{-}air}$ = external radiation dose from air, rad per day

The external dose to all receptors from soil was calculated as follows (Eckerman and Ryman 1993):

$$RD_{Ext\text{-}soil} = C_{soil} \quad DF_{soil}$$

where:

$RD_{Ext\text{-}soil}$ = external radiation dose from soil, rad per day
C_{soil} = activity of radionuclide in untilled soil, picocuries per gram
DF_{soil} = factor for converting activity in soil to external dose from untilled soil

The total external dose from all radiological COPCs in soil was the sum of the external doses from each radiological COPC.

The external dose factor for soil (DF_{soil}) was calculated as follows (Sample et al. 1997):

$$DF_{soil} = F_{above} \quad F_{ruf} \quad DCF \quad CFb \quad ECF \quad 1.05 \quad F_{below} \quad E_\gamma n_\gamma \quad \Phi_\gamma \quad CFa$$

where:

F_{above} = fraction of time spent above ground, unitless
F_{ruf} = dose rate reduction factor accounting for ground roughness, unitless
DCF = dose conversion factor for external radiation from soil contaminated to a depth of 1 centimeter (0.39 inches) (Eckerman and Ryman 1993), sieverts per second per becquerel per cubic meter
CFb = 5.12×10^{11}, factor for converting sieverts per second per becquerel per cubic meter to rad per day per picocurie per gram
ECF = elevation correction factor to adjust dose coefficient for effective height of receptor above ground (Sample et al. 1997), unitless
1.05 = conversion factor to account for immersion in soil rather than water
F_{below} = fraction of time spent below ground, unitless
$E_\gamma n_\gamma$ = photon energy emitted during transition from a higher to a lower energy state, 1 million electron volts (MeV) × proportion of disintegrations producing gamma radiation
Φ_γ = absorbed fraction of energy from gamma energy E_γ

CFa = unit conversion factor, 5.11×10^{-5} rad per day per picocurie per gram per MeV per disintegration

Only gamma radiation was relevant to the external dose.

The external dose to all receptors from air was calculated as follows (Eckerman and Ryman 1993):

$$RD_{\text{Ext-air}} = D \quad DF_{\text{air}}$$

Where:

$RD_{\text{Ext-air}}$ = external radiation dose from air, rad per day
D = activity of radionuclide in air, picocuries per cubic meter
DF_{air} = factor for converting activity in air to external dose from air

The external dose conversion factor for air (DF_{air}) was calculated as follows:

$$DF_{\text{air}} = 3.2 \quad 10^{5} \quad DCF$$

Where:

3.2×10^{5} = factor for converting sieverts per second per becquerel per cubic meter to rad per day per picocurie per cubic meter (Eckerman and Ryman 1993)
DCF = dose conversion factor for external radiation from immersion in air (Eckerman and Ryman 1993), sieverts per second per becquerel per cubic meter

P.2.1.4.2 Internal Dose from Radionuclides

The internal exposure to radionuclides was calculated from the activity in the receptor's tissues. The internal activities of radionuclides were calculated using uptake factors and activities in soil and food. Internal radiation doses were calculated by multiplying the activity in tissues by the sum of alpha, beta, and gamma decay energies, where alpha and beta energies were assumed to be completely absorbed. Because gamma rays, like x-rays, may pass through the tissues without depositing their energy, gamma energies were adjusted to account for greater absorption by larger organisms (e.g., the mule deer) at a given energy level and for greater absorption by all receptors at lower energy levels.

The internal dose (rad per day) to plants, soil-dwelling invertebrates, and wildlife receptors was calculated as follows (Sample et al. 1997):

$$RD_{\text{Int}} = C_n \quad DF_{\text{Int}}$$

where:

$$DF_{\text{Int}} = CFa \quad (\quad F \quad E_\alpha n_\alpha \quad \Phi_\alpha + E_\beta n_\beta \quad \Phi_\beta + E_\gamma n_\gamma \quad \Phi_\gamma)$$

and where:

RD_{Int} = internal radiation dose, rad per day
C_n = activity of radionuclide in receptor tissue, picocuries per gram
DF_{Int} = factor for converting radiological COPC activity in tissue to internal dose
CFa = unit conversion factor, 5.11×10^{-5} rad per day per picocurie per gram per MeV per disintegration
F = 5, quality factor for biological effect of alpha radiation (Kocher and Trabalka 2000), unitless

$E_\alpha n_\alpha$ = average energy emitted as alpha radiation, MeV per disintegration × proportion of disintegrations producing an alpha particle
Φ_α = absorbed fraction of energy from alpha energy E_α
$E_\beta n_\beta$ = average energy emitted as beta radiation, MeV per disintegration × proportion of disintegrations producing a beta particle
Φ_β = absorbed fraction of energy from beta energy E_β
$E_\gamma n_\gamma$ = photon energy emitted during transition from a higher to a lower energy state, MeV × proportion of disintegrations producing gamma radiation
Φ_γ = absorbed fraction of energy from gamma energy E_γ

In addition to estimating internal exposures, activities of radiological COPCs and concentrations of chemical COPCs in some receptor tissues were also used to estimate the ingestion dose to predators eating those receptors.

P.2.1.4.3 Tissue Concentrations and Activities

The activity of a radiological COPC and concentration of a chemical COPC in receptor tissue results from ingestion and inhalation of radiological and chemical COPCs in soil and food. Accumulation from ingested matter was modeled according to EPA guidelines (EPA 1999). The *CRCIA* (DOE 1998) contains a model for receptor- and chemical-specific accumulation from inhalation of particulates in air as a result of absorption and excretion (see *CRCIA*, Appendix I-D). For radionuclides, inhalation was normalized to ingestion of soil (DOE Standard 1153-2002). Because of a lack of available receptor- and chemical-specific data, absorption was assumed to be a receptor-specific parameter equal for all chemical and radiological COPCs and excretion was assumed to be a chemical-specific parameter common to all receptors.

The activity of radiological COPCs and concentration of chemical COPC in receptor tissue, with the exception of carbon-14 and tritium, was calculated as follows:

$$C_n = C_{\text{n-ing}} \quad C_{\text{n-inh}}$$

C_n = activity of radiological COPCs and concentration of chemical COPCs in receptor tissue, picocuries per gram or milligrams per kilogram
$C_{\text{n-ing}}$ = activity of radiological COPCs and concentration of chemical COPCs in receptor tissue resulting from ingestion, picocuries per gram or milligrams per kilogram
$C_{\text{n-inh}}$ = activity of radiological COPCs and concentration of chemical COPCs in receptor tissue resulting from inhalation, picocuries per gram or milligrams per kilogram

where for radiological COPCs:

$$C_{\text{n-inh}} = D_s \quad IR_{\text{air}} \quad PT\ IT \quad a_{\text{receptor}} \quad W_{\text{receptor}} \quad 0.001$$

where:

$C_{\text{n-inh}}$ = activity of radiological COPCs and concentration of chemical COPCs in receptor tissue resulting from inhalation, picocuries per gram or milligrams per kilogram
D_s = concentration in air from resuspended untilled soil particles (milligrams per cubic meter air or picocuries per cubic meter air)
IR_{air} = daily inhalation rate of soil, cubic meters air per kilogram body weight per day
$PT\ IT$ = unitless factor to adjust inhalation relative to ingestion for radionuclides (DOE Standard 1153-2002)
a_{receptor} = biotransfer rate of chemical in receptor, days per kilogram)
W_{receptor} = body weight, kilograms

0.001 = factor for converting kilograms to grams for radiological COPCs, kilograms per gram

and D_s was calculated as follows:

$$D_s = C_{soil} \quad _d$$

where:

C_{soil} = concentration in untilled soil, milligrams per kilogram or picocuries per gram
$_d$ = dust loading constant, 150 micrograms per cubic meter, converted to kilograms per cubic meter or grams per cubic meter (Zach 1985).

and where for chemical COPCs:

$$C_{n\text{-}inh} = D_s \quad IR_{air} \quad \alpha$$

where:

$C_{n\text{-}inh}$ = concentration of chemical COPCs in receptor tissue resulting from inhalation, milligrams per kilogram
IR_{air} = daily inhalation rate of air, cubic meters air per kilogram body weight per day
α = fractional absorption coefficient, unitless
= excretion constant, day^{-1}

IR_{air} was the receptor's inhalation rate of air (cubic meters air per kilogram body weight per day). It was receptor-specific, and it was derived from EPA guidelines (EPA 1993) using the fraction of dioxygen in dry atmosphere and average annual Hanford temperature as was done in the *CRCIA* (DOE 1998). IR_{air} values were from regression equations based on body weight, with the exception of the Woodhouse's toad, which was based on the metabolic rate of an adult bullfrog (EPA 1993).

For both radiological and chemical COPCs, the concentration of contaminant from ingestion was calculated as follows:

$$C_{n\text{-}ing} = C_{soil} \quad AF\text{-}Ts \quad C_w \quad AF\text{-}Tw \quad C_a \quad AF\text{-}Ta \quad C_p \quad AF\text{-}Tp$$

where:

$C_{n\text{-}ing}$ = concentration of contaminant in receptor tissue from ingestion, picocuries per gram or milligrams per kilogram
C_{soil} = concentration of contaminant in untilled soil, picocuries per gram or milligrams per kilogram
C_w = concentration of contaminant in surface-water, picocuries per milliliter or milligrams per liter
C_a = concentration of contaminant in animals, picocuries per gram or milligrams per kilogram
C_p = concentration of contaminants in plants, picocuries per gram or milligrams per kilogram

where C_a, the concentrations of chemicals or radionuclides in animal food was calculated as C_n for the prey item as a receptor and *AF-Ts*, *AF-Tw*, *AF-Ta*, and *AF-Tp* were the receptor's uptake factors for the different ingested media: soil or sediment (kilogram/kilogram), water (liter/kilogram or milliliter/gram), animals (kilogram/kilogram), and plants (kilogram/kilogram), respectively.

$$AF{-}Ts = I_s \quad a_{\text{receptor}}$$
$$AF{-}Tw = I_w \quad a_{\text{receptor}}$$
$$AF{-}Ta = I_a \quad a_{\text{receptor}}$$
$$AF{-}Tp = I_p \quad a_{\text{receptor}}$$

and:

$$a_{\text{receptor}} = a_{\text{cow}} \quad W_{\text{cow}} \quad W_{\text{receptor}}$$

where:

a_{receptor}	=	biotransfer rate of chemical in receptor, days per kilogram
a_{cow}	=	biotransfer rate of chemical in cow, days per kilogram
W_{cow}	=	body weight of cow (kilograms) = 200 kilograms
W_{receptor}	=	body weight of receptor, kilograms
I_p	=	daily ingestion rate of plant matter, kilograms wet weight plant per day
I_a	=	daily ingestion rate of animal matter, kilograms wet weight animal per day
I_s	=	daily ingestion rate of soil or sediment, kilograms dry matter per day
I_w	=	daily ingestion rate of water, liters per day

BAFs for wildlife receptors corrected the biotransfer factors for a 200 kilogram cow (Baes et al. 1984) for differences in body weight between cow and receptor. This approach was conservative and assumed that net uptake and assimilation efficiency would be more similar across organisms than the biotransfer factor, which is a function of body weight, uptake efficiency (absorption, elimination), and excretion.

I_p, I_a, I_s, and I_w were the receptor's ingestion rates for plant food, animal food, soil or sediment, and water. The ingestion rates for solid matter were calculated as follows:

$$I_p = IR_f \quad PF \quad W$$

$$I_a = IR_f \quad AF \quad W$$

$$I_s = IR_f \quad SF \quad W$$

where:

IR_f	=	daily specific ingestion rate of food, kilograms wet weight per kilograms body weight per day
PF	=	fraction of diet that is plant, unitless
W	=	body weight, kilograms
AF	=	fraction of diet that is animal, unitless
SF	=	dry soil or sediment ingested as a fraction of daily food (wet weight) ingested, unitless

The ingestion rate for water (I_w) was calculated as follows:

$$I_w = IR_w \quad W$$

where:

IR_w	=	daily specific ingestion rate of water, liters per kilogram body weight per day
W	=	body weight, kilograms

These were the general equations, and not all receptors ingested plant, animal, soil, sediment, and water. Only receptors exposed to soil were assumed to inhale untilled soil particles resuspended in air. Per the simplifying assumptions, exposure models for onsite and offsite terrestrial receptors at Hanford did not include ingestion of water and sediment. Models for riparian receptors at the Columbia River (see Sections P.3.1.2 and P.3.2.1.2) included ingestion of water and sediment, but not soil. When a receptor did not ingest a medium, the concentration and ingestion rate for that medium were taken to be zero, the calculated BAF and fraction of total dose were zero, and thus that medium did not contribute to the receptor's tissue concentration.

Exposure calculations for most radiological COPCs were based on the assumption that radionuclides would be present as particulates in soil or vapors in air. However, special consideration was given to carbon-14 and tritium, as these radiological COPCs are processed by vegetation with natural carbon and hydrogen, respectively. Thus, the vegetation pathways for carbon-14 and tritium would be dependent on the exchange of carbon and hydrogen between plants and the environment. For this assessment, guidance from Regulatory Guide 1.109 (NRC 1977) was used to account for the BAF of carbon-14 and tritium in plants. This was done through the use of correction factors, along with the assumption that all carbon-14 would be released in oxide form (carbon monoxide or carbon dioxide) and tritium would be released as water vapor. These correction factors were applied to the air concentration (e.g., picocuries per cubic meter) estimated at the point of exposure by the air model.

The concentration of carbon-14 in vegetation was calculated with the assumption that its ratio to the natural carbon in vegetation would be equal to the ratio of carbon-14 to natural carbon in the atmosphere surrounding the vegetation as follows (NRC 1977):

$$C_{p(C\text{-}14)} = D_{C\text{-}14} \quad p \quad 0.11/0.16$$

where:

$C_{p(C\text{-}14)}$ = concentration of carbon-14 in vegetation, picocuries radiological COPC per gram wet plant tissue
$D_{C\text{-}14}$ = concentration of carbon-14 in the surrounding air, picocuries per cubic meter air
p = ratio of the total annual release time to the total annual time during which photosynthesis occurs; a conservative ratio of 1.0 was used
0.11 = fraction of the total plant mass that is natural carbon, grams carbon per gram wet plant tissue
0.16 = concentration of natural carbon in the atmosphere, grams carbon per cubic meter air

The concentration of tritium in vegetation was calculated based on the equilibrium between moisture in the air and water in plants as follows (NRC 1977):

$$C_{p(H\text{-}3)} = D_{H\text{-}3} \quad 0.80 \quad (0.5/\text{humidity})$$

where:

$C_{p(H\text{-}3)}$ = concentration of tritium in vegetation, picocuries radiological COPC per gram wet plant tissue
$D_{H\text{-}3}$ = concentration of tritium in the surrounding air, picocuries per cubic meter air
0.80 = site-specific assumed fraction of the total plant mass that is water, grams plant water per gram wet plant tissue
0.5 = ratio of tritium concentration in plant water to tritium concentration in atmospheric water, curies per gram plant water per curies per gram water in air
humidity = humidity of the atmosphere, grams water per cubic meter air

A site-specific value of 68 percent or 0.68 grams per cubic meter (USFS, NPS, and USFWS 2000) was used for humidity.

The concentration of carbon-14 and tritium in vegetation was used as the total plant concentration for these radiological COPCs throughout the risk assessment, instead of estimating concentrations for specific parts of the plants (i.e., above ground and below ground). The concentrations of carbon-14 and tritium in the tissues of all terrestrial animal receptors were assumed to be equal to the concentrations in plants.

P.2.1.4.4 Exposure Doses from Chemicals

Exposure was estimated only for wildlife exposed to chemical COPCs via ingestion and inhalation. The average daily dose (ADD) for chemical COPCs was compared to benchmark doses to characterize risk. For plants and soil-dwelling invertebrates exposed to chemicals by multiple pathways (direct contact, ingestion) resulting from living in soil, exposure was not calculated. The assessment of impacts for plants and soil-dwelling invertebrates was made by comparing estimated soil concentrations to soil benchmark concentrations for these receptors (see Section P.2.1.5).

The doses to terrestrial wildlife receptors from chemical COPCs in soil were calculated as the sum of doses from inhaling air containing suspended soil and ingesting soil, food (plant and animal fractions), and water as follows:

$$ADD_{total} = ADD_{plant} \quad ADD_{animal} \quad ADD_{soil} \quad ADD_{water} \quad ADD_{air}$$

where:

ADD_{total}	=	total ingestion-equivalent dose of chemical from plant food, animal food, soil, and air, milligrams per kilogram body weight per day
ADD_{plant}	=	dose of chemical from ingestion of plants, milligrams per kilogram body weight per day
ADD_{animal}	=	dose of chemical from ingestion of animals, milligrams per kilogram body weight per day
ADD_{soil}	=	dose of chemical from ingestion of soil, milligrams per kilogram body weight per day
ADD_{water}	=	dose of chemical from ingestion of water, milligrams per kilogram body weight per day
ADD_{air}	=	ingestion-equivalent dose of chemical from inhalation of soil in air, milligrams per kilogram body weight per day

The dose of chemical from ingestion of plants (ADD_{plant}) was calculated as follows:

$$ADD_{plant} = C_p \quad IR_p = C_p \quad IR_f \quad PF$$

where:

C_p	=	concentration in plants, milligrams per kilogram wet weight
IR_p	=	daily ingestion rate of plant matter, kilograms fresh plant per kilograms body weight per day
IR_f	=	daily food ingestion rate, kilograms wet weight per kilograms body weight per day
PF	=	plant fraction of diet (ADD_{animal}).

The dose of chemical from ingestion of animals (ADD_{animal}) was calculated as follows:

$$ADD_{animal} = C_a \quad IR_a = C_a \quad IR_f \quad AF$$

where:

C_a	=	concentration in animal prey, milligrams per kilogram wet weight
IR_a	=	daily ingestion rate of animal matter, kilograms wet weight animal per kilogram body weight per day
IR_f	=	daily food ingestion rate, kilograms wet weight per kilogram body weight per day
AF	=	animal fraction of diet

Soil-dwelling invertebrates were the animal prey of the side-blotched lizard, Woodhouse's toad, Great Basin pocket mouse, and western meadowlark. The Great Basin pocket mouse was the animal prey of the coyote and the burrowing owl. Note that, for predators of the Great Basin pocket mouse, C_a was calculated as C_n with the Great Basin pocket mouse treated as a receptor.

The dose of chemical from ingestion of soil (ADD_{soil}) was calculated as follows:

$$ADD_{soil} = C_{soil} \quad IR_s = C_{soil} \quad IR_f \quad SF$$

where:

C_{soil}	=	concentration in soil, milligrams per kilogram dry soil
IR_s	=	ingestion rate of soil by the receptor, kilograms dry soil per kilograms body weight per day
IR_f	=	daily food ingestion rate, kilograms wet weight per kilogram body weight per day
SF	=	dry soil ingested as a fraction of daily food (wet weight) ingested, unitless

The dose of chemical from ingestion of water (ADD_{water}) was calculated as follows:

$$ADD_{water} = C_w \quad IR_w$$

where:

C_w	=	concentration in water, milligrams per liter water
IR_w	=	daily specific ingestion rate of water, liters per kilogram body weight per day

The dose of chemical from inhalation of soil in air (ADD_{air}) was calculated as follows:

$$ADD_{air} = D_s \quad IR_{air} \quad \alpha \quad (\quad a_{receptor} \quad W_{receptor})$$

where:

D_s	=	concentration in air from resuspended untilled soil particles, milligrams per cubic meter air
IR_{air}	=	daily inhalation rate of air, cubic meters per kilogram body weight per day
α	=	fractional absorption coefficient, unitless
	=	excretion constant, day^{-1}
$a_{receptor}$	=	biotransfer rate of chemical in receptor, days per kilogram
$W_{receptor}$	=	receptor body weight, kilograms

The factor, $\alpha \quad (\quad a_{receptor} \quad W_{receptor})$, relates the efficiency of uptake into blood from the lung to the efficiency of uptake into blood from the gastro-intestinal tract and was used to convert inhaled dose to ingested dose for the purposes of estimating the risk from exposure of inhaled substance in terms of ingestion-based toxicity reference values (TRVs). This factor was derived by taking the ratio of the equations for bioaccumulation in tissue of a substance inhaled (DOE 1998:I-D.10) and that of the substance ingested (EPA 1999:Equation 5-3), written in terms of dose. This approach assumes that once

a molecule of the substance is in the bloodstream its fate is independent of the pathway by which it came to be there. In other words, a unit tissue concentration could result either from inhalation or ingestion of soil ($C_{\text{n-ing}} = C_{\text{n-inh}}$), and

$$C_{\text{n-ing}} = C_{\text{n-inh}}$$
$$C_{\text{soil}} \quad AF\text{-}Ts = C_{\text{soil}} \quad _{d} \quad IR_{\text{air}} \quad \alpha$$
$$C_{\text{soil}} \quad a_{\text{receptor}} \quad I_s = D_s \quad IR_{\text{air}} \quad \alpha$$
$$C_{\text{soil}} \quad IR_s \quad a_{\text{receptor}} \quad W_{\text{receptor}} = D_s \quad IR_{\text{air}} \quad \alpha$$
$$\text{Dose}_{\text{ingested}} \quad (\quad a_{\text{receptor}} \quad W_{\text{receptor}}) = \text{Dose}_{\text{inhaled}} \quad \alpha/\text{K}$$
$$\text{Dose}_{\text{ingested}} = \text{Dose}_{\text{inhaled}} \quad \alpha \quad (\quad a_{\text{receptor}} \quad W_{\text{receptor}})$$

where:

$$I_s = IR_s \quad W_{\text{receptor}}$$

C_{soil} = concentration of contaminant in untilled soil, picocuries per gram or milligrams per kilogram

$AF\text{-}Ts$ = $I_s \quad a_{\text{receptor}}$

$_{d}$ = dust loading constant, 150 micrograms per cubic meter, converted to kilograms per cubic meter or grams per cubic meter (Zach 1985).

IR_{air} = daily inhalation rate of air, cubic meters air per kilogram body weight per day

a = fractional absorption coefficient, unitless

= excretion constant, day^{-1}

a_{receptor} = biotransfer rate of chemical in receptor, days per kilogram

I_s = daily ingestion rate of soil or sediment, kilograms dry matter per day

IR_s = ingestion rate of soil by the receptor, kilograms dry soil per kilograms body weight per day

W_{receptor} = body weight of receptor, kilograms

D_s = concentration in air from resuspended untilled soil particles, milligrams per cubic meter air

$\text{Dose}_{\text{ingested}}$ = dose of chemical from ingestion resulting in unit of chemical in tissue, milligrams per kilogram body weight per day

$\text{Dose}_{\text{inhaled}}$ = dose of chemical from inhalation resulting in unit of chemical in tissue, milligrams per kilogram body weight per day

Area use factors and temporal use factors were assumed to equal 1 for conservatism, and, thus, did not appear in the exposure equations.

P.2.1.5 Toxicological Benchmarks

The benchmark for combined internal and external exposure from all radionuclides was 0.1 rad per day for the side-blotched lizard, Woodhouse's toad, mule deer, mourning dove, Great Basin pocket mouse, meadowlark, coyote, and burrowing owl and 1 rad per day for plants and soil-dwelling invertebrates (IAEA 1992). Chemical benchmarks (TRVs) for plants and soil-dwelling invertebrates exposed to soil were soil concentrations (milligrams per kilogram) and TRVs for terrestrial receptors potentially impacted by chemicals in surface soil were doses (milligrams per kilogram body weight per day). All TRVs are chemical-specific literature values from a variety of published sources (e.g., Efroymson, Will, and Suter 1997; Efroymson et al. 1997; EPA 2009; Sample, Opresko, and Suter 1996).

P.2.1.6 Risk Indices

As discussed earlier in the introduction to Section P.2.1, the long-term impacts on ecological resources of potential radionuclide and chemical releases were evaluated by comparing estimates of exposure for a

given ecological receptor for a given chemical or radiological COPC under each alternative to threshold exposures associated with a known level of adverse effect of the COPC on that type of receptor. The estimate of chemical exposure for plants and soil-dwelling invertebrates was the predicted soil concentration under each alternative (see Appendix G). The methods for estimating exposure doses for terrestrial receptors from predicted air and soil concentrations were defined in Section P.2.1.4. The exposure concentrations or doses associated with a known level of adverse effect were the TRVs (see Section P.2.1.5). The comparison of these two values was made by calculating a risk index, the dimensionless ratio of the exposure estimate (concentration or dose) to corresponding TRV (concentration or dose). Calculated risk indices, Hazard Quotients for individual chemical COPCs and Hazard Indices for all radiological COPCs combined, were used to compare *TC & WM EIS* alternatives (see Chapter 5, Section 5) and identify exposures posing little or no risk (Hazard Quotient or Hazard Index less than or equal to unity).

The risk indices were calculated as follows:

for plants and soil-dwelling invertebrates exposed to chemical COPCs in soil,

$$H = C_{soil} \quad TRV$$

where:

H = Hazard Quotient
C_{soil} = concentration in untilled soil, milligrams per kilogram or picocuries per gram
TRV = toxicity reference value, milligrams per kilogram

$$H = ADD_{total} \quad TRV$$

for wildlife receptors exposed to chemical COPCs in soil and air,

where:

H = Hazard Quotient
ADD_{total} = total ingestion-equivalent dose of chemical from plant food, animal food, soil, and air, milligrams per kilogram body weight per day
TRV = toxicity reference value, milligrams per kilogram body weight per day

for all receptors, the Hazard Index is the sum of external and internal doses from all radiological COPCs divided by the *TRV*, that is,

$$HI = (RD_{Ext} + RD_{Int}) \quad TRV$$

where:

HI = Hazard Index
RD_{Ext} = external radiation dose from exposure to all radiological COPCs in air, soil, sediment, and/or water, rad per day
RD_{Int} = internal radiation dose from all radiological COPCs, rad per day

Except where an exposure parameter or *TRV* was not available for a given receptor or COPC, the dose (ADD_{total}) and Hazard Quotient for all chemical COPCs and the dose ($RD_{Ext} + RD_{Int}$) summed over all radiological COPCs and the Hazard Index were calculated for all terrestrial receptors potentially exposed at the two locations under all *TC & WM EIS* alternatives using predicted air and soil concentrations resulting from air releases during operations. Tables with predicted air and soil concentrations, input parameters, and calculations of dose and risk indices are provided in *Calculating Risk Indices for ong-*

Term Impacts to Ecological Receptors Releases to Air (SAIC 2008a). Results are summarized in Section P.2.2 using maximum Hazard Quotients and Hazard Indices.

P.2.2 Results and Discussion

Radiological and chemical hazards estimated for terrestrial ecological receptors due to exposure to contaminant release to the air and subsequent deposition are discussed below, while hazards due to releases into the air and subsequent deposition in the Columbia River and releases into the groundwater for aquatic receptors and terrestrial wildlife feeding in the Columbia River are discussed in Section P.3.

P.2.2.1 Onsite Terrestrial Resources

The results of the assessment for radiological and chemical contaminant releases to air and subsequent deposition estimated for terrestrial receptors at the onsite maximum-exposure location under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives, as well as the alternative combinations, are summarized in Tables P–3, P–4, and P–5.

Table P–3. Long-Term Impacts of Radiological COPC Air Deposition on Terrestrial Resources at the Onsite Maximum-Exposure Location: Hazard Indices by Receptor and Alternative

Alt.	Hazard Index by Receptor								
	Plant	Soil Invertebrates	Side-Blotched Lizard	Mule Deer	Mourning Dove	Great Basin Pocket Mouse	Meadowlark	Coyote	Burrowing Owl
Tank Closure									
1	7.67×10^{-4}	8.51×10^{-3}	7.35×10^{-3}	6.48×10^{-3}	9.81×10^{-3}	7.33×10^{-3}	9.58×10^{-3}	9.24×10^{-3}	8.15×10^{-3}
2A	3.43×10^{-3}	1.17×10^{-2}	1.09×10^{-2}	7.35×10^{-3}	1.54×10^{-2}	1.67×10^{-2}	1.24×10^{-2}	1.12×10^{-2}	1.29×10^{-2}
2B	2.77×10^{-3}	3.18×10^{-3}	3.52×10^{-3}	9.47×10^{-4}	5.53×10^{-3}	9.10×10^{-3}	2.85×10^{-3}	2.02×10^{-3}	4.64×10^{-3}
3A	3.08×10^{-3}	3.60×10^{-3}	7.82×10^{-3}	5.08×10^{-3}	9.87×10^{-3}	1.37×10^{-2}	7.11×10^{-3}	6.23×10^{-3}	9.00×10^{-3}
3B	2.62×10^{-3}	3.00×10^{-3}	3.30×10^{-3}	8.23×10^{-4}	5.21×10^{-3}	8.64×10^{-3}	2.65×10^{-3}	1.85×10^{-3}	4.37×10^{-3}
3C	3.09×10^{-3}	3.60×10^{-3}	7.82×10^{-3}	5.10×10^{-3}	9.94×10^{-3}	1.37×10^{-2}	7.12×10^{-3}	6.24×10^{-3}	9.00×10^{-3}
4	2.92×10^{-3}	3.36×10^{-3}	4.23×10^{-3}	1.49×10^{-3}	6.34×10^{-3}	1.01×10^{-2}	3.52×10^{-3}	2.63×10^{-3}	5.42×10^{-3}
5	2.61×10^{-3}	3.07×10^{-3}	4.22×10^{-3}	1.64×10^{-3}	6.18×10^{-3}	9.78×10^{-3}	3.56×10^{-3}	2.72×10^{-3}	5.34×10^{-3}
6A, Base Case	4.59×10^{-3}	6.32×10^{-3}	8.28×10^{-3}	1.87×10^{-3}	1.26×10^{-2}	2.16×10^{-2}	6.63×10^{-3}	4.62×10^{-3}	1.10×10^{-2}
6A, Option Case	5.26×10^{-3}	7.55×10^{-3}	9.30×10^{-3}	2.17×10^{-3}	1.42×10^{-2}	**2.42×10^{-2}**	7.46×10^{-3}	5.23×10^{-3}	1.24×10^{-2}
6B, Base Case	4.69×10^{-3}	6.44×10^{-3}	8.49×10^{-3}	2.01×10^{-3}	1.29×10^{-2}	2.20×10^{-2}	6.83×10^{-3}	4.79×10^{-3}	1.13×10^{-2}
6B, Option Case	5.03×10^{-3}	7.14×10^{-3}	8.77×10^{-3}	2.18×10^{-3}	1.34×10^{-2}	2.26×10^{-2}	7.07×10^{-3}	4.99×10^{-3}	1.16×10^{-2}
6C	2.65×10^{-3}	3.13×10^{-3}	3.52×10^{-3}	9.39×10^{-4}	5.50×10^{-3}	9.08×10^{-3}	2.85×10^{-3}	2.02×10^{-3}	4.64×10^{-3}
FFTF Decommissioning									
1	0	0	0	0	0	0	0	0	0
2	6.56×10^{-7}	6.62×10^{-7}	6.57×10^{-6}	6.56×10^{-6}	6.57×10^{-6}	6.59×10^{-6}	6.56×10^{-6}	6.56×10^{-6}	6.57×10^{-6}
3	6.56×10^{-7}	6.62×10^{-7}	6.57×10^{-6}	6.56×10^{-6}	6.57×10^{-6}	6.59×10^{-6}	6.56×10^{-6}	6.56×10^{-6}	6.57×10^{-6}
Waste Management									
1	0	0	0	0	0	0	0	0	0
2, DG1	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}
2, DG2	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}
2, DG3	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}
3, DG1	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}
3, DG2	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}
3, DG3	9.49×10^{-11}	9.70×10^{-10}	2.23×10^{-12}	6.59×10^{-12}	2.72×10^{-11}	1.40×10^{-11}	2.70×10^{-12}	2.21×10^{-12}	2.01×10^{-12}

Table P–3. Long-Term Impacts of Radiological COPC Air Deposition on Terrestrial Resources at the Onsite Maximum-Exposure Location: Hazard Indices by Receptor and Alternative *(continued)*

Alt.	Hazard Index by Receptor								
	Plant	Soil Invertebrates	Side-Blotched Lizard	Mule Deer	Mourning Dove	Great Basin Pocket Mouse	Meadowlark	Coyote	Burrowing Owl
Combination									
1	7.67×10^{-4}	8.51×10^{-3}	7.35×10^{-3}	6.48×10^{-3}	9.81×10^{-3}	7.33×10^{-3}	9.58×10^{-3}	9.24×10^{-3}	8.15×10^{-3}
2	2.77×10^{-3}	3.18×10^{-3}	3.53×10^{-3}	9.54×10^{-4}	5.54×10^{-3}	9.10×10^{-3}	2.86×10^{-3}	2.02×10^{-3}	4.65×10^{-3}
3	4.69×10^{-3}	6.44×10^{-3}	8.50×10^{-3}	2.02×10^{-3}	1.29×10^{-2}	2.20×10^{-2}	6.83×10^{-3}	4.79×10^{-3}	1.13×10^{-2}

Note: The maximum Hazard Index is indicated by **bold** text. Hazard Index is unitless.
Key: Alt.=Alternative; COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Table P–4. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Onsite Maximum-Exposure Location: Maximum Risk Index by Alternative

Alternative	Maximum Hazard Quotient		
	Hazard Quotient	Chemical COPC	Receptor
Tank Closure			
1	1.16	Xylene	Great Basin pocket mouse
2A	1.52×10^{2}	Mercury	Side-blotched lizard
2B	1.66×10^{2}	Mercury	Side-blotched lizard
3A	3.92×10^{2}	Mercury	Side-blotched lizard
3B	1.23×10^{2}	Xylene	Great Basin pocket mouse
3C	3.92×10^{2}	Mercury	Side-blotched lizard
4	1.57×10^{2}	Mercury	Side-blotched lizard
5	1.49×10^{2}	Xylene	Great Basin pocket mouse
6A, Base Case	2.70×10^{2}	Xylene	Great Basin pocket mouse
6A, Option Case	2.74×10^{2}	Xylene	Great Basin pocket mouse
6B, Base Case	1.72×10^{2}	Mercury	Side-blotched lizard
6B, Option Case	1.71×10^{2}	Mercury	Side-blotched lizard
6C	1.71×10^{2}	Mercury	Side-blotched lizard
FFTF Decommissioning			
1	2.12×10^{3}	Xylene	Great Basin pocket mouse
2	7.60	Xylene	Great Basin pocket mouse
3	7.65	Xylene	Great Basin pocket mouse
Waste Management			
1	3.29	Xylene	Great Basin pocket mouse
2, DG1	2.59×10^{1}	Xylene	Great Basin pocket mouse
2, DG2	1.66×10^{2}	Xylene	Great Basin pocket mouse
2, DG3	2.89×10^{2}	Xylene	Great Basin pocket mouse
3, DG1	2.63×10^{1}	Xylene	Great Basin pocket mouse
3, DG2	1.67×10^{2}	Xylene	Great Basin pocket mouse
3, DG3	2.89×10^{2}	Xylene	Great Basin pocket mouse

Table P–4. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Onsite Maximum-Exposure Location: Maximum Risk Index by Alternative *(continued)*

Alternative	Maximum Hazard Quotient		
	Hazard Quotient	Chemical COPC	Receptor
Combination			
1	**2.12×10^{3}**	Xylene	Great Basin pocket mouse
2	1.66×10^{2}	Mercury	Side-blotched lizard
3	3.25×10^{2}	Xylene	Great Basin pocket mouse

Note: The maximum Hazard Quotient of all receptors is indicated by **bold** text. Risk indices are unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Table P–5. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Onsite Maximum-Exposure Location: Maximum Risk Index by Receptor

Receptor	Maximum Hazard Quotient			
	Analysis	Alternative	Hazard Quotient	Chemical COPC
Plants	Combination	1	4.69×10^{1}	Toluene
Soil-dwelling invertebrate	Tank Closure	3A, 3C	2.33	Mercury
Side-blotched lizard	Tank Closure	3A, 3C	3.92×10^{2}	Mercury
Great Basin pocket mouse	Combination	1	2.12×10^{3}	Xylene
Coyote	Combination	1	2.69×10^{2}	Xylene
Mule deer	Waste Management	3, DG3	8.14×10^{1}	Formaldehyde
Western meadowlark	Tank Closure	3A, 3C	2.35×10^{2}	Mercury
Mourning dove	Tank Closure	3A, 3C	1.94×10^{1}	Mercury
Burrowing owl	Tank Closure	3A, 3C	1.64×10^{1}	Mercury

Note: Risk indices are unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group.

The maximum combined radionuclide Hazard Index from emissions under all alternatives was calculated to be 0.024 for the Great Basin pocket mouse under Tank Closure Alternative 6A, Option Case. Table P–3 presents the maximum Hazard Indices associated with air emissions of radiological COPCs calculated to reach the onsite receptors under each of the alternatives. There would be no releases of radiological COPCs under FFTF Decommissioning Alternative 1 and Waste Management Alternative 1. Exposures to radiological COPCs from air emissions under all alternatives would be below the 1-rad-per-day benchmark for soil-dwelling invertebrates and plants and the 0.1-rad-per-day benchmark for terrestrial wildlife receptors (i.e., the side-blotched lizard, Great Basin pocket mouse, coyote, mule deer, mourning dove, burrowing owl, and western meadowlark). Estimated hazards for the representative species indicated that no adverse effects are expected for onsite terrestrial receptors from exposure to radiological COPCs from air emissions. Because the direct impacts of air exposure are expected to be small, any associated, potential indirect impacts on the ecosystem are expected to be correspondingly minor.

Exposure to chemicals from air emissions under all alternatives exceeds the Hazard Quotient criterion of 1.0 for one or more receptors at the onsite maximum-exposure location. The highest Hazard Quotient for each alternative or alternative combination was either for side-blotched lizards exposed to mercury or mice exposed to xylene (see Table P–4). Mercury had the highest Hazard Quotient for soil-dwelling invertebrates, lizards, and birds (Tank Closure Alternatives 3A and 3C). Xylene had the highest Hazard Quotient for the Great Basin pocket mouse and coyote (Alternative Combination 1). Toluene had the

highest Hazard Quotient for plants (Alternative Combination 1) and formaldehyde the highest Hazard Quotient for the mule deer (Waste Management Alternative 3, Disposal Group 3). The maximum Hazard Quotient from emissions under all alternatives was calculated to be 2120 for the Great Basin pocket mouse exposed to xylene under Alternative Combination 1, the No Action Alternatives for Tank Closure, FFTF Decommissioning, and Waste Management (see Table P–5). One other chemical COPC, benzene, had Hazard Quotients exceeding 1 for terrestrial receptors at the onsite maximum-exposure location: the Great Basin pocket mouse under all Tank Closure and Waste Management alternatives except the No Action Alternatives and the Great Basin pocket mouse and mule deer under FFTF Decommissioning Alternative 1.

The benzene, toluene, and xylene Hazard Quotients above 1.0 would be unlikely to indicate significant risk to mammals for three reasons. First, benzene, toluene, and xylene concentrations were overestimated because these substances are expected to dissipate (volatilization, biodegradation), not accumulate in soil, as was assumed for the risk calculations. High-end estimates of the half-lives of benzene, toluene, and xylene in soil are 39 days, 22 days, and 28 days, respectively (Howard et al. 1991). Second, the soil-dwelling invertebrate *AF-S* might have been overestimated. The *AF-S* was based on a *Daphnia* BCF using a log $_{ow}$ regression applied to soil-dwelling invertebrates exposed to soil pore water in equilibrium with soil at 1 percent organic carbon. *Daphnia* are aquatic organisms, and uptake via water is expected to be greater than uptake via soil. The Great Basin pocket mouse feeds on soil-dwelling invertebrates, so an overestimate of the *AF-S* would result in greater chemical intake via ingestion of soil-dwelling invertebrates. Third, the use of lowest-observed adverse effect levels (LOAELs), which are greater than no observed adverse effect levels, would result in further reduction of the Hazard Quotients. LOAELs are toxicological benchmarks associated with low levels of adverse effect on individuals, but which may not cause significant adverse impacts on populations. LOAELs are acceptable benchmarks for species that are not threatened or endangered. Thus, Hazard Quotients for the representative species likely overestimated the potential for adverse effects on onsite terrestrial resources.

The mercury Hazard Quotients above 1.0 does not necessarily indicate high risk to soil-dwelling invertebrates, lizards, and birds at the onsite maximum-exposure location. The mercury TRV used to calculate the Hazard Quotients was the no observed adverse effect level for methyl mercury, which is highly toxic compared to the forms of mercury typically found in terrestrial environments. Mercury Hazard Quotients can be used to compare alternatives with confidence, but Hazard Quotients exceeding 1 should not be used as the basis to conclude that ecological resources at the onsite maximum-exposure location would be adversely impacted.

A potential adverse impact that could not be evaluated using the Hazard Quotients was the potential acidification of soil or water by deposition of the chemical COPCs nitrogen and sulfur dioxides. The deposition of nitrogen and sulfur dioxides in air emissions from site and WTP operations would be unlikely to acidify soil at Hanford. The Soil Survey for Benton County, Washington, describes the representative soil, the Quincy series, as ranging from mildly to moderately alkaline throughout (pH 7.8 to 8.4) and strongly effervescent in the lower part, indicating abundant calcium carbonate and acid-buffering capacity (NRCS 2008; Rasmussen 1971). The Quincy (Rupert) sand is derived from extensive alluvial and lacustrine flood deposits rather than from the basaltic rock in the area. The Burbank loamy sand, the second most widely distributed soil unit on the site, is very similar to the Quincy sand. The chemical properties table for Benton County does not indicate that the Quincy or Burbank soils are particularly saline. Soils in wetter regions of the Western United States, especially soils derived from acidic parent materials, have little buffering capacity from calcium carbonate and other minerals because these minerals are leached out. In contrast, soils in arid regions such as Hanford tend to have a relatively high buffer capacity because soluble ions (particularly basic ions and associated minerals) tend to accumulate in the upper portion of the soil profile. With a pH greater than 8 in the upper 20 centimeters according to the Natural Resources Conservation Service Soil Series Database and a reported soil pH of 7

for the 200 Area (Ecology 2003), soil acidification due to acid deposition from site and WTP emissions would not be a concern.

P.2.2.2 Offsite Terrestrial Resources

The results of the assessment for radiological and chemical contaminant releases to air and subsequent deposition estimated for terrestrial receptors at the offsite maximum-exposure location under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives, as well as the alternative combinations, are summarized in Tables P–6, P–7, and P–8.

The maximum combined radionuclide Hazard Index from emissions under all alternatives was calculated to be 0.0000515 for the Great Basin pocket mouse under the Tank Closure Alternative 6A, Option Case. Table P–6 presents the maximum Hazard Indices associated with air emissions calculated to reach the terrestrial receptors at the offsite maximum-exposure location (the Columbia River) under all alternatives. Exposure to radiological COPCs from air emissions under all alternatives was below the l-rad-per-day benchmark for soil-dwelling invertebrates and plants and the 0. l-rad-per-day benchmark for terrestrial wildlife receptors (i.e., the Woodhouse's toad, Great Basin pocket mouse, coyote, and mule deer). Estimated hazards for the representative species indicated that no adverse effects are expected for offsite terrestrial receptors from exposure to radiological COPCs from air emissions. Because the direct impacts of air exposure are expected to be small, any associated, potential indirect impacts on the ecosystem would be correspondingly minor.

Table P–6. Long-Term Impacts of Radiological COPC Air Deposition on Terrestrial Resources at the Offsite Maximum-Exposure Location: Hazard Indices by Receptor and Alternative

Hazard Index by Receptor									
Alternative	**Plant**	**Soil Invertebrates**	**Woodhouse's Toad**	**Mule Deer**	**Mourning Dove**	**Great Basin Pocket Mouse**	**Meadowlark**	**Coyote**	**Burrowing Owl**
Tank Closure									
1	1.16×10^{-6}	9.80×10^{-6}	1.16×10^{-5}	1.03×10^{-5}	1.40×10^{-5}	1.12×10^{-5}	1.37×10^{-5}	1.34×10^{-5}	1.21×10^{-5}
2A	1.08×10^{-5}	2.11×10^{-5}	1.77×10^{-5}	1.42×10^{-5}	3.42×10^{-5}	4.42×10^{-5}	2.45×10^{-5}	2.11×10^{-5}	2.92×10^{-5}
2B	1.03×10^{-5}	1.17×10^{-5}	8.67×10^{-6}	6.53×10^{-6}	2.27×10^{-5}	3.53×10^{-5}	1.33×10^{-5}	1.03×10^{-5}	1.95×10^{-5}
3A	1.04×10^{-5}	1.19×10^{-5}	1.43×10^{-5}	1.21×10^{-5}	2.84×10^{-5}	4.13×10^{-5}	1.90×10^{-5}	1.60×10^{-5}	2.54×10^{-5}
3B	9.55×10^{-6}	1.08×10^{-5}	6.12×10^{-6}	4.05×10^{-6}	1.96×10^{-5}	3.17×10^{-5}	1.05×10^{-5}	7.67×10^{-6}	1.66×10^{-5}
3C	1.04×10^{-5}	1.19×10^{-5}	1.43×10^{-5}	1.21×10^{-5}	2.85×10^{-5}	4.13×10^{-5}	1.90×10^{-5}	1.60×10^{-5}	2.54×10^{-5}
4	1.02×10^{-5}	1.16×10^{-5}	8.92×10^{-6}	6.71×10^{-6}	2.32×10^{-5}	3.60×10^{-5}	1.36×10^{-5}	1.06×10^{-5}	2.00×10^{-5}
5	9.65×10^{-6}	1.11×10^{-5}	1.11×10^{-5}	8.94×10^{-6}	2.47×10^{-5}	3.71×10^{-5}	1.55×10^{-5}	1.27×10^{-5}	2.17×10^{-5}
6A, Base Case	1.18×10^{-5}	1.47×10^{-5}	7.95×10^{-6}	4.69×10^{-6}	2.76×10^{-5}	4.61×10^{-5}	1.45×10^{-5}	1.03×10^{-5}	2.37×10^{-5}
6A, Option Case	1.29×10^{-5}	1.67×10^{-5}	8.93×10^{-6}	5.28×10^{-6}	3.08×10^{-5}	**5.15×10^{-5}**	1.63×10^{-5}	1.15×10^{-5}	2.65×10^{-5}
6B, Base Case	1.22×10^{-5}	1.52×10^{-5}	1.10×10^{-5}	7.72×10^{-6}	3.10×10^{-5}	4.98×10^{-5}	1.77×10^{-5}	1.34×10^{-5}	2.70×10^{-5}
6B, Option Case	1.26×10^{-5}	1.60×10^{-5}	1.13×10^{-5}	8.00×10^{-6}	3.16×10^{-5}	5.05×10^{-5}	1.81×10^{-5}	1.37×10^{-5}	2.75×10^{-5}
6C	9.88×10^{-6}	1.15×10^{-5}	8.67×10^{-6}	6.50×10^{-6}	2.26×10^{-5}	3.53×10^{-5}	1.32×10^{-5}	1.03×10^{-5}	1.95×10^{-5}
FFTF Decommissioning									
1	0	0	0	0	0	0	0	0	0
2	1.64×10^{-9}	1.65×10^{-9}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}
3	1.64×10^{-9}	1.65×10^{-9}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}	1.64×10^{-8}

Table P–6. Long-Term Impacts of Radiological COPC Air Deposition on Terrestrial Resources at the Offsite Maximum-Exposure Location: Hazard Indices by Receptor and Alternative (*continued*)

Hazard Index by Receptor									
Alternative	**Plant**	**Soil Invertebrates**	**Woodhouse's Toad**	**Mule Deer**	**Mourning Dove**	**Great Basin Pocket Mouse**	**Meadowlark**	**Coyote**	**Burrowing Owl**
Waste Management									
1	0	0	0	0	0	0	0	0	0
2, DG1	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
2, DG2	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
2, DG3	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
3, DG1	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
3, DG2	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
3, DG3	2.19×10^{-13}	2.23×10^{-12}	4.53×10^{-15}	1.52×10^{-14}	6.25×10^{-14}	3.23×10^{-14}	6.21×10^{-15}	5.10×10^{-15}	4.62×10^{-15}
Combination									
1	1.16×10^{-6}	9.80×10^{-6}	1.16×10^{-5}	1.03×10^{-5}	1.40×10^{-5}	1.12×10^{-5}	1.37×10^{-5}	1.34×10^{-5}	1.21×10^{-5}
2	1.03×10^{-5}	1.17×10^{-5}	8.69×10^{-6}	6.54×10^{-6}	2.28×10^{-5}	3.53×10^{-5}	1.33×10^{-5}	1.03×10^{-5}	1.96×10^{-5}
3	1.22×10^{-5}	1.52×10^{-5}	1.10×10^{-5}	7.73×10^{-6}	3.10×10^{-5}	4.98×10^{-5}	1.77×10^{-5}	1.34×10^{-5}	2.70×10^{-5}

Note: The maximum Hazard Index is indicated by bold text. Hazard Index is unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Exposures to chemicals from air emissions under all alternatives exceed the Hazard Quotient criterion of 1.0 only for the Great Basin pocket mouse exposed to xylene under FFTF Decommissioning Alternative 1 and Alternative Combination 1, which includes FFTF Decommissioning Alternative 1 (see Table P–7). The maximum Hazard Quotient from emissions under all alternatives was calculated to be 2.42. The highest Hazard Quotient for each alternative or alternative combination was either for the western meadowlark exposed to mercury or the Great Basin pocket mouse exposed to xylene (see Table P–7). Table P–8 summarizes the maximum Hazard Quotient for each receptor. Mercury had the highest Hazard Quotient for soil-dwelling invertebrates, the Woodhouse's toad, and the three bird species–mourning dove, western meadowlark, and burrowing owl (Tank Closure Alternatives 3A and 3C). Xylene had the highest Hazard Quotient for the Great Basin pocket mouse and the coyote (Combination 1). Toluene had the highest Hazard Quotient for plants (Combination 1) and formaldehyde the highest Hazard Quotient for the mule deer (Waste Management Alternative 3, Disposal Group 3). No other chemical COPCs had Hazard Quotients exceeding 1 for terrestrial receptors at the offsite maximum.

Table P–7. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Offsite Maximum-Exposure Location: Maximum Risk Index by Alternative

Alternative	**Maximum Hazard Quotient**		
	Hazard Quotient	**Chemical COPC**	**Receptor**
Tank Closure			
1	4.20×10^{-3}	Xylene	Great Basin pocket mouse
2A	3.30×10^{-1}	Mercury	Western meadowlark
2B	3.60×10^{-1}	Mercury	Western meadowlark
3A	4.30×10^{-1}	Mercury	Western meadowlark
3B	2.45×10^{-1}	Mercury	Western meadowlark
3C	4.30×10^{-1}	Mercury	Western meadowlark
4	3.10×10^{-1}	Mercury	Western meadowlark
5	2.96×10^{-1}	Mercury	Western meadowlark
6A, Base Case	3.33×10^{-1}	Mercury	Western meadowlark
6A, Option Case	3.32×10^{-1}	Mercury	Western meadowlark

Table P–7. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Offsite Maximum-Exposure Location: Maximum Risk Index by Alternative *(continued)*

Alternative	Maximum Hazard Quotient		
	Hazard Quotient	Chemical COPC	Receptor
Tank Closure *(continued)*			
6B, Base Case	3.73×10^{-1}	Mercury	Western meadowlark
6B, Option Case	3.73×10^{-1}	Mercury	Western meadowlark
6C	3.73×10^{-1}	Mercury	Western meadowlark
FFTF Decommissioning			
1	2.41	Xylene	Great Basin pocket mouse
2	8.65×10^{-3}	Xylene	Great Basin pocket mouse
3	8.71×10^{-3}	Xylene	Great Basin pocket mouse
Waste Management			
1	4.54×10^{-3}	Xylene	Great Basin pocket mouse
2, DG1	4.03×10^{-2}	Xylene	Great Basin pocket mouse
2, DG2	1.98×10^{-1}	Xylene	Great Basin pocket mouse
2, DG3	3.36×10^{-1}	Xylene	Great Basin pocket mouse
3, DG1	4.12×10^{-2}	Xylene	Great Basin pocket mouse
3, DG2	2.00×10^{-1}	Xylene	Great Basin pocket mouse
3, DG3	3.36×10^{-1}	Xylene	Great Basin pocket mouse
Combination			
1	**2.42**	Xylene	Great Basin pocket mouse
2	3.60×10^{-1}	Mercury	Western meadowlark
3	3.76×10^{-1}	Xylene	Great Basin pocket mouse

Note: The maximum Hazard Quotient of all receptors is indicated by **bold** text. Risk indices are unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Table P–8. Long-Term Impacts of Chemical COPC Air Deposition on Terrestrial Resources at the Offsite Maximum-Exposure Location: Maximum Risk Index by Receptor

Receptor	Maximum Hazard Quotient			
	Analysis	Alternative	Hazard Quotient	Chemical COPC
Plants	Combination	1	5.35×10^{-2}	Toluene
Soil-dwelling invertebrates	Tank Closure	3A, 3C	4.26×10^{-3}	Mercury
Woodhouse's toad	Tank Closure	3A, 3C	2.97×10^{-1}	Mercury
Great Basin pocket mouse	Combination	1	2.42	Xylene
Coyote	Combination	1	3.07×10^{-1}	Xylene
Mule deer	Waste Management	3, DG3	9.58×10^{-2}	Formaldehyde
Meadowlark	Tank Closure	3A, 3C	4.30×10^{-1}	Mercury
Mourning dove	Tank Closure	3A, 3C	3.55×10^{-2}	Mercury
Burrowing owl	Tank Closure	3A, 3C	2.99×10^{-2}	Mercury

Note: Risk indices are unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group.

Estimated hazards for the representative species indicate that no adverse effects are expected for offsite terrestrial receptors from exposure to chemicals from air emissions. The xylene Hazard Quotients above 1.0 are unlikely to indicate significant risk to small mammals for the reasons discussed for the onsite terrestrial maximum-exposure location. Because the direct impacts of air exposure are expected to be small, any associated, potential indirect impacts on the ecosystem would be correspondingly minor.

As described above for onsite soils, the deposition of nitrogen and sulfur dioxides in air emissions from the Tank Closure, FFTF Decommissioning, and Waste Management alternatives would be unlikely to acidify offsite soils because of the natural buffering capacity of area soils. Thus, soil acidification due to deposition of chemical COPCs from site and WTP emissions would not be a concern.

P.2.2.3 Uncertainties

Uncertainty exists about the actual magnitude of future exposures and the threshold doses or benchmark concentration TRVs used to evaluate the long-term impact on terrestrial ecological resources from air releases. The uncertainties for chemical and radiological exposure estimates come from errors in the source terms and transport models. Additional uncertainties are found in the BAFs and uptake factors, which are linear models based on simplifying assumptions. The uncertainties for toxicity and radiological effects thresholds arise from extrapolating from laboratory experiments on test species to Hanford receptor species in natural environments, and uncertainty about the chemical to which ecological receptors would be exposed, e.g., chemical COPC breakdown products, which can have greater toxicity than the COPC itself. The lack of TRVs for some chemical COPCs and some receptors results in uncertainties. TRVs for some chemical COPCs were not available for soil-dwelling invertebrates or the Woodhouse's toad, western meadowlark, mourning dove, and burrowing owl. As a result, there are uncertainties associated with the ecological risk evaluation. It was not known if these receptors would be more sensitive than mammals. The effect of chemicals deposited on microbial crusts was not known. Combined, these uncertainties produced limited underestimates of risk and moderate overestimates of risk for different combinations of receptors and chemical or radiological COPCs. These errors were unbiased with respect to the alternatives being evaluated in this *TC & WM EIS*, and thus the results presented above accurately reflect the relative impacts of alternatives on ecological resources. In addition, conservative exposure assumptions and TRVs mitigated these uncertainties and allow for confidence in "no risk" conclusions.

P.2.3 Summary of Terrestrial Impacts

Estimated radiation doses resulting from any of the alternatives were less than the 0.1-rad-per-day benchmark and did not exceed the 1-rad-per-day benchmark for terrestrial receptors at the on- and offsite maximum-exposure locations. Hazard Indices associated with these alternatives all were below 1.0. Estimated chemical doses resulting from any of the alternatives exceeded the Hazard Quotient criterion of 1.0 at the offsite terrestrial maximum-exposure location (the Columbia River) only for the Great Basin pocket mouse exposed to xylene under FFTF Decommissioning Alternative 1. The low magnitude of the Hazard Quotients and the conservative exposure assumptions mean that impacts on populations of small mammals from these alternatives would not be likely at the offsite maximum-exposure location. Although there were Hazard Quotients above 1 for mammals exposed to xylene and soil-dwelling invertebrates, lizards, and birds exposed to mercury at the onsite maximum-exposure location for many alternatives, the conservative exposure assumptions and toxicity benchmarks suggest that adverse impacts on ecological resources from these alternatives at the onsite maximum-exposure location, while possible, would not be likely. Calculated risk indices for terrestrial resources from air releases were used in this *TC & WM EIS* to compare alternatives and evaluate cumulative impacts.

P.3 IMPACTS ON COLUMBIA RIVER AQUATIC AND RIPARIAN RESOURCES RESULTING FROM FUTURE CONTAMINANT RELEASES

Ecological resources in the Columbia River and its riparian habitat would potentially be adversely impacted by two types of contaminant releases: air releases during site and WTP operations in the near-term future and groundwater releases in the distant future. The different actions involved in the different alternatives would result in different amounts and timing of air releases, different amounts of waste remaining in the tanks, and different waste forms disposed of at the site, thereby potentially contributing to future groundwater releases to the Columbia River. The focus was on long-term future

impacts on the river because no additional fast-moving substances would be added to the tanks under any of the alternatives. Groundwater modeling for Hanford has shown that the discharge of fast-moving substances in the plumes has already peaked, and there was no evidence of adverse impact on aquatic and riparian receptors (Bryce et al. 2002). Concentrations of radionuclides and chemicals resulting from deposition of airborne contaminants were predicted as described in Appendix G. Groundwater contaminated by leaching from the 200 Areas would eventually reach and discharge into the Hanford Reach of the Columbia River, and these discharges were predicted as described in Appendix O. These predicted release concentrations were used to evaluate the impacts on Columbia River aquatic and riparian ecological resources.

The potential for adverse effects on Columbia River aquatic and riparian ecological resources of potential releases of radionuclides and chemicals through air emissions during waste handling and WTP operations and future groundwater releases under the different alternatives was evaluated using a quantitative risk assessment approach (EPA 1992, 1997). The general approach to the assessment of potential for adverse effects or impacts on ecological resources is discussed in Section P.2.1. Impacts of deposition of oxides of sulfur and nitrogen on the water's pH were evaluated based on buffering capacity and predicted concentrations.

P.3.1 Impacts of Air Releases During Operations

Potential adverse impacts on Columbia River aquatic and riparian ecological resources resulting from air releases of radionuclides or chemicals during WTP operations were evaluated for all alternatives. Under all alternatives, radionuclides and chemicals emitted to the air during WTP operations would potentially be transported away from the source to the Columbia River and to offsite terrestrial locations. The potential impacts on terrestrial ecological resources (i.e., terrestrial biota) at the offsite maximum-exposure location (the Columbia River) from contaminants released by air emission are discussed in Section P.2. The evaluation of potential adverse impacts on aquatic and riparian ecological resources (e.g., aquatic biota and their predators) at the Columbia River is described below.

P.3.1.1 Methods

The general approach for assessing potential adverse effects on aquatic and riparian ecological resources is discussed in Section P.2.1. The assumptions; receptors; exposure pathways and uptake mechanisms (routes); predicted air, soil, sediment, and surface-water concentrations; exposure model equations; and benchmarks used to model exposure for aquatic and riparian ecological resources potentially impacted by contaminant releases are described in the relevant sections below. The calculated Hazard Quotients, Hazard Indices, and other quantitative evaluations of long-term adverse impacts on aquatic and riparian resources from air releases are summarized and discussed in Section P.3.1.2. Impacts of deposition of oxides of sulfur and nitrogen on the pH were evaluated based on buffering capacity and predicted concentrations.

P.3.1.1.1 Key Assumptions

The following key assumptions were made in the evaluation of potential impacts on Columbia River aquatic and riparian resources of exposure to radionuclides and chemicals released to air during closure operations:

- There would be no riparian soil contamination prior to tank closure activities.
- Soil contamination from air releases would not coincide with soil contamination from groundwater releases.

- Concentrations of constituents in tissues of fish preyed upon by predators (least weasel and bald eagle) would be in equilibrium with concentrations in nearshore surface-water.

- The concentrations of inorganic chemical and radiological COPCs in Columbia River nearshore sediment would be equal to riparian soil concentrations.

- The concentrations of organic chemical COPCs in Columbia River sediment would be in equilibrium with concentrations in nearshore surface-water.

These assumptions allowed for a conservative assessment of the impact of air releases on ecological resources.

P.3.1.1.2 Receptors and Exposure Pathways and Routes

The receptors selected to represent the Columbia River aquatic and riparian ecological resources, including special status species (Chapter 3, Section 3.9.4.1), are listed in Table P–2. These receptors were selected because they were among those expected to have higher exposures than those not selected from their group due to their higher ingestion rates per unit body weight for prey, water, and sediment or soil. Special status species were not expected to be more highly exposed or more sensitive to contaminants than the selected species. The selected representative receptors were sediment-dwelling benthic invertebrates, aquatic biota, including salmonids, raccoon, spotted sandpiper, least weasel, and bald eagle. All were ECEM receptors except the spotted sandpiper, which was substituted for the common snipe because the spotted sandpiper has a more aquatic diet.

The exposure pathways evaluated in the ecological risk analysis for this *TC & WM EIS* are shown in Table P–2 for all ecological receptors. The exposure medium, exposure route, and receptor are indicated for each pathway evaluated in the analysis of impacts on aquatic and riparian resources from air releases.

P.3.1.1.3 Predicted Sediment and Surface-Water Concentrations

The riparian soil, sediment, and surface-water concentrations under Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1, 2 and 3 (Hanford and Idaho Options); and Waste Management Alternatives 1, 2, and 3 were calculated from the modeled air deposition rates at the Columbia River (see Appendix G). The riparian soil concentrations resulting from air deposition would be cumulative and were calculated assuming deposition on the riparian shoreline and accumulation on the ground surface over the operations period. Sediment concentrations of inorganic chemical and radiological COPCs would be the cumulative soil concentrations calculated as described in Section P.2.1. Sediment concentrations of organic chemical COPCs were calculated as the product of the maximum nearshore surface-water concentration, the organic carbon-partitioning coefficient (K_{oc}) and the fraction of organic carbon content, which was conservatively assumed to be 0.04, four times greater than the ECEM value (DOE 1998). The maximum nearshore surface-water concentration (C_w) and water column surface-water concentration (C_{wc}) were calculated assuming that the amount of material deposited on the water surface of the Hanford Reach on an annual basis is mixed into a 0.5 meter-deep nearshore zone extending 40 meters into the river and throughout the water column. The resulting sediment and surface-water concentrations under Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1, 2, and 3 (Hanford and Idaho Options); and Waste Management Alternatives 1, 2, and 3 were used as the source terms in the exposure model described below.

P.3.1.1.4 Exposure Model Calculations

The exposure model calculated external and internal doses from radiological COPCs for all receptors and ingestion doses from chemical COPCs for wildlife receptors. To calculate internal doses for radiological COPCs in receptors exposed by direct contact with sediment (benthic invertebrates) and surface-water

(aquatic biota, including salmonids) and to calculate the ingested doses for wildlife receptors exposed to chemical COPCs in these biota (spotted sandpipers, raccoons, least weasels, and bald eagles), the concentrations of radiological and chemical COPCs in benthic invertebrates and aquatic biota were required.

For benthic invertebrates the concentration of COPCs was calculated as follows:

$$C_a = C_{sed} \quad ASF$$

and for trophic-level-3 fish (salmonids) the concentration was calculated as follows:

$$C_a = C_w \quad CF_{fish} \quad FCM_3 \quad CF$$

where:

C_a = concentration in animal food, milligrams per kilogram wet weight or picocuries per gram wet weight
C_{sed} = sediment concentration, milligrams per kilogram dry sediment or picocuries per gram dry sediment
ASF = sediment-to-benthic invertebrate bioaccumulation factor, kilograms dry sediment per kilogram wet tissue
C_w = nearshore surface-water concentration, milligrams per liter or picocuries per liter
CF_{fish} = water-to-fish bioconcentration factor, liters water per kilogram wet tissue
FCM_3 = food chain multiplier for trophic-level-3 fish
CF = unit conversion factor, 1 for chemical COPCs, 0.001 kilograms per gram for radiological COPCs

Food chain multipliers (FCMs) are factors accounting for the accumulation and biomagnification in fish via the food web (EPA 1995).

P.3.1.1.4.1 External Doses from Radionuclides

External doses to all aquatic receptors would result from exposure to radiological COPCs in soil, air, water, and sediment. External doses to Woodhouse's toad adults from radionuclides in soil and air are evaluated in Section P.2.2. Exposure of Woodhouse's toad tadpoles was evaluated along with aquatic biota and salmonids. Wildlife receptors (raccoon, spotted sandpiper, bald eagle, and least weasel) would be exposed externally to radionuclides in soil, air, and water. External radiation from soil, sediment, and water was modeled as described in *Methodology for Estimating Radiation Dose Rates to Freshwater iota Exposed to Radionuclides in the Environment* (Blaylock, Frank, and O'Neal 1993). External radiation doses for aquatic biota, including Woodhouse's toad larval forms and salmonids; raccoons; spotted sandpipers; benthic invertebrates; bald eagles; and least weasels were adjusted for the fraction of time the receptors were assumed to be immersed in water away from sediment, sufficiently near the water to receive external radiation, on nearshore soil, resting on sediment, and immersed in sediment (see Table P–2). Those fractions (based on professional judgment) were: aquatic biota, immersed in water, 0.9, resting on sediment, 0.1, and immersed in sediment, 0; raccoon, near water, 0.083, above ground, 0.5, below ground, 0.5, resting on sediment, 0, and immersed in sediment, 0; spotted sandpiper, near water, 0.5, above ground, 1, resting on sediment, 0, and immersed in sediment, 0; benthic invertebrates, immersed in sediment, 0.9, immersed in water, 0.1, and resting on sediment, 0; bald eagle, near water, 0.05, resting on sediment, 0, and immersed in sediment, 0; and least weasel, immersed in water, 0.2, above ground, 0.5, below ground, 0.5, resting on sediment, 0, and immersed in sediment, 0. For this *TC & WM EIS*, aquatic biota and benthic invertebrates were assumed to spend their entire lives in water. Therefore, the fractions of time spent immersed in water (F_{imm}), at the sediment-water interface (F_s), and

immersed in sediment (F_{in}) sum to unity for these receptors. For aquatic biota and benthic invertebrates, F_{imm} can be calculated by subtraction ($1 - F_s - F_{in}$).

The external doses (rad per day) to all aquatic receptors from water and sediment were calculated, respectively, as follows:

$$RD_{\text{Ext-water, imm}} = C_w \quad DF_{\text{water, imm}}$$

and

$$RD_{\text{Ext-sed}} = C_{\text{sed}} \quad DF_{\text{sediment}}$$

where:

$RD_{\text{Ext-water, imm}}$	=	external radiation dose from immersion in water
C_w	=	total activity of radiological COPC in water, picocuries per liter
$DF_{\text{water, imm}}$	=	factor for converting activity in water to external dose from water immersion
$RD_{\text{Ext-sed}}$	=	external radiation dose from sediment
C_{sed}	=	activity of radionuclide in sediment, picocuries per gram
DF_{sediment}	=	factor for converting activity in sediment to external dose from sediment

The external dose factor for immersion in water ($DF_{\text{water, imm}}$) was calculated as follows (Blaylock, Frank, and O'Neal 1993):

$$DF_{\text{water, imm}} = (F_{\text{imm}}) \quad 0.001 \quad CFa \quad [(1-\Phi_\beta) \quad E_\beta n_\beta + (1-\Phi_\gamma) \quad E_\gamma n_\gamma]$$

where:

F_{imm}	=	fraction of time receptor spends immersed in water, unitless
0.001	=	factor for converting liters to grams
CFa	=	unit conversion factor, 5.11×10^{-5} rad per day per picocurie per gram per MeV per disintegration
Φ_β	=	absorbed fraction of energy from beta energy E_β
$E_\beta n_\beta$	=	average energy emitted as beta radiation, MeV per disintegration × proportion of disintegrations producing a beta particle
Φ_γ	=	absorbed fraction of energy from gamma energy E_γ
$E_\gamma n_\gamma$	=	photon energy emitted during transition from a higher to a lower energy state, MeV × proportion of disintegrations producing gamma radiation

Values of F_{imm} are given in the first paragraph of this subsection. The calculation of exposure of ecological receptors to radiological COPCs in sediment included the dose from the decay products, known as daughters. This conservative approach to calculating dose was adopted because sediment is a more permanent medium than water and air, and radiological COPCs and their daughters would remain longer in sediment than in soil; soil-loss processes are ignored in the calculation of dose from COPCs in soil. The activity of each of the daughter radionuclides equals the activity of the parent multiplied by the fraction of the decays in the immediately preceding generation that yield the daughter. Exposure factors for the daughter radionuclides were used to calculate the contribution of the daughters to the summed exposure from the parent and all daughter radionuclides for both external and internal doses radiation from radiological COPCs in sediment.

The external dose factor for sediment ($DF_{sediment}$) was calculated as follows (Blaylock, Frank, and O'Neal 1993):

$$DF_{sediment} = (0.5 \quad F_s + F_{in}) \quad CFa \quad [(1 - \Phi_\beta) \quad E_\beta n_\beta + (1 - \Phi_\gamma) \quad E_\gamma n_\gamma]$$

where:

0.5	=	factor to account for assumption that a receptor at the sediment-water interface receives external radiation from sediment only from below, so the dose is only half of the dose from immersion
F_s	=	fraction of time receptor spends at the sediment-water interface, unitless
F_{in}	=	fraction of time receptor spends buried in sediment, unitless
CFa	=	unit conversion factor, 5.11×10^{-5} rad per day per picocurie per gram per MeV per disintegration
Φ_β	=	absorbed fraction of energy from beta energy E_β
$E_\beta n_\beta$	=	average energy emitted as beta radiation, MeV per disintegration × proportion of disintegrations producing a beta particle
Φ_γ	=	absorbed fraction of energy from gamma energy E_γ
$E_\gamma n_\gamma$	=	photon energy emitted during transition from a higher to a lower energy state, MeV × proportion of disintegrations producing gamma radiation

Values of F_s and F_{in} are given in the first paragraph of this subsection. To calculate external exposure to all aquatic receptors from radiological COPCs in water and sediment, $DF_{water,\ imm}$ and $DF_{sediment}$ values were multiplied by the modeled activities of the corresponding radionuclides in surface-water and the corresponding radionuclides and their daughters in sediment.

The external dose (rad per day) to all wildlife receptors from air (Eckerman and Ryman 1993) was calculated per the equations presented in Section P.2.1.4. To calculate external exposure to all aquatic receptors from radiological COPCs in air, DCF values were multiplied by the modeled activities of the corresponding radionuclides in air.

The external dose (rad per day) for all wildlife receptors from proximity to water containing radiological COPCs was calculated as follows (Eckerman and Ryman 1993):

$$RD_{Ext\text{-}water,\ near} = C_w \quad DF_{water,\ near}$$

where:

$RD_{Ext\text{-}water,\ near}$	=	external radiation dose from proximity to water, rad per day
C_w	=	total activity of radiological COPC in nearshore surface-water, picocuries per liter
$DF_{water,\ near}$	=	factor for converting activity in water to external dose from water

The external dose factor for water ($DF_{water,\ near}$) for wildlife receptors was calculated as follows (Blaylock, Frank, and O'Neal 1993):

$$DF_{water,\ near} = C_w \quad F_{near} \quad 0.001 \times CFa \quad [(1 - \Phi_\gamma) \quad E_\gamma n_\gamma]$$

where:

C_w	=	total activity of radiological COPC in nearshore surface-water, picocuries per liter
F_{near}	=	fraction of time receptor spends near the water, unitless
0.001	=	factor for converting liters to grams

CFa = unit conversion factor, 5.11×10^{-5} rad per day per picocuries per gram per MeV per disintegration
Φ_γ = absorbed fraction of energy from gamma energy E_γ
$E_\gamma n_\gamma$ = photon energy emitted during transition from a higher to a lower energy state, MeV × proportion of disintegrations producing gamma radiation

To calculate external exposure to all aquatic receptors from radiological COPCs in water, $DF_{\text{water, near}}$ values were multiplied by the modeled total activities of the corresponding radionuclides in surface-water.

P.3.1.1.4.2 Internal Doses from Radionuclides

The internal exposure to radionuclides was calculated from the activity in tissues, rather than from the daily ingestion, using the equations presented in Section P.2.1.4. The internal activities of radiological COPCs were calculated by using BAFs and BCFs, along with radiological COPC activities in sediment and water. For radionuclides in sediment, radiation by daughter radionuclides was also included in internal dose calculations. Decay energies and absorption fractions for gamma radiation for radiological COPCs and daughter radionuclides came from Eckerman and Ryman (1993); Blaylock, Frank, and O'Neal (1993); and Sample et al. (1997).

The internal dose to aquatic receptors and wildlife receptors was calculated as follows (Sample et al. 1997):

$$RD_{\text{Int}} = C_n \quad DF_{\text{Int}}$$

where:

$$DF_{\text{Int}} = CFa \quad (\quad F \quad E_\alpha n_\alpha \quad \Phi_\alpha + E_\beta n_\beta \quad \Phi_\beta + E_\gamma n_\gamma \quad \Phi_\gamma)$$

and

RD_{Int} = internal radiation dose from ingestion of radiological COPCs, rad per day
C_n = activity of radionuclide in receptor tissue, picocuries per gram
DF_{Int} = factor for converting radiological COPCs activity in tissue to internal dose
CFa = unit conversion factor, 5.11×10^{-5} rad per day per picocuries per gram per MeV per disintegration
F = 5, quality factor for biological effect of alpha radiation (Kocher and Trabalka 2000), unitless
$E_\alpha n_\alpha$ = average energy emitted as alpha radiation, MeV per disintegration × proportion of disintegrations producing an alpha particle
Φ_α = absorbed fraction of energy from alpha energy E_α
$E_\beta n_\beta$ = average energy emitted as beta radiation, MeV per disintegration × proportion of disintegrations producing a beta particle
Φ_β = absorbed fraction of energy from beta energy E_β
$E_\gamma n_\gamma$ = photon energy emitted during transition from a higher to a lower energy state, MeV × proportion of disintegrations producing gamma radiation
Φ_γ = absorbed fraction of energy from gamma energy E_γ

To calculate internal exposure to all aquatic receptors from ingested radiological COPCs, DF_{Int} values were multiplied by the modeled activities of the corresponding radionuclides in receptor tissues. For receptors ingesting sediment or prey exposed to sediment, only the fraction of tissue activity or concentration coming from sediment directly or indirectly through ingested prey was multiplied by the DF_{int} values for daughters of radiological COPCs.

Following the approach for terrestrial plants (see Section P.2.1.4), the concentration of carbon-14 in benthic invertebrates was calculated assuming that the ratio of carbon-14 to the natural carbon in tissue would be equal to the ratio of carbon-14 to the natural carbon in Columbia River nearshore surface-water:

$$C_a = C_w \quad 0.11/0.014$$

where:

C_a = concentration of carbon-14 in benthic invertebrates, picocuries per gram wet tissue
C_w = concentration of carbon-14 in nearshore surface-water, picocuries per liter
0.11 = fraction of the total animal mass that is natural carbon, grams carbon per gram wet tissue
0.014 = concentration of natural carbon in Columbia River in nearshore surface-water, grams carbon per liter water

The concentration of natural carbon in Columbia River nearshore surface-water was calculated from median alkalinity (57 milligrams calcium carbonate per liter) and pH (7.8) values for the Columbia River (Poston et al. 2007) and equilibrium constants for the aqueous carbonate solution, $p_1 = 6.3$ and $p_2 = 10.25$ (Stumm and Morgan 1970).

Likewise, the concentration of tritium in benthic invertebrates was calculated assuming that the specific activity of tritium in tissue would be equal to the specific activity in Columbia River nearshore surface-water:

$$C_a = C_w \quad 0.8/1{,}000$$

where:

C_a = concentration of tritium in benthic invertebrates, picocuries per gram
C_w = concentration of tritium in nearshore surface-water, picocuries per liter
0.8 = fraction of animal mass that is water
1,000 = grams water per liter

The concentrations of carbon-14 and tritium in fish would be equal to those of benthic invertebrates. The concentrations of carbon-14 and tritium in wildlife receptors would be equal to the concentrations in their animal prey.

P.3.1.1.4.3 Exposure Doses from Chemicals

For aquatic and riparian receptors exposed to chemicals by multiple pathways (direct contact, ingestion, respiration) resulting from living in sediment or surface-water, exposure was not calculated. The assessment of impacts for these receptors was made by comparing estimated sediment, sediment pore water, or surface-water concentrations to appropriate benchmark concentrations for these receptors (see Section P.3.1.1.5). Exposure was estimated only for wildlife receptors exposed to chemical and radiological COPCs via ingestion. Inhalation was not included because there would be little to no resuspension of sediment or riparian soil into air. The ingestion ADD for chemical COPCs was compared to benchmark doses to characterize risk.

The ingestion doses to aquatic wildlife receptors from chemical COPCs in surface-water and sediment were calculated as the sum of doses from ingesting water, sediment, and food, as follows:

$$ADD_{\text{total}} = ADD_{\text{water}} \quad ADD_{\text{sediment}} \quad ADD_{\text{food}}$$

where:

ADD_{total} = total dose of chemical from ingestion of water, animal food, and sediment, milligrams per kilogram body weight per day
ADD_{water} = dose of chemical from ingestion of water, milligrams per kilogram body weight per day
$ADD_{sediment}$ = dose of chemical from ingestion of sediment, milligrams per kilogram body weight per day
ADD_{food} = dose of chemical from ingestion of animal food, milligrams per kilogram body weight per day

and

$$ADD_{water} = C_w \quad IR_w \quad CF$$

where:

C_w = nearshore surface-water concentration, milligrams per liter
IR_w = ingestion rate of water by the receptor, liters per kilogram body weight per day
CF = unit conversion factor, 1 for chemical COPCs

and

$$ADD_{sediment} = C_{sed} \quad IR_s = C_{sed} \quad IR_f \quad SF$$

where:

C_{sed} = concentration in sediment, milligrams per kilogram dry sediment
IR_s = ingestion rate of sediment by the receptor, kilograms dry sediment per kilogram body weight per day
IR_f = daily food ingestion rate, kilograms wet weight per kilogram body weight per day
SF = sediment ingested as a fraction of food ingested, kilograms dry sediment per kilogram wet weight food

and

$$ADD_{food} = C_a \quad IR_a = C_a \quad IR_f \quad AF$$

where:

C_a = concentration of chemical COPC in animal food, milligrams per kilogram wet food
IR_a = ingestion rate of animal food by the receptor, kilograms wet food per kilogram body weight per day
IR_f = daily food ingestion rate, kilograms wet weight per kilogram body weight per day
AF = animal fraction of diet: prey

Spotted sandpipers and raccoons were assumed to eat benthic invertebrates living in nearshore sediment and exposed to nearshore sediment pore water. Bald eagles and least weasels were assumed to eat fish, such as salmonids, exposed to nearshore surface-water.

The area use factor and the temporal use factor were assumed to equal 1 for conservatism, so they did not appear in the exposure equations.

P.3.1.1.5 Toxicological Benchmarks

The benchmark for combined internal and external exposure from all radionuclides is 0.1 rad per day for the spotted sandpiper, raccoon, least weasel, and bald eagle (IAEA 1992) and l-rad-per-day for aquatic biota and benthic invertebrates (NCRP 1991). Chemical benchmarks for aquatic biota, including Woodhouse's toad larval forms and salmonids were surface-water concentrations (milligrams per liter); TRVs for benthic invertebrates exposed to water and sediment were sediment concentrations (milligrams per kilogram); and TRVs for wildlife receptors potentially impacted by chemicals released to the Columbia River via air emissions were doses (milligrams per kilogram per day). All TRVs were chemical-specific literature values from a variety of published sources (e.g., Jones, Suter, and Hull 1997; Sample, Opresko, and Suter 1996; Suter and Tsao 1996).

P.3.1.1.6 Risk Indices

As discussed in Section P.2.1, the long-term impacts on ecological resources of potential radionuclide and chemical releases were evaluated by comparing estimates of exposure for a given ecological receptor for a given chemical or radiological COPC under each alternative to threshold exposures associated with a known level of adverse effect of the COPC on that type of receptor. The estimate of chemical exposure concentration under each alternative for sediment-dwelling (benthic) invertebrates was the predicted sediment concentration, and for aquatic biota, including salmonids, it was the predicted surface-water concentration (see Appendix G). The methods for estimating exposure doses for aquatic and riparian receptors from predicted air, water, and sediment concentrations were defined in Section P.3.1.1.4. The exposure concentrations or doses associated with a known level of adverse effect were the TRVs (see Section P.3.1.1.5). The comparison of these two values was made by calculating a risk index, the dimensionless ratio of the exposure estimate (concentration or dose) to corresponding *TRV* (concentration or dose). Calculated risk indices, Hazard Quotients for individual chemical COPCs and Hazard Indices for all radiological COPCs combined, were used to compare *TC & WM EIS* alternatives (see Chapter 5) and identify exposures posing little or no risk (Hazard Quotient or Hazard Index less than or equal to unity).

The risk indices were calculated as follows:

for benthic invertebrates exposed to chemical COPCs in sediments,

$$H = C_{sed} \; TRV$$

where:

H = Hazard Quotient
C_{sed} = concentration in sediment, milligrams per kilogram dry sediment
TRV = toxicity reference value, milligrams per kilogram

for aquatic biota, including salmonids exposed to chemical COPCs in surface-water,

$$H = C_w \; TRV$$

where:

H = Hazard Quotient
C_w = nearshore surface-water concentration, milligrams per liter
TRV = toxicity reference value, milligrams per liter

for wildlife receptors exposed to chemical COPCs in air, sediment and surface-water,

$$H = ADD_{total} \; TRV$$

where:

H = Hazard Quotient
ADD_{total} = total dose of chemical from ingestion of water, animal food, and sediment, milligrams per kilogram body weight per day
TRV = toxicity reference and value, milligrams per kilogram body weight per day

and for all receptors, the Hazard Index is the sum of external and internal doses from all radiological COPCs divided by the *TRV*, that is,

$$HI = (RD_{Ext} + RD_{Int}) / TRV$$

where:

HI = Hazard Index
RD_{Ext} = external radiation dose from exposure to all radiological COPCs in air, soil, sediment, and/or water, rad per day
RD_{Int} = internal radiation dose from all radiological COPCs, rad per day
TRV = toxicity reference value, rad per day

Except where an exposure parameter or TRV was not available for a given receptor or COPC, the dose (ADD_{total}) and Hazard Quotient for all chemical COPCs and the dose ($RD_{Ext} + RD_{Int}$) summed over all radiological COPCs and the Hazard Index were calculated for all aquatic and riparian receptors potentially exposed at the Columbia River under all *TC & WM EIS* alternatives using predicted air, surface-water, and sediment concentrations resulting from air releases during operations. Tables with predicted air, surface-water, and sediment concentrations; input parameters; and calculations of dose and risk indices are available in *Calculating Risk Indices for ong-Term Impacts to Ecological Receptors Releases to Air* (SAIC 2008a).

Radiological and chemical hazards estimated for potential aquatic receptors and terrestrial wildlife feeding in the Columbia River due to exposure to contaminants released to the air and subsequently deposited in the Columbia River are summarized below using maximum Hazard Quotients and Hazard Indices. Hazards due to discharge from groundwater for aquatic receptors and terrestrial wildlife feeding in the Columbia River are discussed in Section P.3.2.

P.3.1.2 Results and Discussion

The results of the screening analysis for radiological contaminant releases to air and subsequent deposition estimated for aquatic receptors and terrestrial wildlife feeding in the Columbia River under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives, as well as the alternative combinations, are summarized in Tables P–9, P–10, and P–11.

Table P–9. Long-Term Impacts of Radiological COPC Air Deposition on Aquatic and Riparian Resources at the Columbia River: Hazard Indices by Receptor and Alternative

Alternative	Hazard Index by Receptor					
	Benthic Invertebrate	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/ Salmonids
Tank Closure						
1	2.86×10^{-4}	1.04×10^{-4}	4.99×10^{-5}	1.24×10^{-7}	3.17×10^{-6}	6.57×10^{-7}
2A	4.91×10^{-4}	9.33×10^{-4}	4.49×10^{-4}	2.33×10^{-5}	4.67×10^{-5}	8.36×10^{-6}
2B	2.10×10^{-4}	8.41×10^{-4}	4.16×10^{-4}	4.40×10^{-5}	6.50×10^{-5}	9.97×10^{-6}
3A	2.11×10^{-4}	8.90×10^{-4}	4.60×10^{-4}	8.31×10^{-5}	1.03×10^{-4}	1.37×10^{-5}
3B	1.98×10^{-4}	7.87×10^{-4}	3.79×10^{-4}	2.26×10^{-5}	4.28×10^{-5}	7.50×10^{-6}
3C	2.11×10^{-4}	8.90×10^{-4}	4.60×10^{-4}	8.31×10^{-5}	1.03×10^{-4}	1.37×10^{-5}
4	2.10×10^{-4}	8.50×10^{-4}	4.17×10^{-4}	3.75×10^{-5}	5.79×10^{-5}	9.19×10^{-6}
5	1.99×10^{-4}	8.35×10^{-4}	4.20×10^{-4}	5.70×10^{-5}	7.72×10^{-5}	1.10×10^{-5}
6A, Base Case	2.71×10^{-4}	1.16×10^{-3}	5.55×10^{-4}	1.74×10^{-5}	3.87×10^{-5}	8.56×10^{-6}
6A, Option Case	3.01×10^{-4}	**1.30×10^{-3}**	6.18×10^{-4}	1.75×10^{-5}	3.92×10^{-5}	9.14×10^{-6}
6B, Base Case	2.77×10^{-4}	1.21×10^{-3}	5.91×10^{-4}	4.46×10^{-5}	6.69×10^{-5}	1.16×10^{-5}
6B, Option Case	2.84×10^{-4}	1.22×10^{-3}	5.97×10^{-4}	4.47×10^{-5}	6.70×10^{-5}	1.16×10^{-5}
6C	2.06×10^{-4}	8.40×10^{-4}	4.15×10^{-4}	4.39×10^{-5}	6.49×10^{-5}	9.89×10^{-6}
FFTF Decommissioning						
1	0	0	0	0	0	0
2, Hanford Option	1.78×10^{-10}	1.35×10^{-9}	6.50×10^{-10}	4.14×10^{-11}	8.49×10^{-11}	1.22×10^{-11}
2, Idaho Option	2.43×10^{-13}	1.83×10^{-12}	8.69×10^{-13}	5.87×10^{-14}	1.68×10^{-13}	1.99×10^{-14}
3, Hanford Option	1.78×10^{-10}	1.34×10^{-9}	6.49×10^{-10}	4.14×10^{-11}	8.47×10^{-11}	1.22×10^{-11}
3, Idaho Option	0	0	0	0	0	0
Waste Management						
1	0	0	0	0	0	0
2, DG1	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
2, DG2	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
2, DG3	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
3, DG1	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
3, DG2	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
3, DG3	1.09×10^{-11}	8.34×10^{-13}	3.62×10^{-13}	9.10×10^{-16}	5.06×10^{-15}	5.33×10^{-14}
Combination						
1	2.86×10^{-4}	1.04×10^{-4}	4.99×10^{-5}	1.24×10^{-7}	3.17×10^{-6}	6.57×10^{-7}
2	2.10×10^{-4}	8.41×10^{-4}	4.16×10^{-4}	4.40×10^{-5}	6.50×10^{-5}	9.97×10^{-6}
3	2.77×10^{-4}	1.21×10^{-3}	5.91×10^{-4}	4.46×10^{-5}	6.69×10^{-5}	1.16×10^{-5}

Note: The maximum Hazard Index is indicated by **bold** text. Hazard Index is unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Table P–10. Long-Term Impacts of Chemical COPC Air Deposition on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Alternative

Alternative	Maximum Hazard Quotient		
	Hazard Quotient	Chemical COPC	Receptor
Tank Closure			
1	4.35×10^{-2}	Ammonia	Aquatic Biota/Salmon
2A	3.90×10^{-1}	Mercury	Spotted sandpiper
2B	4.25×10^{-1}	Mercury	Spotted sandpiper

Table P-10. Long-Term Impacts of Chemical COPC Air Deposition on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Alternative *(continued)*

Alternative	Maximum Hazard Quotient		
	Hazard Quotient	**Chemical COPC**	**Receptor**
Tank Closure *(continued)*			
3A	**5.08×10^{-1}**	Mercury	Spotted sandpiper
3B	2.89×10^{-1}	Mercury	Spotted sandpiper
3C	5.08×10^{-1}	Mercury	Spotted sandpiper
4	3.66×10^{-1}	Mercury	Spotted sandpiper
5	3.50×10^{-1}	Mercury	Spotted sandpiper
6A, Base Case	3.93×10^{-1}	Mercury	Spotted sandpiper
6A, Option Case	3.92×10^{-1}	Mercury	Spotted sandpiper
6B, Base Case	4.41×10^{-1}	Mercury	Spotted sandpiper
6B, Option Case	4.40×10^{-1}	Mercury	Spotted sandpiper
6C	4.40×10^{-1}	Mercury	Spotted sandpiper
FFTF Decommissioning			
1	6.89×10^{-2}	Benzene	Aquatic Biota/Salmonids
2, Hanford Option	4.14×10^{-2}	Ammonia	Aquatic Biota/Salmonids
2, Idaho Option	9.33×10^{-3}	Benzene	Aquatic Biota/Salmonids
3, Hanford Option	4.09×10^{-2}	Ammonia	Aquatic Biota/Salmonids
3, Idaho Option	4.82×10^{-3}	Benzene	Aquatic Biota/Salmonids
Waste Management			
1	6.92×10^{-3}	Benzene	Aquatic Biota/Salmonids
2, DG1	1.36×10^{-2}	Benzene	Aquatic Biota/Salmonids
2, DG2	5.64×10^{-2}	Benzene	Aquatic Biota/Salmonids
2, DG3	5.64×10^{-2}	Benzene	Aquatic Biota/Salmonids
3, DG1	1.41×10^{-2}	Benzene	Aquatic Biota/Salmonids
3, DG2	5.69×10^{-2}	Benzene	Aquatic Biota/Salmonids
3, DG3	5.67×10^{-2}	Benzene	Aquatic Biota/Salmonids
Combination			
1	8.51×10^{-2}	Benzene	Aquatic Biota/Salmonids
2	4.25×10^{-1}	Mercury	Spotted sandpiper
3	4.41×10^{-1}	Mercury	Spotted sandpiper

Note: The maximum Hazard Quotient of all receptors is indicated by **bold** text. Risk indices are unitless.
Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility.

Table P–11. Long-Term Impacts of Chemical COPC Air Deposition on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Receptor

Receptor	Maximum Hazard Quotient			
	Analysis	Alternative	Hazard Quotient	Chemical COPC
Benthic invertebrate	Tank Closure	2A	6.83×10^{-2}	Ammonia
Aquatic Biota/ Salmonids	Combination	3	1.16×10^{-1}	Benzene
Spotted sandpiper	Tank Closure	3A, 3C	5.08×10^{-1}	Mercury
Raccoon	Tank Closure	3A, 3C	4.31×10^{-2}	Mercury
Least weasel	Tank Closure Combination	6B, Base Case 3	2.38×10^{-2}	Mercury
Bald eagle	Tank Closure Combination	6B, Base Case 3	4.16×10^{-2}	Mercury

Note: Risk indices are unitless.
Key: COPC=constituent of potential concern.

The maximum combined radionuclide Hazard Index from emissions under all alternatives was calculated to be 0.0013 for the spotted sandpiper under Tank Closure Alternative 6A, Option Case. Table P–9 presents the maximum Hazard Indices associated with air emissions calculated to reach the Columbia River under all alternatives. Exposure to radiological and chemical COPCs from air emissions under all alternatives would be below the 1-rad-per-day benchmark for benthic invertebrates and aquatic biota, including salmonids and the 0.1-rad-per-day benchmark for terrestrial wildlife receptors (i.e., spotted sandpiper, raccoon, least weasel, and bald eagle). Estimated hazards for the representative species indicate that no adverse effects are expected for aquatic receptors and terrestrial wildlife feeding in the Columbia River from exposure to radiological COPCs from air emissions. Because the direct impacts of air exposure are expected to be small, any associated, potential indirect impacts on the ecosystem would be correspondingly minor.

No receptor exposed to chemical COPCs deposited in the Columbia River as a result of air emissions under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives had a screening Hazard Quotient exceeding 1 (see Table P–10). The highest Hazard Quotient was 0.51 for the spotted sandpiper exposed to mercury in nearshore surface-water under Tank Closure Alternatives 3A and 3C. Hazard Quotients for terrestrial mammals, i.e., the raccoon and least weasel, and piscivorous birds feeding in the Columbia River on benthic invertebrates and salmonids, respectively, did not exceed 0.1 (see Table P–11). Given the conservative exposure assumptions and toxicological benchmarks, ecological receptors in the Hanford Reach would be unlikely to be at unacceptable risk due to the deposition of chemical COPCs emitted to the air under any alternative.

As was the case for Hanford soils, the buffering capacity of the Hanford Reach would be sufficient to maintain the pH within the National Ambient Water Quality Criteria acceptable range for aquatic life (pH = 5.0–9.0) and Washington Ambient Surface-water Quality Standards for the Hanford Reach (pH = 6.5–8.5) despite deposition of nitrogen and sulfur dioxides from air emissions under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives. Two weak acids (sulfurous acid and nitrous acid) and a strong acid (nitric acid) potentially result from the dissolution of nitrogen and sulfur dioxides in river water. According to the *Hanford Site Environmental Report for Calendar Year 200 (Including Some Early 2007 Information)* (Poston et al. 2007), the Hanford Reach has a reported alkalinity of 57 milligrams calcium carbonate per liter and a pH of 7.8. An alkalinity of 57 milligrams calcium carbonate per liter would keep the pH at or above 7.8, given the addition of 0.0139 milligrams nitrogen dioxide per liter (Alternative Combination 3) and 0.0001 milligrams sulfur dioxide per liter (Alternative Combination 2), the maximum predicted nearshore surface-water concentrations. The resulting pH would not fall outside the permissible range of pH for the Hanford Reach (6.5–8.5), and the estimated change in the pH would not exceed the maximum allowable 0.5

induced variation limit (Poston et al. 2007). The pH of the Hanford Reach is thus potentially lowered only slightly by the deposition of nitrogen and sulfur dioxides released into the air under all *TC & WM EIS* alternatives, and aquatic biota are unlikely to be adversely impacted by pH changes.

P.3.1.3 Uncertainties

Uncertainty exists about the actual magnitude of future exposures and the threshold doses or benchmark concentration TRVs used to evaluate the long-term impact on aquatic and riparian ecological resources from air releases. The uncertainties for chemical and radiological exposure estimates come from error in the source terms and transport models. Additional uncertainties are found in the BAFs and uptake factors, which are linear models based on simplifying assumptions. The uncertainties for toxicity and radiological effects thresholds arise from extrapolating from laboratory experiments on test species to Hanford receptor species in natural environments, and uncertainty about the chemical to which ecological receptors would be exposed, e.g., chemical COPC breakdown products, which can have greater toxicity than the COPC itself. The lack of TRVs for some chemical COPCs and some receptors resulted in uncertainties. Combined, these uncertainties produced limited underestimates of risk and moderate overestimates of risk for different combinations of receptors and chemical or radiological COPC. These errors were unbiased with respect to the alternatives being evaluated in this *TC & WM EIS*, and thus, the results presented above accurately reflect the relative impacts of alternatives on ecological resources. In addition, conservative exposure assumptions and TRVs mitigated these uncertainties and allow for confidence in "no risk" conclusions.

P.3.2 Future Impacts of Groundwater Releases

The potential for adverse effects on Columbia River aquatic and riparian resources from potential releases of radionuclides and chemicals to groundwater under the different Tank Closure, FFTF Decommissioning, and Waste Management alternatives was evaluated using a quantitative risk assessment approach (EPA 1992, 1997). Groundwater contamination in the distant future would be possible under all alternatives because some waste would be generated and disposed of on site or contaminated soil would be left in place under all alternatives. Radionuclides and chemicals would potentially be transported to the Columbia River and its riparian habitat. The potential for adverse impacts on aquatic and riparian resources at the Columbia River is described below.

P.3.2.1 Methods

The general approach for assessing potential adverse effects on aquatic and riparian ecological resources was discussed in Section P.2.1. The assumptions, receptors, exposure pathways and uptake mechanisms (routes), predicted sediment and surface-water concentrations, exposure model equations, and benchmarks used to model exposure for aquatic and riparian ecological resources potentially impacted by contaminant releases are described in the relevant sections below. The calculated Hazard Quotients, Hazard Indices, and other quantitative evaluations of long-term adverse impacts on aquatic and riparian resources from groundwater releases are summarized and discussed in Section P.3.2.2. The impact of nitrate discharge on the eutrophication of surface-water was evaluated based on ambient and predicted concentrations.

P.3.2.1.1 Key Assumptions

The following key assumptions were made in the evaluation of potential impacts on Columbia River aquatic and riparian resources from exposure to radionuclides and chemicals through groundwater releases:

- Exposure of riparian vegetation and soil-dwelling biota to seep water was inconsequential because groundwater discharges at discrete points along the shore and either discharges

underwater or flows only a short distance—5 meters (16.6 feet)—through the riparian zone before entering the river.

- Concentrations in groundwater at the Columbia River overestimated seep and sediment pore water concentrations because Columbia River water mixes with them to varying degrees.

- Groundwater flux was assumed to be approximately 1 cubic meter per second because the river flux is approximately 3,000 times greater than the flux from groundwater, and the flux of the Columbia River is approximately 3,300 cubic meters per second (Bryce et al. 2002).

- The tissue concentrations in fish preyed upon by predators (least weasel and bald eagle) would be in equilibrium with nearshore surface-water concentrations.

- Surface-water and sediment contamination from groundwater releases would not coincide with soil contamination from air releases because material released to air during site and WTP operations would dissipate before slow-moving constituents discharge to the Columbia River.

P.3.2.1.2 Receptors and Exposure Pathways and Routes

The receptors selected to represent the Columbia River aquatic and riparian ecological resources potentially exposed to groundwater releases, including special status species (Chapter 3, Section 3.9.4.1), are listed in Table P–2. These receptors were selected because they were expected to have higher exposures than those not selected from their group, due to their higher ingestion rates per unit body weight for prey, water, and sediment or soil. Special status species were not expected to be more highly exposed or more sensitive to contaminants than the selected species. The selected representative receptors were benthic invertebrates; muskrat; spotted sandpiper; raccoon; bald eagle; least weasel; and aquatic biota, including salmonids. All were ECEM receptors except the spotted sandpiper, which was substituted for the common snipe because the spotted sandpiper has a more aquatic diet. The muskrat was added as a receptor exposed primarily to groundwater discharging at seeps along the river because of its relatively high water ingestion rate and small size compared to other mammals, such as the mule deer or coyote. For this evaluation, the muskrat was assumed to be exposed by ingestion of only seep water to assess the importance of this pathway.

The exposure pathways evaluated in the ecological risk analysis for this *TC & WM EIS* are shown in Table P–2 for all ecological receptors. The exposure medium, exposure route, and receptor are indicated for each pathway evaluated in the analysis of impacts on aquatic and riparian resources from releases to groundwater.

P.3.2.1.3 Predicted Seep, Sediment, and Surface-Water Concentrations

Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1 and 2; and Waste Management Alternatives 1, 2, and 3 (Disposal Groups 1, 2, and 3) have groundwater modeling results. Separate groundwater modeling results do not exist for FFTF Decommissioning Alternative 3, because it did not result in release to groundwater. These alternatives would potentially impact seep, sediment pore water, sediment, and surface-water. The concentrations were calculated from the modeled groundwater concentrations at the Columbia River resulting from the varying radiological and chemical COPC inventories in place under the different alternatives (see Appendix O).

Seep and sediment pore water concentrations were equal to the modeled peak annual average groundwater concentration at the Columbia River. Seep concentrations were used to assess potential impacts on wildlife receptors drinking water in the riparian zone. Peak annual average nearshore surface-water concentrations were used to estimate adverse impacts on aquatic biota (e.g., periphyton, plankton, larval mayflies, juvenile salmonids, and lower-trophic-level fish). Sediment concentrations for

nonpolar hydrophobic organic compounds were calculated assuming equilibrium partitioning between sediment and sediment pore water. Sediment and sediment pore water concentrations were used to assess potential impacts on sediment-dwelling biota and their predators. Nearshore surface-water concentrations used to estimate body burdens in fish (e.g., salmonids) and dose to predators of fish were calculated assuming that the groundwater would be mixed throughout a 0.5 meter-deep, 40 meter-wide shallow zone along the facility side of the river. With a reported maximum velocity of 0.25 meters per second in the nearshore environment of redds (USGS 2000), the nearshore flux was estimated as 5 cubic meters per second. The flux of groundwater into the river over this reach was one three-thousandth of the flux of the Columbia River in the Hanford Reach, approximately 1 cubic meter per second (Bryce et al. 2002). The groundwater (i.e., seep and sediment pore water), sediment, and nearshore surface-water concentrations under Tank Closure Alternatives 1 through 6C; FFTF Decommissioning Alternatives 1 and 2 (Hanford and Idaho Options); and Waste Management Alternatives 1, 2, and 3 (Disposal Groups 1, 2, and 3) were used as the source terms in the exposure model described in the following subsections.

P.3.2.1.4 Exposure Model Calculations

The exposure model calculated ingestion doses from chemicals for wildlife receptors and external and internal doses from radionuclides for all receptors using the equations for $RD_{\text{Ext-water, imm}}$, $RD_{\text{Ext-water near}}$, $RD_{\text{Ext-sed}}$ and RD_{Int} presented in Section P.3.1.1. There was no external dose to receptors from air for radionuclides released to the groundwater and discharged to the Columbia River.

Exposure was not calculated for aquatic and riparian receptors exposed to chemicals by multiple pathways (direct contact, ingestion, respiration) resulting from living in sediment or surface-water. The assessment of impacts on aquatic and sediment-dwelling biota was made by comparing estimated sediment or nearshore surface-water concentrations to appropriate benchmark concentrations for these receptors (see Section P.3.2.1.5).

P.3.2.1.5 Toxicological Benchmarks

The benchmark for combined internal and external exposure from all radionuclides was 0.1 rad per day for the muskrat (IAEA 1992). Radiological and chemical benchmarks for the other receptors were the same as those in Section P.3.1.1.5.

P.3.2.1.6 Risk Indices

As discussed in Section P.2.1, the long-term impacts on ecological resources of potential radionuclide and chemical releases were evaluated by comparing estimates of exposure for a given ecological receptor for a given chemical or radiological COPC under each alternative to threshold exposures associated with a known level of adverse effect of the COPC on that type of receptor. The estimate of chemical exposure concentration under each alternative for sediment-dwelling (benthic) invertebrates was the predicted sediment concentration, and for aquatic biota, including salmonids, it was the predicted nearshore surface-water concentration (see Appendix O). The methods for estimating exposure doses for aquatic and riparian receptors from predicted groundwater concentrations and discharge at the Columbia River were defined in Section P.3.1.1.4. The exposure concentrations or doses associated with a known level of adverse effect were the TRVs (see Section P.3.1.1.5). The comparison of these two values was made by calculating a risk index, the dimensionless ratio of the exposure estimate (concentration or dose) to corresponding TRV (concentration or dose). Calculated risk indices, Hazard Quotients for individual chemical COPCs and Hazard Indices for all radiological COPCs combined, were used to compare *TC & WM EIS* alternatives (see Chapter 5) and identify exposures posing little or no risk (Hazard Quotient or Hazard Index less than or equal to unity).

The risk indices were calculated as follows:

for benthic invertebrates exposed to chemical COPCs in sediment,

$$H = C_{sed} \quad TRV$$

where:

H = Hazard Quotient
C_{sed} = concentration in sediment, milligrams per kilogram dry sediment
TRV = toxicity reference value, milligrams per kilogram

for aquatic biota, including salmonids, exposed to chemical COPCS in nearshore surface-water,

$$H = C_w \quad TRV$$

where:

H = Hazard Quotient
C_w = nearshore surface-water concentration, milligrams per liter
TRV = toxicity reference value, milligrams per liter

for wildlife receptors exposed to chemical COPCs in groundwater, sediment, and nearshore surface-water,

$$H = ADD_{total} \quad TRV$$

where:

H = Hazard Quotient
ADD_{total} = total dose of chemical from ingestion of water, animal food, and sediment, milligrams per kilogram body weight per day
TRV = toxicity reference value (milligrams per kilogram body weight per day)

and for all receptors, the Hazard Index is the sum of external and internal doses from all radiological COPCs divided by the TRV, that is,

$$HI = (RD_{Ext} + RD_{Int}) \quad TRV$$

where:

HI = Hazard Index
RD_{Ext} = external radiation dose from exposure to all radiological COPCs in air, soil, sediment, and/or water, rad per day
RD_{Int} = internal radiation dose from all radiological COPCs, rad per day
TRV = toxicity reference value, rad per day

Except where an exposure parameter or TRV was not available for a given receptor or COPC, the dose (ADD_{total}) and Hazard Quotient for all chemical COPCs and the dose ($RD_{Ext} + RD_{Int}$) summed over all radiological COPCs and the Hazard Index were calculated for all aquatic and riparian receptors potentially exposed at the Columbia River under all *TC & WM EIS* alternatives using predicted groundwater, seep, nearshore surface-water, and sediment concentrations resulting from releases to groundwater. Tables with predicted groundwater, seep, nearshore surface-water, and sediment

concentrations; input parameters; and calculations of dose and risk indices are available in *Calculating Risk Indices for ong-Term Impacts to Ecological Receptors Releases to Groundwater* (SAIC 2008b).

Radiological and chemical hazards estimated for potential aquatic receptors and terrestrial wildlife feeding in the Columbia River due to exposure to contaminants released to the groundwater and discharged to the Columbia River are summarized below using maximum Hazard Quotients and Hazard Indices.

P.3.2.2 Results and Discussion

The results of the screening analysis for radiological and chemical contaminant releases to groundwater due to site and WTP operations and subsequent discharge to the Columbia River estimated for aquatic receptors and riparian wildlife feeding in the Columbia River under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives are summarized in Tables P–12, P–13, and P–14.

Table P–12. Long-Term Impacts of Radiological COPC Groundwater Discharge on Aquatic and Riparian Resources at the Columbia River: Hazard Indices by Receptor and Alternative

Alternative[a]	Hazard Index By Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/ Salmonids
Tank Closure							
1	**2.02×10^{-2}**	5.05×10^{-5}	5.41×10^{-3}	2.34×10^{-3}	6.18×10^{-4}	1.77×10^{-3}	3.21×10^{-4}
2A	4.87×10^{-3}	5.25×10^{-6}	1.21×10^{-3}	5.23×10^{-4}	1.10×10^{-4}	3.13×10^{-4}	5.89×10^{-5}
2B, 3A, 3B, 3C, 6C	3.00×10^{-3}	4.98×10^{-6}	7.52×10^{-4}	3.26×10^{-4}	1.13×10^{-4}	3.22×10^{-4}	5.85×10^{-5}
4	2.69×10^{-3}	4.86×10^{-6}	6.76×10^{-4}	2.93×10^{-4}	1.13×10^{-4}	3.21×10^{-4}	5.79×10^{-5}
5	3.05×10^{-3}	9.55×10^{-6}	8.08×10^{-4}	3.51×10^{-4}	1.15×10^{-4}	3.28×10^{-4}	5.87×10^{-5}
6A, Base Case	1.35×10^{-3}	4.65×10^{-6}	3.48×10^{-4}	1.52×10^{-4}	1.13×10^{-4}	3.20×10^{-4}	5.60×10^{-5}
6A, Option Case	7.11×10^{-6}	4.71×10^{-6}	2.07×10^{-5}	1.09×10^{-5}	1.11×10^{-4}	3.14×10^{-4}	5.39×10^{-5}
6B, Base Case	1.35×10^{-3}	4.64×10^{-6}	3.48×10^{-4}	1.52×10^{-4}	1.13×10^{-4}	3.20×10^{-4}	5.60×10^{-5}
6B, Option Case	5.47×10^{-6}	5.37×10^{-6}	1.94×10^{-5}	1.08×10^{-5}	1.13×10^{-4}	3.19×10^{-4}	5.49×10^{-5}
FFTF Decommissioning[a]							
1	1.05×10^{-6}	9.76×10^{-6}	1.07×10^{-5}	1.01×10^{-5}	1.98×10^{-6}	5.60×10^{-6}	9.42×10^{-7}
2	7.43×10^{-7}	6.69×10^{-6}	7.65×10^{-6}	7.06×10^{-6}	1.80×10^{-6}	5.10×10^{-6}	8.56×10^{-7}
Waste Management							
1	3.35×10^{-8}	5.79×10^{-9}	6.56×10^{-8}	2.91×10^{-8}	6.12×10^{-8}	1.75×10^{-7}	2.90×10^{-8}
2, DG1-A	6.39×10^{-6}	5.97×10^{-6}	7.00×10^{-5}	3.11×10^{-5}	4.43×10^{-5}	1.27×10^{-4}	2.06×10^{-5}
2, DG1-B	7.36×10^{-6}	7.20×10^{-6}	8.21×10^{-5}	3.65×10^{-5}	5.99×10^{-5}	1.71×10^{-4}	2.81×10^{-5}
2, DG1-C	1.34×10^{-5}	1.49×10^{-5}	1.58×10^{-4}	7.02×10^{-5}	9.56×10^{-5}	2.74×10^{-4}	4.41×10^{-5}
2, DG1-D	5.47×10^{-5}	6.69×10^{-5}	6.75×10^{-4}	3.00×10^{-4}	4.73×10^{-4}	1.35×10^{-3}	2.19×10^{-4}
2, DG1-E	1.58×10^{-5}	1.79×10^{-5}	1.88×10^{-4}	8.35×10^{-5}	1.16×10^{-4}	3.31×10^{-4}	5.33×10^{-5}
2, DG1-F	7.88×10^{-6}	7.86×10^{-6}	8.87×10^{-5}	3.94×10^{-5}	6.71×10^{-5}	1.92×10^{-4}	3.15×10^{-5}
2, DG1-G	6.38×10^{-6}	5.96×10^{-6}	6.98×10^{-5}	3.10×10^{-5}	4.45×10^{-5}	1.28×10^{-4}	2.07×10^{-5}
2, DG2, SG2-A	6.02×10^{-6}	5.93×10^{-6}	6.74×10^{-5}	3.00×10^{-5}	4.33×10^{-5}	1.24×10^{-4}	2.01×10^{-5}
2, DG2, SG2-B, Base Case	6.25×10^{-6}	6.21×10^{-6}	7.02×10^{-5}	3.12×10^{-5}	4.38×10^{-5}	1.26×10^{-4}	2.03×10^{-5}
2, DG2, SG2-B, Option Case	6.35×10^{-6}	6.33×10^{-6}	7.14×10^{-5}	3.18×10^{-5}	4.43×10^{-5}	1.27×10^{-4}	2.05×10^{-5}
2, DG3, Base Case	7.26×10^{-6}	7.48×10^{-6}	8.28×10^{-5}	3.68×10^{-5}	4.46×10^{-5}	1.28×10^{-4}	2.05×10^{-5}

Table P–12. Long-Term Impacts of Radiological COPC Groundwater Discharge on Aquatic and Riparian Resources at the Columbia River: Hazard Indices by Receptor and Alternative *(continued)*

Alternative[a]	Hazard Index By Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/ Salmonids
Waste Management *(continued)*							
2, DG3, Option Case	7.35×10^{-6}	7.60×10^{-6}	8.40×10^{-5}	3.74×10^{-5}	4.49×10^{-5}	1.29×10^{-4}	2.06×10^{-5}
3, DG1, SG1-A	1.06×10^{-5}	9.96×10^{-6}	1.12×10^{-4}	4.96×10^{-5}	7.76×10^{-5}	2.22×10^{-4}	3.62×10^{-5}
3, DG1, SG1-B	1.06×10^{-5}	9.96×10^{-6}	1.12×10^{-4}	4.96×10^{-5}	7.76×10^{-5}	2.22×10^{-4}	3.62×10^{-5}
3, DG1, SG1-C	1.45×10^{-5}	1.49×10^{-5}	1.60×10^{-4}	7.13×10^{-5}	8.34×10^{-5}	2.40×10^{-4}	3.81×10^{-5}
3, DG1, SG1-D	5.44×10^{-5}	6.55×10^{-5}	6.62×10^{-4}	2.94×10^{-4}	4.56×10^{-4}	1.31×10^{-3}	2.11×10^{-4}
3, DG1, SG1-E	1.69×10^{-5}	1.79×10^{-5}	1.90×10^{-4}	8.46×10^{-5}	1.06×10^{-4}	3.04×10^{-4}	4.86×10^{-5}
3, DG1, SG1-F	1.06×10^{-5}	9.93×10^{-6}	1.11×10^{-4}	4.95×10^{-5}	7.74×10^{-5}	2.21×10^{-4}	3.61×10^{-5}
3, DG1, SG1-G	1.06×10^{-5}	9.96×10^{-6}	1.12×10^{-4}	4.96×10^{-5}	7.76×10^{-5}	2.22×10^{-4}	3.62×10^{-5}
3, DG2, SG2-B Base Case	1.10×10^{-5}	1.04×10^{-5}	1.16×10^{-4}	5.16×10^{-5}	8.22×10^{-5}	2.35×10^{-4}	3.84×10^{-5}
3, DG2, SG2-B Option Case	1.11×10^{-5}	1.05×10^{-5}	1.17×10^{-4}	5.20×10^{-5}	8.19×10^{-5}	2.34×10^{-4}	3.82×10^{-5}
3, DG3, SG3-A Base Case	1.10×10^{-5}	1.04×10^{-5}	1.16×10^{-4}	5.18×10^{-5}	8.23×10^{-5}	2.36×10^{-4}	3.84×10^{-5}
3, DG3, SG3-B Option Case	1.13×10^{-5}	1.08×10^{-5}	1.20×10^{-4}	5.33×10^{-5}	8.08×10^{-5}	2.31×10^{-4}	3.77×10^{-5}
Combination							
1	**2.02×10^{-2}**	6.03×10^{-5}	5.42×10^{-3}	2.35×10^{-3}	6.20×10^{-4}	1.77×10^{-3}	3.22×10^{-4}
2	3.01×10^{-3}	1.76×10^{-5}	8.30×10^{-4}	3.64×10^{-4}	1.60×10^{-4}	4.54×10^{-4}	8.00×10^{-5}
3	1.36×10^{-3}	1.75×10^{-5}	4.25×10^{-4}	1.90×10^{-4}	1.59×10^{-4}	4.50×10^{-4}	7.72×10^{-5}

[a] FFTF Decommissioning Alternative 3 does not result in discharges to the Columbia River.

Note: The maximum Hazard Index is indicated by **bold** text. Hazard Index is unitless.

Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility; SG=Subgroup.

Table P–13. Long-Term Impacts of Radiological and Chemical COPC Groundwater Discharge on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Alternative

Alternative[a]	Maximum Hazard Quotient or Hazard Index		
	Hazard Quotient or Hazard Index	Chemical or Radiological COPC	Receptor
Tank Closure			
1	2.14×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
2A	2.20×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
2B, 3A, 3B, 3C, 6C	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
4	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
5	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
6A, Base Case	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
6A, Option Case	2.15×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
6B, Base Case	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
6B, Option Case	2.21×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
FFTF Decommissioning			
All radionuclides	Spotted sandpiper		
All radionuclides	Spotted sandpiper		

Table 13. Long-Term Impacts of Radiological and Chemical COPC Groundwater Discharge on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Alternative *(continued)*

Alternative[a]	Maximum Hazard Quotient or Hazard Index		
	Hazard Quotient or Hazard Index	**Chemical or Radiological COPC**	**Receptor**
Waste Management			
1	4.72×10^{-3}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-A	2.69×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-B	1.33×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-C	3.69×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-D	4.12×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-E	2.30×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-F	3.02×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
2, DG1, SG1-G	2.54×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG2, SG2-A	2.57×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG2, SG2-B Base Case	7.74×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG2, SG2-B Option Case	5.25×10^{-1}	Chromium[b]	Aquatic Biota/Salmonids
2, DG3, Base Case	7.77×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
2, DG3, Option Case	4.99×10^{-1}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-A	2.47×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-B	1.89×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-C	3.69×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-D	4.12×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-E	2.30×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
3, DG1, SG1-F	3.02×10^{0}	Chromium[b]	Aquatic Biota/Salmonids
3,DG1, SG1-G	2.34×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG2, SG2-A	2.38×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG2, SG2-B, Base Case	8.18×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG2, SG2-B, Option Case	5.26×10^{-1}	Chromium[b]	Aquatic Biota/Salmonids
3, DG3, SG3-A, Base Case	8.03×10^{-2}	Chromium[b]	Aquatic Biota/Salmonids
3, DG3, SG3-B, Option Case	5.00×10^{-1}	Chromium[b]	Aquatic Biota/Salmonids
Combination			
1	2.14×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
2	2.22×10^{1}	Chromium[b]	Aquatic Biota/Salmonids
3	**2.23×10^{1}**	Chromium[b]	Aquatic Biota/Salmonids

a FFTF Decommissioning Alternative 3 does not result in discharge to the Columbia River.

b For purposes of long-term impacts, it was assumed that this is hexavalent chromium.

Note: The maximum Hazard Quotient or Hazard Index is indicated by **bold** text. Hazard Quotient and Hazard Index are unitless.

Key: COPC=constituent of potential concern; DG=Disposal Group; FFTF=Fast Flux Test Facility; SG=Subgroup.

Table P–14. Long-Term Impacts of Radiological and Chemical COPC Groundwater Discharge on Aquatic and Riparian Resources at the Columbia River: Maximum Risk Index by Receptor

Receptor	Maximum Hazard Quotient or Hazard Index			
	Analysis	Alternative	Hazard Index or Hazard Quotient	Chemical or Radiological COPC
Benthic invertebrate	Tank Closure and Combination	1	1.20×10^{-1}	Chromium[a]
Aquatic biota/Salmonids	Combination	3	2.23×10^{1}	Chromium[a]
Muskrat	Tank Closure and Combination	1	4.71×10^{-3}	Chromium[a]
Spotted sandpiper	Combination	1	8.17×10^{-1}	Chromium[a]
Raccoon	Tank Closure and Combination	1	2.95×10^{-1}	Uranium
Least weasel	Combination	3	6.44×10^{-1}	Nitrate
Bald eagle	Tank Closure and Combination	1	2.08×10^{-2}	Chromium[a]

[a] For purposes of long-term impacts, it was assumed that this is hexavalent chromium.

Key: COPC=constituent of potential concern.

The maximum combined radionuclide Hazard Index from groundwater discharge under all of the alternatives was calculated to be 0.02 for benthic invertebrates under Tank Closure Alternative 1. Table P–12 presents the Hazard Indices associated with groundwater discharge to the Columbia River under all of the alternatives. Exposure to radiological COPCs from groundwater discharge under all of the alternatives was below the 0.1-rad-per-day benchmark for wildlife receptors (i.e., muskrat, spotted sandpiper, raccoon, least weasel, bald eagle) and the 1-rad-per-day benchmark for benthic invertebrates and aquatic biota, including salmonids and the Woodhouse's toad. Estimated hazards for the representative species indicated that no adverse effects are expected for aquatic receptors and terrestrial wildlife feeding in the Columbia River from exposure to radiological COPCs from groundwater discharge. Because the direct impacts of groundwater discharge are expected to be small, any associated potential indirect impacts on the ecosystem would be correspondingly minor.

Exposure to chemical COPCs discharged into the Columbia River as a result of releases to groundwater under the various Tank Closure, FFTF Decommissioning, and Waste Management alternatives exceeded the Hazard Quotient criterion of 1.0 under all Tank Closure alternatives and Waste Management Alternatives 2 and 3, Disposal Groups 1-C, 1-D, 1-E, and 1-F. In all cases, the maximum Hazard Quotient was for aquatic biota, including salmonids, exposed to chromium, assuming it was in hexavalent form (see Table P–13). The highest Hazard Quotient was 22.3 for salmonids exposed to hexavalent chromium in nearshore surface-water under Alternative Combination 3 (see Table P–14), which includes Waste Management Alternative 2, Disposal Group 2. Hazard Quotients for terrestrial predators feeding on Columbia River benthic invertebrates and salmonids did not exceed 0.82. No other chemical COPCs had Hazard Quotients exceeding 1 for aquatic and riparian receptors at the Columbia River.

The chromium Hazard Quotients above 1.0 did not necessarily indicate high risk to aquatic biota, including salmonids, at the Columbia River. The chromium TRV for hexavalent chromium used to calculate salmonid Hazard Quotients was the sensitive species test effect concentration affecting 20 percent of the test population (EC_{20}). Hexavalent chromium is highly toxic compared to the trivalent form of chromium, which is more likely to occur in oxygenated aquatic environments. Hexavalent chromium Hazard Quotients can be used to compare alternatives, but they should not be used as the sole basis for concluding that ecological resources at the Columbia River would be adversely impacted.

Given the magnitude of the Hazard Quotients and the conservative exposure assumptions and toxicological benchmarks, aquatic biota and sediment-dwelling biota in the Hanford Reach and their terrestrial predators would be unlikely to be at unacceptable risk due to the discharge of chemical COPCs in groundwater under any alternative. The modeled concentrations in nearshore surface-water and sediment overestimated risk due to the conservative model assumptions, namely that all groundwater discharge occurs in the 40-meter nearshore zone, when in reality groundwater would likely discharge throughout the riverbed and would thus be highly diluted. The model also assumed that nearshore sediment would be in equilibrium with discharging groundwater, which ignored the likely movement of surface-water into the uppermost sediment layer where benthic organisms are found.

Nitrate in discharging groundwater under two alternatives could potentially contribute to eutrophication in nearshore surface-water of the Hanford Reach. Dissolved concentrations of nitrite and nitrate as nitrogen in surface-water at the Richland Pumphouse immediately downstream of Hanford did not exceed 1.0 milligrams per liter during 2006 (Poston et al. 2007). Modeled maximum nitrate concentrations in Columbia River nearshore surface-water ranged from 0 milligrams per liter (FFTF Decommissioning alternatives) to 1.51 milligrams per liter (Alternative Combinations 2 and 3). Only the Tank Closure alternatives and thus the alternative combinations have predicted maximum nearshore surface-water concentrations exceeding the 2006 ambient concentrations. Whether increased nitrate inputs would actually result in eutrophication depends on the amount of available phosphorus.

P.3.2.3 Uncertainties

Uncertainty exists about the actual magnitude of future exposures and the threshold doses or benchmark concentration TRVs used to evaluate the long-term impact on aquatic and riparian ecological resources from groundwater releases. The uncertainties for chemical and radiological exposure estimates came from error in the source terms and transport models. Additional uncertainties were found in the BAFs and uptake factors, which were linear models based on simplifying assumptions. The uncertainties for toxicity and radiological-effects thresholds arose from extrapolating from laboratory experiments on test species to Hanford receptor species in natural environments and uncertainty about the chemical form to which ecological receptors would be exposed, e.g., hexavalent or trivalent chromium. The lack of TRVs for some chemical COPCs and some receptors resulted in uncertainties. Combined, these uncertainties produced limited underestimates of risk and moderate overestimates of risk for different combinations of receptors and chemical or radiological COPCs. Conservative exposure assumptions and TRVs mitigated these uncertainties and allow for confidence in "no risk" conclusions. There were large uncertainties about the impact of nitrate in groundwater releases on potential eutrophication in the Columbia River. These errors in risk indices and nitrate impacts on eutrophication were unbiased with respect to the alternatives being evaluated in this *TC & WM EIS*, and thus, the results accurately reflect the relative impacts of alternatives on ecological resources.

P.3.3 Summary of Aquatic Impacts

Estimated radiation doses resulting from air deposition and groundwater discharge for any of the alternatives were less than the 0.1-rad-per-day and 1-rad-per-day benchmarks for ecological receptors exposed to radiological COPCs at the Columbia River. All Hazard Indices associated with these alternatives were below 1.0. Only estimated exposures of aquatic biota to hexavalent chromium in nearshore surface-water under all Tank Closure alternatives and Waste Management Alternatives 2 and 3, Disposal Groups 1-C, 1-D, 1-E, and 1-F, exceeded the Hazard Quotient criterion of 1.0 at the Columbia River. Based on the conservative nature of the exposure assumptions, the estimated Hazard Indices and Hazard Quotients for the representative receptors indicated that no adverse effects are expected from chemical or radiological COPCs in air and groundwater releases to the Columbia River resulting under the various alternatives evaluated. No impacts are expected on the pH of water from additional nitrogen and sulfur dioxides resulting from air emission and deposition in the Hanford Reach. The potential impact on aquatic biota in the Hanford Reach of nitrate in groundwater discharge is uncertain. Calculated

risk indices for aquatic and riparian resources from air and groundwater releases were used in this *TC & WM EIS* to compare alternatives and evaluate cumulative impacts.

P.4 REFERENCES

ANL (Argonne National Laboratory), 1999, *Risk Impact Technical Report for the Hanford Groundwater Vadose Zone Integration Pro ect*, DOE/CH/CRE-7-1999, U.S. Department of Energy Center for Risk Excellence, December.

Baes, C.F., III, R.D. Sharp, A.L. Sjoreen, and R.W. Shor, 1984, *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture*, ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Baker, D.A., and J.K. Soldat, 1992, *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the A uatic Environment*, PNL-8150, Pacific Northwest Laboratory, Richland, Washington, June.

Blaylock, B.G., M.L. Frank, and B.R. O'Neal, 1993, *Methodology for Estimating Radiation Dose Rates to Freshwater iota Exposed to Radionuclides in the Environment*, ES/ER/TM-78, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee, September.

Bryce, R.W., C.T. Kincaid, P.W. Eslinger, and L.F. Morasch, 2002, *An Initial Assessment of Hanford Impact Performed with the System Assessment Capability*, PNNL-14027, Pacific Northwest National Laboratory, Richland, Washington, September.

DOE (U.S. Department of Energy), 1995, *Hanford Site Risk Assessment Methodology*, DOE/RL-91-45, Rev. 3, Richland Operations Office, Richland, Washington, May.

DOE (U.S. Department of Energy), 1998, *Screening Assessment and Re uirements for a Comprehensive Assessment, Columbia River Comprehensive Impact Assessment*, DOE/RL-96-16, Rev. 1, Pacific Northwest National Laboratory and CRCIA Management Team, March.

DOE and Ecology (U.S. Department of Energy, Richland Operations Office, Richland, Washington, and Washington State Department of Ecology, Olympia, Washington), 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, DOE/EIS-0189, August.

Eckerman, K.F., and J.C. Ryman, 1993, *External Exposure to Radionuclides in Air, Water, and Soil*, Federal Guidance Report No. 12, EPA-402-R-93-081, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C., September.

Ecology (Washington State Department of Ecology), 2003, Paragon Analytics, Inc. *TOC and pH Results for WTPTOC, TOC Method ASA- 0-3 and Solid pH Water 25 Degrees Celsius Method, EPA150.1, Data Package ID: TC030705 -1 and PH030705 -1*.

Efroymson, R.A., M.E. Will, and G.W. Suter, II, 1997, *Toxicological enchmarks for Contaminants of Potential Concern for Effects on Soil and itter Invertebrates and Heterotrophic Process: 1 7 Revision*, ES/ER/TM126/R2, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997, *Toxicological enchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1 7 Revision*, ES/ER/TM-85/R3, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee, November.

EPA (U.S. Environmental Protection Agency), 1992, *Framework for Ecological Risk Assessment*, EPA/630/R-92/001, Risk Assessment Forum, Washington, D.C., February.

EPA (U.S. Environmental Protection Agency), 1993, *Wildlife Exposure Factors Handbook*, EPA/600/R-93/187, Office of Research and Development, Office of Health and Environmental Assessment, Washington, D.C., December.

EPA (U.S. Environmental Protection Agency), 1995, *Great akes Water uality Initiative Technical Support Document for the Procedure to Determine ioaccumulation Factors*, EPA-820-B-95-005, Office of Water, Washington, D.C., March.

EPA (U.S. Environmental Protection Agency), 1997, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*, EPA-540/R/97/006, Office of Solid Waste and Emergency Response, Washington, D.C., June.

EPA (U.S. Environmental Protection Agency), 1999, *Screening evel Ecological Risk Assessment Protocol for Ha ardous Waste Combustion Facilities*, Vol. 3, Peer Review Draft, EPA530-D-99-001C, Office of Solid Waste and Emergency Response, Washington, D.C., August.

EPA (U.S. Environmental Protection Agency), 2000, *Ecological Soil Screening evel Guidance-Draft.* Exhibit 1–3, "Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs," Washington, D.C., June 27.

EPA (U.S. Environmental Protection Agency), 2009, *Integrated Risk Information System*, accessed through http://www.epa.gov/iris, March 5.

Eslinger, P.W., C. Arimescu, B.A. Kanyid, and T.B. Miley, 2002, *User Instructions for the Systems Assessment Capability, Rev. 0, Computer Codes*, Vol. 2, *Impact Modules*, PNNL-13932, Pacific Northwest National Laboratory, Richland, Washington, June.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991, *Handbook of Environmental Degradation Rates*, Lewis Publishers, Inc., Chelsea, Michigan.

IAEA (International Atomic Energy Agency), 1992, *Effects of Ioni ing Radiation on Plants and Animals at evels Implied by Current Radiation Protection Standards*, Technical Report Series No. 332, Vienna, Austria, March.

Jones, D.S., G.W. Suter, II, and R.N. Hull, 1997, *Toxicological enchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated iota: 1 7 Revision*, ES/ER/TM-95/R4, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee, November.

Kocher, D.C., and J.R. Trabalka, 2000, "On the Application of a Radiation Weighting Factor for Alpha Particles in Protection of Non-human Biota," *Health Physics Society Journal*, Vol. 79, pp. 407–411.

NCRP (National Council on Radiation Protection and Measurements), 1991, *Effects of Ioni ing Radiation on A uatic Organisms*, NCRP Report No. 109, Bethesda, Maryland, August 30.

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

NRCS (Natural Resources Conservation Service), 2008, *Official Soil Series Descriptions (OSD) with Series Extent Mapping Capabilities: uincy Series*, accessed through http://ortho.ftw.nrcs.usda.gov/osd/osd.html, November.

Poston, T.M., R.W. Hanf, J.P. Duncan, and R.L. Dirkes, eds., 2007, *Hanford Site Environmental Report for Calendar Year 200 (Including Some Early 2007 Information)*, PNNL-16623, Pacific Northwest National Laboratory, Richland, Washington, September.

Rasmussen, J.J., 1971, *Soil Survey of enton County Area*, *Washington*, U.S. Department of Agriculture, Soil Conservation Service, July.

SAIC (Science Applications International Corporation), 2008a, *Calculating Risk Indices for ong-Term Impacts to Ecological Receptors Releases to Air*, Germantown, Maryland.

SAIC (Science Applications International Corporation), 2008b, *Calculating Risk Indices for ong-Term Impacts to Ecological Receptors Releases to Groundwater*, Germantown, Maryland.

Sample, B.E., D.M. Opresko, and G.W. Suter, II, 1996, *Toxicological enchmarks for Wildlife: 1 Revision*, ES/ER/TM-86/R3, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee, June.

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter, II, and C.J.E. Welsh, 1997, *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*, ORNL/TM-13391, Oak Ridge National Laboratory, Oak Ridge, Tennessee, October.

Stumm, W., and J.J. Morgan, 1970, *A uatic Chemistry: An Introduction Emphasi ing Chemical E uilibria in Natural Waters*, Wiley-Interscience, New York, New York.

Suter, G.W., II, 1993, *Ecological Risk Assessment*, Lewis Publishers, Boca Raton, Florida.

Suter, G.W., II, and C.L. Tsao, 1996, *Toxicological enchmarks for Screening Potential Contaminants of Concern for Effects on A uatic iota: 1 Revision*, ES/ER/TM-96/R2, U.S. Department of Energy, Office of Environmental Management, Oak Ridge, Tennessee, June.

USFS, NPS, and USFWS (U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service), 2000, *Federal and Managers' Air uality Related Values Workgroup (F AG), Phase I Report*, December.

USGS (U.S. Geological Survey), 2000, *Use of Rearing Habitat by Juvenile Fall Chinook Salmon in the Hanford Reach of the Columbia River, Washington*, accessed through http://biology.usgs.gov/wfrc/crrlhome/rearing.htm, October 13.

Zach, R., 1985, "Contribution of Inhalation by Food Animals to Man's Ingestion Dose," *Health Physics*, Vol. 49, pp. 737–745.

Federal Register

63 FR 26846, U.S. Environmental Protection Agency, 1998, "Guidelines for Ecological Risk Assessment," May 14.

U.S. Department of Energy Standards

DOE Standard 1153-2002, *A Graded Approach for Evaluating Radiation Doses to A uatic and Terrestrial iota*, July 2002.